

REVIEW ARTICLE

GIANTS OF THE OLIGOCENE: THE EVOLUTIONARY HISTORY AND SYSTEMATICS OF BALUCHISTAN'S *PARACERATHERIUM*: A SCIENTIFIC REVIEW

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ABSTRACT

This paper reviews the historical discovery, the highly debated taxonomic classification, evolution, biogeographic distribution, significance, and anatomical structures of these Oligocene giant, hornless rhinoceroses. They belong to the subfamily Indricotheriinae (family Paraceratheriidae) and were the largest terrestrial mammals known to date. This paper focuses particularly on *Paraceratherium bugtiense*, discovered in the Bugti Hills of Balochistan, Pakistan. Paleontologists named these prehistoric giant mammals *Baluchitherium*, *Indricotherium*, and *Paraceratherium*. They were biogeographically widespread across Eurasia during the Oligocene (34 to 23 Ma). Their evolutionary history is closely tied to changing paleogeographic barriers, notably the uplift of the Tibetan Plateau, the closure of the Tethys Sea, and especially the submergence of the Turgai Strait.

KEYWORDS

Giant Rhinoceros, *Paraceratherium*, Oligocene, Balochistan, Pakistan.

1. INTRODUCTION

Paraceratheres are extinct giant hornless rhinocerotoids that were the largest land mammals ever to exist. They are widely known as *Baluchitherium*, or the Beast of Balochistan (Fortelius and Kappelman, 1993; Prothero, 2013). The scientific chronicle of this largest mammal began in the early twentieth century within the rugged terrain of Balochistan, Pakistan. The First fossil Discovery was recorded in 1908–1911 by British Paleontologist Pilgrim, who initially described fragmentary jaw remains from the Bugti Hills of Balochistan, naming them *Aceratherium bugtiense* (Pilgrim, 1908). Shortly thereafter, in 1911, Clive Forster-Cooper discovered unusually large skeletal structures in the same region near 'Lundo Chur' of Dera Bugti; he officially established the genus *Paraceratherium* based on the distinct downward-pointing lower incisor tusks. Foster-Cooper found fossils "remarkable for their unusually large bones; perhaps even more remarkably, these fossils didn't belong to dinosaurs but to an extremely large mammal (Foster-Cooper, 2011a, b & c). Foster-Cooper (1913) uncovered much larger bones, establishing the iconic genus *Baluchitherium*.

He originally proposed *Thaumastotherium*, but changed it to *Baluchitherium* because the former was already occupied by an insect genus. He established the genus *Baluchitherium*, meaning "Beast of Balochistan," due to its unparalleled mammalian dimensions (Forster-Cooper, 1913a & b). The next discovery was recorded in 1916 by a Russian paleontologist, Aleksei Borissiak, who unearthed massive indricothere fossils near Turgai in northern Turkmenistan, giving them the generic title *Indricotherium* (Borissiak, 1916). Pavlova established the genus *Indricotherium* (*I. transouralicum*) based on specimens found in Kazakhstan (Pavlova, 1922). In 1922, another team led by Roy Chapman Andrews of the American Museum of Natural History (AMNH), a colossal scientific expedition to Central Mongolia, discovered the first complete skull of these giant creatures (Granger and Gregory, 1923). Legendary American paleontologist Henry Fairfield Osborn named *B. grangeri* based on a highly complete skull found during the Roy Chapman Andrews Central Asiatic Expeditions (Henry Fairfield Osborn, 1923).

Cooper described the first definitive comparative analysis bridging *Paraceratherium* anatomy with Osborn's and Pavlova's discoveries (Cooper, 1924). In some study, reconstructed the animal, naming it *Baluchitherium granger* (Granger & Gregory, 1935 & 1936).

For decades, centers of scientific expertise alternatively categorized these giant quadrupeds under three distinct names based on local discoveries: *Paraceratherium* (Pakistan/South Asia), *Baluchitherium* (Pakistan/Central Asia), and *Indricotherium* (Kazakhstan/Russia). Their extensive anatomical comparisons firmly established that these fossils represented the same genus of animal in the mid-twentieth century. Following the rigid codes of the International Code of Zoological Nomenclature (ICZN), *Paraceratherium* Forster-Cooper, 1911 was prioritized as the senior synonym, making *Baluchitherium* and *Indricotherium* junior synonyms. Despite this scientific consolidation, the name *Baluchitherium* remains deeply embedded in regional and popular literature (Deng et al., 2021).

These giant mammals (Paraceratheres) were widespread in Mongolia, China, Central Asia, and the Indian Subcontinent, associated with similar faunas and similar environments during the Oligocene. Some remains were found in Eastern Europe, Turkey, Georgia, Serbia, Bulgaria, Romania, and the Caucasus (Figure 1) (Spassov, 1989; Antoine et al., 2008; Sen et al., 2011; Gabunia, 1964; Deng et al., 2021). Key foundational and modern research papers on these giant creatures include works by (Pilgrim, 1908; 1910; Borissiak, 1916; 1923; Foster-Cooper, 1924; Welcomme et al., 2004). Four valid genera of Paraceratheres are known between middle Eocene-Oligocene in Asia: Forstercooperia Wood, 1939 (middle-late Eocene Asia) (= Pappaceras Wood, 1963); Juxia Chow and Qiu, 1964 (late Eocene Asia) (= Imequiuncisoria Wang, 1976); Urtinotherium Chow and Qiu, 1963 (late Eocene Asia); and Paraceratherium Forster-Cooper, 1911a, b, c (= Baluchitherium Forster-Cooper, 1913b = Indricotherium Borissiak, 1923 = Aralotherium Borissiak, 1939 = Dzungariotherium Qiu, 1973 (Oligocene Asia)) (Lucas ve Sobus, 1989).

