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A new skull of *Decennatherium rex* Ríos, Sánchez and Morales, 2017 from Batallones-4 (upper Vallesian, MN10, Madrid, Spain)

María Ríos and Jorge Morales

ABSTRACT

Giraffids are pecoran ruminants with bi-lobed canines and a special type of cranial appendage called ossicones, which are epiphyseal in origin and don't fuse completely to the skull until later in life. Although the family Giraffidae has only two extant living African genera, in the past this family was much more diverse and widespread. Today we can recognize more than 40 fossil species, from multiple sites in Eurasia and Africa, which range from the early Miocene (20 m.y.) until today. Here we describe the exceptionally well-preserved remains of the giraffid found in the late Miocene deposits of Batallones-4 (upper Vallesian, MN10, Torrejón de Velasco, Madrid, Spain). Batallones-4 is part of the Cerro de los Batallones fossil site complex, and although it was excavated during the year 2000 there is no published result. The specimen from Batallones-4 has been identified as an old male of *Decennatherium rex* first identified from Batallones-10 as they share key morphological cranial similarities. This new skull helps us to better understand this species cranial anatomy, as well as its morphological development and variability.

María Ríos. Departamento de Paleobiología, Museo Nacional de Ciencias Naturales- Consejo Superior de Investigaciones Científicas, Madrid, Spain. maria.rios.iba@gmail.com
Jorge Morales. Departamento de Paleobiología, Museo Nacional de Ciencias Naturales- Consejo Superior de Investigaciones Científicas, Madrid, Spain. mcnm166@mncn.csic.es

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INTRODUCTION

Giraffids are crown-pecoran ruminants, living relics of a once large and diverse clade called the Giraffomorpha (Sánchez et al., 2015). The Giraffidae is characterized by possessing bi-lobed canines and a type of epiphyseal cranial appendage called ossicone (Hamilton, 1978). There are

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only two extant genera, both of them African, *Okapia* and *Giraffa*, although more than 40 fossil taxa have been described from multiple sites in Eurasia and Africa (Solounias, 2007). Giraffids range from the early Miocene (20 m.y.) until today (Ríos et al., 2017).

Three late Miocene giraffid species have been described from the Iberian Peninsula: *Decennatherium pachecoi* Crusafont, 1952 (early Vallesian, MN9), present in the Calatayud-Teruel, Duero and Tagus basins, *Decennatherium rex* Rios et al., 2017 (late Vallesian, MN10), present in the Madrid basin, and *Birgerbohlinia schaubi* Crusafont, 1952 (early Turolian, MN11) from Piera and Crevillente-2 (Crusafont, 1952; Montoya and Morales, 1991; Montoya, 1994).

The description of the late Miocene (MN10) *Decennatherium rex* from the fossil site of Batallones-10 (Madrid Basin, Madrid province, Spain; Figure 1), represented by a complete sample of cranial, dental and postcranial remains shed light on the complex subject of giraffid evolution (Ríos et al., 2017). *Decennatherium rex* was recovered as a basal offshoot of a sivathere-clade that links together both samotheres and sivatheres, being the earliest evidence of the *Sivatherium*-ossicone plan (Ríos et al., 2017). In this work we describe the cranial remains of *Decennatherium rex* from Batallones-4 (BAT4 hereafter) with the aim of comparing them with the type skulls from Batallones-10, describing the intraspecific variability of the species regarding cranial features and specifically that of the cranial appendages.

Locality

The fossil site of BAT4 (Figure 1) is one of the late Miocene (Vallesian age) localities of the fossil site-complex of Cerro de los Batallones (Batallones Butte). A complete description of the geological setting of the fossil sites in the butte is given by Pozo et al. (2004) and Calvo et al. (2013). Since the discovery of BAT1, the nine researched sites in the Butte have yielded some of the richest and best-preserved Neogene mammal assemblages worldwide (Morales, 2008; Domingo et al., 2011; Valenciano et al., 2015). BAT4, found in the year 2000, was the first fossil locality of Cerro de los Batallones in yielding giraffid remains (Figure 1). During that year some isolated large-size *Hipparion* remains were also found. The deeper levels of the site were excavated during 2009, yielding a rich micromammal fauna together with other macromammal remains identified as Bovidae and Suidae. When comparing it with the fauna from other sites of the Cerro de los Batallones complex, the BAT4 fauna is that of the BAT10-type sites,

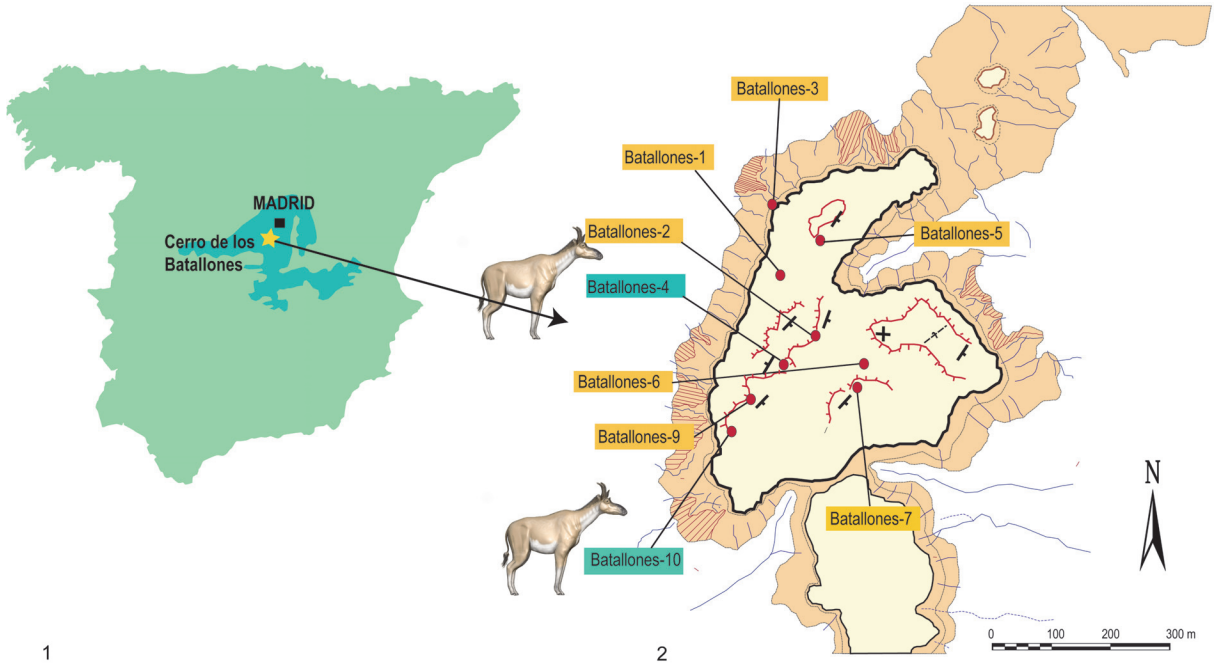

FIGURE 1. Location of Cerro de los Batallones. 1, location of Cerro de los Batallones (yellow star) within Spain; 2, map of Cerro de los Batallones and location of the fossil sites (Modified from Calvo et al., 2013). *Decennatherium rex* illustration by Oscar Sanisidro.

composed mainly by large herbivores. However, the fossil association of BAT4 is scarce when comparing it with the astonishingly rich BAT10.

