HISTORICAL BIOLOGY
2026, VOL. 38, NO. 10, 4398–4407
https://doi.org/10.1080/08912963.2026.2645124

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RESEARCH ARTICLE

Rhinoceros from the Pinjor Formation (Pleistocene) of Makwal, Pakistan

Abrar Hussain and Muhammad A. Khan

Dr. Abu Bakr Fossil Display & Research Centre, Institute of Zoology, University of the Punjab, Lahore, Pakistan

ABSTRACT

Makwal is a Pleistocene site located in Kharian, Gujrat, Punjab, Pakistan. The site has produced abundant Pleistocene (Pinjor Formation) faunal assemblages. In Pakistan, only a few Pleistocene sites have yielded rhinoceros remains. The new material includes conjoined partial mandibles with right p2–m3 and left p2–p4 collected from Makwal. It shows a high morphological similarity with the previously described material of rhinoceros, *Rhinoceros palaeindicus* and *Rhinoceros sivalensis* from the Indian subcontinent. In the large the teeth, it resembles more with *R. palaeindicus*. The Pinjor Formation *Rhinoceros* fossils are revisited and their taxonomic status is reviewed. The synonymy of several species of the genus *Rhinoceros* previously proposed for the Siwalik Pleistocene is discussed, and the synonymy between *R. sivalensis* and *R. palaeindicus* is considered validhence, the described material is attributed to *R. sivalensis*.

ARTICLE HISTORY
Received 22 February 2025
Accepted 6 March 2026

KEYWORDS
Rhinocerotid; Siwalik; Makwal; Pleistocene; Gujrat

HANDLING EDITOR
Dr Rachel A. Racicot, Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt am Main, Germany

Introduction

The Pinjor Formation fauna, representing the Lower-Middle Pleistocene, is diverse, and many mammalian taxa from the Indian subcontinent are known from this Formation, which range from small to large size (e.g. *Gazella* Blainville (1816), *Bubalus* Smith (1827), *Stegodon* Falconer (1857), *Elephas* Linnaeus (1758), *Rhinoceros* Linnaeus (1758)) and supposedly represent either ancestors or close relatives of the modern-day living fauna of the region. However, the mammalian taxa recorded from the Pinjor Formation of Pakistan, specifically from the Pabbi Hills, are not worked in detail. Having pioneered the palaeontological work of Pilgrim (1913) in the Pabbi Hills of Kharian, Keller et al. (1977) did the palaeomagnetic and to some extent palaeontological work; Opdyke et al. (1979) did the same, while Dennell et al. (2005, 2006, 2008) reported the palaeomagnetic work and palaeontological excavations of that area, while Siddiq et al. (2014, 2016, 2016, 2017, 2020, 2021) by exploring the Sardhok Pabbi Hills reported some of the mammalian taxa, and among them, rhinocerotids make small part of it. The rhinocerotids from the Pinjor Formation were assigned to five species of the genus *Rhinoceros*: *R. platyrhinus* Falconer and Cautley (1847), *R. sivalensis* Falconer and Cautley (1847), *R. palaeindicus* Falconer and Cautley (1847), *R. deccanensis* Foote (1874) and *R. sondaicus* Lydekker (1880) (Badam, 1979; Falconer & Cautley, 1847; Khan, 2010; Lydekker, 1881, 1884; Pandolfi & Maiorino, 2016; Siddiq, Akhtar, et al., 2016). The taxonomic status of some of these species is not yet fully resolved like *R. sivalensis*, *R. palaeindicus*, *R. deccanensis*, while the presence of *R. sondaicus* in the Siwaliks is unconfirmed. Hence, the only accurate species of the genus *Rhinoceros* in the Siwaliks is *R. platyrhinus* (Pandolfi and Maiarino 2016) and the preceding statement becomes more accurate taxonomically after Antoine (2012) and Antoine et al. (2022), who synonymised *R. sivalensis*, *R. palaeindicus* and *R. deccanensis* with *R. unicornis* Lydekker (1880), in these words 'In our opinion, *R. unicornis* encompasses all large *Rhinoceros* remains from South Asia that were formerly included within the wastebasket species *R. sinensis* Owen (1870) (and its junior synonyms *R. oweni*, *R. plicidens*, *R. implicidens* or *R. chiai*; Tong (2001), the Javan *R. kendengindicus* Dubois (1908) (Bacon et al., 2008; Hooijer, 1949), as well as the Indo-Pakistani *R. sivalensis*, *R. palaeindicus*, *R. deccanensis*, *R. sinhaleyus* Deraniyagala (1936), or *R. kagavena* (Tong, 2001)'. Therefore, every new specimen is valuable to test this hypothesis.

