Chapter 16

Mammalian Neogene biostratigraphy of the Sulaiman Province, Pakistan

PIERRE-OLIVIER ANTOINE, GREGOIRE MÉTAIS, MAEVA J. ORLIAC, J.-Y. CROCHET, LAWRENCE J. FLYNN, LAURENT MARIVAUX, ABDUL RAHIM RAJPAR, G. ROOHI, AND JEAN-LOUP WELCOMME

The Sulaiman Range is a north–south-trending band of rugged mountains rising 1000–3400 m above sea level that defines the modern political boundary between Balochistan and Punjab provinces and extends northward into North-West Frontier Province (figure 16.1). Late Mesozoic and Cenozoic sedimentary rocks here are primarily marine and accumulated in the Tethys Sea in what is now the Indus Basin, bounded to the northwest by the Axial Belt (Shah 1977), or Bela–Waziristan Ophiolite Zone (Bannert et al. 1992), and to the southeast by the Indo–Pakistani Subcontinent. The east side of the Sulaiman Range is of particular interest since a relatively thick, well-exposed mid-Cenozoic sequence registers the transition from marine shelf to terrestrial deposition episodes related to the uplift and erosion of the orogenic Himalayan highlands and the related closure of the Tethys Sea. Deposition of these thick detrital units resulted from the collision between the Indian and Asian plates, which started near the Paleocene/Eocene transition, ~55 Ma (Beck et al. 1995; Clift et al. 2001).

STRATIGRAPHIC AND HISTORICAL CONTEXT

The fossiliferous outcrops were recognized early in the nineteenth century (Vickary 1846) and were initially described in detail by Blanford (1883), who assigned the terrestrial conglomerates and sandstones overlying the Eocene "Nummulitic Limestone" to the Upper Nari Formation. These sediments—especially in the southern Sulaiman Range, roughly corresponding to the Bugti Hills—soon became famous for their fossil vertebrate faunas (Lydekker 1884; Pilgrim 1907, 1908, 1910, 1912; Forster-Cooper 1913, 1915, 1924), rich in large terrestrial mammals of Miocene to Pleistocene age. The faunas, as a whole, have long been considered as terrestrial, as they provide clear evidence that the environment of deposition was primarily fluvial. The stratigraphic classification of the sediments of the Sulaiman foothills has evolved with the growth of knowledge, and many different names have been applied, both generally and locally (Hemphill and Kidwai 1973; Shah 1977; Welcomme et al. 2001). The intensive fieldwork on the Siwalik series of the Potwar Plateau greatly influenced biostratigraphical interpretation of the entire Himalayan foothills of Pakistan (Pilgrim 1912; Raza and Meyer 1984). The exceptionally well-exposed succession in the Potwar Plateau area of northern Pakistan provides the best standard succession for almost the entire Neogene, and its biostratigraphy is successfully dated by paleomagnetic methods (Johnson et al. 1985; Barry et al. 2002).

The period encompassing the Oligocene and earliest Miocene has long been considered as lacking in the entire Sulaiman Geological Province (e.g., Raza and Meyer 1984). Traditionally, the depositional history of pre-Siwalik continental strata is very poorly known, from the point of view of age, environment, or burial structure. The Murrees sensu lato, which unconformably overlies the Eocene marine rocks in some areas of the Potwar region, may represent this missing sedimentary record.

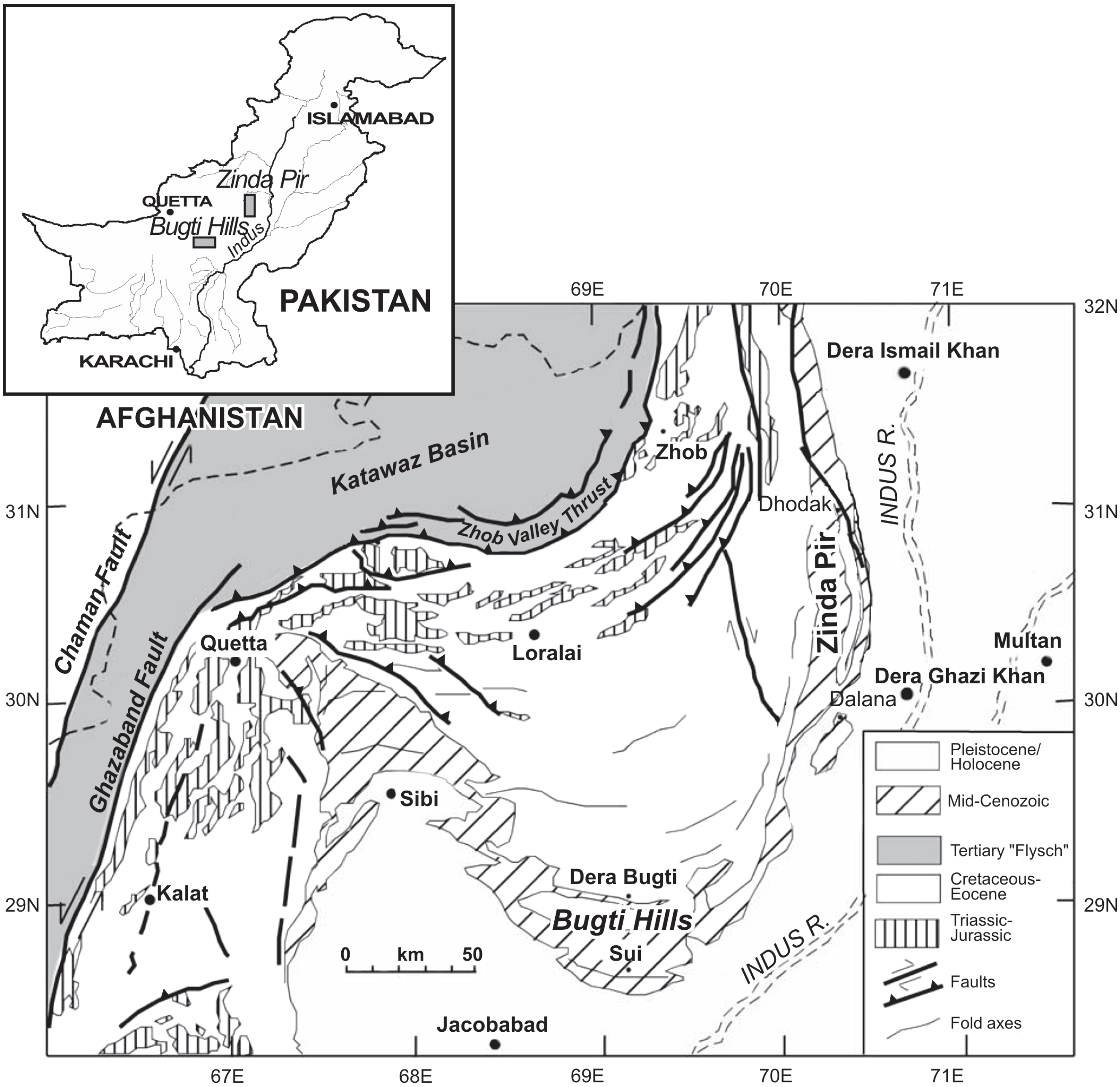


Figure 16.1 Geological map of the Sulaiman Province, Middle Indus Basin, Pakistan. Mammal-yielding localities discussed in the text are located in the Zinda Pir Dome and in the Bugti Hills. Modified after Raza et al. (2002).

However, the Murrees deposits are very poor in fossil remains, and correlations are still delicate to establish with pre-Siwalik deposits of other areas, including those of the Sulaiman Range (Najman and Garzanti 2000; Kumar and Kad 2003).

In the last decades, the continental series of the Sulaiman Range has been investigated as a southern extension of the important framework made in the Potwar Plateau area (Barry, Lindsay, and Jacobs 1982; Barry, Flynn, and Pilbeam1990; Barry et al. 2002) by a Yale University–GSP team since the early 1980s. Important data came with the first collection of small mammals in the Sulaiman foothills (Jacobs et al. 1981; Flynn, Jacobs, and Cheema 1986). Renewed reconnaissance of the Sulaiman foothills started in Dalana, in the Zinda Pir Dome area (Raza et al. 2002). The first attempt to place the fossils in a stratigraphic framework began there (Downing et al. 1993) in coordination with sediment sampling for magnetic stratigraphy (Friedman et al. 1992). Independently, a French expedition led by Jean-Loup Welcomme and the late Leonard Ginsburg was initiated in the famous Bugti Hills in 1995, with the main objective of establishing a proper lithostratigraphic framework in order to determine the stratigraphic provenance of spectacular fossil collections made by Pilgrim and Forster-Cooper nearly a century before. The first survey of the Dera Bugti Syncline produced a detailed section of the Early Miocene deposits that, at some points, lie unconformably on the Eocene marine limestones of the Kirthar Formation (Welcomme et al. 1997) and provided the first unambiguous evidence of (fossiliferous) Oligocene deposits in the Sulaiman Lobe (Welcomme and Ginsburg 1997). These critical results (summarized in Welcomme et al. 1999; Welcomme et al. 2001), led to a reexamination of the age of the Zinda Pir sequence (Lindsay et al. 2005) and had important biostratigraphic implications for the entire Sulaiman Province, the chronology of deposition of exhumed material, and the history of West Himalayan foreland basins, especially the Indus paleodrainage and its tributaries (Downing and Lindsay 2005; Métais et al. 2009). So far, the pre-Siwalik deposits exposed in the Sulaiman Range constitute one of the best terrestrial and fossiliferous archives for the eroded materials from the rising Himalaya.

Formally, the units documenting Neogene time in the Sulaiman Province are as follows, from the base to the top.

Chitarwata Formation, Upper Member (Earliest Miocene)

In the Zinda Pir area, the Chitarwata Formation is up to 480 m thick (Raza et al. 2002; Lindsay et al. 2005) while it is much more condensed in the Bugti Hills (120–260 m thick; Métais et al. 2009; new data). The lower and middle units recognized in the Zinda Pir area (Lindsay et al. 2005) and the Bugti Member of the Bugti Hills (Métais et al. 2009) are considered similar faunally and temporally and, being Oligocene in age, are discussed only in reference to younger sites. The upper part of the Chitarwata Formation in both areas is referred to the earliest Miocene (i.e., roughly corresponding to the Aquitanian marine stage or Agenian European Land Mammal Age; Antoine et al. 2010). The thickness of the upper member varies laterally, but it reaches about 200 m near Dalana (Zinda Pir). The measured thickness is 50 m (at Kumbi, most condensed section) up to 130 m (figure 16.2 [Habib Rahi]; unpublished data) in the Bugti Hills, with two distinct and successive fossiliferous levels (figure 16.3 [level M = 3; Q = level]; Welcomme et al. 2001; Métais et al. 2009). Differences in thickness of the Chitarwata Formation between the Bugti Hills and Zinda Pir are discussed in Métais et al. (2009).

In the Bugti Hills, the upper member of the Chitarwata Formation is the richest stratigraphic interval in terms of fossil vertebrates (table 16.1). It has been widely investigated in the past, and it yields the most diversified Bugti faunas (levels 3bis and 4; Welcomme et al. 2001). However, this interval is only documented by medium-size and large mammals in the Bugti area: no small mammal was recovered. Near Dalana in the Zinda Pir area, five small mammal localities were recovered within this interval (see figure 16.3 [Z113, Z139, Z150, Z135, and Z126, from base to top]; Lindsay et al. 2005). Large mammal remains are scarce, although they occur in various localities (Raza et al. 2002; Barry et al. 2005; Lindsay et al. 2005).

Vihowa Formation (Late Early Miocene–Middle Miocene)

The Vihowa Formation is 720 m thick in the Zinda Pir Dome (Raza et al. 2002). Only the lower part was studied thoroughly (E. H. Lindsay, personal com., 2010). Vihowa thickness is likely to reach only ca. 100–200 m in the Bugti Hills (see figure 16.3), but this is far from being well constrained. Again, only the lower part was sampled densely.

Various sites from three successive levels (levels 5 [=T], 6, and 6sup [=Bugti sup]) document the lowermost part of the Vihowa Formation in the Bugti Hills (late Early Miocene), while a single locality (see figure 16.2 [Lundo W]) is referable to the middle part (Middle Miocene, i.e., considered similar to the Chinji fauna of Potwar Plateau; Welcomme et al. 2001; Métais et al. 2009; Orliac et al. 2009; Antoine et al. 2010). The levels 6 and 6sup yielded both large mammal and micromammal faunas (table 16.2; Welcomme et al. 1997; Welcomme et al. 2001; Métais et al. 2009). For Zinda Pir, three small mammal localities were recovered within this interval (see figure 16.3 [Z124, Z122, and Z120, from base to top]; Lindsay et al. 2005). Large mammal remains are rather scarce, but they occur in various localities (Raza et al. 2002; Barry et al. 2005; Lindsay et al. 2005).

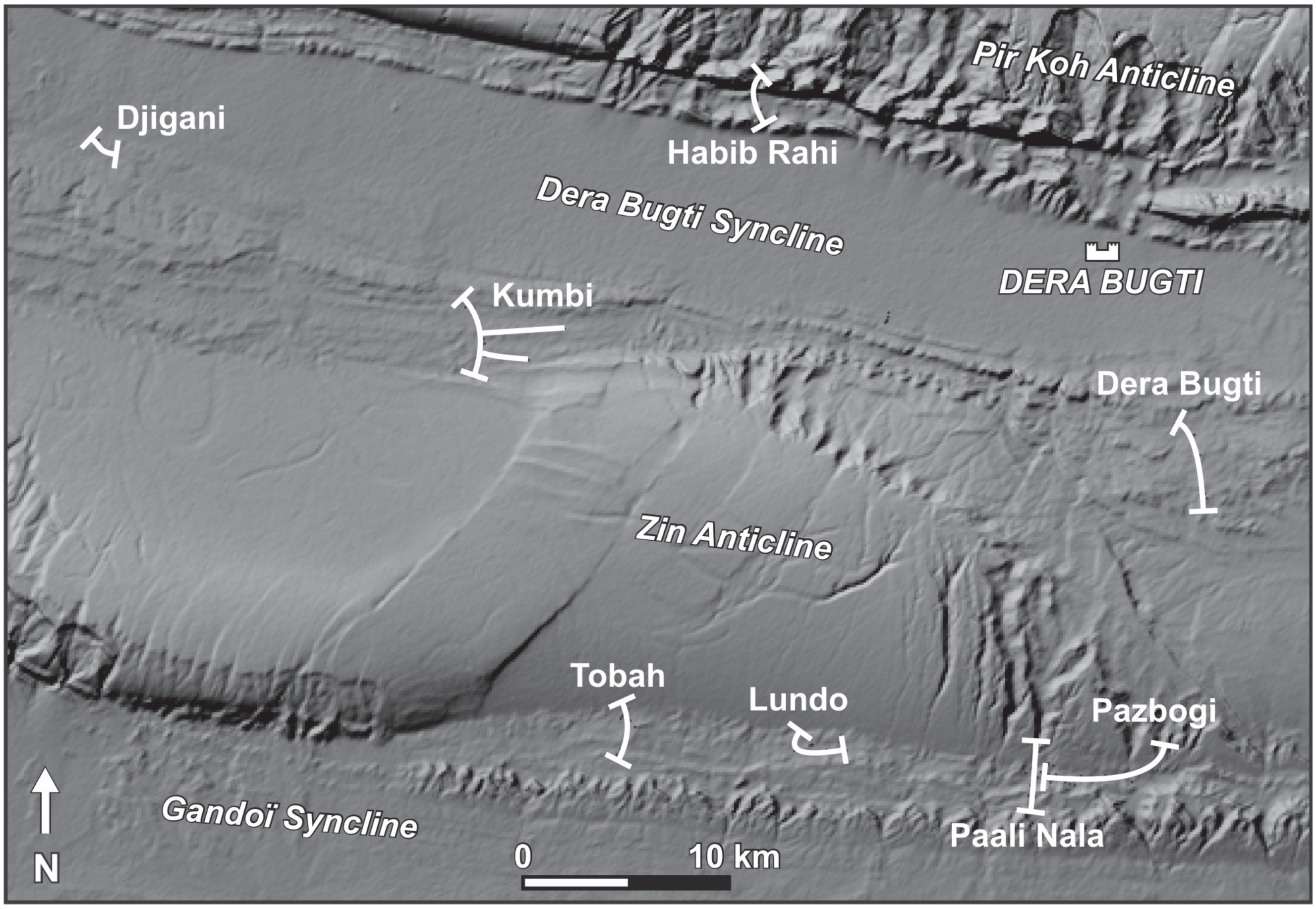


Figure 16.2 Location of main Cenozoic vertebrate-yielding sections from the Bugti Hills, Balochistan, Pakistan.

