ANTLER REMAINS (CERVIDAE, ARTIODACTYLA, MAMMALIA) FROM A NEW LOCALITY IN THE PINJOR FORMATION (1.6-0.8 MA), PAKISTAN

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ABSTRACT – New antler remains from the Pinjor Formation of Sardhok (32°49'39"N, 73°43'51"E), Gujarat district, Punjab Province, Pakistan, are described. In this paper, new fossil data from a new fossil locality with its taxonomic relationships and geological aspects is discussed. A thorough comparison of studied specimens with all known cervid species from Europe and South Asia of this time span supports the assignment of these antlers to *Axis* cf. *A. punjabiensis*. Limited data are available on Siwalik antlers and any new fossil will definitely add to our understanding of this group of mammals.

Key words: Upper Siwalik, Sardhok, Cervidae, antlers, taxonomic affinity, Pakistan.

RESUMO – São descritos novos restos de galhadas da Formação Pinjor de Sardhok (32°49 '39"N, 73°43'51"E), Distrito de Gujarat, Província de Punjab, Paquistão. Neste artigo, são discutidos novos dados fósseis de uma nova localidade com suas relações taxonômicas e aspectos geológicos. Uma comparação minuciosa dos espécimes estudados com todas as espécies conhecidas de cervídeos da Europa e do Sul da Ásia deste período de tempo suporta a atribuição destes chifres à *Axis* cf. *A. punjabiensis*. Dados limitados estão disponíveis para galhadas de Siwalik e qualquer fóssil novo ampliará definitivamente a nossa compreensão deste grupo de mamíferos.

Palavras-chave: Siwalik superior, Sardhok, Cervidae, galhadas, afinidade taxonômica, Paquistão.

INTRODUCTION

Fossil remains of the family Cervidae from the Siwaliks are poorly known and the taxonomic identifications of holotype materials are based on incomplete and very fragmentary specimens (Lydekker, 1876, 1880, 1884). Similarly, the Siwaliks record is still devoid of late Miocene fossils of tribe Pliocervini (Bubenik, 1990; Heintz *et al.*, 1990; Petronio *et al.*, 2007). To address the above-mentioned aspects, there is a strong need to document new fossil material, which can highlight the above-mentioned issues, from the Siwalik continental deposits, and this paper is an attempt to highlight this effort by describing newly discovered antler remains from a new fossil locality (Sardhok), in the Pinjor Formation (Upper Siwaliks) of Pakistan. Since the beginning of paleontological work on the Siwalik deposits which began more than 150 years ago, there are very few publications based on the antler remains from Pliocene-Pleistocene horizons (Lydekker, 1884; Brown, 1926; Azzaroli, 1954; Croitor &

Stefaniak, 2009; Ghaffar *et al.*, 2012). From Early Pliocene–Early Pleistocene, cervids belonging to three different genera (*Axis*, *Cervus* and *Rucervus*) have been described from the Indian subcontinent (Ghaffar *et al.*, 2010, 2011). There are eight known species (*Cervus triplidens*, *C. sivalensis*, *C. colberti*, *Rucervus simplicidens*, *Rucervus* sp. 1, *Rucervus*(?) sp. 11, *Rucervus* sp. 111 and *Axis punjabiensis*) belonging to above mentioned three genera (Azzaroli, 1954; Ghaffar *et al.*, 2010). In the Siwaliks, different species of the tribe Cervini appeared in the early Pliocene, but its extensive diversification and development took place in early/middle Pliocene time (Azzaroli, 1954; Barry *et al.*, 1982; 2002; Barry & Flynn, 1989; Van der Made, 1999; Ghaffar *et al.*, 2010, 2011). From early to middle Pliocene, the first forms referable to the subfamily Cervinae were found in central and western Asia (Croitor, 2006, 2014; Di Stefano & Petronio, 2002; De Vos *et al.*, 1995). From the Siwalik continental deposits, the fossil remains of *Axis punjabiensis* were recovered from the Plio-Pleistocene (Brown, 1926; Barry *et al.*, 2002; Ghaffar, 2005;

Ghaffar *et al.*, 2012). This species shows numerous advanced morphological features, observed in some remains attributed to *Cervavitus novorossiae* (Khomenko, 1913) from Eurasia (Di Stefano & Petronio, 2002). The main objective of this paper is to describe new fossil findings from the new fossil locality and discuss their possible phylogenetic relationships with those of the neighbouring provinces, particularly the Mediterranean Europe and China.

