Ichnos, 11:363–370, 2004

ISSN: 1042-0940 print / 1563-5236 online
DOI: 10.1080/10420940490428724

Taylor & Francis
Taylor & Francis Group

New Eocene Mammal and Bird Footprints from Birjand Area, Eastern Iran

Majid Mirzaie Ataabadi
Department of Geology, Faculty of Science, University of Esfahan, Iran

Ahmad Reza Khazaee
Department of Geology, Faculty of Science, University of Birjand, Iran

New investigations in the Middle Eocene volcanosedimentary deposits, north of Birjand in eastern Iran, have resulted in the recovery of new mammal footprints (described as *Palaeotheriipus sarjeanti* nov. ichnosp.) and the first bird tracks (described as *Gruipeda lambrechti* nov. ichnosp.).

Keywords Footprints, mammals, birds, Eocene, Birjand, eastern Iran

INTRODUCTION

The volcanosedimentary deposits of Chahkand village, in the Birjand area of eastern Iran (Fig. 1), recently have produced a number of vertebrate footprints studied preliminarily by Mirzaie Ataabadi and Sarjeant (2000). These deposits are divided into three volcanosedimentary complexes. The middle (footprint-bearing) complex (Middle Eocene) appears to have been deposited in a terrestrial environment (Fauvelet et al., 1990). New studies on the sedimentology and depositional environment of the middle complex, including the footprint-bearing strata, indicate that these deposits consist of three major lithofacies and seven sublithofacies: (1) A siliciclastic facies that includes a siltstone and a sandstone subfacies, (2) a carbonate facies that includes a micrite and a dolomicrite subfacies, and (3) a volcanosedimentary facies that includes a crystaline, a carbonaceous, and a coarse grained tuff subfacies. These facies indicate that the sediments of the middle complex were deposited in a back arc basin (Nadjafi et al., 2003).

Back arc basins filled with volcanosedimentary sediments in a short period of time, and their evolution takes place in three main stages (Einsel, 2000). The sedimentary basin in the study area appears to represent the second stage of evolution (Nadjafi et al., 2003) where, after the opening of ocean floor in unstable areas in the first stage, the continuing subsidence takes place and volcanic activity in the active arc zone produces a large amount of pyroclastic and tuffaceous material. Inactive arcs accumulate pelagic sediments that occasionally enter these basins (Einsel, 2000).

A preliminary study of the previously found footprints from the middle complex concluded that at least Perissodactyles and Mesonychoids are among the possible track makers (Mirzaie Ataabadi and Sarjeant, 2000). However, Nadjafai et al. (2003) according to the results of the recent work of Mustoe (2002), on the mammalian footprints of Chuckanut Formation in northwest Washington, have championed the Pantodontan and Dinoceratan affinities of these footprints.

MATERIAL AND METHODS

The track-bearing strata are exposed just beyond the western limit of Chahkand village, north of Birjand in eastern Iran. Mammal tracks occur throughout two micritic levels (Fig. 2). The new mammal tracks studied herein are from the second footprint-bearing micritic level and consist of three tracks, one well preserved and two poorly preserved. The footprints and the trackway (Fig. 3) were traced in situ on a transparent sheet and then excavated and separated from their original position. They are now deposited in the Hamedan Museum of Natural History (HMNH), Iran. In addition, latex casts and plaster moulds have been prepared for further detailed studies. The casts and replicas are stored in Esfahan University Geology Museum (EUGM), Iran.

The bird tracks occur only within a single sandstone level in the basal part of the succession. This level shows traces of tiny ripple marks that are indicative of a shore environment. Latex casts and plaster moulds of these avian tracks were carefully prepared for further studies and measurements. A single sandstone slab with some bird track casts, thought to be part of the layer overlying the main bird track-bearing level, was also

Address correspondence to Majid Mirzaie Ataabadi, Department of Geology, University of Helsinki, P.O. Box 64 FIN-00014, Helsinki, Finland. E-mail: majid.mirzaie@helsinki.fi

