TAXONOMY AND DISTRIBUTION OF RHINOCEROSES FROM THE SIWALIK HILLS OF PAKISTAN

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By

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2009

بسم الله الرحمن الرحيم

DEDICATION

Dedicated to

MY CHILDHOOD MENTORS

MUHAMMAD YOUSAF KHAN (LATE)
&
WAZIR BEGUM (LATE)

TAXONOMY AND DISTRIBUTION OF RHINOCEROSES FROM THE SIWALIK HILLS OF PAKISTAN

By Abdul Majid Khan, M. Sc.

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Abstract

Taxonomic studies of the abundant and diverse rhinoceros fossil materials from different formations of the Siwaliks, Pakistan, were undertaken. Most of the fossil remains came from the previously described localities. However some new localities were also explored for the collection of specimens. Over all fifty four specimens, collected from different localities of the lower, middle and upper Siwaliks are described in this dissertation. Among fifty; nine specimens belong to the genus *Rhinoceros*, two specimens belong to the genus *Punjabitherium,* fifteen specimens belong to the genus *Gaindatherium*, seven specimens belong to the genus *Alicornops,* thirteen specimens belong to the genus *Brachypotherium,* and eight specimens belong to the genus *Chilotherium.* All the described specimens include some complete maxillary and mandibular tooth series, isolated teeth and fragments of maxillae or mandibles. A complete right and left maxillary tooth series (P1-M3) of *Rhinoceros sivalensis* is described for the first time from the Tatrot Fm. of the upper Siwaliks. Fossil remains of *Rhinoceros sondaicus* and *Punjabitherium platyrhinus* are also a new addition to the rhinoceros fauna of the Pinjor Fm. of the upper Siwaliks of Pakistan. *Alicornops complanatum* a new binomen proposed by Antoine *et al*., (2003c) is considered valid in the present study for *Chilotherium intermedium complanatum* (Heissig, 1972). *Alicornops* aff. *laogouense* is also described for the first time from the Kamlial Fm. of the lower Siwaliks of Pakistan. Maps showing the stratigraphic ranges of the various taxa of the Siwalik rhinoceroses in correlation to the published records are also presented herein this dissertation. The fossil material was collected from fifteen different localities of the Siwalik Fms. A new fossiliferous locality at Lava (Chinji Fm., Lower Siwaliks), district Chakwal, has been discovered.

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ABDUL MAJID KHAN

LIST OF ABBREVIATIONS

Myr	Million years
Ma	Million years ago
MN	European Mammal Neogene zone scale
N	Numbers
AMNH	American Museum of Natural History, New York
BMNH	British Museum of Natural History, London
PMNH	Pakistan Museum of Natural History, Islamabad
GSI	Geological survey of India, Kolkata
GSP	Geological Survey of Pakistan, Islamabad and Quetta
PUPC 04/11	Punjab University Palaeontological Collection, housed in the department of Zoology, Punjab University, Lahore, Pakistan, (institutional abbreviation) in the text the upper figures of the serial numbers denote the collection year and the lower ones denote the collected number of the specimen of the respective year.
P1	First upper premolar
P2	Second upper premolar
P3	Third upper premolar
P4	Fourth upper premolar
M1	First upper molar
M2	Second upper molar
M3	Third upper molar
p1	First lower premolar
p2	Second lower premolar
p3	Third lower premolar
p4	Fourth lower premolar
m1	First lower molar
m2	Second lower molar
m3	Third lower molar
DP	Deciduous upper premolar
DM	Deciduous upper molar
dm	Deciduous lower molar
Fms/Fm.	Formations/Formation.
r	Right
l	Left

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INTRODUCTION

PRELUDE TO THE SIWALIKS

The Siwaliks are located within the political boundaries of Pakistan, India, Nepal, and Bhutan, and range between 6 to 90 km in width and over 2000 km in length (Acharyya, 1994).The fluvial sequence of the Siwaliks is situated along the Himalayan foothills from Pakistan in the west to Myanmar in the east for about 1689 km (Fig. 1). These sedimentary deposits are over 6000 meters in thickness and provides an amazing opportunity to palaeontologists, geologists and natural history researchers to study fluvial dynamics, palaeomagnetic dating, palaeoclimatology, stratigraphic correlation, isotope geochemistry, and vertebrate biochronology across the last 20 Ma. (Andrews and Cronin, 1982; Pilbeam, 1982).

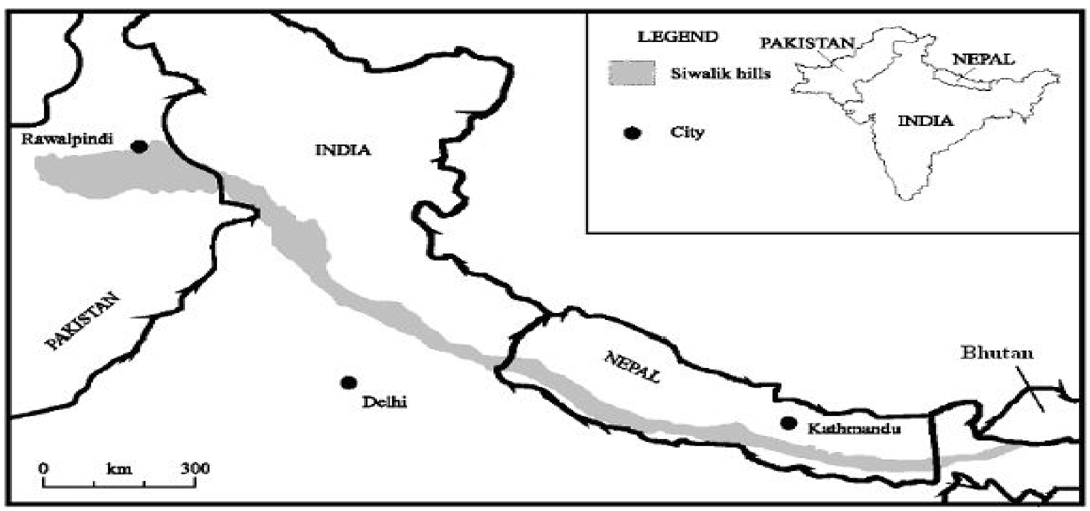

Figure 1: Modified map of the Siwalik Hills taken from Chauhan (2003), showing distribution of the Siwalik sediments along the foothills of Himalayas.

The Siwalik deposits are one of the most comprehensively studied fluvial sequences in the world. They comprise mudstones, sandstones, and coarsely bedded conglomerates deposited at times when the region was a colossal basin during Middle Miocene, to Upper Pleistocene times. Rivers flowing southwards from the Greater Himalayas, resulting in extensive multi-ordered drainage systems, deposited the sediments. Following this deposition, the sediments were uplifted through intense tectonic regimes (commencing in Upper Miocene times), subsequently resulting in a unique topographical entity - the Siwalik Hills or the Siwaliks (Chauhan, 2003).

Medlicott (1864) gave the name Siwaliks to the sub Himalayan rocks. This term was originally derived from the Siwalik Hills in Deharadun (India) and generally used for the molasses-type Neogene sediments of the Himalayan foothill zone. The Siwaliks are noted for their widespread terrestrial vertebrate remains since 1800's. However, the best record of the fossiliferous layers for the Siwaliks (Potwar Plateau) is present in Pakistan. The Potwar Plateau is situated in the Punjab, Pakistan (72°30′ E, 33°00′ N). It is an elevated area comprising some 20,000 km^2 bounded in the north by the Kala Chita hills and Margala Hills, in the south by the Salt Range, in the east by the Jhelum River and in the west by the Indus River (Fig. 2). The Miocene–Pliocene strata have usually been divided into the Kamlial, Chinji, Nagri, and Dhok Pathan Formations. All the aforesaid formations typically consist of gently tilted strata that form shallow strike-valleys and laterally extensive channel sandstones form higher ridges as the surface expression of the large structural synclinorium underlying the Potwar Plateau. Fossils come out of these strata due to erosion and accumulate on the outcrop surfaces between the ridges, providing best conditions for sampling within well-defined stratigraphic intervals.

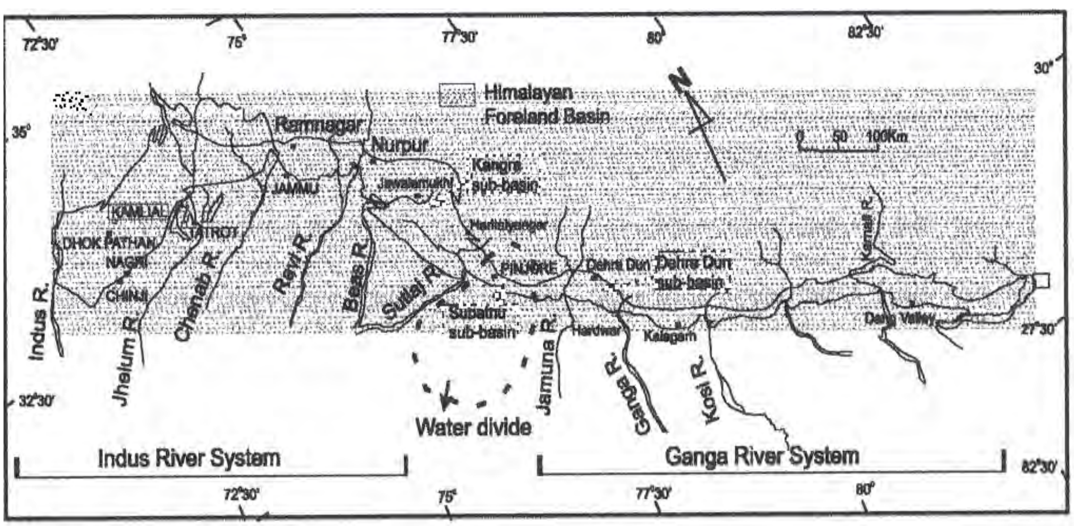

Figure 2: Geologic map of the Himalayan foreland basin. The sub-basins are demarcated on the basis of geophysical data (after Raiverman *et al*., 1983; Source, Suresh *et al*., 2004).

Geology

Geologically the Siwaliks is a foreland basin of the Himalayas filled with molasse-type sediments of the Neogene and early Quaternary age, developed at the foothills of the Himalayan mountain belt. The stratigraphic sequence preserves a continuous record of the continental sedimentation (sediment thickness >6km at places) as well as an equally comparable continuous record of vertebrates, especially of the mammals (Basu, 2004; Flynn, 2003; Flynn *et al*., 1995). In the Siwaliks, the fossil record is good for the interval of 18 to 6 million years (Lihoreau *et al.,* 2004). The Siwaliks in Pakistan can be divided according to the lithological characters into three subgroups- Lower, Middle and Upper, also further into their formation scale lithostratigraphic units. The Upper Siwalik subgroup is further classified into three lithostratigraphic formations including Tatrot, Pinjor, and Boulder Conglomerates. These three units comprise the sequences of the sandstone-mudstone couplets, the parmandal Sandstone and the Boulder Conglomerate Formation, the upper most lithostratigraphic unit (Quade and Cerling, 1995). The Middle Siwaliks comprising Nagri and Dhok Pathan Formations are dominantly arenaceous, consisting of medium-grained, blue-gray, massive sandstones (30 to > 60m) with subordinate representation of clays, mudstones and siltstones. The Lower Siwaliks (Kamlial, Chinji) consists of a sequence of sandstone-mudstone couplets with a marked dominance of the mudstones over the sandstones.

Sedimentology

Several researchers (Bhattacharya and Misra, 1963; Bhattacharya, 1970; Chaudhri and Gill, 1983; Bagati and Kumar, 1994; Raiverman and Suresh, 1997; Raiverman, 2002; Biswas, 1994) have extensively studied and described the clay mineralogy of late Neogene sediments of the Middle Siwaliks. The Siwalik sediments are exposed in folded belts extending from the Salt Range to the Margala Hills in the north, and from the Jhelum River in the east to the Indus on the west in the Potwar Plateau of Pakistan. Detrital clay-mineral suites incorporated in these fluvial deposits have been used as important tools in understanding the derivation of fine-grained sediments, composition and climate of the source terrains (Chamley, 1989). The high transport energy of running water in the river channels scarcely permits the abundant deposition of small, light clay particles, except in specific environments like downstream alluvial plains and floodplains. Near the Indus River the uppermost 3000 feet of the Middle Siwalik sequence (Upper Nagri and Dhok Pathan stages) hold thick beds of conglomerate, which die out eastwards and southeastwards into sandstones and clays. Farther eastwards, across the Soan syncline, a clay facies develops at progressively lower horizons in the Nagri Stage, replacing a considerable portion of the massive sandstones of the type area. The facies change is escorted by a reduction in thickness. The clay minerals like (Illite and smectite) are the most abundant component in the Middle Siwaliks (Bagati and Kumar, 1994; Raiverman and Suresh, 1997; Raiverman, 2002). Major rivers drained higher and Lesser Himalayas, whereas Sub-Himalayan region has been drained by the piedmont drainage and tributaries of major rivers (Kumar *et al.,* 1999; Ghosh *et al*., 2003). The interfingering of channel deposits can be recognized by sand body geometry; color, framework composition and Palaeo-flow pattern.

Lithology

There is a great amount of variation in Lithology of the Siwalik beds. Siwalik Lithology includes sandstone, siltstone, mudstone, and rare Marls and Clays. The Siwaliks have been frequently divided into six or more formations (Cheema, *et al*., 1977). The Miocene Siwaliks were deposited in a fluvial system comparable in size to the modern Indus or Gange's systems. The reconstructed Miocene Indo-Gangetic system extended over 2000 km to the east and 1000 km to the south, with floodplain widths extending from 100 to 500 km. Thus, the Potwar Plateau encompassed only a small part of this ancient foreland basin with the provision of only inadequate information on the entire system (Willis and Behrensmeyer, 1995).The Middle Siwaliks sediments were deposited by contemporaneous fluvial systems, with the larger emergent Nagri system followed by an inter-fan Dhok Pathan system. The tributaries flowing in the Siwaliks were of two types. The first order streams emerged from the mountains at widely spaced intervals (100-200 km) and flowed some hundreds of kilometers southeast across the floodplain to join the stem river (Fig. 3). For the second order streams, Barry *et al*., (2002) has referred the term “emergent” streams, carried relatively unweathered sediment from the mountains and deposited it in order to form distally broadening, low-gradient megafans. Similar in size and morphology to modern rivers in Punjab, such as the Jhelum, Miocene upland-sourced streams were braided and had typical channel belts of more than 5 km wide with individual channel widths on the order of 200 to 400 m. They drained adjacent and distant mountain regions that flowed throughout the year, and were prone to avulsion during unusual flood events. Abandoned channels then became sites of short-lived lakes or swamps with more gradual sedimentation, while the active channels moved to lower and perhaps quite distant areas on the fan. Because of the instability of the channels, alluvial ridges along channels did not form, nor did channels migrate laterally to form extensive sheet bodies (Behrensmeyer *et al*., 1995).

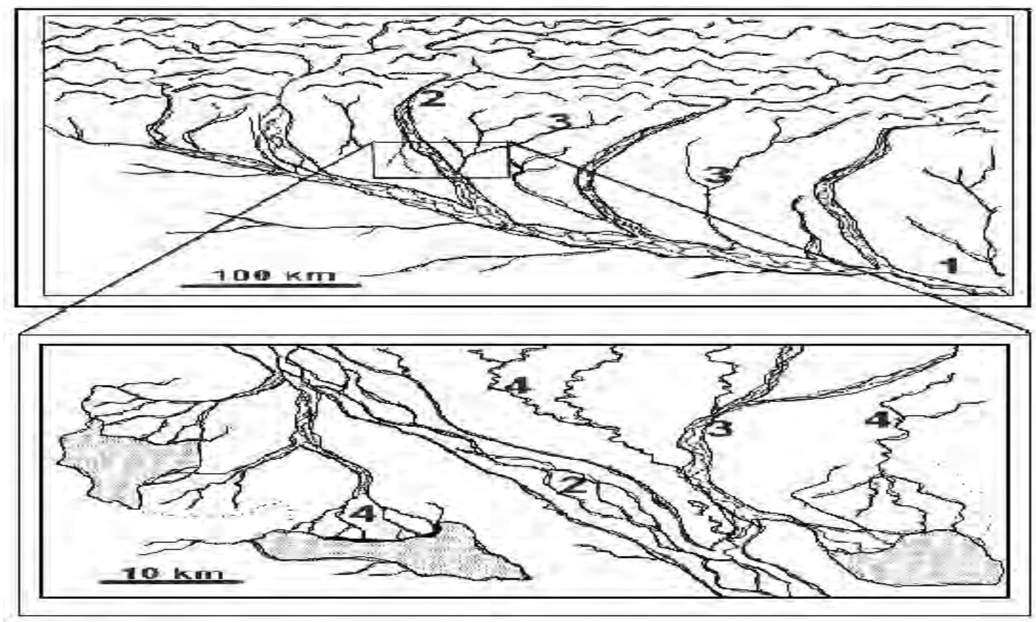

Figure 3: Reconstruction of late Miocene Siwalik fluvial system in plain view. 1= axial stem river, shown flowing eastward to the Bay of Bengal. 2= emergent or upland-sourced rivers, draining mountains and tributary to the axial stem river. 3= interfan or lowland-sourced streams, arising on the floodplain or near the mountain front and generally tributary to the axial or second-order rivers. 4= small streams of the floodplain, often ephemeral. Note that the third- and fourth-order streams may also have drained into low areas on the floodplain, creating seasonal swamps or ponds as indicated by gray stippled areas. The boxed inset approximates the size of the modern Potwar Plateau (Source, Barry *et al*., 2002).

In contrast, the second subtype deposits generally smaller, braided rivers having channel belts of about 1-2 km wide and channels 70-200 m wide. Some of these third-order streams may also have had mountain sources, whereas others had sources at foothills from groundwater on the floodplain (Fig. 3). Channels of the third-order streams also appear to have been less prone to large flood events but had a more frequent rate of avulsion than the second-order, emergent streams (Willis, 1993b; Zaleha, 1997).

Stratigraphy

Pilgrim developed the classic formulation of the Siwalik stratigraphy in a series of articles on the occurrence of fossils and sediments all through the Indian subcontinent (Pilgrim, 1908, 1910, 1912, 1913, 1914, 1932, 1937, 1939). Pilgrim documented seven succeeding "faunal zones" (Gaj, Kamlial, Chinji, Nagri, Dhok Pathan, Tatrot, and Pinjor; Fig. 4) from Early Miocene through Early Pleistocene. Behrensmeyer (1987), Behrensmeyer *et al*., (1995), Willis and Behrensmeyer (1995), Stix (1982) and Willis (1993b) discussed at length the important sedimentologic and taphonomic features of the Siwalik Formations. These formations are fluvial in origin and comprise alternating fine-grained sediments and sandstones, with occasional conglomerates, especially in the upper parts of the section. Characteristic depositional environments include channels, crevasse splays, fills, and floodplain soils. Individual formations are distinguished on the basis of ratios of sand, clay and silt. Potwar Siwalik sediments range between 18.3 and 0.6 Ma (Johnson *et al*., 1985). Variation in the rates of sediment deposition and an obvious extensive depositional gap has made the stratigraphic relationships and ages of the Early Pliocene formations of the Potwar less certain. These include the Tatrot Formation and its equivalents, which contain an important fauna with recorded occurrences of *Elephas, Hippohyus, Sivachoerus*, and *Sus* (Barry *et al*., 1982; Hussain *et al*., 1992) and some older sediment near Rhotas and Jalalpur. Formerly, the Tatrot was included in the upper part of the Gauss Chron (Barry *et al*., 1982), while critical parts of the Rhotas and Jalalpur sequences have been interpreted as being in the Gilbert Chron (Opdyke *et al*., 1979; Johnson *et al*., 1982). Barry *et al.,* (2002) have recommended an age from 3.5 to 3.3 Ma (Table 3) for the Tatrot Formation and Hussain *et al*., (1992) suggested that the Tatrot Formation range between 3.2 and 3.4 Ma. The well-dated fossiliferous and exposed rocks at Mirpur and in the Pabbi Hills, as well as somewhere else throughout the Potwar, cover a slightly longer interval between 3.4-0.6 Ma (Opdyke *et al*., 1979; West, 1981; Johnson *et al*., 1982).

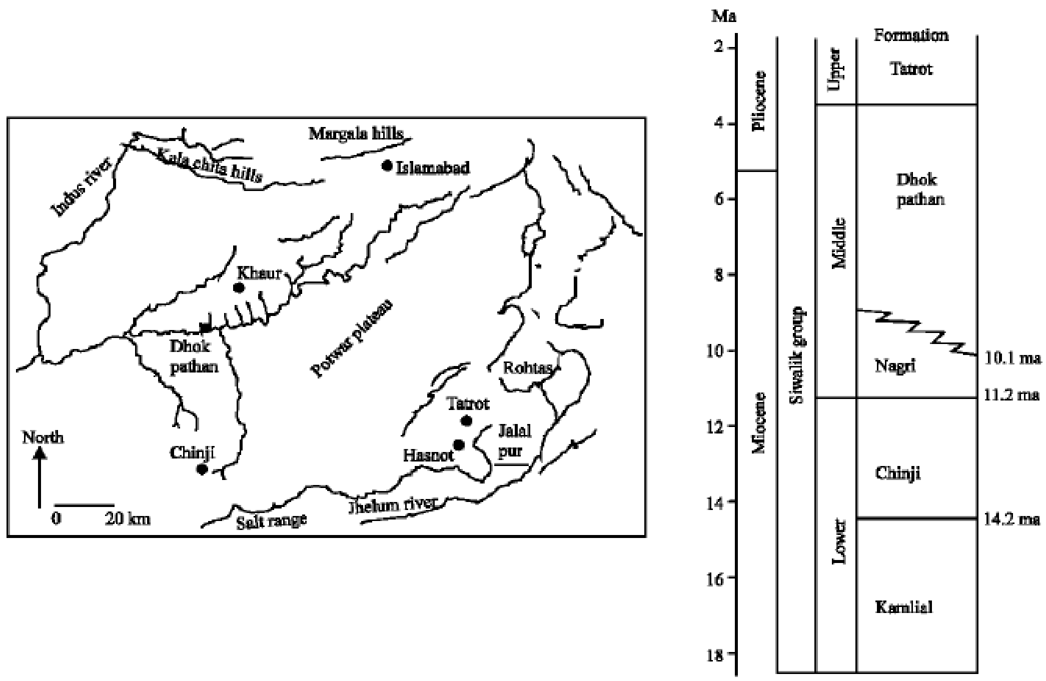

Figure 4: Stratigraphic sections of the Siwaliks of Pakistan. Boundary dates are from Barry *et al*., (2002).

A likely age for the oldest appearance of the Pinjor fauna is 2.4-2.5 Ma and the youngest appearance of fauna is 0.6 Ma (Dennel *et al*., 2006). Nevertheless, the Siwalik interval-zones should not be mystified with stages, as they are chronostratigraphic units. Each interval-zone's lower boundary is defined by a biological event, not a stratigraphic level with a specific age.

Biostratigrapy

The Miocene sediments in the Siwaliks are entirely fluvial in origin and are deposited by large river systems. Some of the sections of these sedimentary deposits exceed 3000 m in thickness and are now exposed on the surface. These sedimentary deposits are generally divided into time successive formations, with the archetypal sequence of the Potwar comprising the Murree, Kamlial, Chinji, Nagri, and Dhok Pathan Formations of Pilgrim (1910, 1913) and what the Geological Survey of Pakistan refers to as the Soan Formation (Cheema *et al*., 1977). It is often intricate to define the boundaries between the formations, however, from the geological or the sedimentological perspective it is best to view the Siwalik sequence as a single genetic unit (Table 1). Pilgrim recognized a succession of consecutive "faunal zones," (Kamlial, Chinji, Nagri and Dhok Pathan) initially using the term in a manner comparable to modern "stage" concept. Pilgrim's units were based on a mixture of contained fauna and lithological criteria. In most instances their super positional relationships could be demonstrated, but the boundaries of the faunal zones were not clearly defined because of mistakes in correlation. As stratigraphic concepts and nomenclature became more precise, Pilgrim's faunal zones came to be used primarily either as lithostratigraphic formations, or as chronostratigraphic "zones," or even as some confusing combination of the two (Pilbeam *et al*., 1979; Barry *et al*., 1980, 1985; Flynn, 1986).

Chronostratigraphy

Fossiliferous rocks in the Siwaliks record important Neogene faunas within different depositional contexts. In the Potwar Plateau, Pakistan, deposition is continuous throughout the Neogene. The fossiliferous Neogene rocks of northern Pakistan are singular in their level of completeness and represent almost the complete Neogene record from about 22 Ma to less than 2 Ma (Keller *et al*., 1977; Opdyke *et al*., 1979; Azzaroli and Napoleone, 1982; Tandon *et al*., 1984; Johnson *et al*., 1985; Friedman *et al*., 1992). Locality dating depends on the accuracy of the particular time scale. Permanent forests and woodlands with some interspersed grasses (mostly C_3) were present about 9 Ma. After that wooded grasslands became widespread on floodplains (Quade *et al*., 1989; Morgan *et al.,* 1994). The faunal record range from 22 to 2 Ma, and while it is the best represented between 18 and 8 Ma, and is fossiliferous throughout. The Siwalik fluvial systems in the Siwaliks extensively reshuffled and scattered the fossil remains. Resultantly, the sediments contain mostly fragmentary and incomplete fossils. Thus, it is difficult to ascertain how closely a known stratigraphic range approximates the true stratigraphic ranges for all. Pilbeam *et al*., (1996) have conducted intensive biostratigraphic surveys in order to determine the first or last occurrences of a few common taxa (for example, hipparionines and hippopotamids). The drainage patterns of the Potwar Plateau are characterized by an arrangement of intermittent streams and smaller river tributaries which have incised shallow ravines in the gently dipping Miocene-age strata. The major streams run perpendicular to strike, are typically spaced every 3-5 km, and are connected along strike by lateral valleys.

Table 1: Stratigraphic sections of the Siwalik group showing Fms. and Zones. (Boundary dates are from Barry *et al*., 2002).

<table>
<tr><th>Ma</th><th>Potwar Fms</th><th>Siwalik Subgroups</th><th>Siwalik Zone</th></tr>
<tr><td rowspan="7">0 –
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2 –
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4 –
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6 –
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8 –
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10 –
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12 --
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14 –
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16 –
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18 –</td><td rowspan="3">Soan Fm.</td><td rowspan="3">Upper Siwalik Subgroup</td><td>Boulder Conglomerate Zones</td></tr>
<tr><td>Pinjor Zone</td></tr>
<tr><td>Tatrot Zone</td></tr>
<tr><td>Dhok Pathan Fm.</td><td rowspan="2">Middle Siwalik Subgroup</td><td>Dhok Pathan Zone</td></tr>
<tr><td>Nagri Fm.</td><td>Nagri Zone</td></tr>
<tr><td>Chinji Fm.</td><td rowspan="2">Lower Siwalik Subgroup</td><td>Chinji Zone</td></tr>
<tr><td>Kamlial Fm.</td><td>Kamlial Zone</td></tr>
</table>

Taphonomy

The Siwalik Group of the Potwar Plateau, in the northern Pakistan, contains a rich vertebrate fossil record in predominantly fluvial deposits that spans for most of the Neogene. The sequences contain a broad range of fluvial deposits and the frequency of facies changes markedly over time and space (Badgley *et al*., 1995b). Taphonomic research to date has focused on the distribution of fossil localities among depositional environments, inferring to conditions of mortality and accumulation, and reconstructing the profusion of taxa in the original community (Badgley and Behrensmeyer, 1980; Badgley, 1986b; Raza, 1983; Behrensmeyer, 1988). At the level of depositional system, the particular distribution of local environments determines the habitats available to organisms. The rates and processes of preservation may vary greatly among these environments in relation to biotic and abiotic components. Recognition of changes in taphonomic selectivity facilitates the distinction between apparent and real changes in original biotas (Koch, 1987; Badgley and Gingerich, 1988). Three vital aspects of fossil assemblages verify the reliability of inferences regarding the original faunal composition, the associations amongst taxa, the rates of morphological evolution within lineages and the patterns of immigration and extinction. Changes in the preservational bias may expose significant environmental changes that can be correlated with changes in biotic composition or fossil productivity (Badgley *et. al*., 1995c; Behrensmeyer, 1988; Kidwell, 1988). Fossil assemblages from the Siwalik deposits reveal features indicative of fluvial transportation and deposition of abraded bones, bones dispersed through the sediment matrix, absence of skeletal association of the fossilized animals and lack of the more transportable elements such as vertebrae and ribs. Teeth and jaws bones are the major constituents of the assemblages.

The taphonomic study of the fossil material collected from the Siwaliks reveal a variety of pre-burial and post-burial processes that affected the bones and teeth deposited in the Siwaliks. Significant modifications were observed in the vast majority of the examined specimens. Extensive weathering cracks are indicative of the long-term exposure of the collected specimens on ground. Partly articulated, partly associated and mostly dispersed skeletal parts point out the long transportation and the significant dispersal of the occurred skeletal elements. Seismo-turbation and faulting caused the post burial fracturing of various skeletal elements.

Palaeo-environment of the Siwaliks

There are evidences that the palaeoclimate during deposition of the Siwalik Group was warm, humid, sub-tropical to tropical, and monsoonal. These evidence comes from the nature of the palaeosols (Cerling *et al*., 1993; Quade *et al*., 1989, 1995; Willis, 1993b; Zaleha, 1994), isotopic studies of marine microfossils (Wright and Miller, 1993), plant material (Sahni and Mitra, 1980), and climate modelling (Iacobellis and Somerville, 1991a,b;

Kutzbach, *et al*., 1989; Prell and Kutzbach, 1992; Ruddiman, *et al*., 1989; Raymo and Ruddiman, 1992). The relatively constant thickness of the horizons of mature palaeosols in different formations (age 15-8 Ma) in the Chinji area was taken to imply constant mean annual rainfall by Willis (1993b). However, studies of the isotopic compositions of palaeosol carbonate nodules and fossil teeth (Cerling, *et al*., 1993; Quade, *et al*., 1989, 1995) suggest a major change in vegetation from dominantly trees and shrubs to dominantly grasslands at 7-4 Ma. Morgan, *et al*., (1994) has proposed the beginning of the change at 9.4 Ma. This change in vegetation was also associated with major changes in the fauna, with less woodland-dependent fauna and more grazing fauna (Barry, *et al*., 1985; Morgan, *et al*., 1994), and a cooler and drier climate. The proposed climate change around 7.4 Ma is not reflected in changes in alluvial architecture, and it seems that climatic changes were not important enough during the deposition of the Nagri and Dhok Pathan Formations to have a marked effect on deposition (Willis, 1993b; Zaleha, 1994). There is evidence for accelerated formation of the Antarctic ice cap since c. 15 Ma, associated with episodically falling sea level, decrease in atmospheric CO_2, and general global cooling (Klootwijk *et al*., 1992; Zaleha, 1994). There is a particularly major eustatic sea level fall at c.10.8 Ma, near the base of the Nagri Formation and a vivid decrease in atmospheric CO_2, from 11 to 8Ma (Freeman and Hays, 1992). It is therefore possible that there was at least a glacial period during deposition of the Nagri Formation, and it is possible that the higher Himalayas were glaciated. Such global climatic change would not essentially have a major effect on the climate of the Indo-Gangetic foreland due to its low latitude and elevation. Zachos *et al*., (2001) have suggested similar transient climates in the Oligocene. Evidence from the modern Indus valley near the Himalayas indicates that aggradations rates increased by an order of magnitude during the last (Pleistocene) glacial advance, and have progressively decreased up to now (Jorgensen *et al*., 1993). Hence, increasing deposition rates in the Nagri Fm. may be associated to increased erosion rates and sediment supply from a partly glaciated locality (Khan *et al*., 1997).

Divisions of the Siwaliks

Hugh Falconer considered the Siwalik beds as a single continuous series of continental deposits Lydekker (1876). Falconer divided the Siwalik series into an upper and a lower division. Based upon the palaeontological evidences Pilgrim (1913) divided the Siwalik series into three divisions i.e., Upper Siwaliks, Middle Siwaliks and Lower Siwaliks. He further divided these divisions into subdivision. These subdivisions are referred to as zones. Later Anderson (1927) and Cotter (1933) used these names in relation to the lithostratigraphic units and referred to them as "stages". Lewis (1937) modified this term (stages) as Chinji Formation, Nagri Formation and Dhok Pathan Formation (Fig. 5), while Kravtchenko (1964) used Soan Formation for the Pinjor and Tatrot zones. Consequently, the Stratigraphic Committee of Pakistan formalized the Siwalik group including Soan, Dhok Pathan, Nagri and Chinji Formations. The Upper Siwaliks is approximately 6,000 feet; the Middle Siwaliks is approximately 6,000 feet and the Lower Siwaliks is approximately 4,000 feet in thickness (Colbert, 1935).

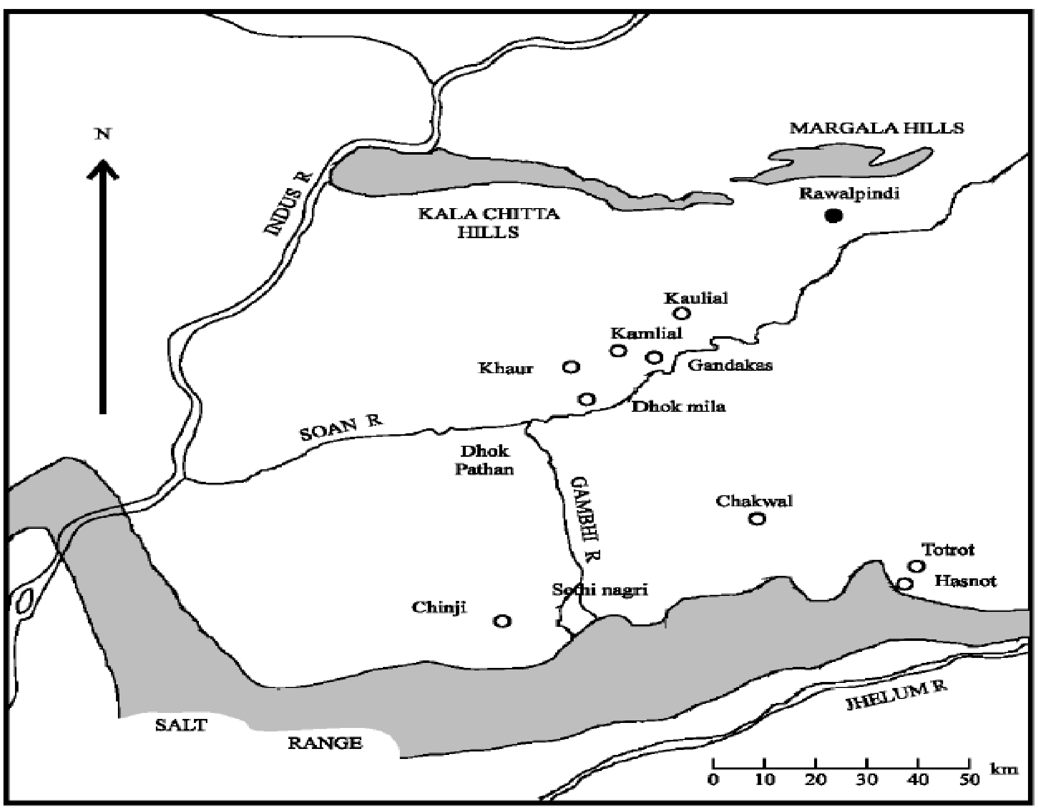


Figure 5: Map of the study section showing main fossil localities.