MATERIALS AND METHODS

Fossil Material

We have studied the specimen BAT-04'00-37 from BAT4 curated by the MNCN-CSIC (Madrid, Spain) which consists in a complete skull with both hemimandibles.

Measurements

We follow the set of measurements proposed by Ríos et al., (2016a, 2016b) (S1, figures S1.1-S1.2). All measurements were taken with digital calipers (Tables 1-7).

Nomenclature

We use the terminology of Barone (Barone 1999) for anatomic nomenclature of the cranial l skeleton, and that published by Azanza (2000) for nomenclature of the dentition.

Institutional / technical abbreviations

MNCN-CSIC, Museo Nacional de Ciencias Naturales-CSIC, Madrid, Spain; Batallones-4, BAT4; Batallones-10, BAT10.

TABLE 1. Ossicone measurements of BAT-04'00-37. In mm.

Ossicone position	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Anterior Right	25	40	42.85	32.52	130	47	10.93	14.07	13			64.79	34.86	43.5
Anterior Left	20	20	40.76	36.62	120				10			64.74	34.86	34.38
Posterior Right	410	333	119.63	57.67	295	95	25.75	23	270	38.68	63.84	280	62	43.5
Posterior Left	400	324	123.01	56.75	290	97	24.42	26.75	220	33.83	62.94	280	62	34.38

TABLE 2. Ossicone bump measurements of BAT-04'00-37. In mm.

Right posterior ossicone: large dorsal bumps					
Knob no.	At height (mm)	Bump length (mm)	Bump width (mm)	Bump height (mm)	Notes
1	50	18.05	13.53	8.67	
2	92	22.74	16.28	7.82	
3	130	23.93	20.3	10.24	
4	170	27.15	29.21	22.31	
5	210	12.93	13.95	8.91	Slightly more medial
6	235	12.65	10.26	4.78	
7	265	23.67	17.63	17.78	
8	300	12.87	13.37	7.5	
Right posterior ossicone: large ventrolateral bump					
1	210	12.47	8.7	6.03	
Right posterior ossicone: small medial bumps					
N=6 total		5.61-13.98	4.63-24	2-5.52	
Left posterior ossicone: large dorsal bumps					
1	50	9.5	9.19	6.44	
2	70	18.36	12.29	10.39	
3	120	25.57	21.52	17.83	
4	160	20.1	14.94	12.53	
5	210	22.82	20.99	25.99	
6	258	26.54	23.77	15.64	
7	305	20.53	14.31	8.41	

TABLE 3. Skull measurements of BAT-04'00-37. Missing measurements due to preservation issues. In mm.

Measurements	mm.
α	8.94
β	87.85
Length skull+ossicones	~750
1	~700
2	
3	350
4	265
5	69.22
6	55.65
7	85
8	59
9	39.66
10	23.71
11	54.85
13	83.18
15	165
16	220
17	116.93
18	172
19	194
20	180
21	124.09
22	185
24	41.47
32	113.16
35	37.94
36	60.14
37	83.13
38	298
39	61.76

SYSTEMATIC PALAEONTOLOGY

Class MAMMALIA Linnaeus, 1758
Order CETARTIODACTYLA Montgelard, Catzeflis and Douzery, 1997
Suborder RUMINANTIA Scopoli, 1777
Infraorder PECORA sensu Webb and Taylor, 1980
Family GIRAFFIDAE Gray, 1821
Genus *Decennatherium* Crusafont, 1952

Type species. *Decennatherium pachecoi* Crusafont, 1952, by original designation.

Decennatherium rex (Ríos, Sánchez and Morales, 2017)
Figures 2-8

Holotype

BAT-10'13-E2-69, skull with ossicones and mandible (Figures 2-8).

Locality, age and horizon

BAT4, BAT10, Cerro de los Batallones, late Vallesian, MN 10, local zone J, Madrid province, Spain. (ca 9 m.y.) (Figure 1).

Emended Diagnosis

Large giraffid with two pairs of ossicones. Smaller anterior pair located above the orbits and anteriorly oriented. Larger posterior pair located posterior to the orbits and posteriorly oriented. Posterior ossicones curved, showing a high number of ridges on their surface. Posterior ossicones exhibit secondary bone growth deposition in adult individuals in the form of dorsal, ventral and dorsoventral round bumps. The location of these bumps has a genetic component. Middle indentation of the hard palate slightly posterior to the M3. Broad occipital. Long premaxillae. Elongated diastema. p3 lacking mesolingual conid. Slightly molarized p4 . Cervical vertebrae of medium length. Scapula with acromion.

TABLE 4. Maxillae measurements and indexes of BAT-04'00-37. In mm.

	P2-M3	P2-P4	M1-M3	P2-P4/P2-M3	M1-M3/P2-M3	P2-P4/M1-M3
Right	178.71	74.13	104.58	0.41480611	0.58519389	0.70883534
Left	179.07	76.27	102.8	0.42592282	0.57407718	0.74192607

TABLE 5. Mandible measurements and indexes of BAT-04'00-37. In mm.

	p2-m3	p2-p4	m1-m3	Mandible height at m1	Mandible width at m1	p2-p4/p2-m3	m1-m3/p2-m3	p2-p4/m1-m3	Mandible height at m1/ Mandible width at m1
Right	182.7	80.12	103.58	58	60	39.94	60.05	66.51	96.66
Left	189.61	72.87	110.51	57		0.38	0.58	0.65	

TABLE 6. Teeth measurements of BAT-04'00-37. In mm.

Teeth	Right/Left	Length
P2	R	
P3	R	27.6
P4	R	24.08
M1	R	30.99
M2	R	35.13
M3	R	37.5
p3	R	24.07
p4	R	26.09
m1	R	34.75
P2	L	22.48
P3	L	25.95
P4	L	24.98
M1	L	27.34
M2	L	37.27
M3	L	36.72
p2	L	20.77
p3	L	24.18
p4	L	21.64

Robust postcranial skeleton. Metacarpals of medium length showing a medium depth palmar trough. Differs from *Decennatherium pachecoi* in: p3 with an isolated wall-like mesolingual conid structure; anterior stylid and conid of the p3 always present; and more robust metapodials (Ríos et al., 2017).