Petronio *et al.* (2007) investigated the phylogenetic relationships between the Pliocervini from China and Europe based on morphological, biochronological and paleogeographical data and found that the origin of European genus *Axis* can be linked to Chinese pliocervines.

Moreover, Heintz *et al.* (1990) also suggested that Cervinae appeared simultaneously in Europe and Siwalik Hills (Indian subcontinent) during the Pliocene time. Hsü *et al.* (1977) mentioned that during the late Miocene and early Pliocene, there was a land connection between the Indian subcontinent and Europe. Indications for the presence of similar biotopes in southeast Europe and Indian subcontinent in late Miocene-early Pliocene permit to suggest a close affinity of these faunas (Van der Made, 1999). The genus *Axis* is widely distributed in central-southern Asia, from Indochina to Iran (Flynn *et al.*, 1991; Di Stefano & Petronio, 2002; Ludt *et al.*, 2004; Meijaard & Groves, 2004; Pitra *et al.*, 2004; Sen *et al.*, 1997) but biogeographic relationships of the family

Figure 1. Map of Pakistan (inset) with different fossil localities from the Siwaliks and an enlargement of study area (Sardhok) and within the study area fossil collection sites (six specimens were collected from six different places, marked by yellow circles), from Gujarat district, Punjab, Pakistan.

Cervidae from the Siwalik continental deposits with China and Europe still needs further research. This issue can only be resolved by collecting and describing new fossil materials of Cervidae. The purpose of this paper is to report the new antler remains from different sites in the Pinjor Formation exposed near Sardhok village which is situated 45 km NE to Gujarat city. The antler remains were collected from an area of 4–5 square kilometres as shown in Figure 1 with six yellow circles. This area has not been explored by the previous pioneer workers (e.g. Falconer & Cautley, 1849; Lydekker, 1876, 1880, 1884; Pilgrim, 1910, 1913, 1937, 1939; Brown, 1926; Matthew, 1929; Colbert, 1935) but later on, it has been visited by different palaeontologists from Pakistan (Sarwar, 1977; Khan & Sarwar, 2002; Ghaffar *et al.*, 2003, 2004; Siddiq *et al.*, 2014; unpublished data). The Pabbi Hills preserve a complete Upper Siwalik sequence in northern Pakistan which formed under a monsoonal regime with strong seasonal contrasts between a relatively cool winter season and a hot wet summer monsoons (Dennell *et al.*, 2006; Dennell, 2008; Keller *et al.*, 1977). Due to uplift and greater resistance to erosion, these sandstones often form ridges and provide useful marker horizons. Most of these sediments in the interior of the Pabbi Hills are dated to the Matuyama Chron (ca. 2.5–0.8 Ma), while the youngest Siwalik sediments on the flanks were formed during the early Brunhes Chron (0.78 Ma) (Keller *et al.*, 1977; Rendell, 2004; Dennell *et al.*, 2006).

