Late Miocene large mammals from Ivand (Northwestern Iran)

Author(s): Majid Mirzaie Ataabadi, Jafar Mohammadalizadeh, Zhaoqun Zhang, Mahito Watabe, Anu Kaakinen, Mikael Fortelius
Source: Geodiversitas, 33(4):709-728.
Published By: Muséum national d'Histoire naturelle, Paris
DOI: http://dx.doi.org/10.5252/g2011n4a7
URL: http://www.bioone.org/doi/full/10.5252/g2011n4a7

Late Miocene large mammals from Ivand (Northwestern Iran)

Majid MIRZAIE ATAABADI
Department of Geosciences and Geography,
University of Helsinki, FI-00014, Helsinki (Finland)
and Laboratory of Evolutionary Systematics of Vertebrates,
Institute of Vertebrate Paleontology and Paleoanthropology,
Chinese Academy of Science, 100044 Beijing (China)
majid.mirzaie@alumni.helsinki.fi

Jafar MOHAMMADALIZADEH
Hamedan Museum of Natural History,
Bu Ali Sina University, Hamedan (Iran)

Zhaoqun ZHANG
Institute of Vertebrate Paleontology and Paleoanthropology,
100044 Beijing (China)
zhangzhaoqun@ivpp.ac.cn

Mahito WATABE
Hayashibara Museum of Natural Sciences, Okayama (Japan)
wmahito@hayashibaramuseum.jp

Anu KAAKINEN
Mikael FORTELIUS
Department of Geosciences and Geography,
University of Helsinki, FI-00014, Helsinki (Finland)
anu.kaakinen@helsinki.fi
mikael.fortelius@helsinki.fi

Mirzaie Ataabadi M., Mohammadalizadeh J., Zhang Z., Watabe M., Kaakinen A. & Fortelius M. 2011. — Late Miocene large mammals from Ivand (Northwestern Iran). *Geodiversitas* 33 (4): 709-728. DOI: 10.5252/g2011n4a7.

ABSTRACT
Large mammalian fossil fauna of the Ivand locality in northwestern Iran is reported for the first time. This new locality is situated north of the city of Tabriz in the geographical proximity of the famous Maragheh fossil sites. A large hipparion, represented by an almost complete skull and mandibles, is recorded from this locality. The skull, most likely of *Hipparion giganteum-Hipparion brachypus* lineage, represents significant evidence of the presence of large hipparionine horses in northwestern Iran in the Late Miocene. A small number

of horn-cores attributed to *Oioceros atropatenes* Rodler & Weithofer, 1890 and *Gazella* sp., in addition to some indeterminate dentition, represent the bovid material in the Ivand fossil assemblage. Postcranial evidence also points to the presence of *Deinotherium giganteum* Kaup, 1829 and Rhinocerotinae indet., while other material adds carnivorans, giraffes and large porcupine rodents to the list of the fauna. Based on the occurrence of these taxa, the Ivand locality can be correlated with the Middle and Upper Maragheh biostratigraphical intervals, thus demonstrating a middle Turolian age (*c.* 8-7 Ma).

KEY WORDS
Mammalia,
Miocene,
Turolian,
Ivand,
Maragheh,
Iran.

RÉSUMÉ

Grands mammifères du Miocène supérieur d'Ivand (nord-ouest de l'Iran).

Un assemblage inédit de grands mammifères fossiles a été trouvé à Ivand, au nord-ouest de l'Iran. Cette nouvelle localité est située au nord de la ville de Tabriz, proche de la célèbre localité de Maragheh. Un hipparion de grande taille, représenté par un crâne presque complet et mandibules, y a été découvert. Le crâne, vraisemblablement rattaché à la lignée *Hipparion giganteum-Hipparion brachypus*, prouve la présence de grands chevaux hipparionines au Miocène supérieur au nord-ouest de l'Iran. Quelques chevilles attribuées à *Oioceros atropatenes* Rodler & Weithofer, 1890 et *Gazella* sp., ainsi que des fragments de dentition non identifiés, représentent le materiel bovin de l'assemblage d'Ivand. Des éléments post-craniens prouvent également la présence de *Deinotherium giganteum* Kaup, 1829 et Rhinocerotinae indet., tandis que d'autres matériels indiquent la présence de carnivores, girafes et porc-épics. Sur la base de l'apparition de ces taxons, la localité d'Ivand peut être corrélée avec le Maragheh moyen et supérieur, ce qui indique un âge de Turolien moyen (*c.* 8-7 Ma).

MOTS CLÉS
Mammalia,
Miocène,
Turolien,
Ivand,
Maragheh,
Iran.

INTRODUCTION

Although vast outcrops of Neogene terrestrial deposits exist in Iran, knowledge of mammalian fossil faunas in the country remains limited due to a lack of sufficient investigations. The only exception is the richly fossiliferous beds of the Maragheh Formation in northwestern Iran. These fossiliferous deposits are located on the southern and eastern slopes of the Sahand volcano in the Maragheh district of eastern Azarbaijan province. Based on the latest studies, the Maragheh Fm. has been divided into three biostratigraphical intervals (Lower, Middle and Upper Maragheh) ranging from 9.5 to 7 Ma in age (Bernor 1986). For more than a century, this famous Late Miocene vertebrate locality received much attention and has been the exclusive source of information on the Neogene mammalian faunas of Iran. However, the recent discovery of new Neogene mammal fossil localities in NW Iran (Ivand and Varzeghan in Figure 1A) demonstrates a wider distribution of mammal-bearing strata in this area and offers opportunities for new insights into these faunas. Here, in addition to the recently reported porcupine rodents from Ivand locality (Sen & Purabrishemi 2010), the large mammalian fauna of this fossil site is studied for the first time.

GEOLOGICAL SETTING

During the Paleogene, Azarbaijan province in NW Iran experienced a wide range of volcanic activity. By the end of the Early Miocene, the last Tethyan seaway disappeared from this area, carbonate deposition terminated, and a major landmass emerged

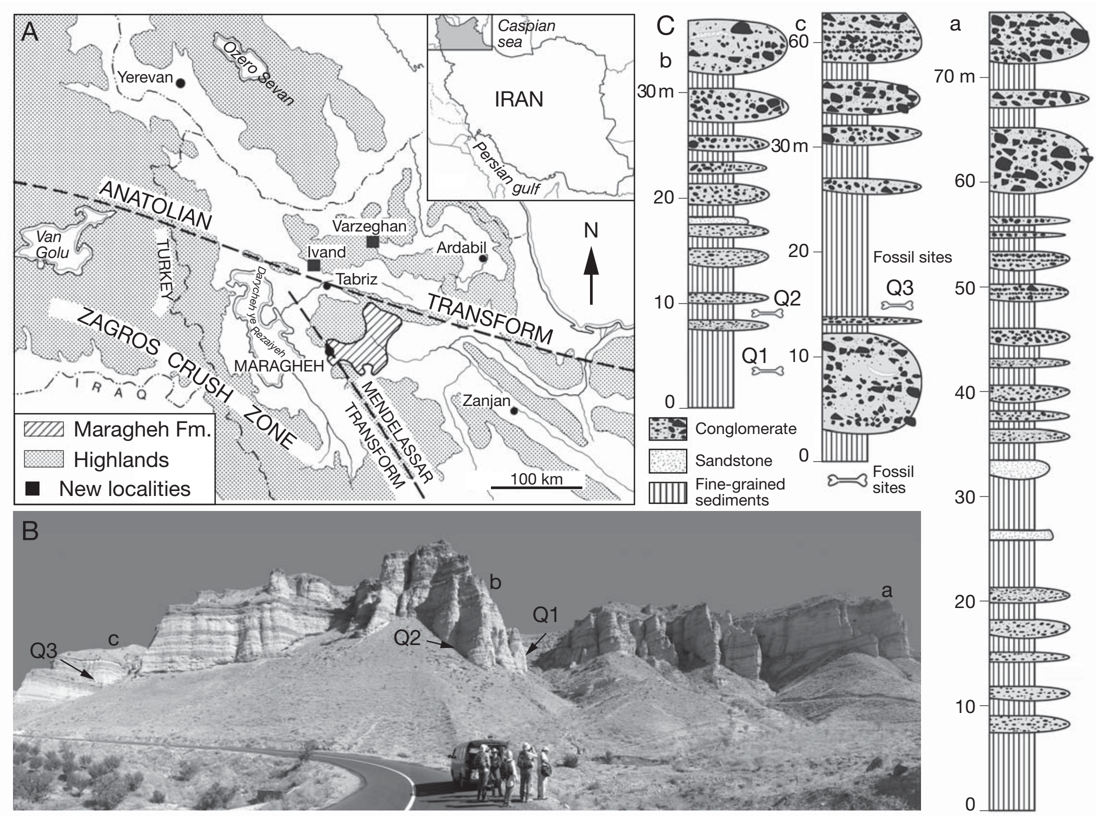

FIG. 1. — **A**, geographic position of the new Late Miocene mammal fossil localities, Ivand (and Varzeghan), in NW Iran (modified after Bernor 1986); **B**, general view of the Ivand locality (looking to the north); arrows point to the approximate level of fossil sites (Q1-3), and lower case letters (**a**, **b**, **c**) refer to the position of the sedimentological logs; **C**, sedimentological logs from the Ivand locality.

(Aghanabati 2004). Consequently, in the early Neogene, this domain was emerged mostly above sea level and featured incipient mountain ranges, basin troughs, and a topography resembling present conditions (Davoudzadeh *et al.* 1997).

The areas north of the Tabriz-Mishu-Maku fault (continuation of the Anatolian transform fault in Fig. 1A) in particular are the segments of the Tabriz-Maku subzone in the western Alborz-Azarbaijan structural zone. During the Late Miocene and Pliocene, this zone, like other parts of Iran, underwent major orogenic movements. Consequently, these tectonic activities established new erosional cycles that filled the locally closed basins with fluvial and lacustrine deposits (Aghanabati 2004). In these basins the Neogene sediments of NW Iran are deposited. Whilst pyroclastic sediments accumulated and preserved abundant mammalian fossils in the Maragheh area (Bernor 1986), in Tabriz area these basins have been filled by fluviatile and lacustrine deposits with abundant freshwater fish and rare mammalian remains (Rieben 1935).