Material

BAT-04'00-37 (skull and mandible).

ANATOMICAL DESCRIPTION

Ossicones

The skull has two pairs of ossicones (Figures 2-5, Tables 1-2). The smaller anterior pair is located above the orbits on the frontals and are anteriorly oriented forming an angle with the skull roof of 53º. There is a slight degree of torsion on the skull so that the angle represents an approximation of the real condition. Its surface has no ridges. The larger posterior pair (ca. 40 cm) is located posterior to the orbits over the parietals and are oriented posteriorly and slightly outwards, with and angle of insertion to the skull roof of approximately 50º in the right ossicone and 40º in the left one. The posterior ossicones are curved,

TABLE 7. Ossicone measurements of *Decennatherium rex* from BAT4 and BAT10. In mm.

Specimen no.	BAT-04'00-37		BAT-10'13-E2-69		BAT-10'07-G4-127	
Measurement/ Element	Posterior Right	Posterior Left	Posterior Right	Posterior Left	Posterior Right	Posterior Left
1	410	400	360	382	355	378
2	333	324	305	332	315	314
3	119.63	123.01	116.11	114.6	103.06	103.74
4	57.67	56.75	51.98	47.31	64.35	68.37
5	295	290	260	260	270	260
6	95	97	82	75	74	75
7	25.75	24.42	23.82	18.63	23.29	22.55
8	23	26.75	25.76	23.97	20.17	20.88
9	270	220	175	198	269	185
10	38.68	33.83	41.54	36.28	36.3	38.18
11	63.84	62.94	50.8	48.71	44.79	48.84
12	280	280	445	445	380	380
13	62	62	63.59	63.54	59.68	59.68
14	43.5	34.38	55.51	49.76	39.78	33.69
Posterior Ossicone Index	0.14	0.14	0.14	0.12	0.18	0.18
Posterior Ossicone Base Index	0.48	0.46	0.45	0.41	0.62	0.66

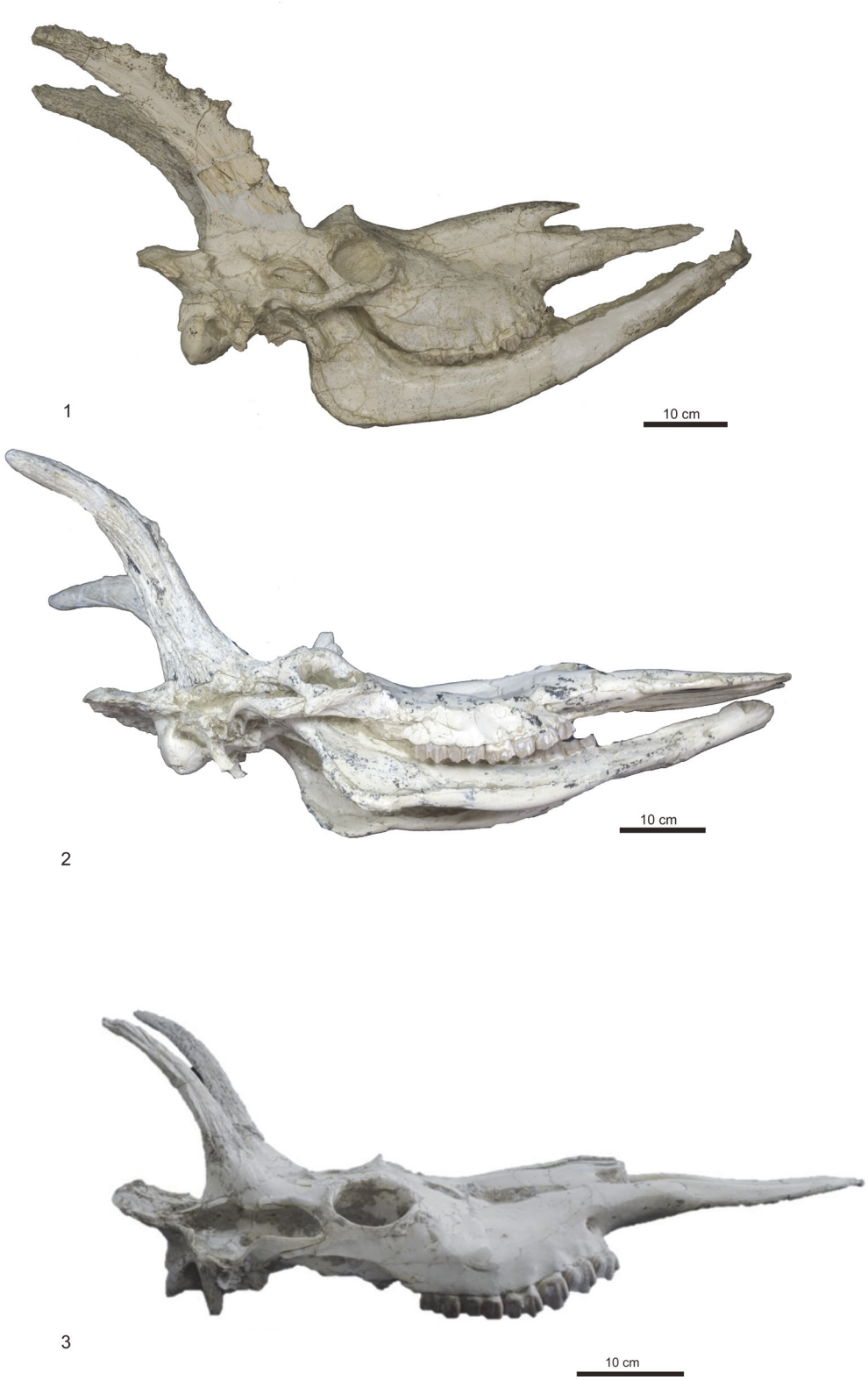

FIGURE 2. Cranial remains of *Decennatherium rex*. 1, morphptype II, BAT-04'00-37, skull in medial/lateral view; 2, morphptype II, BAT-10'13-E2-69, skull in medial/lateral view; 3, morphptype I, BAT-10'08-G3-91, skull in medial/lateral view. Scale bar equals 10 cm.

