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# Using cattle for traction and transport during the Neolithic period

## Contribution of the study of the first and second phalanxes

Daniel HELMER, Émilie BLAISE, Lionel GOURICHON and Maria SAÑA-SEGUÍ

**Abstract:** During the Neolithic period, cattle were used not only for their meat and their milk but also for their strength. Unfortunately, apart from the discovery of specific instruments (yokes, travois, wheels, ards, etc.), it is not easy to demonstrate archaeologically their use for work. Nevertheless, the bone pathologies related to this activity can be analyzed. The methodological approach employed in this study is based on multivariate analyses (PCA) applied to the dimensions of the first and second phalanxes, as well as to shape indices of the same bones determined by the Mosimann method. The measurements of aurochs and domestic cattle bones from nineteen Mesolithic and Neolithic sites form the data matrix. The results of this study attest, on the one hand, that cattle were used for draught and transport during the Neolithic in various parts of Europe and the Near East and, on the other hand, that this use and its corollary, castration, are practices that can be dated back earlier than is generally accepted.

**Keywords:** Neolithic, cattle, castration, draught, transport, phalanxes.

**Résumé :** Durant le Néolithique, les bovins ont été utilisés non seulement pour leur viande et leur lait mais aussi pour leur force (traction et portage animal). Malheureusement, hormis la découverte d'instruments spécifiques (jougs, travois, roues, araires, etc.), la démonstration de leur emploi pour le travail n'est pas aisée d'un point de vue archéologique. L'archéozoologie peut pallier cette difficulté en étudiant les pathologies et les déformations osseuses liées au travail de force. Mais si certaines sont évidentes, d'autres modifications moins marquées ou touchant la morphologie de l'os peuvent être difficiles à évaluer et les analyses univariées permettent de faire ressortir les os « hors normes », mais ne donnent pas, ou très peu, d'éléments pour interpréter ces écarts. Dans cette étude, l'approche méthodologique choisie s'appuie sur des analyses multivariées (analyses en composantes principales : ACP) appliquées sur les dimensions des premières et secondes phalanges ainsi que sur des indices de forme déterminés par la méthode de Mosimann. Cette méthode vise, d'une part, à supprimer pour chaque mesure toutes les informations relatives à la taille et, d'autre part, à isoler la taille isométrique en réduisant l'effet de forme. Les mesures des phalanges 1 prises en compte sont la longueur (GLpe), le diamètre transverse proximal (Bp), le diamètre transverse au milieu de la diaphyse (SD) et le diamètre transverse distal (Bd). Plus compactes, les phalanges sont moins sujettes à la fragmentation que les os longs et présentent l'avantage de se trouver dans les assemblages fauniques en nombre suffisant pour permettre une approche statistique. Elles sont également de bons marqueurs du recours à l'énergie animale en raison des stress mécaniques subis au niveau des extrémités des membres durant ces activités de traction ou de portage. Les déformations se caractérisent par un raccourcissement de la longueur du fût de la phalange, un élargissement proximal ou distal, des exostoses, et le débordement des surfaces articulaires (*lipping* et extension antéro - dorsale distale). La partie proximale des phalanges 1 est plus souvent déformée que la distale : c'est le point majeur de transmission de la force qui se répartit du métapode aux deux phalanges. Les pathologies existent chez les aurochs, mais sauf fractures, elles concernent rarement la conformation générale de la phalange. Les mesures des os d'aurochs et de bœufs domestiques provenant de dix-neuf sites mésolithiques et néolithiques du pourtour méditerranéen (Catalogne, Sud-Est de la France, Grèce, Turquie, Iraq et Syrie) composent la matrice de données et sont comparées à des mesures d'individus référents sauvages, européens et proche-orientaux, et domestiques actuels ayant travaillé (mâles et castrats roumains : Bartosiewicz *et al.*, 1997). Il est ainsi possible de distinguer de manière fiable dans les assemblages archéologiques, les spécimens sauvages des domestiques et de mettre en évidence la présence potentielle de castrats et l'utilisation de la force animale. Cet article modifie grandement la perception des premiers usages de ces grands ruminants. Les résultats de cette étude démontrent non seulement que les bovins ont tiré et porté des charges dès le Néolithique en Europe et au Proche-Orient, mais aussi que cet emploi ainsi que son corollaire, la castration, sont des pratiques bien plus anciennes qu'il n'est couramment admis. Utilisés pour le lait et leur force dès leur domestication, les bovins occupent une place particulière dans l'économie et la symbolique des sociétés et ont pu jouer un rôle majeur dans les échanges et les déplacements. Dans le Sud-Est de la France, si ces animaux ont pu être employés pour porter des charges, les activités semblent peu intensives jusqu'au IV<sup>e</sup> millénaire avant notre ère. En revanche, à la fin du Néolithique dans cette région, la présence récurrente de bovins avec des pathologies (déformations des chevilles osseuses, de vertèbres, des extrémités, antériorisation des phalanges) témoigne de la généralisation du recours à l'énergie animale pour tirer et porter (les individus, conservés jusqu'à un âge

avancé, ont probablement travaillé toute leur vie). Sur certains sites, la fréquence élevée des pathologies et l'intensité des déformations sur les phalanges antérieures 1 et 2 chez ces bovins de petite stature (moins de 1,20 m au garrot) suggèrent des activités plutôt intensives de type traction (labours, et peut-être aussi débardage). Cette utilisation plus fréquente de la force de travail des bovins pourrait être en lien avec une probable intensification des travaux agricoles. Enfin, la présence d'aurochs est également attestée sur des sites campaniformes et confirme leur intérêt particulier pour le grand gibier, pratique par ailleurs abandonnée par les groupes régionaux du Néolithique final.

**Mots clés :** Néolithique, bovins, castration, tirer, porter, phalanges.

**C**ATTLE were the largest farmed animals during the Neolithic period in Europe, Southwest Asia and Africa, and were used not only for their meat and their milk but also for their strength. These animals may have probably participated actively in the exchange networks, as they did until recently in many parts of the world. However, with the exception of the discovery of specific instruments, such as yokes, travois, wheels, ards, etc., it is not easy to identify their use for work. Archaeozoology can overcome this difficulty through the analysis of bone pathologies (Bartosiewicz et al., 1993 and 1997; Bartosiewicz, 2006; Tarrús et al., 2006), but apart from some rare cases (horn cores, spinous vertebrae bones), the observed pathologies can be caused by two factors: illness or work. It is thus important to distinguish the contribution of these two factors.

Several questions must be raised to assess the use of cattle:

- 1) Are the pathologies mainly due to work?
- 2) Are these large domestic cattle castrated?
- 3) When and where does the first evidence of work appear? In Western Europe during the Early Neolithic or in the Near East during the Pre-Pottery Neolithic (PPN)?
- 4) What type of work were they used for: draught, transport?

Among the criteria used to bring to light the domestication of bovines from the study of bones, the most reliable are based on morphological differences (horn-core shapes, but also cranial volume, allometries, etc.) and variations in size. As far as the latter are concerned, very often only size decreases are taken into consideration, yet size increase is also an important criterion (Helmer and Gourichon, 2008; Helmer et al., in prep.). Lastly, the presence of pathologies due to work is an excellent criterion.

There is a plentiful literature on pathologies resulting from the exploitation of the animal strength and particularly about cattle use (Bartosiewicz et al., 1997; Peters, 1998; Groot, 2002; Johanssen, 2002; etc.). The deformations affecting the bones of main interest here are characterized by: a shortening of the length of the phalanx shaft, a proximal and/or distal widening, exostoses, and the overspill of the articular surfaces (lipping and antero-dorsal distal extension). The proximal part of the first phalanx is more often deformed than the distal part; this is the main point of strength transmission spreading from the metapodial to the two phalanges. It is important to recall that the deformations depend on the type and inten-

sity of the work imposed on the animals by farmers, and that not all animals in a herd work, and when they do so (particularly for transport), some only work occasionally.

Aurochs can also develop pathologies, but apart from fractures, these rarely affect the general conformation of the phalanx: for the European (e.g. Fanfarline, La Montagne) or Near Eastern aurochs (e.g. Mureybet, Jerf el-Ahmar and Cheikh Hassan), our observations indicate they concern the epiphyses (exostoses) but never the length.

Castration is difficult to observe and there are several ways of detecting it. It is perceptible, in particular, on horn cores and metapodials (Armitage and Clutton-Brock, 1976; Luff 1994; Bartosiewicz et al., 1997; Sykes and Simmons, 2007). The horns are sometimes deliberately deformed, and generally present flattening or constrictions due to the yoke and the cord securing the yoke to the horns. In some cases, we can also observe pathological perforations of the occipital bones (Early Neolithic of La Draga; Bosch et al., 2000; Tarrús et al., 2006; Llado et al., 2008). Another approach is based on pathological deformations and changes in proportion and size caused by putting castrated animals to work and by the hormonal changes following the ablation of the gonads. Size variation due to castration is only observable when castration occurs before the end of the animal's growth. If it occurs well after three years old, the animal will clearly undergo less change in size. Castrated animals are more docile and with greater muscular mass than normal ones. If they are put to work the ensuing pathologies will therefore be very developed. We chose this approach here by using the first and second phalanges, which are generally most frequent in the archaeological assemblages than whole metapodials or cranial remains.

The Romanian castrated animals used as references here, were exploited for drawing carts, ploughing and log hauling (Bartosiewicz et al., 1997). With the traction work, most of the animal force is directed to move forward and therefore towards the front. The bones in the front part of the animal are thus more heavily impacted by work pathologies than the rear part. The specific tools linked to this action are harnesses and yokes. The horn yoke can deform the horns, the rear of the skull and the cervical vertebrae and the shoulder yoke can affect the first thoracic vertebrae (Bartosiewicz et al., 1997).