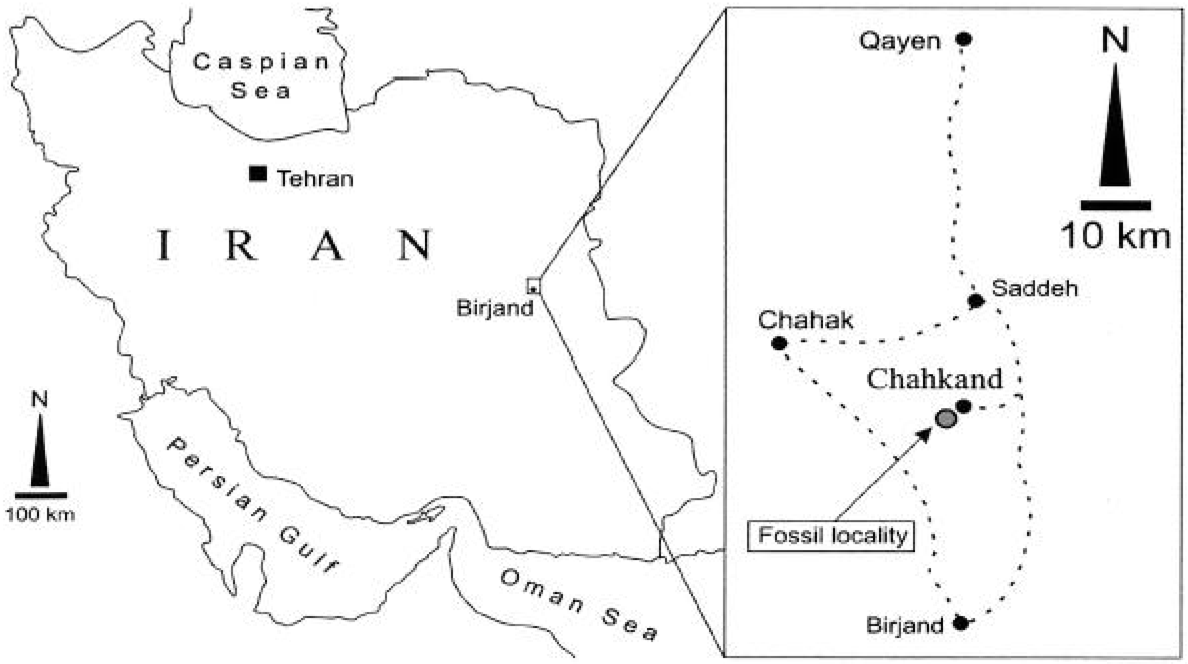

FIG. 1. Locality map of the footprint-bearing strata and the track site in Chahkand village, north of Birjand in eastern Iran.

discovered. These materials also are deposited in the Esfahan University Geology Museum, Iran.

DISCUSSION

The systematics of vertebrate fossil footprints have been the subject of a long debate. With the exception of dinosaurs, there are few ichnotaxonomic studies on the fossil footprints of other vertebrate groups. Scrivner and Bottjer (1986) have provided a summary of the inherent difficulties in the analysis of such footprints. As Sarjeant and Langston (1994) have pointed out, the best way to study and describe these tracks is to infer the most likely taxonomic group that made them either by comparison of ichnological features with probable modern analogues at the lowest possible systematic level or to compare the size of ichnites with appropriate skeletal fossils of groups present in the same or adjacent stratigraphic levels and geographic locations.

Ellenberger (1980) has followed a similar approach in the study of Eocene mammal and bird tracks in Garrigues—Ste—Eulalie (Gard). In this study the same procedure is followed, and only at the ichnospecific level have differences been established. Diagnoses and descriptions are based on the best-preserved footprints; minor variations are not considered to be of taxonomic significance.

SYSTEMATIC ICHNOLOGY

Mammalian Tracks

Ichnogenus *Palaeotheriipus* Ellenberger 1980

Type species *Palaeotheriipus similimedius* Ellenberger 1980

Diagnosis: Large perissodactyl tracks with three short digits. Digit III is larger than the lateral digits II and IV. Digits have rounded ends and diverge 50 degrees from each other. The hoof of the median digit is much bigger than the hooves of the lateral ones. The maximum length is 115 mm and the maximum width is 140 mm.

Remarks: Ellenberger (1980) erected this ichnogenus on material from lacustrine limestones of Garrigues—Ste—Eulalie (Gard). The original materials were 5 tracks in a 3-meter long trackway. Pace prints are 49–51 cm long and stride lengths are 98–102 cm long. These footprints were believed to be made by *Palaeotherium medium*, based on similarities between the skeletal foot structure of *P. medium* and the morphology of these tracks. *P. medium* also was present at the same stratigraphic level of the track area. The estimated digital length from the pad beneath the foot skeleton of *Palaeotherium medium* are: digit II 50 mm; digit III 65 mm and digit IV 50 mm. Estimated digit lengths of *P*. cf. *crassum* are: digit II 45mm; digit III 60 mm and digit IV 45 mm. These digit lengths are almost identical to those measured from the tracks.

Similar tracks from the middle Eocene of d'Apt-Forcalquier basin of France were reported by Bessonat et al. (1969), but they were somewhat bigger in overall dimensions (170 × 160 mm) and digital lengths (digit II 80 mm, digit III 75 mm, and digit IV 85 mm) in comparison with the type species of *Palaeotheriipus*. These footprints were referred to the skeletal taxon *Palaeotherium magnum*. Similar but much smaller tracks also were reported from probable Paleocene deposits of Peru (Gregory, 1916; Lockley et al., 1999).

