EVIDENCES OF EARLY PLIOCENE FOSSIL REMAINS OF TRIBE CERVINI (MAMMALIA, ARTIODACTYLA, CERVIDAE) FROM THE SIWALIKS OF PAKISTAN

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ABSTRACT

In this study we mentioned the Cervini material from the Early Pliocene of the Siwaliks. Previous workers described the cervid taxa from Late Pliocene - Pleistocene but the recent collection of cervids material from two well-known fossil sites extend the range of Cervidae fossils into the Early Pliocene – Pleistocene. Early Pliocene age is assigned to these fossil sites based on magnetostratigraphy combined with biostratigraphy, which provides better age control on these fossils, which can then be used to correlate the biostratigraphy of the Siwalik continental deposits.

Key words: Early Pliocene; Cervidae; magnetostratigraphy; biostratigraphy; Siwaliks; Pakistan.

INTRODUCTION

In this study we mentioned the Cervini material from the upper Middle Siwaliks while previous workers described the cervid taxa from the Upper Siwaliks (Lydekker, 1876, 1880, 1884; Brown, 1926; Arif et al., 1991; Arif and Raza, 1991; Akhtar et al., 1999; Ghaffar et al., 2004). The taxonomic details of family Cervidae from the Siwaliks of Pakistan had been studied for more than one century but the major problem for recent studies faced by the palaeontologists is the stratigraphic analysis of fossils collecting sites. The purpose of this paper is to provide the stratigraphic analyses of two well known fossil sites from where the cervids material is collected and to highlight the older stratigraphic ranges that mentioned by the earlier workers (Figure 1a-b). Magnetostratigraphy is a tool for correlating the normal and reversed polarity zones of a rock succession to the magnetic anomalies of the standard geomagnetic polarity time scales if some approximate age control is available from biostratigraphy. The reversal events are calibrated using isotopic dates on the equivalent terrestrial records throughout the globe. In brief, magnetostratigraphy is a correlation tool rather than an absolute dating method and is often used for the refinement of biostratigraphy (Cande and Kent, 1992). The sediment accumulation rates derived from different sections throughout the Himalayan foreland indicates notable rise during Nagri Formation and records the largest fluctuations after 1.7 Ma (Sangode and Kumar, 2003). Relative abundance of suitable iron oxide that can ideally preserve the in situ records of earth's magnetic field permits successful reconstruction of magnetic polarity events of the Late Cenozoic Siwalik Group of sediments in the Himalayan Foreland Basin (HFB) (Burbank and Beck, 1991; Johnson et al., 1982)

Stratigraphic correlation using the records of remnant magnetic polarity has been done extensively in the Late Cenozoic Siwalik Group of the Potwar Plateau of Pakistan. Raynolds and Johnson (1985) calculated a rate of southward progradation of lateral facies changes up to 30 m/1000 years together with the southward advancement of basin depo-centers at rates of over 20 m/1000 years in the Potwar Plateau of Pakistan. They suggested a rough equilibrium between the modelled northward plate motion of the Indian subcontinent and the southward displacement of depositional processes within the foredeep. There is an increase in sedimentation in all the basins at ~ 10 Ma (the onset of Nagri Formation). Another notable event occured at ~ 5 Ma (Latest Dhok Pathan Formation, Early Pliocene) where there is increase in Bengal Fan sedimentation but a decrease in the Ganga Basin. The maximum of Sediment Accumulation Rate (SAR) in the HFB is increased, but it shows notable minimum values, too. The overall trend suggests that during this period the SAR has increased in the recesses while it remains unaltered in salients (Burbank et al., 1996). The Early Pliocene is the largest period where the SAR appears to be constant for a long time throughout the HFB. At ~ 2.5 Ma (Late Pliocene), the variability in SAR throughout the basin had increased and became optimum after ~ 1.7 Ma (Pleistocene) in all the basins except the Ganga Basin. This period is characterized by the widespread deposition of boulder conglomerates. Thus the SAR variability after 1.7 Ma indicating the large range of maxima and minima, therefore, suggests an enhanced differential tectonic activity in this terminal stage of HFB (Mankinen and Dalrymple, 1979; Sangode and Kumar, 2003).