Traction power is not the only use of bovines. They are also used for transport, either by placing loads directly on the animal, on a pack saddle or a saddle. In this case,

the force used here is mainly directed from top to bottom and affects the spinal column and the phalanges (Rossel et al., 2008). Pack saddles and saddles deform the thoracic and lumbar vertebrae, but the distribution of weight on the front and the back of the spinal column has a strong impact on the phalanges. This is particularly visible on the rear phalanges which become more robust and present similar proportions to the front phalanges ('anteriorization' of the posterior phalanges, see Helmer, 2008; Blaise, 2010) as shown in fig. 1, where only the shape of the proximal articular facets enables us to distinguish both types of phalanx easily. Scatter plots also allow us to visualize this trend. When calculating the regression lines for the front and the rear bones apart, the divergence in slope between both lines is high for the aurochs and low for the domestic bovines (fig. 2). This is obvious with the second phalanx (Helmer, 2008) and is frequently observed in the Neolithic cattle populations from southern France (Blaise, 2010).

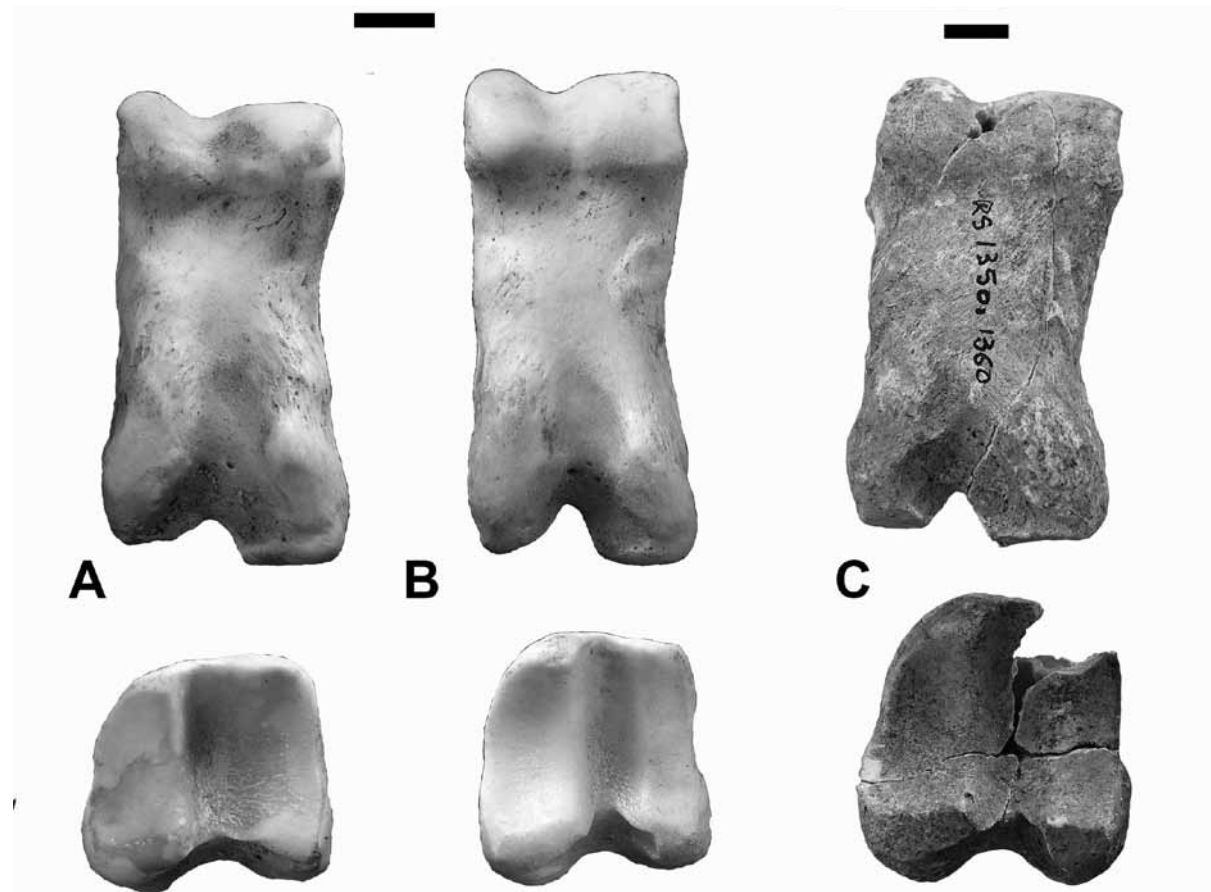
The use of bovines for work does not generally consist of a single task. Some animals can be specialized, in particular for draught work, and performances are increased

when castrated animals are used (greater strength, calmer animals). For transport, there is less specialization, except for specific cases corresponding to a need/requirement of a human group (trade and repeated needs for specific raw materials, etc.), but castration is not necessary. Lastly, for cows, work leads to a marked decrease in lactation, but does not prevent it.

## METHODS

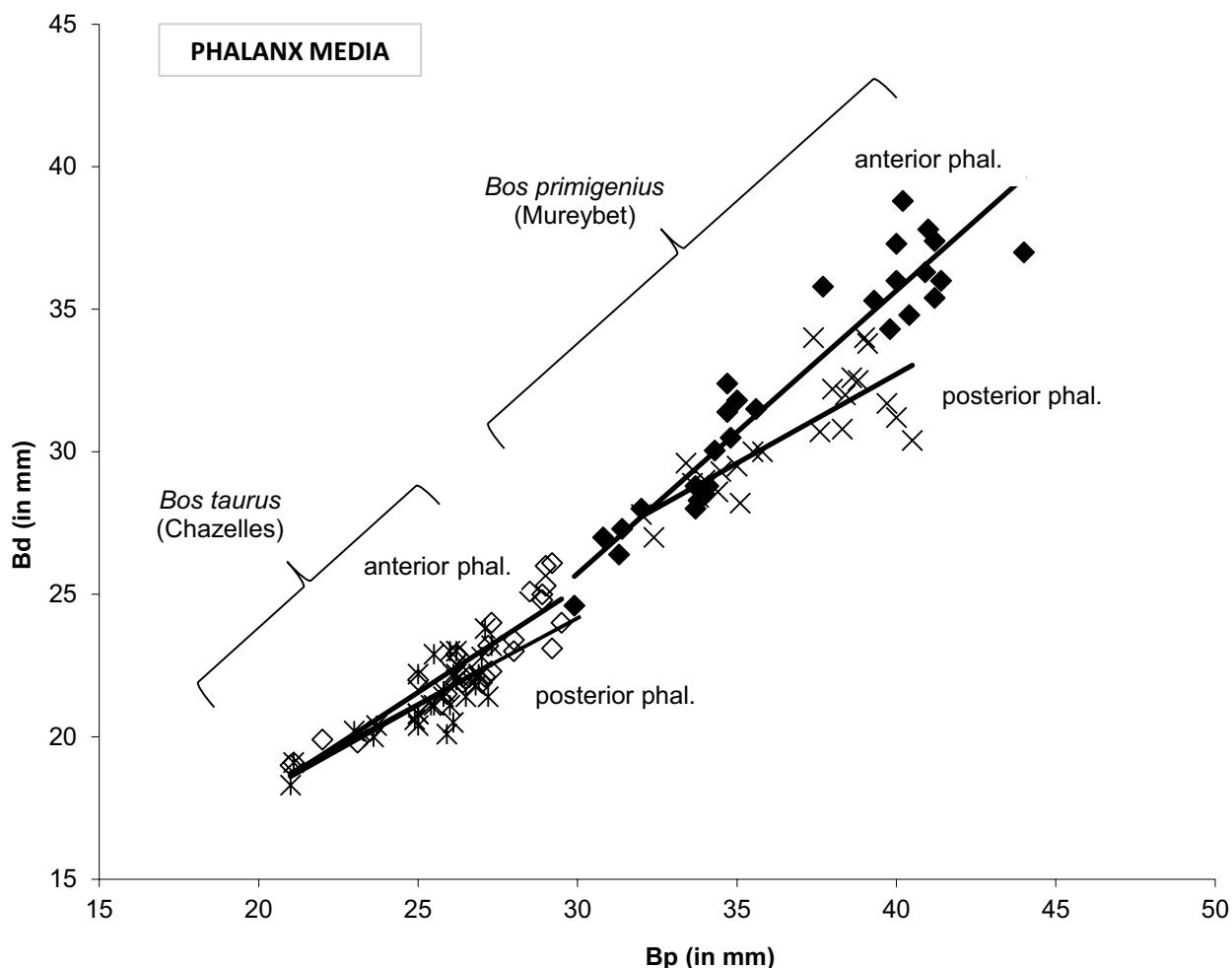
Firstly, it is important to recall that biological size is broken down into isometric variation (proportional) and allometric variation (observable through shape indices). The method used here to study and compare morphometric bone data aims, on one hand, to remove all the information related to size for each measurement, and on the other hand, to separate the isometric size by reducing the effects of shape.

As we could not analyze all the skeletal parts one by one, we will focus mainly on the first and second phalan-



**Fig. 1** – Example of an 'anteriorized' first posterior phalanx of cattle. On the right, palmar and proximal views of fore (A) and rear (B) phalanges from a present-day 'Di Biou' breed from Camargue, compared to an 'anteriorized' rear phalanx (C) from the LPPNB of Ras Shamra.

*Fig. 1* – Exemple de phalange 1 postérieure « antériorisée » de bovin. A droite vues palmaires et proximales d'une antérieure (A) et une postérieure (B) de bovins actuels de race Di Biou de Camargue, comparées à une phalange postérieure « antériorisée » (C) du LPPNB de Ras Shamra.