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These giant rhinos, such as *Paraceratherium*, *Dzungariotherium*, *Aralotherium*, and *Turpanotherium*, have been considered the largest land mammals that ever lived. Their skulls and legs are longer than those of all reported land mammals; their body size was suitable for open woodlands under humid or arid climatic conditions, but the metapodials are not massive in outline (Prothero, 2013). All forms of these giant rhinos, including six genera, have been recorded from northwest to southwest China through the middle Eocene to the late Oligocene. Among them, *Juxia* from the middle Eocene is considered the unequivocal ancestor of all giant rhinos because of a set of primitive and primarily specialized features (Qui and Wang, 2007). The genus *Paraceratherium* was the most widely distributed form of the giant rhino, but aside from East and Central Asia, many records from East Europe and West Asia, and only *Paraceratherium bugtiense*, known from the southwestern corner of the Tibetan Plateau, have ample records and undoubted taxonomic identity and are key to the origin and dispersal history of *Paraceratherium* (Antoine et al., 2004; Antoine et al., 2003; Metais, 2009; Deng, 2013).

A completely preserved skull with an articulated mandible and atlas, representing a new species of *Paraceratherium* from the upper Oligocene Jiaozigou Formation of the Linxia Basin in Gansu Province, China, located at the northeastern border of the Tibetan Plateau. The Jiaozigou fauna of the Linxia Basin also includes the giant rhinos *Turpanotherium* and *Dzungariotherium*, the rodent *Tsaganomys*, the creodont *Megalopterodon*, the chalicotheres *Schizotherium*, the hyracodont *Ardynia*, the rhinocerotid *Aprotodon*, and the entelodont *Paraentelodon*, making it similar to the Nanpoting fauna of the Lanzhou Basin and other Tabenbulukian faunas from Inner Mongolia and Ningxia (Deng et al., 2021). Manias provides a good description of the early discovery of the fragmentary remains of this huge prehistoric ungulate unearthed by scientific expeditions sent to India, Turkestan, and Mongolia (Manias, 2015).

While it was obvious that these fossils were from an immensely large creature, the fragmentary nature of the bones made it difficult to determine its exact nature. The taxonomy and systematic nomenclature of these giant *Paraceratherium* have been a matter of ongoing discussion. While it is widely appreciated that several giant *Paraceratherium* species from roughly contemporaneous Oligocene Asian sediments can be identified, it is still unclear how many species they represent and how they are related to each other. Even today, articles or papers discussing *Paraceratherium* usually require an aside on their confused taxonomy, with different authors forming different conclusions. Fortunately, the exact taxonomy is not required to calculate paleogravity. The only requirement is the ability to estimate the mass and weight of particular specimens (Figure 4) (Hurrell, 2019).

Paleontological and geological research in Pakistan has found numerous fossils belonging to different groups of prehistoric organisms. Pakistan is rich in paleontological evidence of vertebrates (Karl et al., 2024). In the geological time scale, *Baluchitherium* roamed Asia in the Oligocene epoch (30 Mya). According to plate tectonics, some 200 mya, the subcontinent was locked – it was a part of the great Gondwana continent, which comprised South America, Africa, the subcontinent, Australia, and Antarctica (Figure 1) (Karl et al., 2025; Muhammad and Safi, 2026). This block had been dismantled into parts and slowly moved apart from each other. Some 55 mya, one part of the Indian plate hit the Asian plate, and 43 million years ago the contact between the two was complete. This collision brought about the Great Himalayan Mountains. During the Oligocene, the geology, hydrology, and seasonal changes of the subcontinent were well known. The Himalayas' floods inundated Tethys Lake, situated between the Himalayas and the Indian subcontinent, replacing it with the salt range plateau and the Indo-Ganges plain. The annual elevation differences across the subcontinent led to explosive monsoon rains (Safi and Karl, 2024). The Indian-Asian plate collision changed the whole climate of the region.

Heavy rains and erosion turned Balochistan into a lush green rainforest like today's Amazon. The conditions were suitable for a hornless rhinoceros, or *Baluchitherium*, to flourish. The lush forest provided enough vegetation for the bulk-eating mammal to survive. *Baluchitherium* lived for 11 million years, from nearly 35 to 24 million years ago. After working on the *Baluchitherium*, Welcomme tried to uncover the entire environment it shared (Antoine et al., 2004). The team discovered the diverse fossils of fish, turtles, crocodiles, rodents, and other small mammals. Welcomme and his team studied 40 sites that described 12 distinct levels of different geological ages. They also discovered prehistoric trees, flowers, and leaves. Amazingly, the team found shark teeth, fish, and shells, which suggested that around 32 million years ago an epicontinental sea had appeared in the heart of Balochistan, which was a rare phenomenon. Pakistan is an 'El Dorado' for fossil hunters. However, serious attention is also required to highlight the discoveries from Pakistan. It has been a decade since the complete skeleton of the largest land mammal was discovered in Pakistan (Figures 2 & 3) (Ali, 2010).

The first description was done by named the first specimens (*Paraceratherium bugtiense*) from the Bugti Hills of Balochistan, Pakistan (Pilgrim, 1908). The mammal's fossils were first discovered in 1910 by English paleontologist Sir Clive Forster Cooper, who christened his finding *Baluchitherium*, or 'the beast of Balochistan.' The early reconstructions were done and published detailed anatomical descriptions of *Baluchitherium osborni* in the Philosophical Transactions of the Royal Society (Forster-Cooper, 1924). The modern discoveries were made by they described new fossil remains and sexual dimorphism from the original type locality in Balochistan. Welcomme's team included three more Frenchmen from the University of Montpellier – Dr Pierre-Olivier Antoine, Dr Laurent Marivaux and Dr Gregoire Metais (Antoine et al., 2004). Jean-Loup Welcomme, who came to Pakistan to follow in Cooper's footsteps. They worked painstakingly for months in the scorching heat of the Dera Bugti Hills and found not just an almost-complete skeleton of the mammal dating back at least 30 million years, but also other extinct fauna corresponding to the same period.

French paleontologist Jean-Loup Welcomme led expeditions under the "Mission Paléontologique Française au Balochistan" in the Bugti Hills of Dera Bugti, where he was hosted, provided local workers, security, and daily provisions by the late Nawab Akbar Bugti to unearth the fossils of the *Baluchitherium* in the 1990s, retracing the steps of British paleontologist Clive Forster Cooper, identifying Dera Bugti as the original site of the giant fossil discoveries (Antoine et al., 2004). The scorched, dusty hills of Dera Bugti held invaluable treasure that could have made the world a richer place. In 1997 and 1999, the team discovered major skeletal remains, revealing a creature standing roughly 5 meters tall and weighing around 20 tons (Figures 2 and 3) (Guardian, 1999; Siddiqui, 2012; Scientia Magazine, 2020). These priceless collections of prehistoric giants' fossils gathered during the expedition were stored in Dera Bugti. After the bones were found in 1999 and analyzed for data, permission was sought to take them to France, where a complete replica could be built. Nawab Akbar Bugti did not want the bones to be taken away initially and asked the scientists to make the replica here.