In this work, we are describing an incomplete mandible of the genus *Rhinoceros* from the Pleistocene deposits of Makwal, Pakistan. This locality is numbered 642 in Dennell et al. (2005), and it is a very important Pinjor Formation locality as it provides palaeomagnetic and palaeontological details. This locality is situated in the administrative boundaries of Makwal but close to the village Bharot as mentioned by Dennell et al. (2005),

CONTACT Muhammad A. Khan akbaar111@gmail.com Dr. Abu Bakr Fossil Display & Research Centre, Institute of Zoology, University of the Punjab Lahore, Quaid-e-Azam Campus, Lahore, Punjab 54590, Pakistan

who excavated it in 1989 and reported the presence of *Damalops palaeindicus* (Falconer, 1859), *Hemibos triqueticornis* Rutimeyer (1867), *Equus sivalensis* Falconer & Cautley (1849), *Rhinoceros sivalensis*, *Gazella*, suid, *Pachycrocuta brevirostris* (Gervais 1850), and *Felid* sp. (medium) from this site. After their work, this locality was not visited by any researchers for a long time and recently a reconnaissance was done in 2023 by the authors.

Geographic and geological settings

Locality 642 (32°52'318″ N; 73°54'452″ E) is situated near village Bharot but lies in the administrative boundaries of village Makwal in Kharian, Gujrat, Punjab, Pakistan (Figure 1). The locality is dominated by yellow-brown silts present top of a low hill in front of sandstone (to which Dennell et al. called as Sandstone 12), and these are predominant over the clay and sandstone. The specimen described in this study was eroded by excavation done by workers from the silt from the nearby excavation area of Dennell et al. (2005, fig. 3). Further details are provided by Dennell et al. (2005): It was originally located on a small stream channel that was peripheral to any main or permanent river course. The fossils accumulated on a land surface is characterised by flash-flood conditions where pulses of sand were deposited, possibly as a suspended load, and subsequently became dry and desiccated. The yellow-brown silts containing the fossils overlay silty clays and fine purple clays that contain lamination lines (or a weakly developed cross-bedding), suggesting some alteration to the stream flow. Desiccation cracks are evident by their subsequent infilling of finer purple clay, and suggest periods of drying out. These cracks bisected and displaced some bones and thus developed after fossils had been accumulated. The immediate environment of the site was probably a loop in a braided channel system where the banks of the stream were breached and the sands deposited as a suspended load at the bend of the loop. The locality is dated to 1.2–1.4 Ma palaeomagnetically (Dennell et al., 2005).

Material and methods

The material includes a partially preserved mandible with right p2–m3 and partial crown of left p2 and complete p3–p4. The specimen was collected by surface collection. It was recovered in different pieces coated with sedimentary material. The dentary was transported to the Institute of Zoology, University of the Punjab, Lahore, Pakistan, where it was prepared. The broken parts were assembled with GMSA glue. Measurements were taken with the help of a digital Vernier calliper in millimetres (mm) and are provided in Table 1. The photography was done with Canon 6D, and photos are arranged in Adobe Photoshop CC 7.0. The dental terminology for the description of teeth follows Antoine et al. (2010).

Abbreviations: NHMUK, Natural History Museum, London; i, lower incisor; *L*, length; m, lower molar; M, upper molar; mm, millimetre; p, lower premolar; P,

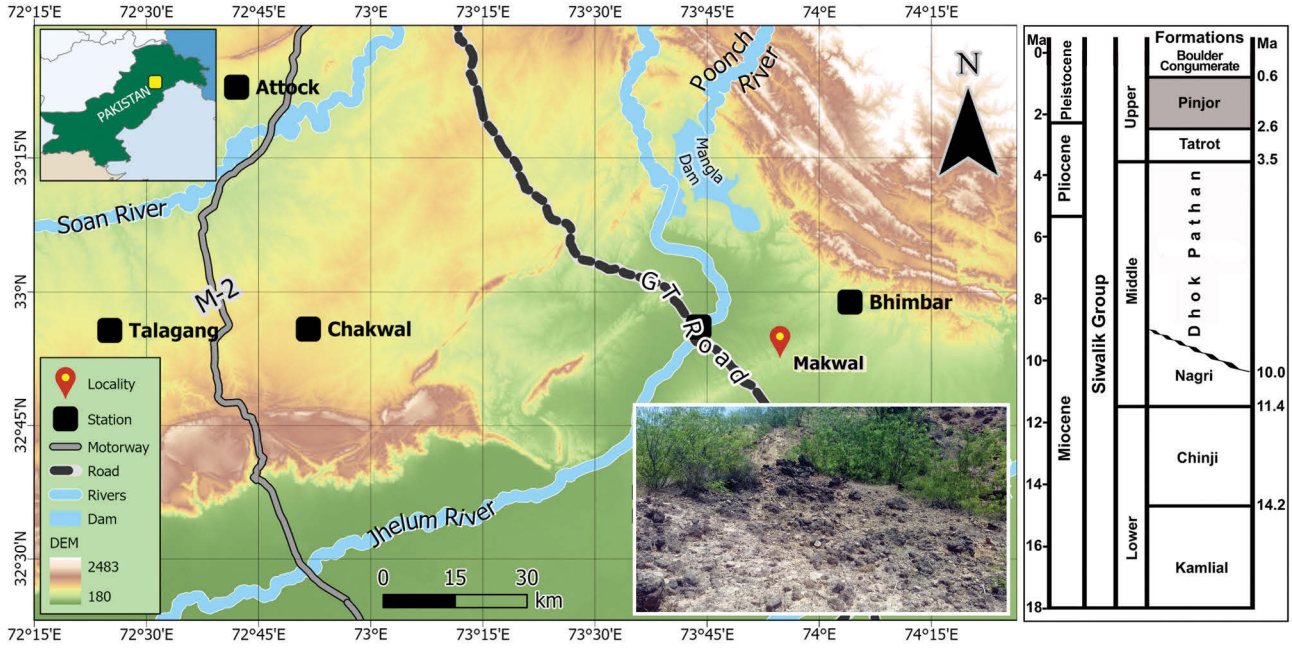

Figure 1. Location of the locality 642 in the Pabbi Hills of Kharian, Gujrat, Punjab, Pakistan.