**Fig. 2** – 'Anteriorization' of the posterior second phalanxes: comparison of the regression line slopes of the Mureybet aurochs and the cattle from Grotte de Chazelles. The regression lines calculated respectively for the anterior and posterior cattle phalanxes from Chazelles are nearly parallel, compared to those of the aurochs phalanxes which are clearly divergent: the metric study confirms the observations based on the general bone morphology.

**Fig. 2** – Mise en évidence de l'antériorisation des phalanges 2 postérieures : comparaison de la pente des droites de régression des antérieures et des postérieures des aurochs de Mureybet et des bœufs de la Grotte de Chazelles. Les droites de régression des antérieures et des postérieures de Chazelles sont presque parallèles, comparées à celles des aurochs qui sont clairement divergentes : l'étude métrique confirme les observations basées sur la morphologie générale des os.

xes, which are almost always present at archaeological sites and frequently present pathologies. Moreover, these elements are generally better preserved than others due to their compact morphology. Most of the data will be based on the first phalanxes, from both the fore and hind limbs. They are less represented than the second phalanxes in Neolithic bone assemblages due to the fragmentation and the butchering techniques, but they are longer and thus respond more to mechanical stress induced by work. The second phalanxes are only used when the first ones are not sufficient for an adequate study. The distinction between anterior and posterior phalanxes has been made using the criteria defined by E. Dottrens (Dottrens, 1946), which prove to be discriminating even in the case of 'anteriorization'.

The measurements of the first phalanxes considered here are (cf. Driesch, 1976): the greatest length of the peripheral (abaxial) half (GL<sub>pe</sub>), the breadth of the proximal end (Bp), the smallest breadth of the diaphysis (SD)

and the breadth of the distal end (Bd). The same measurements are used for the second phalanxes except for the main length (GL).

Classically, the most widely used method for studying bone size in a given population is the univariate analysis. This method allows bringing to light non-standard bones, i.e. whose measurement values outside the 95% confidence interval (2 standard deviations below and above the mean) but it is sometimes difficult to interpret such outliers. In order to demonstrate this, we will take the example of the recent Cardial assemblage from La Draga (Banyoles, Catalonia), where the number of measurements of the first phalanxes is greater than or equal to 30, and where palaeopathological signs of traction on cattle extremities are documented (Bosch et al., 2000; Tarrús et al., 2006; Llado et al., 2008; Saña 2011; Antolin et al., 2014). It is also noteworthy that aurochs is a typical component of the Northern Spanish wild fauna at that time.



According to the distribution of the metric values, two phalanxes fall outside the 95% confidence intervals for three measurements (in italic below). The first one is very big (GLpe = 66.1 mm; Bd = 35.28 mm; SD = 31.6 mm; Bd = 33.7 mm), but we do not know if this bone belonged to a large domestic animal, for instance a castrated animal, or to a female aurochs. No element allows us to answer this question, but in the first hypothesis the possible slight pathologies observed suggest that the animal would have not worked a lot. Based on the assumption that it is an aurochs, we will name it DrU in the following analyses ('U' for *urus*). The other phalanx (GLpe = 52.5; Bd = 34.5; SD = 30.4; Bd = 32.6), named DrA, is very stocky and could have belonged to a wild bovine or a cas-

trated animal. In order to improve the diagnosis Principal Component Analysis are also applied using the software package PAST for morphometrics (version 3.18).

Different archaeological case studies from Western Europe and the Near East are explored now using this procedure of analysis. The elements considered to construct the matrix are formed of several groups of data (table 1, references therein and appendix for raw measurements). Eight series from the Final Neolithic of southern France (La Fare, La Citadelle, La Brémonde, Grotte du Hasard, Grotte de Chazelles) and from the Bell Beaker culture in Provence (Grotte Murée, La Balance rue Ferruce, Les Calades), one from the Early Neolithic in Catalonia (La Draga, 5430–4796 cal. BC), two from Mesolithic

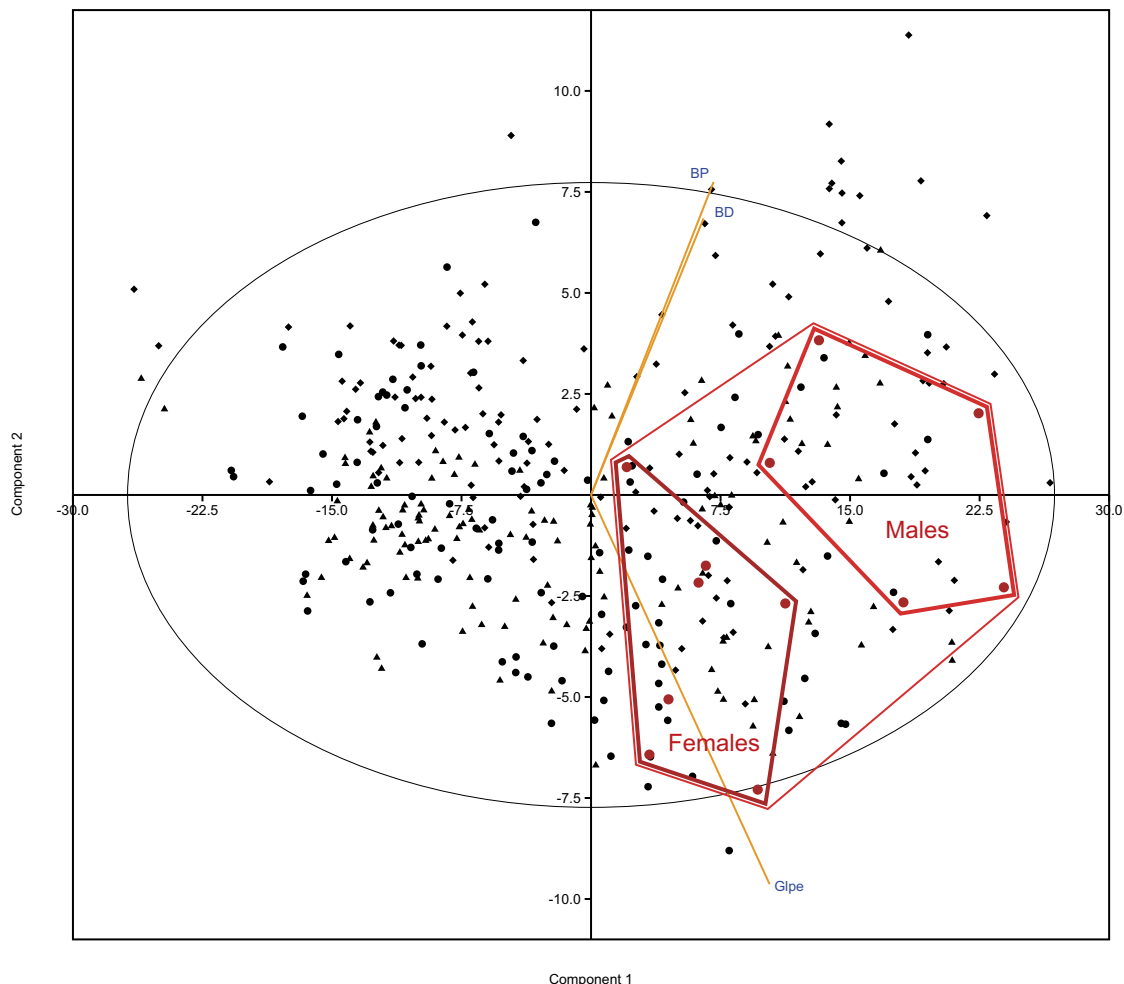
Site	Region	Period	N spec.	Faunal studies
* Danish sites	Danemark	Mesolithic	10	Degerbøl & Fredskild, 1970
* La Montagne	Bouches-du-Rhône (Southern France)	Mesolithic	2	Helmer & Monchot, 2006
La Draga	Catalonia (Spain)	Early Neolithic	28	Saña, 1993, Tarrús et al., 2006
La Fare (phase 1)	Alpes-de-Haute-Provence (Southern France)	Final Neolithic	19	Blaise, 2010
La Fare (phase 2)	Alpes-de-Haute-Provence (Southern France)	Final Neolithic	2	Blaise, 2010
La Citadelle	Bouches-du-Rhône (Southern France)	Final Neolithic	12	Blaise, 2010
La Brémonde	Vaucluse (Southern France)	Final Neolithic	5	Blaise, 2010
Claparouse	Vaucluse (Southern France)	Final Neolithic	2	Helmer, 1979
Grotte du Hasard	Gard (Southern France)	Final Neolithic	17	Helmer, unpublished
Grotte de Chazelles	Ardèche (Southern France)	Final Neolithic	59	Favrie, 2004
Grotte Murée	Alpes-de-Haute-Provence (Southern France)	Bell Beaker	10	Helmer, 1979
La Balance rue Ferruce	Vaucluse (Southern France)	Bell Beaker	3	Helmer, 1979
Les Calades	Bouches-du-Rhône (Southern France)	Bell Beaker	1	Blaise, 2010
* Mureybet	Northern Syria	PPNA	9	Gourichon & Helmer, 2008
* Jerf el Ahmar	Northern Syria	PPNA	7	Helmer et al., 2005
* Göbekli	Southeastern Turkey	PPNA	4	Peters & Schmidt, 2004
Dja'de el-Mughara	Northern Syria	Early PPNB	5	Helmer et al., 2005
Tell Aswad	Central Syria	Middle PPNB	13	Helmer & Gourichon, 2008 & 2017
Tell Halula (1/9)	Northern Syria	Middle PPNB	25	Saña, 1999
Akarçay V	Southeastern Turkey	Middle PPNB	5	Saña & Tornero, 2008
Mezraa-Teleilat	Southeastern Turkey	Middle PPNB	6	Ilgezdi, 2008
Cafer Höyük	Southeastern Turkey	Middle PPNB	8	Helmer, 2008
Akarçay IV	Southeastern Turkey	Late PPNB	10	Saña & Tornero, 2008
Assouad	Northern Syria	Late PPNB	3	Helmer, 1985
Tell Halula (10/34)	Northern Syria	Late PPNB	17	Saña, 1999
Gürcütepe	Southeastern Turkey	Late PPNB	9	Peters et al., 2005
Tell Sotto	Northern Iraq	Late PPNB	5	Helmer, unpublished
Dikili Tash	Northern Greece	Final Neolithic	54	Helmer, unpublished
Total archeological specimens			350	
modern Romania specimens (males and castrated animals)			50	Bartosiewicz et al., 1997
Total Matrix			400	

**Table 1** – Series of archaeological proximal phalanxes of bovines studied or used as reference for the morphometric analyses. \*: aurochs populations.