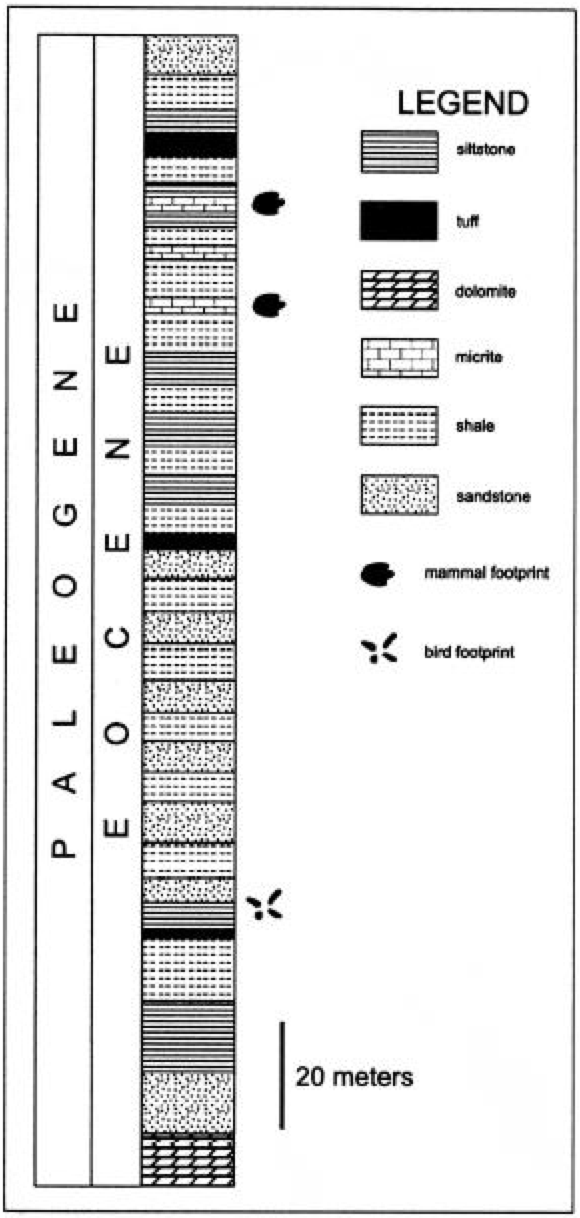

FIG. 2. Stratigraphic column of Eocene deposits and the position of footprint bearing levels in Chahkand village, north of Birjand in eastern Iran (after Nadjafi et al., 2003).

***Range*:** Paleocene—Eocene

Palaeotheriipus sarjeanti **nov. ichnosp.**
Figure 4

Holotype: HMNH–MF1 (Mammal footprint 1) for the pes and HMNH–MF3 for the manus.

Type locality: Second mammal track-bearing micritic level in Chahkand village, north of Birjand in eastern Iran.

Derivation of name: In honor of the late Prof. William A. S. Sarjeant, our collaborator in the study of Eocene vertebrate footprints in eastern Iran, who first proposed that these tracks could represent a new ichnospecies of *Palaeotheriipus*.

Diagnosis: Large tridactyl mammal tracks, with three digital impressions in front of a probable metacarpal pad. Digits clearly visible, with digital impression III subrounded and much broader and longer than the lateral digits II and IV. Lateral digital impressions are almost identical in size and shape. Metacarpal pad almost hemispherical in shape and well developed. Manus less elongate than pes, with median digit III also less developed.

Dimensions: Holotype (HMNH–MF1), right pes. Maximum length 295 mm, maximum width 240 mm. Visible length of digit II 25 mm, digit III 65 mm and digit IV 35 mm. Holotype (HMNH–MF3), right manus. Maximum length 200 mm,