Table 1. Comparative measurement of cheek teeth of *R. sivalensis* (PUPC 23/166) in mm.

Taxa and catalogue	p2 (*L W*)	p3 (*L W*)	p4 (*L W*)	m1 (*L W*)	m2 (*L W*)	m3 (*L W*)
PUPC 23/166 Right	29.14* –	42.27 32.74	48.93 35.27	46.14 ×34.41	57.53 40.91	67.01 × 39.67
Left	31.63 est. –	40.98 * 38.09	48.79 38.09	–	–	–
R. palaeindicus (Falconer & Cautley, 1847)	17 11	34 21	42 27	36 26	50 29	–
PU A/553 (Badam, 1979)	23? 17	39 33	43 39	42 39	51 38?	64 39?
PU A/557 (Badam, 1979)	29? 20	42? 29	–	53 –	–	–
PU S/6 (Badam, 1979)	33 21	40 25	43 26	53 30	–	–
R. sivalensis (Lydekker, 1881)	32 –	–	–	–	–	52 –
R. platyrhinus Falconer and Cautley (1847)	29 19	29 25	42 28	39 32	47 33	–
Dicerorhinus sumatrensis (IVPP V 5779.104; Tong & Guérin, 2009)	20.8 13.7	26.1 17.2	32.3 20.7	34.6 22.7	41.4 25.4	43.5 24.0
Rhinoceros aff. *R. sondaicus* (PUPC 10/81; Siddiq, Akhtar, et al., 2016)	–	35.9 25.0	38.8 24.9	41 29.0	–	–
Rhinoceros sp. (PUPC 10/66; Siddiq, Akhtar, et al., 2016).	–	–	43.5 33.0	41.0 36.5	54.0 35.7	–
R. sondaicus (recent; Guérin, 1980)	25–29.5 15.5–21	33–39 22–27.5	36.5–42.5 24–29	41–46.5 26–32	40.5–51 27–32.5	41–53 24.5–29.5
R. unicornis (recent; Guérin, 1980)	31–32 21.5–24.5	38–42 27–32	41–46 29–34	46–48 28–32.5	52–56.5 31–36	49.5–60 29–35
R. sondaicus (extant) (recent; Guérin, 1980)	29.5 21	39 27.5	42.5 29	46.5 32	51 32.5	53 29.5
R. unicornis (extant) (recent; Guérin, 1980)	32 24.5	42 32	46 34	48 32.5	56.5 36	60 35
Dicerorhinus sumatrensis (extant) (recent; Guérin, 1980)	20.8 13.7	26.1 17.2	32.3 20.7	34.6 22.7	41.4 25.4	43.5 24

*shows the preserved length.

upper premolar; PUPC, Punjab University Palaeontological Collection; *W*, width.

Systematic Palaeontology

Order **Perissodactyla** Owen, 1848
Family **Rhinocerotidae** Gray, 1821
Subfamily **Rhinocerotinae** Gray, 1821
Tribe **Rhinocerotini** Gray, 1821
Subtribe **Rhinocerotina** Gray, 1821
Genus ***Rhinoceros*** Linnaeus, 1758
Rhinoceros sivalensis Falconer and Cautley, 1847

Synonymy
Rhinoceros indicus fossilis Baker and Durand, 1836
Rhinoceros palaeindicus Falconer and Cautley, 1847

(Figures 2–3)

Lectotype

NHMUK PV OR 39626, part of a skull.

Locality

Siwalik Hills, India.

Emended diagnosis

(After Badam, 1979; Colbert, 1942): Unicorn and large species of the genus, with a big horn, deep saddle in the cranial profile; forwardly inclined occiput; cheek teeth characterised by a flat ectoloph, molars with a parastyle, distinct crochet which may unite with the protoloph to enclose a fossette, crista absent, if present incipient. Mandibular corpus is deep, thick and strong; the i1 is absent, i2 is large and does not reach under the p2 lingually; the p1 is absent; molar series is longer than premolar series.

Referred material

PUPC 23/166, partial mandible with right p2–m3 and partial crown of left p2, and complete p3–p4.