According to Barry and Flynn (1989), confusion prevails in the history and usage of biostratigraphic terminology in the Siwaliks. Pilgrim (1910, 1913) recognized a series of successive faunal zones, based on a mixture of contained fauna and lithological criteria. In most instances their superpositional relationships could be demonstrated, but the boundaries of the faunal zones could not be delineated and because of mistakes in correlation, the faunal content of some zones could never be adequately differentiated. Later on, Pilgrim's faunal zones came to be used primarily as lithostratigraphic formations. Barry *et al.*, (1980, 1982) divided the existing zones as interval-zones. Each interval-zone had a defined base and included the entire stratigraphic interval below the base of the succeeding zone. However, the Siwaliks interval-zone boundaries were based on biological events and referred biostratigraphic interval-zone.

The first ruminants appeared in the middle Eocene record (55Ma) of Asia and North America, and their origin lies within the initial artiodactyl radiation (Rose, 1996; Ginsburg *et al.*, 1994). Cervids appeared in the Oligocene and were characterized by a small size and a lack of antlers. Early small cervids, e.g., *Eumeryx* and *Iberomeryx*, appeared in the Middle Oligocene sediments

of Central Asia from where they dispersed to Europe and North America, most probably in the Early Miocene (Savage and Russel, 1983). With the origin of cervids in the late Early Miocene (MN3), a second radiation within the Ruminantia started and led to ruminants becoming a major component in fossil faunas without any record of the initial evolution of antlers. Early to Middle Miocene cervids show great dental and skeletal similarities to their moschid ancestors. The dentition of these early cervids is generally comparable with those of Moschidae with a most advanced brachydont cervoid dentition (Gentry et According to Pitra et al., (2004), the al., 1999). evolutionary radiations of Old World deer occurred at Miocene/Pliocene transition. Molecular phylogenetics based on mitochondrial DNA, nuclear DNA or amino acid sequence comparisons have contributed considerably to resolve evolutionary relationships at the family level, but these studies did not fully resolve the phylogeny of the Cervinae, because they lacked many of the extant Old World deer species.



Figure 1a. Map of Pakistan (inset) with an enlargement of study areas (Dhok Pathan and Hasnot) from Jehlum and Chakwal districts.

According to Di Stefano and Petronio (2003) the Late Miocene *Cervocerus novorossiae* is the most primitive member of the Cervinae and also identified Early/Middle Pliocene *Cervus magnus* from Eurasia, but such type of studies were not conducted yet for subcontinent India including Pakistan, from where the fossils described here were collected. As a result these fossils are the only source that provides clues for Early Pliocene cervids from the Siwaliks of Pakistan. The findings described here are also supported, as (1) the Cervini and Muntiacicni split is reported at the transition of Miocene-Pliocene; due to this reason Early Pliocene age is referred to these fossil sites, (2) Some isolated molar remains of *Hipparion* also indicate the Early Pliocene age, and (3) an unconformity is present close to the Miocene-Pliocene boundary. This unconformity is angular, with the underlying Miocene units having been deformed and eroded prior to deposition of the Pliocene succession. The deposits at Hasnot include a succession of rocks of similar lithology with those at the Dhok Pathan type locality (10.1 Ma – ca 3.5 Ma) (Barry *et al.*, 2002). The mammalian fauna (including cervids, bovids, giraffids and suids) suggests a Late Miocene-Early Pliocene age (Dickinson *et al.*, 2002; this paper).

Tatrot

Dhok

Nagri

Chinji

3.5 ma

10.1 ma

11.2 ma

14.2 ma

The recovered fossils material came from localities of Dhoh Pathan (33° 33' 32.09 N.: 73° 9' 24.56 E) and Hasnot (32° 49' 27.89 N,: 73° 07' 52.68 E). The Dhok Pathan fossil site is situated 65 km NE from Chakwal city and is extremely rich in fossils. The Hasnot fossil site is situated about 54 km west of the Jehlum city in the Potwar Plateau of northern Pakistan (Figure 1a-b), surrounded by extensive Neogene freshwater sedimentary rocks. The region of the Hasnot exposes the most complete sequence of the Siwalik group and yielded a diversified fossil assemblage of the Dhok Pathan Formation. These two fossil sites represent lateral facies associations within the fine-grained fossil-bearing

floodplain deposits that are characteristic of a fluvial depositional environment (Barry et al., 2002; Barry and Flynn, 1989; Wills and Behrensmeyer, 1995; Behrensmeyer et al., 1995).

Lithostratigraphically, the sediments belong to Upper Dhok Pathan Formation (Middle Siwaliks equivalent to European Early Ruscinian), which is characterized by sandstones with alternate clays and scattered conglomerates in the lower part and conglomerate with sandstone and clays in the upper part. The clay is orange brown in color, and the time of deposition ranges from 5.3-3.5 Ma (Pilbeam et al., 1977; Johnson et al., 1982; Barry et al., 1982).