The new fossil localities in the Ivand (and Varzeghan) areas and their mammalian faunas (Fig. 1A), are formed in such local basin troughs with environments different from those of the Maragheh Fm. A significant difference between these new localities and the Maragheh Fm. is the relative scarcity of volcanic and volcaniclastic material such as tuffs and pumice layers in them, which makes geochronology and correlation of the stratigraphic sections very difficult.

Fossil locality

The Ivand fossil locality (38°21'04"N, 46°07'33"E) is located (*c.* 30 km) north of Tabriz, the capital of the eastern Azarbaijan province of Iran (Fig. 1A). The fossil-bearing sequence is about 70 m thick and covers a relatively large area (Fig. 1B). Fossil bones appear as localized concentrations within beds, floating in the sediments rather than resting on bedding plane. The fossil pockets are not restricted to a single horizon, but appear throughout the section. While bones are more abundant in the fine-grained lower and middle parts of the succession, they also may appear within the coarse sandstones and conglomerates.

The lithology of the fossiliferous sequence consists mainly of thick layers of conglomerates interbedded with finer clastic sediments such as sand, silt, and mudstone (Fig. 1C). The base of the sequence is covered, and hence, inaccessible for study. The fine-grained sediments associated with the conglomerates are pink, cream, and grey in colour with frequent pedogenic features such as mottling and burrows. Conglomerate beds have a mainly matrix-supported texture, are poorly to moderately sorted, and are typically structureless or crudely stratified. Normal grading and sparse evidence of imbrication is visible in finer-grained conglomerates. Contacts with underlying and overlying beds are typically sharp; scouring is often present at the base of the conglomerates. The clast types present in the conglomerate beds consist mainly of local volcanic sources. The grains are usually rounded to sub-rounded and vary in size from a few centimeters to 30 cm. Thin sand interlayers showing cross-bedding are present within the conglomerate beds or as separate layers. The conglomerate bodies are typically sheet-like in geometry and range from a few decimeters thick in the lower parts of the section to several meters thick in the upper part of the succession. The conglomerates also show a general coarsing upward trend in the section.

The characteristics of the conglomerates suggest they are deposits of gravity flows, sheet flows, and to a lesser extent, channelized flows on an alluvial fan (cf. Blair & McPherson 1984). A vertical trend of coarsening and thickening upward of the beds suggests an overall progradational pattern of the alluvial fan (Heward 1978) in the Ivand locality.

MATERIAL AND METHODS

Although no articulated specimen has been collected from the Ivand locality, the fossil material are very well preserved and do not show any sign of weathering or abrasion. Substantial fossil material, including about 200 catalogued specimens, has been collected from several fossil quarries in this locality during the field season of 2002 and has been deposited in the Hamedan Museum of Natural History, Bu Ali Sina University, Hamedan, Iran. As is typical of the Old World Turolian faunas, hipparionine horses predominate. About 60 specimens of hipparionine horses, including several cranial and postcranial materials have been collected. Bovids are less abundant, but are represented by 24 specimens, including several mandibles, isolated dentitions, and a few horncores. Among the other mammalian material are about 20 specimens of very large postcranials belonging to Proboscidea and Rhinocerotidae. Only one carnivore specimen has been found. The current study is based on the best preserved fossils from this collection with known provenance in Ivand locality. These fossils are from Quarries 1-3 (Fig. 1B, C).

Moreover, small collections of mammal fossils from Ivand locality have been temporarily deposited at the Universities of Esfahan and Tabriz. These collections, also from different quarries, are not catalogued and were unavailable for a thorough study. Also, a small collection of Ivand fossils is present at the Department of the Environment branch in Maragheh and National Museum of Natural History in Tehran.

To compare some of the postcranial material in this research, measurements of similar skeletal elements from relevant taxa have been gathered from collections of Muséum national d'Histoire naturelle, Paris and also from Antoine & Saraç (2005), Deng (2002), and Huttunen & Göhlich (2002).

Abbreviations

Institutions

AMNH	American Museum of Natural History, New York;
BSP	Bayerische Staatssammlung für Paläontologie and Historische Geologie, Munich;
DOE	department of the environment (Environment Protection Organization), Maragheh;
HMNH	Hamedan Museum of Natural History, Hamedan;
HMV	Hezheng Paleontological Museum, Gansu;
MMTT	National Museum of Natural History, Tehran;
MNHN	Muséum national d'Histoire naturelle, Paris.

Other abbreviations

DAP	antero-posterior diameter;
DP	deciduous upper premolar;
DT	medio-lateral diameter;
DW	distal width;
FL	femoral length;
I	upper incisors;
i	lower incisors;
MN	mammal Neogene faunal zone;
Mx	measurement number x;
M1-3	upper molars;
m1-3	lower molars;
P2-4	upper premolars;
p2-4	lower premolars;
POB	preorbital bar;
POF	preorbital fossa;
POW	width at process olecrani;
PW	proximal width of the ulna.

SYSTEMATIC PALEONTOLOGY

Order PERISSODACTYLA Owen, 1848
Family Equidae Gray, 1821
Genus *Hipparion* de Christol, 1832

Hipparion sp. large
(Fig. 2)

Locality. — Quarry 2, Ivand district, north of Tabriz, Iran.

Material examined. — Skull (HMNH-IV1) and mandible (HMNH-IV2) (Fig. 2; Table 1).

Description

The skull is quite long and belongs to a large adult male (large canines present). The muzzle is elongated and broad, even though the application of extra material in fixing the broken snout has made the muzzle artificially longer (Fig. 2A-C). The narial opening and nasal area have been damaged during excavation and subsequently restored, so details of this area are missing. The POF is very well preserved on the right side and partially filled with sediment on the left side (Fig. 2A). The POF is far from the orbit, sub-triangular in shape, relatively large and deep, and antero-posteriorly oriented. There is no posterior pocketing. The anterior rim of the POF is well expressed and appears above the medial part of P3. The posterior border of the POF is located above the anterior part of M2. The ventral rim of the POF is not straight, features undulation, and is above the line of the lower border of the orbit. The infra-orbital foramen is at the antero-ventral border of the fossa, placed slightly inferiorly. The orbit is round and its anterior border is situated close to the posterior border of M3. The facial crest is very strong and is far from the alveoli and the ventral border of the POF. The anterior border of the facial crest is situated above the medial part of P4. The palate is elongated and wide. The choanae, although filled with sediment, are well preserved. They are wide and their anterior border is situated at the level of contact between M2 and M3.

The upper tooth row is long and complete at both sides, including P2-4, M1-3. All the teeth are moderately worn and the enamel morphology is visible (Fig. 2D). The protocone is elliptical and flattened lingually, especially in the molars. The enamel plication is rich (mean plication is 20) with deep plis. The hypocone is elliptical with relatively deep distal hypoconal grooves. The plicabaline is strong, short and single or long and double/multiple.

The mandible is elongated with a narrow snout and cup. The symphysis is short and narrow. The condyle and coronoid processes and the ascending ramus, though not preserved, have been restored (Fig. 2E-G). The tooth row is long and the teeth are large and wide (Fig. 2H). The parastylid is relatively well developed and closed. The metaconid is elliptical to round and the metastylid is rounded. The entoconid is elliptical to round. The ectoflexid is V- or U-shaped and moderately deep and narrow, reaching the middle of the tooth; only in m1 it reaches the linguaflexid. A plicabalinid is present in some of the teeth.

TABLE 1. — Measurements (in mm) of *Hipparion* sp. large from the Ivand locality, NW Iran. Bold numbers refer to measurements; question mark (?) indicates uncertainty. **Skull** (HMNH-IV1): **1**, muzzle length: prosthion-middle of the line connecting the anterior borders of P2; **2**, palatal length: middle of the line connecting the anterior borders of P2-anterior border to the choanae; **3**, length from the anterior border of the choanae to the vomer; **6**, basilar length: basion-prosthion; **7**, length of the premolars; **8**, length of the molars; **9**, length of the teeth row; **10**, choanal length; **12**, maximal breadth of the choanae; **13**, palatal breadth between P4 and M1; **14**, minimal muzzle breadth; **15**, muzzle breadth: distance between the posterior border of the I3s; **18**, frontal breadth: distance between the most external points of the posterior borders of the orbits; **25**, facial height: height of the skull in front of P2; **28**, anteroposterior diameter of the orbit; **29**, dorsoventral diameter of the orbit; **30**, length of the naso-incisival notch: prosthion-posterior end of the narial opening; **31**, cheek length: posterior end of the narial opening-anterior border of the orbit; **32**, distance between the orbit and the preorbital fossa; **33**, maximal length of the preorbital fossa; **34**, distance between the back of the preorbital fossa and the infraorbital foramen; **35**, height of the preorbital fossa: perpendicular to its maximal length; **36**, distance between the preorbital fossa and the facial crest; **37**, height of the back of the infraorbital foramen above the alveolar border; **38**, height of the back of the preorbital fossa above the alveolar border. **Mandible** (HMNH-IV2): **1**, maximal length: posterior point of the articular condyle-anterior point situated between the i1s; **2**, muzzle length: middle of the line connecting the anterior borders of p2 to a point situated between the i1s; **3**, length of the premolars; **4**, length of the molars; **5**, length of the tooth row; **7**, muzzle breadth: breadth at the posterior borders of i3; **10**, depth of the jaw behind m3; **11**, depth of the jaw between p4 and m1; **12**, depth of the jaw in front of p2; **13**, symphysial length; **14**, minimal breadth of the symphysis. **Upper right** (HMNH-IV1) **and lower right** (HMNH-IV2) **teeth**: **2**, occlusal length; **3**, protocone length (in upper teeth) and preflexid length (in lower teeth); **4**, occlusal breadth (in upper teeth) and double-knot length (in lower teeth); **5**, postflexid length; **6**, anterior occlusal breadth. **Facial morphology** of *Hipparion* sp. large (HMNH-IV1): terms after Bernor *et al*. (2003).