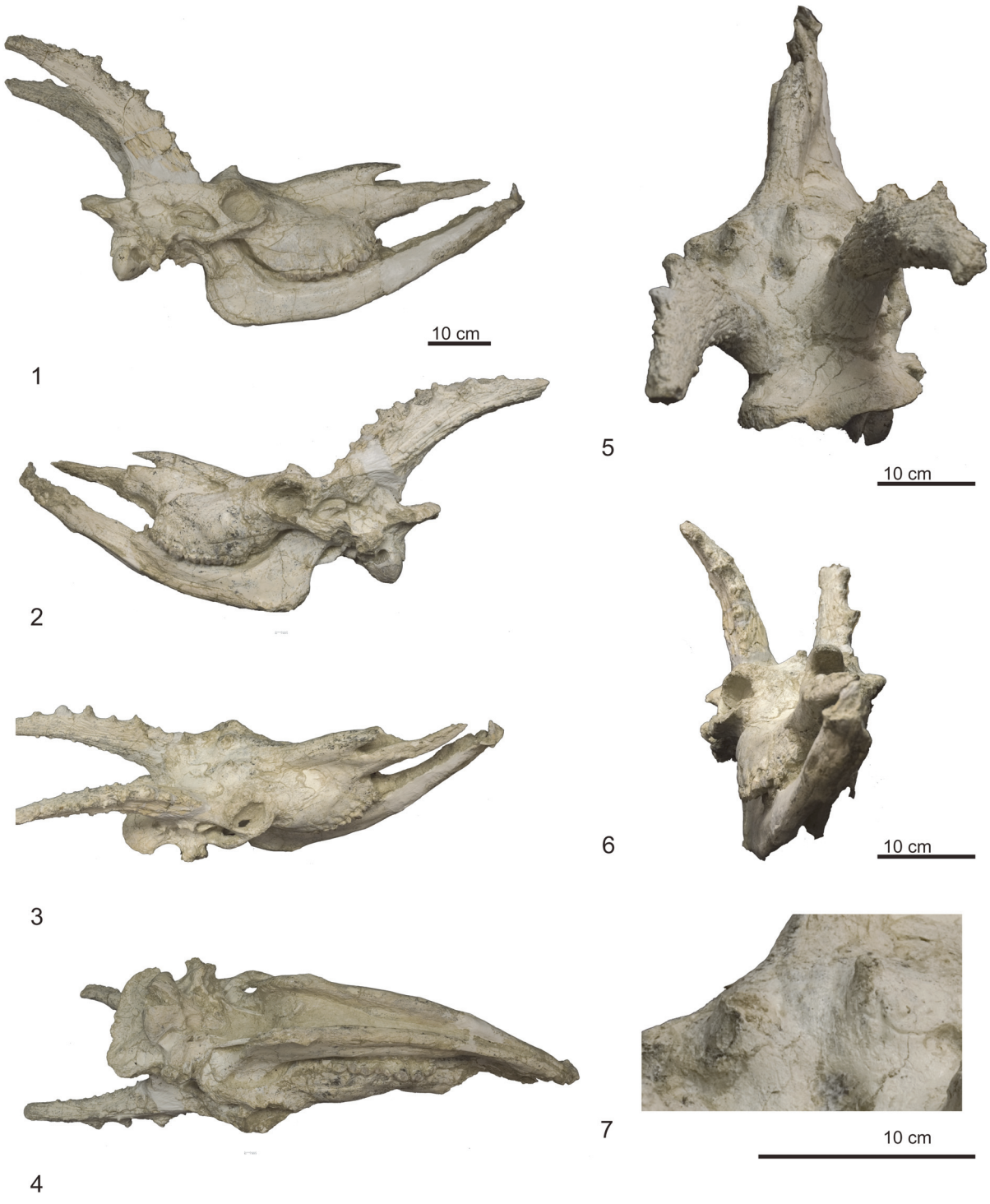

FIGURE 3. Cranial remains of *Decennatherium rex* from BAT4. 1-6, BAT-04'00-37, skull in 1, right side view; 2, left side view; 3, dorsolateral view; 4, ventral view; 5, cranial view; 6, caudal view; 7, close-up of the anterior ossicones, dorsal view. Scale bar equals 10 cm.

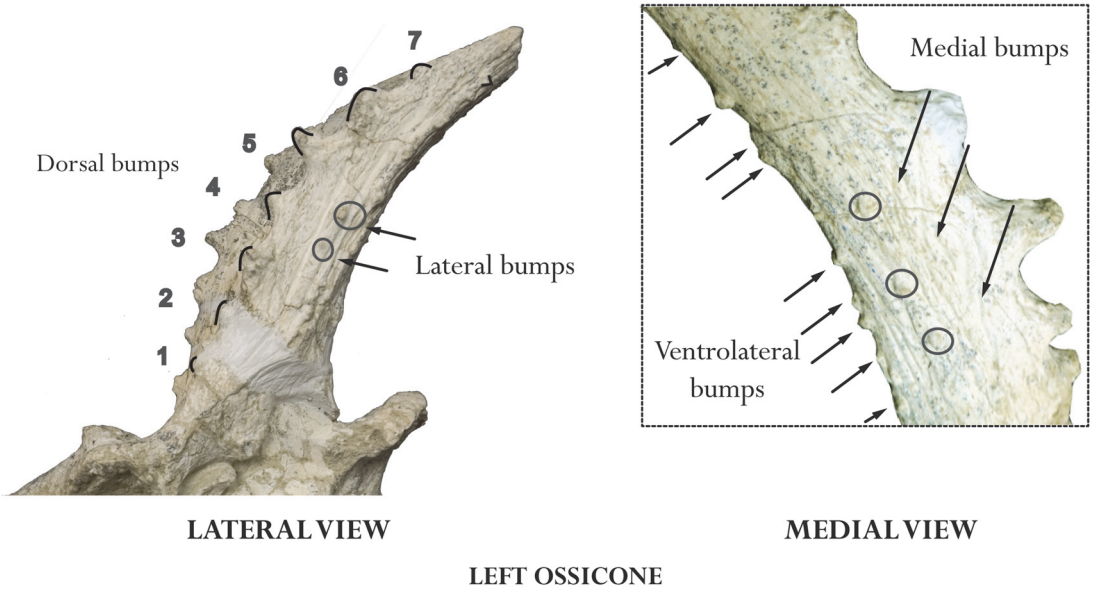

FIGURE 4. Left posterior ossicone dorsal, lateral, medial, and ventrolateralbumps of *Decennatherium rex* from BAT4. BAT-04'00-37, skull in lateral view and medial view.

showing a high number of deep ridges on their surface that run longitudinally from the base to the tip. They also show several (mainly anterior) bumps (Figure 4, Table 2). The right posterior ossicone shows eight large dorsal bumps and a larger ventrolateral one, six small ventrolateral bumps, six small medial bumps and six small ventral bumps. The left posterior ossicone shows seven large dorsal bumps, seven small ventromedial bumps, three small medial bumps, nine small ventrolateral bumps and two small lateral bumps (Figure 4). The tips are blunt.

The surface of the ossicones is very porous, as in extant *Giraffa*. This may indicate that even with their large size they were covered in integument, irrigated by the cornual artery (O'Brien et al., 2016).