Eventually, however, permission to take the bones for a brief period was given on the condition that they would be returned soon. That, unfortunately for the discovery, did not happen. A report in the 'Express Tribune' indicates that the remains may have been damaged or lost during the 2006 military operation in which Nawab Akbar Bugti was killed, leaving researchers with only photographs and measurements (Siddiqui, 2012). Another report published in 'Dawn News' revealed that Nawab Akbar Khan Bugti kept the *Baluchitherium* bones in 10 metallic containers, fortunately (Ali, 2010). After his assassination, the fossils were recovered and sent to the museum of the 'Geological Survey of Pakistan' (Ali, 2010).



Figure 1: Biogeographical distribution of *Paraceratherium*. Localities of the Early Oligocene species are marked in yellow, while red indicates Late Oligocene species. Dispersals of *Paraceratherium* between South Asia and other localities had to pass through the Tibetan region because most of Central Asia—including southeastern Kazakhstan, the Turpan Basin, and the Tarim Basin—was covered by the Tethys Ocean during the Oligocene (Paleogeographic map courtesy of Deep Time Maps; Spicer et al., 2020; Deng et al., 2021).



Figure 2: Photo shows the French paleontologist Jean-Loup Welcomme and his team reconstructing the skeleton of a *Baluchitherium* in Dera Bugti, Balochistan (Mission Paléontologique Française au Pakistan) (Courtesy of: Jean-Loup Welcomme).



Figure 3: Photo shows Nawab Akber Bugti (1st on the left with a stick) and Jean-Loup Welcomme (third from the left, wearing a white Balochi turban and a yellow shalwar-kameez) with others visiting the reconstructed skeleton of a *Baluchitherium* in Dera Bugti (Photo courtesy of Jean-Loup Welcomme).

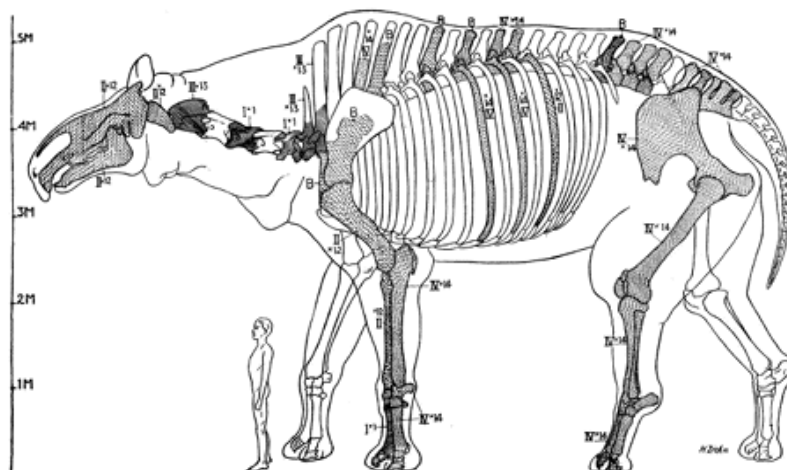


Figure 4: The *Baluchitherium* (*Paraceratherium*) restoration is provided in Granger & Gregory (1936, Fig. 46). The differential shading indicates the parts belonging to animals of the four size grades studied by the team—Grade I being the maximum and Grade IV the minimum size. Bones marked B are from the Borissiak collection. See Hurrell (2019) for a further description.



Figure 5: A model of the *Baluchitherium* featured in the size comparison with *Loxodonta africana* (Courtesy of Sameer Prehistorica, prehistoric animal size reconstructions).

2. SYSTEMATICS

Order Perissodactyla Owen, 1848

Family Hyracodontidae Cope, 1879

Subfamily Indricotheriinae Borissiak, 1923

Genus *Paraceratherium* Forster-Cooper, 1911

Paraceratherium bugtiense (Pilgrim, 1910)

Size: Stood about 5 meters (16 feet) tall and weighed up to 20,000 kg (20 tons) (Prothero, 2013).

Age: Lived during the Oligocene epoch, roughly 34 to 23 million years ago (Prothero, 2013).

Location: Discovered primarily in South and Central Asia, notably Balochistan, Pakistan (Antoine et al., 2004).

2.1 The Foundational Discoveries and Taxonomic Revisions

These historic references track the initial naming confusion. The fossils were so massive and fragmentary that they were initially categorized as separate genera before being unified under *Paraceratherium*.

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2.2 Localities of discovered fossils, Mapping and stratigraphy

2.2.1 Primary Mapping Localities (Bugti Hills Basin)

Lundo Chur (Type Locality: J2) (Welcomme et al., 2001)

Geospatial Context: Located on the southern side of the Zin Mountain Range and approximately 25 km southeast of Dera Bugti Town.

Stratigraphy: Fluvial yellow sands capped by a ferruginous crust in the upper part of the Bugti Member.

Mapping Notes: Historically recorded as *Lundo chur* in colonial maps (Forster-Cooper, 1924; Pilgrim, 1912). This site yielded the dental and postcranial structures proving regional sexual dimorphism, often mapped as DBJ2 (Dera Bugti locus J2) or SUI-1 (Antoine et al., 2004).

Kumbi Locality (Locality: Kumbi 3)

Geospatial Context: Located on the northern side of the Zin Mountain Range (Antoine and Welcomme, 2000).

Stratigraphy: Stratigraphically correlated as the northern lateral equivalent to the Lundo Chur J2 yellow sands layer.

Mapping Notes: Also mapped under the acronym DB3. This upper-tier site defines the absolute uppermost boundary of the Paraceratheres stratigraphic range in South Asia before the major Miocene faunal turnover occurs 25 meters higher up (Antoine et al., 2004; Welcomme et al., 2001).

Gandoi Syncline (Southern Basin Levels)

Geospatial Context: Located in the southern extremities of the Dera Bugti footprint.

