

## ***Sivaceros gradiens* Pilgrim 1937 (Mammalia, Bovidae, Boselaphini) from the Lower Siwaliks of Dhok Bun Amir Khatoon, Chakwal, Pakistan: systematics and biostratigraphy**

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Received: 30.12.2008

**Abstract:** A left horn core of *Sivaceros gradiens* Pilgrim 1937 from Dhok Bun Amir Khatoon in the Lower Siwaliks of Pakistan was recovered, identified, and compared. Earlier specimens of *S. gradiens* excavated from the Lower Siwaliks of Pakistan were difficult to date. Conversely, the new material of *S. gradiens* from the Lower Siwaliks of Dhok Bun Amir Khatoon suggests an early Middle Miocene age (lower Chinji) for this species.

**Key words:** *Sivaceros gradiens*, boselaphines, Lower Siwaliks, Middle Miocene, Dhok Bun Amir Khatoon

### **Introduction**

The Dhok Bun Amir Khatoon area comprises a nearly continuous geological record spanning from 18.4 to 4.5 Ma and exposes all 5 of the Siwalik formations (Kamlial, Chinji, Nagri, Dhok Pathan, and Soan) (Johnson et al., 1982). Cheema (2003) and Khan et al. (2008) described the Dhok Bun Amir Khatoon fauna in the middle part of the Chinji formation as comprising both macro- and microvertebrate assemblages. One of the most important aspects of the continuing research on the Dhok Bun Amir Khatoon site is the recovery of early Miocene ruminants from the genus

*Palaeohypsodontus* (Khan et al., 2008) and an upper 4th premolar from an unidentified artiodactyl (personal communication, Flynn and Barry).

The studied material of *S. gradiens* was recovered by M.A. Khan during an investigation that was part of the joint exploration program between the Zoology Department of the Government College University of Faisalabad and the Zoology Department at Punjab University, Lahore, Pakistan.

The holotype of *S. gradiens* (AMNH 19448) was first described by Pilgrim (1937, p. 795). His initial description was based on a partial skull, a lower jaw,

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a maxilla, and 3 molars (Pilgrim, 1937, pp. 841-843; 1939, p. 243). *Sivaceros gradiens* has been compared with *Miotragocerus* by Thenius (1956, p. 316) and subsequently with *Tragocerus gradiens* by Gentry (1970, p. 313; 1974, p. 175). Thomas (1984, p. 44) revived the earlier name *S. gradiens* for the holotype because he considered *S. gradiens* less derived from the complex of *Tragocerus* in the Siwaliks. Thomas (1984, p. 31) studied 2 horn cores (UZM 69/720, UZM 69/718), as well as a fragment of a skull (UZM 69/716), housed at Punjab University, Lahore, Pakistan, and designated those remains as paratypes of *S. gradiens*. The paratypes were collected by Sarwar (1977) and the locality is characteristic of the Kamliyal formation (personal communication, Sarwar).

The origin of *S. gradiens* holotype AMNH 19448 is unknown. Pilgrim (1937) attributes the holotype to a locality 12 miles east of the Chinji Bungalow, and he estimated that it was situated in the upper Chinji. If this was the exact locality, the holotype would have an Eocene origin (Thomas, 1984). It is more likely that the holotype specimen was collected 12 miles northeast of the Chinji Bungalow, which should be the Nagri formation (Colbert, 1935, p. 44). The geological map of Colbert (1935) shows the Chinji-Nagri formation boundary further south than is now

recognized. New maps with better formation boundaries within the Siwaliks show the areas south of the Chinji Bungalow, which belong to the top most part of the Chinji formation (Raza et al., 1983). This erroneous age assignment was based on incomplete locality information of the holotype and the paratypes.

Our new discovery of *S. gradiens* from a Middle Miocene site in Dhok Bun Amir Khatoon enables us to calibrate the stratigraphic position of this species. Previous researchers were unable to conclusively date former fossil remains of this species (Pilgrim, 1937, 1939; Thomas, 1984). Thus, the significance of this study is to shed new light on the age of *S. gradiens*.

### Materials and methods

The fossil site (72°55'45.4E, 32°47'26.4N) is located in Dhok Bun Amir Khatoon village, 23 km west of Chakwal District, Punjab, Pakistan (Figure 1). The fossiliferous deposits consist of shales, siltstones, and sandstones. The locality represents lateral facies associations and pedogenesis within the fine-grained, fossil-bearing floodplain deposits that are characteristic of fluvial depositional environments.