Litra Formation (Late Miocene)

The Litra Formation, in the Zinda Pir area, is 1700 m thick (Raza et al. 2002); no concentrated survey was done in that interval (E. H. Lindsay, personal com., 2010). It is most likely much thinner in the Bugti Hills, but this hypothesis is not constrained by formally measured sections, except in the Habib Rahi area (ca. 150 m; see figure 16.2; unpublished data). Two localities referable to this stratigraphic interval are recognized in the Bugti Hills (see figures 16.2 [Djigani] and 16.3 [levels 7 and 7sup]; Welcomme et al. 1997; Welcomme et al. 2001; Antoine, Duranthon, and Welmomme 2003b). They have yielded a large mammal fauna similar to what is observed in the lower part of the Middle Siwaliks in the Potwar Plateau, including the First Local Appearance (FLA) of *Hipparion* sensu lato (table 16.3; Antoine, Duranthon, and Welmomme 2003b).

Post-Miocene Formations (Chaudhwan Formation, Pliocene–Pleistocene)

The Chaudhwan Formation is ca. 1500 m thick in Zinda Pir (Raza et al. 2002). In the Bugti area, its thickness is not constrained by measured sections, but it appears as highly variable depending on local tectonic context: the corresponding deposits are much deformed and consist essentially of boulder conglomerates and fluvial terraces, mainly observable in the Dera Bugti Syncline and in Habib Rahi (see figures 16.1 and 16.2). Welcomme et al. (1997) mention only egg shells of an unidentified struthioniform (ostrich). Crochet et al. (2009) report prehistoric rock paintings in the vicinity of Lundo (see figures 16.1 and 16.2), with anthropomorphic, geometric, and zoomorphic (e.g., cervid and felid) sketches attesting to favorable climatic conditions in the area around the Last Glacial Maximum and during subsequent periods.

—-1
—0
—+1

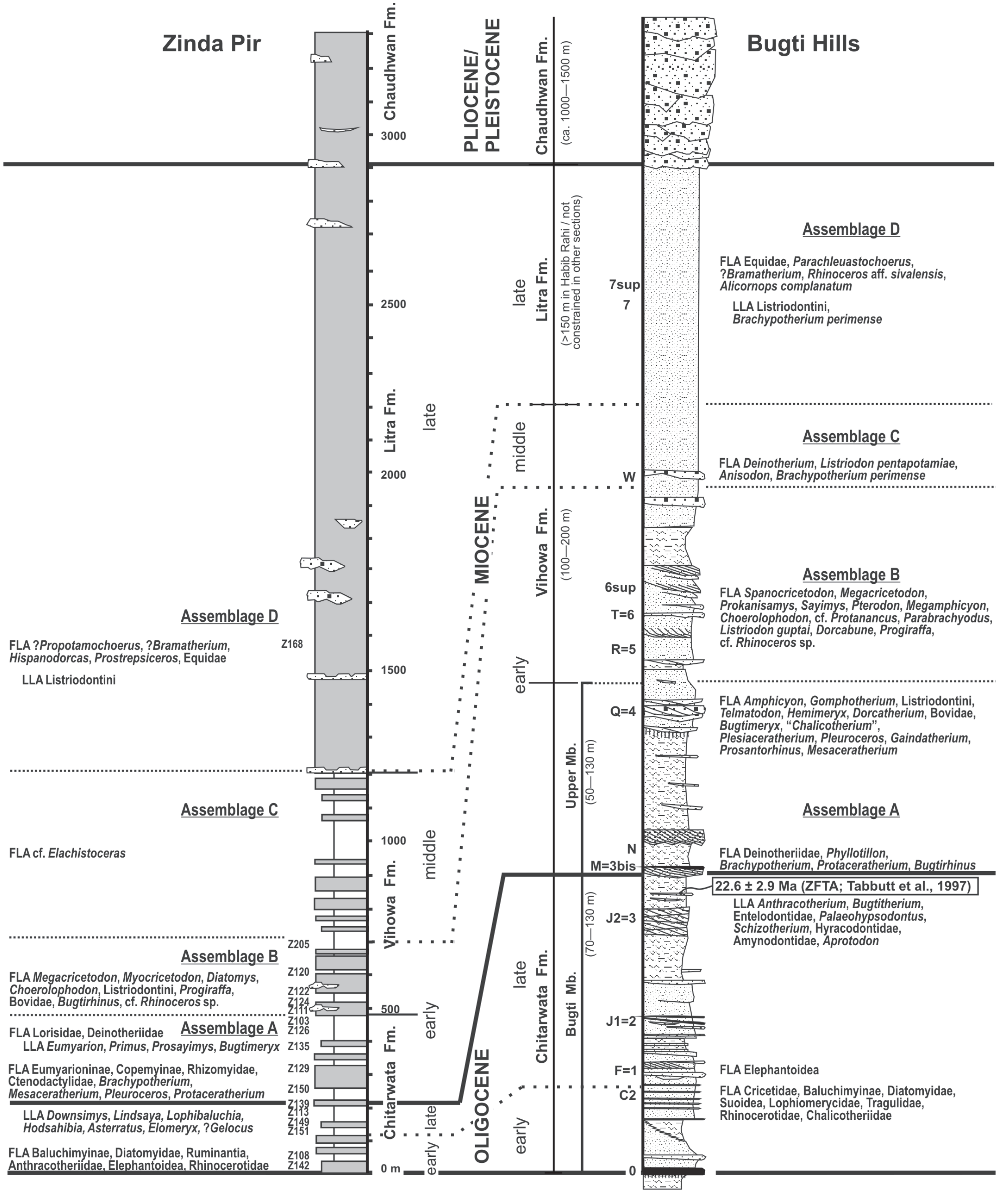


Figure 16.3 Stratigraphic sections of post-Eocene deposits of the Sulaiman Province (Zinda Pir Dome, to the left; Bugti Hills, to the right), with First Local Appearances (FLA) and Last Local Appearances (LLA) of index mammals and tentative correlation to the GPTS. Zinda Pir localities appear as "Z numbers" in the left column. Completed and modified after Marivaux et al. (1999, 2001, 2005, 2006), Welcomme et al. (2001), Raza et al. (2002), Antoine et al. (2003b, 2010), Barry et al. (2005), Gradstein et al. (2005), Lindsay et al. (2005), Métais et al. (2009a, 2009b), and Orliac et al. (2009, 2010).

Table 16.1
Mammals from the Upper Member of the Chitarwata Formation (Earliest Miocene) of the Sulaiman Province

Soricidae	
	genus and species indet. ZP
Chiroptera	
	genus and species indet. ZP
Tupaiidae	
	genus and species indet. ZP
Lorisidae	
	genus and species indet. ZP
Sciuridae	
	genus and species indet. ZP
	Petauristinae gen et sp. indet. ZP
Cricetidae	
	Eumyarion kowalskii ZP
	?*Eumyarion* sp. ZP
	Democricetodon sp. ZP
	Democricetodon sp. A ZP
	Spanocricetodon khani ZP
	Spanocricetodon sulaimani ZP
	Spanocricetodon sp. ZP
	Primus sp. ZP
Rhizomyidae	
	Prokanisamys arifi ZP
	Prokanisamys sp. ZP
Ctenodactylidae	
	genus and species indet. ZP
	"Z135 *Sayimys* sp." ZP
	Prosayimys flynni ZP
	Prosayimys sp. ZP
	?baluchimyine indet. ZP
	Diatomyidae
	Marymus dalanae ZP
Carnivora	
	genus and species indet. ZP
Amphicyonidae	
	Amphicyon shahbazi BH
	genus and species indet. ZP
Proboscidea	
	genus and species indet. ZP
Deinotheriidae	
	Prodeinotherium sp. ZP, BH
	P. pentapotamiae BH
Elephantoidea	
	genus and species indet. ZP, BH
	Gomphotherium sp. ZP, BH
Sanitheriidae	
	?*Sanitherium jeffreysi* ZP
	Sanitherium jeffreysi BH
Palaeochoeridae	
	Pecarichoerus sp. BH
Suidae	
	Listriodon affinis BH
Anthracotheriidae	
	Parabrachyodus sp. ZP
	P. hyopotamoides ZP
	Microbunodon silistrense ZP
	Sivameryx palaeindicus ZP, BH
	Hemimeryx cf. *blanfordi* BH
	Telmatodon sp. BH
	?*Masritherium* sp. ZP
	genus and species indet. ZP
Tragulidae	
	genus and species indet. ZP
	Dorcatherium sp. ZP, BH
Giraffidae	
	Progiraffa exigua ZP
Bovidae	
	Eotragus sp. BH
Ruminantia incertae sedis	
	Bugtimeryx pilgrimi ZP, BH
Chalicotheriidae	
	Phyllotillon naricus BH
	"*Chalicotherium*" *pilgrimi* BH
	genus and species indet. ZP
Rhinocerotidae	
	Protaceratherium sp. ZP, BH
	Plesiaceratherium naricum BH
	Mesaceratherium welcommi ZP, BH
	Pleuroceros blanfordi ZP, BH
	Brachypotherium gajense ZP, BH
	B. fatehjangense ZP, BH
	Prosantorhinus shahbazi BH
	Gaindatherium cf. *browni* BH
	?cf. *Rhinoceros* sp. BH
	Bugtirhinus praecursor BH
	genus and species indet. ZP

NOTE: ZP, Zinda Pir; BH, Bugti Hills

SOURCES: Completed and modified after Welcomme et al. (2001), Raza et al. (2002), Ginsburg and Welcomme (2002), Antoine et al. (2004, 2010), Barry et al. (2005), Gradstein et al. (2004), Lindsay et al. (2005), Métais et al. (2009a, 2009b), Orliac et al. (2009, 2010) and references therein, and new data.

Table 16.2
Mammals from the Vihowa Formation (Late Early to Middle Miocene) of the Sulaiman Province

Erinaceidae
Amphechinus sp. ZP
genus and species indet. ZP
Soricidae
genus and species indet. ZP, BH
Chiroptera
genus and species indet. ZP
Tupaiidae
genus and species indet. ZP
Sivaladapidae
Guangxilemur sp. ZP
Sciuridae
Petauristinae gen. et sp. indet. ZP
genus and species indet. ZP
Cricetidae
Democricetodon sp. B ZP
Democricetodon sp. X ZP
Spanocricetodon khani BH
Spanocricetodon sulaimani ZP
Spanocricetodon sp. BH
Megacricetodon ?daamsi BH
Megacricetodon sp. ZP
?*Megacricetodon* sp. ZP
Myocricetodon sivalensis ZP
Myocricetodon sp. 1 ZP
Myocricetodon sp. 2 ZP
Myocricetodon sp., large ZP
Rhizomyidae
Prokanisamys arifi ZP
Prokanisamys cf. *benjavuni* BH
Prokanisamys benjavuni BH
Prokanisamys sp. ZP
Ctenodactylidae
genus and species indet. ZP
Sayimys intermedius BH
Sayimys cf. *intermedius* ZP
Sayimys sp. ZP
Diatomyidae
Diatomys sp.
Creodonta
Hyanailouros sulzeri ZP
Pterodon bugtiensis BH
genus and species indet. ZP
Carnivora
Megamphicyon giganteus BH
Amphicyon shahbazi BH
genus and species indet. ZP
Deinotheriidae
Deinotherium sp. ZP
Prodeinotherium pentapotamiae BH
Elephantoidea
Gomphotherium browni BH
Gomphotherium cooperi BH
Choerolophodon corrugatus ZP, BH
cf. *Protanancus chinjiensis* ZP
genus and species indet. ZP
Sanitheriidae
genus and species indet. ZP
Suidae
Listriodon guptai ZP, BH
?*Listriodon affinis* ZP
Anthracotheriidae
Parabrachyodus hyopotamoides BH
Microbunodon silistrense ZP
Sivameryx palaeindicus ZP, BH
?*Sivameryx palaeindicus* ZP
genus and species indet.
Tragulidae
Dorcatherium sp. ZP
Dorcatherium cf. *parvum* BH
genus and species indet. ZP
Giraffidae
Progiraffa exigua ZP, BH
?*Giraffokeryx* sp. ZP
Bovidae
Eotragus noyei ZP
Eotragus sp. ZP
cf. *Elachistocerus* sp. ZP
genus and species indet. ZP
Chalicotheriidae
Anisodon sp. BH
genus and species indet. ZP
Rhinocerotidae
?*Plesiaceratherium naricum* BH
Mesaceratherium welcommi BH
Pleuroceros blanfordi BH
Brachypotherium fatehjangense BH
Brachypotherium gajense BH
Brachypotherium perimense ZP, BH
cf. *Rhinoceros* sp. ZP, BH
Bugtirhinus praecursor ZP
genus and species indet. ZP

NOTE: ZP = Zinda Pir; BH = Bugti Hills.

SOURCES: Completed and modified after Welcomme et al. (2001); Ginsburg and Welcomme (2002); Raza et al. (2002); Barry et al. (2005); Gradstein et al. (2004); Lindsay et al. (2005); Métais et al. (2009a, 2009b); Orliac et al. (2009); Antoine et al. (2010), references therein; and new data.

Table 16.3
Mammals from the Litra Formation (Late Miocene) of the Sulaiman Province

Deinotheriidae	
	Deinotherium sp. BH
Elephantoidea	
	Gomphotherium sp. ZP
	Choerolophodon corrugatus ZP, BH
	genus and species indet. BH
Suidae	
	Listriodon sp. ZP, BH
	?*Propotamochoerus* sp. ZP
	Parachleuastochoerus sp. BH
Giraffidae	
	?*Bramatherium perimense* BH
	?*Bramatherium* sp. ZP
	genus and species indet. ZP
Bovidae	
	Prostrepsiceros vinyaki ZP
	Hispanodorcas terrubiae ZP
	Reduncini gen. et sp. indet. ZP
	genus and species indet. BH
Equidae	
	Cormohipparion (*Sivalhippus*) *theobaldi* ZP
	Hippotherium sp. ZP, BH
Rhinocerotidae	
	Alicornops complanatum BH
	Brachypotherium perimense BH
	Rhinoceros aff. *sivalensis* BH
	genus and species indet. ZP

NOTE: ZP = Zinda Pir = BH, Bugti Hills.
SOURCES: Completed and modified after Welcomme et al. (2001), Raza et al. (2002), Antoine et al. (2003b, 2010), Zouhri and Ginsburg (2003), Gradstein et al. (2004) and references therein, and new data.