Stratigraphy: Basal strata tracking from Level 0 up through Level C2.

Mapping Notes: Critical for plotting the onset of Paraceratheres dispersal into the Indian subcontinent during the Early Oligocene (Marivaux et al., 2001; Welcomme et al., 2001).

Khajuri Nala ("Upper Nari" Zone)

Geospatial Context: Located in the eastern sector of the Bugti Hills.

Stratigraphy: Basal ferruginous crust of the Bugti Member.

Mapping Notes: Crucial mapping junction where *Paraceratherium bugtiense* horizons overlap seamlessly with the giant amynodontid *Cadurcotherium indicum* (Antoine et al., 2004; Welcomme and Ginsburg, 1997).

2.2.2 Emerging Outposts & Northern Extensions

Shagala Area of Zhob District Basin

Geospatial Context: Located in the Kakar-Khorasan / Katawaz region of the northern area of Balochistan.

Stratigraphy: Lower-to-middle Eocene horizons within the Shagala Formation.

Mapping Notes: Yields older primitive rhinocerotoid variants linked to early baluchithere expansion trends (*Pakitherium shagalai*). Useful for making an Eocene-Oligocene transitional lineage layer on maps (Metais et al., 2009; Malkani, 2014).

3. EVOLUTIONARY TIMELINE OF THE PARACERATHERES' LINEAGE

The evolutionary trajectory of the Paraceratheres reflects a unidirectional and rapid transition toward extreme body mass, originating from dog-sized cursorial forms in the early Eocene and culminating in giant canopy browsers by the Late Oligocene (Table 1).

Table 1: Evolutionary Timeline of the <i>Paraceratherium</i> Lineage (adapted from Antoine et al., 2004; Lucas and Sobus, 1989; Wang et al., 2016).			
Epoch	Genus/Eco-Morph	Approx. weight	Anatomical Keys
Early Eocene (~50mya)	<i>Forstercooperia</i> (Primitive Tethytherian runner)	50- 80 kg	*A large dog-sized *Cursorial (running) limb structure *Unspecialized brachydont dentition

Table 1 (Cont): Evolutionary Timeline of the *Paraceratherium* Lineage (adapted from Antoine et al., 2004; Lucas and Sobus, 1989; Wang et al., 2016).

Epoch	Genus/Eco-Morph	Approx. weight	Anatomical Keys
Late Eocene (~40 mya)	<i>Juxia</i> (Elongating browser)	300-500 Kg	*Sheep-sized *Elongation of cervical vertebrae begins *Highly cursorial, slender limbs
Early Oligocene (~32mya)	<i>Urtinotherium</i> (Transitional giants)	~5 Metric tons	*Cow-Elephant sized *Transitional graviportal limb thickening *Specialized downward-pointing incisors
Late Oligocene (~26mya)	<i>Baluchitherium</i> / <i>Paraceratherium</i> (Absolute Megafaunal Pinnacle)	~15- 17 metric tons	* Colossal canopy browser * Pillar-like, strictly graviportal legs (Peak Zenith) * Deeply excavated, pneumatized neck joints

3.1 Quantitative Mass Estimation and Allometric Scaling

Modern volumetric models cementing it as the heaviest terrestrial

mammal to ever walk the Earth, tightly constrained limb scaling laws place the standard adult body mass index between 15.0 and 17.5 metric tons (Figure 5; Table 2).

Table 2: Comparative Anatomical Indices of Extant and Extinct Megafauna (adapted from Owen-Smith, 1988; Fortelius and Kappelman, 1993; Larramendi, 2016)

Species / Taxon	Shoulder Ht (m)	Femur Length (cm)	Est. Mass (t)	Primary Ecological Niche
 <i>Baluchitherium osborni</i>	4.8	150	17.0	High Canopy Arboreal Browser
 <i>Loxodonta africana</i> (Elephant)	3.2	105	6.0	Mixed Structural Grazer/Browser
<i>Ceratotherium simum</i> (White Rhino)	1.8	55	2.3	Obligate Ground Lawn Grazer
<i>Mammuthus primigenius</i> (Mammoth)	3.4	115	5.5	Cold Steppe Tundra Mixed Forager

4. BIOGEOGRAPHY AND THE TIBETAN MIGRATION ROUTE

4.1 Oligocene Distribution Models

Paraceratherium was geographically distributed through China, Mongolia, Central Asia, and the Indo-Pakistani subcontinent. *How did these giants of South Asia freely interact with northern Central Asian populations?* This question long puzzled researchers, as direct eastward or westward migration across Central Asia was strictly impossible for terrestrial animals via Tethys. During the Oligocene, the closing of the Tethys Sea, the flooded Tarim Basin, and the marine margins of the submerged Turgai Strait completely isolated Kazakhstan from South Asia (Figure 1; Table 3) (Deng et al., 2021).

4.2 The Low-Elevation Tibetan Corridor

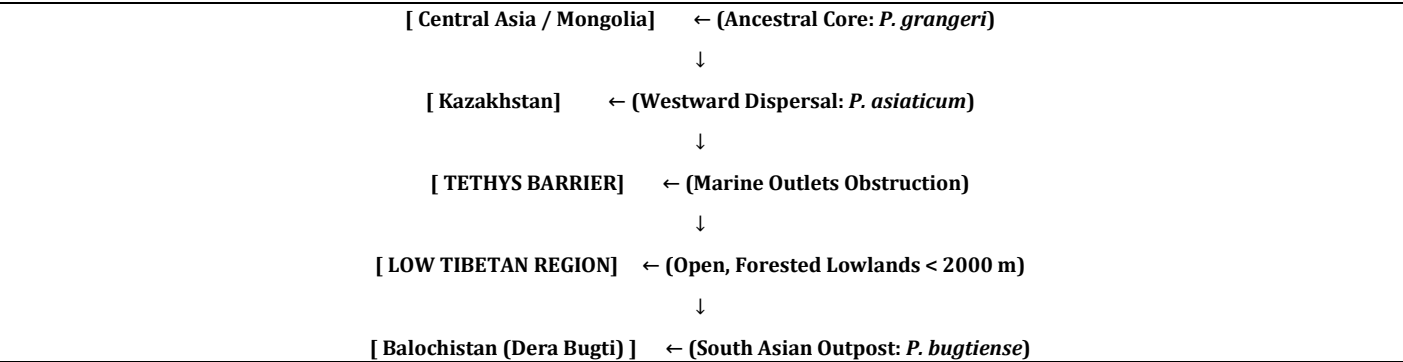
P. bugtiense represents a range expansion of *Paraceratherium* from Central Asia via the Tibetan region based on the paleogeographical literature. *P. lepidum* and *P. linxiaense* were found on the northern side of the Tibetan Plateau by the late Oligocene. The Tibetan region likely hosted some areas with low elevation, possibly under 2000 m during the Oligocene, and the lineage of giant rhinos could have dispersed freely along the eastern coast of the Tethys Sea and perhaps through some