Description

PUPC 23/166 contains the alveoli of i2, right p2–m3 and left partial crown of p2 and complete p3–p4 (Figure 2). The corpus is robust but highly weathered and broken. The preserved symphysis length is 138.47 mm, gutter width under p2 is 53.55 mm and overall preserved symphysis width is 86.66 mm. A large mental foramen is present under the right p2, while that of the left side is missing. The length of the mental foramen is 7.17 mm, while its height is 6.20 mm. The alveoli for the i2s are not well preserved. The alveolus for the left i2 is moderately large and deep but does not reach under p2. The right p2 is partially broken resulting in loss of the enamel from the labial side while the enamel is fully preserved on the lingual side. A small groove is present at the base of the tooth lingually indicating that it was bilobed. The p3 is better preserved. It is highly worn resulting in the partial loss of the anterior or mesial valley. The paraconid is small and broken; the metaconid is the largest cusp, reaching in length to the hypoconid. The posterior or distal valley is U-shaped. The p4 is larger than the p3, and the distinction between the cusps is more evident. The paraconid is much larger than that of the p3. The anterior valley is much larger than the posterior; both are U-shaped. The labial groove

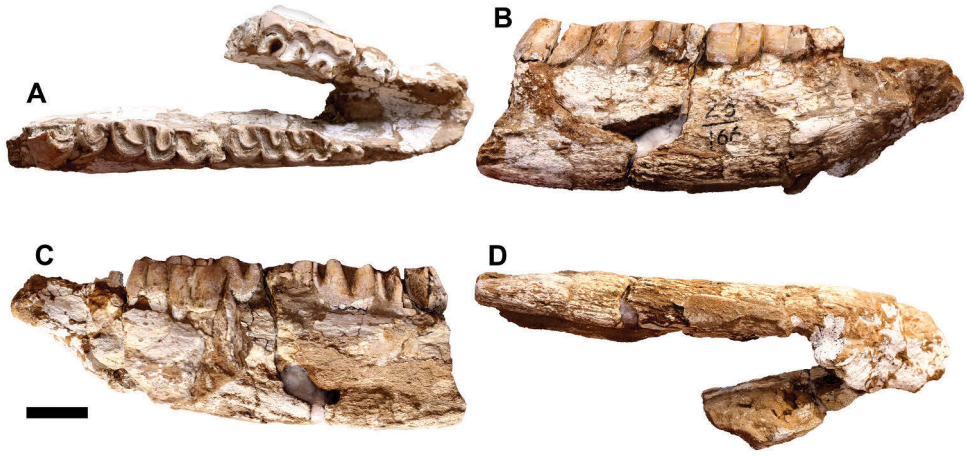

Figure 2. PUPC 23/166, a partial dentary with right p2–m3 and left partial crown of p2, and complete p3–p4. Views: A. Occlusal. B. Labial. C. Lingual. D. Ventral. Scale = 50 mm.

is also well developed that results in the non-flat ectolophid. The m1 is broken in which the paraconid is completely missing, the enamel of the protoconid is broken, the apex of the metaconid is missing and also the anterior valley is not preserved. The labial groove is deeper than that of the p4. The posterior valley is small and U-shaped; the tooth is well worn. The paraconid is well preserved in the m2, and it is also large reaching in height and length to the metaconid and entoconid. The anterior valley is large, deep and U-shaped. The metaconid is the highest cusp and extended more lingually. The labial groove is large and wide, the posterior valley is less deep than the anterior valley, and it is U-shaped. The paraconid is complete while the proto- and metaconid are partially preserved in m3. The anterior valley is deep and U-shaped; the paraconid is large but thin lingually. In the left p3, the paraconid is completely missing while the proto- and metaconid are partially broken, resultantly the anterior valley is missing.

Comparison

The large size and the presence semi-nephroid moderately hypsodont teeth in which premolars are molariform in the described material (PUPC 23/166) associate it with the family Rhinocerotidae. This family is represented by the genus *Rhinoceros* in the Pleistocene/Pinjor Formation in the Siwaliks. Four species of this genus are reported from the Pinjor Formation, *R. sivalensis*, *R. palaeindicus*, *R. platyrhinus* and *R. sondaicus* (Badam, 1979; Siddiq, Akhtar, et al., 2016). Only few characters of lower dentition or mandible are useful to distinguish these species, based on the resemblance to extant species (Badam, 1979). For example, Badam (1979), based on the previous material as he did not describe mandibles or lower teeth of *R. sivalensis*, observed that the mandibles of *R. palaeindicus* and *R. sivalensis* are devoid of p1 and this is in contrast to *Rhinoceros unicornis* where p1 frequently persists; *R. sondaicus* and *R. unicornis* characterise by the presence of large tusk, loss of central incisors and an alveolus extension of the lower incisors that reaches posteriorly the lingual side of p2, and the last character differentiates both species from *Dicerorhinus sumatrensis* Fischer (1814) (Groves & Leslie, 2011; Suraprasit et al., 2016; Tong & Guérin, 2009). In PUPC 23/166, the alveolus of incisor is not as deep (ending before p2) as in *R. sondaicus* and *R. unicornis* (Figure 2) in which it extends under the p2 and is closer to the condition in *Dicerorhinus sumatrensis*.