Lower Siwaliks

Kamlial Formation: (Fig. 6)

Pilgrim considered the lithological division between the two formations of the Lower Siwaliks as very sharp while it is quite unconvincing among those of the Middle and Upper Siwaliks. Pilgrim did not established difference between lithostratigraphic, biostratigraphic and chronostratigraphic units and entities while defining the Siwalik divisions. The Stratigraphic committee of Pakistan refers the term Kamlial Formation after the Kamlial village. Prior to its formation this rock unit has prevalently been called Kamlial stage (Wadia, 1957; Pascoe, 1959). This formation is transitional with the overlying Chinji Formation and underlying Murree Formation. Lithologically this zone is distinct from the overlying Chinji Formation. It consists of river sediments, containing numerous beds of conglomerates. Fossils are scarce, but seem to be definitely more primitive than the Chinji Formation (Colbert, 1935).

Table 2: Location, age and thickness at type locality of various Siwalik Fms. of the Potwar Plateau (Source, Barry *et al*., 2002).

Formations	Location of Type Localities	Age (Ma) (From Barry *et al*., 2002).	Thickness at Type Locality
Kamlial Formation	Lat. 33° 15'N Long. 72° 30'E	18.4-14.2	90 m and about 700 m in Soan Gorge
Chinji Formation	Lat. 32° 41'N Long. 72° 22'E	14.2-11.2	800 m
Nagri Formation	Lat. 32° 25'N Long. 72° 14'E	11.2-10.1	650 m
Dhok Pathan Formation	Lat. 33° 07'N Long. 72° 14'E	10.1- ca 3.5	900 m
Soan Formation	Lat. 32° 22'N Long. 72° 47'E	3.5-Recent	300 m

Figure 6: Profile view of the boundary between Kamlial (a) and Chinji (b) Fms.

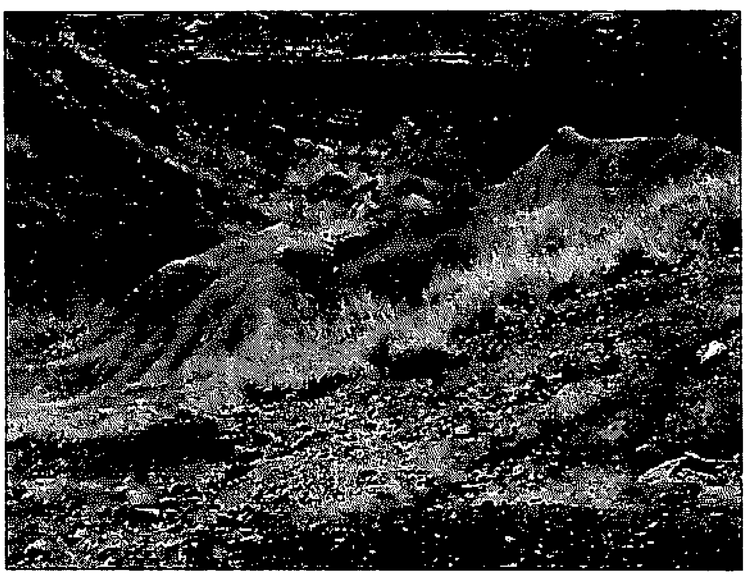


Figure 7: Dhok Bun Ameer Khatoon, Chinji Fm. (The Lower Siwaliks)

Fauna of Kamlial Fm.: Primates, Suids, *Proboscideans,* Rhinocerotids, Carnivores, Anthracotheres and Artiodactyls.

Chinji Fm: (Fig. 7)

A characteristic phase of about 2,300 feet of bright red clays, carrying beds of what Pilgrim has termed "pseudo-conglomerates." This Formation contains the typical Lower Siwalik fauna. Lewis (1937) used the term Chinji Formation. At type locality the lower contact of Chinji Formation with Kamlial Formation is gradational, while the upper contact is conformable with the Nagri Formation. The Stratigraphic Committee recommended the name Chinji Formation with type section near Chinji. It contains characteristic phase of bright red clays. It contains typical Lower Siwalik fauna (Colbert, 1935).

Fauna of Chinji Fm: Rhinocerotids in this Fm. includes *Caementodon oettingenae, Chilotherium intermedium, Chilotherium blanfordi, Aprotodon fatehjangense, Brachypotherium perimense, Didermoceros* aff. *sumatrensis, Didermoceros* aff. *abeli, Aceratherium* sp., *Eurhinoceros* sp. inc. sed., *Gaindatherium browni, Gaindatherium vidali*. Other mammalian fauna includes *Carnivores*, Chalicotheres, Suids, Primates, Rodentia, Anthracotheres, Tragulids, Bovids and Giraffes.

The middle Siwaliks

Nagri Fm.: (Fig. 8)

The Nagri type locality is located at the north of river Ghabir. Its name has been given on type locality - Sethi Nagri Village. Much of the vertebrate fossil record comprises fragmentary specimens that are widely dispersed across eroding outcrops and typified by forerunners of the Dhok Pathan fauna and by numerous holdovers from the Chinji fauna. The Lower division of the Middle Siwaliks composed of red clays that include nodules. Lewis (1937) used the term Nagri Formation, while Pascoe (1964) described it as Nagri Stage. The stratigraphic Committee of Pakistan formalized it as Nagri Formation after the village of Sethi Nagri. The Nagri Formation is conformable with the underlying Chinji Formation and overlying Dhok Pathan Formation (Colbert, 1935).

Fauna of Nagri Fm: Rhinocerotids in the Nagri Fm. includes *Caementodon oettingenae, Aprotodon fatehjangense, Gaindatherium vidali, Chilotherium intermedium, Brachypotherium perimense, Eurhinoceros* aff. *sondaicus.* Other mammalian fauna includes Primates, sciurid, Carnivores, Proboscideans, *Hipparion* small and large species, Chalicotheres, Anthracotheres, Tragulids and Bovids.

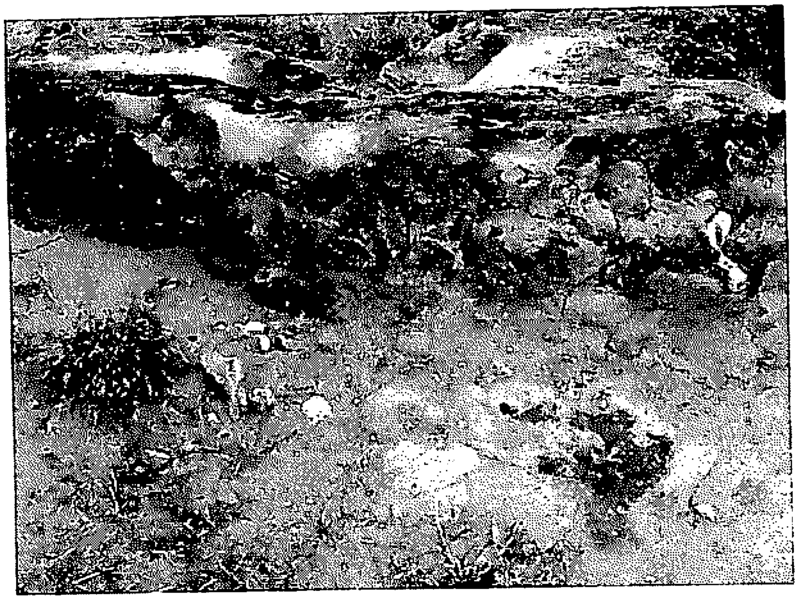


Figure 8: Upper part of the Nagri Fm. Dina, district Jhelum

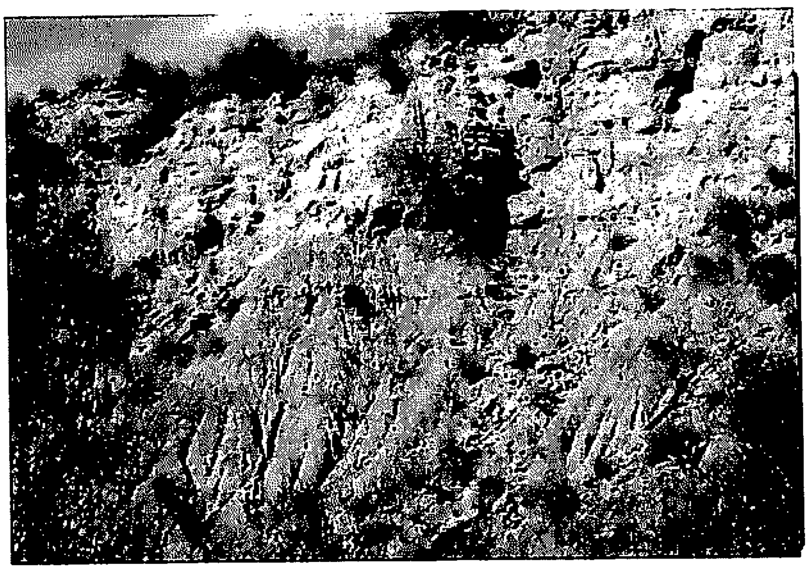


Figure 9: Dhok Pathan Fm. (the Middle Siwaliks)

Dhok Pathan Fm: (Fig. 9)

The term Dhok Pathan Zone was used by Pilgrim (1910), which was later modified as Dhok Pathan Formation by Lewis (1937). The stratigraphic Committee of Pakistan formalized it as Dhok Pathan Formation. The sediments in the Dhok Pathan Formation grade down through a considerable thickness of unfossiliferous beds into the Nagri beds. It comprises light colored sand, containing considerable amounts of unweathered igneous minerals notably feldspar, an abundantly fossiliferous horizon containing the typical Middle Siwalik fauna (Colbert, 1935).

Fauna of Dhok Pathan Fm: Rhinocerotids in the Dhok Pathan Fm. includes *Brachypotherium perimense, Rhinoceros* (*Rhinoceros*) aff. *sivalensis, Alicornops complanatum, Rhinoceros planidens, R. iraraicus, Aceratherium lydekkeri, Chilotherium intermedium.* Other mammals include Primates, Rodents, Carnivores, Artiodactyles, Proboscideans, Equids and Hipparion etc.

Upper Siwaliks: (Figs. 10-12)

Soan Fm:

Medlicott (1864) referred this rock sequence as Upper Siwaliks. Pilgrim used Tatrot and Pinjor Zones for this Formation. Kravtchenko (1964) used the term Soan Formation, which was formalized by the Stratigraphic Committee of Pakistan. The lower contact of the Formation is not conformable with the Dhok Pathan Formation and the upper contact is terminated by a boulder bed with an angular unconformity. Tatrot is built of resistant layers of grey conglomeratic sandstone, below which are two coarser and thinner beds. The lower bed is composed of rounded and subangular pebbles of pink granite, porphyrite, various quartzites, chert and purple sandstone. The upper bed is similar and rather coarser in composition than the lower bed. Lithologically these beds contrast with the underlying Dhok Pathan rocks with prevailing orange and pink colors. The pebble components in Dhok Pathan formation are quite different and less varied than the Tatrot Formation. Barry *et al.,* (2002) has recommended an age from 3.5 to 3.3 Ma (Table 2) for the Tatrot Formation and Hussain *et al*., (1992) suggested that the Tatrot Formation might be older than previously thought and could be in a range between 3.2 and 3.4 Ma. According to Dennell *et al*., (2006) the Upper Siwaliks span the Late Pliocene to Middle

Pleistocene, ca. 3.3–0.6 Ma, and are among the longest fluvial sequences of their age in the world. Since Pilgrim's (1910, 1913) classic studies, they have been subdivided into three lithological and faunal stages: the Tatrot, Pinjor and Boulder Conglomerate. Researchers in India (Azzaroli and Napoleone, 1982; Ranga Rao *et al*., 1988) and Nepal (Corvinus and Nanda, 1994) have maintained these divisions, and refined Pilgrim's scheme by using magnetic polarity zonation. As a result, they place the Tatrot–Pinjor boundary at the Gauss–Matuyama boundary, 2.58 Ma (Cande and Kent, 1995), and the end of the Pinjor Stage at 0.78 Ma, just above the Brunhes–Matuyama boundary. The Boulder Conglomerate Stage, that follows is defined by coarse and often conglomeratic deposits, and marks the end of the Upper Siwalik series. As a result of tectonic disruption and fore-deep sedimentation, the timing of the end of the Pinjor Stage and the inception of conglomeratic deposition varies considerably between drainage basins (Opdyke *et al*., 1979; Rendell *et al*., 1989), and thus the Boulder Conglomerate Stage is not synchronous across the top of the Upper Siwaliks.

Fauna of Soan Fm.: Rhinocerotids include *Rhinoceros sivalensis*, *Rhinoceros sondaicus, Punjabitherium platyrhinus*, *Rhinoceros kendengindicus* and *Rhinoceros sondaicus.* Other mammals include Proboscideans, Artiodactyls, Perissodactyls, carnivores and rodents etc.

Figure 10: Jari kas, Pinjor Fm.(the Upper Siwaliks), 1 Km Southeast of Jari Kas, Mirpur Azad Kashmir

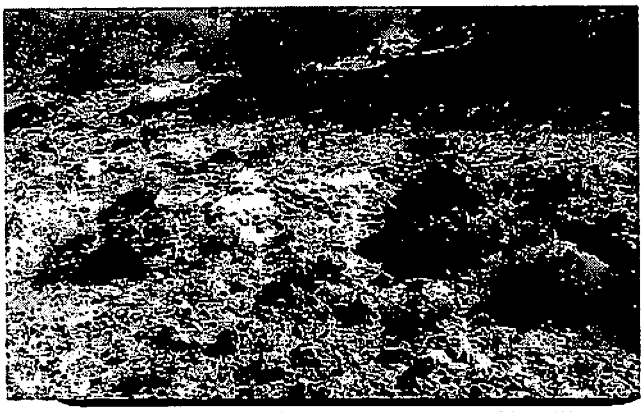


Figure 11: Sar Dhok, Pinjor Fm. (the upper Siwaliks) near Sar Dhok village, Gujrat, Pakistan

Figure 12: Boulder conglomerates near Khural Sharif, 6 Km Northeast of Dina, Jhelum (The upper Siwaliks).

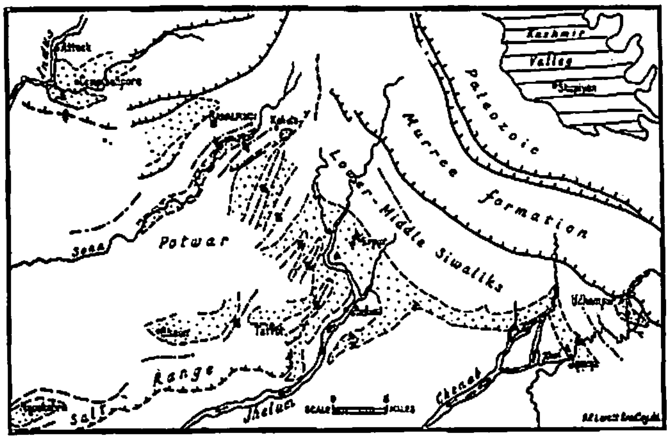


Figure 13. Sketch map showing structural pattern and distribution of Upper Siwalik beds in the NW Punjab Upper Siwaliks = stippled; Kashmir Pleistocene = ruled; major Pliocene anticlines = broken line with dots; major over-thrusts = solid or broken lines with right angle intervals (Source, De Terra and De Chardin, 1936).

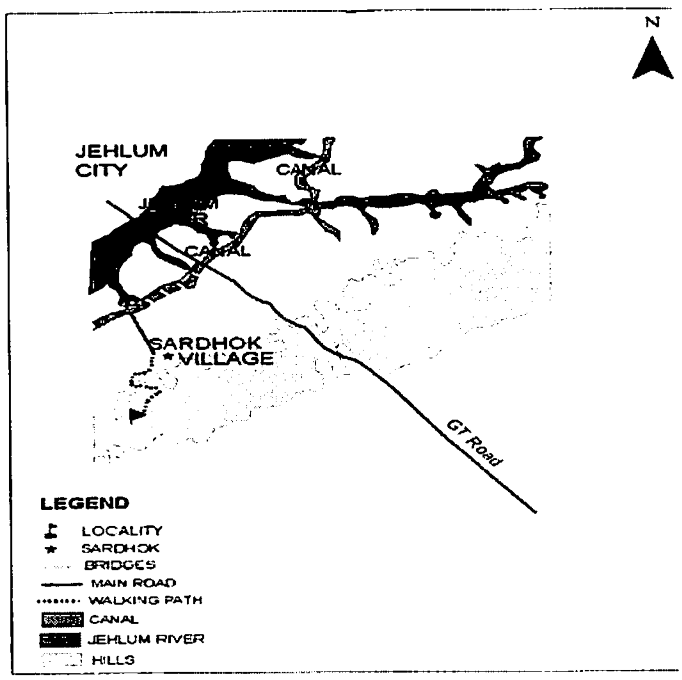


Figure 14: Map showing upper Siwalik beds of the study section in the Pabbi Hills, Sar Dhok, Gujrat, Pakistan

REVIEW OF THE FOSSIL RHINOCEROSES

Studies on systematics, biostratigrapy and palaeoecology of the Family Rhinocerotidae during the last couple of decades have been done by Hooijer, (1958, 1966); Heissig (1972, 1975, 1976, 1981, 1989, 1999); Guerin (1980a and b, 1982, 1985, 1994a, b); Fortelius (1982); Groves (1983); Prothero *et al*., (1986, 1989); Fortelius and Heissig (1989); Cerdeño (1992, 1995) and Cerdeño and Nieto (1995) and many others. The Family Rhinocerotidae was widely spread during the Cenozoic all through North America, Asia, Europe, and Africa. Besides their wide geographical distribution, rhinocerotids constitute a common element within Cenozoic faunas as predominant large herbivore in mammalian communities. Fossil rhinos have been unequally treated in palaeontological studies.

Family Rhinocerotidae originated with the evolution of the first ungulates fifty million years ago. Rhinoceroses belong to the mammalian order Perissodactyla that includes odd-toed hoofed mammals and are grouped with even-toed hoofed mammals (Artiodactyls) in the Ungulates (McKenna and Bell, 1997; Holbrook, 1999; Wood, 1927). Radinsky (1966, 1967) modified Perissodactyl classification by treating Ceratomorpha, Hippomorpha and Ancylopoda as suborders. Phylogenetically the family Rhinocerotidae is included within the order Perissodactyla. The greatest difference between species lies in their dentition (Penny, 1987). Rhinoceroses have 24 - 44 teeth, mostly premolars and molars for grinding having dental formula 1-2/0-1, 0/1-1, 3-4/3-4, 3/3. The canines and incisors are vestigial except for the lower incisors in Asian rhinos, which are developed into powerful slashing tusks. In grazing rhinoceroses, the cheek teeth are generally hypsodont and subhypsodont, but they are brachydont in many genera. All rhinoceros species have transverse lophs of enamel as a characteristic feature in the cheek teeth. Presently family Rhinocerotidae includes five extant species. Each of these species has unique evolutionary characteristics *(Lacombat,* 2005). These species represent the branching of the family from common ancestry over millions of years. Existing range of family Rhinocerotidae has been limited to the warmer parts of Asia and Africa, but in the Oligocene it extended all around the Northern hemisphere, Europe, Asia and North America (Scott, 1941; Scott and Osborn, 1883). The first recognizable rhinoceros (e.g., *Hyracodon*) appeared in the Eocene as relatively slender and elegant animals. Arising from these running rhinoceroses were several lines which became abundant in most continental regions during the late Miocene. The extreme in size and weight (30 tones) was attained by *Indricotherium*, the largest land mammal that ever lived.

Palaeontologists have studied rhinoceros, in order to academically understand a great number of species ranging in size from the Miocene through Pleistocene and into recent times. The true rhinoceroses are supposed to have been evolved somewhere near the Oligocene genus *Trigonias.* The hornless Baluchitheres evolved from this starting point with aberrant tusks and the Diceratheres with normal tusks but with a pair of laterally placed horns. The remainders of the Oligocene rhinoceroses of the Holarctic region are considered to be a collection of various genera termed as "the Caoenopus group". From this group all subsequent rhinoceroses have evolved along separate lines (Brunet, 1979; and Roman, 1912).

Fossil rhinoceroses in North America

Fossil rhinoceroses were common large-bodied terrestrial herbivores during the Middle Cenozoic in North America. They became extinct on this continent about 4.5 million years ago. Systematics and biostratigraphic distribution of North American rhinoceroses basically follow Prothero (1998). The Late Eocene shows the first climax of new rhinocerotid records with three genera and five species. The Late Eocene shows the first wide expansion of the family in North America, with seven species of four different genera (Cerdeño, 1995; Fig, 15). *Teletaceras radinskyi* and *T.mortivallis* are the most primitive representatives of the Family Rhinocerotidae in the Middle Eocene, probably immigrants from Asia (Hanson, 1989). According to Prothero at the end of the middle Eocene, there are indications of the presence of *Penetrigonias.* This genus is represented by three species during the Late Eocene. Three other genera are also present throughout the Late Eocene: *Trigonias* with *T. osborni* and *T. wellsi, Amphicaenopus platycephalus,* and *Subhyracodon mitis. A. platycephalus* and *Penetrigonias* are present in the middle Oligocene, but they have not been recorded during the Early Oligocene. The earliest Oligocene has observed a nominal diversity, implying the extinction of seven rhinoceros species, although two of them were discovered again from the early Oligocene (Prothero, 1998). In North America most species continued into the Late Miocene, and the diversity slightly decreased. *Menoceras* appeared in the Early Miocene, followed by other immigrants during the late Early Miocene. The turnover between Early and Middle Miocene implies the extinction of the cursorial rhinocerotids and the appearance of the brachypodial Teleoceratini and Alicornopini (Cerdeño, 1995). The Family Rhinocerotidae reaches its maximal diversity through Middle Miocene and earliest Late Miocene. *Subhyracodon occidentale* is the only species known in the Early Oligocene, and is followed by the *S. tridactylum. Subhyracodon* gave rise to the genus *Diceratherium* with three species. *D. armatum* was replaced by *D. niobrarense.* Another genus *Menoceras* appeared and is considered as a European immigrant with closer relationships with *Pleuroceros* and *Protaceratherium* (Prothero *et al.,* 1986, 1989). According to Cerdeño (1995) *Floridaceras whitei* is the first North American acerathere in the early late early Miocene, very close to *Aceratherium*. Other Aceratherinae (*Brachypotherium, Teleoceras, Peraceras* and *Aphelops*) are already present by the early Middle Miocene. *Peraceras* is present until the late Miocene, while the other two remain until the end of the Miocene, when rhinos became nearly extinct in North America. The genus *Peraceras* appears to be close to the European *Alicornops.* The genus *Teleoceras* and the *Aphelops* are close to *Chilotherium* and the other Eurasian teleoceratines (Cerdeño, 1995). *Teleoceras* is the most diversified genus with eight recognized species in North America (Prothero, 1998).

Rhinoceroses disappeared from North America, and so did the aceratheres. The absence of rhinoceroses in South America seems to be due to the extinction of rhinocerotids in North America before the Panama land bridge was established during the Pliocene. Although a tooth fragment indicates the presence of a relict form into Pliocene times in North America (Madden and Dalquest, 1990).

North American rhinocerotid genera include; *Teletaceras, Trigonias, Amphicaenopus, Subhyracodon, Aphelops, Penetrigonias*, *Subhyracodon, Diceratherium*, *Peraceras*, *Menoceras and Floridaceras.*

Fossil rhinoceroses in Europe

Most important rhinoceros genera *Ronzotherium* and *Mesaceratherium* remained almost restricted in the Oligocene of Europe. Both genera are close to each other, and seem to be related to the North American *Trigonias* (Heissig, 1989; Cerdeño, 1995). *P. pleuroceros* gave a short appearance in the Late Oligocene-Early Miocene corresponds to the rare (Cerdeño, 1995), although previously related to the North American *Menoceras* (Prothero *et al*., 1986, 1989).

Diaceratherium (Brunet *et al*., 1987; Cerdeño, 1993) and *Protaceratherium* (Yan and Heissig, 1986; Cerdeño, 1995) are two other Oligocene lineages that continue into the Early Miocene. The *Diaceratherium* is a teleoceratine closely related to the younger *Brachypotherium,* probably having its origin among *'Brachypotherium'* from the Asian Oligocene. *Protaceratherium* evolved in Europe with five successive species until the early-middle Miocene. The phylogenetic relationships of *Protaceratherium* are not well established; and it may have some affinity with Oligocene-Miocene North American genera (Prothero, *et al*., 1986; Cerdeño, 1995).

Four other rhinoceros genera appear through the Early Miocene of Europe including; *Prosantorhinus, Brachypotherium* (Cerdeño, 1993, 1996a), *Lartetotherium* (Ginsburg, 1974; Cerdeño, 1986), and *Hispanotherium* (Cerdeño, 1995). *Hispanotherium* and other iranotheriines are better represented in the Miocene of Asia. *Alicornops* and *Acerorhinus* appear during the late Aragonian. *Alicornops* is also close to the above mentioned genera, but ranked in the tribe Alicornopini (Cerdeno, 1995).

Chilotherium and *Ceratotherium* briefly appear in southeastern Europe during the latest Turolian (Solounias, 1981; Geraads, 1988). The Plio-Pleistocene in Europe has yielded the genus *Stephanorhinus,* which coexisted with *Coelodonta* during the Late Pleistocene (Guerin, 1980a). Both genera widely spread throughout Eurasia, but *Stephanorhinus* include some endemic species in Western Europe. The Asian *Elasmotherium* also appears in Eastern Europe in the middle Pleistocene.

European rhinocerotid genera include; *Ronzotherium, Mesaceratherium, Menoceras, Diaceratherium Protaceratherium, Protaceratherium, Lartetotherium*, *Hispanotherium*, *Diaceratherium, Prosantorhinus, Brachypotherium, Lartetotherium, Acerorhinus*, *Aceratherium, Alicornops, Chilotherium, Ceratotherium*, *Coelodonta*, *Stephanorhinus, Elasmotherium.*

Fossil rhinoceroses in Asia

Abundant and very diverse fossil rhinoceroses have been discovered throughout Asia. Hanson (1989) recognized the presence of *Teletaceras* in Asia, with the species *T. borissiaki* Beliajeva from the Late Eocene of Artem (Maritime Province, Russia). Two possible Rhinocerotidae genera *'Ronzotherium* and *Aprotodon'* were present in the Late Eocene-Early Oligocene. *Ronzotherium* is restricted to the Early Oligocene with two species, *R. orientate* and *R. brevirostre* (Heissig, 1969; Russell and Zhai, 1987). *Aprotodon* appeared in the Early Oligocene, and evolved in Asia until the early Late Miocene with *A. fatehjangense* (Beliajeva, 1954; Heissig, 1972; Wang, 1992). Taxa attributed to the genera *Aceratherium* and *Brachypotherium* are present in the Late Oligocene of Asia. *Protaceratherium* represented by the species *P. minutum* is also recorded in the Late Oligocene (Russell and Zhai, 1987). *Protaceratherium* is present in the Middle Miocene of Asia with the species *P. gracile* (Young, 1937a, b). *Protaceratherium* would have migrated several times between Asia and Europe. The Early Miocene record of Asian rhinoceroses is not well established. Forster-Cooper (1934) recognized two species of *'Aceratherium'* and *Chilotherium smith-woodwardi,* Within the Dera Bugti fauna. Heissig (1972) ascribed *Chilotherium smith-woodwardi* in the genus *Aprotodon*. *A. blanfordi* (Lydekker) was also recorded in the Middle Miocene levels of the Siwaliks. Colbert (1935) and Heissig (1972) partially synonymized *A. blanfordi* to *Aprotodon fatehjangense.* Savage and Russell (1983) cited some species from Dera Bugti that appeared in the more recent levels of Chinji (Heissig, 1972). Sahni and Mitra (1980) has reported the presence of *Rhinoceros sivalensis* in the Gaj Series (Early Miocene of Pakistan), but this species was defined in the Pliocene and mostly considered to be a synonym of *R. unicornis* (Heissig, 1972; Laurie *et al*., 1983; Groves, 1983). The Middle Miocene Asia has yielded three important lineages including, *Chilotherium, Brachypotherium,* and *Hispanotherium.* The first two have a wide temporal distribution. The same species of each genus is present in the Siwaliks throughout the Middle and Late Miocene (Heissig, 1972). Many other species of *Chilotherium* has been recorded during the Late Miocene (Ringstrom, 1924; Tung *et al*., 1975; Qiu and Yan, 1982; Zheng, 1982; Li *et al*., 1984; Tsiskarishvili, 1987). Cerdeño (1996b) and Inigo and Cerdeño (1997) have considered *Hispanotherium* with four Middle Miocene species, as closely related to the Late Miocene *Iranotherium* and probably *Ninxiatherium*. *Gobitherium mongoliense* is a rare species of the early Middle Miocene whose relationships are not well established (Cerdeño, 1996b). *Acerorhinus,* previously considered as a subgenus of *Chilotherium* by Heissig (1975) is well represented from the late Early Miocene to the Late Miocene of Asia with five species.

Gaindatherium described by Colbert (1934) has a middle-Late Miocene distribution with two successive species described in the Siwaliks (Heissig, 1972). It seems to be more closely related to the genus *Lartetotherium* than to *Rhinoceros* as previously discussed by Colbert (Cerdeño, 1995). The Turolian of western Asia observed a short appearance of the African genus *Ceratotherium,* with *C. neumayri.* Tsiskarishvili (1987) reported the presence of *Diceros gabuniai* in the Vallesian of the Caucasus. Cerdeño (1995) has recommended reexamination of the generic ascription of that form. The genera *Rhinoceros* and *Punjabitherium* (Khan, 1971a) extend back to the Early Pliocene. *Dicerorhinus* appears at the beginning of the Pleistocene *(D. lantianensis;* Xu, 1989). *R. sivalensis* from the Early Pliocene of the Siwaliks has been considered as a subspecies of *R. unicornis* (Groves, 1983; Laurie *et al*., 1983), as well as the middle Pleistocene *R. kendengindicus* (Guerin, 1980b). Hussain *et al*., (1992) has described *Rhinoceros* s.l. in the Late Pliocene of Pakistan. According to Guerin (1980a), Li *et al*., (1984), Xu (1986) and Qiu (1990) *Stephanorhinus etruscus, S. hemitoechus, S. kirchbergensis,* and *Coelodonta antiquitatis* are present throughout Asia as well as

Europe in Plio-Pleistocene times. Chow (1978) established a second species of *Coelodonta, C. nihowanensis,* in the Early Pleistocene of China. Different species of *Elasmotherium* including *E. lagrelii, E. caucasicum, E. sibiricum, E. peii* and *E. inexpectatum* (Ringstrom, 1924; Guerin, 1980a; Chow, 1979) were described from the Late Pliocene to Late Pleistocene.

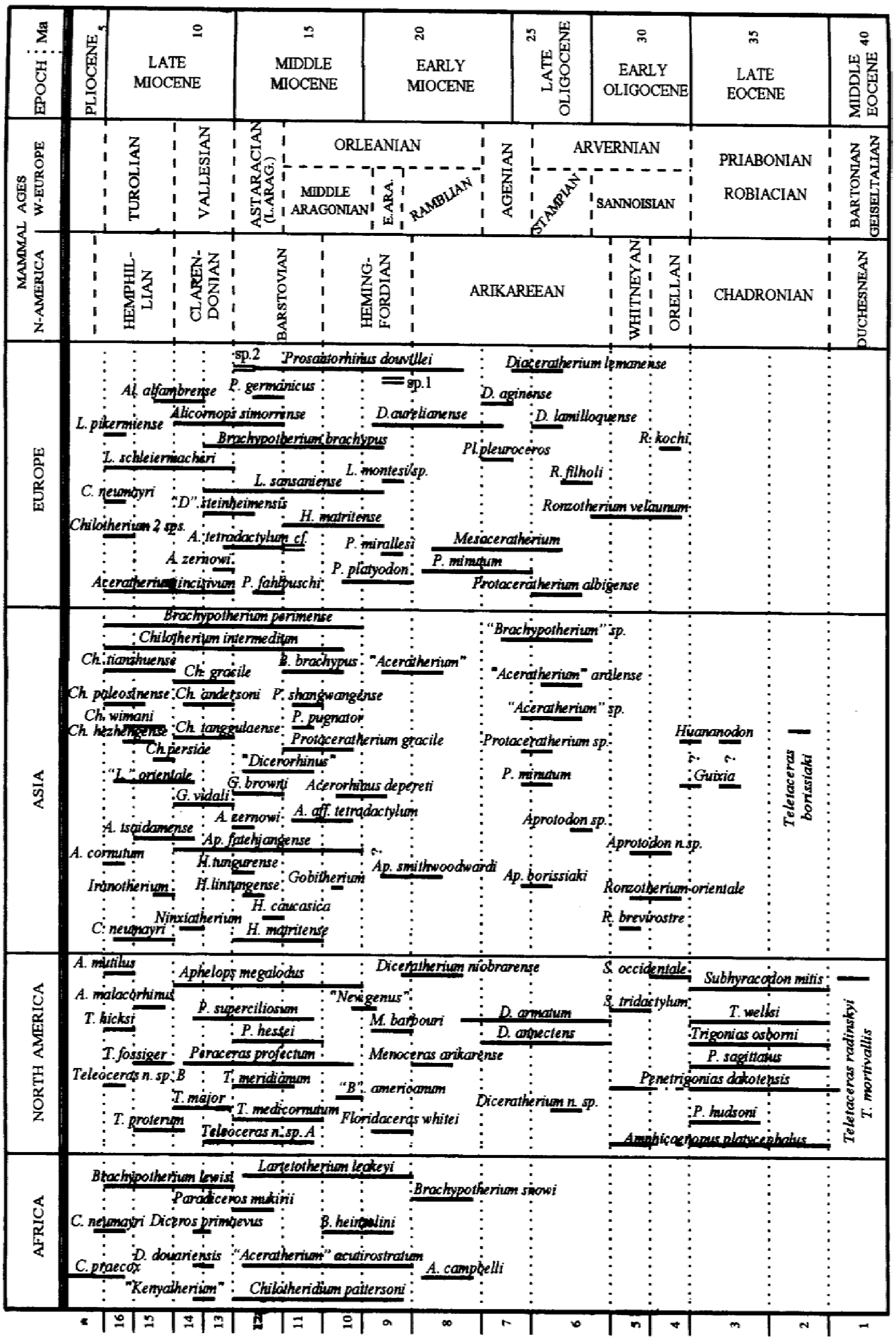
Important Asian rhinocerotids genera includes; *Teletaceras, Ronzotherium, Aprotodon, Protaceratherium* , *Aceratherium*, *Chilotherium, Rhinoceros, Hispanotherium, Iranotherium, Ninxiatherium, Gobitherium, Acerorhinus, Gaindatherium, Lartetotherium, Ceratotherium*, *Diceros*, *Punjabitherium*, *Stephanorhinus*, *Coelodonta* and *Elasmotherium.*

Fossil rhinoceroses in Africa

The early African rhinoceroses belong to the genera *Brachypotherium* and *'Aceratherium'* (Hooijer, 1963; Hamilton, 1973) probable immigrants from Europe and Asia. The *Brachypotherium* is represented by *B. snowi, B. heinzelini,* and *B. lewisi* throughout the Miocene, although it is not recorded during the Middle Miocene. *Aceratherium* begins with *A. campbelli* in the Early Miocene, followed by *A. acutirrostratum* in the Middle Miocene. At this time *Chilotheridium pattersoni* (Hooijer, 1971) and *Lartetotherium leakeyi* (Hooijer, 1966) were common.

The lineages leading to the present African forms are established through late Middle and Late Miocene (Cerdeño, 1995). *Paradiceros mukirii* is the Middle Miocene form belonging to the dicerotine group, and *Diceros* and *Ceratotherium* appear during the Late Miocene, although *Diceros* has not been recorded during the latest Miocene, since Geraads (1988) has recognized *Diceros pachygnathus* as *Ceratotherium neumayri*. The early Late Miocene species *Diceros primaevus* previously ascribed to the genus *Dicerorhinus* is now recognized as *Diceros* (Geraads, 1986). The living species *D. bicornis* has been described from Early Pliocene times and *C. simum* from Late Pliocene (Guerin, 1980a). A moderately known *Kenyatherium,* has been reported from the early Late Miocene of Kenya (Aguirre and Guerin, 1974). Guerin (1980b, 1985) has reported *Stephanorhinus hemitoechus* from North Africa in middle-late Pleistocene sites. African genera include; *Brachypotherium, Aceratherium,* *Chilotheridium*, *Lartetotherium*, *Paradiceros*, *Diceros*, *Ceratotherium*, *Kenyatherium* and *Stephanorhinus*.