MAMMALIAN FAUNAS

Fossil mammals can be split into two categories, roughly corresponding to the collection methods used in the field: prospecting (middle-sized and large mammals) and screening/washing (small mammals).

Small Mammals

Neogene micromammal stes were much more investigated in the Zinda Pir area than in the Bugti Hills (Welcomme et al. 2001; Lindsay et al. 2005; figure 16.4*a*). The Zinda Pir Chitarwata and Vihowa formations notably yielded diversified rodent assemblages (Lindsay et al. 2005). By contrast, no micromammal locality is available in Neogene deposits of the Bugti Hills, with the exception of two successive levels—documenting the same assemblage—in the base of the Vihowa Formation (levels 6 and 6sup, late Early Miocene; Welcomme et al. 1997; Métais et al. 2009). Interestingly, a wide array of micromammals (marsupials, insectivores, bats, dermopterans, primates, and rodents) was recovered in the Bugti Member of the Chitarwata Formation in the Bugti Hills (Paali C2, Early Oligocene; Marivaux et al. 2001; Marivaux et al. 2001 2005). To our knowledge, neither marsupial nor lagomorphs nor dermopteran remains have been found in the Neogene of the Sulaiman Province so far.

Lipotyphla and Chiroptera

Unidentified soricid remains were recovered from the upper member of the Chitarwata Formation in Zinda Pir (Z113 and Z150) and from the lower part of the Vihowa Formation in both the Bugti Hills (level 6; Welcomme et al. 1997) and Zinda Pir (Z122; Lindsay et al. 2005). *Amphechinus* sp. and an unidentified hedgehog are mentioned in the lower part of the Vihowa Formation (Z122; Lindsay et al., 2005). Bats of uncertain affinities occur in Z113 (upper member of the Chitarwata Formation, earliest Miocene) and in Z124–Z122 (lower part of the Vihowa Formation, late Early Miocene; Lindsay et al., 2005).

Euarchontes

By contrast with the rich and diversified primate and dermopteran fauna unearthed in the Bugti member of the Chitarwata Formation in the Bugti area (Paali C2, Early Oligocene; Marivaux et al. 2001; Marivaux et al. 2005; Marivaux et al. 2006), Neogene deposits of the Sulaiman Province have yielded only scarce euarchontan remains from Zinda Pir, consisting of unidentified Tupaiidae (Z113, upper Chitarwata Formation; Z122, lower Vihowa Formation) and Lorisidae (Z135, upper Chitarwata Formation; Lindsay et al. 2005). The sivaladapid adapiform *Guangxilemur* sp. occurs in the lower part of the Vihowa Formation (Z122; Lindsay et al. 2005). The corresponding stratigraphic interval is restricted to the Early Miocene period (see tables 16.1 and 16.2 and figure 16.4*a*). No Neogene euarchontan is identified in the Bugti Hills.

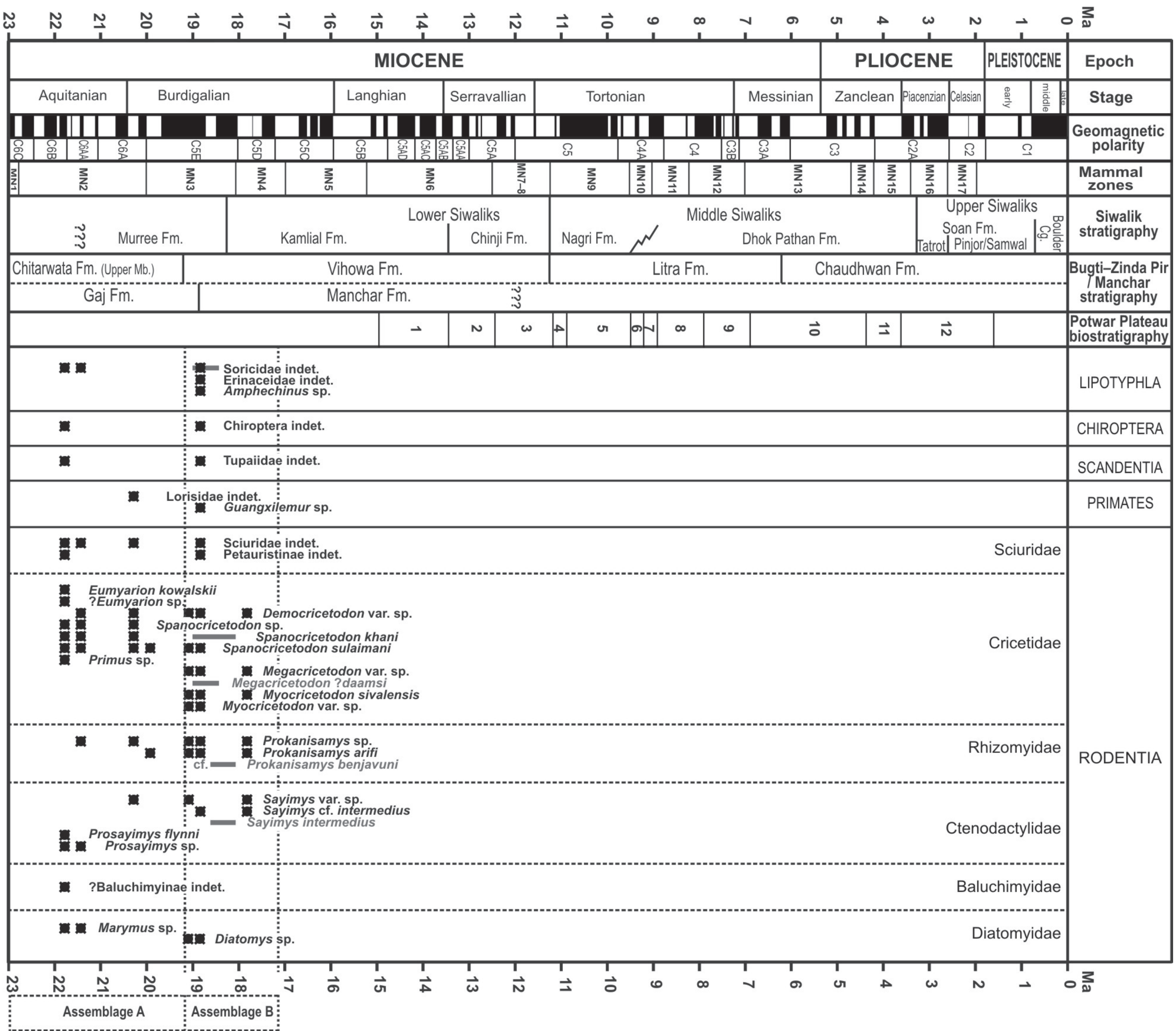
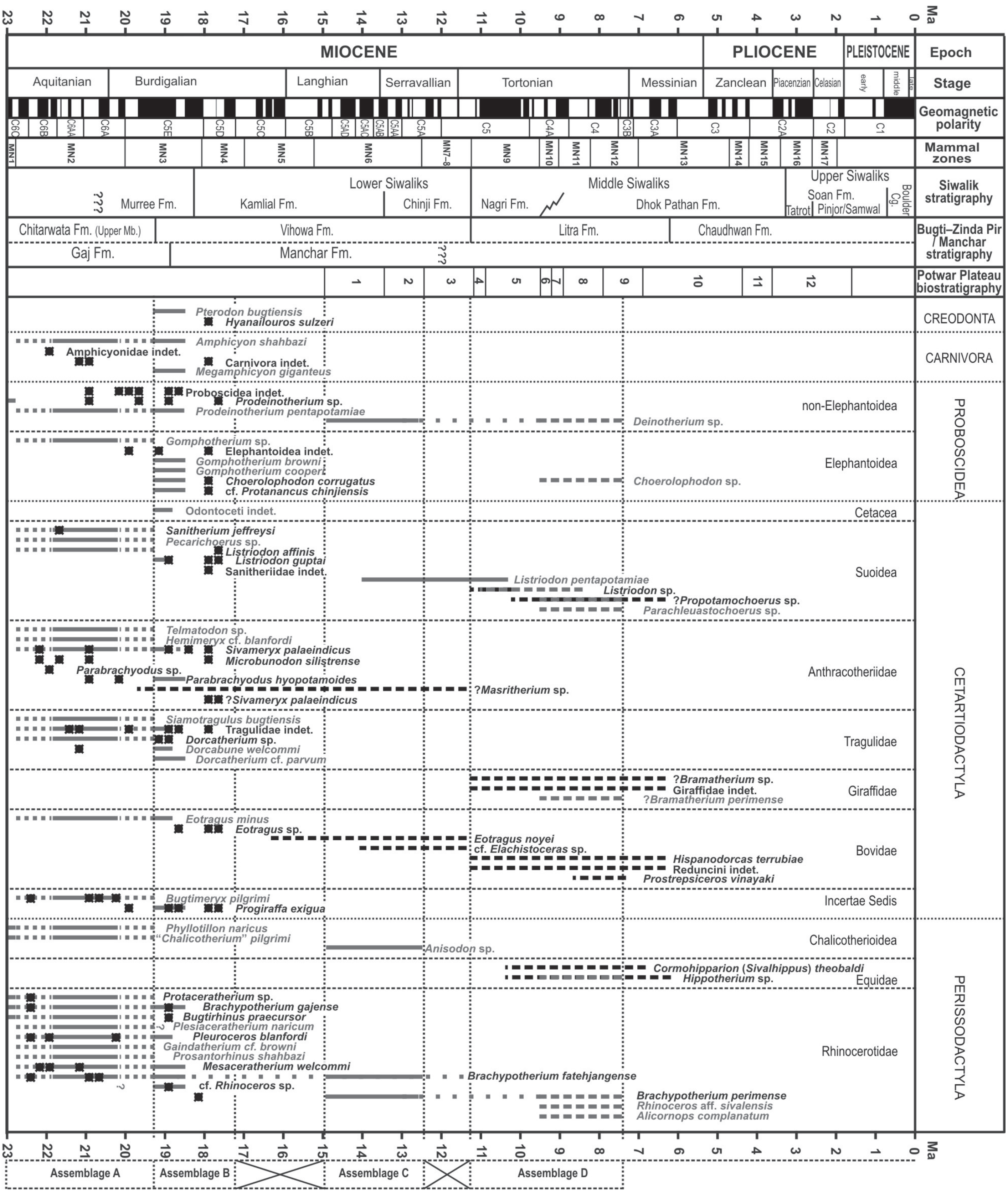


Figure 16.4 (a) Biostratigraphical range of small mammals from the Neogene of the Sulaiman Province, Pakistan. Taxa restricted to the Bugti Hills appear in gray. Taxa from Zinda Pir (most of them correlated to the GPTS) and/or from the whole Sulaiman Province (Zinda Pir + Bugti Hills) appear in black. Uncertain ranges are indicated by dashed lines. Taxa are sorted by order and/or family, and then by order of appearance. Completed and modified after Welcomme et al. (2001), Raza et al. (2002), Gradstein et al. (2005), Lindsay et al. (2005), Métais et al. (2009), and references therein. (b) Biostratigraphical range of large mammals from the Neogene of the Sulaiman Province, Pakistan. Taxa restricted to the Bugti Hills appear in gray. Taxa from Zinda Pir (most of them correlated to the GPTS) and/or from the whole Sulaiman Province (Zinda Pir + Bugti Hills) appear in black. Uncertain ranges are indicated by dashed lines. Taxa are sorted by order and/or family, and then by order of appearance. Completed and modified after Welcomme et al. (2001), Ginsburg and Welcomme (2002), Raza et al. (2002), Antoine et al. (2003b, 2010), Zouhri and Ginsburg (2003), Gradstein et al. (2005), Lindsay et al. (2005), Métais et al. (2009a, 2009b), Orliac et al. (2009), references therein, and new data.


Ma
Epoch
MIOCENE
PLIOCENE
PLEISTOCENE
Stage
Aquitanian
Burdigalian
Langhian
Serravallian
Tortonian
Messinian
Zanclean
Piacenzian
Gelasian
early
middle
late
Geomagnetic polarity
C6C C6B C6AA C6A C5E C5D C5C C5B C5AD C5AC C5AB C5AA C5A C5 C4A C4 C3B C3A C3 C2A C2 C1
Mammal zones
MN1 MN2 MN3 MN4 MN5 MN6 MN7–8 MN9 MN10 MN11 MN12 MN13 MN14 MN15 MN16 MN17
Siwalik stratigraphy
Murree Fm.
Lower Siwaliks
Kamlial Fm.
Chinji Fm.
Middle Siwaliks
Nagri Fm.
Dhok Pathan Fm.
Upper Siwaliks
Soan Fm.
Tatrot
Pinjor/Samwal
Boulder Cg.
Bugti–Zinda Pir / Manchar stratigraphy
Chitarwata Fm. (Upper Mb.)
Vihowa Fm.
Litra Fm.
Chaudhwan Fm.
Gaj Fm.
Manchar Fm.
Potwar Plateau biostratigraphy
1 2 3 4 5 6 7 8 9 10 11 12
CREODONTA
Pterodon bugtiensis
Hyanailouros sulzeri
CARNIVORA
Amphicyon shahbazi
Amphicyonidae indet.
Carnivora indet.
Megamphicyon giganteus
PROBOSCIDEA
non-Elephantoidea
Proboscidea indet.
Prodeinotherium sp.
Prodeinotherium pentapotamiae
Deinotherium sp.
Elephantoidea
Gomphotherium sp.
Elephantoidea indet.
Gomphotherium browni
Gomphotherium cooperi
Choerolophodon corrugatus
cf. Protanancus chinjiensis
Choerolophodon sp.
CETARTIODACTYLA
Cetacea
Odontoceti indet.
Suoidea
Sanitherium jeffreysi
Pecarichoerus sp.
Listriodon affinis
Listriodon guptai
Sanitheriidae indet.
Listriodon pentapotamiae
Listriodon sp.
?Propotamochoerus sp.
Parachleuastochoerus sp.
Anthracotheriidae
Telmatodon sp.
Hemimeryx cf. blanfordi
Sivameryx palaeindicus
Microbunodon silistrense
Parabrachyodus sp.
Parabrachyodus hyopotamoides
?Masritherium sp.
?Sivameryx palaeindicus
Tragulidae
Siamotragulus bugtiensis
Tragulidae indet.
Dorcatherium sp.
Dorcabune welcommi
Dorcatherium cf. parvum
Giraffidae
?Bramatherium sp.
Giraffidae indet.
?Bramatherium perimense
Bovidae
Eotragus minus
Eotragus sp.
Eotragus noyei
cf. Elachistoceras sp.
Hispanodorcas terrubiae
Reduncini indet.
Prostrepsiceros vinayaki
Incertae Sedis
Bugtimeryx pilgrimi
Progiraffa exigua
PERISSODACTYLA
Chalicotherioidea
Phyllotillon naricus
"Chalicotherium" pilgrimi
Anisodon sp.
Equidae
Cormohipparion (Sivalhippus) theobaldi
Hippotherium sp.
Rhinocerotidae
Protaceratherium sp.
Brachypotherium gajense
Bugtirhinus praecursor
Plesiaceratherium naricum
Pleuroceros blanfordi
Gaindatherium cf. browni
Prosantorhinus shahbazi
Mesaceratherium welcommi
Brachypotherium fatehjangense
cf. Rhinoceros sp.
Brachypotherium perimense
Rhinoceros aff. sivalensis
Alicornops complanatum
23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 Ma
Assemblage A
Assemblage B
Assemblage C
Assemblage D

Rodentia

In the Sulaiman Province, Neogene rodents are essentially known by micromammal localities from the Zinda Pir area, encompassing the upper member of the Chitarwata Formation (earliest Miocene; see table 16.1) and the lower part of the Vihowa Formation (late Early Miocene; see table 16.2; Lindsay et al. 2005). Only two levels from the lower part of the Chitarwata have yielded rodents in the Bugti Hills (see figures 16.2 [Dera Bugti] and 16.3 [levels 6 and 6sup]), but no micromammal is known from the upper member of the Chitarwata Formation (Welcomme et al. 2001). Correlation based on rodents within the Sulaiman Province is therefore restricted to the late Early Miocene (see figure 16.3).

