



Bubalus platyceros (Bovidae: Mammalia) in the Sardhok Pabbi Hills of Pakistan

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ABSTRACT

The Upper Siwalik (Pleistocene) outcrops known as Pabbi Hills are well-exposed in the vicinity of Sardhok village, Gujrat, Punjab, Pakistan. The locality yielded the typical Pleistocene fauna of the Siwalik Group in Pakistan. The fossils of *Bubalus platyceros* described in this article were excavated from the Pleistocene of Sardhok. The collected specimens represent some of the rarest anatomical elements of the species, found in Pakistan for the first time, and add substantial knowledge on the anatomical features of *Bu. platyceros*. *Bubalus jarikasensis* erected by Akhtar in 2002 is reviewed in this paper and synonymized to *Bu. platyceros*.

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Authors' Contribution

MAK, MA and MI presented the concept of the study and designed it. MSK and SG did acquisition of data. MAB, MUI, MA, SGA and AMQ analysed and interpreted the data. MAB and MUI drafted the manuscript.

Key words

Bovini, *Bubalus*, Palaeontology, Siwaliks, Pabbi hills

INTRODUCTION

The genus *Bubalus* originated in Asia and its fossil record is confined to the Pleistocene sediments of Eurasia (Lydekker, 1878; Pilgrim, 1939; Koenigswald, 1986; Akhtar, 1992). Most of the fossil relatives of *Bubalus* are found in the Siwalik Group. The African material from Setif (Algeria), Modder River, Free State Province (South Africa), and Naivasha (Kenya), assigned to *Bubalus* was synonymised with *Syncerus* by Gentry (2010). However, he synonymized *Buffelus palaeindicus* to *Bubalus* from Tunis. Extant Bubalina are found in Asia where five species of *Bubalus* live (Hassanin and Ropiquet, 2004). Today, *Bu. bubalis* (the water buffalo), a domestic species, is found in many parts of the world whereas *Bu. arnee* (the wild water buffalo) is native to the Indian subcontinent and Southeast Asia (Akhtar, 1992; Lever, 1985). *Bubalus mindorensis* (the tamaraw) is native to Philippine whereas *Bu. depressicornis* (the high mountain anoa), and *Bu. quarlesi* (the low mountain anoa) are endemic to Indonesia (Hernández and Vrba, 2005).

The Pabbi Hills are famous for Pleistocene fluvial deposits (Keller *et al.*, 1977; Opdyke *et al.*, 1979; Dennell *et al.*, 2006, 2008) belonging to the Upper Siwalik

Subgroup in Pakistan (Arif, 1985; Shah, 1977, 2009). The outcrops of Sardhok in the district of Gujrat, Pakistan are well known for their Pleistocene fauna (Sarwar, 1977; Akhtar, 1992; Siddiq, 2015). Lithologically, the outcrops are composed of the subordinate conglomerate, and dominant sandstone and mudstone. Due to the extreme weathering, the topography of the area has resulted in badland at the most sites. However, there are certain sequences which represent the continuity of lithological layers and among these the mudstone is the oldest. The conglomerates include clasts of various petrography. The sandstone is medium grained, but occasionally coarser, moderately sorted, grey to dark grey, and often contains conglomeratic lenses. The mudstone is yellow to pale yellow, and silty with occasional sandstone lenses (Shah, 2009).

Additional remains of *Bu. platyceros*, a rarely reported buffalo taxon of the Siwalik are reported here. It is pertinent to mention that after the specimens described by Falconer (1868), Lydekker (1878), Pilgrim (1937) and Badam (1979) this collection is an important addition in providing

Institutional abbreviations

BMNH, British Museum of Natural History, London; GSI, Geological Survey of India; P-C Mus., The Powell-Cotton Museum, Quex Park, Birchington, Kent; PUPC, Punjab University Palaeontological Collection; UZ, University of the Punjab, Department of Zoology.

Anatomical abbreviations

M, Upper molar; p, Lower premolar; m, Lower molar.

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examples on the details of dentition for this species, as the earlier authors only described skull remains (Falconer, 1868; Lydekker, 1878; Pilgrim, 1937); moreover, the previously reported specimens are recovered from the Indian Siwaliks.