**Tabl. 1** – *Séries de phalanges proximales archéologiques de bovins étudiées ou utilisées comme référence pour les analyses morphométriques. \*: populations d'aurochs.*

European aurochs, from Denmark (Degerbøl and Fredskild 1970) and La Montagne (France), three from PPNA Near Eastern aurochs (dating from 9500–8700 cal. BC for Mureybet, Jerf el-Ahmar and Göbekli), seven from Neolithic Near Eastern domestic animals (dating from 8700–8200 cal. BC for Dja'de el-Mughara, 8200–7500 cal. BC for Tell Aswad, Tell Halula 1/9, Akarçay MPPNB, Mezraa-Teleilat MPPNB and Cafer Höyük, and 7500–6500 cal. BC for Assouad, Tell Halula 10/34, Gürcütepe and Tell Sotto), one series from the Greek Final Neolithic (Dikili Tash), and one from present-day domestic animals from Romania (bulls and castrated animals), giving a total of 400 first phalanxes. The reference specimens used for non-working animals are the groups of European and Near Eastern aurochs, and for animals that have worked we chose the present-day cattle from Romania (Bartosiewicz et al., 1997). Note that in multivariate analyses, the measurements considered are: GLpe, Bp and Bd; SD has been removed as it was not available for the castrated cattle from Romania.

We will proceed first with the analysis of the principal components (PCA) performed on the raw data (fig. 3 and 4). Most of the information is carried by the first component (91.78% of variance). The raw measurements are correlated with the first component (correlation coefficient = 0.989,  $P(\text{uncorr}) = 0$ ). Size variations evolve jointly and are the consequence of two factors, first the sexual dimorphism as it can be seen on figure 3 within the aurochs population, but also the evolution in size of wild animals towards domestic animals, which is thus, *pro parte*, isometric. On axis 2, the variables are less correlated (correlation coefficient = 0.118,  $P(\text{uncorr}) = 0.01$ ) and variability is less significant (7.59%): this partly reflects the difference in the fore/hind bones (based on the slenderness indices: GLpe/Bp and/or GLpe/Bd). Moreover, for the Romanian male bovines (cf. raw data from Bartosiewicz et al., 1997), the two main components displayed clearly the distinction between non-castrated (bulls) and castrated (oxen) animals (fig. 4), most of the latter showing higher



**Fig. 3** – Principal Component analysis (PCA) on the raw measurements of first phalanxes (see appendix for the data): example of the morphometric differences between male and female European aurochs (red dots). Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior. The ellipse corresponds to the 95% confidence.

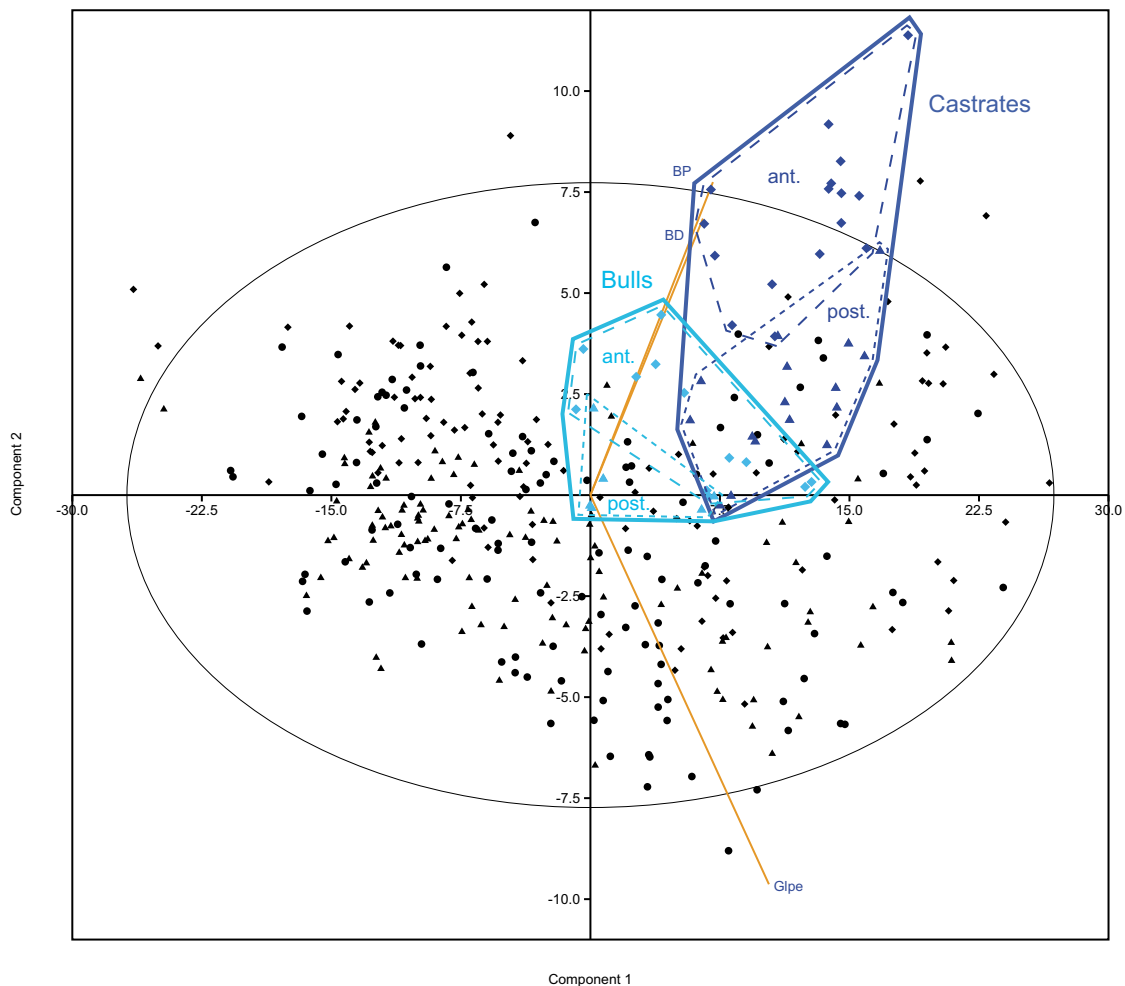
**Fig. 3** – Analyse en composantes principales (ACP) des mesures brutes des phalanges 1 (voir annexe pour les données) : exemple des différences morphométriques entre les mâles et les femelles chez les aurochs européens (points rouges). Symbole losange : phalange antérieure; triangle : phalange postérieure; disque : position non déterminée. L'ellipse correspond à l'intervalle de confiance de 95%.



values, even if there is a slight overlap between both populations. The former did not work, or worked very little, unlike the latter and thus this disparity characterizes the difference between pathological and healthy animals. Overall, on this projection plane, the first component corresponds mainly to an isometric reduction in size, and the second component to an allometric variation due to the morphology (anterior *versus* posterior bones) or deformation of the phalanges because of marked work constraints.