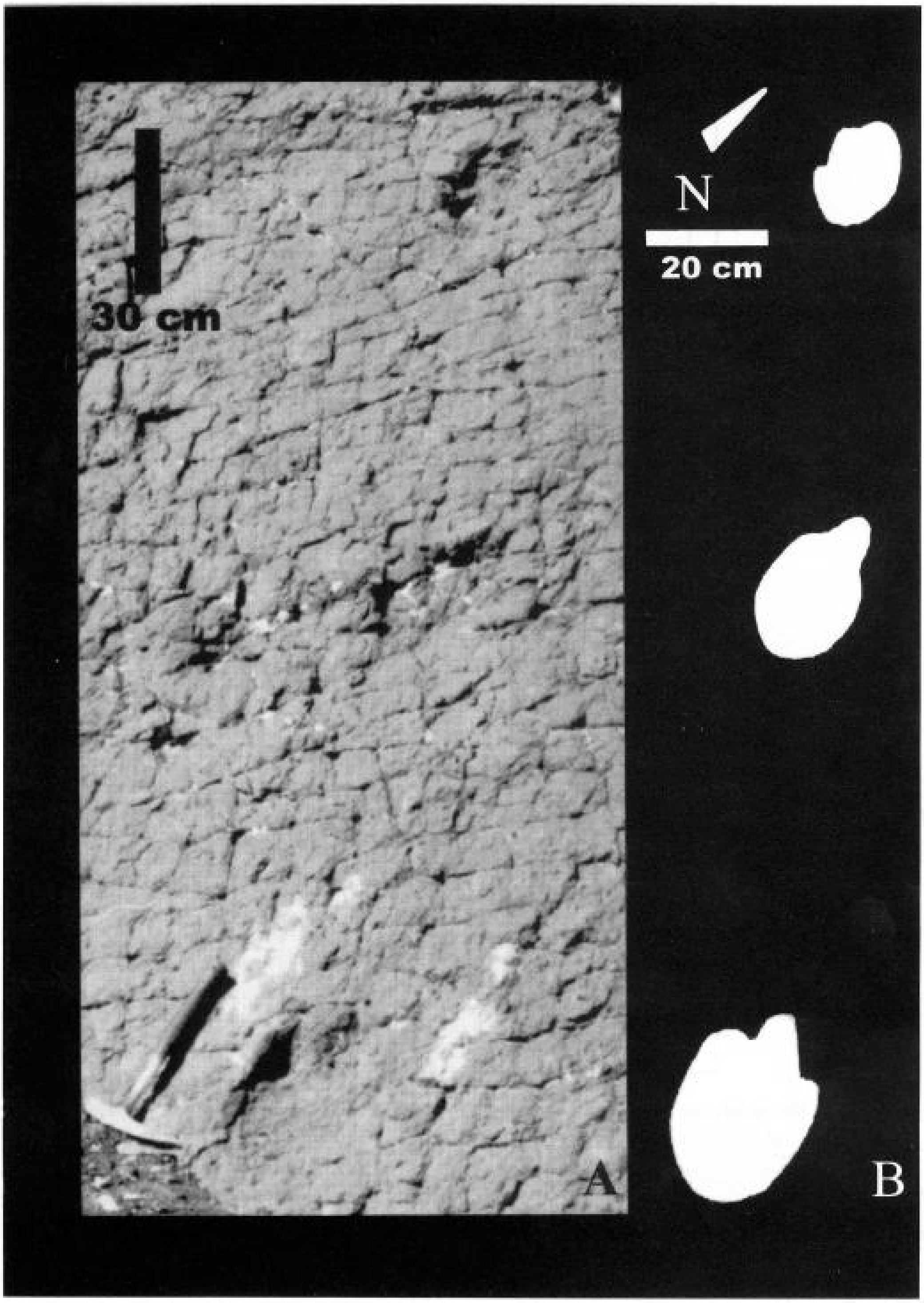

FIG. 3. Track-bearing surface with new mammalian footprints. (**A**) The in situ view of the trackway before being excavated and (**B**) the map showing the tracks and the trackway shown in Fig. 3(**A**).

maximum width 240 mm. Visible length of digit III 25 mm, digits II and IV not clearly discernable.

Divarication of digits: Holotype (HMNH–MF1), right pes. Interdigital angle between digit II–III 20 degrees and digit III–IV 25 degrees.

Holotype (HMNH–MF3), right manus. Interdigital angle between digit II-III 20 degrees and digit III-IV 23 degrees.

Pace: 100 cm (right pes–left pes).

Stride: 195 cm (right pes–right pes).