Figure 15: Biostratigraphic and geographic distribution of the family Rhinocerotidae (Source Cerdeño, 1998).


EPOCH : Ma
PLIOCENE
LATE MIOCENE
MIDDLE MIOCENE
EARLY MIOCENE
LATE OLIGOCENE
EARLY OLIGOCENE
LATE EOCENE
MIDDLE EOCENE
10
15
20
25
30
35
40
MAMMAL AGES
W-EUROPE
N-AMERICA
TUROLIAN
VALLESIAN
ASTARACIAN (L.ARAG.)
ORLEANIAN
MIDDLE ARAGONIAN
E.ARA.
RAMBLIAN
AGENIAN
ARVERNIAN
STAMPIAN
SANNOISIAN
PRIABONIAN
ROBIACIAN
BARTONIAN
GEISELTALIAN
HEMPHIL-LIAN
CLAREN-DONIAN
BARSTOVIAN
HEMING-FORDIAN
ARIKAREEAN
WHITNEYAN
ORELLAN
CHADRONIAN
DUCHESNEAN
EUROPE
sp.2
Prosantorhinus douvillei
Diaceratherium lemanense
Al. alfambrense
P. germanicus
sp.1
D. aginense
L. pikermiense
Alicornops simorrense
D. aurelianense
D. lamilloquense
Brachypotherium brachypus
R. kochi
Pl. pleuroceros
L. schleiermacheri
L. montesi sp.
L. sansaniense
R. filholi
C. neumayri
"D". steinheimensis
Ronzotherium velaunum
H. matritense
Chilotherium 2 sps.
A. tetradactylum cf.
P. mirallesi
Mesaceratherium
A. zernowi
P. minutum
P. platyodon
Aceratherium incisivum
P. fahlbuschi
Protaceratherium albigense
ASIA
Brachypotherium perimense
"Brachypotherium" sp.
Chilotherium intermedium
Ch. tianzhuense
B. brachypus
"Aceratherium"
Ch. gracile
"Aceratherium" aralense
Ch. paleosinense
Ch. andersoni
P. shangwangense
"Aceratherium" sp.
Ch. wimani
P. pugnator
Ch. habereri
Ch. tanggulaense
Protaceratherium gracile
Protaceratherium sp.
Huananodon
Ch. persiae
"Dicerorhinus"
"L." orientale
G. browni
Acerorhinus depereti
P. minutum
Guixia
Teletaceras borissiaki
G. vidali
A. zernowi
A. aff. tetradactylum
A. tsaidamense
Aprotodon sp.
Ap. fatehjangense
Aprotodon n.sp.
A. cornutum
H. tungurense
Ap. smithwoodwardi
Ap. borissiaki
Iranotherium
H. lintungense
Gobitherium
Ronzotherium orientale
H. caucasica
Ninxiatherium
R. brevirostre
C. neumayri
H. matritense
NORTH AMERICA
A. mutilus
Aphelops megalodus
Diceratherium niobrarense
S. occidentale
Subhyracodon mitis
A. malacorhinus
"New genus"
S. tridactylum
T. hicksi
P. superciliosum
D. armatum
T. wellsi
M. barbouri
P. hessei
D. annectens
Trigonias osborni
T. fossiger
Peraceras profectum
Menoceras arikarense
P. sagittatus
Teleoceras n. sp. B
T. meridianum
Penetrigonias dakotensis
"B". americanum
T. major
T. medicornutum
Diceratherium n. sp.
T. proterum
Floridaceras whitei
P. hudsoni
Teleoceras n. sp. A
Amphicaenopus platycephalus
Teletaceras radinskyi
T. mortivallis
AFRICA
Brachypotherium lewisi
Lartetotherium leakeyi
Brachypotherium snowi
Paradiceros mukirii
C. neumayri
Diceros primaevus
B. heinzelini
D. douariensis
"Aceratherium" acutirostratum
C. praecox
A. campbelli
"Kenyatherium"
Chilotheridium pattersoni
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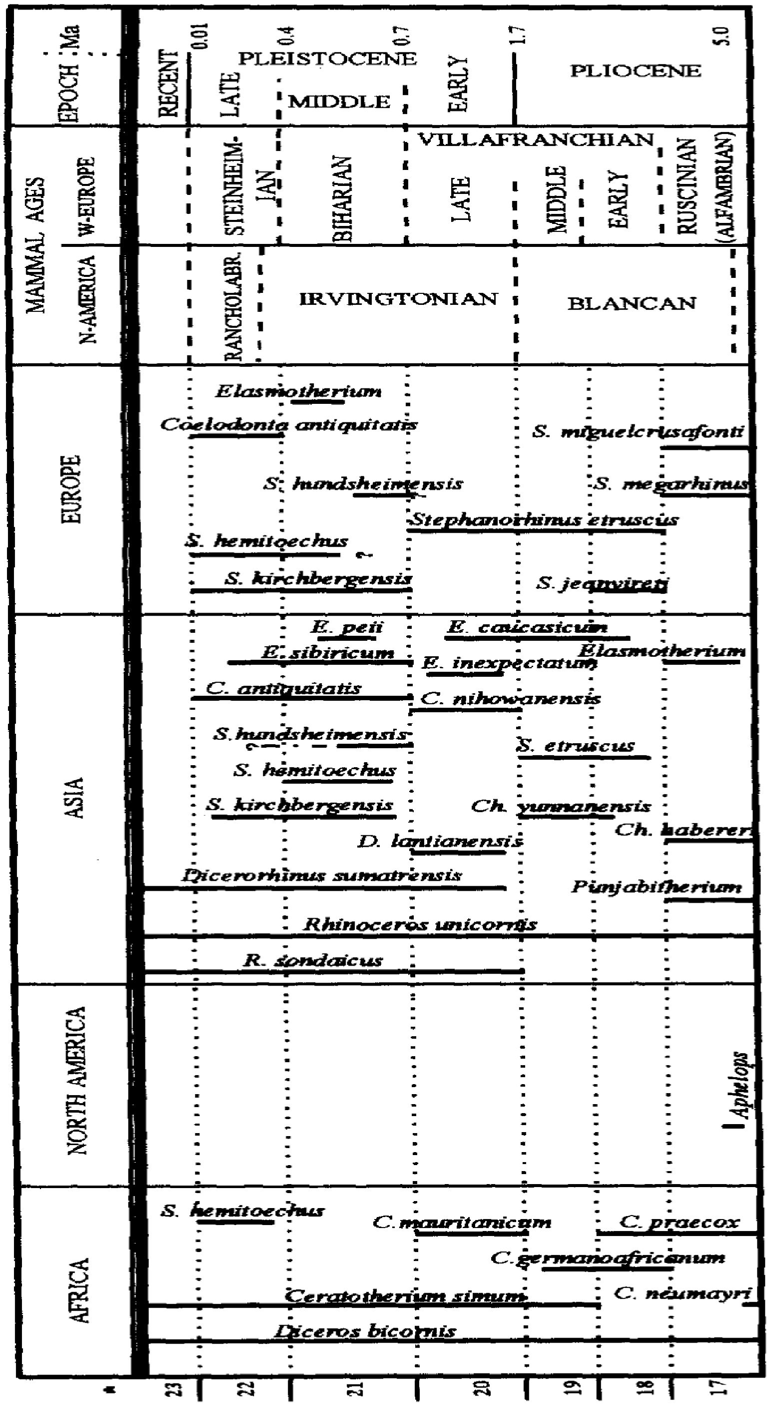

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FOSSIL RHINOCEROSES IN PAKISTAN

Forster-Cooper (1934) has documented two species of *Aceratherium* and *Chilotherium* from the Dera Bugti, Baluchistan, Pakistan. Rhinocerotids described from Dera Bugti includes *Protaceratherium sp.; Plesiaceratherium sp.; Hoploaceratherium* sp.*; Aprotodon blanfordi; Brachypotherium perimense; Dicerorhinus shahbazi; Dicerorhinus* cf. *abeli* and *Coementodon oettingenae* (Antoine, *et al*., 2003a and b).

Savage (1967), and Savage and Russel (1983) reported some species from Dera Bugti that appears in the more recent levels of the Chinji Formation. Rhinoceroses described from different levels of the Manchar Fm. include *Aprotodon fatehjangense*, *Gaindatherium browni*, Rhinocerotidae, genus and species indet, *Chilotherium intermedium* and *Brachypotherium perimense* (Cerdeño, 1995).The *Chilotherium* was later ascribed to the genus *Aprotodon* (Heissig, 1972). *Aprotodon blanfordi* (Lydekker) was also present in the Middle Miocene levels of the Siwaliks and partially synonymized to *Aprotodon fatehjangense* (Colbert, 1935; Heissig, 1972). Heissig (2003) has reported the diversity and species composition of rhinoceroses in three regions of different faunal history including the Siwaliks of Pakistan. Rhinocerotid taxa described from the Siwaliks of Pakistan include *Chilotherium*, *Brachypotherium*, *Aprotodon*, *Rhinoceros, Gaindatherium* and *Caementodon* (Heissig, 2003). Sarwar (1971, 1973) has described some remains of *Rhinoceros kendengindicus* and *Pliotriplopus chinjiensis* from the Pinjor and Chinji Fms. of the Siwaliks of Pakistan. The strong diversity declines from the latest Miocene onward resulted in nearly complete disappearance of the Aceratheriinae, except for the presence of *Chilotherium* in Asia throughout the Pliocene (Cerdeño, 1998). Antoine (2002a and b), Antoine, *et al*., (2004), Metais *et al*., (2009) and Antoine and Welcomme, (2000) have described various rhinocerotid genera from Oligocene and Miocene fossiliferous formations of Dera Bugti. Rhinocerotid fauna of the Siwaliks of Pakistan includes; *Brachypotherium perimense, Chilotherium blanfordi, Didermoceros* aff. *sumatrensis, Didermoceros* aff. *abeli, Aceratherium* sp., *Eurhinoceros* sp. inc. sed., *Gaindatherium browni*, *Gaindatherium vidali, Caementodon oettingenae, Aprotodon fatehjangense, Eurhinoceros* aff. *sondaicus, Chilotherium intermedium complanatum, Chilotherium intermedium intermedium, Rhinoceros* (*Rhinoceros*) aff.

sivalensis, Rhinoceros sivalensis, Coelodonta platyrhinus, Pliotriplopus chinjiensis and *Rhinoceros kendengindicus.*

Despite the work done by the previous workers, many morphological aspects of this group remains to be settled. This is true specifically for species and for genera as well. Recently, a worth identifying collection has been made by the author from different formations of the Siwalik Hills of Pakistan. The collected material so far appears to be very much promising and shows a great diversity in the crown structure of the cheek teeth. In the light of present material there is a strong need for the revision of the unsettled forms of the extinct rhinoceros. The revision may add new information to the known classification and evolutionary trends of the group.

Collection Methodology: Various fossiliferous localities in different Fms. of the Siwaliks were visited repeatedly from 2005 to 2008 for collection of rhinoceros fossils. Different collection methods have been employed in order to discover rhinoceros remains. Surface collection has been the primary means of the collecting remains of the rhinoceros. Although, excavations were done at localities where dense concentrations of fossil bones occur in situ within sandstone with alternate clay and conglomerate. The fossil remains of rhinoceroses described in the present study comprise collection from lower to upper Siwaliks. Different Formations of the Siwalik Hills were investigated comprehensively. Resultantly worth identifying specimens of rhinoceros were collected. Some rhinoceros specimens collected from the Dhok Pathan and Tatrot Formations already present in the Palaeontology Laboratory, Department of Zoology, University of the Punjab, Lahore, Pakistan, are also included in this research work. During fieldwork by the author, most of the specimens were found partly exposed and were excavated, while a few more were found lying completely exposed on the surface. The embedded fossil material was cautiously excavated with the help of geological hammers, chisels, fine needles, penknifes, hand lences and brushes. In the laboratory, the material was carefully washed; cleaned and prepared for study. Using various types of gums such as Araldite, peligom, magic stone, Elfy, Elite and Fixin, broken parts were assembled. The catalogue numbers of the specimens consist of series i.e., yearly catalogued number and serial catalogued number, so figures on the specimen represents the collection year and serial number of that year. For example, 2004/11, the upper figure denotes the collection year and the lower one the serial number of the respective year (Table 3). Various measurements of the specimens in millimeters were taken with the help of metric Vernier Calipers. A digital camera (Canon- EOS 350 D) was used to photograph the studied specimens and amended hard copies were prepared by using Adobe Photoshop.

Objectives of the Present Study

The main objective of this study is to provide the first complete documentation of the Siwalik Rhinoceroses by disseminating knowledge regarding taxonomy and distribution of the Siwalik Rhinoceroses. An ecologically important group, the rhinoceroses, was selected for the study as the collected rhinoceros fossils presented notable diversity and thus could provide significant taxonomic, biostratigraphic and palaeo-environmental information.

STUDY MATERIAL

Table 3: List of the studied specimens, mentioning the relevant localities.

Family Rhinocerotidae	**Specimen no.**	**Position**	**Formation/ Locality**	**Co- ordinates**
Rhinoceros sondaicus	PUPC 67/145 PUPC, 67/145a PUPC 67/145b PUPC 67/145c PUPC 67/145d	lP2-M3 rP4-M1 rP2 rP3 lp4 and lm3	Pinjor (South of Sar Dhok, Gujrat)	32° 49 761 N 73° 43 947 E
Rhinoceros sivalensis	PUPC07/37 PUPC07/38 PUPC 07/39 PUPC 07/40	rPI-M3 lPI-M3 lm2 rm1	Tatrot (400 meters west of Tatrot Village)	--
Punjabitherium platyrhinus	PUPC 07/168 PUPC 07/167	rP3 lM1	Pinjor (Jari Kas, Mirpur)	33° 06 236 N 73° 50 012 E

Gaindatherium browni	PUPC02/146 PUPC 02/147 PUPC08/123 PUPC08/124 PUPC 07/107 PUPC 02/08 PUPC 86/146 PUPC 07/41 PUPC 07/42 PUPC02/11 PUPC 02/155	rP1 rP2 rP3 rP4 lP4 lM1 lM1 rM3 rM3 rp2 rm3	Chinji (Dhok Bun Ameer Khatoon) Lava (Chinji Fm.) Dhok Bun Ameer Khatoon	32°47 480 N 72° 55 572 E 32° 36 608N 71° 57 108 E 32°47 480 N 72° 55 572 E
Gaindatherium vidali	PUPC 08/125 PUPC 84/61 PUPC 07/101 PUPC 07/102	D3 rP2 rP4 rM1	Lava, upper Chinji Fm.	32° 36 608N 71° 57 108 E

Alicornops complanatum	PUPC02/110 PUPC 07/143 PUPC 00/98 PUPC 02/13	D2-4 lD4 rd2-m1 rd3-m1and ld2-m1	Dhok Pathan Fm. (south-west of Dhok Pathan rest house)	33° 06 758N 72° 20 382E
Alicornops aff. *laogouense*	PUPC 07/46 PUPC 07/47 PUPC 07/48	lP3-M3 rP2-M2 lp4-m1	Kamlial Fm.	Lat. 33° 15'N Long. 72° 30'E
Chilotherium intermedium	PUPC 97/84 PUPC 08/01 PUPC 07/93 PUPC 07/94 PUPC 08/02 PUPC 07/ 95 PUPC 29/99 PUPC 02/109	lP3 rp4-m3 rP3-M3 lp2-m1 rP2-m3 rm2 lm1 lm3	Chinji Fm. Nagri Fm.(Khokhar Zair, Chakwal) Dhok Pathan Fm.	33° 11 900N 72° 21 427E 32° 39 283N 72° 52 457E 33° 07 575N 72° 22 189E
Brachypotherium perimense	PUPC 07/54 PUPC 08/119 PUPC 07/51 PUPC 69/499 PUPC 02/149 PUPC 83/736 PUPC 83/731 PUPC 83/732 PUPC 83/734 PUPC 83/735 PUPC 02/108 PUPC 83/727 PUPC 69/513	lp3-m2 rm3 DM1-DM4 lP1 rP1 lP4 rP4 lM1 lM2 lM3 rM3 lm2 lm3	Nagri Fm. Dhok Pathan	32° 39 283 N 72° 52 457 E 32° 46 408N 72° 29 816E 33° 06 908N 72° 20 617E 33° 06 790N 72° 20 465E

Thesis Layout

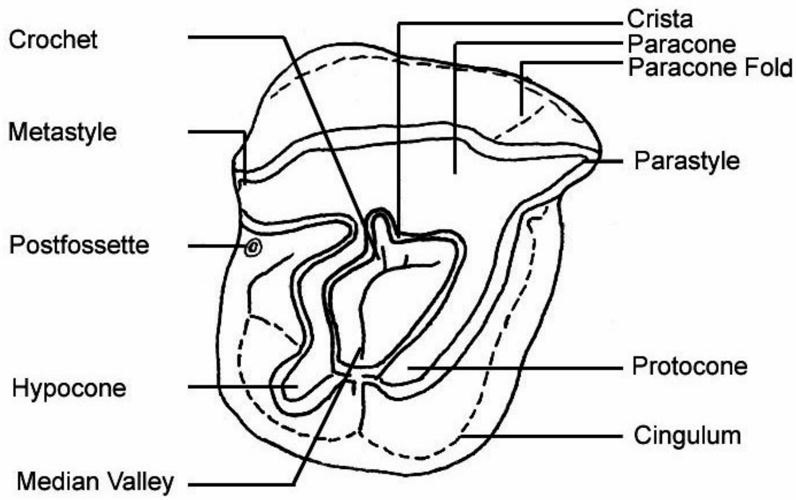
This thesis consists of four distinct, separate and autonomous units structured in a format directed by Doctoral Programme Coordination Committee (DPCC) of the University of the Punjab, Lahore, Pakistan. Consequently, repetition of description, discussion and systematics does take place. The first chapter entitled "Prelude to the study section and review of fossil rhinoceroses" includes mainly geography, geology, Sedimentology, Lithology, Stratigraphy, Biostratigrapy, Taphonomy, Chronostratigraphy and Palaeo-environment of the study section; and "Review of the Fossil Rhinoceroses" which elaborates various extinct forms of rhinoceroses particularly from the Siwaliks and from various parts of the world in general. The dental morphology of rhinoceroses used in identification and description of the studied specimens is also included in this chapter. In the third chapter titled "Systematic Palaeontology" the taxonomical and morphological features of the studied rhinoceros material is elaborated and presented. The findings of the present study are compared and correlated with fossil rhinoceroses from the Siwaliks as well as from other regions of the world.

Finally, the fourth chapter entitled "Palaeo-biogeography of the Siwalik Rhinoceroses" has discussed the distribution of rhinoceroses found at different stratigraphic levels of the Siwaliks. Rhinoceros fauna described from Dera Bugti and Manchar Fm. are also discussed briefly in order to present an overview of the fossil rhinoceroses in the region. The references and appendices are given at the end of the thesis.

Tooth Morphology

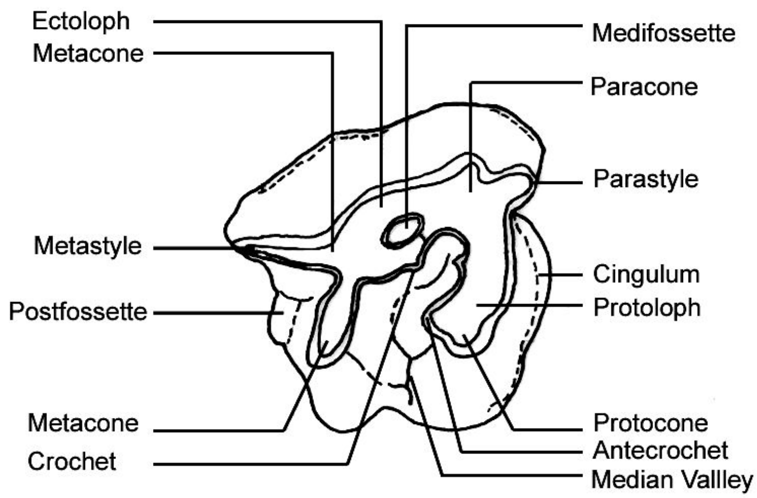
Tooth cusp nomenclature in this thesis follows that of Heissig (1972) and Cerdeño (1995) as shown in the figures 16A-D. Tooth length and breadth were measured at maximum level. Heights were measured at the level of the mesostyle of the upper molar, the metalophid of the lower molar and the protoconid of the lower premolar. Paired measurements given for teeth are occlusal length and occlusal width, and all measurements are in millimeters. In the discussion comparisons are made with published fossils by Palaeontology department of the British Museum of Natural History, London (Institutional abbreviation, BMNH), the American Museum of Natural History (AMNH), the Geological Survey of Pakistan (GSP), the Geological Survey of India (GSI) and the specimens housed in the Palaeontolgy Laboratory of the Department of Zoology, University of the Punjab

(Institutional abbreviation, PUPC). The studied material is the property of the Palaeontolgy Laboratory of the Department of Zoology, University of the Punjab, Lahore, Pakistan. The spelling of some of the revised or confusing words is given in accordance with the latest literature. The references are compiled to follow the pattern of the Pakistan Journal of Zoology, published by Zoological Society of Pakistan. The published research work from the thesis has been included as appendix 1 (reprints/proof), as directed by the Doctoral Program Coordination Committee of the University of the Punjab, Lahore, Pakistan.



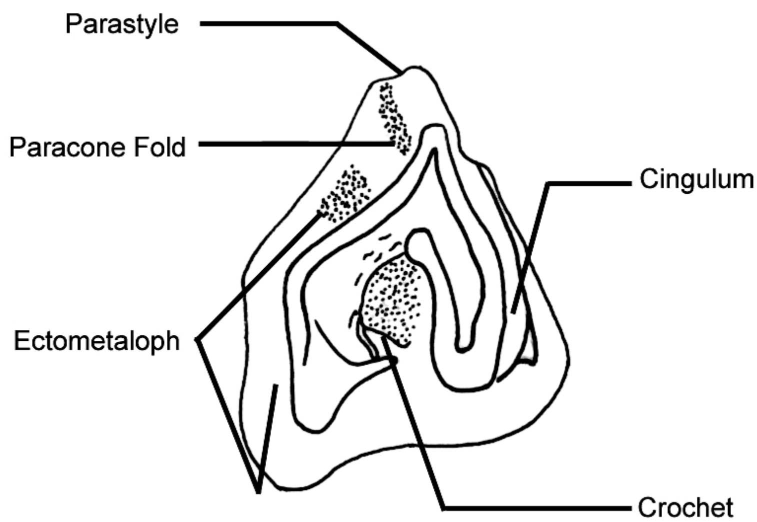
16A: Upper premolar

Buccal
Posterior ┼ Anterior
Lingual



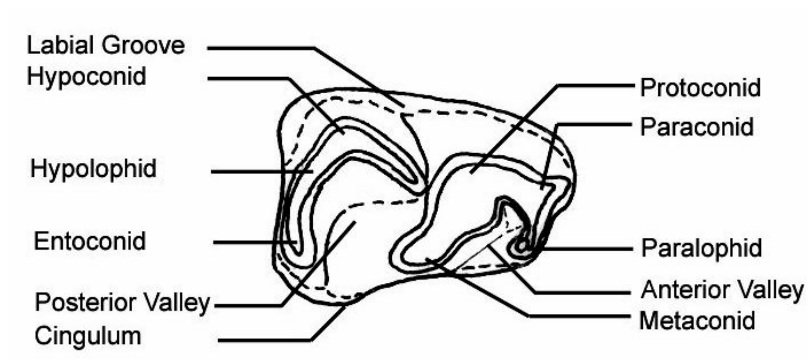
16B: Upper first molar

Buccal
Posterior ┼ Anterior
Lingual



16C: Upper third molar

Buccal
Posterior ┼ Anterior
Lingual



16D: Lower Molar

Buccal
Posterior ┼ Anterior
Lingual

Figures 16A-D: Terminology and morphology of rhinoceros tooth crown, modified after Heissig (1972).

***Chapter* 2**

SYSTEMATIC PALAEONTOLOGY

SYSTEMATIC PALAEONTOLOGY

Family	Rhinocerotidae OWEN, 1848
Subfamily	Rhinocerotinae OWEN, 1845
Tribe	Rhinocerotini OWEN, 1845
Subtribe	Rhinocerotina OWEN, 1845
Genus	***Rhinoceros*** LINNAEUS, 1758

Rhinoceros sondaicus **DESMAREST, 1822**

(Figs.1-5; Table1-3)

Rhinoceros javanicus GEOFRROY AND CUVIER, 1824
Rhinoceros inermis LESSON, 1838
Rhinoceros nasalis GRAY, 1868
Rhinoceros floweri GRAY, 1868

Stratigraphic and geographic distribution : Early Pleistocene to recent of Borneo, Recent of the Sundarbans, Eastern Bengal, Assam, Burma, Malay Peninsula, Sumatra and Java.

Material studied: PUPC 67/145, a maxillary fragment with lP2-M3; PUPC 67/145a, a right maxillary fragment with rM1 and preserved roots of rM2 and rM3; PUPC, 67/145b, an isolated rP2, PUPC 67/145c, an isolated rP3; PUPC 67/145d, a broken mandibular ramus with preserved lp4 and lm3 and base with roots of p3, m1 and m2.

Stratigraphic and geographic distribution of the present material: Sardhok; Upper Pleistocene to recent of the Siwaliks.

Description:

Upper Dentition:

PUPC 67/145 (Figs.1A-C) is a left maxillary fragment with well preserved premolars and molars from P2-M3. The premolars are sub-hypsodont and are in middle wear. The crista is weakly developed in the premolars, and is confined to the upper part of the ectoloph. Anterior and posterior cingula are well developed. Lingual and buccal cingula are absent. Ectoloph is convex and has a paracone fold along the entire height of the tooth.

Molars are sub-hypsodont and in middle wear. The crochet is moderately developed and crista is completely absent in the molars. M1 and M2 are roughly quadrate, and

M3 is triangular in outline. Anterior and posterior cingula are well-developed in the molars. Lingual and buccal cingula are absent. Ectoloph presents a well developed parastyle and a thick paracone fold much projected in the 3rd molar, typical of *Rhinoceros sondaicus*. There is no protocone fold; however the premolars have an enamel fold at the antero-external angle of the postfosette. There is a backward extension of the internal portion of the protoloph.

P2 is a well preserved tooth. Anterior cingulum is present, approximately at the level of the middle of the crown height. Half of the metaloph along with the hypocone is broken. The internal pass of the median valley is very shallow. The protocone and paracone are separate from one another at the summit, but are united above the posterior cingular level. The anterior face of the tooth shows a vertical depression extending from the cingular level to the base of the crown, separating the protocone from the paracone. The protocone gradually increases in thickness from the top to the cingular level and becomes uniform in thickness from the cingular level to the base of the crown. The ectoloph is almost straight with a moderately developed parastyle fold, however metastyle is indistinct. A weakly developed crista projects into the median valley and joins the crochet a few millimeters below the occlusal surface to enclose a shallow medifossette. The crochet is bifurcated. A small tubercle is present at the antero-lingual face of the hypocone. P3 has a sinuous outline of the buccal wall. A strong parastyle and a well developed paracone fold are present along most of the crown height. A tetra-lobed crochet projects into the median valley. The lobe of crochet that arises from the apex of metaloph joins the protoloph to enclose a medifossette. A fine and weakly developed crista projects into the medifossette as well as postfossette from the ectoloph. A small enamel projection from the antero-external angle of the postfossette is present, which diminishes at about half of the depth of the postfossette. A small tubercle is present at the lingual side of the hypocone.

P4 is a well preserved. Protoloph and metaloph is almost equal in length and are placed obliquely to the ectoloph. There is a moderately developed bifurcated crochet reaching the metaloph to enclose a medifossette. Postfossette is deeper than the medifossette. Posterior half of the ectoloph is slightly concave. Posterior cingulum is divided by a v-shaped incision and show crenulations. A weak spur like enamel projection corresponding to a small crista is present on the ectoloph towards the

1A

1B

Figure1A-B: *Rhinoceros sondaicus*. PUPC 67/145, A- occlusal view, B- lingual view of a maxillary fragment with lP2-M3, scale bar 30mm.

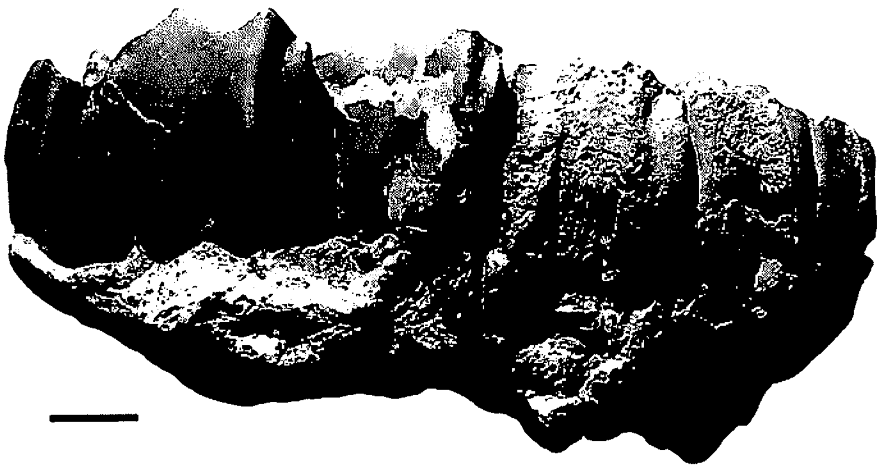


Figure1C: *Rhinoceros sondaicus*. PUPC 67/145, buccal view of a maxillary fragment with lP2-M3, scale bar 30mm

Figure 2: *Rhinoceros sondaicus*. PUPC 67/145a, occlusal view of a maxillary fragment with rP4-M1, scale bar 30mm

postfossette. A tubercle is present at the lingual base of the hypocone. Protocone and hypocone are united at the level of the posterior cingulum.

M1 is well preserved and in middle wear. A duplicated and moderately developed crochet is present; it almost reaches the protoloph. Antecrochet and crista are absent. Parastyle fold is strong. The protocone has a backward extension and has no constriction. The median valley is narrow at the level of the crochet due to the protocone bulge. A small tubercle is present at the lingual base of the hypocone. A small spur-like enamel projection is present in posterior valley. There is no protocone fold on the molar. The posterior cingulum show crenulations and is divided by a V-shaped incision. The ectoloph is concave behind the parastyle fold showing sinuosity. The metaloph is placed somewhat obliquely to the protoloph.

M2 is slightly larger than M1, but similar in morphology to M1. A spur like tubercle projects from the apex of the hypocone into the postfossette and diminishes at the level of the posterior cingulum. Median valley is deeper than the postfossette. Crochet has almost reached the protoloph and is bifurcated. There is no crista.

M3 is triangular in outline. Median valley is wide and deep to the base of tooth lingually. Crochet is moderately developed. A weak antecrochet is also present. A spur like enamel projection is also present on the ectometaloph towards the median valley. There is no crista. The parastyle area of M3 is lost. The parastyle fold is strong. Ectometaloph presents a convex outline. PUPC 67/145a, rP4-M1 (Fig.2); PUPC 67/ 145b, rP2 (Figs. 3A-B) and PUPC 67/145c, rP3 (Fig.4A-B) have similar morphology and dimensions to their counterparts in the left maxillary fragment and therefore seems to belong to the same individual. Anterior half of the ectoloph and paracone are broken in rP3. The metacone is broken in rP2.

3A

3B

Figure 3A-B: *Rhinoceros sondaicus*, PUPC 67/145b, A- occlusal view, B- buccal view of an isolated rP2, scale bar 30mm.

4A

4B

Figure 4A-B: *Rhinoceros sondaicus*, PUPC 67/145c, A- occlusal view, B- lingual view of an isolated rP3, scale bar 30mm.

Lower Dentition:

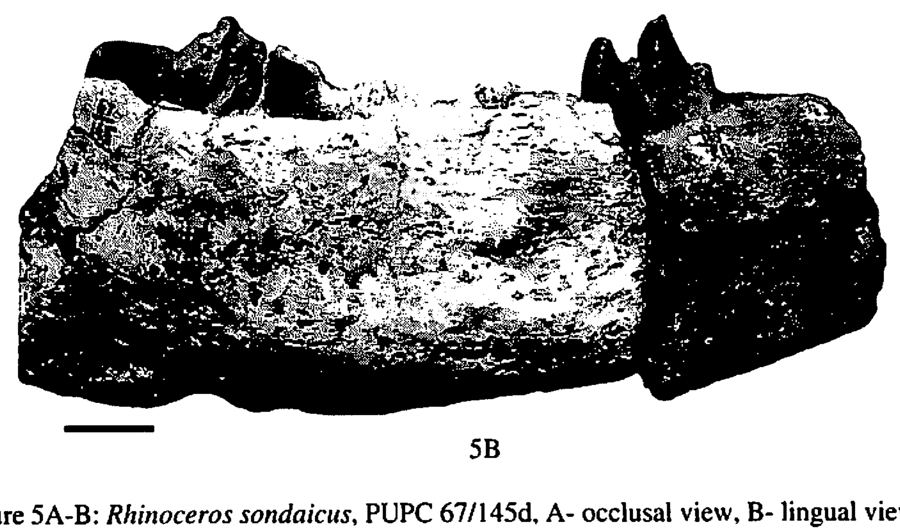
PUPC 67/145d (Figs. 5A-B) is a broken left mandibular ramus with well preserved p4 and m3. Buccal profile of the horizontal ramus is concave from m2 to p4 level. Roots of p3, m1 and m2 are also preserved. The premolar in the ramus has weakly developed anterior and posterior cingula. Lingual and buccal cingula are absent. Lingually the anterior valley is U-shaped and the posterior valley is V-shaped. Labial groove is well developed and angularly V-shaped in appearance. Paralophid is slightly shorter than the metalophid. Both trigonid and talonid have shallow basins.

The m3 has not yet been erupted completely out of the dentary. In m3 the anterior and posterior valleys are widely U-shaped. The posterior valley is wider and deeper than the anterior valley. Paralophid is slightly shorter than the metalophid. Metaconid is more developed than the entoconid. Hypolophid and metalophid are obliquely placed to the ectolophid. Measurements regarding the mandibular ramus are given in table 1.

Table 1: Measurements of the mandibular ramus of *Rhinoceros sondaicus.*

Specimen no.	Mandibular ramus	measurements
PUPC 67/145d	Width of horizontal ramus at p4	49.5 mm
	Width of horizontal ramus at m3	58.0 mm
	Depth of horizontal ramus at p4	73.0 mm
	Depth of horizontal ramus at m3	96.5 mm
	Length of the molar series at root level	165 mm

5A



5B

Figure 5A-B: *Rhinoceros sondaicus*, PUPC 67/145d, A- occlusal view, B- lingual view of a broken mandibular ramus, scale bar 30mm.

COMPARISON AND DISCUSSION

Flower (1876) and Osborn (1898) elaborated distinguishing characteristics of *Rhinoceros sondaicus* and *Rhinoceros unicornis*. Colbert (1935, 1942) compared the skull, mandibles and dentition of *Rhinoceros sondaicus* with those of *Rhinoceros unicornis* and *Gaindatherium browni* and considered it as an intermediate form between both species. According to Colbert, *R. sondaicus* is more primitive in the characteristics of the skull, mandible and dentition, and regarded the *R. sinensis* from the Pleistocene of China as an intermediate between the living forms. From the Upper Siwaliks of Pakistan and India four fossil rhinoceros species i.e. *Rhinoceros sivalensis, Rhinoceros palaeindicus, R. kendengindicus* and *Punjabitherium platyrhinus* have been described by Colbert (1935, 1942), Matthew (1929), Sarwar (1971) and Khan (1971a); however most of them have been synonymized in due course of time. Presently *Rhinoceros sivalensis* is the only species recognized from the upper Siwaliks of Pakistan.