Skull

There is an almost complete skull in the BAT4 sample (Figures 3-5, Tables 1-7), only lacking a portion of the premaxillae. Contrary to most of BAT10 skulls, it has no diagenetic dorsoventral deformation, although there is a longitudinal distortion that affects the position of the ossicones (Figure 3).

In dorsal view the two supraorbital foramina are placed behind the anterior ossicones on the frontals. The occipital is wide and rugose indicating strong neck musculature and the superior occipital edge extends backwards and upwards. There is no development of the frontal sinus to hollow the ossicones. The nasal bone is prominent and the rostral process of the nasal is developed (Figure 5.1).

In lateral view the lacrimal canal foramen is closed and the caudal lacrimal process is barely developed. The supraorbital canal orifices are rounded and wide. The ethmoidal fissure is open. The temporal fossa is deep and subrectangular. The orbit is circular, and the supraorbital margin is massive and has a very rugose surface (Figure 5.1). The zygomatic process of the frontal bone is also very developed and rugose, and the zygomatic arch is prominent under the orbit. The occipital condyles are massive and are oriented backwards and slightly upwards. The masseteric is large, with an α value of 8.94 (n=1) and a β value of 87.85º (Figure 6), which fall within the range of the specimens from BAT10 Figure 6. These values indicate a relatively large masseteric fossa in comparison to other giraffids, which may indicate a mixing feeding with slightly more grazing habits (Solounias, 2007). This is also supported by the

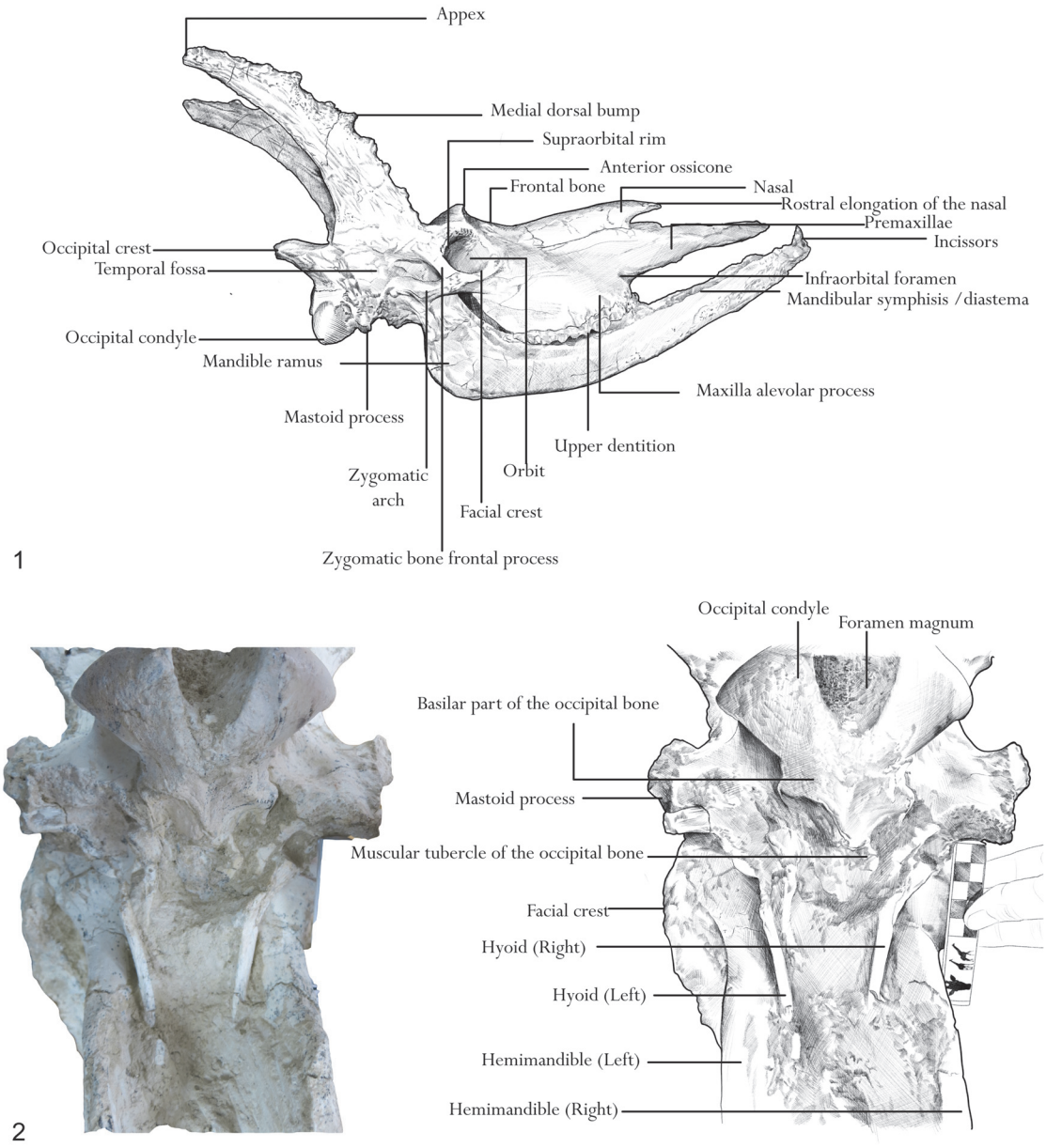

FIGURE 5. Interpretative drawings of *Decennatherium rex* from BAT4. BAT-04'00-37. 1, lateral view; 2, ventral view. Drawings by Rubén Guerrero Torralba.

presence of an enlarged maxilla and a large masseter profundus (Figure 5.1) (Ríos et al., 2017). The rostral elongation of the nasal bone points downwards and forms an angle with the premaxillae of approximately 20º. The premaxilla portion that is preserved is thick proximally, narrows distally, and is oriented downwards. The mandibular symphysis and lower incisors are horizontal in relation to the basipalatal axis. The maxillar tuberosity is very developed.