lowlands of this region (Deng et al., 2021). Phylogenetic mapping of newly discovered species such as *Paraceratherium linxiaense* on the northeastern border of the Tibetan Plateau in the Linxia Basin, Gansu, China proves that migration occurred directly through the modern Tibetan region (Deng et al., 2021).

Cladistic analysis links the South Asian *P. bugtiense* as a direct derivative of *P. asiaticum* that migrated southward through Tibet from Central Asia, because *Paraceratherium* required open woodlands and extensive vegetation to sustain its heavy frame. Their unchecked migration reveals that the Tibetan Plateau did not exist as a high-altitude barrier during the Late Oligocene, which was a free corridor across the eastern coast of the Tethys Ocean (Deng et al., 2021).

For accurate geospatial mapping, *Paraceratherium* fossil localities across Pakistan are primarily situated within the Bugti Hills syncline of eastern Balochistan. These sites sample the Chitarwata Formation, specifically the Bugti Member, tracking an environmental timeline from the Early Oligocene down to the Late/latest Oligocene. A compiled gazetteer of key fossil coordinates and collection sites has been structured that follows for GIS mapping integration (Table 3; Figure 1) (Antoine et al., 2004; Welcomme et al., 2001; Deng et al., 2021).

Table 3: Evolutionary, Biogeography and the Tibetan Migration Route (adapted from Deng et al., 2021).



5.FAUNAL EXTINCTIONS

Some views about the extinction of these Oligocene giants are a combination of local stratigraphy, paleoclimate shifts, and some ecological pressures:

5.1 Stratigraphic evidence of the turnover

The extinction event is precisely bracketed within a 25-metre vertical rock window separating two distinct fossil zones (Welcomme et al., 2001):

The Terminal Oligocene Baseline (Lundo Chur J2 / DB3): This horizon represents the absolute uppermost stratigraphical boundary for indricotheres in South Asia. Fission-track dating places this zone at approximately 22.6 ± 2.9 Ma. It is dominated by a Paleogene relic fauna,

including *Paraceratherium bugtiense*, the amynodontid *Cadurcotherium indicum*, the rhinocerotid *Aprotodon*, the entelodontid *Paraentelodon*, and the pseudo-bovid *Palaeohypsodontus* (Antoine et al., 2004).

The Basal Miocene Horizon (DBM / DB3bis): Located exactly 25 meters above the J2 sands, these conglomerates show a complete ecological wipeout of the previous fauna. No indricotheres survive. They are replaced by an aggressive wave of modern Neogene immigrants: elasmotheriine rhinocerotids, deinotheres (proboscideans), true bovids, and listriodontine suids (Welcomme et al., 2001).

5.2 Paleoclimate Shifting & Isotopic Anomalies

Stable isotope data ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) extracted from the teeth enamel of these mammals across the Chitarwarta Formation highlight a severe environmental shift at the boundary (Martin et al., 2011):

Global Boundary Event: Marine records display a massive positive oxygen isotope excursion at the Oligocene-Miocene boundary, reflecting global cooling, a sharp drop in deep-ocean temperatures, and a sudden expansion of Antarctic ice caps.

Local Landscape Aridity: The global pulse triggered a highly unstable climate (The vast, humid, fluvio-deltaic floodplain) that sustained South Asia throughout the Oligocene rapidly deteriorated the Balochistan region, which experienced an intense shift toward environmental aridity, drastically shifting the local flora.

5.3 The Paleo-Ecological Dynamics

The faunal turnover data demonstrate that *Paraceratherium* fell victim during the early Miocene epoch (~23 million years ago) due to its own extreme evolutionary specialization and shifts in its environment (Antoine et al., 2004; Swisher et al., 1999):

Loss of Canopy: As an ultra-large tree browser, a single adult *Paraceratherium* required hundreds of kilograms of leaves, twigs, and buds daily. The transition from open woodlands to drier, scrub-dominated or grass-dominated environments destroyed its primary food canopy (Deng et al., 2021). These specialized feeding mammals lost their selective advantage. Their low-crowned molars (brachyodont) were incapable of grinding abrasive, silica-rich grasses without causing lethal dental wear (Jernvall and Fortelius, 2002).

Immigrant Competition: The closing of the Tethys Ocean and the collision of the Indian and Eurasian plates opened new terrestrial corridors that facilitated the influx of advanced proboscideans (primitive elephants like gomphotheres) from Africa, and smaller, highly agile, and metabolically more active herbivores like early bovids and smaller rhinocerotids (Tassy, 1990; Deng et al., 2021). These newcomers competed directly for food resources, proved more adaptable to changing forage landscapes, and outcompeted the slow-breeding indricotheres (Putshkov, 2001).

Tectonic Activity and Monsoonal Adjustments: The continued uplift of the Himalayan chain disrupted regional air currents, initiating a broad transition from dense, humid sub-tropical canopy forests to open and arid savannah woodlands across Central and South Asia (Clift et al., 2008).

5.4 Taphonomic Evidence of Predation

Fossil evidence from the Bugti beds reveals a dramatic, high-stakes predator-prey relationship that risks their calves and juveniles. *Astorgosuchus bugtiensis*, a massive, broad-snouted crocodilian reaching estimated lengths of 10 to 11 meters, was co-existing in the same riverine and deltaic strata. Some healed and unhealed puncture marks on the lower limb bones and phalanges of juvenile and sub-adult *Baluchitherium* specimens excavated from these fossil beds in Balochistan have been recorded (Martin et al., 2019).