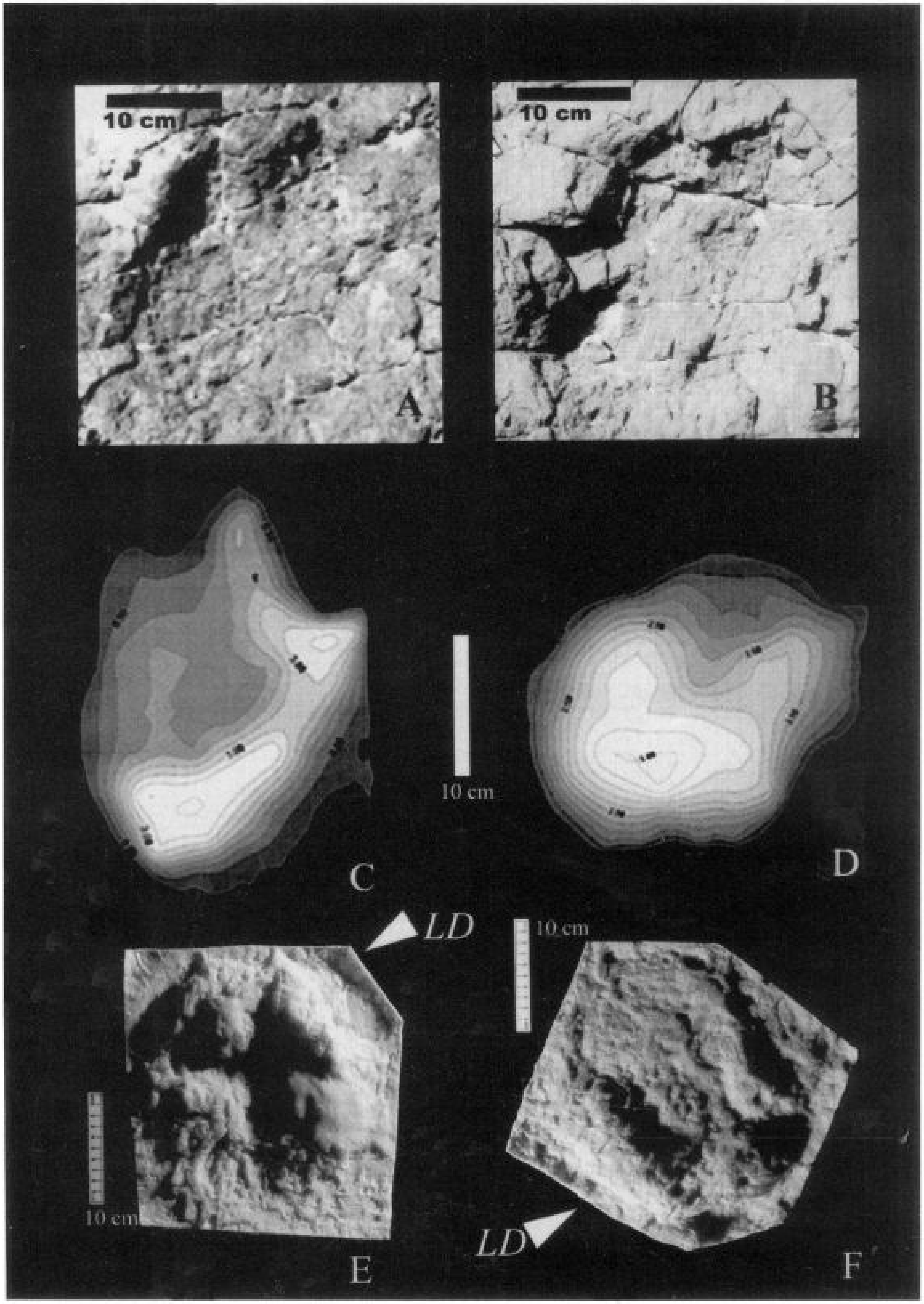

FIG. 4. *Palaeotheriipus sarjeanti* nov. ichnosp. Chahkand village, north of Birjand, eastern Iran. (**A**) HMNH–MF1, surface showing mould of the holotype right pes impression. (**C**) Topomap of the footprint shown in Fig. 4(**A**). (**E**) Latex cast of the right pes shown in Fig. 4(**A**). LD: light direction. (**B**) HMNH–MF3, surface showing the mould of holotype right manus impression. (**D**) Topomap of the footprint shown in Fig. 4(**B**). (**F**) Latex cast of the right manus shown in Fig. 4(**B**). *LD*: light direction.