In ventral view (Figure 5.2) the anterolateral edges of the occipital are rugose and prominent and anteriorly oriented. The foramen magum is rounded and deep, and the intercondylar groove is wide. The jugular process is very developed and rugose, but not as much as in *Giraffa*. The expansion of the retroarticular process is not fused to the bullae. The bullae are not very developed, being similar to those of the specimens from BAT10 and *Giraffa* rather than the large bullae of *Okapia*. The

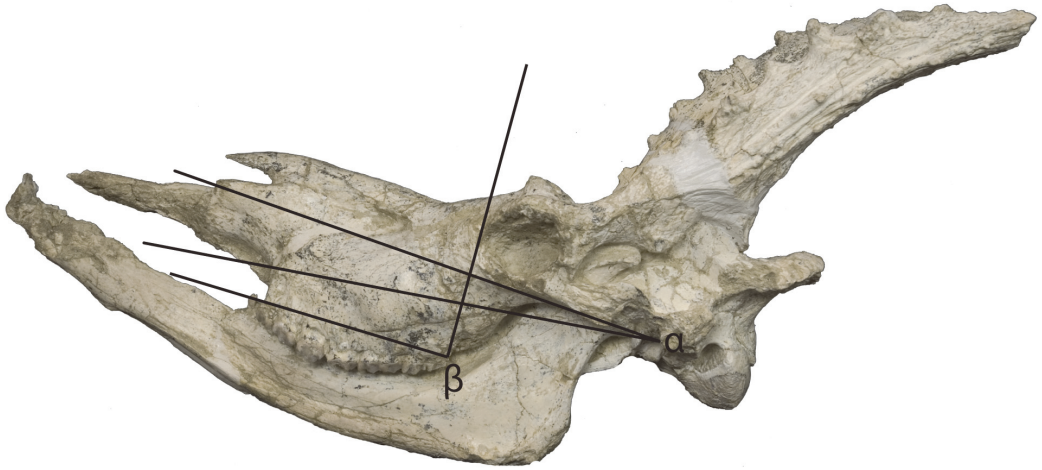

FIGURE 6. Skull angles of *Decennatherium rex* from BAT4. BAT-04'00-37. Defined by Solounias, 2007. Scale bar equals 10 cm.

position of the sheath of the eardrum varies little relative to the bullae in comparison to other giraffids. The auditory meatus is circular and laterally oriented. The bassioccipital muscular tubercles of the occipital are very prominent and rounded as in the specimens from BAT10 and are much more developed than in *Giraffa* and *Okapia*. The mastoid is reduced. The middle indentation of the hard palate is slightly posterior to the M3. The stylohial part of the hyoid bone is long and thin. These features are also present on the skull of the type series from BAT10.

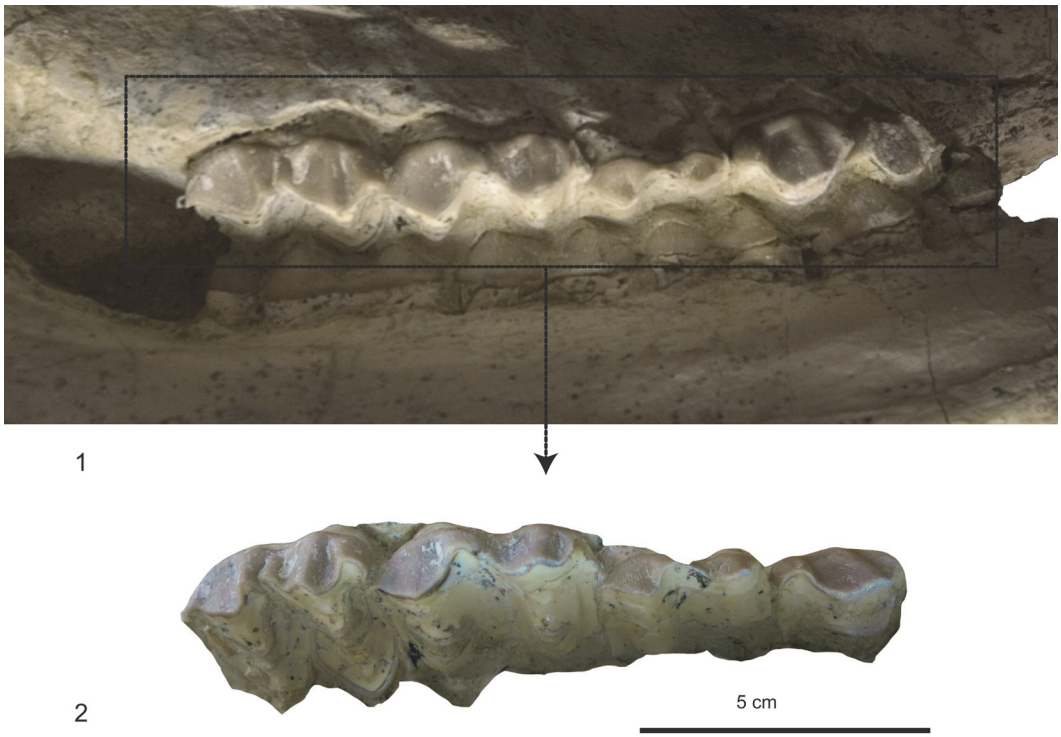

FIGURE 7. Dental remains of *Decennatherium rex* . BAT-04'00-37, 1, P4-M3 labial view; 2, P4-M3 occlusal view. Scale bar equals 5 cm.

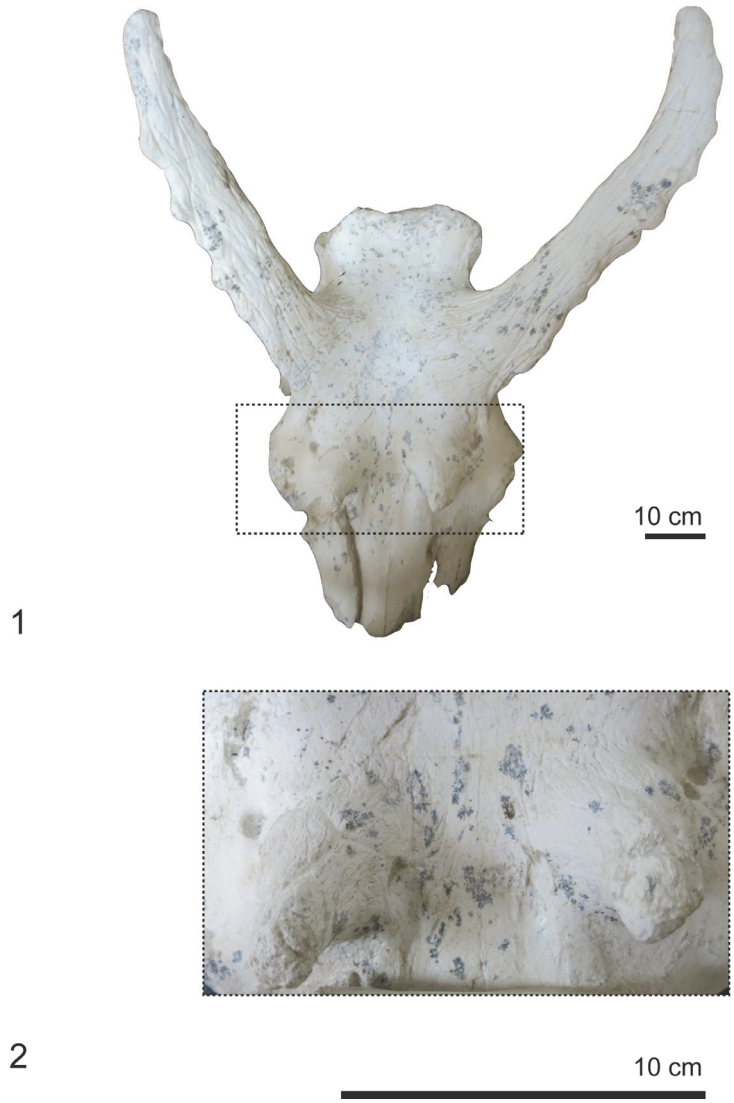

FIGURE 8. Male skull from Batallones-10, BAT-10'07-G4-127. 1, Dorsal l view; 2. close-up of the anterior ossicones, dorsal view. Scale bar equals 10 cm.