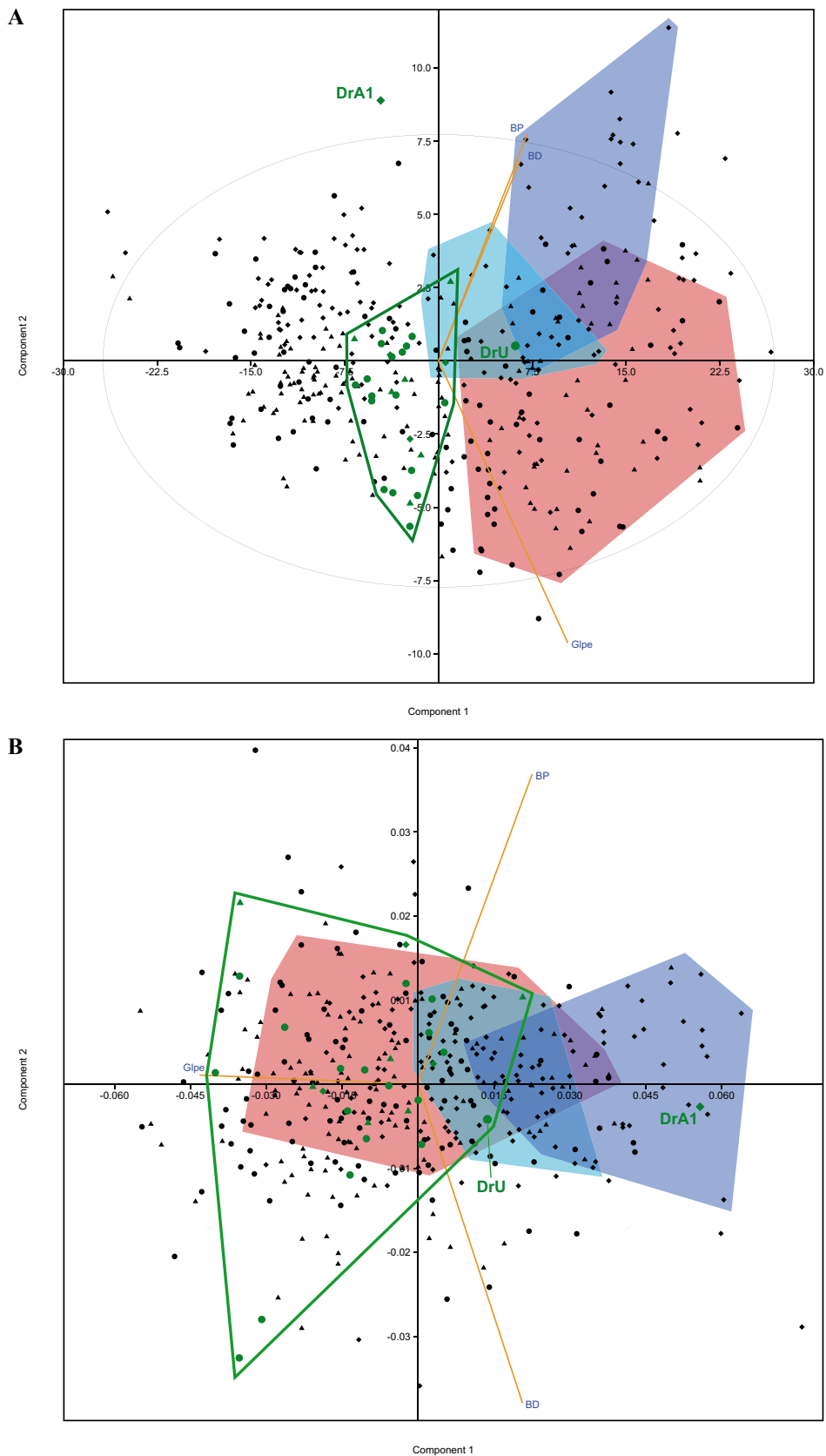
Then, we will analyze the shape indices using the log-shape ratios according to the approach of Mosimann (Mosimann, 1970; Lleonart et al., 2000), in order to test

whether size variations correspond or not to variations in shape (fig. 5). For each specimen, the isometric size is expressed as the geometric mean of the log values of the three measurements (GLpe, Bp and Bp) and a log-shape ratio (LSR) is calculated for each measurement by dividing its log value by the isometric size. Regarding the LSR data, the first component of the PCA expresses 85.59% of this variability, the second component only 14.41% (ax 1 correlation coefficient = 0.703, P(uncorr) = 0 but not with the second one ax 2 correlation coefficient = 0.013, P(uncorr) = 0.414). The two first compo-



**Fig. 4** – PCA on raw measurements of first phalanges: example of range of variation of the anterior and posterior phalanges from present-day Romanian male cattle (non-castrates in sky blue, castrated in dark blue) showing the impact of castration and work on the morphometry of the phalanges. The anterior and posterior phalanges are mainly distributed according to the second component, regardless of whether or not the animals worked, while the difference between the animals that worked and the others is expressed by a decrease in the GLpe and an increase in the breadth of the extremities (Bp and Bd): all the castrated animals are thus offset towards the top and the right. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior. The ellipse corresponds to the 95% confidence.

**Fig. 4** – ACP des mesures brutes des phalanges 1 : exemple des domaines de variation des antérieures et des postérieures chez les bovins mâles actuels de Roumanie (non castrés en bleu ciel, castrés en bleu foncé) montrant l'impact de la castration et de la mise au travail sur la morphométrie des phalanges. Que les bêtes soient coupées ou pas, les antérieures et les postérieures se distribuent essentiellement en fonction de la seconde composante (axe 2), mais la différence entre les animaux ayant travaillé et les autres s'exprime par une diminution de GLpe et une augmentation des diamètres transverses des extrémités (Bp et Bd) : l'ensemble des castrats est donc décalé vers le haut et la droite. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure. L'ellipse correspond à l'intervalle de confiance de 95%.



**Fig. 5** – Early Neolithic of Catalonia. A: PCA on the raw measurements; B: PCA on the LSR. In green symbols, specimens from La Draga; red area: European aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian cattle. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 5** – Néolithique ancien de Catalogne. A: PCA sur les mesures brutes; B: PCA sur les indices de forme (LSR). Symboles en vert : spécimens de La Draga; zone rouge : aurochs européens; zone bleu ciel : taureaux entiers roumains; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure; triangle : phalange postérieure; disque : antérieure ou postérieure.

nents thus enable us to visualize variations in shape and to interpret them.

### CASE STUDY IN WESTERN EUROPE: THE EARLY NEOLITHIC OF LA DRAGA (CATALONIA)

The sites dating from the Early Neolithic Cardial culture have not, up until now, yielded enough first phalanxes to be studied and La Draga in Catalonia is the only site with enough bones to be analyzed. The PCA applied on raw measurements (fig. 5A) brings to light a group formed by practically all the specimens, with two exceptions. The large-sized phalanx (DrU) falls within the range of the European aurochs and the other one (DrA1) is a far apart, located on top of the whole distribution. The hypothesis envisaged here is that DrU belongs to an aurochs. For the second specimen, the difference compared to the other phalanxes of the site is of the same type as that observed between bulls and oxen within the Romanian population; it could thus be from a castrated animal.

The results obtained by the PCA applied to the LSR (fig. 5B) show that aurochs are located at the centre of the projection, which is not surprising as it is the basic shape, and for Romanian bulls the castrated animals are clearly scattered on the right of the non-castrated animals (stronger Bp and Bd, weaker GLpe). The distribution of the LSR of the phalanxes from La Draga confirms the precedent results obtained from the raw measurements: DrU remains within the range of the European aurochs, whereas DrA1 is separated from the rest of the La Draga phalanxes, in the same way as the Romanian castrated animals are very different from the non-castrated bulls.

In conclusion, in this recent Cardial settlement, the aurochs is present but not dominant, and among the domestic bovines, at least one was used for work and was likely castrated.

In order to generalize this demonstration, it can be compared to other examples. First, we will consider European bovines from the fourth millennium cal. BC in southern France, then we will assess Near Eastern data from the eighth and ninth millennia cal. BC, i.e. from the beginning of cattle domestication.

### CASE STUDIES IN WESTERN EUROPE: THE END OF THE NEOLITHIC IN SOUTHEASTERN FRANCE (PROVENCE AND LANGUEDOC)

In Provence, this group comprises phalanxes from Bell Beaker (N = 14) and Final Neolithic sites (N = 40). The differences in measurements between these two periods are not significant (for Bp,  $t = 0.11$ ; P (same mean) = 0.91) and we can conduct an univariate study on all the first phalanx measurements.

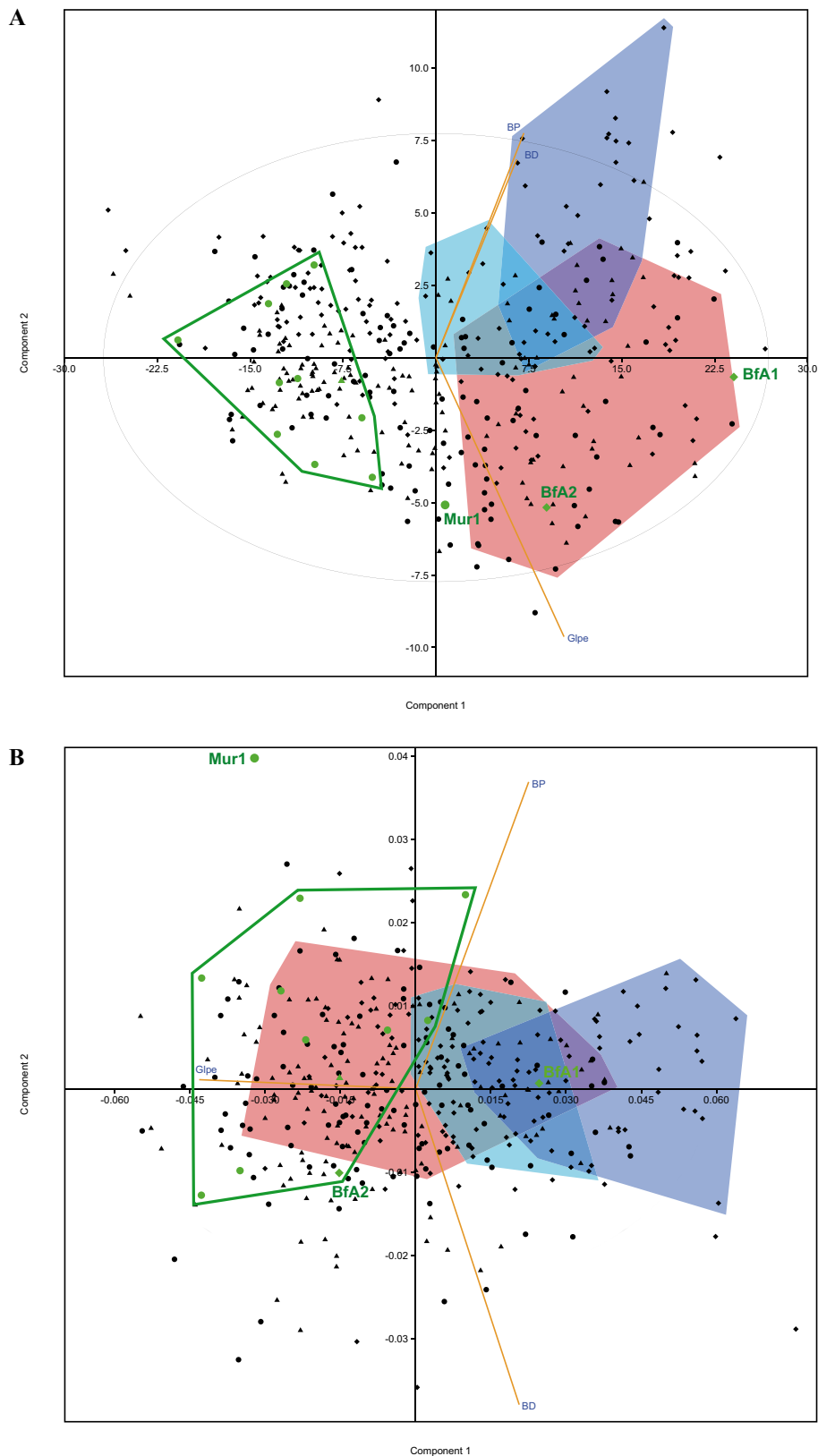
On first analysis, the distributions are not normal. When the measurements falling outside the 95% confidence interval are eliminated, the distributions all become normal in spite of the fact that several measurements exceed the confidence interval again (in italic below). The latter measurements concern only four phalanxes: two anterior phalanxes from La Balance (Bf1: GLpe = 80.0; Bp = 44.0; SD = 37.0; Bd = 40.8; and Bf2: GLpe = 72.0; Bp = 33.0; SD = 28.3; Bd = 32.7), one hind phalanx from La Fare 1 (LFAd1: GLpe = 55.0; Bp = 33.6; SD = 28.3; Bp = 32.7) and one posterior phalanx from Grotte Murée (Mur1: GLpe = 66.0; Bp = 32.5; SD = 25.0; Bp = 25.0). To improve legibility, we will study the projections by chronological period: first, the Bell Beaker culture, then the Final Neolithic.