Figure 1b. Map of Potwar Plateau (northern Pakistan) with fossil sites and stratigraphic section of the major Siwalik formations (modified from Behrensmeyer and Barry, 2005 and the boundary dates are from Barry et al., 2002).

According to Dickinson et al. (2002), an unconformity is present close to the Miocene- Pliocene boundary. This unconformity is angular (generally<1-5° angularity), with the underlying Miocene units having been deformed and eroded prior to the deposition of the Pliocene succession. This unconformity also indicates the accumulation of siliciclastic-rich sediments in Pliocene time. The fossil sites (Figure 1a-b) from the Siwaliks also confirm these characteristics. Analysis of hypsodonty and dietary structure of the mammalian plant- eater community in Europe shows that the Miocene-Pliocene boundary was marked by a strong decrease in mesodont species and mixed feeders, and an increase in brachydont species and omnivores (Fortelius et al., 2006). This is also confirmed by the hypsodont/brachydont teeth of the described species. Fossil records of cervid taxa reveal that these were browsers. Information from red silty clay and loess of the Late Miocene have been studied and correlated. Complete summary profiles with projected isotopic ages and fossil bearing beds have been assembled. Pliocene environments progressed from less warm moist, cool- dry, slight-warmer-moister with sparse grassland and dry grassland based on corresponding

paleo-climatic environments and the characters of mammalian assemblages contained in each unit (Xiangxu et al., 2006). The primitive cervids were probably tropical in distribution, inhabited interspersed woodland or open country (not closed forest) and probably lived in eastern Eurasia or India (not western Eurasia or Southern Asia). The open woodlands or grassy woodlands environments are also indicated by the carbon isotope record after 7.4 Ma (Barry et al., 2002). The fossil record Cervus shows that elaphus occurs in both interglacial/woodland and glacial/steppe faunal complexes (Kahlke, 1976; Lister, 1984; 1986; Sommer et al., 2008), suggesting that the species has a broad tolerance of different habitats.

MATERIALS AND METHODS

The cervids material used in this study had been collected from two different fossil sites of Dhok Pathan and Hasnot (Figure 1a). The collections were carried out during different field seasons and were collected primarily from surface deposits. In addition, some of the specimens used in this study already were in the collection of the Paleontology Laboratory, University of the Punjab, Lahore, Pakistan and had been collected in the past from the above-mentioned localities of Dhok Pathan and Hasnot.

SYSTEMATIC PALEONTOLOGY

Order Artiodactyla Owen, 1848 Family Cervidae Goldfuss, 1820 Subfamily Cervinae Goldfuss, 1820 Tribe Cervini Weber, 1928

Genera

Rucervus Hodgson, 1838, Cervus Linnaeus, 1758 Axis Smith and Pedgeon, 1827

Species

Rucervus simplicidens (Lydekker, 1876) Cervus triplicidens Lydekker, 1876 Cervus sivalensis Lydekker, 1884 Cervus rewati Arif, shah and Vos, 1991 Axis punjabiensis (Brown, 1926)

Referred Specimens: Maxillary and mandibular fragments mentioned in Table 1.

DISCUSSION

In this study we mentioned the 17 cervids specimens already described with some systematic dispute and later on confirmed by other authors (Azzaroli, 1954, Ghaffar, 2010). But their stratigraphic confusions are still prevailed and in this paper same are addressed to confirm these biases. The specimens (PUPC # 83/104, 84/115, 87/276, 2002/20) referred to Rucervus simplicidens has been collected from the upper Middle Siwaliks (Early Pliocene). The specimens (PUPC # 69/146, 83/286, 98/77, 2003/34) referred to Cervus triplicidens and also collected from the upper Middle Siwaliks (Early Pliocene). The specimens (PUPC # 84/119, 87/279) referred to Cervus sivalensis and also collected from the upper Middle Siwaliks (Early Pliocene). The specimen (PUPC # 2002/06) referred to Axis punjabiensis and also collected from the upper Middle Siwaliks (Early Pliocene). The specimens (PUPC # 83/105, 85/96, 2001/34, 2002/01, 2002/35, 205/12) referred to Cervus rewati and also collected from the upper Middle Siwaliks (Early Pliocene).