These scar marks match the inter-dental spacing of an adult *Astorgosuchus*. The riverine margins and watering holes were zones of extreme ambush risk. A juvenile *Baluchitherium*, weighing between 1 and 3 metric tons, would be highly vulnerable to the lateral death-roll and crushing clamping forces of *Astorgosuchus* if grabbed by a limb while drinking. This intense evolutionary pressure likely favored rapid juvenile growth rates, enabling calves to outgrow the critical "predation window" as quickly as possible (Martin et al., 2019).

5.5 Paleo-Ecological Dynamics and Extinction Drivers

The eventual disappearance of *Baluchitherium* during the early Miocene epoch (~23 million years ago) highlights the vulnerability of hyper-specialized megafaunal organisms to shifts in their environment (Antoine et al., 2004; Swisher et al., 1999).

6. CONCLUSIONS

Paraceratherium, historically known as "*Baluchitherium*," remains a benchmark for analyzing the upper structural limits of terrestrial mammalian evolution. Emerging from primitive tridactyl ancestors in Central Asia, these giant browsers exploited open woodlands across the Oligocene landscape. Its unique skeletal remains in the Bugti Hills of Balochistan provide crucial evidence for a low-altitude, moist Tibetan corridor before the major tectonic uplifts of the Neogene period, forever shifting our understanding of Cenozoic geography and mammalian gigantism.

Baluchitherium osborni remains a foundational case study in macroevolutionary biology, highlighting the maximum possible physical size for land-dwelling mammals. Its unique structural architecture successfully bypassed the mechanical vulnerabilities of extreme weight, yet its dependence on specialized canopy ecosystems ultimately left it vulnerable to planetary-scale climate shifts. Modern discoveries across Pakistan continue to supply crucial empirical evidence, enriching our understanding of this fascinating chapter in mammalian prehistory.

DECLARATION

Author Contributions

All authors contributed equally to the conception, execution, analysis, and preparation of the manuscript.

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Competing Interests

The authors declare that they have no competing interests.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study did not involve human participants, human tissues, animals, or other subjects requiring ethical approval.

Informed Consent

Informed consent was not required for this study because it did not involve human participants or identifiable personal data.

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Artificial Intelligence (AI) Use

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

REFERENCES

- Ali, S. I. 2010. *Baluchitherium*: The largest land mammal. Dawn. <https://www.dawn.com/news/592377/baluchitherium-the-largest-land-mammal>
- Antoine, P.-O., Karadenizli, L., Saraç, G., Sen, S. 2008. A giant rhinocerotoid (Mammalia, Perissodactyla) from the late Oligocene of north-central Anatolia (Turkey). *Zoological Journal of the Linnean Society*, 152(3), 581–592.
- Antoine, P.O., Shah, S. M. I., Cheema, I. U., Crochet, J.Y., de Franceschi, D., Marivaux, L., Métivier, G., Welcomme, J.L., Métais, G. 2004. New giant rhinocerotoids (Mammalia, Perissodactyla) from the Oligocene of Bugti Hills, Pakistan: Geological and paleontological implications. *Journal of Asian Earth Sciences*, 22(4), 275–293.
- Antoine, P.O., Shah, S. M. I., Cheema, I. U., Crochet, J.Y., de Franceschi, D., Marivaux, L., Métais, G., Welcomme, J.L., Jaeger, J.J. 2004. New remains of the baluchithere *Paraceratherium bugtiense* from the late Oligocene of Pakistan. *Journal of Asian Earth Sciences*, 22(4), 311–327 / 405–412.
- Antoine, P.O., Welcomme, J.L., Marivaux, L., Baloch, I., Benammi, M., Chaïmanee, Y. 2004. First discovery of "*Chalicotherium*" (Mammalia, Perissodactyla) in the late Oligocene of the Bugti Hills (Balochistan, Pakistan). *Journal of Vertebrate Paleontology*, 24(1), 218–222.