The study area (Sardhok) is characterized by brown to grayish-brown, fine, medium to coarse-grained sandstones with pebbles and large-scale cross stratifications, brown mudstones, pedogenic horizons, and well-imbricated stratified conglomerates. The Pinjor Type Locality in the Chandigarh region, India has been dated from 2.48 to 0.63 Ma, on the basis of magnetostratigraphy (Kumaravel *et al.*, 2005). The Pinjor mammalian fauna marks the end of the Siwalik vertebrate fossil record since the overlying Boulder Conglomerate Formation, the youngest formation of the Siwalik Group. This Boulder Conglomerate Formation is devoid of any type of fossils (Nanda, 2002). Pilgrim (1913) named this horizon as Pinjor zone, whereas Shah (1977, 2009) named it as Soan Formation; and Johnson *et al.* (1982) named it as Late Matuyama. The Pinjor Formation in the study area is mainly characterized by Pleistocene sands and variegated clays. The upper part of Pinjor Formation is dated 0.6 Ma while the lower boundary of the formation is dated at 2.58 Ma (Nanda, 2008). From the present fossil site, a number of fossils remains including those of *Elephas*, *Equus*, giraffes, rhinos and bovids have been collected (Sarwar, 1977; Khan & Sarwar, 2002; Ghaffar *et al.*, 2004; Ghaffar, 2005; Siddiq *et al.*, 2014).

In the Upper Siwalik, two biostratigraphic interval-zones, *Elephas planiformis* Interval-Zone (3.6–2.6 Ma) and *Equus sivalensis* Interval-Zone (2.6–0.6 Ma) are recognized on the basis of magnetostratigraphy and mammalian fauna (Rendell, 2004). Twenty-five taxa made their appearance during the *Elephas planiformis* Interval-Zone and these taxa mainly include mammals of

Eurasian affinity, *i.e.* cervids (*Cervus*), equids (*Equus*), elephantids (*Elephas*), giraffids (*Sivatherium*) and suids (*Sus* and *Sivachoerus*) while 48 other taxa are restricted to *Equus sivalensis* Interval-Zone (Barry *et al.*, 1982; Nanda, 2002). The Pinjor mammalian fauna is also characterized by the dominance of herbivore community of woodland habitat with a few adapted for riverine gallery forests. The principal feature of this herbivore community is the continuation into the modern South Asian wildlife assemblages which is evident by the different species of Cervidae in these assemblages (Arif *et al.*, 1991; Ghaffar, 2005). Although the findings of this paper are based on fragmentary materials, scarce data are available on antler remains, making this description significant.

MATERIAL AND METHODS

The described specimens were collected from the sediments of Pinjor Formation exposed near Sardhok village, Punjab, Pakistan. The collections were made by authors during different field trips that took place during 2010–2012 (2010/specimen number 72; 2011/specimen number 125; 2012/specimen number 215). In addition, other specimens (1967/specimen number 107; 1967/specimen number 293; 1968/specimen number 286) described in this study are in the collections of Abu Bakr Fossil Display and Research Centre, University of the Punjab, Lahore, Pakistan and had been collected (Dr. Abubakr and colleagues) in the past from the above-mentioned locality (Sardhok).

Measurements of the antlers under study were taken in centimetres with the help of metric Vernier calipers, according to the method described by De Vos (1984) with a Dial Caliper Mitutoyo. The terminology regarding different parts of antler follows De Vos (1984). The morphological and metrical characters of the specimens are described and their systematic determination is discussed. The catalogue number of the specimens consists of series *i.e.* yearly catalogue number and the serial catalogue number, so the figures of the specimen represent the collection year (numerator) and the serial number (denominator) of that year (e.g. year 2010/specimen number 72). The examined specimens are distinguished on the basis of morphology of the antlers and by comparing these antlers with other species of the genus *Axis* (Azzaroli, 1954; Di Stefano & Petronio, 2002; Croitor, 2014; Croitor & Stefaniak, 2009; Ghaffar *et al.*, 2012).

Institutional abbreviations: PUPC, Punjab University Paleontological Collection stored in Zoology Department, Lahore, Pakistan; BMNH, British Museum of Natural History, United King; AMNH, American Museum of Natural History, United States of America.