Skull (HMNH-IV1)	1	2	3	6	7	8	9	10	12	13	14	15
	165?	120	> 90	> 400	84	75.3	157	> 90	46	65	42.5	68
18	**25**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
145	66	61.6	47.4	128	225	45	65.2	64	36	36.4	49.4	70
Mandible (HMNH-IV2)	**1**	**2**	**3**	**4**	**5**	**7**	**10**	**11**	**12**	**13**	**14**	
	420?	100	81.6	70	152.6	52.4	82	67.5	50	70	33.5	

Upper right (HMNH-IV1) and Lower right (HMNH-IV2) teeth	P2	P3	P4	M1	M2	M3	p2	p3	p4	m1	m2	m3
2	32.2	25.7	24.1	22.7	22.8	22.8	31.1	26.6	24	21.4	21.6	25.4
3	8.7	8.7	8.7	7.9	7.8	7.8	7	7.8	7	?	6.1	6.4
4	25.7	25.9	25.5	22.8	22.5	20.1	12.5	15.3	14.3	12.6	12.1	11.3
5							?	13.3	11.6	8.8	9.8	8.6
6							12.5	14.4	11.4	10.8	10.3	9.3

Facial morphology of *Hipparion* sp. large (HMNH-IV1)	
Relationship of lacrimal to the preorbital fossa (POF)	Long preorbital bar (POB) with the anterior edge of the lacrimal placed more than half the distance from the anterior orbital rim to the posterior rim of the fossa.
Nasolacrimal fossa	Nasomaxillary fossa sharply reduced compared to nasolacrimal fossa.
Orbital surface of lacrimal bone	With foramen.
POF morphology	Subtriangular shaped and antero-posteriorly oriented.
Fossa posterior pocketing	Not pocketed, but with a posterior rim.
Fossa medial depth	Moderate depth, 10-15 mm in the deepest place.
POF medial wall morphology	Without internal pits.
Fossa peripheral border outline	Strong, strongly delineated around entire periphery.
Anterior rim morphology	Present.
Placement of infraorbital foramen	Inferior to or encroaching upon anteroventral border of the preorbital fossa.

COMPARASION

The hipparion skull from Ivand (HMNH-IV1) has been compared to several species of hipparionine horses, from localities in the eastern Mediterranean and northern Black Sea regions. The bivariate plots of the POB width (distance between the anterior rim of the orbit and the posterior rim of the POF) against the P2-orbit distance, which serve as a useful measure of skull (face) length (Forsten 1983), appear in Figure 3. Here, Ivand skull clusters with *H. giganteum* Gromova, 1952 from Grebeniki, *H. brachypus* Hensel, 1862 from Pikermi, and *Hipparion* sp. large from Samos (Fig. 3A). The results of a similar plot show the distinction, based

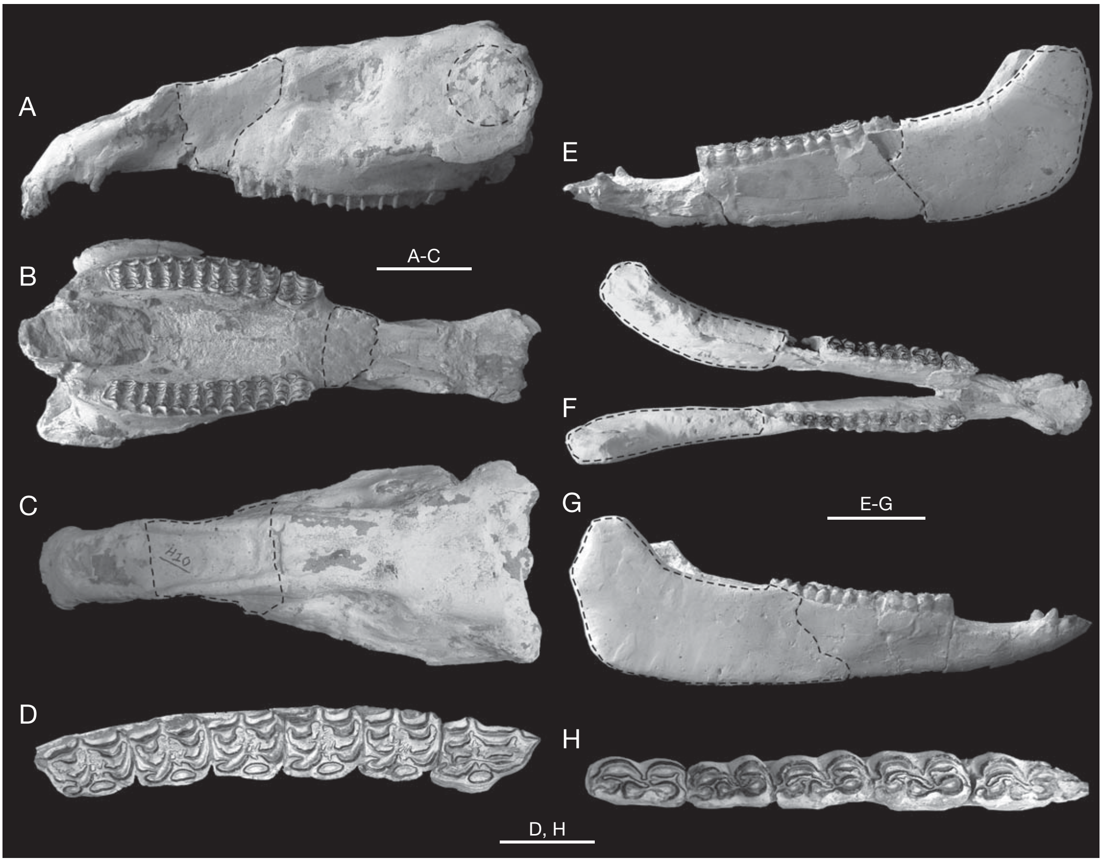

Fig. 2. — *Hipparion* sp. large, Ivand locality, NW Iran: **A**-**C**, skull (HMNH-IV1) in left lateral (**A**), ventral (**B**) and dorsal (**C**) views; **D**, right tooth row in occlusal view; **E**-**G**, mandible (HMNH-IV2) in left lateral (**E**), dorsal (**F**) and right lateral (**G**) views; **H**, left tooth row in occlusal view. Broken lines on the fossil specimens delineate extra material used erroneously in restoration (**A**-**C**, **E**-**G**). Scale bars: A-C, 80 mm; D, H, 30 mm; E-G, 75 mm.

on this criterion, of the Ivand skull from those of other known hipparion species in Maragheh (Fig. 3B), including "*H*". *gettyi* Bernor, 1985; "*H.*" aff. *moldavicum* (*H. moldavicum* Gromova, 1952 *sensu* Watabe & Nakaya 1991b); *Hipparion prostylum* Gervais, 1849; and *H. campbelli* Bernor, 1985 (*H. urmiense* Gabunia, 1959 *sensu* Watabe & Nakaya 1991b).

The large-sized skull from Ivand (HMNH-IV1), as the logarithmic ratio diagram shows (Fig. 4A), is comparable in its basic dimensions and morphology to *H. brachypus* from Pikermi (Koufos 1987b), Hadjidomovo (Hristova *et al.* 2003), and Akkaşdaği (Koufos & Vlachou 2005). However, the Ivand skull has a longer muzzle (M1), which is indeed an artifact of incorrect restoration, and a wider snout (M15). Figure 4B shows that the large-sized skull from the Ivand locality is not comparable in size and morphology to any of the hipparionine horses from Maragheh (Bernor 1985).

Hipparion brachypus is characterized by large size, an elongated skull with a relatively wide muzzle, and a deep narial opening. The preorbital fossa is oval, antero-posteriorly oriented, well-marked, deeply posteriorly pocketed, and situated far from the orbit. The upper cheek teeth also show rich enamel plication with deep plis (Koufos 1987a; Koufos & Vlachou 2005; Vlachou & Koufos

TABLE 2. — Measurements (in mm) of *Deinotherium giganteum* Kaup, 1829 and Rhinocerotinae indet. postcranials from the Ivand locality (NW Iran). Abbreviations: **proc**, process; **art**, articularis; **prox**, proximalis.

Deinotherium giganteum	
Ulnae (HMNH-IV135)	
Proximal width at proc. coronoideus	250
Proximal depth	330
Length of the incisura trochlearis	130
Width at the proc. olecrani	110
Radius (HMNH-IV115)	
Proximal width at caput radii	120
Proximal depth at caput radii	80
Tibia (HMNH-IV119)	
Proximal width	270
Proximal depth	160
Depth of the medial facies art. prox.	160
Depth of the lateral facies art. prox.	100
Calcaneus (HMNH-IV118)	
Maximum height	230
Maximum width	150
Height of the medial facet	70
Width of the medial facet	70
Height of the lateral facet	50
Width of the lateral facet	40
Unciform (HMNH-IV117)	
Maximum height	150
Dorsal height	80
Maximum width	140
Maximum depth	170
Diagonal depth	210
Metapod (HMNH-IV114)	
Proximal width	90
Width of the facies art. prox.	50
Depth of the facies art. prox.	70
Minimum width of the diaphysis	70
Rhinocerotinae indet.	
Femur (HMNH-IV137)	
Maximum length	> 450
Width at third trochanter	140
Proximal width	150
Maximum proximal depth	160
Distal depth	140
Width of the condyles	90

2009). Ivand skull (Fig. 4A) also partially resembles *H. giganteum* from Grebeniki, Moldavia (Gromova 1952). *Hipparion giganteum* is also a large hipparion with a single, elliptical, and deep POF with strong posterior pocketing, located far from the orbit and facial crest. Nevertheless, the large-sized skull from Ivand has a sub-triangular POF which lacks posterior pocketing. Ivand skull is also comparable to a large-sized skull from Samos (AMNH 22838), described as *H.* cf. *proboscideum* (Sondaar 1971). This specimen from Samos features more facial height than does the large skull from Ivand. Unlike the type skull of *H. proboscideum* Studer, 1911, AMNH 22838 bears a single and deep POF (Sondaar 1971), which makes it morphologically similar to the *H. brachypus* skull from Akkaşdaği (Koufos & Vlachou 2005).