PUPC no. and Dental position	Place of collection	Assigned to
83/104, rm1-2	Hasnot (Jhelum)	R.sipmlicidens (Lydekker, 1876)
84/115, IM2-3	Dhok Pathan (Chakwal)	R.sipmlicidens
85/97, lm2-3	Hasnot (Jhelum)	R .sipmlicidens
87/276, rp2-m1	Dhok Pathan (Chakwal)	R. sipmlicidens
2002/20, lm2-3	Dhok Pathan (Chakwal)	R. sipmlicidens
69/146, lm1-3	Dhok Gaal (Jhelum)	C. triplidense, Lydekker, 1876
98/77, 1 & r M2-3, L& r m1-3	Dhokpathan (Chakwal)	C. triplidens
2003/34, Maxilla with molars (l&r M1-3)	Dhok Pathan (Chakwal)	C. triplidens
83/286, lm2-3	Dhok Pathan (Chakwal)	C. sivalensis Lydekker,1876
84/119, lm2-3	Dhok Pathan (Chakwal)	C. sivalensis
87/279, rm3, rm1-3	Dhok Pathan (Chakwal)	C. sivalensis
2002/6, lp2-4	Dhok Pathan (Chakwal)	A. punjabiensis (Brown, 1926)
83/105,rm2-3	Hasnot (Jhelum)	C. rewati, Arif & Shah, 1991
85/96,rp4-m1	Hasnot (Jhelum)	C. rewati
2001/34,rm2-3	Dhok Pathan (Chakwal)	C. rewati
2002/1,rm2-3	Dhok Pathan (Chakwal)	C. rewati
2002/35,lm1-3	Dhok Pathan (Chakwal)	C. rewati

 Table 1.-Fossils of tribe Cervini, Abbreviations; PUPC: Punjab University Paleontological collection; M: upper molars, m: Lower molars; p: lower premolars; r: right; l; left; R: Rucervus, C: Cervus.

As concerns the fossil record and stratigraphic analysis from the Early Pliocene, our analyses are also supported by mitochondrial DNA analysis (Ghaffar, 2005; Ghaffar *et al.*, 2010; Ludt *et al.*, 2004). Concerning the phylogenetic relationships of different cervid taxa, much more fossil material including the maxillae and associated antlers is needed to confirm these biases from the Siwalik continental deposits. Summary of the described specimens and species is given in table 1. **Conclusion:** The different species within family Cervidae described here represent the stratigraphic range from Early Pliocene – Pleistocene times (5.3-1.6 Ma), not from Late Pliocene – Pleistocene (3.5-1.6 Ma; Upper Siwaliks). Barry and Flynn (1989) also mentioned the first appearance of family Cervidae from the Upper Siwaliks at 2.5 Ma. Perhaps one basic reason for this dispute was the stratigraphic confusions that has been resolved now as a result of refined magnetostratigraphy (Johnson *et al.*, 1982), as an example Chinji Formation

was considered as Pliocene age in previous literature (Matthew, 1929; Colbert, 1935), but now the age of this Formation is considered as Late Miocene (14.2- 11.2 Ma). Similarly, the age of Dhok Pathan Formation is 10.1 - ca 3.5 Ma or Late Miocene - Pliocene (Barry *et al.*, 2002; Barry and Flynn, 1989; Cheema *et al.*, 1977) and hence the species described here are from the upper Middle Siwaliks extending the stratigraphic range of Cervidae from Middle Siwaliks – Upper Siwaliks.

Acknowledgements: We are grateful to Raja M. Ibrahim (senior Librarian, Library services, CIIT, Islamabad) and Ms. Sana Javed (HEC Digital Library) for providing the important literature. This research has been supported by grant made to Abdul Ghaffar (Vertebrate evolution, Biogeographic relationships and Paleoenvironments of the Siwaliks of Pakistan) by Higher Education Commission, Pakistan (HEC. No. 20-898/R&D/07).