Sciuridae are documented by unidentified remains from the upper member of the Chitarwata Formation (Z113, Z139, and Z135, from base to top) and from the lower part of the Vihowa Formation (Z122; Lindsay et al. 2005). A petauristine of uncertain affinities occurs in the same interval (Z113 and Z122; Lindsay et al. 2005), and a ratufine is found at Z135.

Cricetidae are by far the most diversified rodents of this interval, with at least 16 species (Welcomme et al. 2001; Lindsay et al. 2005). *Eumyarion kowalskii* (Z113), *E.* sp. (Z139), *Spanocricetodon* sp. and *Spanocricetodon khani* (Z113–Z135), and *Primus* sp. are restricted to the upper member of the Chitarwata Formation. This part of the section records also the First Local Appearance (FLA) of *Democricetodon* (*D.* sp. and *D.* sp. A, in Z150) and *Spanocricetodon sulaimani* (Z113), while a couple of other species referable to *Democricetodon* appear in the lower part of the Vihowa Formation (*D.* sp. X, Z124; *D.* sp. B, Z122; Lindsay et al. 2005). *Megacricetodon* sp. and *Myocricetodon* (*My.* sp. 1, *My. sivalensis*, *My.* sp. 2, and *My.* sp., large) have their FAD in the base of the Vihowa Formation in the Zinda Pir Dome (Z124; Lindsay et al. 2005).

In Zinda Pir, the rhizomyids *Prokanisamys* sp. and *P. arifi* occur in the upper part of the Chitarwata Formation (Z150) and persist in the lower part of the overlying Vihowa Formation (up to Z122; Lindsay et al. 2005). *P.* cf. *benjavuni* is recorded in the levels 6 and 6sup of the Bugti Hills (lower Vihowa Formation, late Early Miocene; Métais et al. 2009).

Ctenodactylidae are documented by various species in Zinda Pir (see tables 16.1 and 16.2 and figure 16.4). *Prosayimys flynni* (Z113) and *P.* sp. (Z113 and Z150) are restricted to the upper part of the Chitarwata Formation (Lindsay et al. 2005). The FLA of *Sayimys* sp. is recorded in the same interval, but definitive *Sayimys* (*S.* cf. *intermedius*) appears in the lower part of the Vihowa Formation (Z122; Lindsay et al. 2005), which coincides with the occurrence of *S. intermedius* in the Bugti Hills (level 6sup; Welcomme et al. 2001).

Three enigmatic teeth were identified as *Baluchimys* sp. and *Zindapiria quadricollis* in a single locality of the upper member of the Chitarwata Formation (Z113; Lindsay et al. 2005), but these records are possibly poorly preserved muroids.

Diatomyidae are documented by *Marymus dalanae* (Z113, Z139, and Z150) in the upper member of the Chitarwata Formation (earliest Miocene) and by *Diatomys* sp. in the lower part of the Vihowa Formation in the Zinda Pir Dome (Z124 and Z122, late Early Miocene; Lindsay et al. 2005; Flynn 2007).

The absence of any micromammal site from the upper part of the Chitarwata Formation (earliest Miocene) in the Bugti Hills prevents testing the rodent first appearances as observed in Zinda Pir for the corresponding interval. However, the rodent assemblages from the lower part of the Vihowa Formation are totally homotaxic in both areas (see table 16.2), at the genus or species level, with notably *Megacricetodon* and *Sayimys* appearing in the same interval in the Bugti Hills (level 6 and/or level 6sup; Welcomme et al. 2001; Métais et al. 2009) and in Zinda Pir (Z124, base of the Vihowa Formation; Lindsay et al. 2005).

Large Mammals

Ferae

Pending a revision of a few medium-size specimens unearthed in the upper part of the Chitarwata Formation in the Bugti Hills (Samane, level 4, earliest Miocene; see figure 16.1), and due to the sampling method used in the field—surface collection favoring large specimens—creodonts and carnivore remains are either unidentified to genus and species or referred as hyaeonodontid creodonts and amphicyonid carnivores (i.e., large or gigantic taxa). Their fossil record is so far restricted to the Early Miocene in the Sulaiman Province (see figure 16.4*b*).

The hyaenodontids *Pterodon* and *Hyanailouros* are documented in the lower part of the Vihowa Formation. Corresponding remains are referred to *P. bugtiensis* in the Bugti Hills (levels 6 and 6sup, late Early Miocene; Ginsburg and Welcomme 2002; Métais et al. 2009) and to *H. sulzeri* in coeval deposits of Zinda Pir (Z120; Lindsay et al. 2005).

In the Bugti Hills, the amphicyonid *Amphicyon shahbazi* occurs in several localities encompassing the top of the Chitarwata Formation (level 4, earliest Miocene) and the lower part of the Vihowa Formation (see figure 16.3 [levels 5 –6 sup, late Early Miocene]), while its close ally *Megamphicyon giganteus* occurs only in the lower part of the Vihowa Formation (levels 5–6sup, late Early Miocene; Ginsburg and Welcomme 2002; Métais et al. 2009). On the other hand, only unidentified carnivore and amphicyonid remains have been unearthed in coeval Zinda Pir deposits (Lindsay et al. 2005).

Proboscidea

Until recently, the Paleogene history of proboscideans was restricted to Africa, and elephants and their close relatives were supposed to disperse toward Eurasia during the late Early Miocene (Shoshani and Tassy 1996). This dispersal was given strong biostratigraphic significance and named Proboscidean Datum Event (PDE) by Madden and Van Couvering (1976). The recognition of a diagnostic elephantoid incisor from the Bugti Member of the Chitarwata Formation in the Bugti Hills (locality DB-J1, late Oligocene; Antoine, Welcomme, et al. 2003), the discovery of another tusk lower in the same stratigraphic interval in 2004 (level 2=F; Bugti Member, Chitarwata Formation; unpublished data), and the subsequent mention of an unidentified elephantoid in the lower Chitarwata at Zinda Pir (Oligocene Z108; Lindsay et al. 2005; now rejected as definitive) seriously challenge the concept of PDE as a single event occurring at ca. 17.5 Ma (late Early Miocene; Madden and Van Couvering 1976), and indicate rather that proboscideans dispersed several times from Africa to adjacent plates in Middle Cenozoic times, as suspected by Tassy (Barry, Flynn, and Pilbeam).

Deinotheriidae have their FLA in the upper member of the Chitarwata Formation (earliest Miocene), with *Prodeinotherium* sp. (level 3bis; tusk and dental fragments) and *P. pentapotamiae* (level 4; dental remains) in the Bugti Hills (see figure 16.3 and table 16.1). Scarce remains are reported from the same interval in Zinda Pir (Z129 and upward; Raza et al. 2002; Lindsay et al. 2005). These small deinotheres occur also throughout the Vihowa Formation (late early to middle Miocene) throughout the Sulaiman Province, and in coeval deposits of the Potwar Plateau (Kamlial and Chinji formations; Welcomme et al., 2001; pers. obs. POA) and Europe (e.g., Antoine et al. 1997). A larger deinotheriid referable to *Deinotherium* sp. occurs in the level 7sup of the Bugti Hills (Djigani, middle late Miocene; new data).

In the Sulaiman Province, the earliest elephantoid remains identified at genus level are referred to *Gomphotherium* sp. They originate from the upper part of the Chitarwata Formation in the Bugti Hills (see figure 16.3 [level 4, earliest Miocene]; Welcomme et al. 2001; Métais et al. 2009). The elephantoid assemblage is much more diversified in the subsequent stratigraphic interval—that is, in the lower part of the Vihowa Formation in the Bugti Hills (levels 6 and 6 sup.; late Early Miocene)—with *Gomphotherium browni*, *G. cooperi*, *Zygolophodon metachinjiensis*, *Choerolophodon* cf. *corrugatus*, and *Protanancus chinjiensis* (Welcomme et al. 2001; Métais et al. 2009). The two latter taxa are also recognized in the middle part of the Vihowa Formation (Z205; Lindsay et al. 2005). *C. corrugatus* persists until the middle Late Miocene in the Bugti Hills (level 7sup at Djigani; new data), as in Potwar Plateau (Dhok Pathan Formation; Pilbeam et al. 1979, 1996).

Cetartiodactyla

Odontoceti

An unidentified odontocete is mentioned in the lower part of the Vihowa Formation (level 6), in the Bugti Hills (Welcomme et al. 1997). The available tooth belongs probably to a river dolphin, given the fluvial depositional environment of the whole formation (Welcomme et al. 2001; Métais et al. 2009).

Ruminantia

Initially, Pilgrim (1908) referred dental remains to a primitive giraffid, *Progiraffa exigua*, with the mention "Dera Bugti Area," which was later refined as "upper Nari" of "Dakko Nala" (Pilgrim 1911). Pilgrim (1912) described two new species of ruminants from the base of the "Gaj" in the Bugti Area, based on sparse dental material; the species were doubtfully assigned as *Gelocus*(?) *gajensis* and *Prodremotherium*(?) *beatrix*. At that time, both genera were common ruminants restricted to the Oligocene of Europe. Despite this weak biochronological evidence of Oligocene age, Pilgrim (1912), probably influenced by the sequence observed in the Sind Province to the south, revised his former opinion concerning the probable occurrence of Oligocene deposits in the Bugti Hills (Pilgrim 1908) and argued for an early Miocene age for the whole Bugti fauna. Later on, there was no further extensive study of the ruminants from the Bugti Hills, principally due to the uncertain geographic and stratigraphic provenance of the described material, and the lack of fieldwork in the Sulaiman Lobe until the early 1980s and late 1990s (Raza and Meyer 1984; Welcomme et al. 1997).

Recent washing and screening in the lower Chitarwata Formation near Dera Bugti led to the discovery of new ruminant material with typically Oligocene taxa (Métais, Welcomme, and Ducrocq 2009). The upper Chitarwata has also yielded ruminant remains whose affinities remain somewhat obscure. Most efforts made by MPFB in the past decade have focused on the lower Chitarwata, and further investigation is necessary to better determine the diversity and stratigraphic ranges of Neogene ruminants of the Bugti Hills. Ginsburg, Morales, and Soria (2001) reassessed the systematics of ruminants collected by Pilgrim (1908, 1911, 1912) and Forster-Cooper (1915), in light of new material collected in 1997–1998 from the early Miocene strata of the Bugti Hills (essentially the levels 4, uppermost Chitarwata, and 6, basal Vihowa), allowing them to describe six taxa, referred to Giraffidae, Tragulidae, or Bovidae. Even if Ginsburg, Morales, and Soria (2001) did not indicate the geographic location of their material, and thus tended to perpetuate errors made by ancient authors, we were able to reassess the stratigraphic allocation of the concerned specimens thanks to their inventory number.

Bugtimeryx pilgrimi was erected by Ginsburg, Morales, and Soria (2001), based on mandibular, dental, and postcranial material collected from level 4 in the Bugti Hills (uppermost Chitarwata; see figures 16.3 and 16.4*b* and table 16.1). In the same article, *Gelocus* (?) *gajensis* (Pilgrim, 1912) and *Prodremotherium* (?) *beatrix* (Pilgrim 1912) were tentatively referred to *Bugtimeryx*, and this new genus was included within Giraffidae, without further discussion. Barry et al. (2005) and Lindsay et al. (2005) mention *B. pilgrimi* in several localities referred to the upper Chitarwata (Z151–Z133; see figure 16.4*b*), but rather consider it as a representative of "Pecora, incertae sedis." *Progiraffa exigua* occurs in the uppermost Chitarwata (Z126) and the lower Vihowa in the Zinda Pir (Z124–Z205; see figure 16.4*b*; Barry et al. 2005; Lindsay et al. 2005) and only in the lower Vihowa deposits in the Bugti Hills (level 6; Ginsburg, Morales, and Soria 2001). The type specimen of *P. exigua* was until recently all that was known of the taxon, but the new collections show that the species is rather common in the Early Miocene deposits of Zinda Pir (see figure 16.4*b*; Barry et al. 2005). Even if Ginsburg, Morales, and Soria (2001) also consider it as a giraffid closely related to *Canthumeryx* from Gebel Zelten (Libya, late Early Miocene), this taxon is of uncertain affinities within Ruminantia, following Barry et al. (2005).

The earliest Tragulidae from the Bugti Hills occur in the Bugti Member of the Chitarwata Formation at Paali C2 (Early Oligocene; see figure 16.3; Marivaux et al. 2001; Métais, Welcomme, and Ducrocq 2009). Higher in the series, Ginsburg, Morales, and Soria (2001) mention a supposedly primitive species of *Siamotragulus* (*S. bugtiensis*) based on mandibular, dental, and postcranial material from the uppermost Chitarwata (see figure 16.3 [level 4, earliest Miocene]). Small mandibular, dental, and postcranial remains from the base of the Vihowa Formation (see figure 16.3 [level 6, late Early Miocene]) are referred to *Dorcabune welcommi* by Ginsburg, Morales, and Soria (2001). *Dorcabune* was initially described by Pilgrim (1910, 1915) in the base of the lower Manchar Formation of Sind—that is, in levels considered as coeval to lower Vihowa deposits from the Sulaiman Province (late Early Miocene; for correlation, see figure 16.4*b*). In Zinda Pir, Barry et al. (2005) and Lindsay et al. (2005) mention unidentified tragulids in the upper Chitarwata (Z150–Z126, earliest Miocene) and *Dorcatherium* sp. in the lower Vihowa (Z127–Z116, late Early Miocene; see figure 16.4*b*).

A large taxon documented only by postcranials from the uppermost Chitarwata and the lowermost Vihowa formations in the Bugti area was tentatively referred by Ginsburg, Morales, and Soria (2001) to Tragulidae, under the name "?*Siamotragulus indicus* (Forster-Cooper 1915)." The corresponding remains most probably document an unidentified tragulid, since the type specimen (NHM M15421) of "*Gelocus indicus* Forster-Cooper 1915," for which the stratigraphic provenance is unknown, rather shows close affinities with the lophiomerycid *Nalameryx sulaimani* Métais, Welcomme, and Ducrocq 2009 from the Early Oligocene locality of Paali C2 in the Bugti Hills (Bugti Mb., lower Chitarwata). This family is restricted to Eurasian Paleogene localities (Métais, Welcomme, and Ducrocq 2009).