MATERIALS AND METHODS

Most of the remains of *Bu. platyceros* described in this article were previously collected from the Sardhok locality and housed in the Dr. Abu Bakr Fossil Display and Research Centre, Zoology Department, University of the Punjab, Lahore, Pakistan. New material, including a hemimandible and isolated dentitions, have been collected as a result of recent excavations in the Sardhok area. Most of the specimens were fully exposed whereas small excavations were performed to retrieve the specimens that were only partially exposed. A digital Vernier caliper was used for the measurements of the specimens; the specimens were measured at their maximum length and width. Uppercase letters refer to the upper teeth and lowercase letters refer to the lower teeth. The specimens catalogue number (e.g. 2013/55) consists of numerator (collection year) and denominator (serial number). The photographs were taken with digital camera and the plates were prepared in Adobe Photoshop CC (trial version). The tooth terminology and measurement follow Gentry *et al.* (1999), as illustrated below (Fig. 1).

SYSTEMATIC PALAEOLOGY

Family Bovidae Gray 1821
Subfamily Bovinae Gray 1821
Tribe Bovini Gray 1821
Subtribe Bubalina Rüttimeyer 1865
Genus *Bubalus* Smith 1827

Bubalus platyceros Lydekker, 1878

Holotype. GSI B237, a complete skull (Pilgrim, 1937).

Type locality. Upper Siwaliks of the Siwalik Hills, India (Pilgrim, 1937). Exact provenience unknown.

Stratigraphic range. Upper Siwaliks; Middle to Late Pleistocene (Pilgrim, 1937; Nanda, 2002, 2008).

Geographic distribution. The species is reported from India and Pakistan.

Referred material (Tables I and II)

Upper dentition: PUPC 1968/63, partial right M1; UZ 1970/47, left M1; PUPC 1966/140, left M1; PUPC 1967/01, left M2; PUPC 1967/38, left M2; PUPC 1967/303, right M2; PUPC 1966/60, left M2; PUPC 1966/142, left M2; PUPC 1966/17, right M2; PUPC 1966/16, right M2;

PUPC 1967/405, right M3; PUPC 1967/266, partial right M3; PUPC 1967/264, left M3; PUPC 1967/305, left M3.

Lower dentition: PUPC 2010/01, right hemimandible with p2-m3; PUPC 1966/102, right p3; PUPC 1966/135, right m1; PUPC 1966/141, right m1; PUPC 1966/63, left m1; PUPC 1966/143, left m1; PUPC 1967/267, left m1; PUPC 2010/21, right mandible fragment with m1; PUPC 1967/410, partial right m2; PUPC 1966/136, left m2; PUPC 2010/02, left mandible fragment with m2; PUPC 2011/122, right mandible fragment with m2-3; PUPC 1966/15, right m2; PUPC 1967/409, left m2; PUPC 2013/55, left m2; PUPC 1966/64, m2; PUPC 1966/19, right m3; PUPC 2013/54, left m3.

Locality and age: Sardhok in Pabbi Hills, district Gujrat, Pakistan; Upper Siwalik Subgroup (Pleistocene).

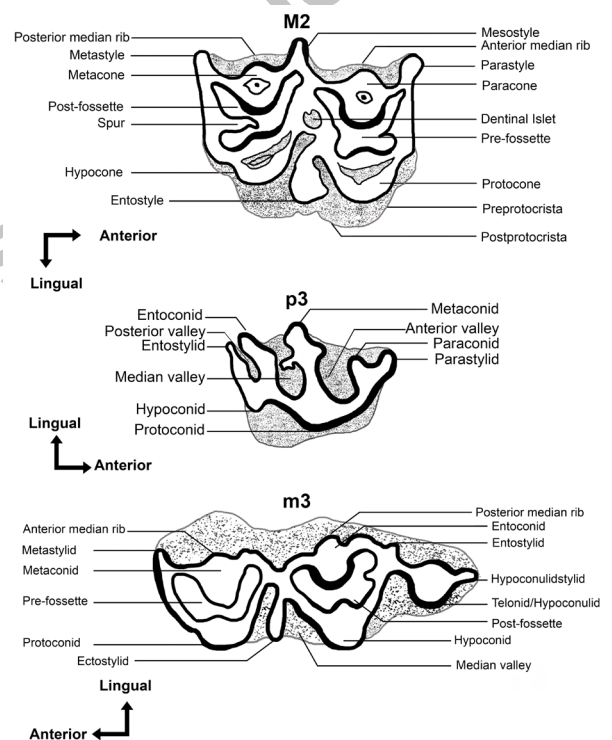


Fig. 1. Pencil sketch of the upper 2nd molar, lower 3rd premolar and 3rd molar of *Bu. platyceros*, showing the terminology used in the text.