REFERENCES

- Akhtar, M., A. Ghaffar and M. A. Qureshi (1999). On *Cervus punjabiensis* Brown from the Siwalik Hills of Pakistan and Azad Kashmir. Punjab Uni. J. Zool., 14, 93-96.
- Arif, M. and S.M. Raza (1991). New findings of Cervidae (Mammalia) from the Upper Siwaliks of Potwar-Mirpur Areas, Pakistan. Proceedings Pakistan Congress of Zoology, 11, 275-281.
- Arif, M., S. M. I. Shah and J. D. Vos (1991). Cervus rewati sp. nov. (Mammalia, Cervidae) from the Upper Siwaliks of Pakistan. Geological Survey of Pakistan, Memoirs, 17, pt.11.
- Azzaroli, A. (1954). Critical observations upon Siwalik deer. Proceedings of the Linnaean Society of London, 75-87.
- Barry, J. C., A. K. Behrensmeyer and M. Morgan (1980). A geologic and biostratigraphic framework for Miocene sediments near Khaur Village, northern Pakistan. Postilla, 183: 1-19.
- Barry, J. C., E. H. Lindsay and L. L. Jacobs (1982). A biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology, 37: 95-130.
- Barry, J. C., N. M. Johnson, S. M. Raza and L.L. Jacobs (1985). Neogene mammalian faunal change in Southern Asia: Correlations with climatic, tectonic, and eustatic events. Geology, 13: 637-640.
- Barry, J. C., M. Morgan, L. J. Flynn, D. Pilbeam, A. K. Behrensmeyer, S. M. Raza, I. Khan, C. Badgely, J. Hicks and J. Kelley (2002). Faunal and Environmental change in the Late Miocene Siwaliks of Northern Pakistan. Palaeobiology, 28: 1-72.

- Barry, J. C. and L. J. Flynn (1989). Key biostratigraphic events in the Siwalik Sequence. In: European Neogene Mammal Chronology (ed. E.H. Lindsay *et al.*), New York, 557-571.
- Behrensmeyer, A. K., B. J. Wills and J. Quade (1995). Floodplains and paleosols of Pakistan Neogene and Wyoming Paleogene deposits: a comparative study. Palaeogeography, Palaeoclimatology, Palaeoecology, 115: 37-60.
- Behrensmeyer, A. K. and J. C. Barry (2005). Biostratigraphic surveys in the Siwaliks of Pakistan: A method for standardized surface sampling of the vertebrate fossil record Palaeontologia Electronica, 8(1): 1-24.
- Brown, B. (1926). A new deer from the Siwalik. American Museum Novitates, 242:1-6.
- Burbank, D. W., R. A. Beck and T. Mulder (1996). The Himalayan Foreland, in Yin A. and Harrison, M. (eds.), Asian Tectonics: Cambridge University Press, 149-188.
- Burbank, D. W. and R. A. Beck (1991). Models of aggradation versus progradation in the Himalayan foreland. Ceologische Rundschau, 80: 623-638.
- Cande, S. C. and D. V. Kent (1992). A new geomagnetic polarity timescale for the Late Cretaceous and Cenozoic. Journal of Geophysical Research, 97B:13917-13951.
- Cheema, M. R., S. M. Raza and H. Ahmad (1977). Cainozoic, in Shah, S. M. I. (ed.), "Stratigraphy of Pakistan." Geological Survey of Pakistan Memoirs, 12: 56-98.
- Colbert, E. H. (1935). Siwalik Mammals in the American Museum of Natural History. Transactions of the American Philosophical Society, new series, 26: 1-401.
- Dickinson, J. A., M. W. Wallace, G. R. Holdgate, S. J. Gallagher, L. Thomas (2002). Origin and Timing of the Miocene-Pliocene Unconformity in Southeast Australia. Journal of Sedimentary Research, 72(2): 288-303.
- Di Stefano, G. and C. Petronio (2003). Systematics and evolution of the Eurasian Plio-Pleistocene tribe Cervini (Artiodactyla, Mammalia). Geol. Romana, 36: 311–334.
- Fortelius, M., J. Eronen, L. P. Liu, D. Pushkina, A. Tesakov, I. Vislobokova and Z. Zhang (2006). Late Miocene and Pliocene large land mammals and climatic changes in Eurasia, Palaeogeography, Palaeoclimatology, Palaeoecology, 238, (1-4): 219-227.
- Gentry, A. W., G. E. Rossner and E. P. S. Heizman (1999). Suborder Ruminantia, in Rossner, G. E and Heissing, K. (eds.), The Miocene land mammals of Europe. Munchen, Dr. Friedrich Pfeil, 225-258.