Interestingly, several Oligocene localities of Zinda Pir have yielded scarce remains of ruminants (Barry et al. 2005). Locality Z108, stratigraphically situated in the lower part of the Chitarwata Formation, has produced an indeterminate lophiomerycid (considered as conspecific to *Nalameryx sulaimani* by Métais, Welcomme, and Ducrocq 2009) and ?*Gelocus gajensis*. The generic status and familial affinities of ?*Gelocus gajensis* are still debated, but either of these taxa can be useful for biochronology. We consider as highly dubious the referral of isolated postcranial remains with a tragulid pattern from the upper Chitarwata Formation and the lower Vihowa Formation in the Bugti Hills (levels 4 to 6, early Miocene; Ginsburg, Morales, and Soria 2001) to the probable Oligocene lophiomerycid "*Gelocus indicus* Forster-Cooper 1915" (see figure 16.3).

At locality Z142, stratigraphically equivalent to Z108 (lower member, Chitarwata Formation, Oligocene; Lindsay et al. 2005), Barry et al. (2005) recognized the bovid-like ruminant *Palaeohypsodontus zinensis*, which is also known in the late Oligocene locality of Lundo Chur J2 in the Bugti area (Métais et al. 2003). There is no mention of this taxon in Miocene deposits of the Bugti area, but it is worth noting that *P. zinensis* is also reported from the locality Z121, situated in the late Early Miocene Vihowa Formation (Lindsay et al. 2005). This occurrence may correspond to the LAD of this puzzling genus.

Bovids are well represented throughout the Early Miocene of the Sulaiman Province. The earliest undisputable remains (horn core, tooth fragments, and postcranials were unearthed in the uppermost Chitarwata Formation (see figures 16.3 [level 4, earliest Miocene]and 16.4*b*; reinterpreted after Ginsburg, Morales, and Soria 2001) and in the lowermost Vihowa (level 6, late Early Miocene) in the Bugti area. All of them are referred to the minute species *Eotragus minus* (Ginsburg, Morales, and Soria 2001). The occurrence of "Bovidae indet." in the lower Vihowa (see figures 16.3 [Z110–Z120, late Early Miocene] and 16.4*b*) dates back to ca. 19.5 Ma among Zinda Pir occurrences (Lindsay et al. 2005). Higher in the Zinda Pir series, Raza et al. (2002) mention *Eotragus noyei* and cf. *Elachistoceras* sp. (Vihowa Formation, middle Miocene), while the Litra Formation (Late Miocene) records the occurrence of more advanced forms, such as *Prostrepsiceros vinayaki*, *Hispanodorcas terrubiae*, and an unidentified representative of Reduncini. In the Potwar Plateau, *Elachistoceras khauristanensis* occurs only in the Late Miocene, with a 11.5–7.4 Ma range, but its inferred FLA is estimated at ca. 14.0 Ma (Barry et al. 2002). In the same area, cf. *Prostrepsiceros vinayaki* has a short inferred interval (8.6–7.4 Ma) that slightly exceeds its observed time range (8.3–7.9 Ma; Barry et al. 2002). The Reduncini include Recent African reedbucks (*Kobus*) and waterbucks (*Redunca*) and their extinct relatives from the Old World, with a late Miocene to early Pleistocene Asian range (McKenna and Bell 1997).

No fossil cervid is known from the Neogene of the Bugti Hills and Zinda Pir (Welcomme et al. 2001; Raza et al. 2002; Lindsay et al. 2005), even though an undisputable cervid is portrayed with dichotomic branches in the pre-Holocene cave paintings of Lundo (Crochet et al. 2009).

Anthracotheriidae

Historically, the classic "Bugti Bone Beds" yielded abundant remains of anthracotheres, which were described in detail by Pilgrim (1912) and Forster-Cooper (1913, 1924). The generic and specific diversity of anthracotheriids from Bugti was certainly overestimated by these authors, and upon revision of ancient collections (without any lithostratigraphic control), Pickford (1987) recognized eight species belonging to six genera. Validity of these taxa and implied stratigraphic ranges of the species they would represent in the Bugti Hills remain unclear, making it difficult to use anthracotheriids for biochronologic, paleogeographic, and paleoenvironmental purposes. Anthracothere remains are well represented throughout the Chitarwata Formation in the Bugti Hills, but they tend to be taxonomically more diverse in the upper Chitarwata (Métais et al. 2009). *Anthracotherium* cf. *bugtiense* and another large anthracotheriine, as well as the bothriodontine *Elomeryx* sp., have been found in basal beds of the Chitarwata Formation near Bugti (Early and Late Oligocene; see figure 16.3; Métais et al. 2009). Dental remains of anthracotheres are rare at Paali C2 (basal Chitarwata, Early Oligocene; see figures 16.2 and 16.3), but several postcranial elements suggest the presence of a small species we refer to *Microbunodon* cf. *silistrense*. *Anthracotherium* cf. *bugtiense* ranges up to duricrust J2 (Late Oligocene) but is absent from the overlying levels M and Q (earliest Miocene; see figure 16.3). *Microbunodon* is neither registered in the upper Chitarwata (earliest Miocene) nor in the Vihowa Formation (late Early to Middle Miocene) in the Bugti area, while *Microbunodon silistrense* ranges from the upper Chitarwata (Z151, Z139, Z209) up to the lower Vihowa (Z121, Z120) at Zinda Pir (Lindsay et al. 2005).

In the Bugti area, the upper Chitarwata Formation, referred to the earliest Miocene, has yielded an entirely different assemblage of anthracotheres, mostly documented by fossils from ferruginous duricrust 4 or Q (see figure 16.3), with dental and postcranial remains of *Sivameryx palaeindicus*, *Hemimeryx* cf. *blanfordi*, *Parabrachyodus* cf. *hyopotamoides*, and possibly *Telmatodon* sp. (see figure 16.4*b*; Welcomme et al. 2001; Métais et al. 2009). In Zinda Pir, the anthracotheriid assemblage of the upper Chitarwata is somewhat distinct in the absence of *Hemimeryx* and possibly *Telmatodon*, and the occurrence of *Microbunodon*, a genus recorded from the lower Chitarwata in the Bugti area (Lindsay et al. 2005; Métais et al. 2009). *Hemimeryx* cf. *blanfordi* and *Parabrachyodus* cf. *hyopotamoides* are also recorded in the base of the Vihowa Formation (level 6, late Early Miocene) in the Bugti area. Anthracotheres from Zinda Pir have not been described yet, with the exception of *Elomeryx* cf. *borbonicus* from the Oligocene locality Z108 (Ducrocq and Lihoreau 2006). Only a broad revision of the anthracotheriid material from the Sulaiman Province, encompassing both Zinda Pir and Bugti samples, is likely to provide a satisfactory explanation to such a taxonomic/stratigraphic discrepancy.

Downing et al. (1993) and Raza et al. (2002) reported the presence of an indeterminate anthracotheriid and remains questionably referred to *Masritherium* from the Chitarwata Formation, as well as the occurrence of an unidentified anthracotheriid along with ?*Hyoboops sp.* (=*Sivameryx*) in the Vihowa Formation. To our knowledge, no hippopotamid has been mentioned for Neogene deposits of the Sulaiman Province.

Suoidea

Even though Suoidea are not abundant in terms of number of specimens, all three Eurasian families—that is, Sanitheriidae, Palaeochoeridae ("Old World peccaries"), and Suidae—are represented in mid-Cenozoic deposits of the Sulaiman Province.

Remains referable to Sanitheriidae are scarce, but they occur throughout the Chitarwata and Vihowa formations (Early Oligocene–Middle Miocene; see figure 16.4*b*; Lindsay et al. 2005; Orliac et al. 2010). A right P3 from Paali C2 (Bugti member, Chitarwata Formation, Early Oligocene; see figure 16.3), strongly reminiscent of the holotype of "*Hyotherium(?) jeffreysi* Forster-Cooper 1913" but with a simpler structure, is identified provisionally as *Sanitherium* sp. (*Hyotherium* is a suid, and in our opinion, Sanitheriidae are monogeneric, *Diamantohyus* Stromer 1926 being a junior synonym of *Sanitherium* Von Meyer 1866; Orliac et al. 2010). A sanitheriid referred to as "?*Diamantohyus jeffreysi*"—here, "?*S. jeffreysi*"—is recorded in both the lower member (Z144, Oligocene) and the upper member of the Chitarwata Formation in Zinda Pir (Z156, earliest Miocene; Lindsay et al. 2005). *S. jeffreysi* occurs in coeval deposits from the Bugti Hills, based on a mandibular fragment with m1–3 found at Samane (see figure 16.3 [level 4, earliest Miocene); unpublished data). An unidentified sanitheriid is also listed in the late Early Miocene of Zinda Pir (Z120, lower Vihowa; Lindsay et al. 2005).

Palaeochoeridae (sensu van der Made 1997) are documented unquestionably by a single specimen, an M3 referable to *Pecarichoerus* sp., from the upper member of the Chitarwata Formation at Samane in the Bugti Hills (see figure 16.3 [level 4, earliest Miocene]; unpublished data). This specimen strongly recalls the European *Taucanamo grandaevum*, from the late Early Miocene of France (MN 4; Orliac, Antoine, and Duranthon 2006). This family has not been mentioned in Zinda Pir so far (Lindsay et al. 2005). The Late Oligocene locality of Lundo J2, in the Bugti Hills (Bugti Member, Chitarwata Formation; see figure 16.3), yielded recently a mandibular fragment with m2–3 with morphology and measurements strongly comparable to the holotype of "*Microbunodon sminthos*" figured and described by Forster-Cooper (1913:fig. 5). Pickford (1987) subsequently reassigned this holotype, initially considered as belonging to an anthracotheriid "from the Upper Oligocene deposits of Dera Bugti" (Forster-Cooper 1913:514), to the palaeochoere genus *Pecarichoerus* Colbert 1933, otherwise known from Middle Miocene localities of the Potwar Plateau (Chinji Formation; Colbert 1933), Thailand, and China (Pickford et al. 2004). To date, no specimen documenting this puzzling palaeochoere has been unearthed in Neogene deposits of the Sulaiman Province.

Suidae occur throughout the continental series in the Bugti Hills—that is, from the Bugti member of the Chitarwata Formation at Paali C2 (Early Oligocene) up to the level 7 (Litra Formation, Late Miocene; see figure 16.3 and table 16.3). A few specimens from Paali C2, referrable to the hyotheriine *Hyotherium*, remain unidentified at species level (Orliac et al. 2010). This subfamily occurs only in the base of the Chitarwata Formation so far. Higher in the series, Suidae are only represented by Listriodontinae, Tetraconodontinae, and Suinae.

Listriodontinae have their FLA in the upper member of the Chitarwata Formation in the Bugti Hills, with *Listriodon affinis* (see figure 16.3 [level 4, earliest Miocene]; Orliac et al. 2009); this species is also mentioned from the lower part of the Vihowa Formation in Zinda Pir (Z205, late Early Miocene; Lindsay et al. 2005). *L. guptai* occurs in the base of the Vihowa Formation in both the Bugti Hills (see figures 16.3 [level 6] and 16.4*b*) and Zinda Pir (Z124, Z210, Z120, and Z205; "*L. gupti*" of Lindsay et al. 2005). The sublophodont listriodont *L. guptai* is very close morphologically to *L. akatikubas* from the late Early Miocene of Maboko, Kenya (ca. 16.5 Ma; Orliac et al. 2009). Fully lophodont listriodonts are found higher in the Vihowa Formation and referred to as either *Listriodon pentapotamiae* in the Bugti Hills (see figure 16.3 [level W, Middle Miocene]; Welcomme et al. 2001) or *Listriodon* sp. in the Vihowa Formation (late Early to Middle Miocene) and the Litra Formation (Late Miocene; Raza et al. 2002). The inferred stratigraphic range of *L. pentapotamiae* in the Potwar Plateau is 14.0–10.3 Ma (Barry et al. 2002:69). As such, the Litra specimens from the Sulaiman Province count among the few attested co-occurrences of listriodontine suids with hipparionine equids and may constitute the Last Local Appearance (LLA) for both *Listriodon* and Listriodontini (Barry et al. 2002; Raza et al. 2002).

Tetraconodontinae are only represented by an m3 from the Litra Formation of the Bugti Hills, identified as *Parachleuastochoerus* sp. (see figures 16.3 [level 7, early to middle Late Miocene] and 16.4*b* and table 16.3; Antoine, Welcomme, et al. 2003). This genus is known from the late Middle Miocene of Europe (MN 7–8; Golpe Posse 1972) and the early Late Miocene of China (correlated with MN10; Pickford and Liu 2001)

Suinae are likely to occur in the Litra Formation (Late Miocene) of Zinda Pir, with ?*Propotamochoerus* sp. (Raza et al. 2002). The only species referred to this suine genus to be documented in the Potwar Plateau is *P. hysudricus*, with a Late Miocene inferred stratigraphic range (10.2–6.5 Ma; Barry et al. 2002:69).

Perissodactyla

Perissodactyls are particularly abundant in the Neogene of the Bugti Hills, and they provide critical information for the age assessment (Welcomme et al. 2001; Antoine, Ducrocq, et al. 2003; Antoine, Duranthon, and Welmomme 2010; Métais et al. 2009).

No equoid is recorded in Chitarwata and Vihowa deposits: Hipparionine equids occur only in the top of the Miocene series—that is, in the Litra Formation (Zinda Pir) and in levels 7 and 7sup (Sartaaf = Djigani; Bugti Hills)—in deposits probably equivalent in age to the Dhok Pathan Formation of the Potwar Plateau (see figure 16.3; DB7; Welcomme et al. 1997; Antoine, Duranthon, and Welmomme 2003; Zouhri and Ginsburg 2003). The hipparionine teeth from Djigani recall those of *Hippotherium nagriense* (Nagri Formation; early Late Miocene) and *Cormohipparion* (*Sivalhippus*) *theobaldi* from the lower part of the Dhok Pathan Formation of Potwar Plateau, which indicates an age earlier than middle Turolian (Zouhri and Ginsburg 2003). *Hipparion* sensu lato in Zinda Pir is recorded at Z168—that is, 1500 m above the base of the Chitarwata Formation, at ca. 10.5 Myr (see figure 16.3; Raza et al. 2002). Raza et al. (2002) mention *C.* (*S.*) *theobaldi* in the same formation, without further precision concerning its stratigraphic range.

Ancylopoda are uncommon but present throughout the post-Eocene series in the Bugti Hills (Métais et al. 2009) and in the Zinda Pir Dome (Raza et al. 2002; Lindsay et al. 2005). In the latter area, all the specimens remain unidentified. In the Bugti Hills, the large schizotheriine *Phyllotillon naricus* is documented by dental and postcranial remains from the upper part of the Bugti member of the Chitarwata Formation (Oligocene in age) up to the top of the formation (level 4 (=Q); earliest Miocene), while the smaller chalicotheriine "*Chalicotherium*" *pilgrimi* seems to be restricted to the upper member, in levels 3bis (=M) and 4 (Métais et al. 2009). Higher in the series, a few postcranial and dental specimens unearthed from the middle part of the Vihowa Formation in the Bugti Hills (level W; Middle Miocene) are similar to specimens from Sansan in France and thus referable to *Anisodon* sp. (Anquetin, Antoine, and Tassy 2007).