Description

General description for upper molars: The upper dentition includes first, second and third molars (Fig. 2). The molars are large and bulky. The enamel is rugose. The traces of depository material are present. The cingulum is absent. The cusps are more distinct labially. The protocone, hypocone, paracone and metacone are well developed. The protocone is comparatively robust and massive. A

shallow vertical groove is present on the anterior side of protocone. Another shallow vertical groove is present on the posterior side of hypocone. The preprotocrista is larger than postprotocrista. The prehypocrista is smaller than posthypocrista. The slender metacone has pre- and postmetacristae of equal length. The entostyle is present between the protocone and hypocone. The entostyle is closer to hypocone as compared to protocone.

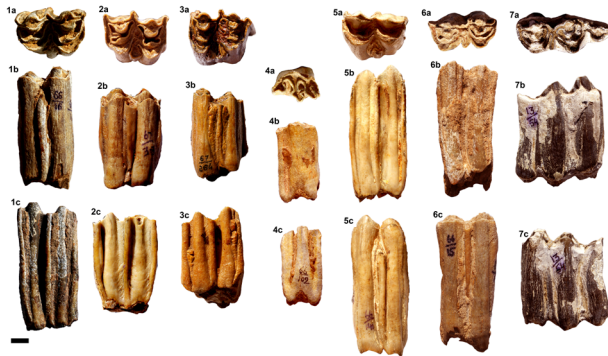


Fig. 2. *Bubalus platyceros*, selected specimens: 1. PUPC 66/16, rM2; 2. PUPC 67/303, rM2; 3. PUPC 67/264, IM3; 4. PUPC 66/102, rp3; 5. PUPC 66/141, rm1; 6. PUPC 66/15, rm2; 7. PUPC 13/54, lm3. Views: a, occlusal; b, lingual; c, labial. Scale bar 10 mm.

The anterior and posterior median ribs are prominent. A vertical groove is present between the anterior rib and parastyle, which is narrow at the base and broad towards the apex. The mesostyle, parastyle and metastyle are broad at the base and gradually tapering towards the apex. The prefossette has a “U” shape appearance with an indentation present, whereas the postfossette shows indentations and a spur. Overall, the pre- and postfossettes are deep with minor indentations. The metastyle is comparatively robust in third molars than in second molars.

General description for lower dentition: The premolars have traces of cements labio-lingually. The p2 is in late wear and elongated (Figs. 2.3a-c). The anterior side is prominent occlusally. The parastylid is weakly developed. An anterior valley is present between parastylid and praconid and the posterior valley is present between the metaconid and entoconid, which is comparatively deep apico-basally. The base of entostylid is shelf like. The shallow vertical groove is present postero-labially as in the p3 and p4 (Fig. 3a-c). The p3 is longer than p2. The paraconid is bulky. The metaconid is and broad. The antero-posterior valleys are prominent and deep labially. The p4 has a vertical groove between protoconid and hypoconid. The entoconid, protoconid and metaconid are somewhat crescentic. The metaconid is distinct from the

protoconid. The hypoconid is long. The metaconid and entoconid have lingual extensions.