The characteristics shared by *Rhinoceros sondaicus* and *R. sivalensis* include; a distinct crochet (more developed and rounded in *R. sivalensis*) that may unite with the protoloph to enclose a fossette; well developed parastyle; no mesostyle and U-shaped anterior valley in the lower molars. However *R. sondaicus* differ from the later species in having a well developed paracone fold, development of crista in the premolars and complete absence of lingual cingulum (well developed in *R. sivalensis*). The protocone is constricted by anterior and posterior grooves in *R. sivalensis* whereas in *R. sondaicus* protocone is unconstricted. Tooth dimensions of *R. sondaicus* (Tables 2-3)are greater than those of the material described in the present study as *R. sivalensis* and *Gaindatherium browni* (Tables 4 and 8).

Dental characters of the rhinocerotid material from the Pleistocene of Pakistan are identical to those of *Rhinoceros sondaicus* reported from the middle Pleistocene to recent of Java and Sumatra, Pleistocene of northern Vietnam (Bacon *et al*., 2008), and Myanmar (Maung-Thein *et al*., 2006). Characteristics shared by the present material with the previously reported material of *Rhinoceros sondaicus* includes: presence of the strong parastyle fold, sinuous ectoloph being concave posterior to the parastyle, absence of the antecrochet, and presence of a moderately developed crochet (Hooijer, 1946; Pocock, 1945). Present material also shows a marked resemblance with

Rhinoceros sondaicus described by Beden and Guerin (1973) from Pleistocene of Phnom Loang, Kampot (Cambodge) region. The dimensions of the present material are also similar to those described by Colbert (1942) and Maung-Thein *et al*., (2006) for *Rhinoceros sondaicus*.

According to Colbert (1942) *Gaindatherium browni* differs from *Rhinoceros sondaicus* in having an overall smaller body size; less expansion of the nasals; lower ascending ramus; shallower saddle in cranial profile; zygomatic arch more angular at posterior termination; posterior margin of the palate with small median projection; narrow premaxillaries; teeth more brachydont; and absence of crista and crochet. Crown pattern in *R. sondaicus* is much more complex and evolutionarily advanced than Gaindatherium *browni* as well *R. sivalensis.*

The upper dentition in the present material differs from *Rhinoceros unicornis* in having a weaker crista in the premolars and the complete absence of crista in molars; besides parastyle buttress is more prominent in *R. sondaicus* than in *R. unicornis*. The ectoloph is concave behind the paracone fold in *R. sondaicus*, being rather flat in *R. unicornis*. In the premolars of the present material an enamel fold in the antero-external angle of the postfossette is present; however it is very different from the protocone fold of *Rhinoceros unicornis*.

Rhinoceros sinensis described by Matsumoto (1921) from the Pleistocene of China resembles to the present fossils in the backward extension of the protoloph, presence of the well-developed parastyle fold, and the sinuosity of the ectoloph. However it differs from *Rhinoceros sondaicus* in having more hypsodont teeth and in the development of crista in the upper molars. The comparative measurements of the cheek teeth of *Rhinoceros sondaicus* in the present study are given in the tables 2-3.

Table 2. The comparative measurements of the upper cheek teeth of *Rhinoceros sondaicus.*

		P2	P3	P4	M1	M2	M3
R. sondaicus Present study (right dentition)	L W	33.0 41.5	-	44.0 53.5	56.5 59.5	X	X
R. sondaicus Present study (left dental series)	L W	37.0 41.0	43.0 50.0	44.0 50.0	53.0 58.0	59.0 61.0	59.0 48.0
R. sondaicus (Colbert,1942)	L W	X X	38.0 48.8	43.8 52.6	46.9 53.2	49.3 55.6	42.6 47.6
R. sondaicus (Hooijer, 1962, from Pleistocene of Java)	W (ant. width)	39.0-45.0	48.0-57.0	51.0-62.0	54.0-65-0	55.0-62.0	48.0-56
R. sondaicus guthi (Beden and Guerin, 1973)	L	40.0	47.5-49	50.5	55.0	54.5-55.0	53-52
R.sondaicus (Maung-Thein *et al*., 2006)	L	X	X	X	53.14	52.32	54.36
R .unicornis (from Beden and Guerin, 1973)	L W	37.5-39.0	46.0-50.0	41.5-48.5	45.0-48.0	53.0-61.0	55.0-67.0
R. sivalensis (present study)	L W	35.0 37.0	41.5 48.0	45.0 52.0	48.0 51.0	53-0 56-0	46.0 49.0
R. sinensis Matsumoto (1921)	L W	X	47.0	50.0-54	65.0	63.0-75.0	54.0-68.0

Table 3. The comparative measurements of the lower cheek teeth of *Rhinoceros sondaicus.*

		p2	p3*	p4	m1*	m2*	m3
R. sondaicus Present material	L W	X	36.5 27.5	43.0 27.0	42.0 30.5	53.0 31.0	55.0 26-5
R. sondaicus Colbert (1942)	L W	X X	35.9 25.0	38.8 24.9	41.0 29.0	43.9 30.2	44.5 26.1

* Measurements correspond to the preserved base of the tooth and are taken at root level.

Rhinoceros sivalensis FALCONER AND CAUTLEY, 1847

(Figs. 6-8; Table 4-6)

Rhinoceros palaeindicus

Distribution: The Upper Siwaliks of Pakistan and India.

Type Specimen: Part of a skull (BMNH 39626).

Co Types: BMNH 39625, a skull; BMNH 39646, a mandibular symphysis; BMNH 39647, part of a skull

Geographic distribution: India and Pakistan.

Stratigraphic level: Upper Siwaliks, late Pleistocene

Diagnosis: A large species of the genus. Molar with the parastyle buttress, distinct crochet that may unite with the protoloph to enclose a fossette and without a crista. The molars with strong parastyle, no mesostyle and protocone constricted by posterior and anterior grooves. The metaloph somewhat short, very backwardly directed on M2 and there is a great projection of the protoloph. The anterior valley of the lower molar is U shaped with a long paralophid and the buccal groove is shallow.

Material studied: right maxillary with PI-M3, PUPC 07/37; left maxillary with PI-M3, PUPC 07/38; lm2, PUPC 07/39; rm1, PUPC 07/40.

Locality: Tatrot (Tatrot Fm. upper Siwaliks).

Description:

Upper Dentition:

PUPC07/37 and PUPC07/38, P1- M3 (Fig. 6) are excellently preserved specimens having the complete right and left cheek tooth series, respectively. Both specimens were collected separately, but they appear to belong to the same individual, because the molars and premolars are morphologically very similar and have the same dimensions. However, the palate and other parts of the skull have been weathered away during preservation. All teeth are well preserved; even P1 is also present in both specimens, which confirm the young age of the animal. Parts of the palate and zygomatic arch are also present proximally. The zygomatic arch looks to be heavy and extends just above the anterior part of the 2nd molar. The premolar series is slightly shorter (129 mm) than the molar series (133 mm). The premolars are subhypsodont and in middle wear. On P2-P4 the parastyle is very short and straight. The protoloph is directed backward, thickening lingually, and longer than metaloph. The metaloph is obliquely continuous with a crochet, thinner and shorter in premolars than in molars.

Figure 6: *Rhinoceros sivalensis*, PUPC 07/37 and 07/38, combined occlusal views, Scale bar 30 mm.

There is abundant cement on the occlusal surface of the molars. M1 is in middle wear while M2-M3 are in early stage of wear.

The first premolars are very small in dimensions (table: 4) and are single rooted with the triangular occlusal surface. Traces of cement are present and the enamel is wrinkled. There is no trace of buccal or lingual cingula in the P1, but the other premolars have a well-developed cingulum on the lingual side. A thin layer of cement is covering the valley of the P1. The crown of P1 is low and sub triangular. The enamel is thick which allows us to identify it as a first premolar rather than a deciduous molar. The lingual surface of the protocone of P1 is flat, and the lateral surface is rounded. The protoloph and metaloph are of different widths. The hypocone is well developed and there are no paracone and metacone ribs on the P1.

The second premolars (right and left P2) are roughly quadrate, but lingually narrow. The buccal enamel is thin and the lingual enamel edge is thick. The buccal side of the tooth has no mesostyle but anterior median rib is moderately developed. A narrow cingulum is present along the anterior side of the protocone. A strong postfossette is present. Crista is absent, crochet is moderate, and antecrochet is very strong. The crochet extends into the median valley but not strong enough to enclose it. The parastyle fold is absent. The protocone and hypocone of P2 are separated on the occlusal surface. The metaloph is posteriorly oblique. The lingual cingulum forms a tubercle at the entrance of the median valley. The postfossette is isolated from the marginal enamel. The ectoloph is rather flat by certain retention of the parastyle buttress.

In third premolars (P3) the ectoloph is flat and without enamel folding and inclines lingually at the metaconal area. The median valley separates the protocone and hypocone. The cingulum is present on the lingual side as well as the posterior one. The vertical projection of the cingulum isolates the postfossette. The ectoloph is in the form of sharp blade. The protocone is slightly constricted and about to connect with the hypocone by the lingual bridge. The antecrochet is well developed and the hypocone is not constricted. The crista is absent in the premolars and the parastyle buttress is present. The protoloph slopes a little backwards, is greater than the metaloph and joins the ectoloph high up; from this point a well-marked parastyle directs forwards and outwards. The metaloph runs right angle to the ectoloph and forms a somewhat oblique crest. There are no paracone and metacone ribs. There is no trace of secondary folds. The postfossette is triangular and somewhat elongated. Anterior and posterior cingula are low and discontinuous because of the contact with the 2nd and 4th premolars. The P4 are well preserved and subhypsodont. Protocone is well developed and constricted. The protocone and hypocone are separated. The cingulum is present on the lingual side as well as the posterior one. There is a presence of parastyle buttress as well as the anterior median rib. The ectoloph is rather flat. The crochet is well developed, extends to the protoloph, almost enclosing a median fossette. The lingual opening of the median valley is narrow. There is no trace of buccal cingulum; however a thick layer of cement is present on the buccal side. The metaloph is continuous and oblique directed backwards without constriction. The postfossette is comparatively deeper than the medifossette, as the medifossette looks to be filled with the cement. The anterior protocone groove is not prominent and the parastyle is short. The anterior, lingual, and posterior cingula are well developed and form a continuous wall, high above the base of the premolars. The protoloph and metaloph are of different widths and their lingual surfaces are rounded.

The first molars (M1) are well preserved and in middle wear. The right one has a horizontal crack along the medial side of the ectoloph. The enamel is present at the anterior as well as the posterior side. The protocone is somewhat constricted. On the posterior side the enamel is projected vertically to form a postfossette. The projection of the enamel is called hypoconal flange (Gentry, 1987). The ectoloph is flat and the metacone rib is absent on the ectoloph. The metaloph is slightly shorter than the protoloph. The parastyle is prominent at the anteroexternal side of the ectoloph. Crista is absent and a well-developed crochet extends from the metaloph into the median valley. The crochet and antecrochet move towards each other and close the median valley on its half way to the ectoloph. An external cement coating is present. The postfossette is isolated from the margin of the crown and possess a thick enamel investment. There is no buccal cingulum. The enamel is thinly wrinkled on the ectoloph. A thin layer of cement covers the ectoloph. The antecrochet is well developed and extends lingually but does not reach the entrance of the median valley.

The second molar (M2) is well developed and roughly quadrate. The enamel is thick and the cingulum is present anteriorly as well as posteriorly. The opening of the median valley is wide at the entrance. A deep horizontal crack along the ectoloph has separated it from the rest of the crown. The parastyle projects well beyond the mesial edge of the tooth and have a weak fold on the buccal edge. The paracone rib is present on the ectoloph; the metacone rib is absent but the metastyle is present. The ectoloph is somewhat turned inward at the mesial limit of the metacone and is directed towards the postfossette. A small tubercle is present towards the entrance of the median valley. The crochet is very strong and extends towards the protoloph, closing off the median valley by the union of protoloph. The ectoloph is flat and without enamel folding. The hypocone is not constricted. The molars are covered with thin, irregular cement on their buccal walls. The lingual surface of the protocone is rounded. The entrance to the median valley is open and the lingual cingulum is absent. The postfossette is not isolated because the hypoconal flange projection is very small vertically.

The upper third molars (M3) are triangular and have a paraconal groove. The protocone is not constricted on the occlusal surface but it is at the base. The crista is absent and the antecrochet is very weak. The crochet is well developed and looks like a pillar in the median valley. The protoloph is posteriorly oblique and the cingulum is present at the lingual base of the protoloph. The posterior cingulum is well developed. The molars are in early wear. The lingual valley is wide and the enamel is moderately thick. The parastyle is marked, forming an obtuse angle with the ectometaloph. The protoloph is sigmoid, continuous and flat without any groove with strong anterior constriction and the antecrochet at the base of the crown (trefoil shaped). The ectometaloph is convex without any constriction. The measurements of the upper cheek teeth are provided in table 4.

Table 4. The measurements of the cheek teeth of *Rhinoceros sivalensis*.

Specimen no.	Position	Length	Width
PUPC 07/37 and 07/38	P1	19	18
	P2	35	37.2
	P3	41.5	48
	P4	45	52
	M1	48	51
	M2	53	56
	M3	46	49

Lower Dentition:

PUPC 07/39, m2 and PUPC 07/40, m1 (Fig. 7-8) belong to the lower dentition. The specimens are in early wear. The cingulum is present at the base of the crown buccally. The enamel is very rugose and the rugosity is more prominent buccally. The anterior valley is narrower than the posterior one. Anterior valley is V-shaped and the posterior one is U-shaped. The protoconid, the hypoconid, and the entoconid are well developed.

The hypolophid is longer than the metalophid. The metalophid and hypolophid are separated by the vertical groove that is present on the buccal side of the tooth and the groove is prominent in PUPC 07/40. Traces of cement are also present. The paralophid is wide and transversely oriented. The measurements of the specimens are provided in table 5.

Table 5. The measurements of the lower cheek teeth of *Rhinoceros sivalensis*

Specimen no.	Position	Length	Width
PUPC 07/39	m2	57	39
PUPC 07/40	m1	43	29

A

B

C

Figure 7A-C: *Rhinoceros sivalensis*, PUPC 07/39, rm1, A- Occlusal view, B- buccal view, C- lingual view, Scale bar 20 mm.

A

B

Figure 8A-B: *Rhinoceros sivalensis*, PUPC 07/40, rm1, A- lingual view, B- buccal view. Scale bar 20 mm.

COMPARISON AND DISCUSSION

The studied specimens are collected from the Tatrot Formation of the Upper Siwaliks. The Upper Siwaliks have yielded three fossil rhinoceroses (Matthew, 1929) that are *Coelodonta platyrhinus* Falconer and Cautley, *Rhinoceros sivalensis* Falconer and Cautley (including *Rhinoceros palaeindicus* Falconer and Cautley), and *Rhinoceros sinhaleyus* Deraniyagala (Deraniyagala, 1951). Shani and Mitra (1980) stated that *Rhinoceros sivalensis* is the only rhinoceros in the Gaj series of Pakistan. Bacon *et al* (2008) considered many species referred to as *Rhinoceros* throughout the Quaternary of South Asia, such as *Rhinoceros sivalensis* and *Rhinoceros kendengindicus* Dubois1908. Colbert (1938) has reported *Rhinoceros sivalensis* from Myanmar. Dennell *et al*., (2006) has reported 87 specimens of *Rhinoceros sivalensis* from the upper Siwaliks (Pabbi hills, Upper Pliocene) of Pakistan. These specimens include a complete cranium (642EX1602), two mandibles (341GB33 and 642EX1062), a scapula (73EX5) and numerous limb and teeth specimens from locality 642 in the Pabbi Hills, Punjab, Pakistan.

Rhinoceros sivalensis was defined on the basis of single teeth (Colbert, 1935, 1943), without any new findings since its original description (Tong, 2001). Colbert (1935, 1943) described only a first upper molar and a fourth upper premolar (AMNH 19793, ANSP 14630) from the Upper Siwaliks of the subcontinent. The studied material includes a complete series of premolars and molars identified as *Rhinoceros sivalensis*, which add significant knowledge to the known record of this species in the Siwaliks.

The genus *Rhinoceros* is recorded from the Pliocene through the Pleistocene and into recent times (Cerdeño, 1998). The genus *Rhinoceros* includes four species: the two extant *Rhinoceros unicornis,* type of the genus, and *Rhinoceros sondaicus*, both recorded from Pleistocene to Recent in India and Southeastern Asia, respectively; *Rhinoceros sinensis* from the Pleistocene of southwestern China; and *Rhinoceros sivalensis*, from the Pleistocene of the Siwalik Hills of India and Pakistan. Features observed on the studied teeth (well developed crochet not enclosing a median fossette, a rather flat ectoloph, certain retention of parastyle buttress and absence of crista) are present in the species *Rhinoceros sivalensis*, which allows its determination as such species. *Rhinoceros sivalensis* is a large species that seems to be rather close to

Rhinoceros unicornis, showing similarities in the structure of the skull (Colbert, 1942).

The studied material from Tatrot Formation is comparable with the material described by Matthew (1929) as *R. sivalensis,* from the middle Siwaliks, in having unconstricted protocone, crochet moderate on M3, postfossette retained on all teeth, median valley open on all teeth, premolars slightly shorter than molars, and concave external face. Matthew considered *R. palaeindicus* as a probable synonym of *R. sivalensis* and rejected the supposed differences in the skull proportions and dentition of both species, considering them within the limits of individual variation. The molar (rM1) AMNH No.19793 described by Colbert (1935) as *R. sivalensis* agrees with our material in having distinct crochet and absence of crista. The width of M1 described by Colbert (1935) is greater when compared to the M1 in the present material.

The material in the present study appears to agree fairly well with the AMNH No.19793 (rM1), described by Colbert (1935), in having distinct crochet and absence of crista. The lP4 in the present collection is closely comparable both in morphology and size to the lP4 (ANSP No.14630) described by Colbert (1943) from lower Pleistocene, upper Siwaliks of Northern India. The crochet is double in P4 of the present collection while in ANSP 14630 it is single. However, the P4 of *R. sivalensis* figured by Lydekker (1881: Pl. V, fig, 6) has also a double crochet.

Compared with *R. sinensis* Owen 1870, the present material revealed significant differences with *R. sivalensis* in having more hypsodont Cheek teeth, well developed crochet and crista. Parastyle buttress is not well marked in both *R. sinensis* and *R. sivalensis.* The cheek teeth in *R. sivalensis* resemble *R. sondaicus* in having less hypsodonty and presenting a crochet; but they differ in the absence of crista, flatness of the ectoloph, and prominence of parastyle buttress.

Upper cheek teeth in *Rhinoceros sivalensis* have similarities with *Rhinoceros sinhaleyus* (Deraniyagala, 1951) in having the open median valley; a well-developed crochet that may unite with the protoloph to enclose a fossette; absence of crista; presence of anterior cingulum at the lingual base of the protoloph, and posterior cingulum well developed. The postfossette is not isolated in *Rhinoceros sivalensis* but it is in *Rhinoceros sinhaleyus*. Cheek teeth of *Rhinoceros sivalensis* in the present study are similar to *Rhinoceros unicornis* in having the anterior constriction on the protoloph; while this feature is always absent in *Rhinoceros sondaicus* (Guerin, 1980a). The size of the studied material is comparable to other *Rhinoceros* fossils described from the Siwaliks and from other localities in South Asia (Table 6). The smaller measurements of M1 in the present material as compared to Colbert's M1 (AMNH 19793) may be attributed to the age differences of the individuals. The present material may belong to a sub-adult whereas AMNH 19793 corresponds to a fully adult individual. However, the P4 ANSP 14630 described by Colbert (1943) is comparable in crown morphology and size to the P4 in the present material.

Dennell *et al*., have discovered the fossils of *Rhinoceros sivalensis* from the hyaenid localities (73 and 642) in the upper Siwaliks of Pabbi Hills, Pakistan, which indicates that it was vulnerable to predation or scavenging. However in addition to its vulnerability to predators, reduction in forest cover and deterioration of overall environment may have lead *Rhinoceros sivalensis* to extinction.

Comparative measurements of the described specimens are provided in table 6.

Table 6. The comparative measurements of the cheek teeth of *Rhinoceros sivalensis* (Bacon, *et al*., 2008; Maung-Thein, *et al*., 2006; Falconer and Cautley, 1847; Colbert, 1943; Heissig, 1972; Beden and Guerin, 1973)**.**

No.	Position		*R. sivalensis* Present material	*R. sivalensis*	*R. unicornis*	*R. sondaicus*	*R. sinensis*
PUPC 07/37, 38	P1	L W	19.0 18.0	X	X	X	X
	P2	L W	35.0 37.2	X	37.5 40.0	40.0 44.0	26.0 36.0
	P3	L W	41.5 48	35.0 48.0 *(R(R)*aff. *sivalensis*; (103)	46.0 53.0	47.5 57.0	47.0 51.0
	P4	L W	45 52	43.5 58 (ANSP 14630)	41.5 62.0	50.5 61.0	50.0 57.0
	M1	L W	48 51	61 80 (AMNH 19793)	45.0 58.0	55.0 62.0	65.0 63.0
	M2	L W	53 56	X	53.0 59.0	54.5 61.5	63.0 63.0
	M3	L W	46 49	X	55.0 53.0	53.0 46.0	54.0 57.0
PUPC 07/39	m1	L W	57 39	X	44.3-46.7 29.9-30.7-	42.5 26.9	X
PUPC 07/40	m2	L W	43 29	X	50.0 29.0-	43.2 28.6	X

Genus *Punjabitherium* KHAN 1971

Type species: *Rhinoceros platyrhinus* Falconer and Cautley 1847

, from upper Siwaliks of India.

Rhinoceros platyrhinus Falconer and Cautley 1847.

Dicerorhinus platyrhinus Pilgrim 1910.

Coelodonta platyrhinus Matthew 1929.

Coelodonta platyrhinus Colbert 1935.

PUNJABITHERIUM cf. *PLATYRHINUS* (Falconer et Cautley)
(Figs. 9-10; Table 7)

Lectotype: BMNH No. 33662, a battered skull.

Neotype: BMNH No. 36661, a nearly complete skull.

Diagnosis: A large bicorn rhinocerotid; skull without nasal septum; postglenoid and posttympanic processes of the squamosals united below the external auditory meatus; inclination of occiput backward; premaxilla with two incisors; cheek teeth hypsodont with well-developed crochet and crista.

Material studied: PUPC 07/168, (rP3); PUPC 07/167, (lM1)

Locality: Jari kas, Mirpur, Azad Kashmir, Pakistan

Stratigraphic Level: Upper Siwaliks, Pleistocene of the Siwaliks

Description:

Upper Dentition:

PUPC 07/168, P3 (Fig. 9) is a well-preserved premolar probably the third. The tooth is in late wear and many morphological features of the crown are vanished. The protocone is round and bulbous and much larger than the hypocone. Protocone and paracone are well preserved and unconstricted. The protocone and paracone are separate from one another due to the deep and open medisinus. The ectoloph is almost straight. Metaloph is placed obliquely to the protoloph. Protoloph is somewhat longer in length than the metaloph. Parastyle is slightly developed, however metastyle is indistinct and metacone rib is weakly developed. Due to wear medifossette is not visible; however a slight depression corresponding to medifossette is present at the apex of the medisinus, probably formed by the fusion of the crochet and crista. A short and shelf-like anterior cingulum is present, which diminishes at the antero-lingual side of the protocone. Cingulum is absent at the lingual, posterior and buccal sides of the tooth. Postfossette is well developed and deep.

PUPC 07/167, M1 (Fig. 10) is a well-preserved hypsodont tooth. From size and length-width index it appears to be a molar, probably the first. The tooth is in middle wear and shows many morphological features. The protocone is round and bulbous and much larger than the hypocone. Protocone and paracone are half broken anteriorly. The protocone and hypocone are separate from one another, but are united at the level of the lingual tubercle. The protocone is thick right from the base up to the preserved crown height. The ectoloph is almost straight. Metaloph has a slight posterior inflection. Protoloph is somewhat longer than the metaloph. Parastyle and metastyle are indistinct and metacone rib is weakly developed. From the metaloph a strong and rounded crochet projects into the median valley. A depression at the apex of the median valley corresponds to the medifossette. There is no trace of cingulum except a rudimentary tubercle on the lingual side of the hypocone. Postfossette is well developed and deep. Median valley is deep and narrow lingually; however towards the apex it is broader and deep. Comparative measurements of the specimens are given in Table 7.

Figure 9: *Punjabitherium platyrhinus*, PUPC 07/ 168, rP3, occlusal view, Scale bar 30mm.

Figure 10: *Punjabitherium platyrhinus*: PUPC 07/ 167, lM1, occlusal view, Scale bar 30mm.

COMPARISON AND DISCUSSION

Falconer and Cautley (1847) collected some fossil remains (some broken skulls and ramii) from upper Siwaliks of India in the vicinity of Jamuna River and identified them as *Rhinoceros platyrhinus*. Lydekker (year) described a molar present in the Science and Arts Museum of Dublin, collected from the upper Siwaliks of India, and referred it to *Rhinoceros platyrhinus*. The only characters discussed by him are an accessory fossette (medifossette), large crochet, and a combing plate (crista). Lydekker went on to distinguish *Rhinoceros platyrhinus* from *Rhinoceros palaeindicus* on the basis of the presence of an accessory fossette formed by the union of crochet and crista, which is absent in the latter species. Lydekker also considered *Rhinoceros platyrhinus* as a rhinoceros of rare occurrence and confined to the typical Siwaliks in the vicinity of Ganga and Jamuna Rivers. Matthew (1929) suggested that *Rhinoceros platyrhinus* might have been the ancestor of *Coelodonta antiquitatis* (Blumenbach). However Lydekker (1881), Matthew (1929, 1931), and Colbert (1935) considered *Rhinoceros platyrhinus* different from other Pleistocene genera of Rhinocerotidae on the basis of certain characters (absence of the nasal septum, presence of the complex molar pattern, two horn pads and the union of the postglenoid and posttympanic process of the squamosals below the external auditory meatus) and recommended for it a separate genus, or at least subgenus. So the generic ascription of *Rhinoceros platyrhinus* went on revising among genera *Rhinoceros, Dicerorhinus, and Coelodonta*, till the discovery of a well preserved skull with last molars by Khan (1971) from the upper Siwaliks of India near the base of the Pinjor stage. Khan (1971) erected the genus *Punjabitherium* and preserved the specific name *platyrhinus*; hence the species became *Punjabitherium platyrhinus*, including as synonyms the species *Rhinoceros platyrhinus* Falconer and Cautley 1847; *Coelodonta platyrhinus* Matthew 1929; *Coelodonta platyrhinus* Colbert 1935, and *Dicerorhinus platyrhinus* Pilgrim 1910.

Prothero and Schoch (1989) placed the *Punjabitherium* within the Rhinocerotoidea as incertae sedis; however Cerdeño (1995) has considered *Punjabitherium* as a sister group of *Rhinoceros* on the basis of the cladistic analysis. The greater length and width of *Punjabitherium* distinguish it from *Rhinoceros sivalensis* and *Rhinoceros unicornis*. The complex cheek teeth structure and the union of postglenoid and posttympanic processes of the squamosals below the external auditory meatus in *Punjabitherium* render it different from *Dicerorhinus*. It is also different from *Coelodonta* due to the absence of the supporting nasal septum. From *Diceros* and *Ceratotherium* it differs in having well-developed premaxillae with two incisors (Khan, 1971a).

The specimens in the present collection resemble fairly well morphologically and metrically to those described by Lydekker (1881), Matthew (1929, 1931) and Colbert (1935); however the accessory fossette is not fully visible in the present specimens due to wear. The presence of a shallow depression at the extremity of the median valley corresponds very well to the medifossette present in the specimens described by the above-mentioned authors. The specimens in the present collection are different from the corresponding teeth of *Rhinoceros sivalensis* from Tatrot (Upper Siwaliks) both in morphology and size. Presence of lingual cingulum, absence of crista, shape and size of the protocone and hypocone in *Rhinoceros sivalensis* rendered it different from *Punjabitherium platyrhinus.* The collection of the present specimens from the upper Siwaliks of Pakistan however rejects Lydekker's opinion regarding the confined distribution of this species only in the typical Siwaliks of India near the Ganga and Jamuna River.

Table 7. Comparative measurements of *Punjabitherium platyrhinus.*

Specimen No.		*Punjabitherium platyrhinus*	*Coelodonta platyrhinus*
PUPC 07/168, P3	L W	46.5 55.5	X (56)
PUPC 07/167, M1	L W	51.5 73.5*	51.0 78.0

(*) – Estimated width due to broken parastyle enamel.

Genus *Gaindatherium* **COLBERT**, 1934

***Gaindatherium browni* COLBERT**, 1934

(Fig. 11-21; Table 8)

Type species: *Gaindatherium browni* Colbert, 1934

Type specimen: An almost complete skull (AMNH 19409).

Diagnosis: An Upper Tertiary rhinoceros of medium size, with a "saddle shaped" skull having a single horn on the nasals, and with brachydont, simple molar teeth. The orbit is located in an approximately central position above the first molar; the occiput is vertical; the postglenoid and posttympanic are fused, forming a closed tube for the external auditory meatus. There are two upper incisors, of which the lateral one is quite small; the upper molars are without an antecrochet or crista, and the crochet is but slightly developed.

Material studied: PUPC 02/146, (rP1)**;** PUPC 02/147, (rP2); PUPC 08/123, (rP3); PUPC 08/124, (rP4); PUPC 07/107, (lP4); PUPC 86/146, (lM1); PUPC 02/08, lM1; PUPC 07/41 and PUPC 07/42, (rM3); and PUPC 02/11, (rp2); PUPC 02/155, (rm3).

Distribution: Lower to Middle Siwaliks.

Localities: Chinji, Dhok Bun Ameer Khatoon and Lava (upper Chinji Formation; Lower Siwaliks).

Stratigraphic Level: The Chinji Formation, Middle Miocene.

Description

PUPC 02/146, P1 (Fig.11A-C) is small and in middle wear. The enamel is thin and the crown is low. Due to wear many details have vanished. The marks are present on the base of the crown, which indicate the birooted teeth. The occlusal outline is triangular. Owing to wear, the ectoloph is very thick. A small prefossette is present. The premolar has no protoloph well developed, so there is not a real median valley; there is an antero-lingual cingulum limiting the tooth in that area. The metaloph is straight and oblique, with the hypocone anterior to the metacone. The parastyle is prominent.

PUPC 02/147, P2 (Fig. 12A-B), has a broken ectoloph and it looks rather small in size and simple. The cingulum is present anteriorly as well as lingually. The occlusal outline is simple and the molar is rather worn. There is no crochet, crista and antecrochet. The entrance of the median valley is closed owing to the joined, not fused massive hypocone and protocone. A shallow postfossette is present. The protoloph and metaloph have almost equal size.

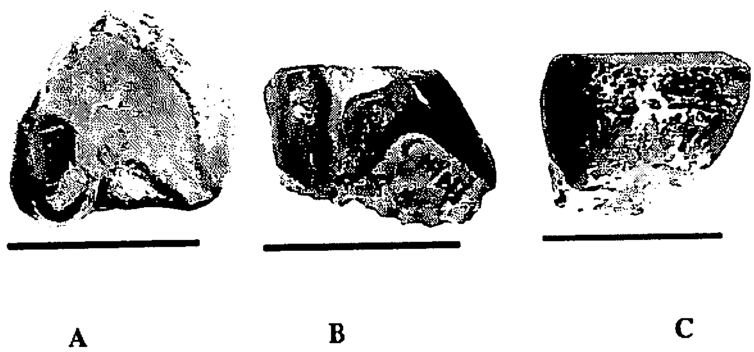


Figure 11A-C: *Gaindatherium browni*, IP1, PUPC 02/146, A- occlusal view, B- Lingual view, C- buccal view, scale bar 20 mm.

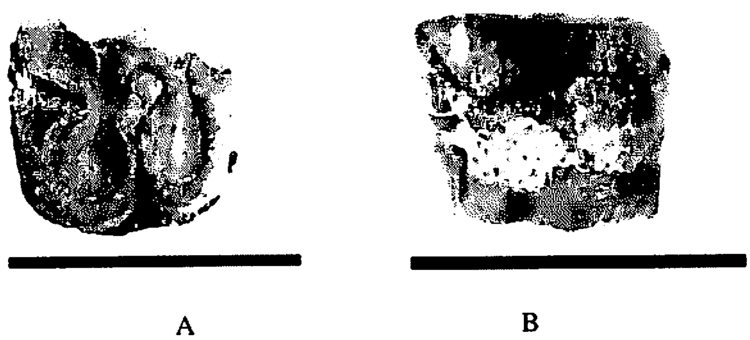


Figure 12A-B: *Gaindatherium browni*, IP2, PUPC 02/147, A- occlusal view, B- lingual view, Scale bar 20 mm.

PUPC 08/123, rP3 (Fig. 13) is well preserved and in late wear. Postfossette and cingulum are not visible due to wear. A slightly developed crochet is present. Slightly developed lingual groove is present. Some parts of the roots are also preserved. The entrance of the median valley is closed due to wear. Ectoloph is undulating in appearance.

PUPC 08/124, rP4 (Fig. 14) is in late wear. The crochet is slightly developed. The median valley is well developed. The ectoloph is broken. The protocone and hypocone are rounded on lingual side. Postfossette is not visible. The entrance of the median valley is closed due to wear, however the valley is deep. Sharp lingual groove is present. Cingulum is not visible at this stage.

PUPC 7/107, P4 (Fig. 15) is in middle wear and labial side is broken, so most of the features cannot be observed in this stage. Crochet is weakly developed. The median valley is well developed. The protocone and hypocone are rounded on lingual side. Vertical and horizontal cracks are present all over the crown due to long term surface exposure. Lingual wall of the postfossette is visible. The ectoloph is broken. The entrance of the median valley is narrow, however the valley is deep. Sharp lingual groove is present. Cingulum is present lingually, anteriorly and posteriorly. The boundary of hypocone and protocone is higher than the cingulum on lingual side.

PUPC 02/08, M1 (Fig. 16) is a well preserved first upper molar and in late wear. Anterior cingulum is well developed, but posterior one is absent probably due to wear. Parastyle is present and the paracone fold is not much prominent. Ectoloph is undulating in outline. The molar is brachydont and rather simple, and is characterized by the complete absence of an antecrochet or a crista. Traces of cement are present all around the tooth.

PUPC 86/146, M1 (Fig. 17) is damaged and partially broken. Anterior cingulum is well developed but posteriorly it is absent. Parastyle is present and the paracone fold is not much prominent. The postfossette is triangular in outline and isolated. Ectoloph is rather flat and have traces of cement. Mesostyle and metacone rib are absent. The specimen is in late wear. The enamel is thin and rugose around the crown. The ectoloph is somewhat convex.

PUPC 07/41 and PUPC 07/42, M3 (Figs. 18A-B; 19A-B) are complete molars. In PUPC 07/41 some part of the maxillary is also preserved. Both teeth are triangular in shape. The parastyle is marked, forming an obtuse angle with the ectometaloph, and a vertical grove is present extending towards the base of the crown. The ectometaloph is convex without any constriction. The median valley in PUPC 07/42 is filled with matrix and the molar is unworn, whereas PUPC 07/41 is in middle wear. The crochet is present in both molars; however the crochet and parastyle buttress are prominent in PUPC 07/41. A cingular border all around the molar base is present in PUPC 07/41; the other specimen does not have cingulum because it had not totally erupted yet. The protocone is not constricted, and is expanded gradually towards the base.