Based on the bivariate plots and log ratio diagrams (Figs 3, 4), the hipparion skull from the Ivand locality likely belongs to a large-sized *Hipparion* species of *H. giganteum-H. brachypus* lineage ("*Hippotherium*" *brachypus*-"*Hippotherium*" *giganteum* lineage, *sensu* Bernor *et al.* 1996b), previously unknown from the cranial material in NW Iran (i.e. the Maragheh area). We refrain from classifying this specimen at the species level because of some differences in its facial morphology, such as the shape of the POF and lack of posterior pocketing, and its inaccurately restored muzzle. The occurrence of large hipparions (similar to *H. brachypus*) in Maragheh was previously evidenced by the presence of medium to large, robust third metapodials (Watabe & Nakaya 1991a; Tobien in Bernor *et al.* 1996a, b). Some of these robust metapodials were assigned to *H. prostylum*, even though they showed greater similarity to the metapodials of *H. brachypus* from Pikermi (Watabe & Nakaya 1991a: fig. 15).

Family RHINOCEROTIDAE Owen, 1845
Subfamily RHINOCEROTINAE Owen, 1845

Rhinocerotinae indet.
(Fig. 5S-U)

LOCALITY. — Quarry 3, Ivand district, north of Tabriz, Iran.

MATERIAL EXAMINED. — Femur (HMNH-IV137; Fig. 5S-U; Table 2).

DESCRIPTION

An almost complete left femur is preserved (Fig. 5S-U). In the proximal part, the femoral head (caput femoris) and trochanter major are missing. The

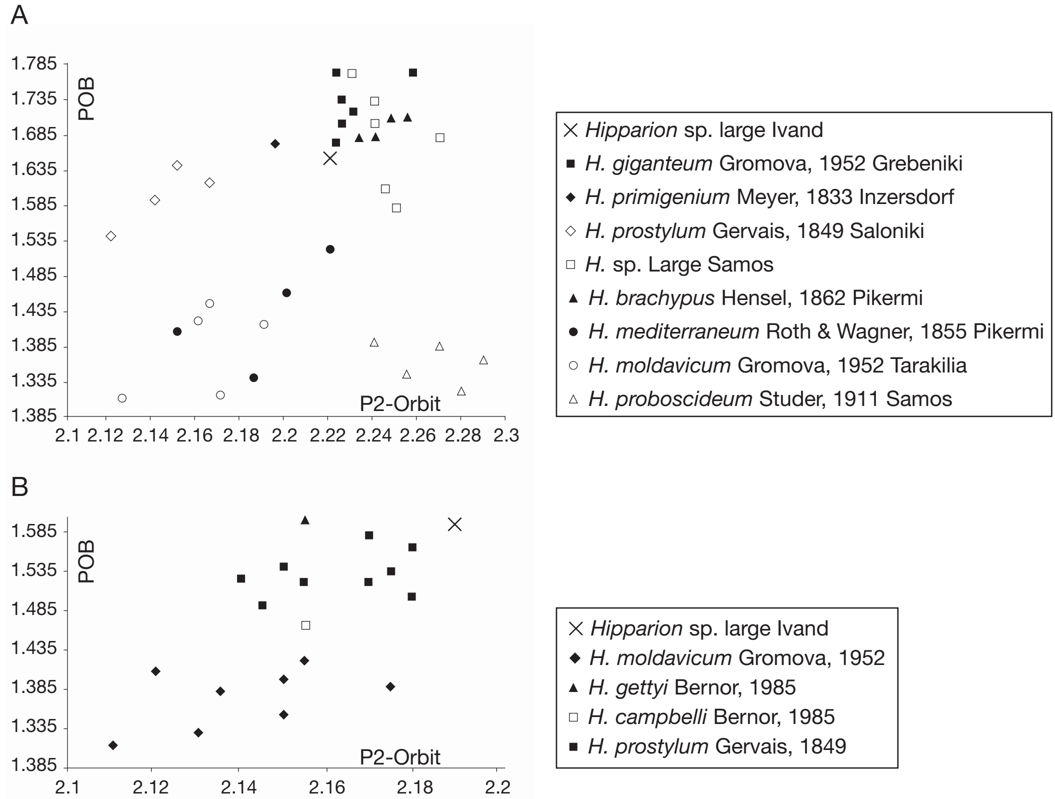

FIG. 3. — Preorbital bar (**POB**) width plotted against the P2-ORBIT distance, comparing *Hipparion* sp. large (HMNH-IV1) from the Ivand locality with: **A**, several other species from the eastern Mediterranean and northern Black Sea regions; and **B**, *Hipparion* species from Maragheh (NW Iran).

third trochanter is broken, but the basal part is preserved. The diaphysis becomes stockier distally from the third trochanter. The distal end is well preserved, and only the posterior and anterior sides are abraded. The medial and lateral trochleas are at the same level. The trochlear trough is damaged. The two condyles somehow diverge downward and the medial condyle is higher in elevation. The intercondyloid fossa is filled with sediment.

COMPARISON

Figure 6A shows the scatter plot of the femoral length against the distal width of well-preserved rhinocerotid femurs from several localities in Greece, Turkey, Iran, and China. The femur from Ivand locality, as illustrated, is clearly distinct from those of *Chilotherium wimani* Ringström, 1924 and *C. persiae* Pohlig, 1887 which are smaller, slenderer, and less massive (Deng 2002). The femur IV137 clusters among the material assigned to *Ceratotherium neumayri* (Osborn, 1900) and *Stephanorhinus pikermiensis* (Toula, 1906) from eastern Mediterranean localities such as Pikermi, Maragheh, and Akkaşdaği (Fortelius *et al.* 2003; Antoine & Saraç 2005). In general, the femur of these species is about 50 cm long and 15 cm wide distally. The total length of the Ivand femur, due to its missing proximal end, is unknown but it is estimated to be about 45 cm. Therefore, the rhinocerotid femur from Ivand locality can be assigned to *Ceratotherium neumayri*/*Stephanorhinus pikermiensis* primarily by size.

Order PROBOSCIDEA Illiger, 1811
Family DEINOTHERIIDAE Bonaparte, 1845
Genus *Deinotherium* Kaup, 1829

Deinotherium giganteum Kaup, 1829
(Fig. 5A-R)

LOCALITY. — Quarry 3, Ivand district, north of Tabriz (Iran).

MATERIAL EXAMINED. — Postcranials, including proximal part of ulna (HMNH-IV135; Fig. 5A-C, Table 2); proximal part of radius (HMNH-IV115; Fig. 5P-R, Table 2); proximal part of tibia (HMNH-IV119; Fig. 5D-F, Table 2); calcaneus (HMNH-IV118; Fig. 5G-I, Table 2); unciform (HMNH-IV117; Fig. 5J-L, Table 2) and one metapodial (HMNH-IV114; Fig. 5M-O, Table 2).

DESCRIPTION

The proximal part of an ulna is preserved (Fig. 5A-C). The tuber olecrani is partly damaged, but shows a slight extension in the medial part. The processus coronoideus medialis and lateralis are round and of approximately the same size. The processus anconaeus is slightly higher than the tuber olecrani. The cross section of the shaft is triangular. The proximal part of a single radius is present (Fig. 5P-R). The shape of the caput radii is sub-triangular. The articular circumference is damaged.

The tibia includes only one proximal part (Fig. 5D-F). In the proximal view, only the condylus lateralis and medialis are visible.

Calcaneus is an almost complete specimen with minor damage (Fig. 5G-I). The tuber calcanei is higher than it is wide. Proximally, there are three facets, two of which are partly preserved. The lateral facet is not preserved. The two astragalus facets are separated by sulcus calcanei. The larger astragalus facet is rounded and the smaller one is on the sustentaculum tali and is partly broken. On the dorsal of the sustentaculum tali, parts of a navicular facet are preserved.

The unciform is nearly complete and has a triangular outline (Fig. 5J-L). The proximal facet is triangular and concave. The distal side has one triangular concave facet and another elongated facet. The third facet is destroyed.

COMPARISON

The morphologies of postcranial skeletons in deinotheriids bear notable similarities (Huttunen 2002). From the postcranial elements described here, the proximal condyle of the ulna from Ivand is very well preserved and allows us to compare it to other deinotheriid specimens from other localities. Figure 6B shows the bivariate plots of the proximal width of the ulna against the width at process olecrani in IV135 and specimens from Maragheh (MN12, NW Iran), Saloniki and Pikermi (MN12, Greece), and Unterzolling (Germany). The plot illustrates that the Ivand material, though slightly smaller in proportion, is close to both *Deinotherium giganteum* from Pikermi and an undetermined specimen from Maragheh. The ulna of the Ivand specimen is obviously larger than the ulna of *Choerolophodon pentelici* (Gaudry & Lartet, 1856) from Saloniki, Greece and of *Prodeinotherium bavaricum* (Meyer, 1831) from Unterzolling (Huttunen & Göhlich 2002). Therefore, based on this comparison, and since *Deinotherium giganteum* is the largest of the Late Miocene mammals in NW Iran, previously recorded from Maragheh, we assign the very large postcranials from the Ivand locality to this species.

Order ARTIODACTYLA Owen, 1848
Family BOVIDAE Gray, 1821
Genus *Oioceros* Gaillard, 1902

Oioceros atropatenes Rodler & Weithofer, 1890
(Fig. 7E, F)

LOCALITY. — Quarry 1, Ivand district, north of Tabriz, Iran.

MATERIAL EXAMINED. — Left horn-core (HMNH-IV200; Fig. 7E, F), right mandible with p4-m3 (HMNH-IV67; Table 3), right mandible with broken m2 and complete m3 (HMNH-IV69; Table 3).