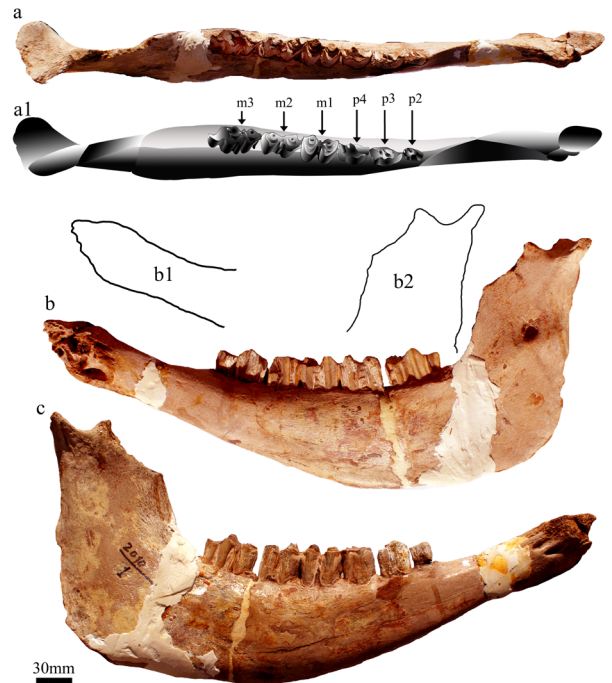


Fig. 3. *Bubalus platyceros*: PUPC 10/01, right hemimandible with p2-m3. a, occlusal view; b, lingual view; b1, outline of the symphyseal surface; b2, outline of the posterior aspect of the ramus; c, labial view. Scale bar 30 mm.

The lower molars are rugose (Fig. 2.5, 2.7). The protoconid, metaconid, hypoconid and entoconid are well preserved. The preprotocristid is larger than postprotocristid. The pre- and posthypocristids are of same size as in pre-postentocristids. An ectostylid is present between the protoconid and the hypoconid. A shallow vertical groove is present between anterior median rib and metastylid. A wide and shallow vertical groove is present between posterior median rib and entostylid. The ectostylid is prominent and extends transversely. The prefossette is narrow with crescentic outline while the postfossette shows indentations and spurs. The metastylid is slender and divergent. The hypoconulids are located posteriorly on the lower third molars (Fig. 2.7a). The hypoconulid is conical and divergent posteriorly.

Mandible. PUPC 2010/01 is a right hemimandible with diastema, ascending ramus, coronoid and angular process retaining the complete series of premolars and ramus (Fig. 3). The mandible body is typical of bovine species; it is labio-lingually narrow, slender and long. The coronoid process is strong and wide, recurved backward

and outward. The ventral posterior edges of the horizontal ramus are thick. The ascent begins right after m3, so there is no gap between the m3 and the ascending ramus. The internal and external surfaces of the jaw posterior to the m3 are marked by rugosities, representing muscle attachments. A pair of mental foramina is present labially, the dorsal one being smaller than the ventral one. The mandibular foramen is prominent lingually. The symphyseal surface is narrow posteriorly in dorsal view (Fig. 3-a1); it is quite robust in caudal view. The condylar and coronoid processes are damaged. There is a shallow open notch between the condylar and coronoid processes (Fig. 3-a1). The comparative measurements of the hemimandible and the cheek teeth are given in Tables I and II, and are plotted in Figure 4.

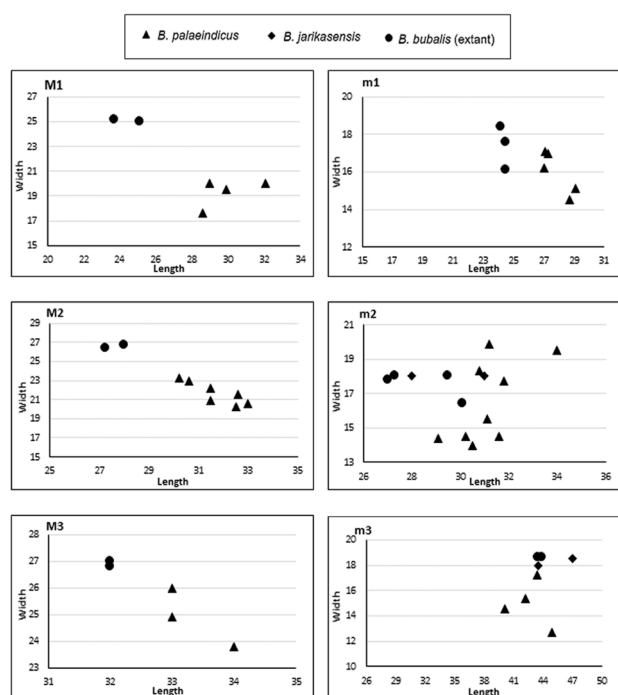


Fig. 4. Bivariate plots of upper and lower molars of *Bu. platyceros*, *Bu. palaeindicus*, and *Bu. bubalis* (extant).