In the Sulaiman Province, the bulk of Neogene perissodactyls is constituted by rhinocerotids, for which nine or ten species are recognized in the upper part of the Chitarwata Formation, seven or eight species in the Vihowa Formation, and at least three in Litra Formation or coeval deposits (see tables 16.1–16.3 and figure 16.4; Welcomme et al. 1997; Raza et al. 2002; Lindsay et al. 2005; Antoine et al. 2010). Most rhinocerotid suprageneric groups recognized in the Old World occur in the Neogene of the area (see figure 16.4). Rhinocerotinae are much diversified throughout the concerned period, with 12 species referred to Rhinocerotina, Aceratheriina, Teleoceratina, and Rhinocerotinae incertae sedis; on the other hand, Elasmotheriinae are represented by a single species (Antoine, Duranthon, and Welmomme 2003; Antoine et al. 2010).

Four basal offshoots of the Rhinocerotinae were unearthed in the upper Chitarwata Formation of both the Bugti Hills and Zinda Pir (earliest Miocene): *Protaceratherium* sp., *Pleuroceros blanfordi*, *Mesaceratherium welcommi*, and *Plesiaceratherium naricum*. The latter may also occur in the basal Vihowa Formation in the Bugti Hills (see table 16.2). *P. naricum* is the earliest representative of a well-known Eurasian genus, so far restricted to the late Early–early Middle Miocene interval (Yan and Heissig 1986; Antoine et al. 2000). *Pleuroceros blanfordi* and *Mesaceratherium welcommi* occur in the upper member of the Chitarwata Formation in the Bugti Hills and the Zinda Pir Dome and in the basal Vihowa Formation in the Bugti Hills (Early Miocene; see tables 16.1 and 16.2; Welcomme et al. 2001; Antoine et al. 2010). Both species are endemic to the Sulaiman Province, but they are sister taxa of the European *P. pleuroceros* and *M. paulhiacense*, respectively, from the earliest Miocene of Western Europe (Antoine et al. 2006, 2010).

Rhinocerotina include all five living rhino species; their fossil record is restricted to the Old World. The earliest representatives of the clade are restricted to Pakistan until the late Early Miocene (*Gaindatherium*; Antoine et al. 2000; Antoine et al. 2010). *Gaindatherium* cf. *browni*, recognized in the upper member of the Chitarwata Formation in the Bugti Hills (earliest Miocene), widely predates the FLA of other representatives of this one-horned genus elsewhere (Heissig 1972). An early putative representative of the extant genus *Rhinoceros* is recognized in the lower part of the Vihowa Formation (late Early Miocene, the Bugti Hills and Zinda Pir; Antoine et al. 2010). Undescribed specimens recovered from the base of the Kamlial Formation in the Potwar Plateau and referable to the same taxon (obs. by POA) help for correlating both intervals (see figure 16.3). Higher in the series, a partial maxilla with M1–3 unearthed in the level 7 (Djigani, the Bugti Hills; see figure 16.3) is referred to *Rhinoceros* aff. *sivalensis*. Undescribed specimens from the lower Dhok Pathan Formation in the Potwar Plateau document the same taxon. Thus, a middle Late Miocene age can be hypothesized for Djigani locality (Barry et al. 2002).

Teleoceratina are hippo-like extinct rhinos, with shortened limb bones adapted to swamps and riversides. *Prosantorhinus shahbazi* is restricted to the earliest Miocene deposits of the Bugti Hills (see table 16.1; Antoine et al. 2010). Prior to the latter recognition, the genus was only recorded in the late Early and early Middle Miocene of Western Europe (e.g., Antoine et al. 2000). Three representatives of the large and robust genus *Brachypotherium* are known. *B. fatehjangense* and *B. gajense* are recorded from the upper Chitarwata Formation and the lowest Vihowa Formation in both the Bugti Hills and Zinda Pir (Early Miocene; see table 16.1; Welcomme et al. 2001; Antoine et al. 2010). *B. gajense* is restricted to this stratigraphic interval, while *B. fatehjangense* persists until the Late Miocene in the Potwar Plateau (middle Dhok Pathan Formation; new data). In the Sulaiman Province, *B. perimense* ranges from the base of the Vihowa Formation in Zinda Pir (late Early Miocene; see table 16.1) up to level 7 in the Bugti Hills (middle Late Miocene; Antoine, Duranthon, and Welmomme 2003). New data from the Potwar Plateau provide similar ranges (LAD at ca. 7.1 Ma; Barry et al. 2002; POA, personal observation). Bugti and Zinda Pir remains document the earliest occurrences of *Prosantorhinus* and *Brachypotherium* at Eurasian and Old World scales, respectively.

Aceratheriina are extinct hornless rhinos, widespread in the Miocene of North America and Eurasia and in the Miocene of Africa. The only aceratheriine sensu stricto recognized in the Sulaiman Province is *Alicornops complanatum*, which occurs in level 7 of the Bugti Hills (Litra Formation, middle Late Miocene; Antoine, Duranthon, and Welmomme 2003). This taxon is abundant throughout the Late Miocene Dhok Pathan Formation in the Potwar Plateau (Colbert 1935; Heissig 1972; new data).

The Elasmotheriinae are the sister group of Rhinocerotinae. They are well represented in the Neogene of Eurasia and the Miocene of Africa (Antoine 2002). *Bugtirhinus praecursor* is the earliest elasmotheriine known so far. This primitive species is restricted to the upper Chitarwata deposits of the Bugti Hills (levels 3bis and 4, earliest Miocene; see table 16.1) and to the base of the overlying Vihowa Formation of Zinda Pir (Z116, late Early Miocene; see table 16.2 and figure 16.4; POA, personal obs.).

NEOGENE FAUNAL SUCCESSION IN THE SULAIMAN PROVINCE AND BIOSTRATIGRAPHICAL CORRELATION

In the present work, biostratigraphical correlation between the Bugti and Zinda Pir areas is mostly based on First Local Appearances (FLA) and observed ranges of hoofed mammals (rhinocerotids, proboscideans, artiodactyls, and hipparionine equids) for the whole Oligocene-Miocene series, as well as rodents for the early Miocene period (see figures 16.3 and 16.4). These assemblages are widely homotaxic, at the generic and/or species level (see tables 16.1–16.3).

In the Sulaiman Province, the best-documented stratigraphic interval spans the Chitarwata Formation and overlying Vihowa Formation (Oligocene to Middle Miocene), while the Potwar Plateau in northern Pakistan yields essentially Neogene deposits, among which Middle and Late Miocene faunas (Chinji, Nagri, and Dhok Pathan formations) are far better known than Early Miocene faunas (Murree and Kamlial formations; Pilbeam et al. 1979; Barry, Lindsay, and Jacobs 1982; Bary et al. 2002). Such a situation does not facilitate correlating the concerned areas.

The tentative correlation to GPTS for Neogene deposits of the Sulaiman Province is primarily based on the "Interpretation B" of Lindsay et al. (2005:fig. *6B*), with revised ages for chrons 6C to 5C (Gradstein et al. 2004). This interpretation is by far the most satisfactory for concerned mammal assemblages (i.e., without hiatus between the top of the Chitarwata Formation and the base of the Vihowa Formation) within C5En.2n, at ca. 19.4 Ma ("C6n" in Lindsay et al. 2005).

As a result, four successive faunal assemblages (A to D from old to young) are recognized in the Neogene of the Sulaiman Province, mainly constrained by perissodactyls (rhinocerotids and hipparionine equids) and rodents (cricetids, rhizomyids, and ctenodactylids) and, to a lesser degree, by deinotheriid proboscideans, sanitheriid and listriodontine suoids, anthracotheriids, and most ruminant groups (tragulids, bovids, and Pecora incertae sedis; see figure 16.4).

Assemblage A (Upper Chitarwata Formation Assemblage: Earliest Miocene)

A major turnover is observed within the Chitarwata Formation in the Sulaiman Province. Lower in the series—that is, in the lower Member (Zinda Pir) and Bugti Member (Bugti Hills)—occurs the Last Local Appearance (LLA) of many groups and genera of Oligocene affinities (see figure 16.3): the rodent *Downsimys* and most baluchimyines (*Lindsaya*, *Lophibaluchia*, *Hodsahibia*, and *Asterratus*; Lindsay et al. 2005), Entelodontidae, the anthracotheriids *Anthracotherium*, *Bugtitherium*, and *Elomeryx*, the chalicotheriid *Schizotherium*, Hyracodontidae (*Paraceratherium bugtiense*), Amynodontidae (*Cadurcotherium indicum*), and early rhinocerotids such as *Epiaceratherium* cf. *magnum*, *Aprotodon smithwoodwardi*, "*Dicerorhinus*" *abeli*, and a close ally of *Diceratherium* (Antoine, Duranthon, and Welmomme 2003; Antoine et al. 2004; Lindsay et al. 2005; Métais et al. 2009). This assemblage is assumed to predate the Oligocene-Miocene transition.

Assemblage A coincides with the appearance of a totally renewed assemblage in the upper Member of the Chitarwata Formation (Z113 and Z139 and localities above in Zinda Pir; levels 3bis and 4 in the Bugti area; Lindsay et al. 2005; Métais et al. 2009; Antoine et al. 2010). The rodent fauna is broadly renewed, with FLAs of *Eumyarion*, Copemyinae (*Democricetodon*, *Spanocricetodon*, and *Primus*), Rhizomyinae (*Prokanisamys*), and Ctenodactylinae (*Prosayimys*). Large mammals having their FLA in this assemblage are the large carnivore *Amphicyon*, Deinotheriidae (*Prodeinotherium*), *Gomphotherium*, Listriodontini suids (*Listriodon*), the anthracotheriids *Telmatodon* and *Hemimeryx*, the tragulid *Dorcatherium*, Bovidae (*Eotragus*), the ruminant *Bugtimeryx*, the chalicotheriids "*Chalicotherium*" and *Phyllotillon*, and the rhinocerotids *Protaceratherium*, *Mesaceratherium*, *Pleuroceros*, *Plesiaceratherium*, *Brachypotherium*, *Prosantorhinus*, *Gaindatherium*, and *Bugtirhinus* (see figure 16.3).

This stratigraphic interval resembles the Gaj Formation in Sind (Métais et al. 2009) and perhaps the poorly documented base of the Murree Formation in the Potwar Plateau (Barry et al. 2002). Given the faunal content and favored correlation to GPTS (see figure 16.4), this assemblage is tentatively correlated to the earliest Neogene standard age, the Aquitanian, and roughly correlated with the Xiejian Chinese Land Mammal Age (CLMA) and the Agenian European Land Mammal Age (ELMA), MN 1–2.

Assemblage B (Lower Vihowa Formation Assemblage: Late Early Miocene)

The Chitarwata-Vihowa formation transition is marked by the LLA of the cricetids *Eumyarion* and *Primus*, the ctenodactylid *Prosayimys*, the sanitheriid suoid *Sanitherium*, the ruminant *Bugtimeryx*, and several rhinocerotids, such as *Protaceratherium* sp., *Plesiaceratherium naricum*, *Prosantorhinus shahbazi*, and *Gaindatherium* cf. *browni*, which only occur in the Chitarwata Formation (see figures 16.3 and 16.4). This transition is supposedly coeval to both the Aquitanian-Burdigalian transition (marine standard scale) and the Agenian-Orleanian European Land Mammal Ages transition.

Assemblage B (lower Vihowa Formation) documents the FLA of key taxa such as the derived muroids *Megacricetodon* and *Myocricetodon*, the ctenodactylid *Sayimys intermedius*, the diatomyid *Diatomys*, the creodonts *Pterodon* and *Hyanailouros*, the carnivore *Megamphicyon*, the elephantoids *Protanancus* and *Choerolophodon*, *Listriodon guptai*, the tragulid *Dorcabune*, the "giraffoid" *Progiraffa*, and the rhinocerotids cf. *Rhinoceros* sp. and *Brachypotherium perimense*. Based on rhinocerotids and early bovids, this stratigraphic interval resembles the lower Manchar Formation in Sind (Raza et al. 1984) and the Kamlial Formation in the Potwar Plateau (Barry et al. 2002). Given the faunal content and favored correlation to GPTS (see figure 16.4), this assemblage is considered late Early Neogene standard age, the Burdigalian, and roughly correlated with the Shanwangian CLMA and the Orleanian ELMA (MN 3–5).

Assemblage C (upper Vihowa Formation assemblage: Middle Miocene)

Assemblage C is only documented by a few large mammals, and as such, it is not well constrained in terms of biostratigraphy. The concerned interval yields the FLA of *Deinotherium*, *Listriodon pentapotamiae*, the bovid cf. *Elachistoceras*, and the chalicotheriid *Anisodon* (see figure 16.3). This stratigraphic interval resembles the upper Manchar Formation in Sind and the Chinji Formation in the Potwar Plateau (Barry et al. 2002). Given the faunal content and favored correlation to GPTS (see figure 16.4*b*), this assemblage is tentatively considered early Middle Miocene, late Langhian–early Serravallian standard ages, and roughly correlated with the Tunggurian CLMA and the Astaracian ELMA (MN 6).

Assemblage D (Litra Formation Assemblage: Late Miocene)

In stratigraphic terms, the Vihowa–Litra formation transition is not well constrained, due to the scarcity of available localities and remains across the whole Sulaiman Province (Welcomme et al. 2001; Raza et al. 2002; Antoine, Welcomme, et al. 2003; Zouhri and Ginsburg 2003).

This assemblage consists only of large mammals (see figures 16.3and 16.4*b*), with the FLA of tetraconodontine and suine suids (*Parachleuastochoerus* and ?*Propotamochoerus*, respectively), of giraffids sensu stricto (?*Bramatherium*), of advanced bovids (*Hispanodorcas*, *Prostrepsiceros*, and an unidentified reduncine), of hipparionine equids (*Cormohipparion* (*Sivalhippus*) *theobaldi* and *Hippotherium* sp.), and of the rhinocerotids *Alicornops complanatum* and *Rhinoceros* aff. *sivalensis* and the LLA of listriodontines (*Listriodon* sp.).

The concerned fauna strongly resembles the magnetostratigraphically constrained assemblages recognized in the upper part of the Nagri Formation and the lower part of the Dhok Pathan Formation in the Potwar Plateau (Heissig 1972; Pilbeam et al. 1979; Barry et al. 2002). As such, this assemblage might be early Late Miocene standard age (late Tortonian) and is tentatively correlated with the late Bahean CLMA interval and the late Vallesian–early Turolian ELMA interval (MN 10–12).

FIRST LOCAL APPEARANCES AS “DATUMS”

Several mammalian taxa have their earliest occurrences in mid-Cenozoic deposits of the Sulaiman Range, either at tribe, family, or even at order level. In this section, we have chosen to focus on key taxa used at a large scale for biochronology and dispersal events, and well represented in the Neogene of the Sulaiman Province, such as proboscideans, suoids, bovids, and rhinocerotids.

Proboscidean Datum Event(s) (Bugti Hills/Zinda Pir)

Early specimens referrable to elephantoids discovered in the Bugti Hills originate from the Lundo section (Welcomme et al. 2001; Antoine, Welcomme, et al. 2003; Métais et al. 2009). The locality DB-J1 where the first tusk was found (Antoine, Welcomme, et al. 2003) is located ca. 40 m below the classical Lundo locality (level J2 = “Chur Lando” of Pilgrim 1908, 1910; Forster-Cooper 1924, 1934), and about 55 m below the Chitarwata–Vihowa formation transition (see figure 16.3). Tabbutt, Sheikh, and Johnson (1997) provided a fission track date of 22.6 ± 2.9 Myr for the yellow sands of “Chur Lando” (i.e., level J2). Locality DB-J1 is necessarily older than 19.7 Myr (and may date back to 25.4 Myr). The second tusk was found in a still older locality, referred to the level F, ca. 20 m lower in the same section (see figure 16.3).