Mandible

The two hemimandibles of BAT-04'00-37 are preserved. The coronoid process is developed, and its uppermost part is oriented laterally. The condylar process is oval and extends medially. The mandibular foramen is large and stands in the caudoventral side of a very shallow pterygoidian fossa. The masseteric fossa is ventrocaudally slightly expanded, and its surface is only slightly rugose except at the vascular incision where there is a more wrinkled and prominent area. This configuration indicates that the deepest part of the masseteric muscle is more developed than the superficial part suggesting grazing masticatory features (König and Liebich, 2005). The diastema is very elongated. The mentonial foramen is large and is located in the middle of the distal part of the mandibular symphysis, right before the incisors start.

Dentition

The mouth of BAT-04'00-37 has been preserved in an anatomic closed position, with the upper teeth resting outside the lower teeth. Due to this only part of the upper teeth is visible, and only the length of the lower teeth can be measured. The lower teeth are not visible. The molars show a high degree of wear, to the extent that there is barely any enamel left (Figure 7).

The P4 (Figure 7, Table 6) is wider than long. The labial cone is moderate and close to the anterior style. The anterior style is moderately developed, thicker than the posterior style.

The M1 (Figure 7, Table 6) has a labial wall with strong parastyle and mesostyle and a much weaker metastyle. The enamel is very rugose. The M2 (Figure 7) is similar to the M1 but larger. The protocone and metaconule are lingually V-shaped and are well separated, with the posterior lobe slightly wider than the anterior one. The paracone is very strong. There is a metaconule-fold. The M3 is very similar to the M1 and M2, but it shows a very pointy metaconule and the metacone is rounder than the paracone.

RESULTS

The giraffid skull from BAT4 is morphologically and metrically almost identical the skulls of the type series of *Decennatherium rex,* although due taphonomical processes some features are different. For instance, the holotype of *Decennatherium rex* from BAT10, the skull of a large male (BAT10'13.E2-69) shows dorsoventral deformation, while the specimen from this study only shows torsion on the sagittal plane altering the location and orientation of the ossicones, but preserving almost in perfect conditions otherwise. They also differ somewhat in the ossicone morphology, as the anterior ossicones in the BAT4 specimen are shorter than those found in other male specimens found in BAT10. We also found an extreme case of secondary bone growth in form of bumps in the BAT4 specimen, which has larger and more numerous bumps than the specimens found in BAT10. We also find the specimen with the higher degree of erosion In the BAT4 specimen. Despite these differences, both the specimens from BAT10 and the specimen from BAT4 share key features that separate them from any other giraffid. Besides sharing many cranial features, as the same bassicranial morphology, the morphology of the dentition and mandible, and the development of the occipital region, the specimens from BAT10, and the specimen of BAT10 share the same ossicone bauplan. The location, development and orientation of their ossicones are almost identical. Their ossicones also share the same curvature and ornamentation based on deep longitudinal ridges and secondary bone growth in the form of bumps. Even further, the disposition of the bumps in the posterior ossicones of BAT-04'00-37 is very similar to the bumps present in BAT-10'07-G4-127 (Figure 8). BAT-10'13-E2-69 (Figure 2) has only a large bump, located in the middle of the ossicone shaft dorsally, in the same place as BAT-04'00-37 and BAT-10'07-G4-127 show their larger dorsal bump.

The ossicone index (Transverse Diameter at the Ossicone Base /Length of the Ossicone (Dorsal) of BAT-04'00-37 lies within the range of the BAT 10 specimens (Table 7). The same happens with the maxillae/mandible indices (Figure 9).

DISCUSSION

Sexual Dimorphism in *Decennatherium Rex*

The *Decennatherium rex* skull from BAT4 corresponds to the Morphotype II of Rios et al. (2017). Morphotype I (e.g. BAT-10'08-G3-91) (Figure 2.3) is characterized by the presence of reduced ossicones, with frontal ossicones reduced to unattached little circular disks with a pointy projection in the middle, and slender and shorter fronto-parietal ossicones. Morphotype II (e.g., BAT-10'13-E2-69, BAT-10'07-G4-127) (Figures 2-8) is characterized by more robust and developed ossicones (both frontal and fronto-parietal) than those of Morphotype I, showing very deep ridges on their surface and a larger size. The fronto-parietal ossicones found in BAT4 are the largest (410 mm) in the entire Batallones sample, including those from the largest individuals from the type locality of BAT10, although not by much (the largest specimen in the BAT10 sample reaches 382 mm in length).

Ríos et al. (2017) linked Morphotype-I and II with female and male individuals, respectively. Hence the specimen BAT-04'00-37, is the most extreme example of a *Decennatherium rex* Morphotype-II found so far, and we considered it should be regarded as a male. *Decennatherium rex* males could have used their larger and more robust headgear as a display structure, and also for fighting between bulls in a *Tetracerus* fashion, with the paired ossicones of the opponents interlocking and applying pressure at the base of the cranial appendages (Bubenik, 1990). The hollow-based ossicones of *Decennatherium rex*, full of sinuses, are well constructed for use in sparring. Also, their cervical vertebrae are massive (Ríos et al., 2017), as is the occipital region of their skull. These features can be interpreted as reflecting a way to resist cranial wrestling, pushing or even butting (Churcher , 1978; Churcher, 1990).