Other abbreviations: A, *Axis*; C, *Cervus*; M, *Metacervocerus*; P1, length of antler beam from brow-tine to rear-tine; P2, length of antler beam from rear-tine to posterior-tine; a1, angle between P1-brow-tine; a2, angle between P2-rear-tine; DAP, anteroposterior diameter, DT, transverse diameter; Ma, million years ago.

SYSTEMATIC PALEONTOLOGY

Order ARTIODACTYLA Owen, 1848
 Family CERVIDAE Goldfuss, 1820
 Subfamily CERVINAE Goldfuss, 1820

Axis Smith & Pedgeon, 1827

Type species. *Axis punjabiensis* (Brown, 1926).

Axis cf. *A. punjabiensis* (Brown, 1926)
 (Figure 2)

Referred material. PUPC 2011/ specimen number 125; PUPC 2010/ specimen number 72; PUPC 1968/ specimen number 286; PUPC 1967/ specimen number 107, PUPC 1967/ specimen number 293; PUPC 2012/ specimen number 215 (antler fragments).

Horizon and locality. Pinjor Formation, Upper Siwalik Subgroup (Pleistocene), Sardhok, Gujarat district, Punjab Province, Pakistan.

Age of fossil sites. Lower Pleistocene; ca 1.6–0.8 Ma.

Holotype. AMNH No. 19911, an incomplete skull with antlers.

Horizon (type material). Pinjor Formation (Pleistocene), Upper Siwalik Subgroup (Pabbi Hills). Two miles (3.2 kilometres) west of Chandigarh, Ambala District, Punjab (India).

Description. The fossils are heavily pearly, well-mineralized and cemented by a yellowish-brown matrix of coarse-grained sandstone. Specimen PUPC 2011/125 is a fragment of right antler with well-developed pedicle, burr with beam and brow-tine but the distal tips are missing (Figures 2A–C). The surface of the beam is rather heavily pearly. The length of the base from the burr to the angle in straight line is 7.0 cm. The length of P1 from the angle

Figure 2. Antler fragments of *Axis* cf. *A. punjabiensis* from Sardhok, Upper Siwaliks, Pakistan: PUPC 2011/125 (A–C); lateral view, inner view, outer view: PUPC 2010/72 (D–F); lateral view, inner view, outer view: PUPC 1968/286 (G–I); outer view, inner view, Lateral view: PUPC 1967/107 (J–L); outer view, inner view, Lateral view: PUPC 1967/293 (M–O); inner view, outer view, Lateral view: 2012/215 (P–Q); outer view, inner view. Scale bar = 30 mm.

between P1 and a1 (brow-tine) to a2 (rear-tine) is 22 cm. Length of P2 is 13.0 cm; the length of the brow-tine (a1) is 6.2 cm. The length of pedicle is 9.5 cm and antero-posterior diameter 4.5 cm (DAP) while 5.0 cm transversally (DT). The angle [(P1) – brow tine (a1)] is 90°. Length of preserved antler outside the curve is 19.0 cm while the circumference of beam above brow-tine is 15.2 cm.

Specimen PUPC 2010/72 is a fragment of left antler with a well-preserved burr and base and a basal part of beam (Figures 2D–F). The length of the base from the burr to the angle in straight line is 5.8 cm. Diameter maximum of the body is 4.1 cm in antero-posteriorly (DAP) and 4.0 cm transversally (DT). Length of preserved antler outside the curve is 11.2 cm while the circumference of beam above brow-tine is 13.0 cm.

Specimen PUPC 1968/286 is a fragment of right antler with a well-preserved burr and base and a basal part of beam (Figures 2G–I). The length of the base from the burr to the angle in straight line is 8.0 cm. Diameter maximum of the body is 4.3 cm in anterior-posteriorly (DAP) and 5.2 cm transversally (DT). Length of preserved antler outside the curve is 12.6 cm while the circumference of beam above brow-tine is 15.0 cm.