Comparison

The teeth differ from Tylopoda in having less transversally extended entostyle/ectostylid and less enamel rugosity (Pickford *et al.*, 1993, 1995; Gibert *et al.*, 2013). The suborder Ruminantia includes four families namely Cervidae, Tragulidae, Giraffidae and Bovidae (Romer, 1974; Akhtar, 1992; Gentry, 1999; Khan *et al.*, 2009, 2014). The cervids are very rare in the Siwaliks outcrops and characterized by teeth without prominent styles/stylids (Azzaroli, 1954; Ghaffar *et al.*, 2012). The

tragulids are small sized ruminants, mostly found in the Lower and Middle Siwaliks (Khan and Akhtar, 2011, 2013). The giraffids are characterized by comparatively broad cones/conoids with strongly rugose enamel (Pilgrim, 1911; Colbert, 1935; Bhatti *et al.*, 2012a, 2012b; Khan *et al.*, 2014).

The studied material can be associated to the tribe Bovini of the family Bovidae in having a large size, hypsodonty, cementation, strong styles/stylids/folds and rugose enamel (Pilgrim, 1937, 1939; Hooijer, 1958). The bovines of the Upper Siwaliks are represented by *Hemibos*, *Proamphibos*, *Leptobos*, *Bison*, and *Bubalus* (Pilgrim, 1937, 1939; Hooijer, 1958; Akhtar, 1992). *Hemibos* is characterized by less pronounced hypsodonty. The genus possesses stout mandible with broad lower teeth and less reduced lower premolars (Pilgrim, 1939). *Proamphibos* differs in having thin enamel which is less rugose comparatively and restricted to the Tatrot Formation (Pliocene).

The studied material differs from *Hemibos*, *Proamphibos* and *Leptobos* in having mediolaterally-expanded mandible in the incisive region, and long and slender mandible behind the canines with relatively narrow lower teeth. *Bos* and other bovines have comparatively short p2 (Hooijer, 1958); the p2 described here is not reduced having well-marked meta- and entoconids. The long and slender mandible with long diastema associates it to the genus *Bubalus* (Pilgrim, 1937, 1939; Hooijer, 1958; Akhtar, 1992). The elongated p2 is also one of the characters of the genus *Bubalus*. The mandible of *Bubalus* differs from that of *Bos* in being longer and more slender, higher at the cheek teeth, with a wider but relatively lower ascending portion; the coronoid process in *Bubalus* is wider and apparently more strongly recurved backward and outward than that in *Bos* (Stremme, 1911).

There are two species of the genus *Bubalus* in the Pleistocene deposits of the Siwaliks: *Bu. platyceros* and *Bu. palaeindicus*. *Bubalus palaeindicus* is related to the modern Indian buffalo (*Bubalus bubalis*), having large size (Falconer, 1868; Lydekker, 1878; Hooijer, 1958; Badam and Sankhyan, 2009). Metrically, the studied specimens are smaller than *Bu. bubalis* (domestic buffalo) and *Bu. palaeindicus* (Tables I and II, Fig. 4). The comparison to other buffalo species (Table II) reveals that these specimens can be allied to *Bu. platyceros* (Pilgrim, 1937). The collected teeth represent all the characters of the Pleistocene subcontinental buffalo, which is indigenous to the Indian subcontinent: hypsodonty, slim mandible fragment and long p2 with prominent anterior valley (Pilgrim, 1939; Hooijer, 1958).

Table I. Comparative measurements (mm) of hemimandible of *Bubalus platyceros*. Referred species from Hooijer (1958). *the studied specimen.

Inventory No.	Nature	Description	<i>B. palaeo-kerabau</i>	<i>B. platyceros</i>	<i>B. bubalis (domestic)</i>
PUPC 10/01*	Right Hemi-mandible with p2-m3	Height of ramus behind m3	-	95.0	-
		Length of mandible from foramen to hinder surface of angle	-	350	-
		Width of mandible below m2	-	30.2	-
		Height of mandible below m1	-	85.2	-
		Length of premolar series (p2-4)	-	64.7	-
		Length of molar series (m1-m3)	-	101	-
		Length of ascending ramus	-	174	-
		Length of horizontal ramus	-	380	-
		Width of mandible at the point of ascending ramus	-	107	-
Coll. Dub. No. 540	Mandible	Total length of premolar and molar series (p2-m3)	-	166	-
		Length of ramus from mental foramen to hinder surface of angle	390	-	310-340
		Length p3-m3	150	-	125-145
		Height of ascending ramus from lower surface of angle to mandibular notch	190	-	125-155
		Height of ramus behind m3	105	-	70.0-85.0