In the Zinda Pir area, Lindsay et al. (2005) mention both “Elephantoidea Indet. genus, indet. species” and “Proboscidea Indet. genus, indet. species” in locality Z108, located in the lower member of the Chitarwata Formation, but we now think these specimens are not definitive. A younger specimen at locality Z154 is clearly an elephantoid and found midway in a significant normal magnetochron, currently considered chron C6Br, and therefore likely somewhat younger than 23 Ma (Flynn et al., chapter 14, this volume). These early occurrences alter considerably the concept of Proboscidean Datum Event as documenting a single dispersal of proboscideans out of Africa in the late Early Miocene (ca. 17.5 Ma; Madden and Van Couvering 1976). Proboscideans rather dispersed several times from Africa to Eurasia during the Oligocene and the Early Miocene, as already argued by Tassy (1990).

The earliest “diversified proboscidean fauna” from the Sulaiman Province occurs in the upper Chitarwata Formation, with the FLA of both Deinotheriidae (see figure 16.3 [levels 3bis and 4 in the Bugti Hills, Z129 in Zinda Pir]) and *Gomphotherium* sp. (see figure 16.3 [level 4 in the Bugti Hills]; Welcomme et al. 2001; Métais et al. 2009). Lindsay et al. (2005) correlate Z129 with C6Bn (ca. 22.5 Ma; Gradstein et al. 2005) and the level 4 may date back to ca. 21 Ma (see figure 16.4*b*).

Sanitheriidae

The sanitheriid *Sanitherium* sp. was recently recognized in the Bugti member of the Chitarwata Formation at Paali C2 (Early Oligocene, ca. 28 Ma; see figure 16.3; Orliac et al. 2010). *Sanitherium jeffreysi* is documented in the upper Member of the Chitarwata Formation at Samane 4 (Early Miocene, ca. 21 Ma; see figure 16.3; Orliac et al. 2010). “?*Diamantohyus jeffreysi*” is mentioned from coeval deposits of the lower Chitarwata Formation in Zinda Pir (Z144; Lindsay et al. 2005). Z144 is located in the same chron as Z108, but higher (C7n or C10n.2n; Lindsay et al. 2005), dating to 24.6 Ma or even 28.6 Ma (see section “Proboscidean Datum Event(s)”).

Both Oligocene occurrences widely predate the previous worldwide FAD of the family, so far considered as occurring during the Early Miocene in Africa (Sperrgebiet, Namibia, ~21–19 Ma; Pickford and Senut 2000, 2002). Such an early settlement of sanitheres in the Indian Subcontinent strongly supports the provocative hypothesis of a late Oligocene–earliest Miocene dispersal event *from* South Asia *toward* Africa, rather than in the opposite direction (Orliac et al. 2010).

Bovidae

The lowest bovid-yielding locality in Zinda Pir is Z120 (lowermost Vihowa), which is correlated with C5En (Lindsay et al. 2005)—that is, estimated at ca. 18.4 Myr (see figure 16.4*b*; Gradstein et al. 2005). The horncore referred to *Eotragus minus* in the Bugti area (Ginsburg, Morales, and Soria 2001) was recovered from coeval deposits (level 6, lowermost Vihowa Formation; see figure 16.4*b*). Both occurrences predate the base of the Kamlial Formation in the Siwalik Group (~18 Ma), where Solounias et al. (1995) have described *Eotragus noyei*, the oldest representative of the family then known.

Furthermore, the uppermost Chitarwata Formation in the Bugti Hills (level 4) yields several unambiguous bovid postcranials (Ginsburg, Morales, and Soria 2001). Given the favored correlation hypothesis between Zinda Pir and the Bugti area, these remains may date back to ca. 21 Ma (see section "Proboscidean Datum Event(s)" and figure 16.4*b*).

Early Miocene Rhinocerotidae and the "African Rhinocerotid Datum"

The rhinocerotid fauna from assemblage A (upper Chitarwata Formation, earliest Miocene: 23–19.4 Ma; see figure 16.4*b*) is exceptionally diversified, with nine cooccurring species in the Bugti Hills: the early elasmotheriine *Bugtirhinus praecursor* and the hornless rhinocerotines *Protaceratherium* sp. and *Plesiaceratherium naricum*, the basal rhinocerotines *Pleuroceros blanfordi* and *Mesaceratherium welcommi*, the teleoceratines *Brachypotherium gajense*, *B. fatehjangense*, and *Prosantorhinus shahbazi*, and the rhinocerotine *Gaindatherium* cf. *browni* (Antoine and Welcomme 2000; Antoine et al. 2010). Coeval homotaxic rhinocerotid assemblages (at genus level) are recorded from the Agenian ELMA of France (MN 1 to MN 2: 23–20 Ma interval; Gradstein et al. 2005), with *Protaceratherium minutum*, *Plesiaceratherium aquitanicum*, *Pleuroceros pleuroceros*, and *Mesaceratherium paulhiacense* (de Bonis 1973; Antoine et al. 2006; Antoine et al. 2010).

Interestingly, the earliest representatives of Rhinocerotidae in Africa are strongly comparable to those of assemblage A, which persist into assemblage B (see figure 16.4*b*): *Brachypotherium heinzelini* and *Aceratherium acutirostratum*, recognized in Napak II and Songhor (Hooijer 1966, 1973; Hooijer and Patterson 1972), as well as *Ougandatherium napakense* from Napak I (Guérin and Pickford 2003), are strongly comparable to the teleoceratine *Brachypotherium fatehjangense*, the acerathere *Mesaceratherium welcommi*, and the earliest elasmotheriine *Bugtirhinus praecursor*, respectively (Antoine et al. 2010). The radiometric age of Songhor is ~19.5 Ma (Pickford 1986; Cote et al. 2007) and Napak might be slightly older (Tassy 1986; Cote et al. 2007), which coincides with the assemblage A–assemblage B transition in terms of age (ca. 19.4 Ma; see figure 16.4*b*).

The close affinities of South Asian, African, and European rhinocerotid assemblages confirm both the presence of land bridges and the absence of ecological barriers between these continental areas during the Early Miocene.

ACKNOWLEDGMENTS

The authors warmly thank Xiaoming Wang, Deng Tao, Li Xiang, Mikael Fortelius, and all the Organizing Committee of the symposium "Neogene Terrestrial Mammalian Biostratigraphy and Chronology in Asia" held in Beijing in June 2009. Everett H. Lindsay provided highly valuable comments on a previous version of the manuscript. We are grateful to Francis Duranthon, Mouloud Benammi, Jean-Jacques Jaeger, Yaowalak Chaimanee, and Dario De Franceschi for their participation in fieldwork, and to Michèle E. Morgan, John C. Barry, David Pilbeam, Everett H. Lindsay, and Iqbal U. Cheema for their valuable help and discussion. This article is dedicated to the memory of Will Downs, Nawab M. A. K. Bugti, and Léonard Ginsburg. This research was supported by the French ANR-PALASIAFRICA Program (ANR-08-JCJC-0017 - ANR-ERC). MPFB Publication no. 39.

REFERENCES

Anquetin, J., P.-O. Antoine, and P. Tassy. 2007. Middle Miocene Chalicotheriinae (Mammalia, Perissodactyla) from France, with a discussion on chalicotheriine phylogeny. *Zoological Journal of the Linnean Society* 151:577–608.

Antoine, P.-O. 2002. Phylogénie et évolution des Elasmotheriina (Mammalia, Rhinocerotidae). *Mémoires du Muséum National d'Histoire Naturelle* (Paris)188, 359 p.

Antoine, P.-O., C. Bulot, and L. Ginsburg. 2000. Les rhinocérotidés (Mammalia, Perissodactyla) de l'Orléanien (Miocène inférieur) des bassins de la Garonne et de la Loire: intérêt biostratigraphique. *Comptes Rendus de l'Académie des Sciences, Sciences de la Terre et des Planètes* (Paris) 330:571–576

Antoine, P.-O., K. F. Downing, J.-Y. Crochet, F. Duranthon, L.J. Flynn, L. Marivaux, G. Métais, A.R. Rajpar, and G. Roohi. 2010. A revision of *Aceratherium blanfordi* Lydekker, 1884 (Mammalia: Rhinocerotidae) from the early Miocene of Pakistan: postcranials as a key. *Zoological Journal of the Linnean Society* 160:139–194.

Antoine, P.-O., S. Ducrocq, L. Marivaux, Y. Chaimanee, J.-Y. Crochet, J.-J. Jaeger, and J.-L. Welcomme. 2003. Early rhinocerotids (Mammalia, Perissodactyla) from South Asia and a review of the Holarctic Paleogene rhinocerotid record. *Canadian Journal of Earth Sciences* 40:365–374.

Antoine, P.-O., F. Duranthon, S. Hervet, and G. Fleury. 2006. Vertébrés de l'Oligocène terminal (MP30) et du Miocène basal (MN1) du métro de Toulouse (SW de la France). *Comptes Rendus Palevol* 5:875–884.

Antoine, P.-O., F. Duranthon, and P. Tassy. 1997. L'apport des grands mammifères (Rhinocérotidés, Suoidés, Proboscidiens) à la connaissance des gisements du Miocène d'Aquitaine (France). In *Actes du Congrès BiochroM'97*, ed. J.-P. Aguilar, S. Legendre, S. and J. Michaux, pp. 581–590. Mémoires et Travaux de l'Ecole Pratique des Hautes Etudes, Institut de Montpellier 21.

Antoine, P.-O., F. Duranthon, and J.-L. Welcomme. 2003. *Alicornops* (Mammalia, Rhinocerotidae) dans le Miocène supérieur des Collines Bugti (Balouchistan, Pakistan): implications phylogénétiques. *Géodiversitas* 25:575–603.

Antoine, P.-O., S. M. I. Shah, I. U. Cheema, J.-Y. Crochet, D. de Franceschi, L. Marivaux, G. Métais, and J.-L. Welcomme. 2004. New remains of the baluchithere *Paraceratherium bugtiense* (Pilgrim, 1910) from the Late/latest Oligocene of the Bugti Hills, Balochistan, Pakistan. *Journal of Asian Earth Sciences* 24:71–77.

Antoine, P.-O. and J.-L. Welcomme. 2000. A new rhinoceros from the lower Miocene of the Bugti Hills, Baluchistan, Pakistan: The oldest elasmotheriine. *Palaeontology* 43:795–816.

Antoine, P.-O., J.-L. Welcomme, L. Marivaux, I. Baloch, M. Benammi, and P. Tassy. 2003. First record of Paleogene Elephantoidea (Mammalia, Proboscidea) from the Bugti Hills of Pakistan. *Journal of Vertebrate Paleontology* 23:978–981.

Bannert, D., A. Cheema, A. Ahmed, and U. Schäffer. 1992. The structural development of the Western Fold Belt, Pakistan. *Geologisches Jahrbuch* B80:3–60.

Barry, J. C., S. Cote, L. MacLatchy, E. H. Lindsay, R. Kityo, and A. R. Rajpar. 2005. Oligocene and early Miocene ruminants (Mammalia, Artiodactyla) from Pakistan and Unganda. *Palaeontologia Electronica* 8(1); 20A: 29 pp; http://palaeo-electronica.org/2005_1/barry22/issue1_05.htm.

Barry, J. C., L. J. Flynn, and D. Pilbeam. 1990. Faunal diversity and turnover in a Miocene terrestrial sequence. In *Causes of Evolution: A Paleontological Perspective*, ed. R. M. Ross and W. D. Allmon, pp. 381–421. Chicago: University of Chicago Press.

Barry, J. C., E. H. Lindsay, and L. L. Jacobs. 1982. A biostratigraphic zonation of the middle and upper Siwaliks of the Potwar Plateau of Northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37:95–130.

Barry, J. C., M. E. Morgan, L. J. Flynn, D. Pilbeam, A. Behrensmeyer, S. M. Raza, I. Khan, C. Badgley, J. Hicks, and J. Kelley. 2002. Faunal and environmental change in the late Miocene Siwaliks of northern Pakistan. *Paleobiology Memoir* 3 (supplement to #2):1–71.

Beck, R. A., D. W. Burbank, W. J. Sercombe, G. W. Riley, J. K. Barndt, J. R. Berry, J. Afzal, A. M. Khan, H. Jurgen, J. Metje, A. Cheema, N. A. Shafique, R. D. Lawrence, and M. A. Khan. 1995. Stratigraphic evidence for an early collision between northwest India and Asia. *Nature* 373:55–58.

Blanford, W. T. 1883. Geological notes on the hills in the neighbourhood of the Sind and Punjab Frontier between Quetta and Dera Ghazi Khan. *Memoirs of the Geological Survey of India* 20:1–136.

Clift, P. D., N. Shimizu, G. D. Layne, and J. Blusztajn. 2001. Tracing patterns of erosion and drainage in the Paleogene Himalaya through ion probe Pb isotope analysis of detrital K-feldspars in the Indus Molasse, India. *Earth and Planetary Science Letters* 188:475–491.

Colbert, E. H., 1933. An Upper Tertiary peccary from India. *American Museum Novitates* 635:1–9.

Colbert, E. H., 1935. Siwalik mammals in the American Museum of Natural History. *Transactions of the American Philosophical Society* 26:1–401.

Cote, S., L. Werdelin, E. R. Seiffert, and J. C. Barry. 2007. Additional material of the enigmatic Early Miocene mammal *Kelba* and its relationship to the order Ptolemaiida. *Proceedings of the National Academy of Science* 104:5510–5515.

Crochet, J.-Y., P.-O. Antoine, L. Marivaux, G. Métais, and J.-L. Welcomme. 2009. Premières descriptions de peintures et gravures rupestres au Baloutchistan (Pakistan). *International Newsletter On Rock Art* 55.

de Bonis, L. 1973. Contribution à l'étude des mammifères de l'Aquitanien de l'Agenais. Rongeurs-Carnivores-Périssodactyles. *Mémoires du Muséum National d'Histoire Naturelle* (Paris) 28:1–192.

Downing, K. F. and E. H. Lindsay. 2005. Relationship of Chitarwata Formation paleodrainage and paleoenvironments to Himalayan tectonics and Indus River paleogeography. *Palaeontologia Electronica* 8(1): 20A; 12 pp; http://palaeo-electronica.org/2005_1/downing20/issue1_05.htm.

Downing, K. F., E. H. Lindsay, W. R. Downs, and S. E. Speyer. 1993. Lithostratigraphy and vertebrate biostratigraphy of the early Miocene Himalayan Foreland, Zinda Pir Dome, Pakistan. *Sedimentary Geology* 87:25–37.

Ducrocq, S. and F. Lihoreau. 2006. The occurrence of bothriodontines (Artiodactyla, Mammalia) in the Paleogene of Asia with special reference to *Elomeryx*: Paleobiogeographical implications. *Journal of Asian Earth Sciences* 27:885–891.