PUPC 23/166 is morphologically more similar to the mandibles described as *R. palaeindicus* by Falconer and Cautley (1847), plate 74, fig.3, plate 75, fig. 2) in having the teeth with U-shaped and large valleys (Figure 2); this is contrary to the mandibles of *R. platyrhinus* described and figured by Falconer and Cautley (1847), Lydekker (1884), and data reported by Badam (1979). Also, the cheek teeth are metrically close to the cheek teeth that are previously described as *R. palaeindicus* (Table 1). PUPC 23/166 is readily distinguishable from the mandible of *R. platyrhinus* in having no incisors between the tusks as such incisors are present in the mandibles described by Falconer and Cautley (1847, plate 75, fig. 10), and this character associates *R. platyrhinus* with *R. sondaicus*. Also, the space between the tusks is larger in *R. palaeindicus* than in *R. sivalensis*, *R. sondaicus* and *R. platyrhinus* (see Badam, 1979; Falconer & Cautley, 1847). PUPC 23/166 is also comparable to *R. palaeindicus* in this respect and in most of the characters, including metric values. However, synonymy of *R.*

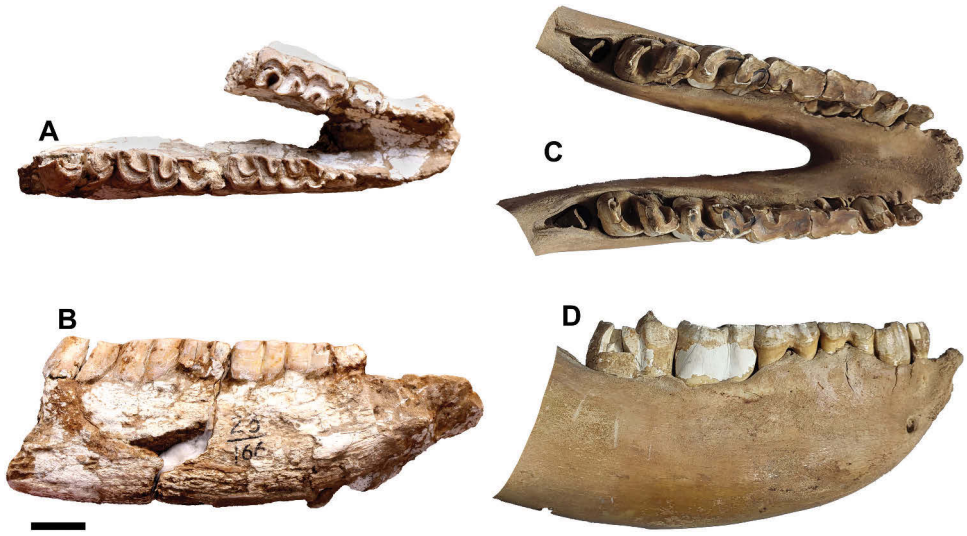

Figure 3. Comparison of PUPC 23/166 with juvenile dentary of *R. sondaicus*. Scale = 50 mm.

palaeindicus is already suggested *R. sivalensis* is suggested by Colbert (1935) and of both species with *R. unicornis* is suggested by Antoine (2012).

For the determination of its possible association with *R. unicornis*, the comparison with the juvenile dentary of *R. unicornis* present in the Institute of Zoology reveals that PUPC 23/166 has close similarity with *R. unicornis*, but also some differences in the mandibular and dental morphology. PUPC 23/166 is quite similar in structure and shape of symphysis, depth and size of ramus, number of mental foramina, morphology of molars, and overall size. However, both differ in the position of the mental foramen which is under the diastema anterior to p2 in PUPC 23/166, whereas it is under the p1 in the *R. unicornis* mandible; the diastema between the tusks and p2 is longer in PUPC 23/166. Also, p1 is missing in PUPC 23/166, and these differences confirm that it cannot be associated to *R. unicornis*.

Discussion

The first ever description of the Siwalik fossil rhinocerotid was made by Baker and Durand (1836) from Dádupur, Uttar Pradesh, India, and they described these remains as *Rhinoceros indicus fossilis*. After that, Falconer and Cautley (1847) described a considerable collection of the fossil rhinocerotids from various areas of the Indian subcontinent. Later, Lydekker (1881) described the rhinocerotid remains from the Siwaliks, describing three species of the genus *Rhinoceros* from the Pinjor Formation, *R. sivalensis*, *R. palaeindicus* and *R. platyrhinus*. A fourth species of the genus, *R. sondaicus*, was recognised almost 100 years later by Heissig (1972) from the Dhok Pathan Formation, and its first occurrence from the Pinjor Formation of Pakistan was reported by Siddiq, Akhtar, et al. (2016). Overall, four species of the genus *Rhinoceros* are reported and described from the Pinjor Formation (2.58–0.6 Ma) of the Siwalik Group. However, synonymy of some of these four mentioned species with other is already proposed by various researchers (Antoine, 2012; Antoine et al., 2022; Badam, 1979; Colbert, 1935, 1942; Hooijer, 1946; Khan, 2010; Matthew, 1929). Among these four species, *R. platyrhinus* was used by Khan (1971) as type species of the new genus *Punjabitherium* Khan E. (1971), based on a slightly crushed skull. Much later, Pandolfi and Maiorino (2016) reassessed all the material allocated to *P. platyrhinus*, validating the species as *Rhinoceros platyrhinus*. Here, we will mainly focus on the synonymy of *R. sivalensis*, and *R. palaeindicus*, and partially on the proposed synonymy of *R. sivalensis* with *R. unicornis*.