DESCRIPTION

The horn-core specimen is partly broken at the base and the tip. The antero-posterior diameter cannot be measured precisely due to the basal missing part on both the anterior and posterior sides. However, we estimate that it exceeds 17 mm. The medio-

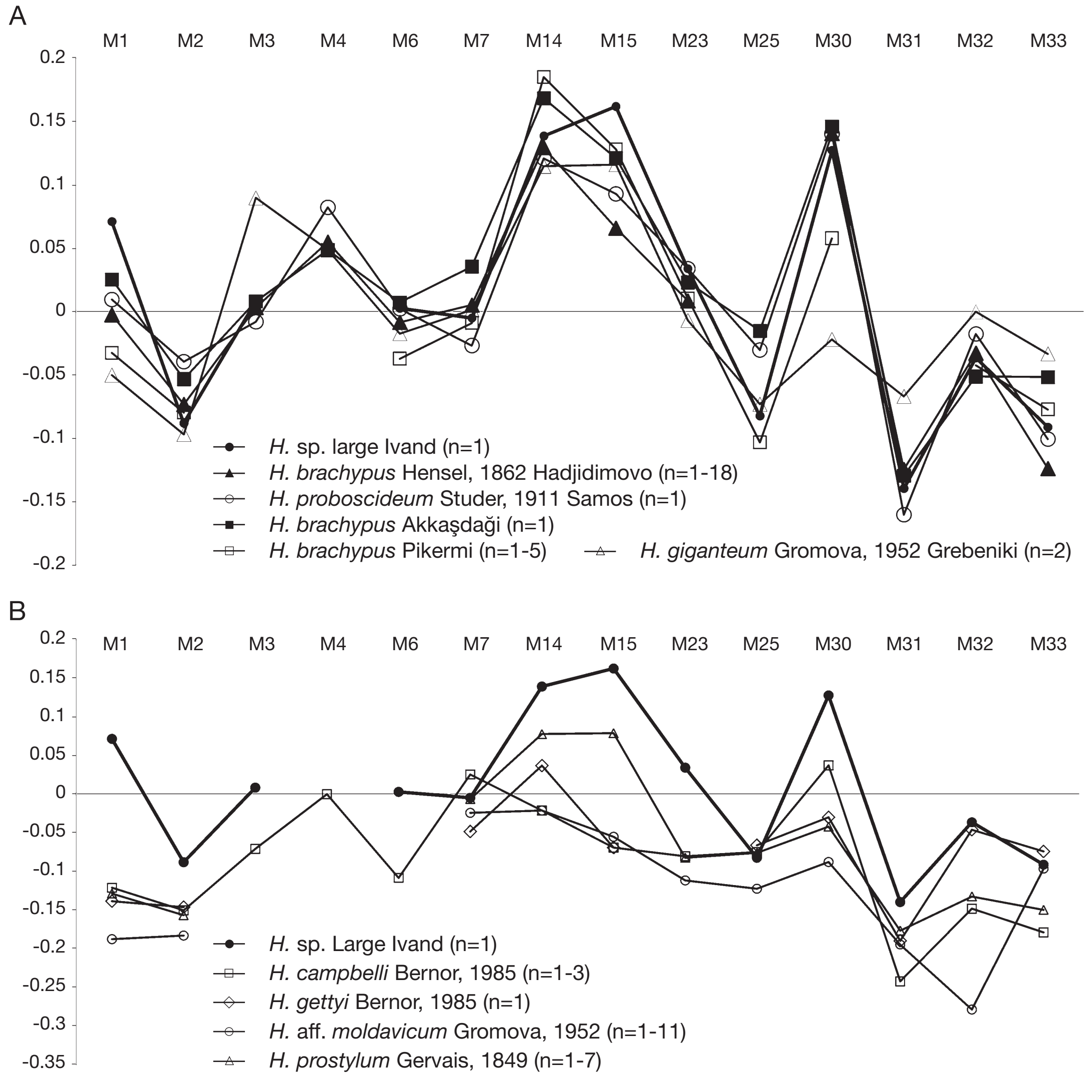

FIG. 4. — Logarithmic ratio diagrams comparing the skull of *Hipparion* sp. Large (HMNH-IV1) from the Ivand locality to: **A**, *H. brachypus* Hensel, 1862, *H.* cf. *proboscideum*, and *H. giganteum* Gromova, 1952 from localities in the eastern Mediterranean and northern Black Sea regions; and **B**, "*H.*" *gettyi* Bernor, 1985, "*H.*" aff. *moldavicum* (*H. moldavicum* Gromova, 1952 *sensu* Watabe & Nakaya 1991b), *H. campbelli* Bernor, 1985 and *H. prostylum* Gervais, 1849 from Maragheh, NW Iran. Standard, *H. primigenium* Meyer, 1833, Höwenegg (Bernor *et al.* 1997).

lateral diameter is 17.4 mm. The DAP and DT at 5 cm above the base are 12.7 mm and 10.9 mm, respectively. The total preserved length is 75 mm from the pedicle. By the preserved part of the orbit and remnant of the frontal, the horn-core is located above the posterior part of the orbit, tilted slightly backwards with a weak curvature. The horn-core is slender with a roughly oval cross section. The antero-posterior and transverse diameters diminish slowly from the base upwards. There are two weak keels, one starting from the antero-lateral side, and the other from the postero-lateral side. These two keels enclose a slightly convex outer surface and a more rounded inner surface. The keels spiral clockwise roughly one gyre from the base to the tip by estimation. There is also a postcornual fossa.

p4 is long and narrow. The paraconid is not separated from the parastylid. The anterior valley is wide. The metaconid is situated posterior to the protoconid. The entoconid is close to the entostylid. A wide and shallow valley separates the protoconid from the hypoconid. m1 is well worn. The parastylid is developed, and well separated from the metaconid. There is no goat fold, thus rendering the anterior border much narrower. The lingual wall is flat with weak metastylids. The entostylid is larger. There is a large basal pillar between the protoconid and the metaconid. m2 is very similar in morphology to m1, except for its larger, more convex lingual wall, and lower basal pillar. The parastylid on m3 is more pronounced and well separated from the metaconid. The basal pillar is small and low. The hypoconulid is large and postero-labially offset.

Comparison

Based on the small size, insertion above the posterior part of orbit, the clockwise torsion on the left horn-core from the base, and two keels, the horn-core IV200 from Ivand locality can readily be assigned to the genus *Oioceros* (type species *Antelope rothii* Wagner, 1857 from Pikermi, Greece) (Gaillard 1902). Since then, numerous species were included or assigned to this genus. De Mecquenem (1924) recognized three species from Maragheh: *O. rothii* (Wagner, 1857), *O. atropatenes* and *O. boulei* Mecquenem, 1924. Heintz (1963) synonymized *O. boulei* with *O. atropatenes* based on his detailed description and comparison. Roussiakis (2003) recently described in detail an almost complete skull with mandibles of *Oioceros rothii* from Pikermi and reviewed the generic status. Besides the type species, he listed only *Oioceros atropatenes* in the genus. The present specimen is smaller and less laterally compressed than *Oioceros rothii* from Pikermi. The main keel is much weaker and the upper part of the horn-core diverges less. The size falls into the variation of *Oioceros atropatenes* from Maragheh, Iran (Heintz 1963). The morphology of the horn-core is also consistent with those from Maragheh. Hence, the horn-core specimen can be assigned to *Oioceros atropatenes*.

Genus *Gazella* Blainville, 1816

Gazella sp.
(Fig. 7A-D, G, H)

Locality. — Quarry 3, Ivand district, north of Tabriz, Iran.

Material examined. — Two left and one right broken frontlets with horn-cores (HMNH-IV138-140; Fig. 7A-D, G, H).

Description

Frontlet HMNH-IV138 (Fig. 7C, D) preserves an almost complete horn-core (80 mm above the pedicle), unfortunately broken in the middle and preserving little of the frontal or orbit. IV139 (Fig. 7G, H) features the preserved supra-orbital fossa, but lacks the tip of the horn-core. IV140 (Fig. 7A, B) preserves a partial orbit and a small part of the parietal, but lacks the tip of the horn-core and has a broken inner side.

Frontlets IV139 and IV140 bear similar sizes and horn-core morphologies. The DAP and DT at the base of IV139 are 25 mm and 21.5 mm, respectively. The horn-cores are located above the orbits, moderately curved posteriorly in lateral view, and straight in anterior view. The base of the horn-core is relatively robust and laterally compressed, and the cross section diminishes greatly upwards. The maximum width lies at the anterior side of the horn-core while the posterior side is narrow. Longitudinal grooves are also present. The supra-orbital fossa is large and oval-shaped, and is located slightly towards the middle of the horn-core mid-line. The dorsal orbital rim is wide and features a postcornual fossa. Frontlet IV138 differs from the two frontlets described above in that it is less curved in lateral view and is less robust at the base; its cross section diminishes gradually from the base upwards.

