



A new species of *Eostyloceros* (Cervidae, Artiodactyla) from the Late Miocene of the Linxia Basin in Gansu, China

TAO DENG^{1,2,3}, SHI-QI WANG¹, QIN-QIN SHI¹, YI-KUN LI^{1,4} & YU LI^{1,4}

¹Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China. E-mail: dengtao@ivpp.ac.cn

²CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing 100101, China

³Department of Geology, Northwest University, Xi'an 710069, Shaanxi, China

⁴University of Chinese Academy of Sciences, Beijing 100049, China

Abstract

A new species, *Eostyloceros hezhengensis* sp. nov., is established based on a skull with its cranial appendages collected from the Late Miocene Liushu Formation of the Linxia Basin in Gansu Province, northwestern China. It is a large-sized muntjak with a distinct longitudinal ridge along the lateral margin of the frontal bone that joins the antler pedicle. The pedicle is short, cylindrical, robust, and extends posteriorly from the rear of the orbit. The anterior and posterior branches arise from the burr and diverge at an angle of 30°. The posterior branch is relatively long, and its tip is strongly curved posteriorly. The anterior branch is straight and situated anteromedially from the posterior branch. The posterior branch is lateromedially compressed, and the anterior branch has a circular cross section. The morphological observation together with a cladistic and a principal component analysis indicate that *E. hezhengensis* is more basal than any known species of the genus *Eostyloceros* in having shorter pedicles, a lower position of the fork above the burr, more slender anterior branches, and a small angle between the anterior and posterior branches. Its age is the middle Late Miocene, corresponding to the late Bahean.

Key words: deer, northwestern China, Neogene, biostratigraphy, Liushu Formation

Introduction

The Linxia Basin in Gansu, China is famous for its rich late Cenozoic mammalian fossils. During 1980s-1990s, several new fossil mammals were studied and published, demonstrating the presence of not only a rich Late Miocene *Hipparion* fauna, but also a typical Late Oligocene *Dzungariotherium* fauna in this basin (Qiu *et al.* 1987, 1988, 1990, 1991; Qiu & Xie 1998). Since 2000, more new species of the Late Oligocene *Dzungariotherium* fauna, the Middle Miocene *Platybelodon* fauna, the Late Miocene *Hipparion* fauna, and the Early Pleistocene *Equus* fauna have been described from the Linxia Basin, including rodents, lagomorphs, primates, carnivores, proboscideans, perissodactyls and artiodactyls (Deng *et al.* 2013). The most fossiliferous part of the Linxia Basin occurs throughout almost the whole Hezheng County, the western half of Guanghe County, the southern half of Dongxiang County, Linxia City, and the eastern border area of Linxia and Jishishan counties, covering about 1300 km². The localities in the Linxia Basin are notable for abundant, relatively complete, well-preserved, and sometimes articulated bones of large mammals. In a recent geological survey for mammalian fossils, a complete muntjak skull with its cranial appendages (appendage = partial frontal bone + pedicle + antler) was collected from Gaojiashan in Guantangou Township, Hezheng County (Fig. 1).

Terminology and abbreviations Antlered and dental terms (Fig. 2) are according to Dong (2004, 2008), and cranial terms are according to Sisson and Grossman (1953). IVPP V or V, specimen prefix of the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China. LX, IVPP's fossil locality number in the Linxia Basin. Nr, specimen prefix of the Birger Bohlin's Qaidam collection.

E. hezhengensis is basal among all known species of the genus *Eostyloceros* in having shorter pedicles, a lower position of the fork above the burr, more slender anterior branches, and a small angle between the anterior and posterior branches, which are consistent with its age (middle Late Miocene or late Bahean, Qiu *et al.* 2013), earlier than *E. propria* (late Late Miocene), *E. blainvillei* (the late Late Miocene Baodean and the Early Pliocene Gaozhuangian), *E. pidoplitschkoi* (Early Pliocene), *E. maci* (Early Pliocene), and *E. longchuanensis* (Early Pleistocene). On the other hand, the deep furrows and high edges on the surface of the antler represent a derived character in the family Cervidae.

Acknowledgements

We are grateful to Qiu Zhanxiang, Wang Banyue, Hou Sukuan, and Xie Guangpu for their support in the fieldwork. We thank Lawrence Flynn for his English improvement, and Gao Wei for his photographs. Two anonymous reviewers and P. Gaubert are kindly acknowledged for their comments on the manuscript. This work was supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (XDB03020104), the Ministry of Science and Technology of China (2012CB821906), and the National Natural Science Foundation of China (40730210).