DISCUSSION

Bubalus platyceros was erected by Lydekker (1878) from the Siwalik Hills of the Indian subcontinent based on a cranium and partial horncores. Later, (Pilgrim, 1937) ascribed *Bu. cf. platyceros*, based on a skull from the Upper Siwalik Subgroup. Berckheimer (1927) while describing *Bu. murrensis* skull from Steinheim pointed out that it more closely resembles *Bu. platyceros* than the Recent *Bu. arnee*. Hooijer (1958) made comparison to *Bu. platyceros* and *Bu. palaeokerabau*, and noted that *Bu. platyceros* differed from *Bu. palaeokerabau* in having horn cores directed obliquely upward with triangular cross section. Koenigswald (1986) suggested that *Bu. murrensis* might be a junior synonym of *Bu. platyceros*. The latter species, *Bu. platyceros*, ranges from the middle to late Pleistocene of the Siwaliks (Nanda, 2008).

Synonymy: The new material of *Bu. platyceros* made it possible to review *Bu. jarikasensis*, recently erected by Akhtar (2002), based on a left mandible bearing the diastema of p3-m1 and well-preserved m2-3 from Jarikas, Mir Pur, Azad Kashmir, Pakistan. The description of *Bu. jarikasensis* was based on a single hemimandible bearing left p3-4 and m2-3 (PUPC 1991/10) and Akhtar (2002) noted that this hemimandible differs from other *Bubalus* species in having no p2 and there is a diastema between p3 and p4. The crowns of the premolars are missing

and the root alveoli are preserved in this hemimandible. However, the absence of p2 is a developmental anomaly not an evolutionary point and such an anomaly has not been reported for *Bubalus* but has been observed in some specimens of primates, artiodactyls, and perissodactyls; like the absence of P2 in the left maxilla of *Tayassu tajacu* (Miles and Grigson, 2003, specimen number BMNH 1921.1.78), the absence of right M3 in the maxilla and right m3 in the mandible of *Colobus polykomos satana* (Miles and Grigson, 2003, 3.31, specimens number, P-C Mus. CamII483) and the absence of left m2-3 in the mandible of *Dendrohyrax validus neumanni* (Miles and Grigson, 2003, specimen number BMNH 1906.6.5.23). Normally, the crown is extended antero-posteriorly at the apex in bovines resulting in a space/gap at the base of teeth. Due to the absence of crown of premolars, this gap becomes visible between the root alveoli and such a gap can't be considered as an evolutionary point to erect a new species. Such is the case with the *Bu. jarikasensis*'s mandible in which a gap appears between the p3 and p4 due to absence of the crown of these premolars.

Moreover, morphometrically, the studied hemimandible (PUPC 2010/01) has the same characteristics as PUPC 1991/10. The morphology and metric values of the teeth are consistent with that of *Bu. platyceros* (Table II; Fig. 2). Metrically, Akhtar (2002) did not compare the specimen PUPC 1991/10 with any other species of *Bubalus*; the size of specimen PUPC 1991/10

is comparable with the potential size of a *Bu. platyceros* hemimandible (PUPC 2010/01). The characters such as missing p2 and presence of gap between alveoli of p3 and p4, are insufficiently diagnostic, as such features are entirely variable even within single individuals and does indeed vary intraspecifically (See Bibi and Güleç, 2008; Mennecart *et al.*, 2011; Allouch, 2014; Kostopoulos and Karakütük, 2015; Suraprasit *et al.*, 2016). Therefore, *Bu. jarikasensis*, erected by Akhtar (2002), is probably a junior synonym of *Bu. platyceros*. The material from Jarikas in Azad Kashmir and Sardhok is morphologically and metrically homogeneous. It can be referred to a single species *Bu. platyceros*.

Table II. The comparative measurements (mm) of the *Bubalus* species. *the studied specimens. Referred data from Lydekker (1876), Akhtar (2002) and Croft *et al.* (2006).