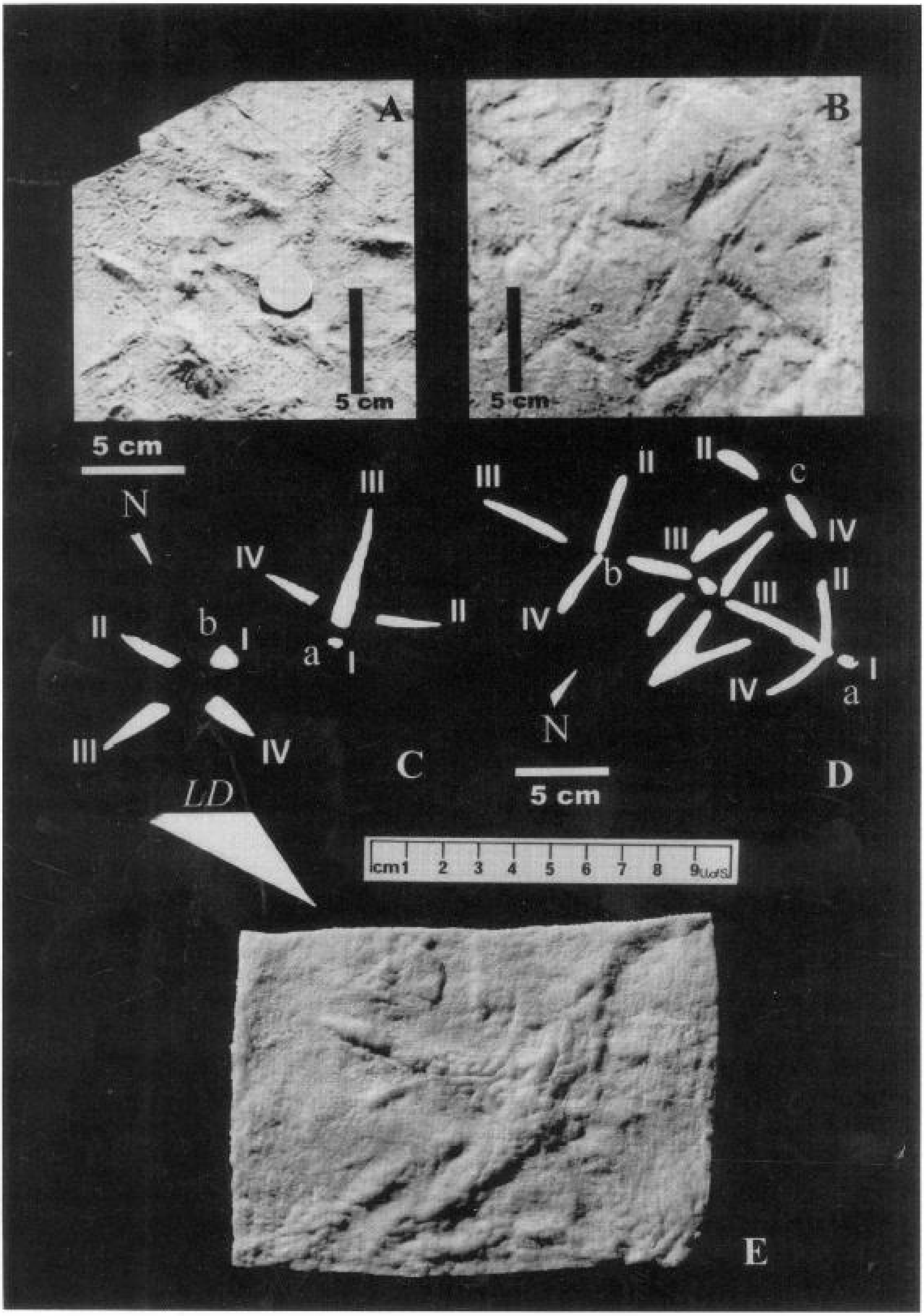

FIG. 5. *Gruipeda lambrechti* nov. ichnosp. Chahkand village, north of Birjand in eastern Iran. (**A**) EUGM–BFS, slab showing the cast of holotype pes impression. (**C**) Map showing the impressions of Fig. 5(**A**). (**B**) Main bird track bearing level showing the moulds of pes impressions. (**D**) Map showing the impressions of Fig. 5(**B**). (**E**) Latex cast of the holotype pes shown in Fig. 5(**A**). *LD*: light direction.

Remarks: The only other ichnospecies of *Palaeotheriipus* (*P. similimedius* Ellenberger, 1980) and footprints referred to the skeletal taxon *Palaeotherium magnum* (Bessonat et al., 1969) mainly differ from *Palaeotherriipus sarjeanti* in their smaller size. *P. similimedius* has a much less complete rear part (metacarpal impression) than *P. sarjeanti*, while the interdigital angles in the latter ichnospecies are much smaller than in *P. similimedius*. Lateral digits are less distinguishable in *P. sarjeanti*, but the median digit is clearly impressed.

The manus for the first time is reported from the Iranian material and is smaller in maximum length and in the relative size of digit III. The pace and the stride length of *P. sarjeanti* is also twice as great as in *P. similimedius*.

Avian Footprints

Ichnogenus *Gruipeda* Panin and Avarm, 1962, emend. Sarjeant and Langston, 1994.
Type species *Gruipeda maxima* Panin and Avarm, 1962, emend. Sarjeant and Langston, 1994.

Diagnosis: Avian footprints showing four digits, three of which (II to IV) are directed forward and large, the fourth (I) directed backward and very short. Their interdigital angle between digits II–IV is 140–165 degrees. The axis of digit I does not correspond with that of digit III. Webbing is absent.

Remarks: *Gruipeda* embraces footprints attributed to at least three orders: Ralliformes (Gruiforms), Charadriiformes, and Ciconiiformes. *Iranipeda* Vialov 1989 resembles *Gruipeda* in many features, so Sarjeant and Langston (1994) synonymized it with the ichnogenus *Gruipeda* Panin and Avarm (1962). Since then, based on the possession of consistently divergent track digits and prominent pad impressions, Doyle et al. (2000) argued that *Iranipeda* Vialov (1989) is distinct from *Gruipeda* Panin and Avarm (1962). However, we agree with Sarjeant and Langston (1994) and believe that *Iranipeda* Vialov (1989) is a synonym of *Gruipeda* Panin and Avarm (1962).

Range: Eocene—Pliocene. Prior to the currently described material, this ichnogenus was recorded originally from the middle Miocene (Helvetian) of Romania (Panin and Avarm, 1962; Panin, 1965), late Eocene of Texas (Sarjeant and Langston, 1994) and Pliocene of Iran (Lambrecht, 1938; Vialov, 1989; Sarjeant and Langston, 1994).

The tracks from northwest Washington (Mustoe, 1993, 2002) also could be assigned to *Gruipeda* Panin and Avarm (1962). Other Eocene bird tracks reported by Moussa (1968) from Utah and Ellenberger (1980) from Garrigues-Ste-Eulalie (Gard) in France could be typical *Antarctichnus* Covacevich and Lamperein 1970.

Gruipeda lambrechti nov. ichnosp.

Figure 5

Holotype: Track no. a on EUGM–BFS (Bird Footprint Slab), basal sandstone levels, Chahkand village, north of Birjand in eastern Iran.