References

- Abbazzi, L. & Croitor, R. (2003) *Eostyloceros* cf. *pidoplitschkoi* Korotkevitch 1964 (Cervidae, Muntiacinae): new element in the Neogene mammal assemblage of lower Valdarno (Tuscany, Central Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 109, 575–580.
- Abdrakhmanova, L.T. (1974) Fossil ruminants from Lake Karabastuz. *Materialy po Istorii Fauny i Flory Kazakhstana*, 6, 83–92.
- Abdrakhmanova, L.T., Bajshashov, B.U. & Kostenko, N.N. (1989) New data on the paleontology of Dzhungarian Aktau (East Kazakhstan). *Vestnik Akademii Nauk Kazakhskoi SSR*, 3, 76–78.
- Azanza, B. & Montoya, P. (1995) A new deer from the lower Turolian of Spain. *Journal of Paleontology*, 69, 1163–1175.
- Azanza, B., Menendez, E. & Alcalá, L. (1989) The Middle-Upper Turolian and Ruscinian Cervidae in Spain. *Bollettino della Società Paleontologica Italiana*, 28, 171–182.
- Bohlin, B. (1937) Eine tertiäre säugetier-fauna aus Tsaidam. *Palaeontologia Sinica, Series C*, 14 (1), 3–111.
- Colbert, E.H. (1936) Tertiary deer discovered by the American Museum Asiatic Expeditions. *American Museum Novitates*, 854, 1–21.
- Deng, T., Qiu, Z.X., Wang, B.Y., Wang, X.M. & Hou, S.K. (2013) Late Cenozoic biostratigraphy of the Linxia Basin, northwestern China. In: Wang, X.M., Flynn, L.J. & Fortelius, M. (Eds.), *Fossil Mammals of Asia: Neogene Biostratigraphy and Chronology*. Columbia University Press, New York, pp. 243–273.
- Dong, W. (2004) The dental morphological characters and evolution of Cervidae. *Acta Anthropologica Sinica*, 23 (Supplement), 286–295.
- Dong, W. (2007) New material of Muntiacinae (Artiodactyla, Mammalia) from the Late Miocene of the northeastern Qinghai-Tibetan Plateau, China. *Comptes Rendus Palevol*, 6, 335–343.
<http://dx.doi.org/10.1016/j.crpv.2007.05.002>
- Dong, W. (2008) A review on morphology and evolution of antlers. In: Dong, W. (Ed.), *Proceedings of the Eleventh Annual Meeting of the Chinese Society of Vertebrate Paleontology*. China Ocean Press, Beijing, pp. 127–144.
- Dong, W., Ji, X.P., Jablonski, N.G., Su, D.F. & Li, W.Q. (2014) New materials of the Late Miocene *Muntiacus* from Zhaotong hominoid site in southern China. *Vertebrata Palasiatica*, 52, 316–327.
- Dong, W., Liu, J.H. & Pan, Y.R. (2003) A new *Euprox* from the Late Miocene of Yuanmou, Yunnan Province, China, with interpretation of its paleoenvironment. *Chinese Science Bulletin*, 48, 485–491.
<http://dx.doi.org/10.1360/03tb9103>
- Dong, W., Pan, Y.R. & Liu, J.H. (2004) The earliest *Muntiacus* (Artiodactyla, Mammalia) from the Late Miocene of Yuanmou, southwestern China. *Comptes Rendus Palevol*, 3, 379–386.
<http://dx.doi.org/10.1016/j.crpv.2004.06.002>
- Geraads, D. (2003) Ruminants, other than Giraffidae, from the Middle Miocene hominoid locality of Çandır (Turkey). *Courier Forschungsinstitut Senckenberg*, 240, 181–199.
- Goloboff, P.A., Farris, J.S. & Nixon, K.C. (2003) T.N.T.: Tree analysis using new technology. Program and documentation, available from the authors. Available from: <http://www.zmuc.dk/public/phylogeny> (accessed 4 November 2014)
- Korotkevich, E.L. (1964) A new species of fossil *Muntiacus* from the Pliocene deposits of the south of the USSR. *Dopovidi Akademii Nauk URSR*, 6, 807–810.