Taxa	Inventory No.	Nature	Length	Width	W/L	
<i>Bubalus platyceros</i>	PUPC 68/63*	rM1	28.60	17.60	0.62	
	UZ 70/47*	lM1	29.90	19.50	0.65	
	PUPC 66/140*	lM1	29.00	20.00	0.69	
	PUPC 67/01*	lM2	30.60	23.00	0.75	
	PUPC 67/38*	lM2	32.60	21.60	0.66	
	PUPC 67/303*	rM2	33.00	20.60	0.62	
	PUPC 66/60*	lM2	31.50	22.20	0.70	
	PUPC 66/142*	lM2	30.20	23.30	0.77	
	PUPC 67/17*	rM2	32.50	20.30	0.62	
	PUPC 67/264*	lM2	31.50	20.90	0.66	
	PUPC 66/16*	rM2	32.10	20.00	0.62	
	PUPC 67/405*	rM3	33.00	24.90	0.75	
	PUPC 67/266*	rM3	34.00	23.80	0.70	
	PUPC 67/305*	lM3	33.00	26.00	0.79	
	PUPC 10/01*	rp2	23.00	11.00	0.49	
		rp3	23.00	11.30	0.49	
		rp4	23.20	10.90	0.47	
		rm1	28.70	14.50	0.51	
		rm2	29.10	14.40	0.49	
		rm3	40.10	14.60	0.36	
		PUPC 66/102*	rp3	23.20	15.40	0.66
		PUPC 66/135*	rm1	27.00	16.20	0.60
		PUPC 66/141*	rm1	27.00	16.20	0.60
PUPC 66/63*		lm1	27.10	17.10	0.63	

Continued on next column.....

Taxa	Inventory No.	Nature	Length	Width	W/L
	PUPC 66/143*	lm1	27.30	17.00	0.62
	PUPC 67/267*	lm1	25.00	10.80	0.43
	PUPC 10/21*	rm1	29.10	15.10	0.52
	PUPC 67/410*	rm2	30.50	14.00	0.46
	PUPC 66/136*	lm2	31.20	19.90	0.64
	PUPC 10/02*	lm2	30.80	18.30	0.59
	PUPC 11/122*	rm2	31.10	15.50	0.50
		rm3	42.20	15.40	0.36
		rm2	30.20	14.50	0.48
	PUPC 66/15*	rm2	30.20	14.50	0.48
	PUPC 67/409*	lm2	31.60	14.50	0.46
	PUPC 13/55*	lm2	31.80	17.70	0.56
	PUPC 66/64*	m2	34.00	19.50	0.57
	PUPC 66/19*	rm3	44.90	12.70	0.28
	PUPC 13/54*	lm3	43.40	17.20	0.40
<i>B. palaeindicus</i>	BMNH 39716	M2	40	30	
		M3	45	-	
<i>B. jarikasensis</i>	PUPC 91/10	m2	31.00	18.00	0.58
		m3	47.00	18.50	0.39
<i>B. bubalis</i> (extant)	UZ 997	m2	28.00	18.00	0.64
		m3	43.50	18.00	0.41
		rm1	28.10	15.50	0.55
	FMNH 92912	rm2	30.10	16.40	0.54
		FMNH 31711?	rm1	29.50	18.40
	UMMZ 157862	rm2	32.80	19.30	0.59
		rm1	24.20	16.10	0.67
	PUZM 517	rm2	29.50	18.00	0.61
		rP3	19.31	22.00	1.14
		rM1	23.70	25.15	1.06
rM2		28.00	26.70	0.95	
rM3		32.00	27.00	0.84	
lP3		19.50	22.00	1.13	
lP4		18.20	21.00	1.15	
	lM1	25.10	25.00	1.00	
		lM2	27.25	26.40	0.97
	lM3	32.00	26.80	0.84	
		lp2	16.50	10.60	0.64
	lp3	21.50	12.40	0.58	
	lp4	22.80	15.00	0.66	
	lm1	24.50	17.60	0.72	
	lm2	27.30	18.00	0.66	
	lm3	43.57	18.60	0.43	
	rp3	21.75	12.90	0.59	
rp4	22.85	14.95	0.65		
	rm1	24.50	17.40	0.71	
	rm2	27.00	17.80	0.66	
	rm3	43.90	18.65	0.42	

CONCLUSIONS

This article reports *Bu. platyceros* for the first time from the Pabbi Hills of Sardhok, Pakistan, extending its geographic range from India to Pakistan. The findings provide important data on the dental morphology of *Bu. platyceros* including size variations from the Siwalik Group. *Bu. jarikasensis*, Akhtar, 2002 is synonymized with *Bu. platyceros* (Lydekker, 1878).

Statement of conflict of interest

The authors have declared no conflict of interest.

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