Comparison

According to the morphology of horn-cores, the three frontlets found at Ivand locality can be separated into two groups. Frontlets IV139 and IV140 show homogenous characteristics and should be classified into one form; IV138 may belong to another form. Horn-cores IV139 and IV140 show great similarities to *Gazella deperdita* (Gervais, 1847) in that they fea-

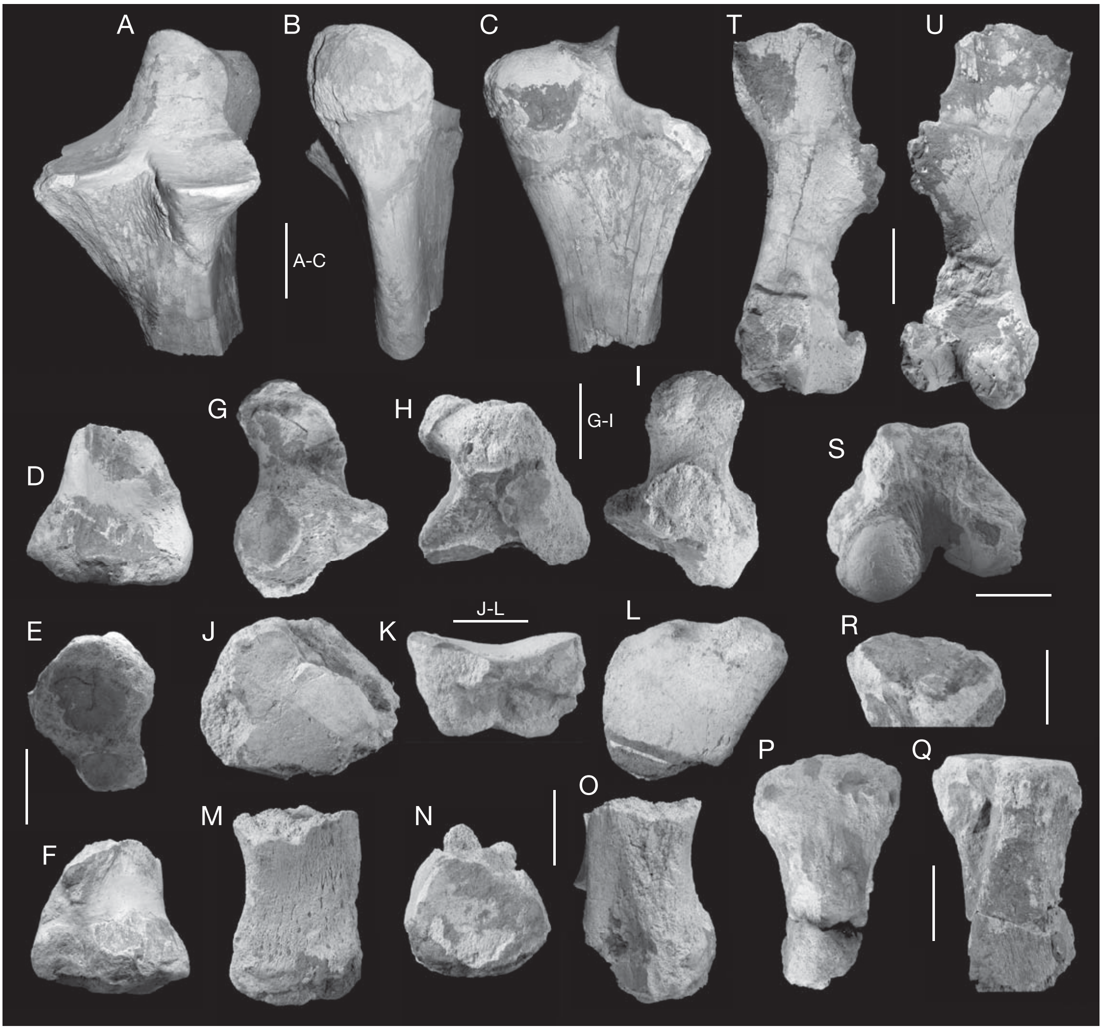

FIG. 5. — *Deinotherium giganteum* Kaup, 1829 (**A**-**R**) and Rhinocerotinae indet. (**S**-**U**) postcranials, Ivand locality, NW Iran: **A**-**C**, ulna (HMNH-IV135) in proximal-anterior (**A**), proximal-posterior (**B**) and proximal-lateral (**C**) views; **D**-**F**, tibia (HMNH-IV119) in proximal-lateral (**D**, **F**) and proximal (**E**) views; **G**-**I**, calcaneus (HMNH-IV118) in proximal (**G**), distal (**H**) and lateral (**I**) views; **J**-**L**, unciform (HMNH-IV117) in distal (**J**), lateral (**K**) and proximal (**L**) views; **M**-**O**, metapod (HMNH-IV114) in lateral (**M**, **O**) and proximal (**N**) views; **P**-**R**, radius (HMNH-IV115) in medial (**P**), dorsal (**Q**) and proximal (**R**) views; **S**-**U**, femur (HMNH-IV137) in distal (**S**), anterior (**T**) and posterior (**U**) views. Scale bars: A-C, 90 mm; D-F, 1 mm; G-I, S, 60 mm; J-L, 35 mm; M-O, 40 mm; P-R, 65 mm; T, U, 45 mm.

ture a robust base, rapidly diminishing cross section, a curved outline in the side view, and a maximum width located at the anterior part. IV138 however, is much less curved in the side view, with the cross section gradually changing from the base upwards. These characteristics fit *Gazella gaudryi* Schlosser, 1904 (Arambourg & Piveteau 1929).

Bovidae indet.

LOCALITY. — Quarry 1, Ivand district, northwest of Tabriz, Iran.

MATERIAL EXAMINED. — Fragmentary right mandible with m2-m3 (HMNH-IV59; Table 3), right m1 (HM-

Table 3. — Measurements (in mm) of the length and width (L/W) of the Bovid teeth from the Ivand locality (NW Iran). Question mark (**?**) indicates unavailable measurements.

Specimen	DP3	DP4	P4	M1	M2	p4	m1	m2	m3
HMNH-IV57					27.5/?				
HMNH-IV58			14/16						
HMNH-IV59								23/14.5	30/14.6
HMNH-IV64				23.5/?	23.7/?				
HMNH-IV65							20.7/12.2		
HMNH-IV67						8.4/4.7	9.7/6.1	10.8/6.4	16.3/6.1
HMNH-IV69								10.8/?	14.5/5.8
HMNH-IV70	18/11.7	20/19.5					25/?		

NH-IV65; Table 3), broken right m2 (HMNH-IV68; Table 3), left maxilla with DP2-M1 (HMNH-IV70; Table 3), fragmentary right maxilla with M1-M2 (HMNH-IV64; Table 3), fragmentary right maxilla with P4-M1 (HMNH-IV58; Table 3), fragmentary left maxilla with M1-M2 (HMNH-IV57; Table 3).

Description

The mandibles and maxillae are too fragmentary to provide any detailed character. DP2 is heavily worn and is long and narrow. The parastyle is prominent but low. There is no mesostyle, and the metastyle is weak. The paracone is the highest cusp, and the metacone is slightly lower. The protocone is large and located anteriorly to the paracone. The hypocone is larger than the protocone. There is no central fossette visible on the occlusal surface. DP3 is longer than DP2 and is submolarized. The parastyle is strong and well separated from the paracone by a wide groove. The mesostyle, however, is less developed, and the metastyle is the least developed. The anterior rib is very strong, and the posterior rib is weak. The central cavities bear a simple enamel outline. DP4 is highly molarized and, except for its smaller size, closely resembles molars. The central fossettes are open in the medium wear.

P4 is subtriangular. The hypocone is relatively well developed, though smaller than protocone, thus rendering the inner wall a less angled shape. The parastyle and metastyle are well developed, while the mesostyle is weak.

On M1, the parastyle is robust, the mesostyle is well developed as a vertical ridge, and the metastyle projects much less. The anterior rib is large, and the posterior rib is weak. There is no basal pillar. M2 closely resembles M1 in tooth morphology. The hypocone triangle is relatively short and is rounder than the protocone triangle. The metastyle is slightly more developed.

m1 shows a rectangular occlusal outline. The parastylid, metastylid, and the entostylid are much reduced. The lingual wall is flat with slightly convex metaconid and entoconid. The protoconid and hypoconid on m2 are triangle shaped. The parastylid is slightly more developed than the metastylid and entostylid. There is no goat fold but there is a low basal pillar. m3 resembles m2, except for its strongly labially offset hypoconulid with a central cavity.

Comparison

With no cranial or horn-cores found, discussing the systematic position of these isolated fragmentary materials in detail is difficult. Based on size and morphology, these teeth are tentatively assigned to one form herein, pending the discovery of better specimens.

This form, like *Urmiatherium polaki* Rodler, 1889, features a developed parastyle, very strong mesostyles, a prominent anterior rib, and a concave labial metacone wall on the upper molars. It differs by having a lower tooth crown, no additional cavities near the central lingual edge of the occlusal surface on the upper molars, a convex shape of the lingual wall, and the well developed basal pillars on the lower molars.

De Mecquenem (1924, 1925) reported some material of *Palaeoryx pallasi* (Wagner, 1857) from Maragheh. The size of the present form from Ivand locality is comparable to this Maragheh