PUPC 02/11, p2 (Fig. 20A-B), is a completely preserved premolar in middle wear. Traces of cement are present, and the anterior and posterior valleys are filled with matrix. The labial groove is deep. The anterior valley is V-shaped and the posterior one is U-shaped. The premolar is triangular in outline, with long double roots. The cingulum is absent. The paralophid is shorter than the metalophid. The hypolophid is longer and transverse.

PUPC 02/155, m3 (Fig. 21A-C), is a well preserved tooth and in middle wear. Thick enamel is present. The trigonid is angularly V-shaped with the narrow and short paralophid and have right-angled metalophid with a slightly constricted metaconid. The talonid is U-shaped with the hypolophid and the entoconid with a posterior groove. No trace of cement. There are neither lingual nor labial cingula. Posteriorly the ectolophid groove is marked to the base of the crown. The paralophid is present and crushed. Hypolophid is oblique but transverse in occlusal view. The measurements of all described teeth are provided in table 8.

Figure 13: *Gaindatherium browni*, PUPC 08/123, rP3, occlusal view, scale bar 20 mm.

Figure 14: *Gaindatherium browni*, PUPC 08/124, rP4, occlusal view, scale bar 20 mm.

Figure 15: *Gaindatherium browni*, PUPC 07/107, lP4, occlusal view, scale bar 20 mm.

Figure 16: *Gaindatherium browni*, PUPC 86/146, lM1, occlusal view, Scale bar 20 mm.

Figure 17: *Gaindatherium browni*, PUPC 02/08, lM1, occlusal view, Scale bar 20 mm.

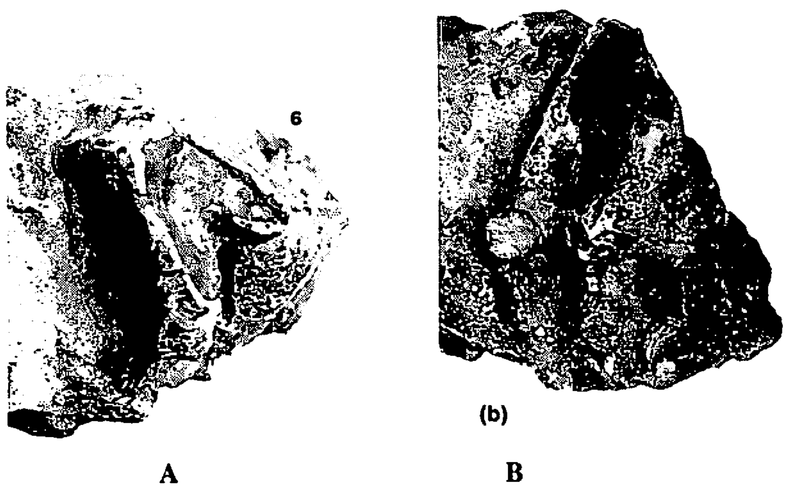
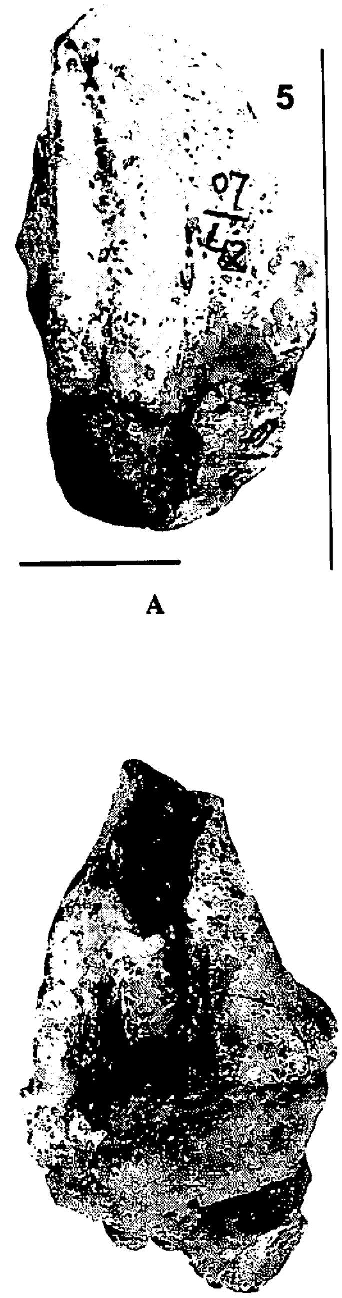


Figure 18A-B: *Gaindatherium browni*, PUPC 07/41, rM3, A- occlusal view, B- lingual view Scale bar 20 mm.



A

B

Figure 19A-B: *Gaindatherium browni*, PUPC 07/42, rM3, A- buccal view, B- lingual view, scale bar 20 mm.

A

B

Figure 20A-B: *Gaindatherium browni*. PUPC 02/11, rp2, A- occlusal view, B- buccal view, Scale bar 20 mm.

A

B

C

Figure 21A-C: *Gaindatherium browni*, PUPC 02/155, rm3, A- occlusal view, B- lingual view, C- buccal view. Scale bar 20 mm.

COMPARISON AND DISCUSSION

Colbert (1934) defined the genus and species *Gaindatherium browni* as a rhinoceros with several homologies with the extant species *Rhinoceros sondaicus* and *R. unicornis*. Many years later, Heissig (1972) included it as a subgenus of *Rhinoceros*.

Gaindatherium has been considered as a smaller genus when compared with *R. sondaicus* (Colbert, 1942). The transition from the *Gaindatherium* lineage to the Pleistocene rhinoceros species is poorly known (Heissig, 1989). *Gaindatherium* has a middle-late Miocene distribution with two successive species i.e. *G. browni* and *G. vidali* described in the Siwaliks (Heissig, 1972; Sehgal and Nanda, 2002). Cerdeño (1995) considered *Gaindatherium* as more closely related to *Lartetotherium* than to *Rhinoceros*. *G. browni* is known from the Lower Siwaliks (Chinji Formation) to the Middle Siwaliks (Nagri Formation) (Tang and Zong, 1987) and other pre-*Hipparion* localities of the Siwaliks group in Pakistan. The taxonomy and history of Oligocene and earlier Miocene rhinoceroses is confused. Many generic names have been used besides those so far mentioned while multitudes of species- level names have been founded and used in differing combinations with the generic names.

The first molar in the present collection is comparable to the molar described by Colbert (1934) for *Gaindatherium browni* in having an open transverse entrance of the median valley; no fusion of protocone and hypocone; presence of cingulum along the base of the preserved crown; presence of a short crochet; absence of antecrochet and crista and a remain of postfossette filled with sediment is also present. The enamel is moderate in thickness.

Both the third molars also have a fair similarity with those described by Colbert (1934) on the basis of the unconstricted protocone, which is expanded gradually towards the base; triangular shape, marked parastyle forming an obtuse angle with the ectometaloph; convex ectometaloph without any constriction; open median valley and presence of crochet. However the crochet and parastyle buttress are prominent in PUPC 07/41. The ectometaloph reaches the lingual corner. A cingular border all around the molar base is present in PUPC 07/41; however PUPC 07/42 does not have cingulum because it had not totally erupted yet.

Crochet size on M1 and M2 of *G. browni* must be variable according to the illustrations of Colbert (1934) and Heissig (1972). P1 was reckoned by Colbert (1935) to be absent in *G. browni* and Heissig (1972), it was however smaller than in the *Dicerorhinus* sp. aff. *sansaniensis* and *Brachypotherium* sp. from Miocene of Saudi Arabia (Gentry, 1987). The antero-labial wall of P3 is very slightly concave in *G. browni* (Heissig, 1972).

Gaindatherium browni share certain resemblances in the dental morphology with *Gaindatherium vidali* from the Nagri Formation (Heissig, 1972). The resemblance lies in the presence of anterior and posterior cingula, absence of lingual cingulum in the molars and absence of crista. However both the species have marked differences. *Gaindatherium vidali* differ from the *Gaindatherium browni* in having the well developed crochet, smaller size; well developed parastyle and parastyle fold, and funnel shaped postfossette. Dimensions of *Gaindatherium browni* are larger than *Gaindatherium vidali* (table 8).

Morphologically the *G. browni* described from Chinji Formation (lower Siwaliks) in the present study are similar to those described by Colbert (1934) and the Chinese *G.* cf. *browni* described by Tang and Zong (1987) in having brachydont teeth; a nearly flat and straight ectoloph; a long protoloph that slightly curls posteriorly; conspicuous parastyle fold; a small enamel projection at the base of the posterolabial side; and the enamel finely striated.

Table 8 . Comparative measurements of the cheek teeth of *Gaindatherium browni* from Chinji Fm.

Specimen No.	Position		*G. browni* Studied material	*G. cf. browni* Tang and Zong, (1987)	*G. browni AMNH 19409*	*G. browni AMNH 29838*	*R. (G). browni* Heissig, (1972)
PUPC 02/146	P1	L W	22.0 23.0	X	X	19.0 22.5	21.0 19.0
PUPC 02/147	P2	L W	24.0 -	X	X	28 34.5	X
PUPC 08/123	P3		32.0 43.0	X	X	32.0 43.0	33.0 42.0
PUPC 08/124	P4		37.0 49.0	X	40.0 51.0	37.0 49.0	32.0 47.0
PUPC 07/107	P4	L W	38.0 X	X	40.0 51.0	37.0 49.0	32.0 47.0
PUPC 86/146	M2	L W	44.0 47.0	X	42.0 52.0	X	42.0 45.0
PUPC 07/41	M3	LW	41.0 47.6	53.0 65.0	37.0 48.0	X	41.0 46.0
PUPC 07/42	M3	L W	39.0 47.0	X	37.0 48.0	X	41.0 46.0
PUPC 02/11	p2	L W H	28.0 19.0 19.8	X	X	28.5 21.5	26.0 17.0
PUPC 02/155	m3	L W	44.0 23.5	X	X	43.0 26.0	42.0 29.0

Gaindatherium vidali Heissig, 1972
(Fig.22-25; table 9)

Aceratherium perimense Falconer and Cautley, 1881

Rhinoceros (*Gaindatherium*) *vidali* Heissig, 1972

Gaindatherium browni Colbert, 1934

Gaindatherium browni Colbert, 1935

Type Species: *Gaindatherium browni* Colbert, 1934

Holotype: 1956 II 260, p3-m2. Collection of Geological Survey of Pakistan. Quetta, Isolated p4, m3, p2, Bayer. Staatslg, palaont. Hist. Geol. Munchen.

Type locality; Nagri, Salt range

Stratigraphic Level: Nagri Fm., Middle Siwaliks.

Material studied: PUPC 08/125, DP3; PUPC 84/61, rP2; PUPC 07/101, rP4; PUPC 07/102, rM2; PUPC 09/58, rM2.

Distribution: Middle Siwaliks for the type specimen; upper Chinji Fm. (Lower Siwaliks) for the present material.

Locality of the present material: Lava, (Upper Chinji Fm.).

Diagnosis: (Heissig, 1972).

Small species of the subgenus *Gaindatherium*, the opposite kind of *browni*, I2 weakly curved. Metacone rib in the upper molar is absent, however upper premolar have a strong metacone rib. Mesostyle is very weak. Secondary folding is also weak. The inner cusp is missing except for a trace of basal pre-protocone fold. Neither internal nor labial cingula are available. The M3 talon is weak; the posterior roots are completely overgrown. The ground of M3 is triangular. Lower P with blunt outer groove, lower molar with narrow tooth pits.

Description

PUPC 08/125, D3 (Fig.22) is a damaged deciduous premolar probably third. The enamel is thin and broken. Anterior and posterior cingula are well developed. Lingual and buccal cingula are absent. The median valley is open lingually. The postfossette is rounded, deep and funnel shaped. Crochet is moderately developed and is about to join the protoloph. Crochet is emerging from the apex of the metaloph, just beneath the ectoloph. Protoloph and metaloph are placed obliquely to the ectoloph. Parastyle and paracone fold are broken. Overall morphology is similar to the permanent premolars; except the absence of the metacone rib in the D3.

PUPC 84/61, rP2 (Fig.23) is fairly identical to the P2 of *G. vidali* described by Heissig (1972) both in morphology and size. The premolar is in late wear. The median valley is visible. A rudimentary anterior cingulum is present; however there is no trace of posterior cingulum. Paracone and metacone ribs are moderately developed. Protocone is broken lingually. Traces of cement are present.

PUPC 07/101, rP4 (Fig.24) is a well preserved first molar and slightly worn. The enamel is rugose. Traces of cement are present all around the tooth. Anterior cingulum is well developed and serrated. Posterior cingulum is limited around the postfossette. There is no cingulum at the lingual and buccal face of the tooth. The postfossette is deep and funnel shaped. Median valley is wide open and protocone and hypocone are far apart from each other. There is no trace of antecrochet or crista. However a delicate crochet extends into the median valley from the apex of the metaloph. Weakly developed mesostyle is present. Parastyle and paracone fold are well developed and prominent. Metastyle is also well developed. Metacone rib is also weakly developed. Protoloph and metaloph are oriented obliquely to the ectoloph. Ectoloph is concave behind the paracone fold. A convexity corresponding to the mesostyle is also present.

PUPC 02/102, rM1 (Fig.25) is completely preserved first molar. Enamel is not rugose. The molar has just erupted. The median valley is filled with matrix. The ectoloph is concave behind the strongly developed paracone fold. There is no antecrochet or crista. The trace of a crochet is visible at the apex of metaloph and is strongly angled against the metaloph. Postfossette is also filled with matrix. Traces of anterior and posterior cingula are visible. There are no lingual and buccal cingula. Median valley has a wide and deep lingual opening.

The comparative measurements of all the specimens are provided in table 9.

Figure 22: *Gaindatherium vidali*, PUPC 08/125, D3, occlusal view, Scale bar 20mm.

Figure 23: *Gaindatherium vidali*, PUPC 84/61, rP2, occlusal view, Scale bar 20mm.

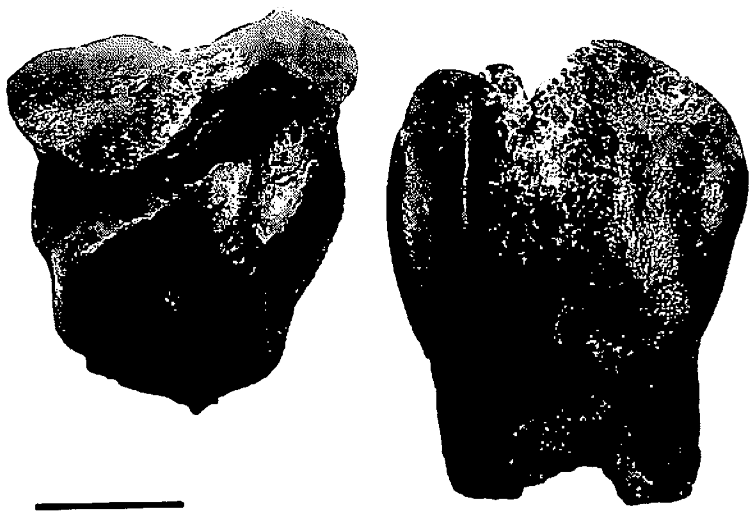


Figure 24: *Gaindatherium vidali* PUPC 02/101, rP4, A- occlusal view, B- buccal view, Scale bar 20mm.

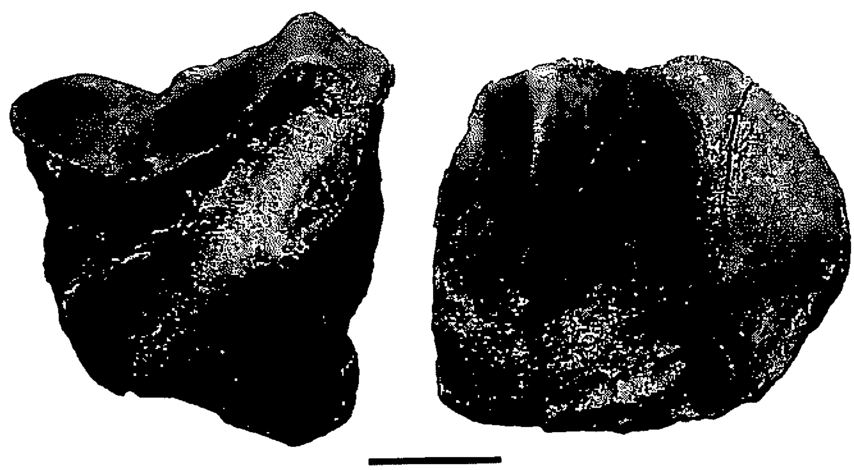


Figure 25: *Gaindatherium vidali*, PUPC 02/102, rM1, A- occlusal view, B- buccal view, Scale bar 20mm.

COMPARISON AND DISCUSSION

Gaindatherium browni is known from the Lower Siwaliks (Chinji Formation) to the Middle Siwaliks (Nagri Formation) and other pre-Hipparion localities of the Siwaliks in Pakistan (Tang and Zong, 1987). Colbert (1934) has described the genus *Gaindatherium* with *G. browni* from Chinji Fm. (Late Miocene) of the Siwaliks. Colbert mentioned that *Gaindatherium browni* have homologies in characters with *R. sondaicus* and *R. unicornis* and considered it as directly ancestral to *Rhinoceros*. According to Colbert the relatively narrow, shallow symphysis and the straight lower incisor are indicative of a relationship with *Rhinoceros*. The transition from the *Gaindatherium* lineage to the Pleistocene *rhinoceros* species is poorly known (Heissig, 1989).*Gaindatherium* has a middle-late Miocene distribution with two successive species i.e. *G. browni* and *G. vidali* described in the Siwaliks (Heissig, 1972; Sehgal and Nanda, 2002). Heissig (1972) revised the genus *Gaindatherium* to sub generic rank under *Rhinoceros*. However based upon the cladistic analysis Cerdeño (1995) and Antoine *et al.,* (2003c) has considered *Gaindatherium* as more closely related to *Lartetotherium* than to *Rhinoceros*.

According to Heissig (1972) sexual dimorphism in *Gaindatherium vidali* is indicated by the presence of a strong constriction of the tooth neck. The specimens in the present study are fairly similar to *Gaindatherium Vidali* described by Heissig (1972) from the Nagri Formation of the lower Siwaliks of Pakistan. The similarities are due to the presence of moderately developed outer ribs and a deeper notch of the inner wall in P2. The distance between the outer ribs is more as compared to the *Gaindatherium browni*. The upper molars show, except the features of the diagnosis; a simple crochet which is strongly angled against the metaloph, the Paracone is narrow and backward, not clearly demarcated, and the Parastyle and paracone folds are strongly developed very similar to that described by Heissig (1972). Features in the molars, like presence of a stronger anterior cingulum, anterior protocone fold, well developed funnel shaped postfossette and presence of a strong metacone rib in the premolars, are the characteristic features of *Gaindatherium Vidali*. The inner cingulum in *Gaindatherium vidali* is weaker than *Gaindatherium browni*. Paracone and metacone are also weakly demarcated as compared to *Gaindatherium browni* which have well marked paracone and metacone. The median valley is more widely open lingually in *Gaindatherium vidali* as compared to the *Gaindatherium browni*. Crochet is strongly angled against the metaloph, very different from very weakly developed crochet of the *Gaindatherium browni*. The dimensions of the present material are closer to *Gaindatherium browni* also; however it differs greatly from *Gaindatherium browni* in crown morphology.

Table 9: Comparative measurements of the cheek teeth of *Gaindatherium vidali*.

Specimen		*G.vidali* present collection	*G.vidali* Heissig (1972)	*G. browni* Heissig (1972)	*G. browni* Colbert (1934)
PUPC 84/61, rP2	L W	24.0 30.0	25.0 32.0	x x	28.0 34.0
PUPC 07/101, rP4	L W H	44.5 50.0 45.0	X 46.0 X	43.0 53.0 46.0	40.0 51.0 X
PUPC 07/102, rM1	L W H	44.4 49.0 42.0	34 44.0 40.0	46.0 52.0 42.0	42.0 52.0 X
PUPC 09/58 lM2	L W H	55.0 54.4 43.0	X x X	46.0 52.0 42.0	42.0 52.0 x
PUPC 08/125, D3	L	40.0 38.4			

Sub-tribe Aceratheriina DOLLO, 1885

Genus *Alicornops* GINSBURG AND GUERIN, 1995

Type Species: *Alicornops simorrensis* (Lartet, 1851) from Simorre, France.

Generic Diagnosis (after Ginsburg & Guérin, 1979, and Cerdeño, 1998)**:** Small aceratheriine. Skull with postglenoid apophysis very developed in contact with the posttympanic one, both slightly oblique anteriorly. Anterior dentition with I1 and i2 developed the latter as a large tusk (greater in males). Upper cheek teeth with paracone fold strong and little projected. Crochet well developed; sometimes crista also developed upper molars usually with continuous lingual cingulum. Lower premolars with lingual and labial cingula. Postcranial skeleton with shortened legs, forefoot tetradactyl.

Stratigraphic and Geographical Distribution: Middle and Late Miocene; Middle Aragonian-Late Vallesian, Europe, Anatolian Peninsula (Turkey), China, Baluchistan and the Siwalik deposits in Punjab, Pakistan.

Alicornops complanatum **(HEISSIG, 1972) n.comb.**

(Fig. 26-29; table 10-11)

Chilotherium intermedium complanatum Heissig, 1972: 61-71; pl. 7, figs 12, 13; pl. 8, figs 1-3; pl. 9, fig. 1. Welcomme *et al*. 1999: 138.

Chilotherium intermedium Heissig 1972: 65-71; table. 33 ; pl. 21, figs 7-9 ; pl. 22, figs 9-12 ; pl. 24, figs 25-27 ; pl. 25, figs 15-18.

? *Aceratherium* sp. cf. *A. simorrense* Guérin *in* Pilbeam *et al*. 1979: 36.

Rhinocerotidae indet. Welcomme *et al*. 1997: 534, 537.

Holotype: Associated cranium and mandible (BSP 1956 II 392) by Heissig (1972).

Locality of the present material: Dhok Pathan Formation, Punjab, Pakistan

Stratigraphic distribution: Dhok Pathan Formation (lower and upper), Upper Miocene (MN10-13; Pilbeam *et al*. 1996). Hypothetical presence in the layers of Sethi Nagri Formation (MN9) (Heissig 1972; Pilbeam, *et al*., 1996)

Geographic distribution: Punjab and central Baluchistan (Pakistan)

Material studied: PUPC 02/110, (left maxillary fragment having deciduous molars D2-4 and anterior end of zygomatic arch; PUPC 07/143, isolated lD4; PUPC 00/98, rd2-m1 and ld3-m1; PUPC 02/131, rd3-m1and ld2-m1 (associated mandibles).

Diagnosis (from Antoine *et al*., 2003c): *Alicornops* differing from the type species by the presence of a crochet sometimes double on P2-4; mesostyle on D2; a simple paralophid on d2; complete absence of I1; presence of antecrochet on P2-3; medifossette on P3-4; crista on P3, absent on upper molars; reduction of labial cingulum on the lower premolars; absence of antecrochet on P4; presence of lingual cingulum on the upper molars; and low dimensions of p2 and d1.

Description:

Upper Dentition:

PUPC 02/110, D2-D4 (Fig. 26 A-C) is a maxillary fragment with three deciduous molars D2-D4. The deciduous molars are molariform, the lingual cusps are separate. The ectoloph is undulating in appearance and has a very strong paracone rib and a strong parastyle. The metacone rib is weakly developed in the ectoloph. The metastyle is also present. The parastyle fold is very prominent and looks like a channel, runs vertically along the anterior end of the paracone. In D2 there is no anterior protocone groove, whereas in D3 and D4 the anterior protocone groove is very prominent. The cingulum is present anteriorly and posteriorly, and forms a shelf, high above the base of the teeth. The tubercles corresponding to the lingual cingulum are present at the entrance of the median valley. The protoloph and metaloph are of different widths and their lingual surfaces are rounded. The crochet is well developed and unites to the ectoloph enclosing part of the median valley forming a fossette. The postfossette is very deep in D2, but it is shallow and rounded in the other premolars. Traces of cement are present in the valleys.

PUPC 07/143, D4 (Fig. 27 A-C) is an isolated upper left fourth deciduous molar. The molar is well preserved but damaged and in the early stage of wear. Enamel is thin. There is no trace of cement in the valleys of the molars. The ectoloph is undulating in appearance and have a very strong paracone rib.

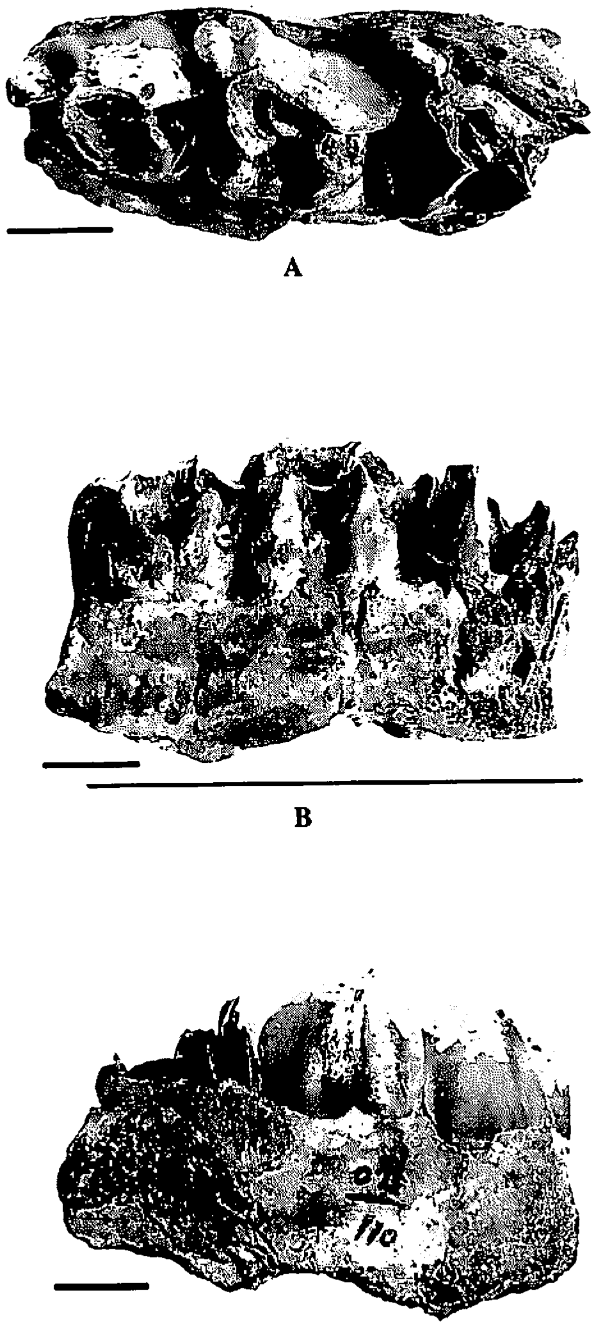


Figure 26A-C: *Alicornops complanatum*, PUPC 02/110, D2-D4, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20mm.

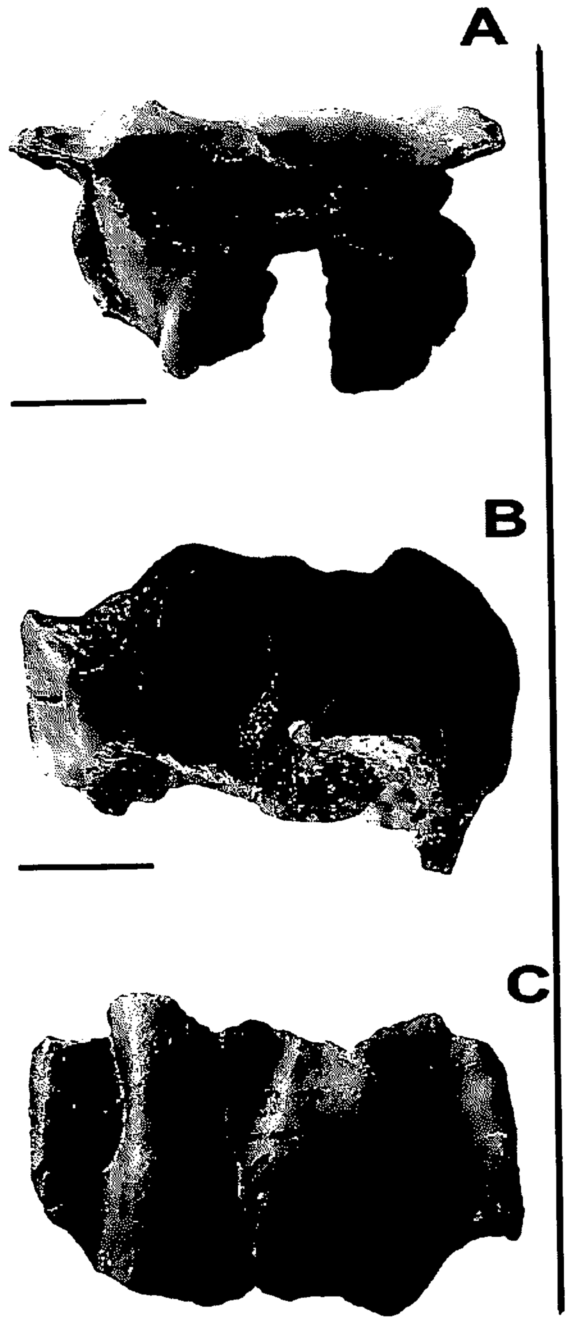


Figure 27A-C: *Alicornops complanatum*, PUPC 07/143, D4, A- occlusal view, B- lingual view, C- buccal view, Scale bar 10mm.

The parastyle is very sharp and prominent with very strong parastyle fold. The protocone is slightly constricted. The protoloph and metaloph are of different widths, and their lingual surfaces are rounded. The protoloph very markedly enlarged above groove, forming rounded protuberance (not antecrochet). The anterior protocone groove is present. The protocone and the hypocone are separated. The deciduous molar has a larger protocone than hypocone. Tooth has a lingual bridge between the protoloph and the metaloph. The crochet and the lingual bridge are well developed. The lingual bridge present between the protoloph and the metaloph is higher than the lingual cingulum. The postfossette is deep and wide but the anterior valley is not much wide. The anterior lingual and posterior cingula are well developed and form a continuous shelf like wall high above the base of the crown.

Lower Dentition:

PUPC 00/98m**,** rd2-m1 and ld3-m1 (Fig. 28 A-B) is an incomplete mandible, lacking the left ascending ramus and part of the right one. The symphysis is thick, and covered with compact sandstone. A horizontal crack is present on the posterior end of the symphysis, which indicates the actual posterior boundary of the symphysis at d3-d4 or d4 level. The horizontal ramii are moderately thick, the lower margin is flat and curves slightly upwards in the anterior part, which is broken below the symphysis. In dorsal view the symphysis is moderately wide with its anterior region narrower than the posterior border. The symphysis is broken anteriorly and it cannot be confirmed either the incisors are present or not. The dorsal surface of the symphysis is flat. Vertical ramus is inclined outwardly. Preserved teeth are right and left d2-m1. The d3 is small and triangular in outline; the d4 is somewhat elongated and triangular. In deciduous premolars the trigonid is reduced and extends forward, narrowly and sharply and the ectolophid fold is sharp and reclines forward. The paralophid of the deciduous premolars is short and bifurcated, protoconid with narrow and flattened fold on ectolophid. The hypolophid is oblique and short. In molars the anterior valley is V-shaped but the posterior valley is U-shaped. The cingulum is absent. A tubercle is present at the entrance of the posterior valley. The paralophid is short in the molars and the hypolophid is oblique in presence. The enamel is thick and wrinkled. The teeth are covered with thin and irregular cement on their buccal walls. The buccal groove is narrow and deeply V-shaped down to the base, and filled with cement in some cases.

Fig. 28 A-B: *Alicornops complanatum*, PUPC 00/98, rd2-m1 and ld3-m1, associated mandibles of a juvenile animal, A- occlusal view, B- buccal view, Scale bar 20mm.

Table 10. The measurements of the mandibular ramus of *Alicornops complanatum*.

Specimen no.	Position	Measurements in mm
PUPC 00/98 Mandible	Length	246
	Distance between posterior borders of symphysis and ascending ramus	153
	Height of horizontal ramus in front of m2	62
	Distance between horizontal ramii in front of m1	52
	Length of symphysis	75
	Antero-posterior diameter of ascending ramus	88

In PUPC 02/131**,** rd3-m1and ld2-m1 (Fig. 29) mandibular ramii are broken, and the teeth are dislocated from their original location. Left dental series comprises d2-m1 and right d3-m1. Only the first molar is fully erupted in the left series and the first molars in the right series is still erupting from the alveolus, just visible at the broken posterior end of the ramus. Crowns are relatively high. There are no traces of cement or secondary folds on the teeth. The labial groove of the ectolophid is well developed. Discontinuous labial cingulum is present. A ridge like enamel projection corresponding to the lingual cingulum is present along the lingual side of paralophid of d2 and the base of the posterior valley of d4. The trigonids are angular. The anterior and posterior cingula are well developed. There is no constriction on metaconid or entoconid. The valley of the talonid is deep. Paralophid of d2 is slightly constricted and is directed forward without any groove. The valley of the talonid is open lingually. Molars have paralophid almost equal in length to the metalophid.

COMPARISON AND DISCUSSION

All the morphological and metric characteristics of the present material from Dhok Pathan Fm. are rigorously identical to those of the deciduous upper and lower dentition of *"Chilotherium intermedium*" *complanatum* described by Heissig (1972) from Dhok Pathan Formation, Punjab, Pakistan. The similarity exists for lower dentition in the presence of relatively high crowns; regressed and short paralophid on d2; rugose enamel; anterior and posterior cingula developed; absence of lingual cingulum and constriction of the lingual conids and smaller dimensions. However the lingual cingulum in the upper teeth is less developed as compared to the specimens ascribed to *Chilotherium intermedium complanatum* by Heissig (1972). The upper deciduous cheek teeth in the present material have a well developed parastyle and a well projected and wide parastyle fold and the crochet is also well developed, very similar to *"Chilotherium intermedium*" *complanatum* described by Heissig (1972).

The present material show resemblance to *Alicornops complanatum* by Antoine *et al*., (2003c) from Sartaaf, Bugti Hills, Baluchistan, Pakistan, in the absence of the continuity of the labial cingulum with the posterior and anterior cingula. The labial cingulum is absent at the base of the labial groove and the lingual cingulum is absent in the present specimens, which is line with the Sartaaf specimens.

The striking morphological and metric resemblance with the holotype of this taxon (a mandible with an associated part of the palate of the same individual) described by Heissig (1972) helps in the identification of the present material as belonging to *Alicornops complanatum*. Heissig (1972) has described *Chilotherium intermedium complanatum* on the basis of some elements of the appendicular skeleton including humerus, tibia, calcaneum, MT II, MT IV, etc., which indicate the reduced size of the animal. The resemblance with the holotype includes the presence of a well developed crochet on D2-4; slight development of antecrochet on D2-3; medifossette on D3-D4, presence of crista on D3 and the low dimensions of d2.