- Antoine, P.O., Welcomme, J.L., Marivaux, L., Métais, G., Baloch, I.M., Benammi, M., Chaimanee, Y., Croft, D. A., Franceschi, M., Marandat, B., Jaeger, J.J. 2004. New remains of the baluchither Paraceratherium bugtiense Pilgrim, 1910 from the Late/latest Oligocene of the Bugti Hills, Balochistan, Pakistan. *Journal of Asian Earth Sciences*, 24(1), 71–77. Available via ScienceDirect and ResearchGate
- Antoine, P.O., Welcomme, J.L., Marivaux, L., Baloch, I., Benammi, M., Chaimanee, Y., Jaeger, J.J. 2003. Early rhinocerotids (Mammalia, Perissodactyla) from South Asia and a review of the Holarctic Paleogene rhinocerotid record. *Canadian Journal of Earth Sciences*, 40(3), 365–374.
- Borissiak, A. A. 1916. L'Indricotherium n. gen., Rhinocéros gigantesque du Paléogène d'Asie [Indricotherium n. gen., a gigantic rhinoceros from the Paleogene of Asia]. *Comptes Rendus de l'Académie des Sciences de Paris*, 162, 520–521. Rhino Resource Center
- Borissiak, A. A. 1923. Sur un nouveau représentant des rhinocéros gigantesques de l'Oligocène d'Asie. *Indricotherium asiaticum*, n. g. n. sp. [On a new representative of the gigantic rhinoceroses of the Oligocene of Asia. *Indricotherium asiaticum*, n. g. n. sp.]. *Mémoires de la Société Géologique de France*, 59, 1–16.
- Chow, M., Chiu, C.S. 1963. New genus of giant rhinoceros from the Oligocene of Inner Mongolia. *Vertebrata Palasiatica*, 7(3), 230–239. (Note: In modern contexts, authors are often transliterated as Zhou, M., & Qiu, Z., but Chow & Chiu matches the original 1963 publication text).
- Chow, M., Chiu, C.S. 1964. An Eocene giant rhinoceros. *Vertebrata Palasiatica*, 8(3), 264–267. (Note: This is the publication that formally established the genus *Juxia*).
- Clift, P. D., Hodges, K.V., Heslop, D., Hannigan, R., Van Long, H., Calves, G. 2008. Correlation of Himalayan exhumation rates and Asian monsoon intensity. *Nature Geoscience*, 1(12), 875–880.
- Deng, T., Qiu, Z.X., Wang, B.Y., Wang, X.M., Hou, S.K. 2013. Late Cenozoic rhinocerotid evolution in Southwest China. In X. M. Wang, L. J. Flynn, & M. Fortelius (Eds.), *Fossil mammals of Asia: Neogene biostratigraphy and chronology* (pp. 243–273). Columbia University Press.
- Deng, T., Lu, X., Wang, S., Flynn, L. J., Sun, D., Wen, W., Zhang, Q., Asim, M. S., Ferruquia-Villafranca, I., Wang, Y. 2021. An Oligocene giant rhino provides insights into Paraceratherium evolution. *Communications Biology*, 4(1), Article 639.
- Forster-Cooper, C. 1911a. New genera of lower Miocene mammals from the Bugti Hills of Balochistan. *Annals and Magazine of Natural History*, 8(47), 604–607.
- Forster-Cooper, C. 1911b. New genera of Oligocene mammals from the Bugti hills. *Annals and Magazine of Natural History*, 8(47), 609–610.
- Forster-Cooper, C. 1911c. LXXVIII.—Paraceratherium bugtiense, a new genus of Rhinocerotidae from the Bugti Hills of Baluchistan—Preliminary notice. *Annals and Magazine of Natural History*, 8(48), 711–716.
- Forster-Cooper, C. 1913a. Baluchitherium osborni, n. gen. n. sp., an extinct giant rhinoceros from Oligocene deposits of Balochistan. *Annals and Magazine of Natural History*, 12(68), 376–381.
- Forster-Cooper, C. 1913b. Correction of generic name (Thaumastotherium to Baluchitherium). *Annals and Magazine of Natural History*, 8(72), 504.
- Forster-Cooper, C. 1924. IX.—On the skull and dentition of Paraceratherium bugtiense: A genus of rhinoceroses from the Oligocene deposits of Dera Bugti in Balochistan. *Philosophical Transactions of the Royal Society of London. Series B*, 212(391–401), 369–410.
- Fortelius, M., Kappelman, J. 1993. The largest land mammal ever imagined: A dissection of Paraceratherium (Indricotherium). *Zoological Journal of the Linnean Society*, 108(1), 85–101.
- Gabunia, L. K. 1964. La faune de mammifères de l'Oligocène du Benara. Mezniereba Press.
- Geological Survey of Pakistan. (n.d.). Museum collections: Vertebrate paleontology (Baluchitherium). Ministry of Energy, Government of Pakistan.
- Granger, W., & Gregory, W. K. 1923. An expedient description of Baluchitherium osborni, a new genus of giant rhinoceros from the Oligocene of Mongolia. *American Museum Novitates*, (78), 1–9.
- Granger, W., & Gregory, W. K. 1935. A revised restoration of the skeleton of Baluchitherium, gigantic fossil rhinoceros of Central Asia. *American Museum Novitates*, (787), 1–3.
- Granger, W., & Gregory, W. K. 1936. Further notes on the gigantic extinct rhinoceros, Baluchitherium, from the Oligocene of Mongolia. *Bulletin of the American Museum of Natural History*, 72, 1–73.
- Hurrell, S. W. 2019. Palaeogravity calculations based on weight and mass estimates of Paraceratherium transouralicum. Oneoff Publishing. <http://dinox.org/hurrell2019h>
- Hutchinson, J. R. 2021. The evolutionary biomechanics of locomotor function in giant land animals. *Journal of Experimental Biology*, 224(11), Article jeb217463. doi:10.1242/jeb.217463.
- Jernvall, J., and Fortelius, M. 2002. Common trends in land mammal diversity and the evolution of tooth shape. *Nature*, 417(6888), 538–540.
- Karl, H.-V., Safi, A., and Tichy, G. 2024. Review of fossil records of prehistoric reptiles, their distribution, and paleobiogeographic evolution in Pakistan. *Scientific Reports in Life Sciences*, 5(3), 1–23. <https://doi.org/10.5281/zenodo.13771832>
- Karl, H.-V., Safi, A., and Tichy, G. 2025. A review of the fossil records of dinosaurs of the Late Jurassic–Early Cretaceous present-day Pakistan. *Scientific Reports in Life Sciences*, 6(3), 61–85. <https://doi.org/10.5281/zenodo.16895340>
- Larramendi, A. 2016. Shoulder height, body mass, and shape of proboscideans. *Acta Palaeontologica Polonica*, 61(3), 537–574. doi:10.4202/app.00136.2014.
- Li, S., Jiangzuo, Q., Deng, T. 2022. Body mass of the giant rhinos (Paraceratheriinae, Mammalia) and its evolution. *Historical Biology*, 1–12. doi:10.1080/08912963.2022.2095908
- Li, Z., Zhang, Y., Li, Y., Xie, K., Mörs, T. 2025. Postcranials of the giant rhino Paraceratherium huangheense from the Early Oligocene Lanzhou Basin, NE Tibetan Plateau. *Palaeontographica Abteilung A*, 324, 1–25.
- Lucas, S. G., and Sobus, J. C. 1989. The systematics of indricotheres. In D. R. Prothero & R. M. Schoch (Eds.), *The evolution of perissodactyls* (pp. 358–378). Oxford University Press.
- Malkani, M. S. 2014. Revised stratigraphy of Balochistan Basin, Pakistan. *Journal of Himalayan Earth Sciences*, 2014(Abtract Volume), 59–60.
- Marivaux, L., Welcomme, J.L., Antoine, P.O., Métais, G., Baloch, I., Benammi, M., Jaeger, J.-J. 2001. A fossil lemur from the Oligocene of Pakistan. *Science*, 294(5542), 587–591.
- Martin, C., Bentaleb, I., Antoine, P.O. 2011. Pakistan mammal tooth stable isotopes show paleoclimatic and paleoenvironmental changes since the early Oligocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 311(1–2), 19–29. doi:10.1016/j.palaeo.2011.07.010.
- Martin, J. E., Antoine, P.O., Perrier, V., Welcomme, J.L., Métais, G., Marivaux, L. 2019. A large crocodyloid from the Oligocene of the Bugti Hills, Pakistan. *Journal of Vertebrate Paleontology*, 39(4), e1671427. <https://doi.org/10.1080/02724634.2019.1671427>
- Métais, G., Antoine, P.O., Baqri, S.R.H., Crochet, J.Y., De Franceschi, D., Marivaux, L., Welcomme, J.L. 2009. Lithofacies, depositional environments, regional biostratigraphy and age of the Chitarwata Formation in the Bugti Hills, Balochistan, Pakistan. *Journal of Asian Earth Sciences*, 34(2), 154–167.
- Métais, G., Welcomme, J.L., Ducrocq, S. 2009. New data on the Eocene mammals from the Shagala Formation (Katawaz Basin, Pakistan). *Journal of Asian Earth Sciences*, 34(4), 493–502.
- Muhammad, N., Safi, A. 2026. A new titanosaurian sauropod, Safisaur niazensis (Malkani, 2026), from the sediments of Kohat, the first