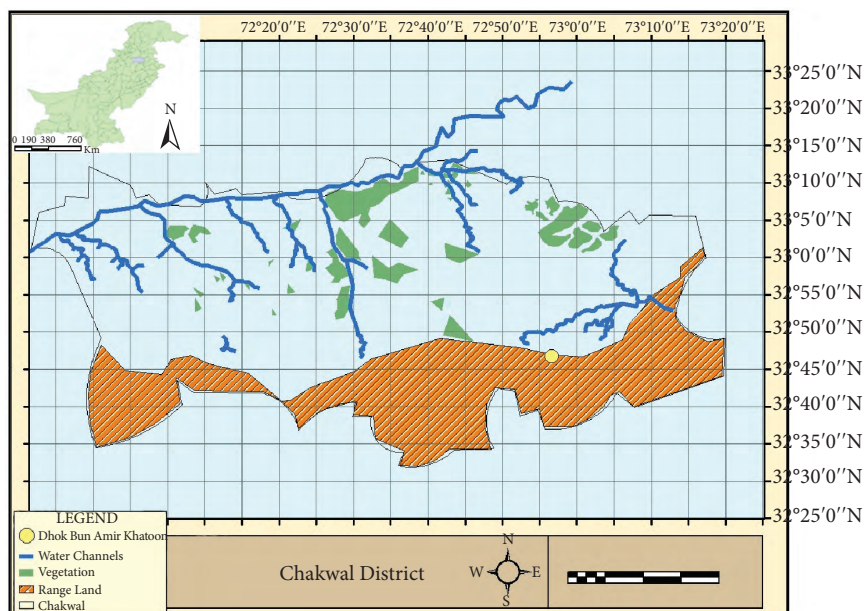


Figure 1. Map of Pakistan with an enlargement of the Chakwal area and the location of Dhok Bun Amir Khatoon, where the described material was found.

A number of field trips have been carried out since 2007. Surface collection was the primary method of collecting remains of vertebrates. As a result, identifiable specimens of boselaphines were discovered. The focus of this study was a left horn core (PUPC 08/8) that was partly exposed and excavated. The embedded material was carefully excavated with the help of chisels, geological hammers, fine needles, pen knives, hand lances, and brushes. In the laboratory, the material was carefully washed, cleaned, and prepared for study.

All measurements are in millimeters. The anteroposterior diameter (APD) corresponds to the large diameter of the horn core base, and it may not be parallel to the sagittal plane. The mediolateral diameter (MLD) is perpendicular to the APD. Comparative material was obtained from the American Museum of Natural History (AMNH) and the Punjab University Palaeontological Collection (PUPC), formerly called the Zoological Museum of Punjab University, Lahore, Pakistan (UZM).

## Results

### Systematic Paleontology

Order ARTIODACTYLA Owen 1848

Suborder RUMINANTIA Scopoli 1777

Family BOVIDAE Gray 1821

Subfamily BOVINAE Gray 1821

Tribe BOSELAPHINI Knottnerus-Meyer 1907

Genus *SIVACEROS* Pilgrim 1937

***Sivaceros gradiens* Pilgrim 1937**

*Miotragocerus gradiens* Thenius 1956

*Tragocerus gradiens* Gentry 1970

**Material:** PUPC 08/8, a left horn core (Figures 2a–2e, Table).

**Description:** The horn core has lost the tip but is complete at the base (Figures 2a–2e). At a length of 150 mm, the horn core base is asymmetric. At a length of 40 mm, the margin at the lateral aspect of the horn core is concave. The horn's cross section appears symmetrical and is shaped like an elongated oval (Figure 2e). It has the same relative proportions at the base of the horn core as the holotype. The horn core bends along its anterior edge. There are well marked anterior and posterior keels. Between the keels, the inner surface of the horn core is relatively flat, similar to both the holotype and the paratypes. The anterior keel terminates medially to the supraorbital foramen.

There are numerous narrow furrows along the anterior edge. The furrows are apparent over most of the horn core's surface. They are regular, fine, and



Figure 2. *S. gradiens* PUPC 08/8. a = anterior view, b = posterior view, c = medial view, d = lateral view, e = section of the horn core about 20 mm above its base. Scale bar = 10 mm.

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Table. Comparative measurements of the referenced *Sivaceros gradiens* specimens, in millimeters.

Description	Holotype AMNH 19448, 12 miles east of the Chinji Bungalow (Lower Siwaliks, Pakistan; Pilgrim, 1937)	Paratype UZM 69/718, Vasnal (Lower Siwaliks, Pakistan; Thomas, 1984)	Studied Specimen PUPC 08/8, Dhok Bun Amir Khatoon (Lower Siwaliks, Pakistan; this paper)
DAP base	43	40	46.4
DT base	24	21	29.5
DAP at 70 mm	35.5	30.2	30
DT at 70 mm			
Index of compression: DT base × 100/DAP base	55.8	52.5	63.5
Estimated length	(175-180)	(180-190)	(180-185)

straight in appearance and run from the base to the apex. The posterior edge is irregular. The posterior keel is less developed and the mediolateral compression is marked (Figures 2a–2e, Table).