Milk molars in the present study show some resemblance to milk molars of *Alicornops simorrense* described by Cerdeño and Sanchez (2000) in having a well developed crochet and its union with the crista. However the crista in the present specimens is weakly developed. Deciduous dentition of *Alicornops simorrense* can show bifurcated crista and anticrochets (Cerdeño and Sanchez, 2000); whereas in the present deciduous dentition crochet is bifurcated very similar to *Alicornops* *simorrense*. Well marked Paracone fold of the present specimens is very similar to *Alicornops simorrense*. Elongation of D2 owing to lengthening of the parastyle in *Alicornops simorrense* is also well represented in the present specimens of *Alicornops complanatum.*

However *Alicornops simorrense* differ from *Alicornops complanatum* in the present study due to the presence of bifurcated cristae and anticrochets. Upper premolars of *Alicornops simorrense* are morphologically quite different from the present material due to the presence of a continuous lingual cingulum, less developed parastyle and paracone fold and shape of the crochet. Crochet in the present specimens is thin and long, quite different from the rounded and thick crochet of *Alicornops simorrense.*

Lower milk molars of *Alicornops simorrense* are long and narrow very similar to the present specimens. However of bifurcated paralophid of d2, and the presence of narrow and flattened fold on buccal face of protoconid in *Alicornops simorrense* is quite different from the specimens in present study. Lower premolars of *Alicornops simorrense* described by Cerdeño and Sanchez (2000) from Spain differ from the present specimens in having a well developed labial cingulum; continuity of the anterior cingulum lingually to the base of anterior valley and presence of small cingular rim at the base of the posterior valley. However lower molars in the present material have reduced and discontinuous labial cingulum similar to those of *A. simorrense*.

Alicornops complanatum was formally recognized in the layers of the Dhok Pathan Formation only (Heissig, 1972) under the specific name "*Chilotherium intermedium complanatum"*. *Chilotherium intermedium* was established on one rM2 from lower Siwaliks of Sindh. Heissig (1972) divided *Chilotherium intermedium* into two subspecies: "*Chilotherium intermedium intermedium"* with restricted distribution in the Chinji and Nagri Formations (Middle Miocene and base of the Late Miocene) and "*Chilotherium intermedium complanatum"* in the layers of the Dhok Pathan Formation (Upper Miocene and base of Pliocene). Guerin (in Pilbeam *et al*., 1979) has also mentioned the presence of "*Aceratherium* sp. cf. *Alicornops simorrense*" in the base of the Dhok Pathan Formation. *Alicornops* appears in the middle Miocene and persists in upper Miocene in Western Europe (Cerdeño and Sanchez, 2000).

Antoine *et al.,* (2003c) on the basis of phylogenetic studies of fossil material from Sartaaf, Baluchistan, Pakistan, proposed the new combination *Alicornops complanatum* for "*Chilotherium intermedium*" *complanatum* and considered it as a sister group of the type species *Alicornops simorrense* (Lartet, 1837) in the consensus tree. This was the first occurrence of *Alicornops* in South Asia. They treated "*Chilotherium intermedium*" *intermedium* (Heissig, 1972) within the Teleoceratina.

The age of the layers of Sartaaf is comparable to that of Dhok Pathan Formation (Antoine *et al,* 2003c) from where the present specimens came from. The age of the present specimens also correlates with that reported by Guerin (1980a) as *Alicornops simorrense* from the Vallesian of Pakistan. *Alicornops complanatum* in the Middle Miocene of the Siwaliks lived in association with *Alicornops simorrense*, *Chilotherium intermedium* and *Brachypotherium perimense*. The present material of *Alicornops* came from upper Kamlial Fm. (MN 5) and the lower and middle Dhok Pathan Fm. (MN 9); however future discovery of more fossil remains of *Alicornops* from the Chinji and Nagri Fms. may bridge up the stratigraphic hiatus and shall reveal patterns of coexistence and evolutionary trends of various *Alicornops* species and other rhinocerotid taxa. The comparative measurements are provided in the table 11.

Table 11. Comparative measurements of the cheek teeth of *Alicornops complanatum.*

Specimen Number	Position		*Alicornops complanatum* Present study	*Alicornops complanatum* (Heissig,1972)	*Alicornops complanatum* (Antoine *et al.*, 2003c)	*A.simorrense* (Cerdeño and Sanchez, (2000)
PUPC 02/110	D2	L	36.0	34.0	X	31.0
		W	28.0	29.0	X	27.0
	D3	L	38.4	34.0	X	37.7
		W	32.4	32.0	X	38.5
	D4	L	43.0	44.0	X	43.9
		W	35.4	35.0	X	36.4
PUPC 07/143	D4		40.0	44.0	X	40.5
			33.0	35.0	X	47.2
PUPC 00/98	d2	L	28.5	27.0	30.0	29.2
		W	19.7	14.0	20.0	21.7
	d3	L	34.0	34.0	34.5	32.1
		W	21.0	19.0	21.5	20.9
	d4	L	37.3	35.0	35.0	33.8
		W	21.4	18.0	21.0	23.6
	m1	L	39.5	35.0	40.5	37.6
		W	23.7	24.0	23.5	22.6
PUPC 02/131	d2	L	29.2	27.0	20.0	27.1
		W	13.4	14.0	12.0	18.4
	d3	L	33.0	34.0	30.0	31.1
		W	19.0	19.0	20.0	22.9
	d4	L	35.6	35.0	34.5	36.1
		W	19.3	18.0	21.5	25.4
	m1	L	39.0	35.0	35.0	38.8

		W	24.0	24.0	-	24.5

Alicornops aff. *laogouense* DENG, 2004

(Fig. 30- 32; Table 12-13)

Type species: *Alicornops laogouense* Deng, 2004

Holotype: HMV 0982, an adult skull without the occipital surface.

Geographical Distribution: Middle Miocene (corresponding to MN6 in Europe) at Laogou, Hezheng, Gansu, China.

Diagnosis (after Deng 2004): Mid-sized skull, about 30 per cent smaller than that of extant *Rhinoceros unicornis*, but larger than other known species of the genus *Alicornops* (*A. simorrense* and *A. alfambrense*). There is no horn on the nasals or the frontal. It differs from *A. simorrense* in the following ways: (1) the nasals are 1·7 times longer than wide, but the width of the nasal base is narrower; (2) the skull is much higher; (3) the skull roof is lozenge-shaped, with a narrower maximal frontal width; (4) the frontal bone narrows posteriorly, but less strongly; (5) the surface between the parietal crests is slightly wider with a minimum width of 25 mm; (6) the nasal notch is situated at the level of the middle of P3, shallower than that of *A. simorrensis* at the level of P4; (7) the postorbital process is much weaker; (8) the anterior margin of the orbit is situated at the level of the anterior part of M1, more anterior than that of *A. simorrensis* at the level of the M1/M2 boundary or anterior part of M2.

Locality of the Present material: Late Miocene (Kamlial Formation) of the Siwaliks, Pakistan.

Material Referred from the Kamlial Formation: PUPC 07/46, lP3-M3 (left maxillary ramus); PUPC 07/47, rP2-M2 (right maxillary ramus); PUPC 07/48, lp4-m1 (left mandibular ramus).

Description

Upper Dentition:

The material collected from the Kamlial Formation includes upper and lower dentition. The chocolate color of the collected material specifies the characteristic of the Kamlial continental deposits. The material is partially damaged and many cracks are present, but the crown morphology is visible.

Buccal cingulum is absent in all upper cheek teeth of PUPC 07/46 (Fig. 30 A-C); the parastyle is sharp; the paracone fold is prominent; weakly developed mesostyle and median rib are present. The buccal wall of the ectoloph is undulating; Hypocone is constricted. The anterior and posterior protocone grooves are present in all the upper cheek teeth and very prominent in the upper fourth premolar.

Upper Premolars: In P2-P4 the anterior and posterior cingula are well developed, however lingual cingulum is weakly developed and discontinuous. The protoloph and metaloph are of different width and their lingual surfaces are rounded. P2-P4 has a lingual bridge between the protoloph and metaloph. Well developed crochet and weak crista are present, which are connected in rP2 and rP3 to form a medifossette. They have triangular postfossette. The entrance of the median valley in P2-3 is closed towards the base whereas P4 has an open entrance.

Upper Molars: The crista is absent. The protocone is wide and rounded and the hypocone is constricted. The labial wall of the ectoloph on M1-M2 forms the wide fold at the metacone. The entrance to the median valley is open; however tubercles are present in it. The anterior and posterior cingula are strongly developed and give an undulating appearance to the protoloph in M1. The M1 and M2 have long and large crochet and moderately developed antecrochet. The lingual cingulum in M2 is entirely absent and the entrance of the median valley is pretty open. M3 is triangular; the ectometaloph is convex. The protocone is expanded gradually towards the base. The crochet is present but it is broken in the molars. The antecrochet is very week and there is no cingulum.

Lower Dentition: The lower dentition includes two mandibular ramii. The buccal and lingual cingula are absent but mini tubercles are present anteriorly at the base of the paralophid. The buccal groove is well developed and deep. The anterior valley is V-shaped and the posterior one is U-shaped in the premolars, while both valleys are V-shaped in the molars.

PUPC 07/46 (Fig. 31 A-C) is a left maxillary ramus with P3-M3. The teeth are slightly broken. The enamel is somewhat shiny and wrinkled. Traces of cement are present at various parts of the teeth. The parastyle is well developed and paracone fold is present.

P3 is a broad crowned and subhypsodont tooth. The protocone is not constricted. Protocone is connected with hypocone through a delicate lingual bridge. The lingual cusps are distinct. Paracone rib is not so prominent. Protoloph is wavy and wide. Metaloph is thinner than protoloph. Ectoloph is constricted in appearance; it is undulating in appearance and not flat from lingual side. Medisinus is developed. Anterior, posterior and lingual cingula are present. Labial groove is prominent. Mesostyle is absent and crochet is present. Median valley is wider from the base to the upper part. Medifossette is not present.

P4 is also broad crowned and hypsodont. The parastyle is sharp. The labial wall is undulating in appearance. The paracone rib is very prominent. Protoloph is slightly wavy. Metaloph is damaged.

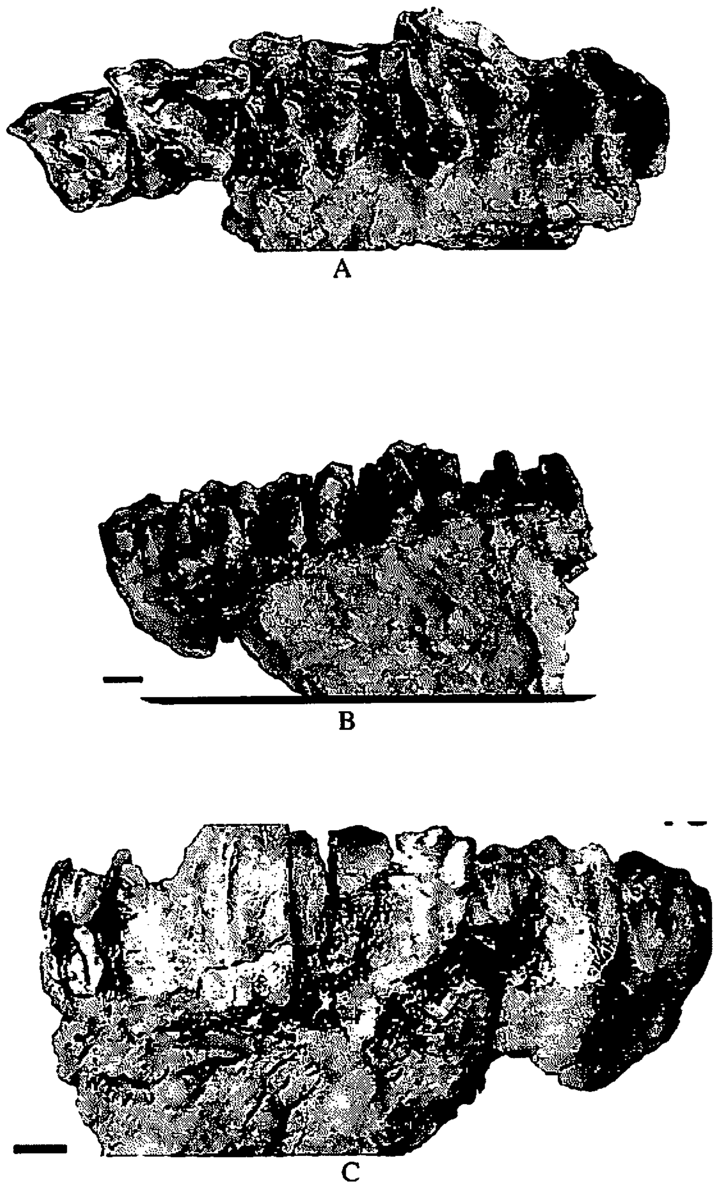


Figure 30 A-C: *Alicornops* cf. *laogouense*, PUPC 07/46, lP3-M3, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20 mm.

There is no constriction of hypocone and protocone. Cingulum is present on the anterior and lingual sides of the tooth. Medisinus is well developed. A bifurcated crochet and a crista are present but lingual bridge is absent. Due to damaged posterior parts the presence of a postfossette is not clear. Median valley is wider at the base than on the upper part. Medifossette is absent.

M1 has constricted protocone and hypocone. Lingual bridge is absent. Paracone is prominent with a well developed paracone rib. Ectoloph is undulating in appearance. Protoloph and metaloph are well developed. Protoloph is thicker than metaloph. Anterior and posterior cingula are present; however posterior cingulum is only present along the hypocone. Crochet and antecrochet are present. Medisinus is also well developed.

M2 has a slightly constricted protocone and hypocone. Hypocone is damaged at the apex. Paracone rib is prominent. Metaloph is broken and medisinus well developed. Ectoloph is undulating in appearance. Anterior and posterior cingula are present but posterior cingulum is present only along hypocone. Median valley is v-shaped. Crochet and antecrochet are present and well developed. Medisinus is also well developed.

M3 is narrow crowned and subhypsodont. There is no cingulum all around the tooth. Median valley is wide and open. Parastyle is present and the parastyle fold is less marked. There is no. Paracone rib is visible, Crochet is present but broken. The remaining tooth is damaged.

PUPC 07/47 (Fig. 27 A-B) is a maxillary ramus with rP2–M2. The teeth are well preserved and the enamel is somewhat shiny and wrinkled. Traces of cement are present at various parts of the teeth. Parastyle as well as parastyle fold are well developed. Ectoloph is undulating in all the teeth. A prominent paracone rib is also present.

P2 is almost half worn. Protocone is not constricted. Metacone rib is developed. Hypocone is slightly rounded. Metaloph is short. Hypocone and metacone are not connected through lingual bridge. Lingual cingulum is present only at the base of the median valley, posterior cingulum is also present and medisinus is not very prominent. Protoloph has a weak connection with the ectoloph and is separated from the ectoloph at the apex.

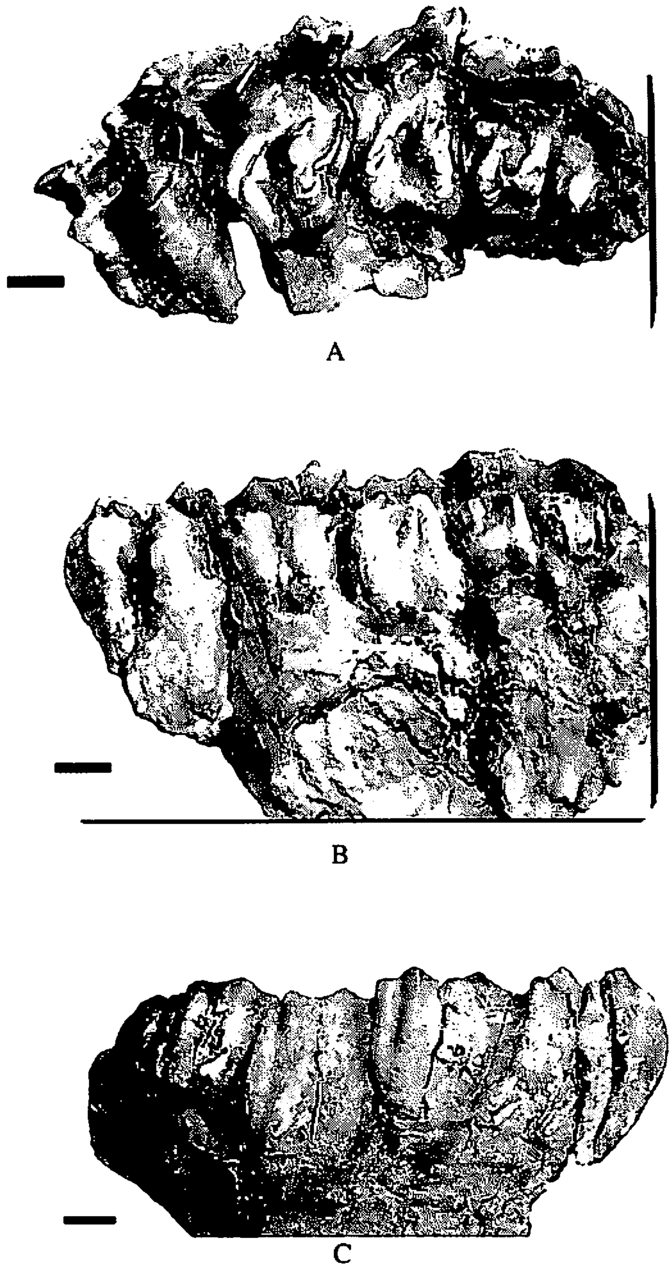


Figure 31 A-B: *Alicornops* cf. *laogouense*, PUPC 07/47, rP2-M2, A- occlusal view, B- lingual, C- buccal view, Scale bar 20 mm.

P3 is subhypsodont and broad crowned. The tooth is in early stage of wear. Protocone is not constricted. Metacone rib is developed. Hypocone is slightly rounded. Metaloph is partially exposed. Hypocone and metacone are connected through lingual bridge. Cingulum is present on anterior and posterior side; however it is absent at the base of the protocone. Medisinus is not very prominent. Antecrochet as well as crista are well developed and unite each other to form a medifossette. A convexity corresponding to mesostyle is present on the ectoloph. Postfossette is triangular and wide.

In P4 Protocone is slightly constricted on postero-lingual surface. Metacone rib is developed. Hypocone is slightly rounded. Metaloph is fully exposed and well developed. Protocone and hypocone are separated and lingual cusps are prominent. Lingual bridge is delicate and present deeply at the base of the median valley. Lingual cingulum is present only on the base of median valley. Anterior and posterior cingula are present. Medisinus is not very prominent. Crochet and crista are absent while antecrochet is well developed and bifurcated.

M1has a strongly constricted pillar-like protocone. Metacone rib is developed. Hypocone is slightly rounded lingually. Metaloph is fully exposed and well developed, and thinner than protoloph. Hypocone and metacone are separated and lingual cusps are prominent. Lingual bridge is not present. Lingual cingulum in the form of a tubercle is present only at the base of median valley. Anterior and posterior cingula are fully developed. Medisinus is very prominent. Crochet is well developed and crista is absent; antecrochet is also well developed.

Protocone in M2 is constricted. Metacone rib is developed. Hypocone is not rounded. Paracone is damaged. Metaloph is fully exposed and well developed, and thinner than protoloph. Hypocone and metacone are separate and lingual cusps are prominent. Lingual bridge is not present. Anterior and posterior cingula are well developed. Lingual cingulum is absent. Crochet is highly developed and crista is absent. Antecrochet is weakly developed.

PUPC 07/48 (Fig. 32 A-C) is a mandibular ramus with d4-m1**. C**rowns of the teeth are relatively high. There are no secondary folds. Irregular and thin traces of cement are present on the teeth. The labial groove is well developed and angular in shape. Anterior and posterior cingula are present. Lingual cingulum in the form of tubercles is present along the base of the anterior valley of the d4. In d4 and m1 the labial cingulum is serrated and absent at the level of the labial groove. The anterior valley is U-shaped and posterior valley is V-shaped in d4; however both anterior and posterior

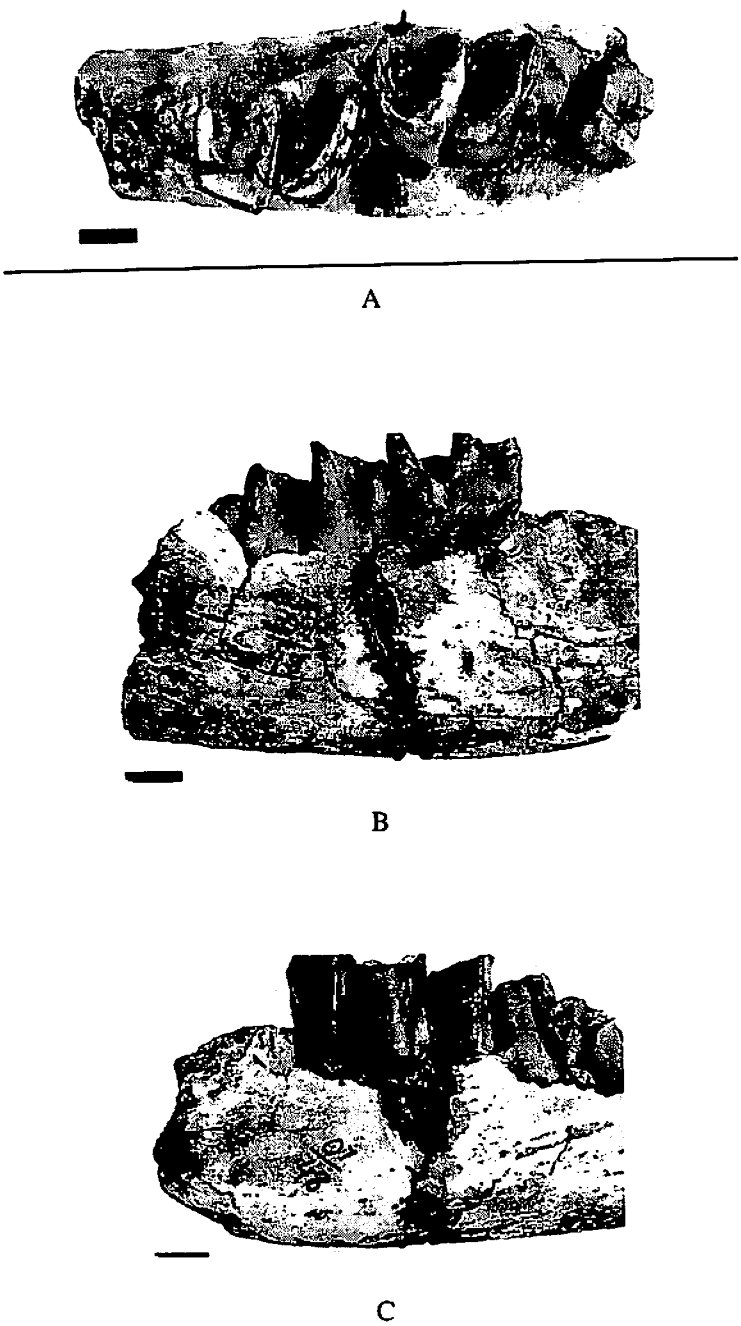


Figure 32 A-C: *Alicornops* cf. *laogouense*, PUPC 07/48, rd4-m1, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20 mm.

COMPARISON AND DISCUSSION

Lartet (1851) erected the species *Rhinoceros simorrense* based on a fragment of skull from Simorre (France) with upper cheek tooth rows from P2 to M3. Hooijer (1966) referred this species to the genus *Aceratherium*, but the generic position has changed several times since then. Ginsburg (1974) considered that this species should be placed in the genus *Dromoceratherium* and Heissig (1976) placed it in the genus *Mesaceratherium*. Subsequently Ginsburg and Guérin (1979) created a new subgenus, *Alicornops,* and assigned *Aceratherium* (*Alicornops) simorrense* as the type species. Yan and Heissig (1996) elevated *Alicornops* to genus level. Later Heissig (1989), Prothero *et al* (1989) and Cerdeño (1992) accepted *Alicornops* as a genus. Cerdeño and Alcalá (1989) established the species *Alicornops alfambrense* from the late Miocene of Spain, also documented later in France and Germany. However Antoine *et al*., (2003c) has considered the inclusion of *A. alfambrense* into the genus *Acerorhinus* as doubtful. Recently, Deng (2004) defined a new species *Alicornops laogouense* from Laogou in Hezeng country, Linxia Basin, Gansu, China, on the basis of an adult skull without the occipital surface. The species is recovered from the Middle Miocene fauna of Tongxin, Ningxia, China and its age corresponds to MN6 in Europe. The species is slightly larger than *Alicornops simorrense*. Cerdeño (1995) performed a cladistic analysis that showed *Alicornops* to have a more crown ward evolutionary position than *Aceratherium*. The dental characters of the rhinocerotid material described here from the Kamlial Formation are fairly similar in dimensions and morphology to *Alicornops laogouense* described by Deng (2004). Upper premolar in the studied specimens are similar in having well developed anterior, lingual and posterior cingula high above the base of the teeth; unconstricted protocone; dissimilar width of the protoloph and metaloph; rounded lingual surfaces of the protocone and hypocone; hypocone larger than the protocone; crochet and crista are weakly developed but united to form a medifossette in P2, its posterior valley is triangular, and projecting parastyle. Antecrochet and crista are absent in 3rd and 4th premolars. P4 has an open median valley with a well developed crochet similar to that of *A. laogouense.*

Upper molars also shows resemblance with *A. laogouense* in having a flattened lingual and rounded lateral surfaces of the protocone ; wide protocone; crista absent; open entrance of the median valley; presence of wide fold at the labial wall of the ectoloph; long and large crochet in M1; anterior and posterior cingula well developed; lingual cingulum in the form of a tubercle in the entrance of median valley in M1; protocone markedly constricted in the M1; weak constriction of protocone and absence of lingual cingulum in M2. M3 in the present material show similarities in having an unconstricted protocone that expands gradually towards the base, narrow crochet, well developed antecrochet, wide median valley; well developed anterior cingulum and absence of lingual cingulum.

The lower dentition in the present collection also shares many morphological characteristics with lower dentition of *Alicornops laogouense*. In the lower premolars the anterior valley is V-shaped and the posterior valley is U-shaped; discontinuous labial cingulum. In molars anterior and posterior valleys are V-shaped and the posterior valley is wide and deep and serrated labial cingulum. However the labial cingulum is not much developed as compared to the holotype. The present material have similarities with *Alicornops simorrense* in the presence of a well developed crochet, strong and little projected paracone fold and in the development of crista in the premolars; however it differs from *Alicornops simorrense* in the absence of continuous labial and cingula in the lower premolars and discontinuous lingual cingulum in the upper premolars.

The material in the present collection when compared with *Alicornops complanatum* described by Antoine *et al*., (2003c) from Bugti hills, Baluchistan shows differences in the morphology of the lower dentition due to the absence of the continuity of the labial cingulum with the posterior and anterior cingula. The labial cingulum in the present material is serrated and is absent along the base of the labial groove; whereas it is continuous in the Sartaaf specimens. Lingual cingulum is present in the Kamlial specimens in the form of tubercles up to the base of the anterior valley; however lingual cingulum is completely absent in *Alicornops complanatum*. Protocone on P2 is more slightly developed than hypocone in *Alicornops complanatum* (Antoine *et al*., 2003c) whereas protocone of the P2 in the present material is very similar to P2 of *Alicornops laogouense*. The specimens ascribed to *Alicornops* aff. *laogouense* from the Kamlial Formation are larger in size than the dental material of *Alicornops complanatum* in the present study from the Dhok Pathan Formation; and *Alicornops simorrense* described by Cerdeño and Sánchez (2000) from France and Spain.

Aprotodon fatehjangense and Brachypotherium perimense have been the most widespread and persistent rhinoceros species in Kamlial, Chinji and Nagri Formations of the Siwaliks. The present material when compared to the above mentioned species shows marked differences in morphology and dimensions as reported by Heissig (1972) form the Siwaliks of Pakistan.

The most widespread rhinocerotid species in the MN6-10 of the European Middle and Upper Miocene is *Alicornops simorrense* especially in upper Aragonian strata (Cerdeño and Sánchez, 2000). It has also been recovered from Romania in the upper Aragonian and lower Vallesian (Codrea, 1992, 1996), in the lower Vallesian of Moldova (Lungu, 1984), and the Middle Miocene in Poland (Kubiak, 1981). Outside Europe it has been reported from the Middle Miocene of Turkey (Heissig, 1976) and the Vallesian of Pakistan (Guérin, 1980a). Ginsburg and Guérin (1979) discovered and identified as *Alicornops sp.* some fossils from the lower Aragonian (MN3) of Wintershof in Germany. *Alicornops alfambrense* is reported only from Spain and France (Cerdeño and Sánchez, 2000).

According to Qui *et al*., (1999) the Middle Miocene *Alicornops laogouense* in the Linxia Basin is of the same age as the Dingjiaergou fauna from Tongxin in Ningxia, China, which corresponds to MN6. After the discovery of *Alicornops laogouense* from the Linxia Basin, it appears that the genus *Alicornops* migrated from western through Eastern Europe, western and southern Asia to the Far East. During MN6 times, its distribution was relatively widespread through the whole Eurasia (Deng, 2004).

According to Guérin (1980a) in Western Europe *Alicornops simmorense* lived together with other rhinocerotid forms, such as *Hoploaceratherium tetradactylum, Aceratherium incisivum,* and *Lartetotherium sansaniense* in open woodland with associated lakes and swamps. The short limb bones and robust metapodials of *Alicornops simmorense* were adapted for life on soft soils in contrast to the long and straight metapodials of other rhinoceroses (Cerdeño, 1998). In China, *Alicornops laogouense* lived together with *Hispanotherium matritense* in a warm environment (Deng and Downs, 2002). A large number of the fossils of the Amebelodontidae, adapted to live in habitats near water, have been found associated with *Alicornops laogouense* in the Linxia Basin, indicating that lakes and rivers were abundant in the environment in which this species lived (Deng, 2004).

The present material came from the upper strata of the Kamlial formation at the transition zone between the upper Kamlial and the lower Chinji formations of the Siwaliks, which represent a warm and humid open woodland environment with abundant rivers and lakes. *Alicornops* aff. *laogouense* lived in association with other rhinocerotids including *Brachypotherium fatehjangense, Brachypotherium perimense, Chilotherium intermedium* and *Caementodon oettingenae*. The type specimen of *Alicornops laogouense* came from Middle Miocene of Laogou, corresponding to MN6 in Europe. The present material came from the Late Middle Miocene of the Siwaliks and its age roughly corresponds to Late MN5 and early MN6 in Europe.

Table 12. The comparative measurements of the upper cheek teeth of *Alicornops* aff. *laogouense.*

No.			*Alicornops* aff. *laogouense* Present study	*Alicornops laogouense* (Deng, 2004)	*Alicornops simorrense* (Cerdeño and Sanchez, 2000)	*Aprotodon fatehjangense* (Heissig, 1972)
PUPC 07/46	P3	L	42.0	39.0	35.6	-
		W	46.0	49.0	42.9	-
	P4	L	52.0	42.0	37.8	-
		W	54.4	57.0	46.2	48.0
		H	48.0	45.0	-	-
	M1	L	-	52.5	45.4	-
		W	55.6	57.5	47.9	-
	M2	L	63.0	52.0	48.9	-
		W	55.0	57.0	49.5	-
	M3	L	46.7	50.0	39.5	54.0
		W	40.5	49.0	44.0	60.0
PUPC 07/47	P2	L	30.0	32.5	31.1	38.0
		W	36.0	39.0	35.7	50.0
		H	33.7	36.0	-	54.0
	P3	L	41.0	39.0	35.6	-
		W	52.0	49.0	42.9	-
		H	41.0	39.5	-	-
	P4	L	46.5	42.0	37.8	-
		W	59.0	57.0	46.2	-
	M1	L	59.0	52.5	46.1	-
		W	57.0	57.5	50.9	-
		H	49.0	41.0	-	-
	M2	L	61.0	52.0	48.9	-
		W	60.0	57.0	49.5	63.0

Table 13. The comparative measurements of the lower cheek teeth of *Alicornops* aff. *laogouense.*

			Alicornops aff. *laogouense* Present study	*Alicornops laogouense* (Deng, 2004)	*Alicornops simorrense* (Cerdeño and Sanchez, 2000)
PUPC 07/48	p4	L	49.0	41.5	32.9
		W	24.0	31.0	23.2
		H	37.0	31.0	-
	m1	L	45.0	44.5	35.6
		W	27.0	29.0	21.9
		H	34.7	30.0	-

Tribe Teleoceratini HAY, 1902

Genus *Chilotherium* RINGSTROM, 1924

Chilotherium intermedium* (LYDEKKER, 1884*)

(Figs. 33-41; Table 14-22)

Rhinoceros sivalensis intermedius, Lydekker, 1884

Aceratherium gajense intermedium, Pilgrim, 1910

Chilotherium intermedium Matthew, 1929

Chilotherium intermedium Colbert, 1935

Holotype: rM2, C34, Geological Survey of India.

Type Locality: Sindh, Pakistan

Stratigraphic Distribution: Lower to middle Siwaliks (Middle Miocene to early Pliocene).

Diagnosis: A *Chilotherium* of medium size. Upper incisor absent; cheek teeth hypsodont; parastyle fold indistinct or lacking; protocone constricted, ectoloph greatly elongated, mandibular symphysis transversely expanded. The trigonid is angularly V-shaped. On the lower molars the lingual and labial cingula are absent, the hypolophid reclines backward and the entoconid have a flat lingual margin.

Material in the present study;

Chinji Formation, Lower Siwaliks (Middle Miocene): PUPC 97/84, lP3**;** PUPC 08/01, a broken mandibular ramus with rp4-m3.

Nagri Formation, Middle Siwaliks (Late Miocene): PUPC 07/93, a maxillary fragment with rP3-M3; PUPC 07/94, a mandibular ramus with lp2-m1; PUPC 08/02, a partially broken mandibular ramus with rp2-m3; PUPC 07/ 95, rm2.

Dhok Pathan Formation, Middle Siwaliks (Late Miocene): PUPC 29/99, a left mandibular ramus with a broken molar with lm1; PUPC 02/109, a mandibular ramus with partially erupted lm3.

Description:

Specimens from Chinji Formation**:**

Upper dentition:

PUPC 97/84, P3, (Fig; 33) is poorly preserved and even some part of the root is also preserved. The premolar is quadrate subhypsodont with the outer wall rather upright and being compressed considerably broader than long. The protoloph and metaloph are parallel. The specimen is in middle wear and hypsodont. The parastyle is well developed and have a vertical groove. Parastyle and metastyle are present in the ectoloph. The ectoloph is flat in appearance and there is no median rib or mesostyle. Crista is absent in the premolar, however crochet is slightly developed. The cingulum is also present in the metaloph and projects upward to form a postfossette. The median valley is narrow in the premolar but open transversely towards the crochet. The slight traces of cement are present posteriorly along the metaloph. Due to the backward extension of the protoloph internal pass of the median valley is very much shallower.

Lower dentition:

In PUPC 08/01(Fig.34 A-C) the horizontal ramus is broader and has greater depth laterally in the anterior region than the posterior one. The buccal profile of the horizontal ramus is slightly concave at the level of p4-m1. The crowns of the teeth are relatively high. The teeth are in the middle stage of wear, less accentuated on m3.

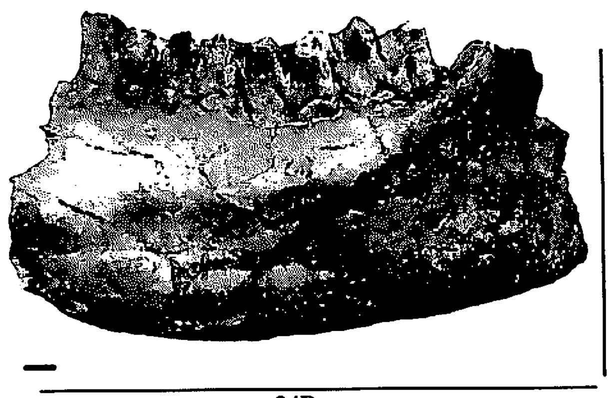
In p4 the anterior cingulum is present and continues lingually as a cingular rim to the base of the anterior valley. Paralophid is short; trigonid is V-shaped and the posterior valley is U-shaped; labial cingulum is absent; hypolophid reclines backwardly; entoconid is lingually flat; the talonid is better developed than the trigonid; labial groove is shallow and U-shaped in both p4 and molars.