TABLE 1
Dimensions (in mm) of *Gruipeda lambrechti* nov. ichnosp

Track No.	L	W	L (I)	L (II)	L (III)	L (IV)	I (II–IV)
EUGM-BFS							
a	80	100	20	50	60	50	160°
b	60	90	20	40	60	50	165°
Main level							
a	60	80	15	40	60	40	140°
b	60	85	—	45	60	40	160°
c	60	90	—	45	60	45	160°

L, pes length; W, pes width; L (I), length of digit I; L (II), length of digit II; L (III), length of digit III; L (IV), length of digit IV; I (II–IV), interdigital angle between digit II and digit IV.

Derivation of name: After K. Lambrecht, who first studied bird footprints of Iran.

Diagnosis: Avian tracks of relatively large size, exhibiting four digits. Digits II, III, and IV directed forward and digits II and digit IVdiverge at an angle of 80 degrees. Digits II, III, and IV are almost identical in size and shape and abruptly terminate in tapering points. They are prominently united proximally. Digit III longer than digits II and IV. Digit I is directed backward, very short, and its axis is offset at a low angle from that of digit III. Digital impressions have no recognizable phalanges and webbing is not observed.

Dimensions: Holotype (track no. a on EUGM–BFS), overall length 80 mm, overall breath 100 mm. Typical length of digit I 20 mm, digit II 50 mm, digit III 60 mm, and digit IV 50 mm. (Table 1). Typical pace is 85–90 mm and stride probably 160 mm.

Divarication of digits: Holotype (track no. a on EUGM–BFS), interdigital angle between digit I and digitII 95 degrees, between digit II and digit III 80 degrees, between digit III and digit IV 85 degrees, and between digit IV and digit I 120 degrees.

Remarks: *Gruipeda lambrechti* is comparable with *Gruipeda intermedia* Panin 1965, particularly in the broad interdigital angle between digit II and digit III and also digit III and digit IV, but differs from it by its smaller size. *G. maxima* Panin and Avarm 1962 is relatively much longer than *G. lambrechti* and has smaller interdigital angles. *G. lambrechti* differs from *G. minima* and *G. calcarifera* in its larger dimensions and broader interdigital angles. *Gruipeda(Iranipeda) abeli* (Vialov 1989) Sarjeant and Langston, 1994, in comparision with *G. lambrechti*, has larger digital length and smaller interdigital angles.

CONCLUSION

Because of the absence of Eocene vertebrate body fossils in Iran, the footprints from north of Birjand, together with those from the Karaj Formation in Zanjan area, north western Iran

(Lockley and Abbassi; *this volume*), are the only direct evidence for the presence of Eocene mammals and birds in Iran.

The poor state of preservation in the first studied tracks (Mirzaie Ataabadi and Sarjeant, 2000) was the main problem that prevented an exact assignment of these tracks to a particular group of Eocene vertebrates. The newly studied materials, however, with their good state of preservation are more reliable for such purposes. Now it has become evident that at least *Palaeotherium* (or a group with similar pedal structure) was present during the middle Eocene in eastern Iran. This finding substantially extends the geographical range of palaeotheres and raises questions about the origin and distribution of this group of mammals in the Eocene. The probable Eocene vertebrates found in eastern Iran suggest strong resemblances with those found in east Asian localities such as those of Indo-Pakistan (Gingerich, 1977; Gingerich et al., 2001) and Mongolia (Maeng and McKenna, 1998). Their relationships with European faunas are still unknown and require further study. The avian tracks that have been found also are indicative of the presence of Ralliforme (Gruiforme), Charadriiforme, or Ciconiiforme shorebirds in the middle Eocene of eastern Iran. As with the mammalian footprints, lack of associated body fossils makes it difficult to assign them to a particular group of Eocene shore birds.

ACKNOWLEDGEMENTS

This work was due to be completed through the contribution of Prof. William A. S. Sarjeant. Unfortunately, his sudden death on July 8, 2002, made us dispair that it would be difficult or impossible to complete this study without his expertise. However, we have completed this work and are grateful for all the help and collaboration that he offered this study. Therefore, we would like to dedicate this paper to him.

Birjand Cultural Heritage Organization kindly provided us with logistic support during the field work, and the University of Birjand assisted with accommodation facilities. The Hamedan Museum of Natural History and its staff are especially appreciated for their hard efforts during the excavation of the tracks and their subsequent exhibition in the Museum.

We are grateful to Nargess Hashemi (Ferdosi University of Mashhad) for providing access to her unpublished Master of Science thesis results on the sedimentology and the depositional environment of track-bearing strata of the middle complex north of Birjand in eastern Iran, Dr. Moussa Noghreian (University of Esfahan) for his help with the French texts, Helen Wong (research assistant to Prof. Sarjeant) who kindly send us some of the references and materials deposited in the University of Saskatchewan, and Robert Weems and John Foster (*Ichnos* reviewers) for their critical views and comments which improved this paper in language and many other aspects. Last, but not least, we thank Vachik Hairapetian (Islamic Azad University, Khorasgan Branch) for his collaboration in preparing the illustrations for this paper.