#### Case from the Bell Beaker culture

The Bell Beaker sites considered here are La Balance-rue Ferruce, Calades, Grotte Murée (Helmer, 1979; Blaise, 2010). The three phalanxes from La Balance—one posterior (BfP1) and two anterior bones (BfA1 and BfA2)—belonged to very large animals, and present slight pathologies (lipping, osteophytes). In the projection plane generated by the PCA of the raw measurements (fig. 6A), the two anterior bones are positioned at some distance from the other phalanxes and fall within the range of variation of the European aurochs. The discrepancy appears on axis 1 and not on axis 2: they could thus be aurochs phalanxes. The same applies to the phalanx from Grotte Murée (Mur1). According to the two first principal components of the LSR (fig. 6B), most of the Bell Beaker phalanxes are distributed on the left, and are rather from slender domestic animals. As for the two large Bell Beaker phalanxes, one (BfA2) is at the bottom and a little outside the aurochs distribution, the other (BfA1) falls within the aurochs and the castrated groups. If we combine both analyses, the diagnostic for BfA2 is very likely an aurochs. On BfA1, the pathologies are not developed enough to result from work, but are similar to those observed on elderly large wild males from Europe and the Near East; we thus can interpret it as an aurochs bone. The same interpretation cannot be applied to the specimen from Grotte Murée which deviates completely from all the reference values: it is neither an aurochs nor a castrated animal. For the time being, we consider it to be an extreme variant.

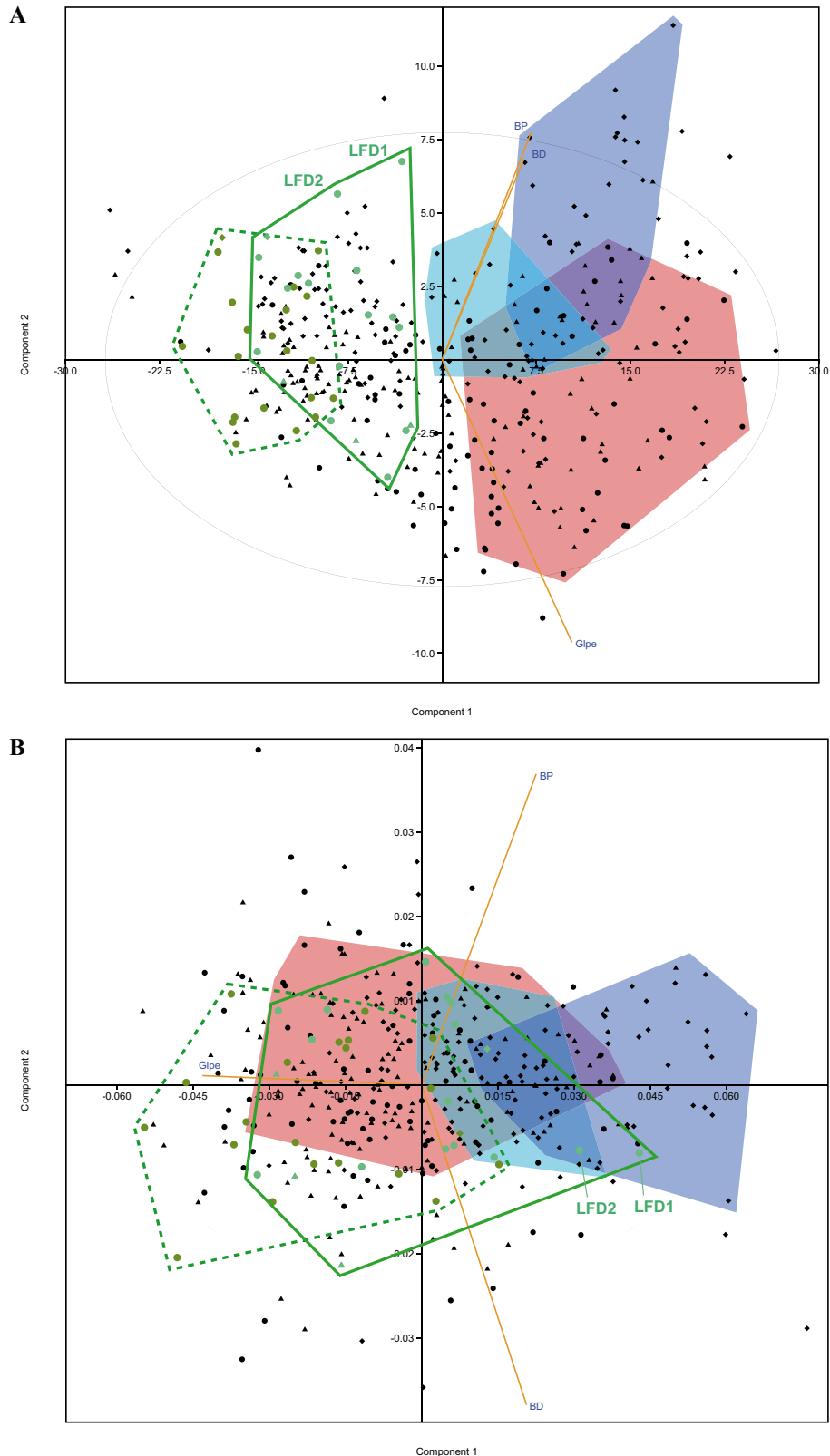
#### Case of the Final Neolithic in Provence

The sites analyzed in Provence are Claparouse, La Brémonde, La Citadelle, and La Fare (phases 1 and 2). A relatively large number of phalanxes are affected by pathologies and some hind bones are 'anteriorized' (Blaise, 2010). The results obtained from the PCA applied to the raw measurements (fig. 7A) show that the range of variation of the bones with pathologies is distributed more to the right compared to the 'healthy' specimens, and two pathological bones from La Fare extend range towards the right-top



**Fig. 6** – Bell Beaker culture in Provence. A : Principal Component analysis on the raw measurements; B : Principal Component analysis on the LSR. In green symbols, specimens from Bell Beaker sites; red area: European aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

*Fig. 6* – Campaniforme de Provence. A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens des sites campaniformes ; zone rouge : aurochs européens ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.



**Fig. 7** – Final Neolithic in Provence. A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the on the LSR. In green symbols, specimens from Final Neolithic sites (olive: non-deformed bones; light green: deformed bones); red area: European aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 7** – Néolithique Final de Provence. A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens des sites du Néolithique final (vert olive : os non déformés ; vert clair : os déformés) ; zone rouge : aurochs européens ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.

(LF1D1 and LF1D2). This increase in size of the Bd and Bp strongly suggests the pattern observed in Romanian bovines. These deformations thus seem to be due to work.

Like in the previous study, the PCA applied to the LSR (fig. 7B) shows a difference towards the right in the variation range of the pathological phalanxes compared to the 'healthy' specimens, and there is again a strong analogy with the Romanian bovines. This confirms that the pathological phalanxes result from work. The two phalanxes LF1D1 and LF1D2 are clearly positioned to the right of the main range of variation for 'healthy' and pathological phalanxes. This situation is similar to that of Romanian cattle. In conclusion, the pathologies are mainly due to work and the presence of castrated bovines is highly probable at La Fare.

### Case of the Final Neolithic in Languedoc

In Languedoc, the two sites considered here (Grotte de Chazelles and Grotte du Hasard) are about ten kilometres apart and are sub-contemporaneous (attributable to the Ferrières culture, 3200–2800 cal. BC). There is no difference in size between the bovines from these two caves and the difference in the Bp averages of the first phalanxes is not significant ( $t = 1.21$ ). The univariate analysis shows that four phalanxes from Chazelles are very small, and two of them are equal or inferior to 2.6 standard deviations below the mean value, which probably represent a case of dwarfism. When these phalanxes are excluded, the distribution normality test shows that the flattening and asymmetry for each measurement are normal but there are too many non-standard measurements among the 72 remaining phalanxes. Two phalanxes from Grotte du Hasard (HsA1: GLpe = 58.4, Bp = 32.2, SD = 27.0, Bd = 29.0; HsP1: GLpe = 58.5, Bp = 29.8, SD = 26.0, Bd = 29.3) and one from Grotte de Chazelles (ChA3: GLpe = 53.9, Bp = 32.0, SD = 24.1, Bd = 29.8) appear to be stronger. Another one from Chazelles (GLpe = 48.1, Bp = 22.5, SD = 18.4, Bd = 22.3) is smaller.