The m1 has a broken paralophid. Labial groove is shallow. Anterior cingulum is present. A cingular rim is present at the base of the anterior valley. The posterior valley is widely V-shaped lingually. An enamel tubercle is present at the base of the posterior valley. Lingual margin of the entoconid is flat. Occlusal outline of m2 is rectangular, longer than broader. Anterior and posterior valleys are widely V-shaped lingually. The metalophid and hypolophid are oblique and the paralophid is short. The trigonid of m3 is angularly V-shaped with the narrow and short paralophid and a right angled metalophid with a slightly constricted metaconid. The entoconid have a posterior groove. No trace of cement is present. There is no labial cingulum. Metalophid and hypolophid are oblique.

Figure 33: *Chilotherium intermedium*, PUPC 97/84, lP3, occlusal view, scale bar 20 mm

34A

Figure 34 A: *Chilotherium intermedium*, PUPC 08/01, rp4- m3, A-occlusal view, Scale 20mm.



34B

34C

Figure 34 B-C: *Chilotherium intermedium*, PUPC 08/01, rp4- m3, B- lingual view, C- buccal view. Scale 20mm.

Table 14: measurements of upper dentition of *Chilotherium intermedium* from the Chinji Formation.

Specimen no.		P3
PUPC 97/84	L W	31.0 42.0

Table 15: measurements of lower dentition of *Chilotherium intermedium* from the Chinji Formation.

Specimen no.	P4		M1		M2		M3	
	L	W	L	W	L	W	L	W
PUPC 08/ 01	53.3	38.4	52.4	35.0	58.0	40.3	66.0	34.0

Table 16: Measurements of the mandibular ramus (PUPC 08/01) are as follows.

Specimen no.	Horizontal ramus	mm
PUPC 08/01	Depth of horizontal ramus at m1	118
	Depth of horizontal ramus at m2	112
	Width of horizontal ramus at m3	61
	Depth of horizontal ramus at m3	123
	Length of the molar series	179

Specimens from Nagri Formation**:**

Upper Dentition: PUPC 07/93 (Fig. 35 A-C) is a maxillary fragment having rP3-M3. The cheek teeth are hypsodont. All the teeth are excellently preserved, in middle wear. The molars are large and wide, the last upper molar triangular in shape. Enamel is thick.

Upper premolars: - The lingual cingula are discontinuous and labial cingula are absent from P3 to P4, ectoloph greatly elongated and medisinus opened except in P3. There is a well-developed paracone rib. Parastyle fold is relatively weak. The protocone is somewhat constricted whereas the hypocone is bulbous. The protoloph and metaloph are of different widths. The crochet and crista are absent except on P3. The protoloph is longer than the metaloph. P3 is small, about half the width of P4 and has well developed anterior cingulum. P4 has a larger protocone than hypocone. In P4 the anterior fold of the protocone is large and deep, which together with the anterior cingulum unites to form an accessory fossette. P4 has cracks present in the occlusal view and trace of cement is preserved.

Upper molars: The anterior, lingual and posterior cingula are present; however the cingulum is discontinuous in M2 and M3 at the lingual face of protocone and hypocone. M1 and M2 have slightly constricted protocone, the parastyle fold is relatively conspicuous, the crochet and antecrochet are short and thick. Protoloph is longer than the metaloph both being at equivalent levels and both perpendicular to the ectoloph. M2 is similar to M1 but protocone of M2 has vertical crack, Parastyle and paracone rib is damaged and Hypocone flange is also partially damaged. M3 is triangular in shape with a slightly convex ectometaloph. The crochet of M3 is strong, very extended and in contact with the protoloph to enclose a fossette. Within the fossette are inflections of varying degree. The crista is prominent and does not connect with the crochet.

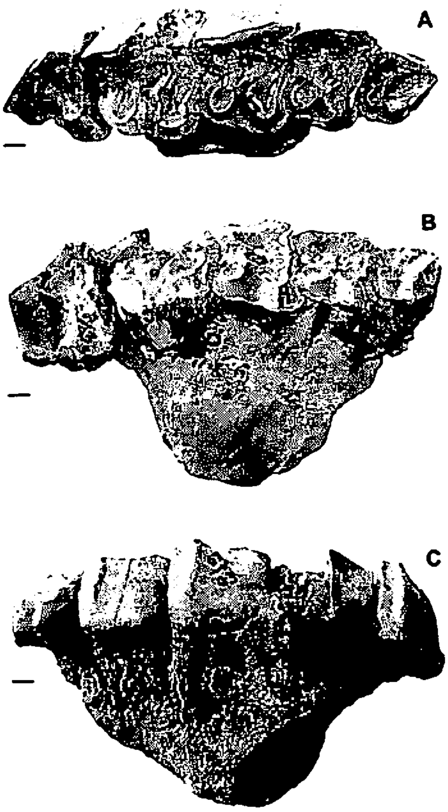


Figure 35 A-C: *Chilotherium intermedium*, PUPC 07/93, P3-M3, A - occlusal view, B- Lingual view, C- Buccal view. Scale bar 20mm.

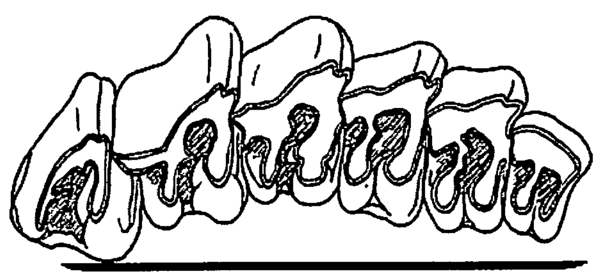


Figure 36. *Chilotherium intermedium*. Geological Survey of India, No. C 100, right upper dentition, occlusal view, one half natural size (from Matthew, 1929).

Lower dentition:

PUPC 08/ 02 (Fig. 37 A-C) is a partially broken mandibular ramus. The horizontal ramus is high and it is broken anteriorly just beneath the p2.The ascending ramus has a shallow horizontal depression on the lateral surface.

Lower Premolars; comparatively the p2 is smaller in length than the other lower cheek teeth of the series and the paralophid is very short and weak. The posterior valley is narrow and U-shaped. A weak labial cingulum is present in p2. Anterior and posterior cingula are present but very much reduced. Paralophid in p3 is short. The posterior valley is U-shaped. The labial cingulum is absent; anterior and posterior cingula are weak. Hypolophid reclines backward slightly and the lingual margin of the entoconid is flat. Labial groove is shallow and widely U-shaped. In p4 the anterior cingulum is present. Lingual cingulum in the form of a cingular rim is present at the base of the anterior valley. Paralophid is short; trigonid is V-shaped and the posterior valley is U-shaped; labial cingulum is absent, backwardly reclining hypolophid and flat lingual margin of the entoconid is present. Labial groove is shallow and U-shaped. The talonid is better developed than the trigonid.

Lower Molars; The paralophid is broken and short in m1. Labial groove is shallow and wide. Anterior cingulum is present. A cingular rim is present at the base of the anterior valley. The posterior valley is widely V-shaped lingually. Enamel tubercle is present at the base of the posterior valley. Lingual margin of the entoconid is flat. Occlusal outline of m2 is rectangular and it is longer than broader. The metalophid and hypolophid are oblique and the paralophid is short. In m3 trigonid is angularly V-shaped with the narrow and short paralophid and a right angled metalophid with a slightly constricted metaconid. The talonid is also V-shaped; the entoconid have a posterior groove. No trace of cement is present. There is no labial cingulum. The ectolophid groove is shallow and not marked to the base of the crown. Metalophid and hypolophid are oblique. Measurements of the mandibular ramus are provided in table 17.

Table 17: Measurements of the mandibular ramus (PUPC 08/02) are as follows.

Specimen no.	Mandibular ramus	mm
PUPC 08/02	Max width of ascending ramus	56.0
	Depth at m1	101.0
	Depth at m2	116.0
	Depth at m3	121.0
	Width at m3	61.0
	Length of the premolar series p2-p4	131.0
	Length of the molar series m1-m3	187.0

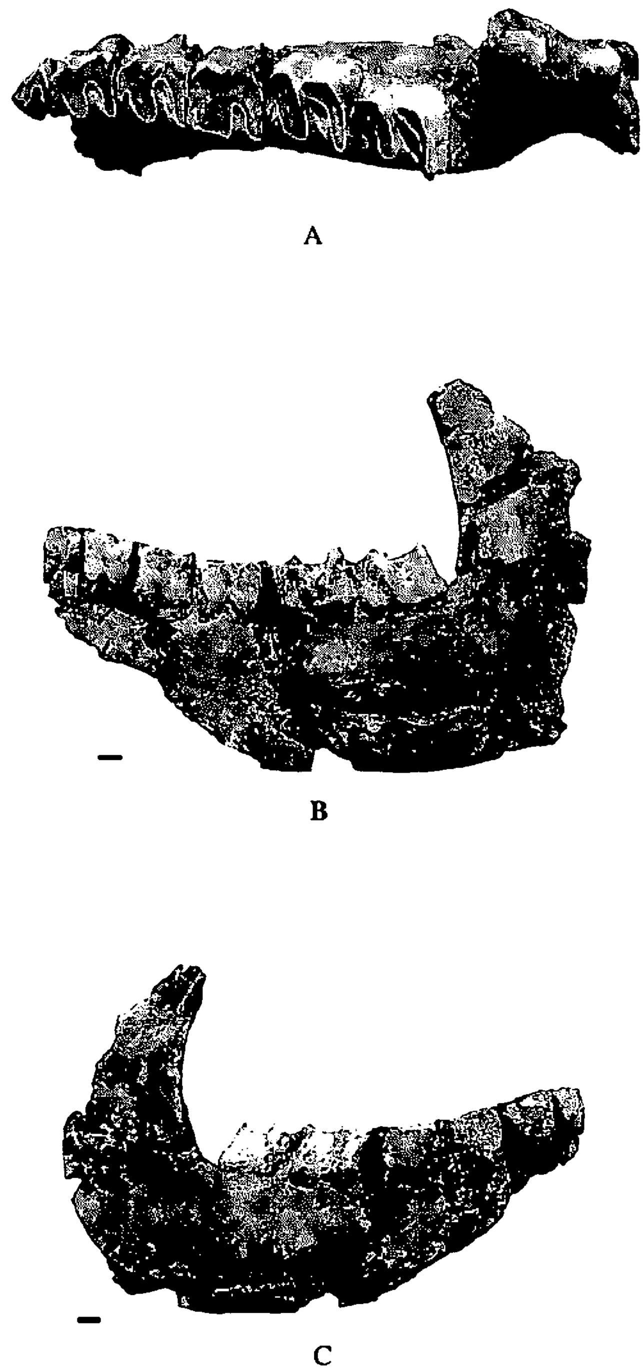


Figure 37 A-C: *Chilotherium intermedium*, PUPC 08/02, rp2- m3, A- occlusal view, B- lingual view, C- buccal view, Scale 20mm.

PUPC 07/94 (Fig. 38 A-C) is left mandibular ramus having p2-m1. All the cheek teeth are excellently preserved and show different morphological features. Most of lower teeth are covered with thin and irregular cement on their labial walls, especially in the labial grooves. Enamel is thick and uniform in thickness. All the teeth are in middle wear. The mandible is moderately long.

Lower premolars: The lingual and labial cingula are absent and the V-shaped labial groove is wide and shallow. Hypolophid is oblique but transverse in occlusal view. The ectolophid fold is sharp but reclines backward. Protoconid of p2 and p4 are partially damaged; p2 is longer than broader, triangular in outline and the anterior end of paralophid is sharp and projecting forward. In p3 the cracks are present in the occlusal view, and the metaconid is partially damaged. The paraconid is well preserved and round in shape. The trigonid is well developed, the paralophid is weak and the metalophid is acute. In p4 the anterior valley is V-shaped and the posterior valley is U-shaped. Its hypolophid is partially damaged.

Lower molars: m1 has a partially damaged paralophid. Entoconid has a clearly flat lingual margin. The labial groove is narrow and deep, projecting towards the base; the trigonid is angularly V-shaped with the narrow and short paralophid and a right-angled metalophid. The m1 has oblique hypolophid but transverse in occlusal view, the ectolophid fold is sharp but reclines backward. It has two roots.

PUPC 07/95 (Fig. 39 A-C) is an isolated, complete, right lower molar. The trigonid is angularly V-shaped with the narrow and short paralophid and a right angled metalophid with a slightly constricted metaconid. Many morphological features are preserved due to middle wear. Entoconid has a clearly flat lingual margin. The labial groove is narrowly and deeply down to the base. Hypolophid is oblique but transverse in occlusal view. A vertical crack is present on the crown. Enamel is thick and thinly wrinkled vertically. It has poor antero-lingual cingulum. The measurements of upper and lower cheek teeth are provided in tables 18-19.

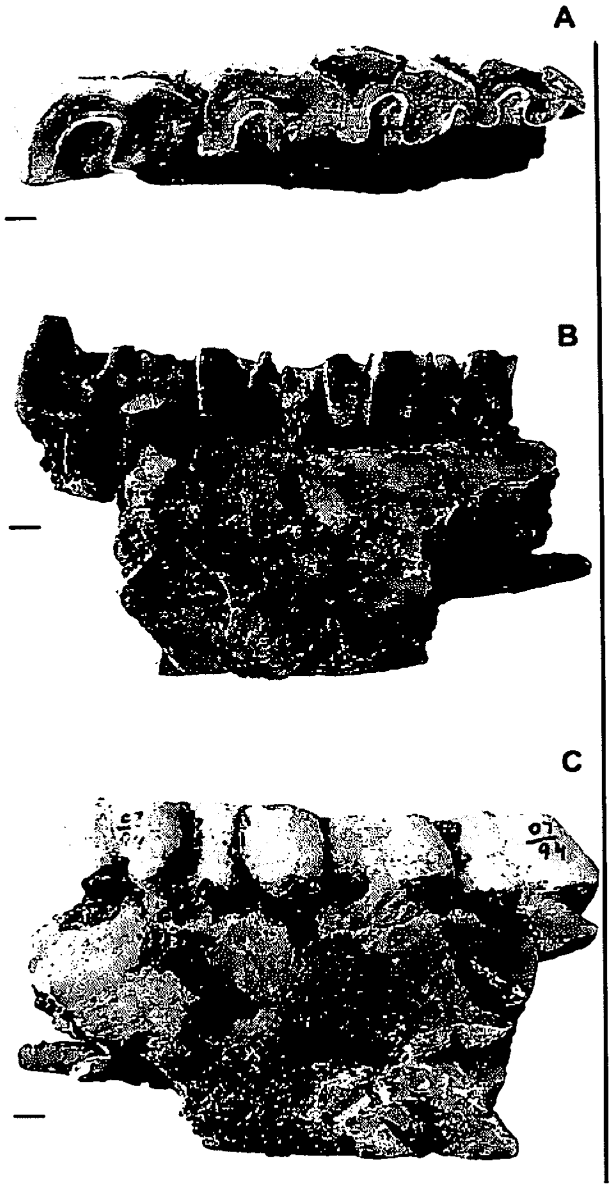


Figure 38 A-C: ***Chilotherium intermedium***, PUPC 07/94, p2-m1, A- occlusal view, B- lingual view C- buccal view. Scale bar 20mm.

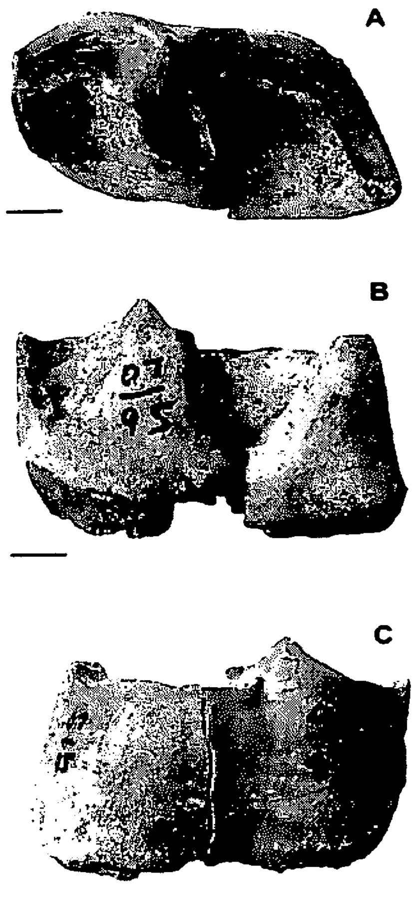


Figure 39 A-C: *Chilotherium intermedium*, PUPC 07/95, an isolated right lower m1. A- occlusal view, B- lingual view, C- buccal view.

Table 18: Measurements of the upper cheek teeth of *Chilotherium intermedium* from the Nagri Formation.

specimen	P3		P4		M1		M2		M3	
	L	W	L	W	L	W	L	W	L	W
PUPC 07/93	41.0	49.0	52.0	64.2	60.0	71.0	64.0	72.0	65.2	70.0

Table 19: Measurements of the lower cheek teeth of *Chilotherium intermedium* from the Nagri Formation**.**

specimen	p2		p3		p4		m1		m2		m3	
	L	W	L	W	L	W	L	W	L	W	L	W
PUPC07/94	-	-	45.5	32.0	48.3	42.0	52.0	39.0	61.0	41.0	69.0	40.0
PUPC07/94	-	-	-	-	-	-	-	-	-	-	69.0	37.0
PUPC08/02	35.0	29.5	46.5	37.5	52.0	38.5	56.0	42.5	62.0	45.0	65.0	42.5

Specimens from the Dhok Pathan Formation:

PUPC 02/109 (Fig. 40 A-C) is an unworn, partially erupted molar in a dentary fragment. The dentary is broken at the anterior boundary of the ascending ramus. The molar has thick enamel. The paralophid is short, curved and complete whereas metalophid is broken at the top because of long surface exposure. The metaconid is slightly constricted whereas entoconid is not erupted yet from the mandible. The molar has a broken trigonid and the metalophid is oblique in appearance.

PUPC 29/99 (Fig. 41 A-B) is a broken 2nd lower molar in a mandibular fragment. The roots of the first molar are also preserved. The paralophid is short and its anterior end extends lingually. The metalophid is obliquely transverse with the constricted metaconid; the hypolophid and entoconid are missing in the molar. The measurements are not possible as the specimens are badly damaged.

Figure 40 A-B: *Chilotherium intermedium*, PUPC 02/109, a broken mandibular ramus having partially erupted m3, occlusal view, Scale bar 20 mm.

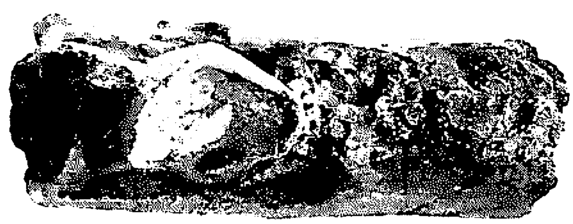


Figure 41A-C: *Chilotherium intermedium*, PUPC 29/99, a mandibular ramus having a broken molar, occlusal view, Scale bar 20 mm.

COMPARISON AND DISCUSSION

The declining diversity of rhinoceroses from the latest Miocene onward resulted in nearly complete disappearance of the Aceratheriinae, except *Chilotherium* in Asia throughout the Pliocene (Cerdeño, 1998). The palaeomagnetic dating indicates that *Chilotherium intermedium* appeared in the Siwaliks from 16.3 Ma BP to 7.6 Ma BP (Flynn *et al*., 1995). Since the establishment of the genus *Chilotherium* by Ringstrom (1924), twelve species have been described, and nineteen other species have been referred to this genus (Deng, 2006b). Lydekker (1881, 1884) described a right M2 from the Siwaliks of Sindh, Pakistan, and named it as *Rhinoceros sivalensis* var. *intermedius*. The characters of this molar include well-developed parastyle fold and little constricted protocone. Pilgrim (1910) revised it as *Aceratherium gajense intermedium*. Matthew (1929) recommended the inclusion of *Rhinoceros sivalensis* var. *intermedius* into the genus *Chilotherium*, and later Heissig (1975, 1989) revised it as *Subchilotherium.* Mathew's consideration is followed in the present study and the rhinocerotid material from the Chinji and Nagri Formations is ascribed to *Chilotherium intermedium*. Ringstrom (1924) stated that the species of *Chilotherium* have no marked differences in their cranial and dental structures. According to Ringstrom the peculiar characters of *Chilotherium* include large and strongly projected parastyle, absent or weak parastyle fold, and almost flat ectoloph. All these characters are represented in the present material and warrant their ascription to *Chilotherium*. Geologically *Chilotherium intermedium* has a long range and persistence with a medium sized body and appeared in the Chinji Formation through the middle Siwaliks, while *Chilotherium blanfordi* appeared in the Bugti beds and lasted through the Kamlial, Chinji and into the Middle Siwaliks (Colbert, 1935).

Colbert (1935) described *Chilotherium intermedium* from the lower and middle Siwaliks with the diagnosis of a well developed parastyle fold and slightly constricted protocone. The present material from the Nagri Formation has well developed parastyle fold with a flat ectoloph and slightly constricted protocone and is similar to Colbert's material.

Heissig (1972) described *Chilotherium intermedium intermedium* from the Chinji and Nagri beds, and *Chilotherium intermedium complanatum* from the Dhok Pathan beds of the Siwaliks of Pakistan, and referred them to the newly created genus *Subchilotherium*. *S.i. intermedium* has a well developed antecrochet; strong posterior groove of protocone on upper molars and wide posterior cingulum in M3. The present upper dentition from Nagri Formation is different from *S.i. intermedium* in having a weak antecrochet in M2 and M3 only, and a weak posterior cingulum in M3; however posterior groove of protocone on upper molars is quite similar to *S.i. intermedium. S.i. intermedium* also has smaller size than the present specimens.

Deng (2006c) proposed a revised diagnosis of *Subchilotherium intermedium* Heissig 1975, and characterize it by the presence of a narrow mandibular symphysis; cheek teeth are subhypsodont, with strongly projected paracone and parastyle. The parastyle fold is sharp, and the lingual cingulum is weak. Premolars have marked molarization and P2/p2 are comparatively small. Upper dentition in the present collection shows similarities to *Subchilotherium intermedium* described by Deng (2006c) from Leilao and Xiaohe, China due to the presence of a medifossette and well developed crista in M3. Lingual cingulum is present in M3 of Chinese specimens as well as in the Nagri specimens. However lingual cingulum in Chinese specimens is a strong pillar according to Deng (2006c) which is quite different from the lingual cingulum of the M3 in the Nagri specimens.

Chilotherium intermedium can be distinguished from *Chilotherium blanfordi* by its moderately prominent parastyle fold and slight constriction of the protocone. The Nagri specimens presented here show strong affinities to the typical *Chilotherium intermedium* in having slightly constricted protocone; well-developed crochet; moderately developed antecrochet in the upper molars and bulbous hypocone. The present material is comparable to that described by Colbert (1935) and figured by Matthew (1929) from the Middle Siwaliks of Pakistan in having a broad and flat ectoloph with a strong and well-developed parastyle, a somewhat oblique protoloph and metaloph; metaloph longer than the protoloph; strong crochet; absence of internal cingulum and moderate constriction of protocone. In *Chilotherium intermedium* the protocone is much less constricted off from the protoloph as compared to *Chilotherium blanfordi*. The lower dentition in the present study has also very close resemblance in morphology to the juvenile dental material of *Chilotherium intermedium* described by Colbert from the Middle Siwaliks in the presence of V-shaped trigonid, absence of lingual and labial cingulum, the backwardly reclining hypolophid and flat lingual margin of the entoconid. The studied specimens show some affinities with *C. wimani* described by Deng (2001a) from Fugu, Shanxi and Linxia basin, China, in the presence of weakly constricted protocone and unconstricted hypoconid, well-developed parastyle fold and paracone ribs, weaker development of crochet, small antecrochet and broad mandibular symphysis. However *Chilotherium wimani* differ greatly from *Chilotherium intermedium* due to low cheek tooth crowns and wavy labial walls in the upper cheek teeth.

Nagri specimens are comparable to *C. anderssoni* from China in having flat labial wall and the absence of the medifossette; however parastyle fold in the present material is more prominent in contrast to the *C. anderssoni* where paracone rib and parastyle fold are almost absent (Deng, 2006b). In the upper premolars of the *C. anderssoni,* the lingual cingulum is weak and discontinuous, while in studied specimens of *Chilotherium intermedium* the lingual cingulum is well developed and continuous in the upper premolars. In upper molars of *C. anderssoni*, the lingual cingulum and the crista are completely absent, and the antecrochet is large enough to fill the whole median valley (Deng, 2006b). In contrast to *C. anderssoni,* lingual cingulum is well developed and continuous in the 1st upper molar of *Chilotherium intermedium*, however in the 2nd and 3rd molars lingual cingulum is present only in the median valley while it is absent on lingual faces of protocone and hypocone. The presence of a prominent crista, a well-developed crochet, a moderate antecrochet and a lingual bridge between the protoloph and ectometaloph of third upper molar in the Nagri specimens distinguish them very well from *C. anderssoni*. Due to inadequacy of the published material of *Chilotherium intermedium* from the Siwaliks or any other geographic region sharp comparisons are not possible. The fossil material described in this study from Chinji and Nagri Formations is rigorously identical in morphology as well as dimensions. Comparative measurements are provided in tables 20-21.

Table 20: Comparative measurements of upper dentition of *Chilotherium intermedium* from the Nagri Fm.

	P2		P3		P4		M1		M2		M3	
	L	W	L	W	L	W	L	W	L	W	L	W
Chilotherium intermedium Present study	31.0	42.0	41.0	49.0	52.0	64.2	60.0	71.0	64.0	72.0	65.2	70.0
"Chilotherium intermedium intermedium" Heissig (1972)	26.0	34.0	29.0	46.0	34.0	47.0	38.0	45.0	45.0	42.0	45.0	53.0
Chilotherium blanfordi AMNH 19408 (Colbert ,1935)	-	-	-	-	-	-	52.0	64.0	64.0	66.0	56.0	61.0
Chilotherium anderssoni By Ringstrom (1924) , taken from Colbert (1935)	-	-	-	-	-	-	-	-	65.0	-	-	-

Table 21: Comparative measurements of the lower Cheek teeth of *Chilotherium intermedium* from the Chinji and Nagri Fms.

Fm.		p2		p3		p4		m1		m2		m3	
		L	W	L	W	L	W	L	W	L	W	L	W
Chinji	PUPC08/01	-	-	-	-	53.3	38.4	52.4	35.0	58.0	40.3	66.0	34.0
Nagri	PUPC07/94 PUPC07/95	-	-	45.5 -	32.0 -	48.3 -	42.0 -	52.0 -	39.0 -	61.0 -	41.0 -	69.0 69.0	40.0 37.0
	PUPC08/02	35.0	29.5	46.5	37.5	52.0	38.5	56.0	42.5	62.0	45.0	65.0	42.5
"Chilotherium intermedium" Heissig (1972)		27.0	14.0	40.0	19.0	41.0	22.0	35.0	25.0	39.0	26.0	38.0	25.0

Tribe **Teleoceratini** HAY, 1885

Genus *Brachypotherium* ROGER, 1904

Brachypotherium perimense **FALCONER AND CAUTLEY, 1847**

(Figs 42-54; Table 22-25)

Cotypes: The specimens figured by Falconer and Cautley, (1847: pl. LXXV, figs. 13-16, and LXXVI, figs. 14-17).

Type locality: Perim Island

Geographic Distribution: Siwalik region

Stratigraphic range: Lower to Middle Siwaliks.

Diagnosis: (translated from Heissig, 1972): Very large species of the genus *Brachypotherium* with relatively high cheek teeth. All generic features are extremely developed. Nasals are shortened and hornless. The upper molars have weak constrictions of the inner cusp; reduced antecrochet usually present. Upper Premolars are molariform, usually with highly convex exterior. Lower molars almost are without buccal fold; cingula usually reduced and short.

Material referred from Dhok Pathan Formation: PUPC 07/51, right upper jaw fragment with milk molars DM1-DM4; PUPC 69/499, lP1; PUPC 02/149, rP1; PUPC 83/736, lP4; PUPC 83/731, rP4; PUPC 83/732, lM1; PUPC 83/734, lM2; PUPC 83/735, lM3; PUPC 02/108, rM3; PUPC 83/727, lm2; PUPC 69/513, lm3 (Dhok Resham and Dhok Pathan type locality; Dhok Pathan Fm., Middle Siwaliks).

Material referred from Nagri Formation: PUPC 07/54, left mandibular ramus with p3-m2; PUPC 08/119, rm3 (East of Sethi Nagri village).

Description:

<u>Specimens from the Dhok Pathan Fm.</u>:

PUPC 07/51(Fig. 42 A-C) is collected from the Dhok Pathan type locality. All the milk molars are covered with a thick layer of cement and in middle wear. The DM1 is covered with matrix and the crown morphology is not observed. The characteristic feature of the milk molars is a strongly developed cingulum, which makes a projected shelf along the lingual side of the cheek teeth. The protocone of the milk molars is strongly pyramidal shaped and has a broad base tapering towards the apex. The anterior and posterior protocone grooves are well developed and pinched off the lateral walls of the protocone resulting in a tomb shaped protocone. In DM2 a metacone rib is present whereas it is absent in DM3. The paracone fold is very prominent in all the milk molars. In both DM3 and DM4 the antecrochet is well developed but the crochet is absent. The hypocone is not constricted and is conical at the apex. The ectoloph is very higher (23 mm) than the lingual cones (protoloph and metaloph). The measurements are provided in table 22.

Table 22. The measurements of the milk molars of *Brachypotherium perimense***.**

Specimen no.	Position	Length	Width
PUPC 07/51	D1	35.0	21.0
	D2	50.0	37.0
	D3	64.0	51.6
	D4	68.4	47.5

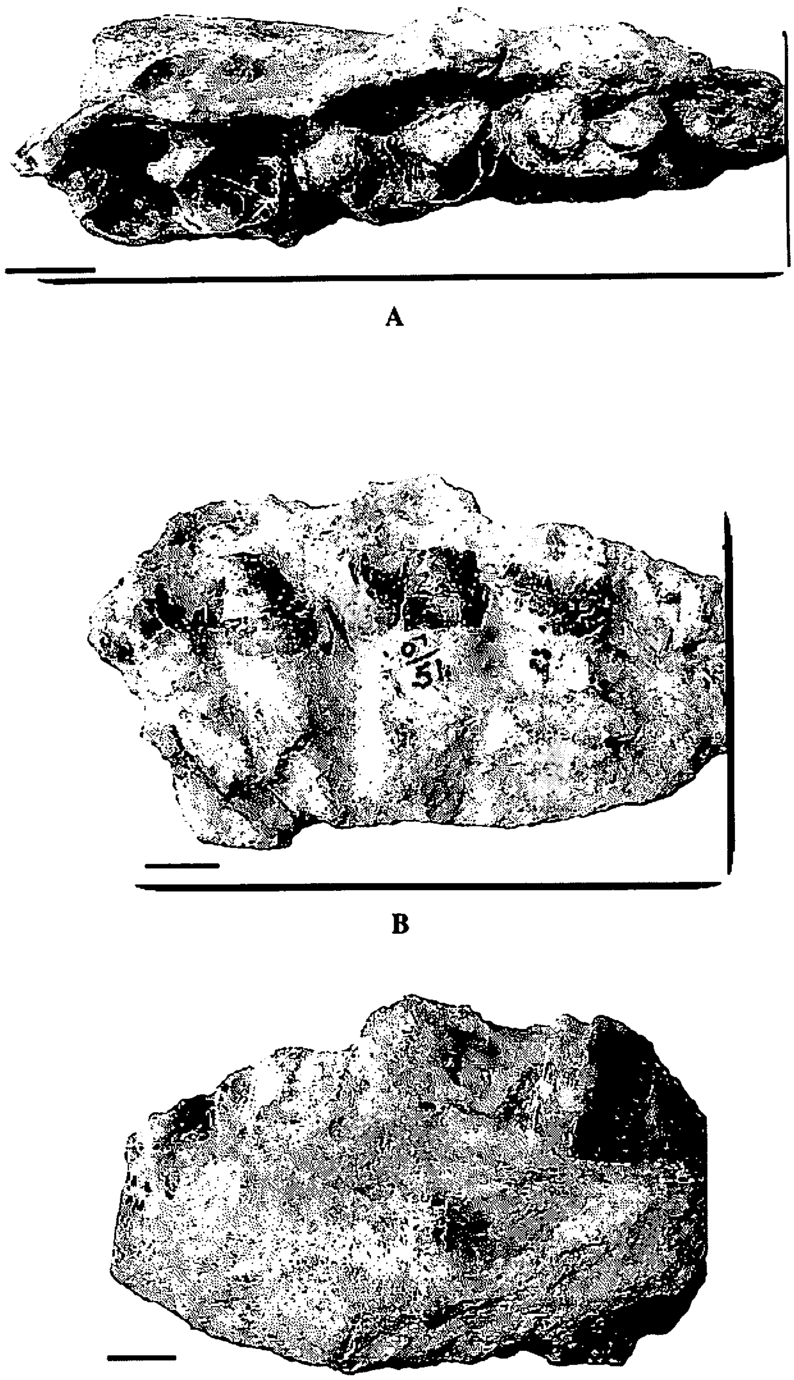


Figure 42 A-C: *Brachypotherium perimense*, PUPC 07/51, DM1-DM4, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20 mm.

Upper Dentition:

PUPC 69/499, P1 (Fig. 43) is in middle wear and well preserved. The protocone has a slight constriction mark anteriorly. The cingulum is present buccally extending along the base of the crown. Lingual cingulum is also present along the base of the protocone. The occlusal outline is triangular. The ectoloph is very thick. The entrance of the median valley is closed due to the presence of a well-developed tubercle that is connected to the lingual cingulum. The tooth has a single root, which is also well preserved.

PUPC 02/149**,** P1 (Fig. 44) is a smaller sized premolar and in middle wear. The enamel is thin and the crown is low. Due to wear many details have vanished. The occlusal outline is triangular. Owing to wear, the ectoloph is very thick. The cingulum is present buccally extending along the base of the crown. A small vertical enamel ridge is present in front of the protoloph. The lingual entrance of the medium valley is closed.

PUPC 83/736 and PUPC 83/731, P4 (Figs. 45- 46A-B) are right and left fourth upper premolars. PUPC 83/731 is well preserved, even with part of the root, while PUPC 83/736 is much worn. Premolars are hypsodont, broader than long. The parastyle is well developed and has a vertical paracone fold. The protoloph is well developed in both premolars, broken in PUPC 83/736. Parastyle and metastyle are developed, the ectoloph being flat in between, partly weathered away owing to long surface exposure. The parastyle is very prominent and the vertical groove is present along its length. The metastyle looks like a pillar but it is damaged at the apex. The enamel is rugose and has weathering cracks. Anterior faces of both premolars show a very strong pressure mark caused by the anterior tooth. The similar pressure marks are also observed at the posterior side of the premolars and the ectoloph has no median rib and look rather flat in appearance. The premolars are hypsodont and molariform. The premolars have lingual cingula at the entrance of the well developed median valleys. The posterior cingulum is united with the metaloph closing a posterior fossette in both specimens. A small crista is present, remaining just a smooth undulation with wear. The crochet and the antecrochet are present. From the metaloph a very strong crochet projects into the median valley. The metaloph and the protoloph are parallel, obliquely placed. Slight traces of cement are present posteriorly (along the metaloph) in PUPC 83/731. The protocone is somewhat constricted and extends backwardly to form a strong antecrochet. The protocone gradually increases in thickness from the apex to the cingular level. Internal pass of the median valley is very shallow. The hypocone is completely bound in with the metaloph.

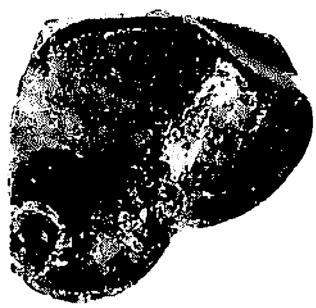


Figure 43: *Brachypotherium perimense*, lP1, PUPC 02/149, occlusal view, Scale bar 20mm.