The synonymy of *R. palaeindicus* with *R. sivalensis* was proposed by Matthew (1929) and accepted by Colbert (1935, 1942). Colbert (1935) provided the following justification for the synonymy of these two: 'Matthew (1929, pp. 531–532) has shown that this species is probably synonymous with *R. sivalensis*. He points out that the supposed differences in the dentition given above really do not exist, and that the skull differences may very well be within the bounds of individual variation'. Later, Badam (1979) studied the lectotype of *Rhinoceros palaeindicus* (NHMUK PV OR 16444) and the lectotype of *Rhinoceros sivalensis* (NHMUK PV OR 39626), pointing four differences: '1. The cranial profile of *Rhinoceros palaeindicus* is less concave than that of *Rhinoceros sivalensis*; 2. The nasal cavity is deep and

wide in *Rhinoceros palaeindicus* and deep but narrow in *Rhinoceros sivalensis*; 3. M3 is situated about 10 cm from the end of the maxilla in *Rhinoceros palaeindicus* while in *Rhinoceros sivalensis* it starts only 3 cm away from the end of the maxilla; 4. The skull of *Rhinoceros palaeindicus* is higher than that of *Rhinoceros sivalensis*.' Nevertheless, despite noticing these differences, his concluding remarks were: 'Due to the absence of a complete skull of *Rhinoceros palaeindicus*, the author has not been able to further justify his stand for the two different species. As such, he has been left with no choice but to treat the above two species as provisional synonyms of each other'. Hence, he also accepted the synonymy between both species but with some doubt. While discussing the biochronology and biogeography of Pleistocene and Holocene rhinocerotids, Antoine (2012) accepted only two species from the Indian subregion, *R. unicornis* and *R. platyrhinus*. He emphasised that 'the Upper Siwalik of India and Pakistan mostly yield *R. unicornis*, whose remains are described under the names *R. sivalensis* and *R. palaeindicus*'. This implies that Antoine (2012) suggested the synonymy of both *R. sivalensis* and *R. palaeindicus* with Indian extant rhino, *R. unicornis*. Although the cheek teeth are morphologically similar to *R. unicornis*, the measurements of the dental material are markedly different from the extant species, particularly that of m3, and there are some morphological differences as well (discussed below). The measurements of PUPC 23/166 are in the size range of previously reported specimens of *R. palaeindicus* (Table 1) but *R. sivalensis* has priority over *R. palaeindicus* as the remains of *R. sivalensis* were first described as *R. indicus fossils* and by the Article 24.2.2 (Determination by the First Reviser) of International Code of Zoological Nomenclature (Ride, 1999) which states 'If two or more names, different or identical, and based on the same or different types, or two or more nomenclatural acts, are published on the same date in the same or different works, the precedence of the names or acts is fixed by the First Reviser unless Article 24.1 applies' where Colbert (1935) is first reviser who fixed the name *R. sivalensis*.

Is *R. sivalensis* (as well as *R. palaeindicus*) synonym of *R. unicornis* as suggested by Antoine (2012)? The answer to this question lies in Table 2. A comparison of the previously described mandibular material from the Siwaliks of the Indian subcontinent and the mandibular material of the extant individual is given in this table with other species. PUPC 23/166 is metrically slightly larger than *R. unicornis* (Table 2 and Figure 4), but the table clearly shows morphological differences between these two taxa that include presence of p1 and i1, i2 root under the p2, position of the mental foramens and small-sized dentition in *R. unicornis*. When the mandibles of the extant species were compared with the previously described material from the Siwaliks, it is revealed that the mandibles of *R. sivalensis* completely lacks i1 and p1. However, one dentary (GSI-C 65) described and figured by Badam (1979, plate 18, fig. 1) as *R. sivalensis* shows the presence of alveoli of i1. This is not correct attribution when compared to material figured by Falconer and Cautley (1847) because GSI-C 65 (Figure 5F) is ditto copy of a specimen described and figured by Falconer and Cautley (1847, plate 75, fig. 10, fig. 5E) as *R. platyrhinus* in every aspect of its morphology. Hence, GSI-C 65 is allocated to *R. platyrhinus*.

Table 2. The morphological characters of mandibles of *R. sondaicus*, *R. unicornis* and *Dicerorhinus sumatrensis* used by Antoine et al. (2022) for phylogenetic analysis in comparison to PUPC 23/166.