- Korotkevitch, E.L. (1970) *Late Neogene Deer from the North Black Sea Area*. Naukova Dumka, Kiev, 175 pp.
- Lartet, E. (1837) Note sur les ossements fossils des terrains tertiaires de Simorre, de Sansan, etc., dans le département du Gers, et sur la découverte récente d'une mâchoire de singe fossile. *Compte-rendu Hebdomadaires des Seances de l'Académie des Sciences, Paris*, 4, 85–93.
- Lin, Y.P., Pan, Y.R. & Lu, Q.W. (1978) The Early Pleistocene mammalian fauna from Yuanmou, Yunnan. In: Institute of Vertebrate Paleontology and Paleoanthropology (Ed.), *Proceedings of Paleoanthropology*. Science Press, Beijing, pp. 101–125.
- Qiu, Z.X. & Xie, J.Y. (1998) Notes on *Parelasmotherium* and *Hipparion* fossils from Wangji, Dongxiang, Gansu. *Vertebrata Palasiatica*, 36, 13–23.
- Qiu, Z.X., Xie, J.Y. & Yan, D.F. (1987) A new chilothere skull from Hezheng, Gansu, China, with special reference to the Chinese “*Diceratherium*”. *Scientia Sinica*, (5), 545–552.
- Qiu, Z.X., Xie, J.Y. & Yan, D.F. (1988) Discovery of the skull of *Dinocrocota gigantea*. *Vertebrata Palasiatica*, 26, 128–138.
- Qiu, Z.X., Xie, J.Y. & Yan, D.F. (1990) Discovery of some Early Miocene mammalian fossils from Dongxiang, Gansu. *Vertebrata Palasiatica*, 28, 9–24.
- Qiu, Z.X., Xie, J.Y. & Yan, D.F. (1991) Discovery of Late Miocene *Agriotherium* from Jiegou, Gansu, and its taxonomic implications. *Vertebrata Palasiatica*, 29, 286–295.
- Qiu, Z.X., Qiu, Z.D., Deng, T., Li, C.K., Zhang, Z.-Q., Wang, B.Y. & Wang X.M. (2013) Neogene land mammal stages/ages of China: toward the goal to establish an Asian land mammal stage/age scheme. In: Wang, X.M., Flynn, L.J. & Fortelius, M. (Eds.), *Fossil Mammals of Asia: Neogene Biostratigraphy and Chronology*. Columbia University Press, New York, pp. 29–90.
- Rafinesque, C.S. (1815) *Analyse de la Nature ou tableau de l'univers et des corps organisés*. L'imprimerie de Jean Barravecchia, Palerme, 223 pp.
- Schaub, S. (1928) Die Antilopen des toskanischen Oberpliocäns. *Eclogae Geologicae Helvetiae*, 21, 260–266.
- Sisson, S. & Grossman, J.D. (1953) *The Anatomy of the Domestic Animals*. W. B. Saunders Company, Philadelphia, 972 pp.
- Spassov, N. (2005) Brief review of the Pliocene ungulate fauna of Bulgaria. *Quaternaire*, Hors-série 2, pp. 201–212.
- Stehlin, H.G. (1928) Bemerkungen über die Hirsche von Steinheim am Aalbuch. *Eclogae Geologicae Helvetiae*, 21, 245–256.
- Teilhard de Chardin, P. & Trassaert, M. (1937) The Pliocene Camelidae, Giraffidae, and Cervidae of South Eastern Shansi. *Palaeontologia Sinica*, New Series C, 1, 1–56.
- Thomas, J.M. (1951) *Eostyloceros pierensis* nov. sp., nouveau cervuline du Pontien européen. *Comptes Rendus Sommaires des Seances de la Societe Geologique de France*, 6, 255–257.
- Vislobokova, I.A. (1983) The fossil deer of Mongolia. *Transaction of the Joint Soviet-Mongolian Paleontological Expedition*, 23, 1–78.
- Vislobokova, I.A. (1985) Concerning a new *Eostyloceros* from the Pliocene of Olkhon Island (Lake Baykal). *Paleontological Journal*, 4, 123–125.
- Vislobokova, I.A. (1990) Fossil deer of Eurasia. *Transactions of the Paleontological Institute*, 240, 1–206.
- Wang, B.Y. & Wu, W.Y. (1979) Artiodactyla. In: Institute of Vertebrate Paleontology and Paleoanthropology (Ed.), *Vertebrate Fossils of China*. Science Press, Beijing, pp. 501–620.
- Wang, S.Q. & Deng, T. (2010) Recovering the missing data of defective fossil specimens using linear regression method. *Vertebrata Palasiatica*, 48, 161–181.
- Wang, X.M., Qiu, Z.D., Li, Q., Wang, B.Y., Qiu, Z.X., Downs, W.R., Xie, G.P., Deng, T., Takeuchi, G., Tseng, Z.J., Chang, M.M., Liu, J., Wang, Y., Biasatti, D., Sun, Z.C., Fang, X.M. & Meng, Q.Q. (2007) Vertebrate paleontology, biostratigraphy, geochronology, and paleoenvironment of Qaidam Basin in northern Tibetan Plateau. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 254, 363–385.
<http://dx.doi.org/10.1016/j.palaeo.2007.06.007>
- Wang, X.M., Xie, G.P., Li, Q., Qiu, Z.D., Tseng Z.J., Takeuchi, G.T., Wang, B.Y., Fortelius, M., Rosenström-Fortelius, A., Wahlquist, H., Downs, W.R., Zhang, C.F. & Wang, Y. (2011) Early explorations of Qaidam Basin (Tibetan Plateau) by Birger Bohlin: reconciling classic vertebrate fossil localities with modern biostratigraphy. *Vertebrata Palasiatica*, 49, 285–310.
- Zdansky, O. (1927) Weitere Bemerkungen über fossile Cerviden aus China. *Palaeontologia Sinica*, Series C, 5 (1), 1–20.
- Zdansky, O. (1925) Fossile Hirsche Chinas. *Palaeontologia Sinica*, Series C, 2 (3), 1–90.
- Zhang, Y.X. & Xue, X.X. (1995) *Taphonomy of Longjiagou Hipparionine Fauna (Turolian, Miocene), Wudu County, Gansu Province, China*. Geological Publishing House, Beijing, 96 pp.