- Ghaffar, A. (2005). Studies on equids, cervids and Carnivora from the Siwalik Hills of Pakistan, PhD thesis, University of the Punjab, Lahore, 1-389.
- Ghaffar, A., M. A. Khan and M. Akhtar (2010). Early Pliocene Cervids (Artiodactyla-Mammalia) from the Siwaliks of Pakistan. Yerbilimleri, 31(3): 217-231
- Ghaffar, A., M. Akhtar, M. A. Khan and M. Nazir (2004). Report on *Cervus sivalensis* from the Upper Siwaliks of Pakistan. Punjab Univ. J. Zool., 19: 83-88.
- Ginsburg, L., J. Morales and D. Soria (1994). The ruminants (Artiodactyla, Mammalia) from the lower Miocene of Cetina de Aragon (Province of Zaragoza Aragon, Spain)- Proceedings of the Koninklijke Nederlandse Akademie Van Wetenschappen, Amsterdam, 97(2): 141-181.
- Johnson, N. M., N. D. Opdyke, G. D. Johnson, E. H. Lindsay and R. A. K. Tahirkheli (1982). Magnetic polarity stratigraphy and ages of Siwalik Group rocks of the Potwar Plateau, Pakistan. Palaeogeography, Palaeoclimatology, Palaeoecology, 37: 17-42.
- Kahlke, H. D. (1976). Die Cervidenreste aus den Travertinen von Taubach. Quartarpalaontologie, 2: 209–223.
- Lister, A. M. (1984). Evolutionary and ecological origins of British deer. Proceedings of the Royal Society of Edinburgh, 82B: 205–229.
- Lister, A. M. (1986). New results on deer from Swanscombe, and the stratigraphical significance of deer remains in the middle and upper Pleistocene of Europe. Journal of Archaeological Science, 13: 319–338.
- Ludt, J. C., W. Schroeder, O. Rottman and R. Kuehn (2004). Mitochondrial DNA phylogeography of red deer (*Cervus elaphus*). Molecular Phylogenetics and Evolution, 1064-1083.
- Lydekker, R. (1876). Molar teeth and other remains of Mammalia from the Indian Tertiaries. Paleontologica Indica, (16) 1: 2-19.
- Lydekker, R. (1880). "Preface" to volume 1 of Paleontologica Indica. Paleontologica Indica, (X), 1: vii-xix.
- Lydekker, R. (1884). Rodents and New Ruminants from the Siwalik and synopsis of Mammalia; Paleontologica Indica, (10) 3: 1-5.
- Mankmen, E. A. and G. B. Dalrymple (1979). Revised geomagnetic polarity time scale for the interval 0-5 m.y. B.P. Journal of Geophysical Research, 84B: 615-626.

- Matthew, W. D. (1929). Critical observations upon Siwalik Mammals. Bulletin American Museum of Natural History, LVI: 437-560.
- Pilbeam, D., J. Barry, G. E. Meyer, S. M. I. Shah, M. H. L. Pickford, W. W. Bishop, H. Thomas and L.L. Jacobs (1977). Geology and palaeontology of Neogene strata of Pakistan. Nature, London, 270: 684-689.
- Pilgrim, G. E. (1910). Notices of new Mammalian genera and species from the Tertieries of India-Calcutta. Records of Geological Survey of India, 40, 63-71.
- Pilgrim, G. E. (1913). Correlation of the Siwaliks with Mammal Horizons of Europe. Records of Geological Survey of India, XLIII. 264-326, pt.4, pls. XXVI-XXVIII.
- Pitra, C., J. Fickela, E. Meijaard and C. P. Groves (2004). Evolution and phylogeny of old world deer. Molecular Phylogenetics and Evolution, 33: 880–895.
- Raynolds, R. G. H. and G. D. Johnson (1985). Rate of Neogene depositional and deformational processes, north-west Himalayan foredeep margin, Pakistan. Geological society of London, Memoirs, 10: 297-311.
- Rose, K. (1996). On the origin of the order Artiodactyla. Proceeding of the National Academy of Science of the USA. 93: 1705-1709.
- Sangode, S. J. and R. Kumar (2003). Magnetostratigraphic correlation of the Late Cenozoic fluvial sequences from NW Himalayas, India, Current Science, 84(8): 1014-1024.
- Savage, D. E. and D. E. Russel (1983). Mammalian Paleofaunas of the World, London. Addison -Wesley. 432pp.
- Sommer, R. S., F. E. Zachos, M. Street, O. Joris, A. Skog and N. Benecke (2008). Late Quaternary distribution dynamics and phylogeography of the red deer (*Cervus elaphus*) in Europe. Quaternary Science Reviews, 27: 714-733.
- Wills, B. J. and A. K. Behrensmeyer (1995). Fluvial systems in the Siwalik Neogene and Wyoming Paleogene. Palaeogeography, Palaeoclimatology, Palaeoecology, 114: 13-35.
- Xiangxu, X., Z. Yunxiang and Y. Leping (2006). Paleoenvironments indicated by the fossil mammalian assemblages from red clay-loess sequence in the Chinese Loess Plateau since 8.0 Ma B.P. Science in China: Series D Earth Sciences, 49(5): 518-530.