Characters	0	1	2	3	*R. sondaicus*	*R. unicornis*	*D. sumatrensis*	PUPC 23/166
50. Foramen mentale:	In front of p2	At level of p2–4			At level of p2-4	At level of p2–4	In front of p2	In front of p2
53. Corpus mandibulae: base	Straight	Convex	Very convex		Straight	Straight	Straight	Slightly convex
61. Cheek teeth: aspect of the enamel	Wrinkled	Wrinkled and corrugated	Corrugated and arborescent		Wrinkled and corrugated	Wrinkled and corrugated	Wrinkled and corrugated	Wrinkled but less
64. Cheek teeth: roots	Distinct	Joined	Fused		Joined	Joined	Joined	Distinct
70. i1 (lower)	Present	Absent			Present	Present	Present	Absent
135. Lower premolars: lingual opening of the posterior valley (lingual view):	U-shaped	V-shaped			1 V-shaped	1 V-shaped	1 V-shaped	U-shaped
136. Lower premolars: lingual cingulum	Always present	Usually present	Usually absent	Always absent	1 usually present	1 usually present	1 usually present	Absent
138. Lower premolars: labial cingulum	Present	Usually absent	Absent		1 usually absent	1 usually absent	1 usually absent	Present
140. d1/p1 (in adults)	Always present	Usually present	Usually absent	Always absent	0 always present	0 always present	0 always present	Absent
151. Lower molars: hypolophid	Transverse	Oblique	Almost mesiodistally oriented		0 Transverse	0 Transverse	1 Oblique	Oblique
152. m2-3: lingual groove of the entoconid	Absent	Present			1 Present	1 Present		Absent

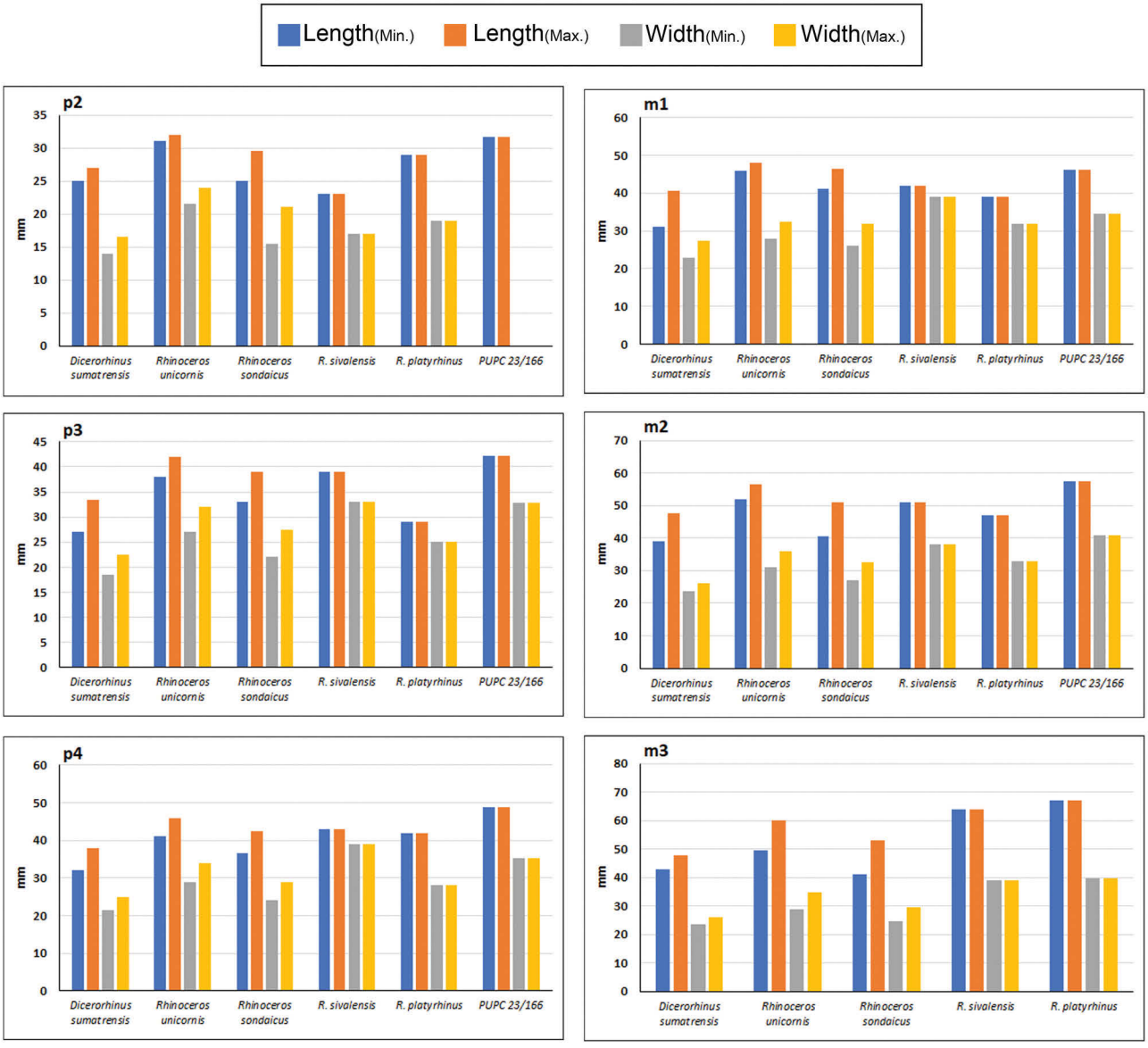

Figure 4. Depiction of comparative metric data of PUPC 23/166 and other *Rhinoceros* species through bivariate analysis.