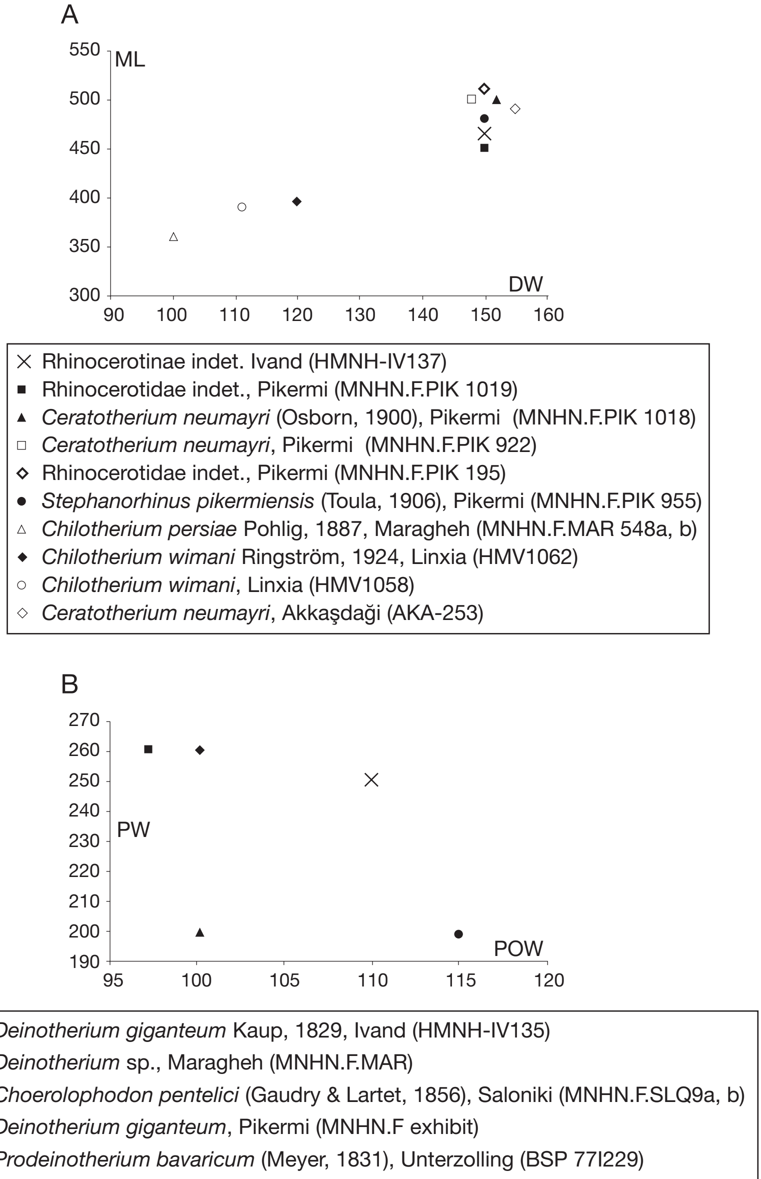

FIG. 6. — **A**, distal width (**DW**) plotted against maximum length (**ML**) of femur in Rhinocerotinae indet. from the Ivand locality and some other Rhinocerotidae Owen, 1845 from Eurasia (Akkaşdaşi data from Antoine & Saraç [2005]; Linxia data from Deng [2002]); **B**, ulna proximal width (**PW**) plotted against its width at process olecrani (**POW**) in *Deinotherium giganteum* Kaup, 1829 from Ivand locality and several other specimens from Europe (Unterzolling data from Huttunen & Göhlich 2002).

taxon. They share similar tooth morphology, such as strong parastyles and mesostyles, weak metastyles, developed anterior ribs, no basal pillars on the upper molars, a slightly convex lingual wall of the lower molars, low but distinct basal pillars, triangular labial lobes on the lower molars, and strongly labially offset hypoconulids on m3. The skull figured by de Mecquenem (1924, 1925:

pl. 4, fig. 1), however, was believed to be that of a *Miotragocerus* Stromer, 1928 (= *Tragoportax* Pilgrim, 1937) by Bohlin (1936) and Gentry (1971, 2000). Gentry (1971) further stated that there was no other convincing evidence of *Palaeoryx pallasi* from Maragheh. Given these poor materials and pending the discovery of more complete fossils, we avoid naming them.

ADDITIONAL MAMMAL FOSSILS FROM IVAND

Other fossil material in the collection of HMNH, not included here, are partially and poorly preserved juvenile skulls, the dentition, and fragmentary postcranials of hipparionine horses, and several indeterminate postcranials of very large mammals, as well as some unprepared material from several fossil quarries in Ivand locality. Notable specimens among this material are: part of an unprepared maxilla with an upper canine and premolars of a medium-sized machairodontine cat, smaller than *Machairodus aphanistus* Kaup, 1833 and *M. giganteus* (Wagner, 1848), and parts of a giraffid radius consisting of the damaged proximal part and the diaphysis. The giraffid remains are proportionally larger than *Palaeotragus* Gaudry, 1861 and are in the size range of *Samotherium* Forsyth-Major, 1888 and *Helladotherium* Gaudry, 1860.

Another significant piece of material from the Ivand locality is a partially preserved skull with the basal parts of the horn-cores of a bovid that resembles *Urmiatherium*. This specimen is stored in the collection of the University of Tabriz. Recently, several isolated teeth of the porcupine rodent *Hystrix aryanensis* Sen, 2001 were reported from this locality (Sen & Purabrishemi 2010). These materials are stored in the same institution.

BIOCHRONOLOGY

Due to geographical proximity of Ivand locality with the famous Maragheh fossil sites (*c.* 150 km), faunal comparison and correlation of these fossil assemblages is of interest. As in other typical Turolian localities of the Old World, hipparions are the most abundant material found in the Ivand locality.

Among the known cranial material of hipparionine horses from the Maragheh area, no large hipparion species as large as *Hipparion* sp. large from Ivand is known. Although, *H. prostylum* from Maragheh is close to *Hipparion* sp. large from Ivand, it is still significantly smaller (Fig. 3B, 4B). *Hipparion* sp. large from the Ivand locality, based on its large size and facial morphology, belongs to Group 1 hipparions of the Woodburne & Bernor (1980) classification (*H. primigenium* Meyer, 1833 group, *sensu* Forsten 1968). This group comprises hipparionine horses with large, well-defined preorbital fossa, situated far from the orbit (wide preorbital bar). The POF in this group is deep, both dorso-ventrally and medially, and is pocketed posteriorly. The anterior rim of the fossa is also detectable (Woodburne & Bernor 1980). The chronological range of this group is from the early Vallesian through the medial Turolian (Bernor 1985).

"*Hipparion*" *gettyi* from the Lower Maragheh biostratigraphical interval in Kopran also belongs to this group, but differs from the Ivand specimen due to its smaller size and different POF morphology.

The large hipparion species, *H. brachypus,* is known at Pikermi and Samos (Greece), Akkaşdaği (Turkey), and Hadjidimovo (Bulgaria) in the middle Turolian (MN12) of the eastern Mediterranean region (Koufos & Vlachou 2005; Vlachou & Koufos 2009). Thus, documentation of a large hipparion from Ivand, in close proximity to the Maragheh and eastern Mediterranean area, is not unexpected.

The large-sized hipparion species from Ivand is comparable in its basic morphology and dimensions to *H. brachypus* and *H. giganteum* (Figs 3A; 4A). *Hipparion giganteum-H. brachypus* lineage was widespread in the Turolian, and especially during MN12, of the eastern Mediterranean region (Vlachou & Koufos 2009).

Among the bovids, *Oioceros atropatenes* is the most abundant species in the Maragheh fossil localities, which mostly occurs in the Middle and Upper levels of the Maragheh Fm. The type

FIG. 7. — *Gazella* sp. (**A**-**D**, **G**, **H**) and *Oioceros atropatenes* Rodler & Weithofer, 1890 (**E**, **F**) from Ivand locality (NW Iran): **A**, **B**, HMNH-IV140 in frontal (**A**) and lateral (**B**) views; **C**, **D**, HMNH-IV138 in frontal (**C**) and lateral (**D**) views; **E**, **F**, HMNH-IV200 in lateral-posterior (**E**) and frontal (**F**) views; **G**, **H**, HMNH-IV139 in lateral (**G**) and frontal (**H**) views. Scale bars: A, B, G, H, 20 mm; C, D, 15 mm; E, F, 25 mm.

locality of *Urmiatherium* in the Maragheh area is Ilkhchi, which is correlated to the upper Maragheh biostratigraphical interval.

Machairodontine cats, broadly distributed in the Late Miocene of Eurasia, are also well represented in the Middle Maragheh fauna by *Machairodus aphanistus* (Bernor 1986).

Furthermore, *Ceratotherium neumayri* was also widespread in the eastern Mediterranean localities. It has a long range in Greece, Turkey and Iran, which is MN 9 to MN 12-13 (Heissig 1996). In Maragheh, *Ceratotherium neumayri* is reported as *Diceros neumayri* Mecquenem, 1905 from the upper levels of the Maragheh Fm. (Bernor 1986).

The only known *Deinotherium* from the Maragheh Fm. is recorded in the Upper biostratigraphical interval of this formation (the K1 locality of Erdbrink *et al.* 1976; identical to MMTT locality 31 of Bernor 1986). The absolute ages obtained from the Zircon fission track and the K/Ar dating of pumicites from higher levels of the Maragheh Fm. imply an age of 7.4 Ma for these levels (Bernor *et al.* 1996).

In addition, Sen & Purabrishemi (2010) documented *Hystrix aryanensis* remains from Ivand locality. This species is previously known from Molayan locality in Afghanistan, *c.* 8-7 Ma.

In conclusion, based on the fossil material from the Ivand locality and their correlations mostly with the Middle and Upper biostratigraphic intervals of the Maragheh Fm. and the chronology of *H. giganteum*-*H. brachypus* lineage in eastern Mediterranean faunas, and also occurrence of *Hystrix aryanensis* in Ivand fauna, we propose a middle Turolian age (MN 12 equivalent, *c.* 8-7 Ma) for this new locality.

CONCLUSIONS

The new locality of Late Miocene fossil mammals in the Ivand district, north of Tabriz extends our knowledge of mammalian faunas in NW Iran beyond the previously well-known localities in the Maragheh area. Among the fossil material from the Ivand locality, the presence of a large hipparion is most notable. This large species, comparable to *H. brachypus* and *H. giganteum* from the eastern Mediterranean and northern Black Sea regions, is the first unequivocal evidence of the presence of a large hipparionine horse in the Late Miocene of NW Iran. Other taxa such as *Hystrix aryanensis*, *Deinotherium giganteum*, *Oioceros atropatenes*, *Gazella* sp., Bovidae indet., Giraffidae indet., Machairodontinae indet., and Rhinocerotinae indet. are also present in this fauna. Based on the biochronology of some of these taxa and their correlation with Maragheh Fm., a middle Turolian age (MN 12 equivalent, *c.* 8-7 Ma) is proposed for this new locality.

Acknowledgements

HMNH staff and volunteers are appreciated for the field work and preparation of the fossil material. P. Tassy and C. Sagne of MNHN, Paris provided MMA access to the Muséum's Late Miocene fossil mammal collections. We express our gratitude to the Iran's DOE and F. Vaez Javadi, M. Medadi, D. Najafi, S. Montazami, R. Goharshahi, M. Peighami, Z. Orak , and G. Zaree for facilitating our fieldtrip to Maragheh and Ivand in 2007. B. Rasoulpour, R. Amirmardfar, N. Abbassi, M. Pourbagheban, S. Naghdi, M. Sohrabi, S. Sohrabi, A. Asadi, and Z. Davoudifard assisted MMA in field and laboratory. P. Mauriès and S. Sen edited the French text. We are grateful to S. Sen, for his constructive comments on an earlier version of this article, and to L. Alcalá and A. Ohler for their remarks on the manuscript. We thank Academy of Finland for financial support.