The pathologies observed in the bone assemblage from Grotte de Chazelles concern two fore phalanxes (ChA1 and ChA2) and a horn core deformed by a rope (yoke) (Favrie, 2004), which implies that at least one animal transported loads. In the projection of the two main components of the raw measurements (fig. 8A), the very small phalanxes (dwarfism) clearly stand out from the others. The two phalanxes with pathologies and the phalanx individualized by the univariate analysis, stand out towards the top and the right, as observed for the bones from the Final Neolithic of Provence.

With the projection of the two main components of the LSR (fig. 8B), the two largest pathological bones are spread out on the right (ChA2 and ChA3), but ChA1 still remains within the range of variation for non-deformed bones.

In the case of Grotte du Hasard, the deformed bones are one hind phalanx (HsP1), already differentiated by the univariate analysis, and three thoracic vertebrae presenting the transverse apophysis folded towards the back. Such latter pathology was observed for instance on early

domestic donkey (Rossel et al., 2008). These vertebrae are T5, T6 or T7, therefore the deformation is not linked to wearing a shoulder yoke but a pack. Thus, some animals were used to transport loads. The pathological posterior phalanx is consistent with the kind of work indicated by the vertebrae, rather than with use for draught.

For these two Final Neolithic sites in Languedoc, the study of size and shape shows that for Chazelles, at least two phalanxes belonged to castrated animals, while there are none at Hasard (fig. 9). However at both sites, the bovines worked either to pull or to carry loads.

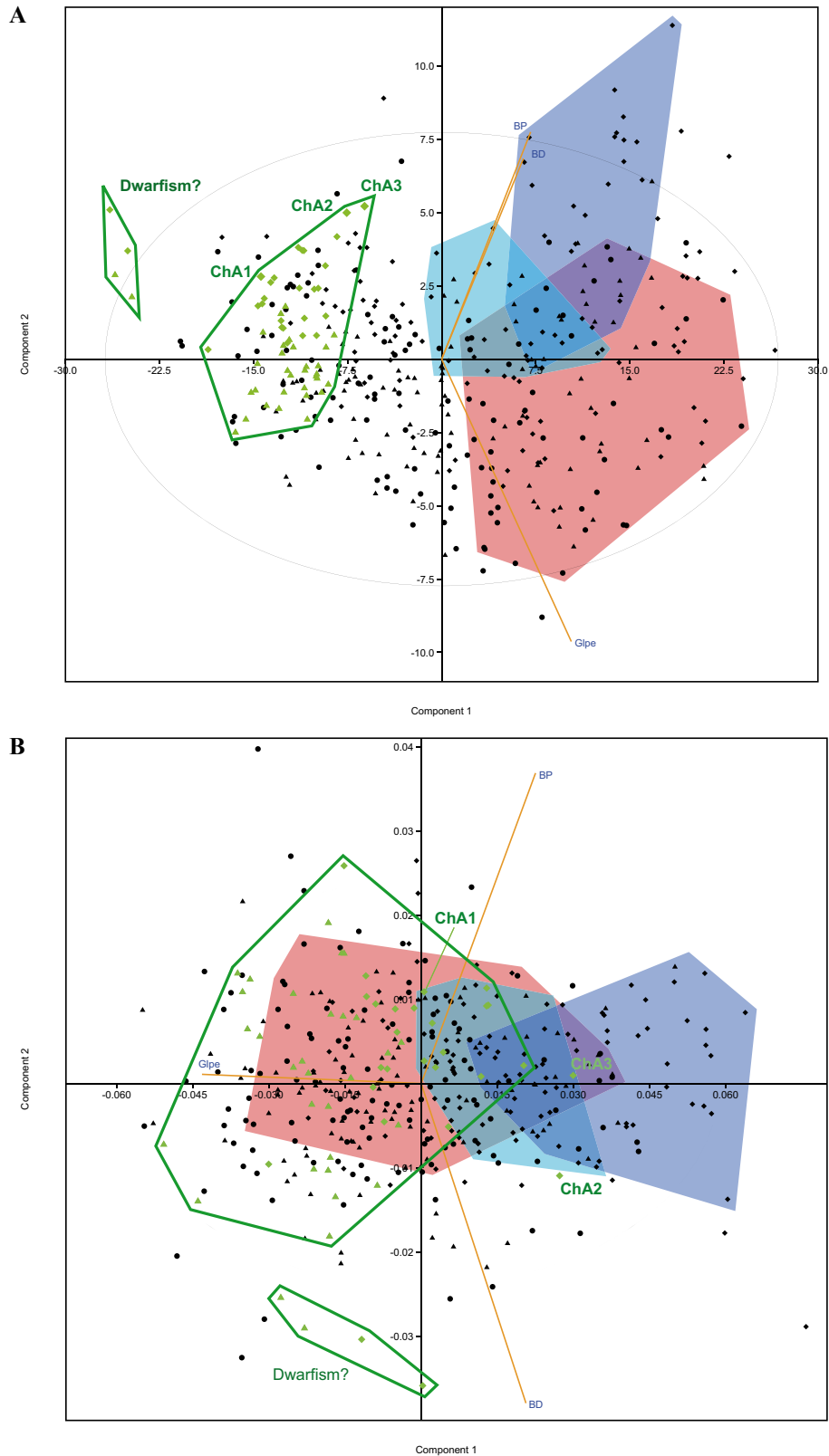
### CASE STUDY IN THE NEAR EAST: THE PRE-POTTERY NEOLITHIC B PPNB)

In Western Europe where domestic cattle are clearly differentiated from local aurochs, it is relatively easy to separate and interpret the remains. But what about the beginning of domestication in the Near East, a period during which the first domestic animals are still large in size and live alongside their ancestors, and where all the transition forms between local aurochs and their domestic descendants are potentially present? Interpretation is more difficult in these contexts, and in the absence of horn cores, the occurrence of the aurochs can be under-estimated. The earliest bovines interpreted as domestic were discovered at Dja'de el-Mughara in the Early PPNB, between 8700 and 8200 cal. BC, on the basis of a clear decrease in sexual dimorphism, which is one of the effects of mammal domestication (Helmer et al., 2005). Unfortunately, the number of first phalanxes from this site is insufficient for performing a morphometric analysis. But another method applied to a different category of bones, the second phalanxes, indicates that the hind bones are 'anteriorized'. For the purposes of our demonstration, we will take three examples dated from the Middle PPNB (8200 to 7500 cal. BC), two Syrian sites, Tell Halula and Tell Aswad, and a Turkish site, Cafer Höyük. The data matrix is the same as previously used except that the comparative aurochs considered here are the Near Eastern populations. The distribution of the data overlaps mostly that of the European aurochs regarding the raw measurements and the shape indices (LSR). For these examples, we will add two Turkish sites, Akarçay and Mezraa Teleilat, but we will only comment the main results so as not to weigh down the text.

#### Tell Halula

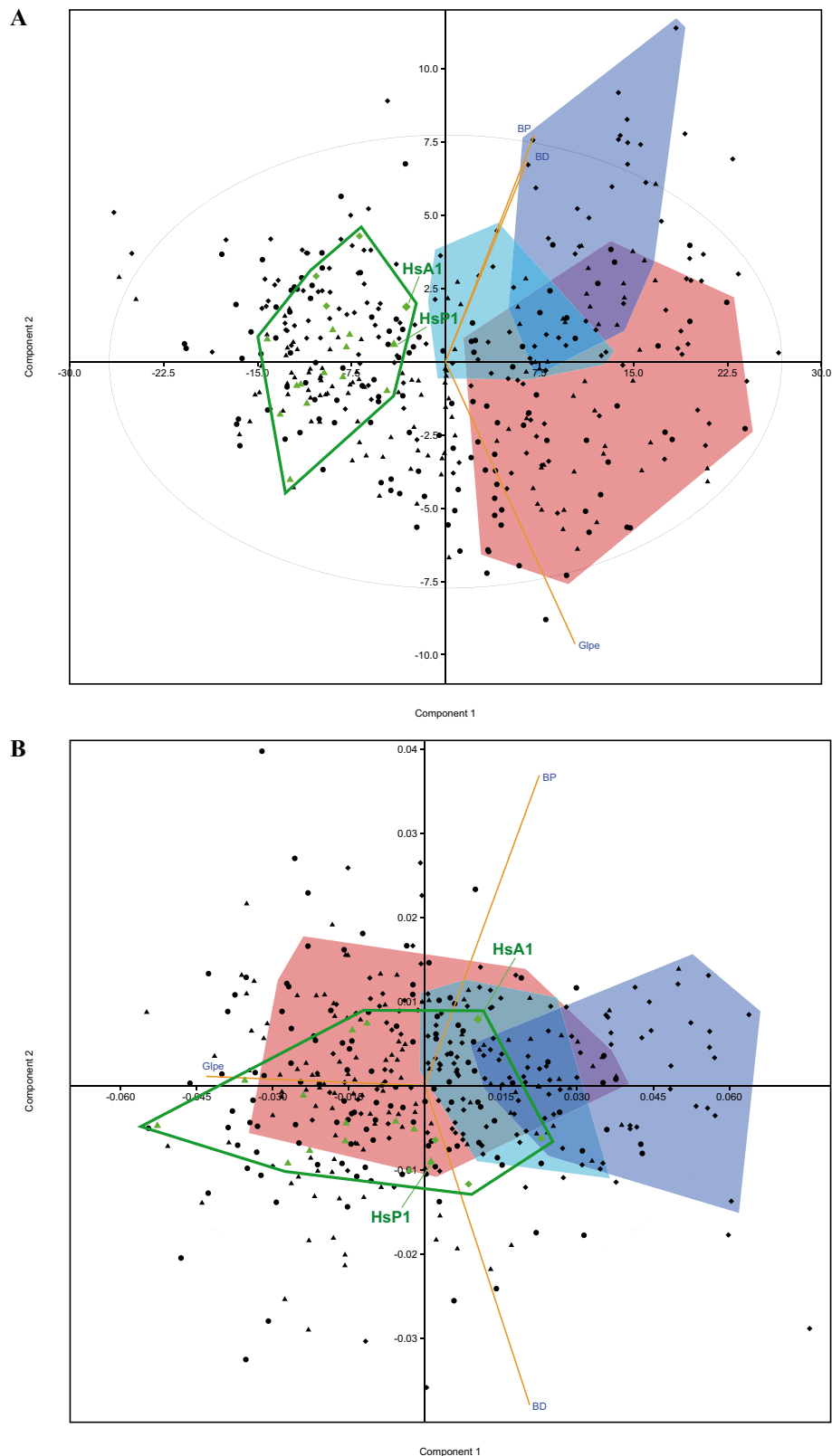
Practically all the bovines from Tell Halula (7800–7000 cal. BC) are domestic (Saña, 1999). They are relatively small animals with slight sexual dimorphism (Helmer et al., 2005). The univariate analysis of each measurement of the first phalanxes shows normal distributions for GLpe, Bp and Bd, but not for SD, as the