Specimen PUPC 1967/107 is a fragment of right antler with a well-preserved burr and base and a basal part of beam (Figures 2J–L). The length of the base from the burr to the angle in straight line is 8.2 cm. Diameter maximum of the body is 4.4 cm in anterior-posteriorly (DAP) and 4.7 cm transversally (DT). Length of preserved antler outside the curve is 18.4 cm while the circumference of beam above brow-tine is 14.5 cm.

Specimen PUPC 1967/293 is a fragment of left antler with a well-preserved burr and base and a basal part of beam (Figures 2M–O). The length of the base from the burr to the angle in straight line is 6.0 cm. The length of the preserved brow-tine (a1) is 2.5 and the angle [(P1) – brow tine (a1)] is 90°. Diameter maximum of the body is 4.7 cm in antero-posteriorly (DAP) and 4.9 cm transversally (DT). Length of preserved antler outside the curve is 12.0 cm while the circumference of beam above brow-tine is 14.8 cm.

Specimen PUPC 2012/215 is a fragment of right antler with a well-preserved burr and poorly preserved base only while the beam is missing (Figures 2P–Q). The length of the base from the burr to the angle in straight line is 6.9 cm. Length of preserved antler outside the curve is 6.5 cm. The detail measurements of different parts of antlers are given in Table 1.

ANALYSIS AND DISCUSSION

Among described antler specimens, only the pedicle, burr with beam and brow-tine are preserved in one specimen (PUPC 2011/125; Figures 2A–C) while the remaining materials (PUPC 2010/specimen number 72; PUPC 1968/specimen number 286; PUPC 1967/specimen number 107; PUPC 1967/specimen number 293; PUPC 2012/specimen number 215; Figures 2D–Q) have only the burr and the beam. Therefore, these can only be identified on the basis of general morphology of beam and burr and by comparing them with the previously described antler materials from the Siwaliks, as well as from Eurasia (*i.e.* Lydekker, 1880; Brown, 1926; Azzaroli, 1952, 1954; Di Stefano & Petronio, 2002; Croitor, 2006, 2014; Croitor & Stefaniak, 2009; Ghaffar *et al.*, 2012). In this regard, the morphology of these specimens is closely comparable to the holotype (AMNH No. 19911), an incomplete skull with antlers originally described by Brown (1926) as *Cervus punjabiensis* and later on based on more antler materials from the Siwaliks is referred as *Axis punjabiensis* by different authors (Azzaroli, 1954; Ghaffar *et al.*, 2012). Moreover, the apparent structure of preserved antlers under study is very similar to specimen PUPC 5-2-2010 (*Axis punjabiensis*) recently described by Ghaffar *et al.* (2012) from another fossil site near Dina village, Jhelum district, Pakistan.

According to Di Stefano & Petronio (2002), *Axis* from the Italian peninsula shows numerous morphological similarities in its antlers, with typical Asian forms confirming a close phyletic relationship, starting from 3-point antler plan to 4-point antler plan. The Late Pliocene species of Europe, *Axis lyra* (Azzaroli, 1992), is represented by a pair of asymmetric antlers that belong to a young individual: one antler is three-tined like *A. punjabiensis*, while another antler bears an incipient small distal bifurcation. Moreover, the antlers of *A. punjabiensis* are slimmer and simple (3-tined) when compared to *Dama eurygonos* (4-tined). Subsequently, in *A. punjabiensis* the beam is strong and continuous and the brow-tine and rear-tine are very short as compared to *D. eurygonos* (Di Stefano & Petronio, 2002; Ghaffar *et al.*, 2012). The generic attribution of different species of Cervidae is still controversial due to very fragmentary nature of materials and the species under study is not the exception. The assignment of this species to *Axis* or *Metacervoceros* still needs more complete cranial materials from the Siwaliks. The general morphology and discussion on these antlers (pers. comm. with Di Stefano) justify the attribution of the materials to *Axis* genus. But on the other hand, some antlers fragment,

Table 1. Measurements (cm) of the antlers under study.