- diplodocoid (Flagellicaudata; Dicraeosauridae) from Pakistan. *Pakistan Journal of Geology*, 10(1), 29–39. <http://doi.org/10.26480/pjg.01.2026.29.39>
- Osborn, H. F. 1923. *Baluchitherium grangeri*, a giant hornless rhinoceros from Mongolia (American Museum Novitates No. 78). American Museum of Natural History.
- Owen-Smith, N. 1988. *Megaherbivores: The influence of very large body size on ecology*. Cambridge University Press.
- Pavlova, M. 1922. *Indricotherium*, a new genus of giant rhinoceros. *Bulletin de la Société des Naturalistes de Moscou, Section Géologique*, 1, 95–110.
- Pilgrim, G. E. 1908. The tertiary and post-tertiary freshwater deposits of Balochistan and Sind. *Records of the Geological Survey of India*, 37(2), 139–166.
- Pilgrim, G.E., 1910. Notices of new mammalian genera and species from the tertiaries of India. *Records of the Geological Survey of India* 40, 63–71.
- Prothero, D. R. 2013. *Rhinoceros giants: The paleobiology of indricotheres*. Indiana University Press.
- Putshkov, P. V. 2001. Regressive evolution of the rhinocerotids and the proboscidean invasion. *Vestnik Zoologii*, 35(4), 33–42.
- Qiu, Z.X., Wang, B.Y. 2007. *Paraceratherium* fossils of China. *Paleontologia Sinica, New Series C*, 29, 1–396.
- Safi, A., Karl, H. 2024. A review of the updated checklists of the amphibians and reptiles of Pakistan: Present and prehistoric. *Journal of Biodiversity and Biotechnology*, 4(1), 22–37. doi:
- Scientia Magazine. 2020. *Baluchitherium: The largest land mammal*. scientiamag.org
- Sen, S., Antoine, P.O., Varol, B., Ayyildiz, T., Sözeri, K. 2011. Giant rhinoceros *Paraceratherium* and other vertebrates from Oligocene and middle Miocene deposits of the Kağızman-Tuzluca Basin, Eastern Turkey. *Naturwissenschaften*, 98(5), 407–423.
- Siddiqui, S. 2012. Dera Bugti operation: Largest mammal fossils may have been bombed into oblivion. *The Express Tribune*. tribune.com.pk
- Spassov, N. B. 1989. On the taxonomic status of *Indricotherium Borissiak* and giant rhinocerotoids: *Indricotheres* (*Perissodactyla*). *Comptes Rendus de l'Académie Bulgare des Sciences*, 42(4), 61–64.
- Spicer, R. A., Su, T., Valdes, P. J., Farnsworth, A., Wu, F.X., Shi, G., Zhou, Z.K., Deng, T., Ding, L., Zhou, Z. 2021. Why 'the uplift of the Tibetan Plateau' is a myth. *National Science Review*, 8(1), Article nwaa091. <https://doi.org/10.1093/nsr/nwaa091>
- Tassy, P. 1990. The "Proboscidean Datum Event": Relative dating and biochronology in Eurasia. In Lindsay, E. H., Fahlbusch, V., & Mein, P. (Eds.), *European Neogene mammal chronology* (pp. 277–286). Springer.
- The Guardian. 1999. Found: Fossil of world's largest land mammal. theguardian.com
- Wang, H., Bai, B., Meng, J., Wang, Y. 2016. Earliest known unequivocal rhinocerotoid sheds light on the origin of *Ernanodontidae* and the early evolution of *Perissodactyla*. *Scientific Reports*, 6(1), Article 39607. doi:10.1038/srep39607.
- Wang, H.B., Bai, B., Meng, J., Wang, Y.Q. 2018. A new species of *Forstercooperia* (*Perissodactyla: Paraceratheriidae*) from Northern China with a systematic revision of *forstercooperiines*. *American Museum Novitates*, 2018(3897), 1–41. doi:10.1206/3897.1.
- Welcomme, J. L., Benammi, M., Antoine, P. O., Marivaux, L., Métais, G., Seguenza, M., Baloch, I. K. 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(1), 119–128.
- Welcomme, J.L., Marivaux, L., Antoine, P.O., Benammi, M., Crochet, J.Y., de Franceschi, D., Métais, G., Shah, S. M. I., Roohi, G., Kazmi, K. H., Jaeger, J.J. 2001. The lagoons of the Bugti Hills and the Oligocene-Miocene transition of South Asia. *Rivista Italiana di Paleontologia e Stratigrafia*, 107(3), 395–415.
- Welcomme, J.L., Marivaux, L., Antoine, P.O., Baloch, I. 2001. The *Baluchitherium* (*Perissodactyla, Mammalia*) faunas of the Oligocene Bugti Hills (Balochistan, Pakistan): Stratigraphy and age. *Lethaia*, 34(3), 189–198.
- Wood, H. E. 1939. Addendum to American Museum Novitates No. 1012. *American Museum Novitates*, 1012, 22. (Note: This specific 1-page addendum formally renamed *Cooperia* to *Forstercooperia* because the original name was already occupied by a genus of nematodes. Retrieved from Rhino Resource Centre
- Wood, H. E. 1963. A primitive rhinoceros from the Late Eocene of Mongolia. *American Museum Novitates*, (2146), 1–12. handle.net