## Discussion

### Taxonomic Position of *Sivaceros*

The morphology of the horn core suggests that it represents one of the earliest known members of the keeled boselaphines. The early boselaphines are characterized by horn cores situated directly above the orbit. The horn core (PUPC 08/8) is larger than those documented for *Eotragus* species and its contours are less concave and convex (Solounias et al., 1995). Moreover, the PUPC 08/8 posterior surface is convex and its medial edge is flattened posteriorly. The horn core is less stout than in both *Protragocerus* and *Miotragocerus* species, and thus cannot be grouped with these 2 genera (Thomas, 1984). *Elachistoceras kauristanensis* differs from the horn core because it is smaller in size and has a very simple conical form with a straight axis (Thomas, 1977; Akhtar and Nayyer, 2001). The horn core presents all of the fundamental characteristics of *S. gradiens*. Similarities include its length, upright appearance, well-defined base, and proposed position directly above the orbit. The morphological boundaries (contour) of the cross

section mirror that of both the holotype and the paratypes of *S. gradiens*.

### Biostratigraphy

In addition to *S. gradiens*, the following mammals were also documented from Dhok Bun Amir Khatoon: rhinoceroses (*Brachypotherium fatehjangense*), tragulids (*Dorcatherium minimus*), giraffids (*Giraffokeryx* sp.), bovids (*Eotragus* sp., *Gazella* sp.), proboscideans (gomphotheriid), and suids (*Listrodon pentapotamiae*).

The faunal assemblages found along with *S. gradiens* (PUPC 08/8) are almost identical to the rich assemblage represented from the Chinji formation at its type locality near the Chinji village (Raza et al., 1983). Raza et al. (1983) listed *S. gradiens* on the faunal list for the Chinji formation around the Chinji Bungalow. However, no description was provided for nonhominoid species (Raza et al., 1983). This paper is the first detailed description of *S. gradiens* from a new area that provides exact information on the locality and stratigraphic location.

Based on the taxa present in the upper stratum of the fossiliferous site, *S. gradiens* can be placed in the early to middle Miocene (Raza et al., 1983; Welcomme et al., 1997, 2001; Antoine and Welcomme, 2000; Lindsay et al., 2005; Khan et al., 2008). The Miocene date is further supported by the

presence of listriodont suids (Welcomme et al., 1997, 2001; Antoine and Welcomme, 2000) for the upper layer. Further support for this age comes from the presence of *Eotragus*, a late/early Miocene bovid of Europe and Pakistan (Solounias et al., 1995; Gentry et al., 1999; Khan et al., 2008), as well from the middle Miocene of China (Ye, 1989). *Brachypotherium fatehjangense* is known from the early Middle Miocene to the late Miocene in south Asia (Pakistan, India, and Thailand; Heissig, 1972; Antoine and Welcomme, 2000; Welcomme et al., 2001; Chavasseau et al., 2006). The recorded specimens of *B. fatehjangense* and *Eotragus* sp. from the fossiliferous site have the greatest affinity with the earliest Middle Miocene forms (Khan et al., 2008). The size and proportions of the Dhok Bun Amir Khatoon specimens of *B. fatehjangense* match those observed in the specimens originating from the earliest Middle Miocene of Pakistan (Welcomme et al., 2001; Khan et al., 2008).

The recovered *S. gradiens* demonstrates that the species does not belong to the upper Chinji formation, as previously believed by Pilgrim (1937, 1939) and Thomas (1984). *S. gradiens* is here considered to come from the lower Chinji, which is earliest Middle Miocene. The chronological age of the Chinji formation ranges from 14.3 to 10.8 Ma (Raza et al., 1983; Cheema, 2003 and references there in). Therefore, we attribute *S. gradiens* from the Dhok Bun

Amir Khatoon locality to the lower Chinji formation at its type locality and to the earliest Middle Miocene age.

Raza et al. (1983) described hominoids from the Lower Chinji, for which magnetostratigraphy indicates an age of 14.5 Ma. The unidentified tooth recovered from the site seems to be an artiodactyl's 4th premolar of the early Miocene (personal communication, Flynn and Barry). In light of the associated fauna, therefore, the Lower Chinji age (14 Ma) is assumed for *S. gradiens*. The combined occurrence of the above mentioned taxa in the locality suggests open but not grassy habitats, including some elements of fairly abrasive vegetation (Janis et al., 2002). The occurrence of *S. gradiens* together with *Eotragus* and *Dorcatherium* is rather indicative of swampy-paludal habitats (Rössner and Mörs, 2001).

### Acknowledgements

We are indebted to the staff of the Pakistan Natural History Museum for providing the required literature. We are grateful to Nadeem Fazal, who took the photos and made the plate. We also thank Adeeb (Faisalabad) for amending the plate and Razzaq for his efficient help during fieldwork. We are also grateful to 2 anonymous reviewers whose comments greatly improved this manuscript, and 1 of them is especially appreciated for giving this manuscript so much time.

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