Flynn, L. J. 2007. Origin and evolution of the Diatomyidae, with clues to paleoecology from the fossil record. In *Mammalian Paleontology on a Global Stage: Papers in Honor of Mary R Dawson*, eds. K. C. Beard and Z.-X. Luo, pp. 173–181. Pittsburgh *Bulletin of Carnegie Museum of Natural History* 39.

Flynn, L. J., L. L. Jacobs, and I. U. Cheema. 1986. Baluchimyinae, a new ctenodactyloid rodent subfamily from the Miocene of Baluchistan. *American Museum Novitates* 284:1–58.

Forster-Cooper, C., 1913. New anthracotheres and allied forms from Baluchistan. *Annals Magazine of Natural History* 19:514–522.

Forster-Cooper, C., 1915. New genera and species of mammals from the Miocene deposits of Baluchistan. *The Annals and Magazine of Natural History* 16:404–410.

Forster-Cooper, C., 1924. The Anthracotheriidae of the Dera Bugti deposits in Baluchistan. *Memoirs of the Geological Survey of India* 4(2):1–59.

Forster-Cooper, C., 1934. XIII. The Extinct Rhinoceroses of Baluchistan. *Philosophical Transactions of the Royal Society of London*, Series B 223:569–616.

Friedman, R., J. Gee, L. Tauxe, K. Downing, and E. H. Lindsay. 1992. The magnetostratigraphy of the Chitarwata and lower Vihowa formations of the Dera Ghazi Khan area, Pakistan. *Sedimentary Geology* 81:–253–268.

Ginsburg, L., J. Morales, and D. Soria. 2001. Les Ruminantia (Artiodactyla, Mammalia) du Miocène des Bugti (Balouchistan, Pakistan). *Estudios Geologicos* 57:155–170.

Ginsburg, L. and J.-L. Welcomme, 2002. Nouveaux restes de créodontes et de carnivores des Bugti (Pakistan). *Symbioses* 7:65–68.

Golpe Posse, J. M. 1972. Suiformes del Terciario español y sus yacimientos. *Paleontologia i Evolucio* 2:1–197.

Gradstein, F. M., J. G. Ogg, and A. G. Smith. 2004. *A Geological Time Scale 2004*. Cambridge: Cambridge University Press.

Guérin, C. and M. Pickford. 2003. *Ougandatherium napakense* nov. gen. nov. sp., le plus ancien Rhinocerotidae Iranotheriinae d'Afrique. *Annales de Paléontologie* 89:1–35.

Heissig, K. 1972. Paläontologische und geologische Untersuchungen im Tertiär von Pakistan. 5. Rhinocerotidae (Mamm.) aus den unteren und mittleren Siwalik-Schichten. *Abhandlungen der Bayerischen Akademie der Wissenschaften Mathematisch-Naturwissenschaftliche Klasse* 152:1–112.

Hemphill, W. R. and A. H. Kidwai. 1973. Statigraphy of the Bannu and Dera Ismail Khan Areas, Pakistan. Uni*ted States Geological Survey Professional Paper* 716B:1–36.

Hooijer, D. A. 1966. Miocene rhinoceroses of East Africa. *Bulletin of the British Museum (Natural History) Fossil Mammals of Africa* 21:117–190.

Hooijer, D. A. 1973. Additional Miocene to Pleistocene rhinoceroses of Africa. *Zoological Mededelingen* 46:149–178.

Hooijer, D. A. and B. Patterson. 1972. Rhinoceroses from the Pliocene of Northwestern Kenya. *Bulletin of the Museum of Comparative Zoology* (Cambridge, MA) 144:1–26.

Jacobs, L. L., I. U. Cheema, and S. M. I. Shah. 1981. Zoogeographic implications of early Miocene rodents from the Bugti Beds, Baluchistan, Pakistan. *Géobios* 15:101–103.

Johnson, N. M., J. Stix, L. Tauxe, P. F. Cerveny, and R. A. K. Tahirkheli. 1985. Paleomagnetic chronology, fluvial processes, and tectonic implications of the Siwalik deposits near Chinji village, Pakistan. *Journal of Geology* 93:27–40.

Kumar, K. and S. Kad. 2003. Early Miocene vertebrates from the Murree Group, northwest Himalaya, India: affinities and age implications. *Himalayan Geology* 24(2):29–53.

Lindsay, E. H., L. J. Flynn, I. U. Cheema, J. C. Barry, K. F. Downing, A. R. Rajpar, and S. M. Raza. 2005. Will Downs and the Zinda Pir Dome. *Palaeontologia Electronica* 8:1–19.

Lydekker, R. 1884. Indian Tertiary and post-Tertiary Vertebrata. *Memoirs of the Geological Survey of India, Palaeontologica Indica*, Series 10, 2(1–2):1–66.

Madden, C. T. and J. A. Van Couvering. 1976. The Proboscidean Datum Event: Early Miocene migration from Africa. *Geological Society of America Abstracts with Programs* 8:992–993.

Marivaux, L., M. Vianey-Liaud, and J.-L. Welcomme. 1999. Première découverte de Cricetidae (Rodentia, Mammalia) oligocènes dans le synclinal sud de Gandoï (Bugti Hills, Balouchistan, Pakistan). *Comptes Rendus de l'Académie des Sciences de Paris*, série IIa 329:839–844.

Marivaux, L., P.-O. Antoine, S.R.H. Baqri, M. Benammi, Y. Chaimanee, J.-Y. Crochet, D. de Franceschi, N. Iqbal, J.-J. Jaeger, G. Métais, G. Roohi, and J.-L. Welcomme, 2005. Anthropoid primates from the Oligocene of the Bugti Hills (Pakistan): Data on early anthropoid evolution and biogeography. *Proceedings of the National Academy of Science* 102:8436–8441.

Marivaux, L., L. Bocat, Y. Chaimanee, J.-J. Jaeger, B. Marandat, P. risuk, P. Tafforeau, C. Yamee, and J.-L. Welcomme. 2006. Cynocephalid dermopterans from the Palaeogene of South Asia (Thailand, Myanmar and Pakistan): systematic, evolutionary and palaeobiogeographic implications. *Zoologica Scripta* 35:395–420.

Marivaux, L., J.-L. Welcomme, P.-O. Antoine, G. Métais, I. Baloch, M. Benammi, Y. Chaimanee, S. Ducrocq, and J.-J. Jaeger. 2001. A fossil lemur from the Oligocene of Pakistan. *Science* 294:587–591.

McKenna, M. C. and S. K. Bell. 1997. *Classification of Mammals Above the Species Level*. New York: Columbia University Press.

Métais, G., P.-O. Antoine, S. R. H. Baqri, M. Benammi, J.-Y. Crochet, D. de Franceschi, L. Marivaux, S. Ducrocq, and J.-L. Welcomme. 2006. New remains of the enigmatic cetartiodactyl *Bugtitherium grandincisivum* Pilgrim, 1908 from the upper Oligocene of the Bugti Hills (Balochistan, Pakistan). *Naturwissenschaften* 93:348–355.

Métais, G., P.-O. Antoine, S. R. H. Baqri, J.-Y. Crochet, D. de Franceschi, L. Marivaux, and J.-L. Welcomme. 2009. Lithofacies, Depositional Environments, Regional Biostratigraphy and Age of the Chitarwata Formation in the Bugti Hills, Balochistan, Pakistan. *Journal of Asian Earth Sciences* 34:154–167.

Métais, G., P.-O. Antoine, L. Marivaux, S. Ducrocq, and J.-L. Welcomme. 2003. New artiodactyl ruminant mammal from the Late Oligocene of Pakistan. *Acta Palaeontologica Polonica* 48:365–374.

Métais, G., J.-L. Welcomme, and S. Ducrocq. 2009. Lophiomerycid ruminants from the Oligocene of the Bugti Hills (Balochistan, Pakistan). *Journal of Vertebrate Paleontology* 29:1–12.

Najman, Y. and E. Garzanti. 2000. Reconstructing early Himalayan tectonic evolution and paleogeography from Tertiary foreland basin sedimentary rocks, northern India. *Geological Society of America Bulletin* 112:435–449.

Orliac, M., P.-O. Antoine, and F. Duranthon. 2006. The Suoidea (Artiodactyla, Mammalia), exclusive of Listriodontinae, from the Orleanian of Béon 1 (Montréal-du-Gers, SW France, MN4). *Géodiversitas* 28:685–718.

Orliac, M. J., P.-O. Antoine, G. Métais, J.-Y. Crochet, L. Marivaux, G. Roohi, and J.-L. Welcomme. 2009. *Listriodon guptai* Pilgrim, 1926 (Mammalia, Suidae) from the early Miocene of the Bugti Hills, Balochistan, Pakistan: New insights into early Listriodontinae evolution and biogeography. *Naturwissenschaften* DOI 10.1007/s00114-009-0547-4

Orliac, M. J., P.-O. Antoine, G. Roohi, and J.-L. Welcomme. 2010. Suoidea (Mammalia, Cetartiodactyla) from the early Oligocene of the Bugti Hills, Balochistan, Pakistan. *Journal of Vertebrate Paleontology* 30:1300–1305.

Pickford, M. 1986. A revision of the Miocene Suidae and Tayassuidae (Artiodactyla, Mammalia) of Africa. *Tertiary Research*, Special Paper 7:1–83.

Pickford, M. 1987. Révision des suiformes (Artiodactyla, Mammalia) de Bugti (Pakistan). *Annales de Paléontologie* 73:289–350.

Pickford, M. and Liu Liping. 2001. Revision of the Miocene Suidae of Xiaolongtan (Kaiyuan), China. *Bollettino della Società Paleontologica Italiana* 40:275–283.

Pickford, M., H. Nakaya, Y. Kunimatsu, H. Saegura, A. Fukuchi, and B. Ratanasthien. 2004. Age and taxonomic status of the Chiang Muan (Thailand) hominoids. *Comptes Rendus Palevol* 3:65–75.

Pickford, M. and Senut, B., 2000. Geology and Palaeobiology of the Namib Desert, Southwestern Africa. *Memoirs of the Geological Survey of Namibia* 18:1–155.

Pickford, M. and B. Senut. 2002. *The Fossil Record of Namibia*. Windhoek: Ministry of Mines and Energy, Geological Survey of Namibia, Namprint.

Pilbeam, D. R., A. K. Behrensmeyer, J. C. Barry, and S. M. I. Shah. 1979. Miocene sediments and Faunas of Pakistan. *Postilla* 179:–1–45.

Pilbeam, D., M. E. Morgan, J. C. Barry, and L. J. Flynn. 1996. European MN Units and the Siwalik Faunal Sequence of Pakistan, In *The Evolution of Western Eurasian Neogene Mammal Faunas*, ed. R. L. Bernor, V. Fahlbusch, and H.-W. Mittmann, pp. 290–306. New York: Columbia University Press.

Pilgrim, G. E. 1907. Description of some new Suidae from the Bugti Hills, Baluchistan. *Records of the Geological Survey of India* 36:45–56.

Pilgrim, G. E. 1908. The Tertiary and Post-Tertiary freshwater deposits of Baluchistan and Sind with notices of new vertebrates. *Records of the Geological Survey of India* 37:139–167.

Pilgrim, G. E. 1910. Preliminary note on a revised classification of the Tertiary freshwater deposits of India. *Records of the Geological Survey of India* 40:185–205.

Pilgrim, G. E. 1911. The fossil Giraffidae of India. *Memoirs of the Geological Survey of India*, New Series 4(1):1–29.

Pilgrim, G. E. 1912. The vertebrate fauna of the Gaj series in the Bugti Hills and the Punjab. *Memoirs of the Geological Survey of India*, New Series 4:1–83.

Raza, S. M., I. U. Cheema, W. R. Downs, A. R. Rajpar, and S. C. Ward,. 2002. Miocene stratigraphy and mammal fauna from the Sulaiman Range, Southwestern Himalayas, Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 186:185–197.

Shah, S. M. I. 1977. Stratigraphy of Pakistan. *Memoirs of the Geological Survey of Pakistan* 12:1–138.

Raza, S. M. and G. E. Meyer. 1984. Early Miocene geology and paleontology of the Bugti Hills. *Geological Survey of Pakistan* 11:43–63.

Shoshani, J. and P. Tassy. 1996. Appendix B. A suggested classification of the Proboscidea. In *The Proboscidea, Evolution and Palaeoecology of Elephants and Their Relatives*, ed. J. Shoshani and P. Tassy, pp. 352–353. Oxford: Oxford University Press.

Solounias, N., J. C. Barry, R. L. Bernor, E. H. Lindsay, and S. M. Raza. 1995. The oldest bovid from the Siwaliks, Pakistan. *Journal of Vertebrate Paleontology* 15:806–814.

Tabbutt, K. D., K. A. Sheikh, and N. M. Johnson. 1997. A fission track age for the Bugti bone beds, Baluchistan, Pakistan In *Third workshop on Siwaliks of South Asia*. *Records of the Geological Survey of Pakistan* 109:53.

Tassy, P. 1986. Nouveaux Elephantoidea (Mammalia) dans le Miocène du Kenya. *Cahiers de Paléontologie : Essai de Réévaluation Systématique*, Éditions du Centre National de la Recherche Scientifique, Paris.

Tassy, P. 1990. The "Proboscidean Datum Event": How many proboscideans and how many events? In *European Neogene Mammal Chronology*, ed. E. H. Lindsay, V. Fahlbusch, and P. Mein, pp. 237–252. New York: Plenum Press.

van der Made, J. 1997. Systematics and stratigraphy of the genera *Taucanamo* and *Schizochoerus* and a classification of the Palaeochoeridae (Suoidea, Mammalia). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* 100:127–139.

Vickary, N. 1846. Geological report on a portion of the Baluchistan Hills. *Quaterly Journal of the Geological Society* 2:260–265.

Welcomme, J.-L., P.-O. Antoine, F. Duranthon, P. Mein, and L. Ginsburg. 1997. Nouvelles découvertes de vertébrés miocènes dans le synclinal de Dera Bugti (Balouchistan, Pakistan). *Comptes Rendus de l'Académie des Sciences de Paris, série IIa* 325:531–536.

Welcomme, J.-L., M. Benammi, J.Y. Crochet, L. Marivaux, G. Métais, P.O. Antoine, and I. Baloch. 2001. Himalayan Forelands: palaeontological evidence for Oligocene detrital deposits in the Bugti Hills (Balochistan, Pakistan). *Geological Magazine* 138(4):397–405.

Welcomme, J.-L. and L. Ginsburg. 1997. Mise en évidence de l'Oligocène sur le territoire des Bugti (Balouchistan, Pakistan). *Comptes Rendus de l'Académie des Sciences de Paris, série IIa* 325: 999–1004.

Welcomme, J.-L, L. Marivaux, P. O. Antoine, and M. Benammi. 1999. Mammifères fossiles des Collines Bugti (Balouchistan, Pakistan). Nouvelles données. *Bulletin de la Société d'Histoire Naturelle de Toulouse* 135:135–139.

Yan Defa and K. Heissig. 1986. Revision and Autopodial Morphology of the Chinese-European Rhinocerotid Genus *Plesiaceratherium* Young 1937. *Zitteliana Abhandlungen der Bayerische Staatssammlung für Paläontologie und historisches Geologie*, München 14:81–110.

Zouhri S. and L. Ginsburg. 2003. Les Hipparions du Miocène supérieur des Bugti-Hills (Balouchistan, Pakistan). *Symbioses*, nouveau serie 9:33–38.