REFERENCES

Bessonat, G., Dughi, R., and Sirugue, F. 1969. Un important gisement d'empereintes de pas de Mammiferes dans le Paleogene du Bassin d'Apt–Forcalquier. *Comptes Rendus de l'Academie des Sciences. Sciences de la Terre et des Planetes*, 268:1376–1379.

Covacevich, R. and Lamperein, C. 1970. Hallazgo de icnitas en Peninsula Fildes, Isla Rey Jorge, Archipelago Setland del Sur, Antarctica. *Series Cientifico del Instituto Antartido Chileno*, 1:55–74.

Doyle, P., Wood, J. L., and George, G. T. 2000. The shorebird ichnofacies: an example from the Miocene of southern Spain. *Geological Magazine*, 137:517–536.

Einsel, G. 2000. Sedimentary basins: evolution, facies and sediment budget. Springer: 792 p.

Ellenberger, P. 1980. Sur les empereintes de pas des gros mammiferes de l'Eocene superieur des Garrigues-Sainte-Eulalie (Gard). Paleovertebrata, Mem. Jub. R. Lacovat: 37–78.

Fauvelet, E. and Eftekharnezhad, J. 1990. Explanatory text of Qayen quadrangle map 1:250000. Geological quadrangle No. K7. Geological survey of Iran: 317 p.

Gingerich, P. D. 1977. A small collection of fossil veretbrates from the Middle Eocene Kuldana and Kohat Formations of Punjab (Pakistan). *Contributions from the Museum of Paleontology. The University of Chicago*, 24:190–203.

Gingerich, P. D., Arif, M., Hussain Khan, I., Haq, M., Bloch, J. I., Clyde, W. C., and Gunnell, G. F. 2001. Gandhera quarry, a unique mammalian faunal assemblage from the early Eocene of Baluchistan (Pakistan). *In* Gunnell, G. F. (ed.), Eocene biodiversity: unusual occurences and rarely sampled habitats. Kluwer Academic/Plenum Publishers: 251–262.

Gregory, H. 1916. Geological reconnaissance of the Cuzco valley, Peru. *American Journal of Science*, 2:241.

Lambrecht, K. 1938. *Urmiornis abeli* n. sp., eine Pliozene Vogelfahrte aus persian. *Paleobiologica*, 6:242–245.

Lockley, M. G., Ritts, B. D., and Leonardi, G. 1999. Mammal track assemblages from the early Tertiary of China, Peru, Europe and North America. *Palaios*, 14:398–404.

Maeng, J. and McKenna, M. C. 1998. Faunal turnovers of Paleogene mammals from the Mongolian plateau. *Nature*, 394:364–367.

Mirzaie Ataabadi, M. and Sarjeant, W. A. S. 2000. Eocene mammal footprints from eastern Iran: a preliminary study. *Comptes Rendus de l'Academie des Sciences. Sciences de la Terre et des Planetes*, 331:543–547.

Moussa, M. T. 1968. Fossil tracks from the Green River Formation (Eocene) near Soldier Summit, Utah. *Journal of Paleontology*, 44:1433–1438.

Mustoe, G. E. 1993. Eocene bird tracks from the Chuckanut Formation, Northwest Washington. *Canadian Journal of Earth Sciences*, 30:1205–1208.

Mustoe, G. E. 2002. Eocene bird, reptile and mammal tracks from the Chuckanut Formation, Northwest Washington. *Palaios*, 17:403–413.

Nadjafi, M., Moussavi–Harami, R., and Hashemi, N. 2003. Attributing the mammalian footprints of the Chahkand Eocene deposits (north of Birjand) to Pantodonts and Dinoceratae. Abstracts of 21th symposium on earth sciences. Geological Survey of Iran: 421–422.

Panin, N. and Avarm, E. 1962. Noe urme de vertebrate in Miocenul Subcarpatilor Ruminesti. *Studii Cercetari de Geologie*, 7:455–458.

Panin, N. 1965. Coexistance de traces de pas de vertebras et de macanoglyphes dans le molasse Miocene des Carpates orientales. *Revue de Roumanian Geologie, Geophysique et Geographie*, 7:141–163.

Sarjeant, W. A. S. and Langston, W. 1994. Vertebrate footprints and invertebrate traces from the Chadomian (Late Eocene) of Trans–Pecos Texas. *Bulletin of the Terxas Memorial Museum*, 36:1–86.

Scrivner, P. J. and Bottjer, D. J. 1986. Neogene avian and mammalian tracks from Death Valley National Monument, California: their context, classification and preservation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 57:285–331.

Vialov, O. S. 1989. Pliocene bird tracks from Iran assigned to the genus *Urmiornis*. *Paleontological Journal*, 23:119–121.