REFERENCES

Aghanabati A. 2004. — [*Geology of Iran*]. Geological Survey of Iran, Tehran, 586 p. (in Persian).

Antoine P. O. & Saraç G. 2005. — Rhinocerotidae (Mammalia, Perissodactyla) from the Late Miocene of Akkaşdaği, Turkey, *in* Sen S. (ed.), Geology, mammals and environments at Akkaşdaği, Late Miocene of Central Anatolia. *Geodiversitas* 27 (4): 601-632.

Arambourg C. & Piveteau J. 1929. — Les vertébrés du Pontien de Salonique. *Annales de Paléontologie* 18: 59-138.

Bernor R. L. 1985. — Systematic and evolutionary relationships of the hipparionine horses from Maragheh, Iran (Late Miocene, Turolian age). *Palaeovertebrata* 15 (4): 173-269.

Bernor R. L. 1986. — Mammalian biostratigraphy, geochronology, and zoogeographic relationships of the Late Miocene Maragheh fauna, Iran. *Journal of Vertebrate Paleontology* 6 (1): 76-95.

Bernor R. L., Solounias N., Swisher III C. C. & Van Couvering J. 1996a — The correlation of three classical "Pikermian" mammal faunas (Maragheh, Samos, and Pikermi) with the European MN unit system, *in* Bernor R. L., Fahlbusch V. & Mittmann H. W. (eds), *The Evolution of Western Eurasian Neogene Mammal Faunas*. Columbia University Press, New York: 137-154.

Bernor R. L., Koufos G. D., Woodburne M. & Fortelius M. 1996b — The evolutionary history and biochronology of European and southeastern Asian

Late Miocene and Pliocene hipparionine horses, *in* Bernor R. L., Fahlbusch V. & Mittmann H. W. (eds), *The Evolution of Western Eurasian Neogene Mammal Faunas*. Columbia University Press, New York: 307-338.

Bernor R. L., Tobien H., Hayek L. A. & Mittmann H. W. 1997. — The Höwenegg hipparionine horses: systematic, stratigraphy, taphonomy and paleoenvironmental context. *Andrias* 10: 1-230.

Bernor R. L., Scott R. S., Fortelius M., Kappelman J. & Sen S. 2003. — Equidae (Perissodactyla), *in* Fortelius M., Kappelman J., Sen S. & Bernor R. L. (eds), *The Geology and Paleontology of the Miocene Sinap Formation, Turkey*. Columbia University Press, New York: 220-281.

Blair T. C. & McPherson J. G. 1984. — Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages. *Journal of Sedimentary Research* A64: 450-489.

Bohlin B. 1936. — Bemerkungen über einige pontischen Antilopen-Gattungen. *Arkiv för Zoologi* 28A (18): 1-22.

Davoudzadeh M., Lammerer B. & Weber-Diefenbach K. 1997. — Paleogeography, stratigraphy, and tectonics of the Tertiary of Iran. *Neues Jahrbuch für Geologie und Paläeontologie. Abhandlungen* 205 (1): 33-67.

De Mecquenem R. 1924. — Contribution à l'étude des fossiles de Maragha. *Annales de Paléontologie* 13: 135-160.

De Mecquenem R. 1925. — Contribution à l'étude des fossiles de Maragha. *Annales de Paléontologie* 14: 1-64.

Deng T. 2002. — Limb bones of *Chilotherium wimani* (Perissodactyla, Rhinocerotidae) from the Late Miocene of the Linxia Basin in Gansu, China. *Vertebrata PalAsiatica* 40 (4): 305-316.

Erdbrink D. P., Priem H. N. A. P, Hebeda E. H., Cup C., Dankers P., & Cloetingh S. A. P. L. 1976. — The bone bearing beds near Maragheh in N. W. Iran I. *Proceedings Koninklijke Nederlandse Akademie van Wetenschappen*: B 79 (2): 85-113.

Forsten A. 1968. — Revision of the Palearctic Hipparion. *Acta Zoologica Fennica* 119: 1-134.

Forsten A. 1983. — The preorbital fossa as a taxonomic character in some Old World Hipparion. *Journal of Paleontology* 57 (4): 686-704.

Fortelius M., Heissig K., Saraç G. & Sen S. 2003. — Rhinocerotidae (Perissodactyla), *in* Fortelius M., Kappelman J., Sen S. & Bernor R. L. (eds), *Geology and Paleontology of the Miocene Sinap Formation, Turkey*. Columbia University Press, New York: 282-307.

Gaillard C. 1902. — Le bélier de Mendès ou le mouton domestique de l'ancienne Égypte. *Bulletin de la Société d'Anthropologie de Lyon* 20: 69-103.

Gentry A. W. 1971. — The earliest goats and other antelopes from the Samos *Hipparion* fauna. *Bulletin of the British Museum (Natural History), Geology* 20: 231-296.

Gentry A. W. 2000. — Caprinae and Hippotragini (Bovidae, Mammalia) in the Upper Miocene, *in* Vrba E. S. & Schaller G. B. (eds), *Antelopes, Deer and Relatives: Fossil Record, Behavioral Ecology, Systematics and Conservation*. Yale University Press, New Haven: 65-83.

Gromova V. 1952. — [Gippariony (rod Hipparion) po materialam Taraklii, Pavlodara i drugim]. *Trudy Paleontologicheskogo Instituta* 36: 1-478 (in Russian).

Heintz E. 1963. — Complément d'étude sur *Oioceros atropatenes* (Rod. et Weith.), Antilope du Pontien de Maragha (Iran). *Bulletin de la Société géologique de France* 5: 109-116.

Heissig K. 1996. — The stratigraphical range of fossil rhinoceroses in the late Neogene of Europe and the eastern Mediterranean, *in* Bernor R. L., Fahlbusch V. & Mittmann H. W. (eds), *The Evolution of Western Eurasian Neogene Mammal Faunas*. Columbia University Press, New York: 339-347.

Heward A. P. 1978. — Alluvial fan sequence and megasequence models with examples from Westphalian D-Stephanian B coalfields, northern Spain, *in* Miall A. D. (ed.), *Fluvial Sedimentology*. Canadian Society of Petroleum Geologists, Memoir 5: 669-703.

Hristova L., Kovachev D. & Spassov N. 2003. — *Hipparion brachypus* Hensel, 1862 from the Late Miocene of Hadjidimovo, Southwestern Bulgaria. *Comptes Rendus de l'Académie bulgare des Sciences* 56 (2): 77-84.

Huttunen K. 2002. — Systematics and taxonomy of the European Deinotheriidae (Proboscidea, Mammalia). *Annalen des Naturhistorischen Museums in Wien* 103A: 237-250.

Huttunen K. & Göhlich U. B. 2002. — A partial skeleton of *Prodeinotherium bavaricum* (Proboscidea, Mammalia) from the middle Miocene of Unterzolling (Upper Freshwater Molasse, Germany). *Geobios* 35 (4): 489-514.

Koufos G. D. 1987a. — Study of the Pikermi hipparions. Part I: Generalities and taxonomy. *Bulletin du Muséum national d'Histoire naturelle*, Paris, 4e sér., 9, section C, 2: 197-252.

Koufos G. D. 1987b. — Study of the Pikermi hipparions. Part II: Comparisons and odontograms. *Bulletin du Muséum national d'Histoire naturelle*, Paris, 4e sér., 9, section C, 3: 327-363. `

Koufos G. D. & Vlachou T. D. 2005. — Equidae (Mammalia, Perissodactyla) from the Late Miocene of Akkaşdaği, Turkey, *in* Sen S. (ed.), Geology, mammals and environments at Akkaşdaği, Late Miocene of Central Anatolia. *Geodiversitas* 27 (4): 633-705.

Rieben H. 1935. — Contribution à la géologie de l'Azerbeidjan persan. *Bulletin de la Société des Sciences naturelles de Neuchâtel* 59: 20-144.

ROUSSIAKIS S. J. 2003. — *Oioceros rothii* (Wagner, 1857) from the Late Miocene of Pikermi (Greece): cranial and dental morphology, comparison with related forms. *Geodiversitas* 25 (4): 717-735.

SEN S. & PURABRISHEMI Z. 2010. — First porcupine fossils (Mammalia, Rodentia) from the Late Miocene of NW Iran, with notes on Late Miocene-Pliocene dispersal of porcupines. *Paläontologisch Zeitschrift* 84: 239-248.

SONDAAR P. Y. 1971. — The Samos *Hipparion*. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* B 74: 417-441.

VLACHOU T. D. & KOUFOS G. D. 2009. — Equidae, *in* KOUFOS G. D. & NAGEL D. (eds), The Late Miocene Mammal Faunas of the Mytilinii Basin, Samos Island, Greece: New Collection. *Beiträge zur Paläontologie* 31: 207-281.

WATABE M. & NAKAYA H. 1991a. — Phylogenetic significance of the postcranial skeletons of the hipparions from Maragheh (Late Miocene), NW Iran. *Memoirs of the Faculty of Sciences, Kyoto University* 56 (1-2): 11-53.

WATABE M. & NAKAYA H. 1991b. — Cranial skeletons of *Hipparion* (Perissodactyla, Mammalia) from Maragheh (Turolian, Late Miocene), NW Iran. *Memoirs of the Faculty of Sciences, Kyoto University* 56 (1-2): 55-125.

WOODBURNE M. O. & BERNOR R. L. 1980. — On superspecific groups of some Old World hipparionine horses. *Journal of Paleontology* 54 (6): 1319-1348.

Submitted on 24 August 2010;
accepted on 17 December 2010.