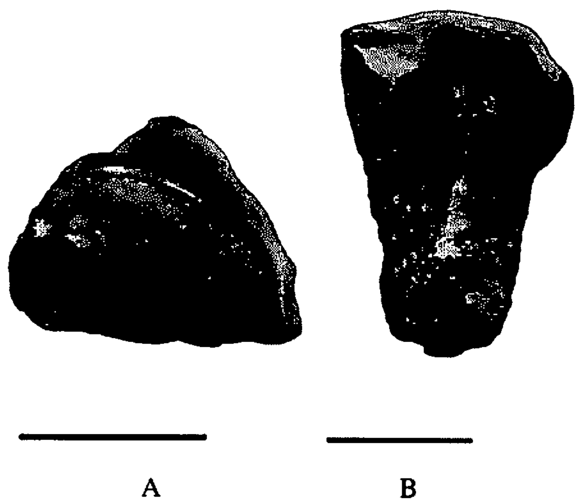


Figure 44 A-B: *Brachypotherium perimense*, PUPC 69/499, rP1, A- occlusal view, B- lingual view, Scale bar 20mm

Figure 45: *Brachypotherium perimense*, PUPC 83/736, rP4, occlusal view, Scale bar 30mm.

A B

Figure 46 A-B: *Brachypotherium perimense*, PUPC 83/731, lP4, A- occlusal view, B - buccal view, Scale bar 30mm

PUPC 83/732, M1 (Fig. 47 A-B) is a well-preserved left first upper molar. The enamel is rugose all over the crown. The cingulum is well developed along the protoloph-metaloph and anteriorly, but absent on the ectoloph. The cingulum is serrated and projected into the entrance of the median valley. The cingulum along the metaloph is raised to close a shallow and short postfossette. The protocone is somewhat constricted and extends backwardly to form a strong antecrochet. The lingual margin of the protocone is flat. The parastyle and metastyle are well developed. The metaloph is short and the tooth is narrower posteriorly than anteriorly; a well-developed crochet is present. The hypocone is not constricted and the molar is covered with thin irregular cement on its anterior and posterior sides.

PUPC 83/734, M2 (Fig. 48 A-C) is a well-preserved left second upper molar, the apex of the paracone, metacone, and hypocone slightly damaged. The tooth is extremely broad and hypsodont. The parastyle and metastyle are well developed. The anterior and posterior faces show very strong pressure marks caused by the respective teeth. The enamel is rugose and the rugosity is prominent on the posterior side of the tooth. Traces of cement are lightly present all over the crown surface; however, these are strongly present in the median valley. Protocone and paracone are well developed. Vertical cracks are present along the outer side of the ectoloph, apparently owing to the long surface exposure of the specimen. The cingulum is present anteriorly along the base of the crown and looks like a shelf. The cingulum is also well developed posteriorly and raised along the metaloph to form a postfossette. The antecrochet extends toward the median valley from the protoloph, and the strong crochet runs into the median valley, almost subdividing it. There is a rudimentary crista, which extends from the ectoloph. The medifossette and postfossette possess a thick enamel investment. The protocone is well separated from the hypocone pillar due to the presence of deep vertical median valley. The protoloph and metaloph are roughly parallel.

PUPC 83/735 and PUPC 02/108, M3 (Figs. 49-50) are left and right upper third molars, respectively. These molars are triangular in shape. The parastyle is marked forming an obtuse angle with the ectometaloph. The protoloph is continuous, sigmoid with strong anterior constriction and antecrochet at the base of the crown. Lingual side of the protocone is very long and flat without any groove. The median valley is widely open lingually. The ectometaloph is convex without any constriction. PUPC 83/735 is an unworn molar that presents two spur like enamel projections into the median valley and extend along its height,

A

B

Fig; 47 A-B: *Brachypotherium perimense*, PUPC 83/732, lM1, A - occlusal view, B - buccal view, Scale bar 30 mm

Figure 48 A-C: *Brachypotherium perimense*, PUPC 83/734, lM2, A- occlusal view, B- lingual view, C- buccal view, Scale bar 30 mm

Fig 49: *Brachypotherium perimense*, PUPC 83/735, lM3, occlusal view. Scale bar 30 mm

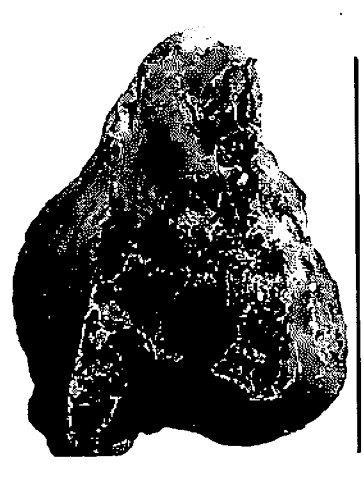


Figure 50: *Brachypotherium perimense*, PUPC 02/108, rM3, occlusal view, Scale bar 30 mm.

which correspond to a double crochet. Enamel is moderate in thickness. PUPC02/108 is in middle wear, and presents a simple crochet. There is a broad cingulum originating low on the base of the anterior side of the protocone and extends along the protoloph reaching the parastyle; the posterior cingulum is weak and low; and there is no lingual cingulum.

PUPC 83/727**,** m2 (Fig. 51 A-C) is excellently preserved together with some part of the dentary. The roots on both sides of the specimen are also visible. The specimen is in early wear and the enamel is rugose. The protoconid, metaconid, hypoconid, and entoconid are well developed. The anterior, U-shaped valley is broader than the posterior, V-shaped one. The metalophid and hypolophid are separated by a shallow buccal groove that ends before the base of the crown. The cingulum is absent all over the crown, but the rugosity is prominent on the buccal side of the tooth, and a tubercle is present on the buccal fold. The hypolophid reclines backward and the entoconid has a flat lingual margin. The paralophid is shorter than the hypolophid and the metalophid. No trace of cement is preserved. The early worn paralophid is wide and transversely oriented.

PUPC 69/513**,** m3 (Fig. 52 A-C) is well preserved. It is in the middle stage of wear. Thick enamel is present. The trigonid is angularly V-shaped with narrow and short paralophid and a right-angled metalophid with a slightly constricted metaconid. The talonid is U-shaped with the hypolophid and the entoconid with posterior groove. No trace of cement is present. There is no lingual cingulum; however a weak serrated labial cingulum is present. The ectolophid groove is marked to the base of the crown. Hypolophid is oblique but transverse in occlusal view. The measurements of the studied specimens from the Dhok Pathan Fm. are provided in table 23.

A

B

C

Figure 51 A-C: *Brachypotherium perimense*, PUPC 83/727, lm2, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20 mm.

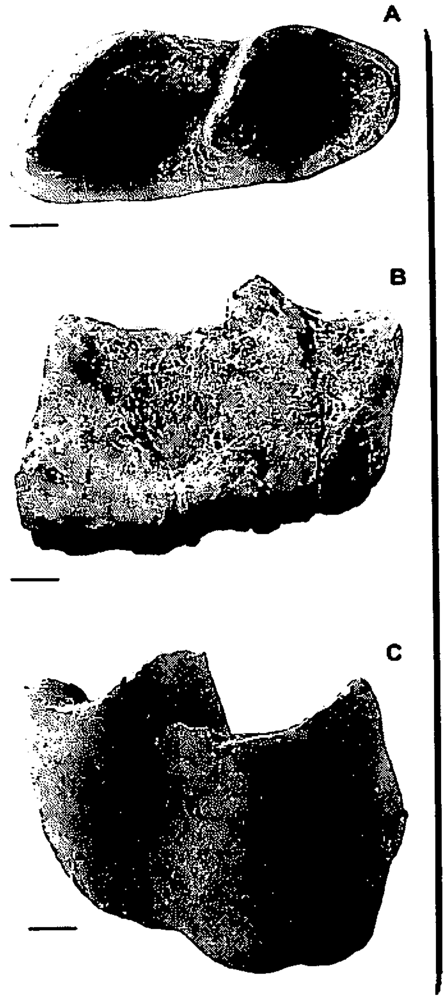


Figure 52 A-C: *Brachypotherium perimense*, PUPC 69/513, lm3, A- occlusal view, B- lingual view, C- buccal view, Scale bar 20 mm.

Table 23: The measurements of the upper and lower cheek teeth of *Brachypotherium perimense* from Dhok Pathan Fm.

Specimen no.	Position	Length	Width
PUPC 69/499	P1	35.0	26.5
PUPC 02/149	P1	34.0	23.7
PUPC 83/736	P4	60	73
PUPC 83/731	P4	62	72
PUPC 83/732	M1	76	85
PUPC 83/734	M2	87	71
PUPC 83/735	M3	70	59
PUPC 02/108	M3	76	57
PUPC 83/727	m2	55	28
PUPC 69/513	m3	78	39

<u>Specimens from the Nagri Fm.</u>:

PUPC 07/54**,** p3-m2 (Fig.53 A-C) is a broken mandibular ramus having p3-m2. All the cheek teeth are well preserved and in early wear. The molars are large and triangular in shape. The enamel is fairly thick and rugose.

In p3 the paraconid is pointed. The protoconid and metaconid are rounded and the hypoconid is broad. The entoconid is pointed and slightly constricted. The paralophid is short and distinct. Metalophid is long and oblique. The anterior valley is weakly developed and V-shaped. The posterior valley is deep and V–shaped. A weak serrated buccal cingulum is present. Anterior and posterior cingula are moderately developed and lingual cingulum is absent.

In p4 the paraconid is broken and slightly worn. Due to wear hypoconid and protoconid junction is present. The hypoconid is broken. The entoconid is pointed. The metalophid is not distinct due to wear. The hypolophid is not prominent and damaged posteriorly. The anterior valley is not well developed and V-shaped. The posterior valley is U-shaped. A serrated buccal cingulum is present anteriorly.

The m1 has a short paralophid. Ectoloph is almost straight without a prominent buccal groove. The anterior and posterior valleys are V-shaped lingually. Anterior and posterior cingula are moderately developed. A weakly developed, discontinuous and serrated buccal cingulum is present anteriorly.

The m2 is excellently preserved. The specimen is in early wear and the enamel is rugose. The protoconid, metaconid, hypoconid, and entoconid are well developed. The anterior and the posterior valleys are lingually V-shaped. The rugosity is prominent on the buccal side of the tooth. A tubercle is present at the base of the buccal fold of the tooth. The hypolophid reclines backward and the entoconid has a flat lingual margin. The paralophid is shorter than the hypolophid and the metalophid. The hypolophid is longer than the metalophid. No trace of cement is preserved. The ectolophid groove though marked on the top of the crown, ends before the neck. The early worn paralophid is wide and transversely oriented. A weak and serrated buccal cingulum is present. Anterior and posterior cingula are present but not well developed. Lingual cingulum is present.

PUPC 08/ 119**,** m3 (Fig. 54 A-B) is in middle wear. The trigonid is angularly V-shaped with a narrow and short paralophid. Metalophid is right-angled. The talonid is U-shaped with a wide and well developed hypolophid and the entoconid with a posterior groove. Hypolophid is oblique but transverse in occlusal view. Traces of cement are present in the buccal groove. The lingual cingulum is absent, whereas anterior, posterior and buccal cingula are present; the labial cingulum is serrated and discontinuous. The ectolophid groove is marked to the base of the crown. The molar is anteriorly suppressed but posteriorly wide. The measurements of the specimens are provided in table 24.


53A


53B


53C

Figure 53 A-C: *B. perimense*, PUPC 07/54, p3-m2, A- occlusal view, B- lingual view, C- buccal view, scale bar 20 mm.

54A

54B

Figure 54 A-B: *B. perimense,* PUPC 08/119, lm2, A- lingual view, B-buccal view, scale bar 20 mm.

Table 24: Measurements of the lower dentition of *Brachypotherium perimense* from the Nagri Formation.

No.	Position	Length	Width
PUPC 07/54	P3	52.0	39.0
	p4	54.5	40.5
	m1	59.0	38.0
	m2	63.0	37.0
PUPC 08/119	m2	66.5	42.0

COMPARISON AND DISCUSSION

Colbert (1935) recognized *Aceratherium perimense* in the Chinji, Nagri and Dhok Pathan formations. Heissig (1972) considered this species to belong in the genus *Brachypotherium*, within the Tribe Teleoceratini, and indicated its presence also in the Kamlial formation (Lower Siwaliks). Antoine *et al*., (2000b) considered the European *Brachypotherium brachypus* as an Asiatic migrant because closely related species have previous occurrence in Pakistan and surrounding areas.

Great dimensions, very thick enamel, unobtrusive ectolophid and brachypodie are important characteristics for the recognition of *Brachypotherium*. *Aprotodon fatehjangense* (Pilgrim, 1910) described from Asia has a very close resemblance with *Brachypotherium brachypus* and *Aprotodon* must be regarded as recent synonym of *Brachypotherium* Roger, 1904 (Antoine *et al*., 2000b).

Gentry (1987) while describing the *Brachypotherium* sp. from Miocene of Saudi Arabia considered the large size and flatness of the labial wall of upper molars and the small size of the paracone rib in comparison with the large flat area, persistent internal cingula on its upper cheek teeth and external cingula on its upper and lower molars as important characteristics for its generic identity. *Brachypotherium* has rather primitive teeth but has developed some specialization of its own. It has evenly flat or slightly concave ectoloph surface behind the rather insignificant paracone rib (Gentry, 1987). A distinctive feature of *Brachypotherium* is the progressive shortening and widening of its limb bones. *Brachypotherium perimense* (Colbert, 1935) is a large species; lower teeth are characterized by the smooth external groove, hardly marked, as it is in other teleoceratines (Cerdeño and Hussain, 1997). These authors described fossil remains of *Brachypotherium perimense* from the Miocene Manchar Formation, Sind, Pakistan, whose morphology is similar to those described by Heissig (1972) from the Siwaliks of Pakistan, the P1 being wider, the M2 narrower, and the lower teeth having closer dimensions. Other postcranial remains from Sind are smaller than those described by Heissig (1972), but this difference in size may be due to the older age of the Manchar Fm. (Lower Chinji) with respect to the latter specimens that belongs to the Middle and Upper Chinji, Nagri, or Dhok Pathan Formations (Cerdeño and Hussain, 1997). The size variation of dental remains may also be attributed to the age differences of the animals.

Upper and lower dentition of *Brachypotherium perimense* from the Dhok Pathan and Chinji Formations in the present study is identical in morphology to that described by Heissig (1972) from the Chinji and Nagri Formations of the Lower and Middle Siwaliks of Pakistan. The specimens collected from the Dhok Pathan Formation are larger in dimensions than the Chinji and Nagri specimens. Heissig (2003) indicated that *B. perimense* is the most frequent species in times of transition and rare during most humid and most arid times and this species point out in the Nagri Formation the beginning of less humid conditions. *Brachypotherium* has often been compared to hippos, and was certainly a marsh or lake dweller (Geraads and Sarac, 2003). The specimens in the present study revealed an agreement when compared with the P4 of *Brachypotherium* sp. described by Li and Qiu (1980) from Xining Basin, Qinghai province. The agreement lies in the presence of a long protocone with a well-developed crochet on the P4 and a small crista; however the present specimens differ from Xining specimens in having a moderately developed antecrochet

The premolars in the present study are comparable to the *Brachypotherium brachypus* described by Cerdeño (1993) from the Miocene of France in having an incomplete labial cingulum and presence of crochet and crista. The molars differ in the absence of the continuous lingual cingulum, though traces of lingual cingulum are present in the median valley of PUPC 83/ 732, but its continuity is not confirmable due to wear. Occlusal length (56.0 mm) of a molar described by Gentry (1987) as *Brachypotherium* sp. from Miocene levels of Saudi Arabia is also comparable to the molars in the present study. The length of the m2 in the present study matches very well to those described by West *et al*. (1978) from Nepal and those described by Heissig (1972) from the Siwaliks of Pakistan. The specimens in the present study are comparatively larger than those described by Colbert (1935) and Heissig (1972). The *Brachypotherium* is supposed to have a preference for soft diet and a more forested environment (Andrew *et al*., 1996, 1997), which is comparable to the middle Miocene Dhok Pathan formation in the Siwaliks. The comparative measurements are provided in table 25.

Table 25: Comparative measurements of the upper and lower dentition of *Brachypotherium perimense.*

Specimen No.	Specimens in the present study.			*B. perimense* (Colbert, 1935)	*Brachypotherium* sp. (Li and Qiu ,1980)	*B. perimense* (Cerdeño and Hussain ,1997)	*B. perimense* (Heissig, 1972)
PUPC 69/499	P1	L	35.0	37.0	X	X	34.0
		W	26.5	25.0			29.0
PUPC 02/149	P1	L	34.0	37.0	X	X	34.0
		W	23.7	25.0			29.0
PUPC 83/736	P4	L	60.0	51.0	31.5	X	53.0
		W	73.0	74.0	_		87.0
PUPC 83/731	P4	L	62.0	51.0	31.5	X	53.0
		W	72.0	74.0	-		87.0
PUPC 83/732	M1	L	76.0	60.0	X		-
		W	85.0	80.0			71.0
PUPC 83/734	M2	L	87.0	69.0	X	64.7, 64.2	72.0
		W	71.0	78.0		63.7, >59	82.0
PUPC 83/735	M3	L	70.0	63.0	X	X	70.0
		W	59.0	63.0			76.0
PUPC 02/108	M3	L	73.0	63.0	X	X	70.0
		W	57.0	63.0			76.0
PUPC 83/727	m2	L	55.0	53.2	X	X	55.0
		W	28.0	28.5 (West *et al.*, 1978)		33.0	30.0
PUPC 08/ 119	m2	L	67.0	64.0	X	X	55.0
		W	37.5	40.0			30.0
PUPC 69/513	m3	L	78.0	72.0	X	X	67.0
		W	39.0	35.0			33.0

Chapter 3

PALAEOBIOGEOGRAPHY OF THE SIWALIK RHINOCEROSES

PALEOBIOGEOGRAPHY OF THE SIWALIK RHINOCEROSES

Rhinocerotids moved from northern Eurasia to Africa and to the Indian subcontinent during the early Miocene. Faunal change between Eurasia and the Subcontinent is better recorded for the late Miocene. The rhinocerotid fauna in Pakistan is abundant and diverse; and distributed among three distinct biostratigraphic regions ranging in age from early Miocene to the Recent. These regions include Bugti hills in Baluchistan, Manchar Fm. in Sind; and the Siwalik hills in Northern Pakistan. The best record for the Pre-Siwalik rhinoceros distribution is better represented in Pakistan, and includes species of the genera; *Paraceratherium, Aceratherium, Chilotherium, Baluchitherium*, and *Brachypotherium* (Made, 1999). The recognition of the *Epiaceratherium cf. magnum* in the early Oligocene of central Baluchistan supports this hypothesis. It is evident from the contemporaneous presence of *Aprotodon* in Kazakastan, Pakistan and China (Qie and Xie, 1997) and that of the giant Hyrachodontid, *Paraceratherium* in Pakistan, Kazakastan, China, Mongolia and Balkans (Lucas and Sobus, 1989) on both sides of the Himalayas and the Tibet Plateau; that Himalayas and the Tibet Plateau played a minimized role in the distribution and dispersal of Rhinocerotids between Asia and the subcontinent throughout the Oligocene (Antoine *et al*., 2003b). The fauna of the South Asia have probably been distinct regionally since before the beginning of the Miocene. The Siwalik fauna maintained a certain resemblance to the modern fauna of Southeast Asia (Jacob, 1980, 1981). The Siwaliks have yielded lineages leading to characteristic high diversity of rhinoceroses different from those of Europe and Africa. The peculiar and characteristic Siwalik fauna clearly had its origin with the shift from the Bugti type of fauna to that in the basal Manchars. About one fourth of the Chinji species are directly related to Bugti forms, while the remainders are presumably immigrants (Raza *et al*., 1984).The fossil rhinocerotid fauna is abundant and diversified, and distributed among distinct subdivisions in the Siwaliks of northern Pakistan.

FOSSIL RHINOCEROSES IN THE BUGTI HILLS:

Tertiary continental layers from the Bugti hills (Baluchistan) have yielded many fossil rhinoceroses. The fossil remains of the diverse rhinocerotid fauna in the Bugti hills have been collected and studied since the beginning of the 20th century (Lydekker, 1881, 1884; Pilgrim, 1910, 1912; Forster-Cooper, 1924, 1934; Flynn, 1986). Within the Dera Bugti fauna Forster-Cooper (1934) documented two species of *Aceratherium* and *Chilotherium*. The *Chilotherium* was later ascribed to the genus *Aprotodon* (Heissig, 1972). *Aprotodon blanfordi* (Lydekker) was also cited in the Middle Miocene levels of the Siwaliks and partially synonymized to *Aprotodon fatehjangense* (Colbert, 1935; Heissig, 1972). Savage (1967), and Savage and Russel (1983) has reported some species from Dera Bugti that appears in the more recent levels of the Chinji Fm. In the southern Suleiman geological province terrestrial detrital deposit facies from the Bugti hills region have yielded the richest Tertiary vertebrate fauna including rhinoceroses to be found in Asia. Among the largest land mammals that ever lived are the Baluchitheres or the Indricotheres (Osborn, 1923; Granger and Gregory, 1936; Fortelius and Kappelman, 1993).The first Indricotheres described was *Paraceratherium bugtiense* (Pilgrim, 1908) from Lando Chur, in the Bugti hills in eastern Baluchistan. Most of the fossils came from the lower Miocene age. Pilgrim reported forms like *Cadurcotherium, Aceratherium* and *Diceratherium* which had their equivalents in the Stampian in Europe. Welcomme and Ginsberg (1997) contended that there are no remains of *Baluchitherium* and *Paraceratherium* in the Miocene Series of Dera Bugti syncline; but these genera are known in Lando Chur. New fossil discoveries by Welcomme *et al*., (2001) from five successive and distinct bone beds fill the supposed Oligocene sedimentary hiatus within the Suleiman geological province. They have proposed an Oligocene age for the lower Chiterwata Fm. According to Welcomme *et al*., (2001) the Eocene of Bugti Hills is void of any Fossil Fauna. However in the early Oligocene *Paraceratherium bugtiense and Diceratherium* sp. are present in the Nari Fm. (lower Chiterwata Fm.).The late Oligocene of the Nari Fm. has yielded *Paraceratherium bugtiense, Aprotodon smith-woodwardi* and *Diceratherium* sp. of the Bugti Hills. In the early Miocene *Plesiaceratherium naricum*, *Dicerorhinus shahbazi* and *Bugtirhinus praecursor* were present. The early-middle Miocene of the Bugti Hills have yielded the richest diversity of rhinoceroses found including; *Plesiaceratherium naricum*, *Protaceratherium* sp., *Aprotodon blanfordi, Brachypotherium perimense, Dicerorhinus shahbazi, Dicerorhinus abeli* and *Bugtirhinus praecursor* (Welcomme *et al*., 1997, 2001; Welcomme and Ginsburg, 1997, Welcomme *et al*., 1999; Marivaux, *et al*., 1999; Antoine and Welcomme, 2000a). Towards the end of the

Middle Miocene there is a strong diversity decline of the Rhinocerotids in Bugti area of Baluchistan. The late Middle Miocene in the Bugti area has yielded only *Aprotodon fatehjangense* and *Brachypotherium perimense*, *Aprotodon blanfordi? Hoploaceratherium* sp., and *Alicornops complanatum* has recently been described by Antoine *et al*., (2003c) from the late Miocene of Sartaaf (Bugti hills). According to Metais *et al*., (2009) rhinocerotid comprises the most diversified large mammalian fauna from the Mid-Cenozoic deposits of the Bugti hills. Fourteen species have been identified and many others are likely to be identified in future. *Epiaceratherium cf. magnum*, *Aprotodon smithwood-wardi*, "*Dicerorhinus" abeli* and an unidentified Diceratheriine close to *Diceratherium* has been reported by Antoine *et al*., (2003a). The rhinocerotid genera from the upper member of the Bugti are distinct and diversified and include *Bugtirhinus praecursor, Protaceratherium* sp., *Plesiaceratherium naricum* and the one horned Rhinocerotine *Gaindatherium* cf. *Browni* (Antoine and Welcomme, 2000a). Six rhinocerotid taxa occur in both the upper Bugti member and in the overlying Vihowa Fm. including; *Aprotodon blanfordi, Mesaceratherium* sp*., Brachypotherium gajense*, *Brachypotherium fatehjangense, Prosantorhinus shahbazi* and a Rhinocerotine very similar to Rhinoceros.

Perissodactyls including rhinoceroses described by Welcomme and Ginsburg (1997) from Dera Bugti (Baluchistan, Pakistan) include *Hipparion* sp.*; Protaceratherium* sp.*; Plesiaceratherium* sp.*; Hoploaceratherium* sp.*; Aprotodon blanfordi; Brachypotherium perimense ; Dicerorhinus shahbazi; Dicerorhinus* cf. *abeli* and *Coementodon oettingenae.*

MANCHAR FORMATION:

The early reports on the palaeontology of the Manchar Fm. have largely been found in the records and memoirs of the Geological Survey of India. Major references and articles on the geology and palaeontology of the Manchar Fm. are those published by Colbert (1935); Blanford (1883); Falconer (1868); Forster cooper (1913, 1923, 1924, 1934); Lydekker (1876, 1878, 1880, 1883, 1884, 1886); Matthew (1929); Pascoe (1964); Pilgrim (1910, 1912, 1913, 1932); Heissig (1972); and Shani and Tripathi (1957).The Manchar Fm. has been the source of type specimens of several of Lydekker's and Pilgrim's species. The type specimen of *Chilotherium intermedium* came from the top of the Gaj Fm. (Lydekker, 1884). The Manchars are very important as a potential source of topotypic material for many poorly known mammalian forms. Other rhinoceroses described from the Manchar Fm. include *Aprotodon fatehjangense*, *Gaindatherium browni*, Rhinocerotidae, genus and species indet, and *Brachypotherium perimense* (Cerdeño, 1995).

Because the physical relationships between the Bugti, Manchar and Chinji regions are not well established; the relative ages of the fauna present in these Fms. can only be established and executed on the basis of the Palaeomagnetic study. According to Pilgrim (1917) presence of the Archaic Rhinocerotids and Anthracotheres (e.g. Indricotheres and Amynodonts), very few Suids and Giraffes and absence of Bovids and Tragulids are indicative of an older age for Bugti fauna as compared to the basal Manchar Fm. The absence of various mammalian forms suggest an older age for middle Manchar Fm. than the Chinji Fm.

RHINOCEROS DISTRIBUTION IN THE SIWALIK:

LOWER SIWALIKS: The Lower Siwaliks comprises the Kamlial and the Chinji Fms.

Kamlial Fm.

Colbert (1935) recognized the presence of *Brachypotherium perimense* in the Chinji, Nagri and Dhok Pathan Fms. Heissig (1972) has also indicated the presence of *Brachypotherium perimense* in the Kamlial Fm. The presence of *Alicornops* outside Europe has been reported by Guerin (1980a) in the Vallesian of the Siwaliks of Pakistan. Antoine (2003c) has also reported *Alicornops* from the Miocene locality of Sartaaf (Bugti hills, Baluchistan, Pakistan) which is equivalent to the Dhok Pathan Fm. of the middle Siwaliks of Pakistan (Pilbeam, *et al*., 1996). Fossils described in the present study bears close affinities with the *Alicornops laogouense* described from the Laogou, Linxia Basin, Gansu, China, described by Deng (2004). This is the first occurrence of *Alicornops* from the Kamlial Fm. in the Siwaliks of Pakistan. Deng (2004) has reported a wide spread distribution of *Alicornops* throughout Eurasia in MN6 times, however Kamlial Fm. in Potwar Plateau corresponds to MN5 in Europe. Pilgrim (1917) named the lower Siwaliks as “Kamlial Zone” on the basis of its correlation to the basal Manchar Fm. Kamlial Fm. has a very poor fossil record and has always been one of the most poorly known of the Pilgrims faunal zones. However, Kamlial Fm. is the second oldest Neogene biostratigraphic unit in Southern

Asia and is considered as transitional in faunal characters between the archaic rhinoceroses and Anthracotheres – denominated Bugti fauna and the younger Siwaliks fauna with rich diversity of ruminants, Suids and proboscideans (Raza et al, 1984). Reports of the Geological survey of Pakistan have indicated that the fauna of the Kamlial Fm. is in fact surprisingly diverse and includes many species which were not previously recorded from here.

Chinji Fm.

Chinji Fm. in the lower Siwaliks of Pakistan has yielded numerous genera and species of fossil rhinoceroses. Heissig (2003) reported four genera of Rhinocerotids in the middle Chinji level of the Siwaliks. These genera include *Aprotodon, Caementodon, Brachypotherium, and Rhinoceros. Aprotodon* has been reported from the different levels of Chinji Fm. (Heissig, 1972). *Aprotodon blanfordi* (Lydekker) was reported by Colbert (1935) and Heissig (1972) from Chinji Fm. Heissig Partially synonymized *Aprotodon blanfordi* to *Aprotodon fatehjangense*. However Antoine (2000b) has considered *Aprotodon* as a probable recent synonym of the genus *Brachypotherium*. Heissig (1972) is of the opinion that Rhinocerotid fauna of the most recent levels of the Chinji Fm. have similarities with some Bugti forms as cited by Savage (1967) and Savage and Russel (1983). *Chilotherium* and *Brachypotherium* were established during the Middle Miocene and the same species of each genus is resent in the Siwaliks throughout the Middle and late Miocene (Heissig, 1972). *Gaindatherium* described by Colbert (1934) from Chinji Fm. has middle to late Miocene distribution with two successive species including; *Gaindatherium browni* and *Gaindatherium vidali*. *Chilotherium intermedium* (Lydekker) was also described from the Chinji Fm. by Colbert (1935).

<u>MIDDLE SIWALIKS:</u>

Nagri Fm.

The Nagri Fm. comprises a shorter time span of sediment deposition as compared to the other Siwalik Fms. between 11.2Ma to 10.1Ma. Workers like Colbert, Matthew, Heissig and some others have reported distribution of various rhinoceros taxa without sharp demarcation of the Chinji, Nagri and Dhok Pathan Fms. Hence Nagri rhinoceroses are not very well documented. Heissig (1972) has described various rhinoceros genera and species of rhinoceros including; *Caementodon oettingenae, Chilotherium intermedium, Aprotodon fatehjangense, Gaindatherium vidali and Brachypotherium perimense* from the Nagri Fm. *Gaindatherium browni* Colbert, 1934, *Aceratherium perimense* Falconer and Cautley, 1847, *Aceratherium blanfordi* Lydekker, 1884 and *Chilotherium intermedium* (Lydekker), 1884 has been reported by Colbert (1935) from the Nagri beds. The present collection described herein this dissertation include fossil remains of *Chilotherium intermedium* and *Brachypotherium perimense* from the Nagri Fm.

Dhok Pathan Fm.

Colbert (1935) has reported *Aceratherium perimense* Falconer and Cautley, 1847, *Rhinoceros planidens* Lydekker, 1876, *Rhinoceros iravadicus* Lydekker, 1876, *Aceratherium lydekkeri* Pilgrim, 1910, *Aceratherium blanfordi* Lydekker, 1884, and *Chilotherium intermedium* (Lydekker, 1884) from different levels of the Dhok Pathan Fm. Heissig (1972) described rhinoceros remains collected from the Dhok Pathan Fm. as belonging to genera *Chilotherium* and *Brachypotherium*. Heissig has divided *Chilotherium intermedium* into two subspecies including; *Chilotherium intermedium intermedium* and *Chilotherium intermedium complanatum*. According to him the first mentioned subspecies only have its distribution in the Chinji and Nagri Fms. and the later is restricted only to the Dhok Pathan Fm. Heissig went on to revise the genus *Chilotherium* as *Subchilotherium* and refute to accept any true species belonging to the *Chilotherium*. However Antoine *et al.,* 2003 proposed a new combination of binomen for *Chilotherium intermedium complanatum* and placed it in the genus *Alicornops* and described it as *Alicornops complanatum.* The present collection includes fossil remains of *Brachypotherium perimense* and *Alicornops complanatum* from different levels of the Dhok Pathan Fm. Distribution of various rhinocerotid species in the Siwalik deposits is given in table 1.

Table 1: Published (Colbert, 1935; Heissig, 1972) and present stratigraphic distribution of rhinoceros species in the Siwaliks.

Fm.	Published rhinoceros species in the Siwaliks	Present collection
Kamlial	*Brachypotherium perimense* *Aprotodon fatehjangense*	*Alicornops* cf. *laogouense*
Chinji	*Gaindatherium browni* *Gaindatherium vidali* *Chilotherium intermedium* *Brachypotherium perimense* *Caementodon oettingenae* *Chilotherium blanfordi* *Aprotodon fatehjangense* *Didermoceros* aff. *sumatrensis* *Didermoceros* aff. *abeli* *Aceratherium* sp. *Eurhinoceros* sp. inc. sed.	*Gaindatherium browni* *Gaindatherium vidali* *Chilotherium intermedium* *Brachypotherium perimense*
Nagri	*Chilotherium intermedium* *Brachypotherium perimense* *Caementodon oettingenae* *Aprotodon fatehjangense* *Gaindatherium vidali* *Eurhinoceros* aff. *sondaicus* *Alicornops complanatum*	*Chilotherium intermedium* *Brachypotherium perimense*
Dhok Pathan	*Chilotherium intermedium complanatum* *Brachypotherium perimense* *Chilotherium intermedium* *Rhinoceros* (*Rhinoceros*) aff. *sivalensis*	*Alicornops complanatum* *Brachypotherium perimense* *Chilotherium intermedium*
Tatrot	*Rhinoceros sivalensis*	*Rhinoceros sivalensis* *Rhinoceros sondaicus*
Pinjor	*Rhinoceros kendengindicus* *Coelodonta platyrhinus*	*Punjabitherium platyrhinus*

UPPER SIWALIKS

Information regarding the fossil rhinoceroses that lived in the upper Siwaliks is not very well documented. Khan (1971) has described *Punjabitherium platyrhinus* collected from the upper Siwaliks of India near the base of the Pinjor stage. DeTerra and Paterson (1936) gave a comprehensive account of Pleistocene of Indian Subcontinent and discussed the glaciations, terrace Fm., fluvo-lacustrine deposits, and the fauna. According to them the beginning of Pleistocene in the Subcontinent is synchronous with the commencement of the first glaciations and is recognized in the subcontinent at the base of the Tatrot beds. Colbert (1935) recognized some rhinoceros fossils as *Coelodonta platyrhinus* and *Rhinoceros sivalensis* present in AMNH from the Upper Siwaliks.

Sarwar (1971) has reported an isolated premolar belonging to *Rhinoceros kendengindicus* from the Pleistocene rocks of the Pinjor Zone of Mirpur, Azad Kashmir, Pakistan. The present collection has yielded complete upper dentition and isolated lower teeth belonging to *Rhinoceros sivalensis* from the Tatrot beds; isolated upper teeth of *Punjabitherium platyrhinus* from Jari Kas (near the base of Pinjor); and upper and lower dentition of *Rhinoceros sondaicus* from Sar Dhok (Upper level of Pinjor) of the upper Siwaliks. Rhinoceros species and their geological ranges in the upper Siwaliks are given in table 2.

Table 2: Published and present occurrence of Rhinoceros species and their geological ranges in the upper Siwaliks; modified after Khan (1971b).

Species	Tatrot	Pinjor	Pleistocene		
			1st to 3rd glacial	3rd inter glacial	4th glacial
Rhinoceros sivalensis	-------------	-----------			
Punjabitherium Platyrhinus		-----------			
Rhinoceros kendengindicus		-----------			
Rhinoceros Sondaicus	-------------	-----------	-----------	----------	-------------
Rhinoceros deccanensis				----------	

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