Secondary Bone Apposition in *Decennatherium Rex*

The bumps present in the *Decennatherium rex* specimens are very similar to those of *Sivathe-*

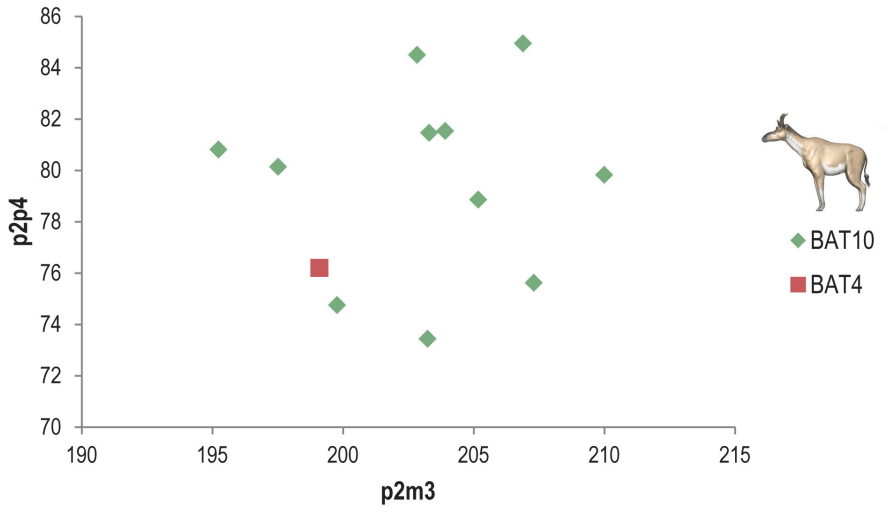

FIGURE 9. Comparison between the total length of the lower teeth and the length of the premolar teeth of the specimens of *Decennatherium rex* from BAT4 and BAT10. *Decennatherium rex Illustration* by Oscar Sanisidro.

rium maurusium/olduvaiense Pomel, 1892 , *Schansitherium tafeli* Killgus, 1922, or *Giraffa camelopardalis* Linneo, 1758 (Solounias, 2007; Guan, 1997) as they all represent examples represent secondary bone apposition in giraffid ossicones and even have a similar rounded and protruding morphology. In the sample from Cerro de los Batallones (BAT10 and BAT4) these bumps are mainly located over the dorsal surface, though they can also appear laterally (Figures 5-7). The largest bump appears always in the middle of the dorsal surface, more or less at the same height both in the right and left ossicones of each individual. The distribution of the bumps in the fronto-parietal ossicones of *Decennatherium rex* agrees with the observations of Solounias et al. (1988) who pointed out that these small irregular protuberances have a somewhat fixed position, with the first and largest bump always located dorsally and in the middle of the ossicone shaft, suggesting a genetic basis for the location of these secondary bone growth. Although these do not seem so easy to appreciate in *Giraffa,* the ossicones pictured by Singer and Boné (1960) show at least one large bump on the proximal part of the posterior ossicones of *Sivatherium maurusium/olduvaiense* that seems present in most of the pictured specimens (Singer and Boné , 1960: plates I-IV), also supporting Solounias observations (Solounias, 2007). There is, however, intraspecific variability, with some specimens showing either a higher number of bumps or larger-sized bumps, and also bumps in different locations. According to Harris (1974) the disparity in size and development of the bumps may represent individual variation. It is also possible that the amount of secondary bone apposition, in the form of ornamentation, may have an ontogenetic component and be correlated to the age of the individual. This is the case of the developmental process occurring in older males of *Giraffa camelopardalis* (Solounias and Tang, 1990) which accumulate secondary bone growth from fighting. This scenario could also be true for *Decennatherium rex*, *Sivatherium maurusium/olduvaiense* and *Schansitherium tafeli,* as we find specimens with bumps within the three taxa; and in the case of *Decennatherium rex*, we can also correlate them with the age thanks to the preservation of the dentition. Another important similarity is that as we do with *Giraffa camelopardalis*, we also find male specimens without the bumps within all three taxa (Singer and Boné, 1960; Guan, 1997; Geraads, 2009; Ríos et al., 2017) indicating these may represent younger adult individuals.

As for sexual dimorphism in the presence of secondary bone apposition, while in *Giraffa camelopardalis* older males the secondary bone covers the entire calvaria, the females show little or no such secondary bone growth. The same could be the case for *Decennatherium rex* females (morphotype I), as we have not found any evidence yet of morphotype I ossicones with any kind of secondary bone apposition in the form of bumps.

The morphology of the fronto-parietal ossicones of BAT-04'00-37, which has more numerous and larger bumps than the BAT10 specimens, fits in the hypothesis of the secondary bone apposition being related to both: age and sex. BAT-04'00-37 skull shows the largest bumps, but also the most worn-out molars (with almost no enamel left), indicating an advanced age for this specimen. This hypothesis must be checked through a) direct histologic analysis of the ossicones and b) microwear analysis to discard the possibility of a more abrasive diet as the agent of the advanced molar wearing (Danowitz et al., 2016), but it appears that these three variables (age, sex and secondary bone apposition) could be intrinsically related not only in the extant *Giraffa camelopardalis*, but also in fossil giraffids dated as far back as the late Miocene, and it may be also indicating a common ancestor for these taxa.

Feeding Habits in *Decennatherium Rex*

Following Solounias (2007) we have analyzed the shape and size of the masseteric fossa as well as other cranial and masticatory features. BAT-04'00-37 results very similar to BAT10 specimens, with α values of 8.94 (n=1) and β values of 87.85º (Figure 4). According to Ríos et al., (2017) these angles fall within the same category as *Schansitherium tafeli, Palaeotragus microdon* Bohlin, 1926, and *Samotherium boissieri* Forsyth Major, 1888 (Solounias, 2007). Only *Samotherium major* Bohlin, 1926, shows α values over 10° while *Canthumeryx sirtensis* Hamilton, 1973*, Okapia johnstoni* Sclater, 1901, and *Giraffa camelopardalis* show α values below 5º. This confirms that *Decennatherium rex* has a relatively larger masseteric fossa than most giraffids and may indicate more grazing habits than in the extant taxa (Ríos et al., 2017). *Decennatherium rex* also shows other grazer masticatory features as an enlarged maxilla and a large masseter profundus. As in other grazers the enlarged maxilla of *Decennatherium rex* tends to move the orbit posteriorly starting above the M3 or further back (Solounias and Dawson-Saunders, 1988).

CONCLUSIONS

We describe here a new complete skull of *Decennatherium rex* from the fossil site of Batallones-4 (MN10, Madrid basin, Spain). The complete skull BAT-04'00-37 corresponds to the Morphotype-II described for this species (identified as males) and offers an insight into the intraspecific variability of *Decennatherium rex* relative to the sexual dimorphism of the cranial appendages. The characteristic features of Morphotype-II are more developed in BAT-04'00-37 than in all the Morphotype-II specimens from the type locality of Batallones-10, with fronto-parietal ossicones sporting larger and more numerous bumps than the BAT10 specimens. The heavily worn-out molars of BAT-04'00-37 very possibly indicate an advanced age for this specimen, and thus the more developed structures of the fronto-parietal ossicones could be related to secondary bone apposition as in extant male giraffes. However this hypothesis will be checked out through the direct histologic analysis of the ossicones.

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