Specimens	Length of base	Length of beam (P1)	Length of brow-tine	DAP	DT	Angle between P1-a1	length of preserved part of antler	Circumference of beam
PUPC2011/125	7.0	22	6.2	4.5	5.0	90°	19	15.2
PUPC2010/72	5.8			4.1	4		11.2	13
PUPC1968/286	8			4.3	5.2		12.6	15
PUPC1967/107	8.2			4.4	4.7		18.4	14.5
PUPC1967/293	6		2.5	4.7	4.9	90°	12	14.8

particularly the specimen PUPC 2011/125, also resembles *M. pardinensis* figured by Croitor & Stefaniak (2009, p. 19) where they argued that *C. punjabiensis* Brown, 1926 from the Upper Siwaliks should be included in this genus as *M. punjabiensis*. This attribution is based on the large body size and high crowned cheek teeth. Moreover, they also argued that the upper cheek teeth crown pattern and 3-point antler plan is morphologically similar to *M. pardinensis*. Based on antler morphology, we agree with this attribution but leave this question open till the next discovery of well-preserved maxilla with antlers of this species from the Siwaliks. Therefore, based on the general morphology and comparison of the antler fragments studied with the previously described antlers from the Siwaliks, these specimens are referred as *Axis* cf. *A. punjabiensis*.

Based on the available fossil record and above observations, it becomes clear that the genus *Axis* is widely distributed in the Siwaliks, Mediterranean Europe and China. Therefore, on the basis of antler remains, we can argue that *A. punjabiensis* is the more prominent species in the Siwaliks. Although eight species of family Cervidae have been described from the Siwalik continental deposits, the species under study is known by more antler remains than any other cervid species. The fossil finds of this genus in the Indian subcontinent and Mediterranean Europe confirms the faunal exchange through the land bridge between these two regions during the late Miocene–early Pliocene as suggested by Hsü *et al.* (1977), the faunal exchange between China and India was also possible because the Tibetan Plateau would not have formed a barrier to the dispersal between these regions (Howell & Petter, 1985; Ghaffar & Akhtar, 2012).

Age of the deposit (study area)

Based on the lithological characteristics, the age of the study area is considered as early Pleistocene or late Matuyama (*i.e.* 1.6–0.8 Ma). The study area is composed of coarse boulder and pebble conglomerates with minor coarse and cross-bedded sandstone. These conglomerates consist of poorly sorted pebbles and boulders of mostly Eocene rocks with a small proportion of older sedimentary rocks, quartzites and igneous rocks. The conglomerate is intercalated with beds of soft sandstone and siltstone of pale brown to ochre colour. At some places of the study area it consists of pebbles of various igneous and metamorphic rocks with a small percentage of Eocene limestone pebbles ranging up to half a meter in diameter and has intercalations of soft, grey sandstone and orange claystone. In some other portions of the study area, the conglomerate is composed of poorly sorted pebbles, cobbles and boulders with a calcareous sandy matrix. Most of the boulders are of limestone, marl and sandstone derived from Tertiary and older rocks of the neighbouring areas. Subordinate sandstone beds are intercalated with the conglomerate. This sandstone is green grey and brown, cross-bedded and usually forms steep or vertical walls and cliffs. Pilgrim (1913) named this stage as Pinjor Formation, Shah (1977) as Soan Formation while Johnson *et al.* (1982)

as Late Matuyama Formation. In general, all these three formations (Pinjor, Soan and Late Matuyama Formation) show an interbedded sequence of mudstone and sandstone. The mudstone is generally yellowish with some brownish shade and the proportion of mudstone increases up-section. The sandstone is fine to medium grained, thin to medium bedded and often show cross-bedding. The present paper not only increases the sample size of antler remains from the Siwalik continental deposits but also highlight the phyletic relationships of family Cervidae in this region. But the exact phylogenetic relationships of different species of the family Cervidae in the Siwaliks and with neighbouring provinces during the time in question needs further research.

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