Figure 5 also shows the mandible of *R. sivalensis* Falconer and Cautley (1847) (Figure 5B–C) which morphologically similar PUPC 13/166 particularly in symphysis, symphysial gutter, orientation and size of corpus. Based on the above characters, specifically, the lack of i1 and p1, it is concluded that *R. sivalensis* (as well as *R. palaeindicus*) cannot be synonymised with the extant species *R. unicornis*. This is further evidenced in Table 2, listing the morphological characters of mandibles of *R. sondaicus*, *R. unicornis* and *Dicerorhinus sumatrensis* used by Antoine et al. (2022) for their phylogenetic analysis in comparison to PUPC 23/166. This table clearly shows that PUPC 23/166 differs from *R. unicornis* in these characters: position of the mental foramen, convex base of corpus mandibulae, less wrinkled aspect of the enamel of the cheek teeth, distinct roots, and absence of i1, U-shaped lingual opening of the posterior valley in premolars, complete absence of lingual cingulum, presence of reduced labial cingulum, absence of p1, oblique hypolophid in molars and absence of lingual groove of the entoconid that are enough to differentiate it from *R. unicornis*. However, a thorough assessment of all the mandibular material of *R. sivalensis* and *R. platyrhinus* is also suggested for future study.

Conclusions

This study is based on the mandible having right p2–m3, and left partial crown of p2 and complete p3–p4 collected from the Pinjor Formation (Early Pleistocene) deposits of Pabbi Hills present in the vicinity of Makwal, Kharian, Punjab, Pakistan. Although the differentiation

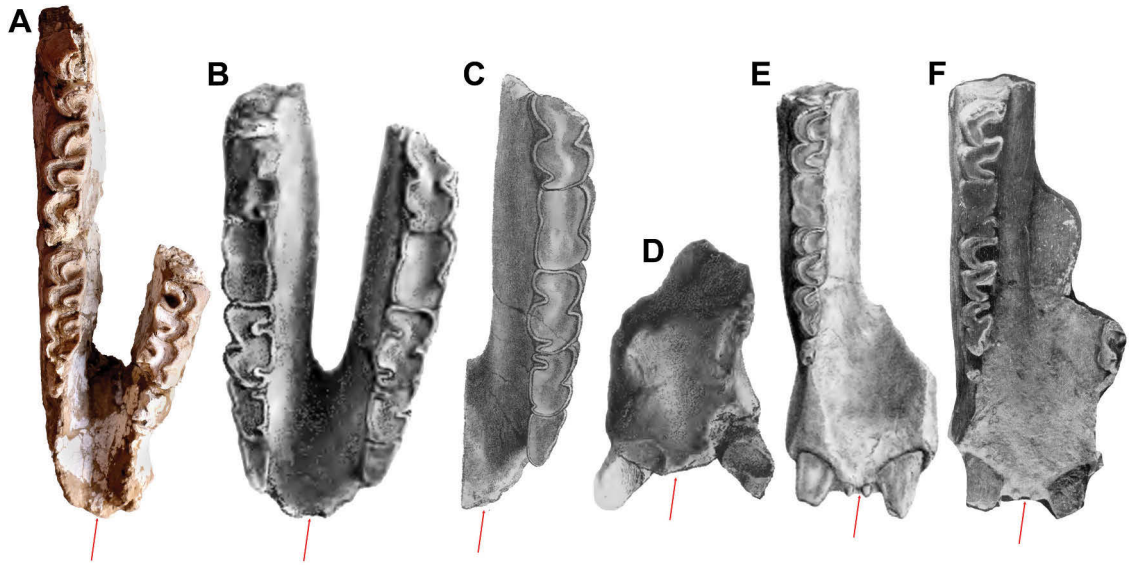

Figure 5. Comparison of PUPC 23/166 with fossil mandibles of *Rhinoceros* from Siwaliks. PUPC 23/166. A. *R. sivalensis*. B. From plate 74, fig. 6 of Falconer and Cautley (1847). C. From plate 75, fig. 6 of Falconer and Cautley (1847); *R. palaeindicus.* D. From plate 74, Fig. 4 of Falconer and Cautley (1847); *R. platyrhinus*. E. From plate 75, fig. 10 of Falconer and Cautley (1847). F. plate 18, fig. 1 of Badam (1979). The arrows points to the position of i1. All in occlusal view and not to scale.

of lower dentition of the genus *Rhinoceros* is challenging, demanding more accurate fossil record, the morphometric comparison of the material reveals close similarity with the previously described material of *Rhinoceros palaeindicus* in most characters, including size and other morphological features. However, the synonymy of *R. palaeindicus* with *R. sivalensis* was already established by Colbert (1935) which is further strengthened by this discovery, and we provided the synonymic view of the species *R. sivalensis* by discussing the metrical and morphological features of the Siwalik Pleistocene and extant *Rhinoceros* with published descriptions and datasets. Our comparison revealed that *Rhinoceros sivalensis* and *R. unicornis* are two valid species in the Siwalik Pleistocene of the Indian subcontinent.

Author contributions

CRediT: **Abrar Hussain:** Data curation, Formal analysis, Methodology, Visualization, Writing – original draft; **Muhammad A. Khan:** Conceptualization, Investigation, Project administration, Supervision, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Abrar Hussain http://orcid.org/0009-0001-2884-3486
Muhammad A. Khan http://orcid.org/0000-0003-1049-895X

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

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