**Fig. 8** – Final Neolithic in Languedoc: Grotte de Chazelles. A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the LSR. In green symbols, specimens from Chazelles; red area: European aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 8** – Néolithique Final du Languedoc : Grotte de Chazelles. A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens de Chazelles ; zone rouge : aurochs européens ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.



**Fig. 9** – Final Neolithic in Languedoc: Grotte du Hasard. A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the LSR. In green symbols, specimens from Grotte du Hasard; red area: European aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 9** – Néolithique Final du Languedoc : grotte du Hasard. A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens du Hasard ; zone rouge : aurochs européens ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.

curve is too flat (flattening =  $-1.122$ ), which shows that a significant number of these bones are relatively thicker, i.e. stockier, than the average. However, no phalanx presents at least two measurements outside the 95% confidence interval. The PCA applied to the raw measurements (fig. 10A) or to the LSR (fig. 10B) do not bring to light any element standing out from the others. Overall, the phalanxes are quite close together and are not entirely within the range of variation of aurochs phalanxes, which is an additional argument for the diagnosis of domestic animals (Saña, 1999). According to the sample of first phalanxes studied here, aurochs and castrated animals were not present at Tell Halula. This does not mean that these bovines did not work, and based on the SD values, the presence of phalanxes with thick shaft suggests the opposite.

### Tell Aswad

The first levels of occupation at Tell Aswad, dated to the end of the Early PPNB, contain only a few remains. Most of the fauna from this site dates from the Middle PPNB, between 8200 and 7500 cal. BC. Cattle bones are sufficiently abundant to assess that the animals are morphologically domestic (small horn core) from the earliest layer of this period (B8). The cattle present the same size as aurochs (and are sometimes larger) and show traces of numerous pathologies. Sexual dimorphism is not apparent according to the biometric data, which is a criterion of domestication (see Arbuckle, 2005; Helmer et al., 2005; Helmer and Gourichon, 2008). Consequently, the interpretation of these data appears straightforward, the population is likely made up of large-sized domestic animals. Principal Component Analysis (PCA) of the raw measurements is applied to a small corpus of twelve phalanxes. The analysis of variance (ANOVA) of the three Middle PPNB series shows that Cafer Höyük and Tell Aswad are comparable ( $P(\text{same}) = 0.96$ ) whereas they are different from Tell Halula (Halula/Cafer  $P(\text{same}) = 0.03$ ; Halula/Aswad  $P(\text{same}) = 0.02$ ). We thus conducted a univariate analysis on the Cafer/Aswad specimens. As we saw for Tell Halula, the distributions are normal for GLpe, Bp and Bd, but the curve is too flat for SD (flattening =  $-1.136$ ). Thus, in this assemblage, there is a set of stocky phalanxes. Out of the twelve phalanxes from Tell Aswad, ten are clustered together and fall within the range of Near Eastern aurochs and two (AwA1 and AwA2) are very stocky fore bones bearing pathologies and clearly located on top of the whole distribution (fig. 11A). One of them falls outside the aurochs range of variation and the other is on the fringes. The hypothesis to test here is thus the presence of castrated animals.

Results from the PCA applied to the LSR (fig. 11B) clearly show that as far as shape is concerned, the stocky phalanxes from Tell Aswad are outside the range of the aurochs and are positioned in the same way as Romanian castrated animals versus non-castrated bulls. We cannot exclude they belong to aurochs since the range of variation of the wild cattle populations is poorly known for the

southern and central Levant, but given the currently available data, the hypothesis of the occurrence of castrated animals can be assumed.

### Cafer Höyük

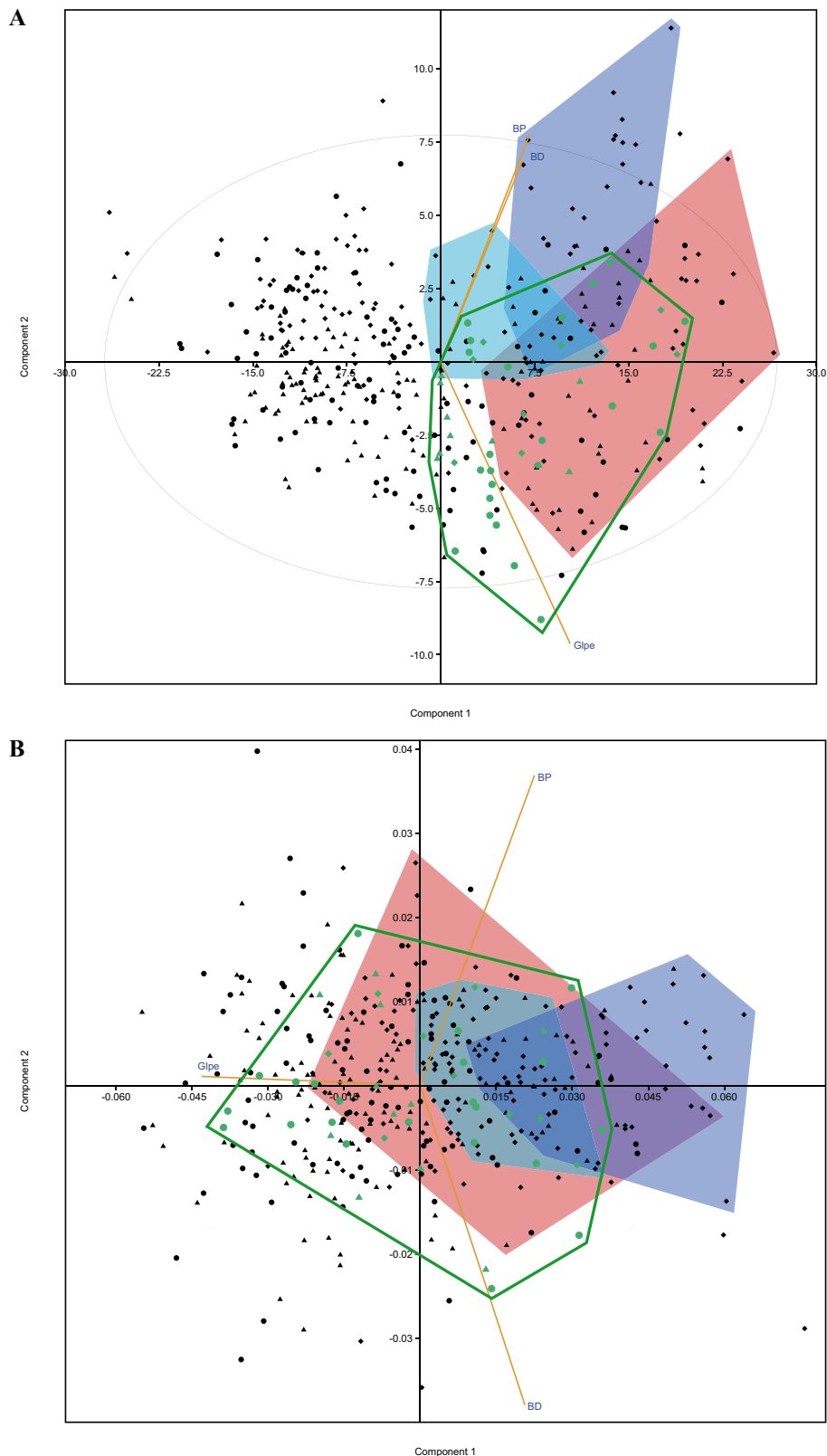
Regarding the eight whole phalanxes from Cafer Höyük, the PCA made on the raw measurements (fig. 12A) indicates that seven are clustered within the aurochs range but a little further to the left and higher up (they are stocky). The remaining phalanx, a fore one (CaA1), shows work-related pathologies (fig. 13) and falls outside the range of variation of wild cattle. It is clearly located higher and further to the right of the other bones from this site, resulting in the same situation as for Romanian castrated animals. Let us recall that other pathologies have been observed on the bovine assemblage, in particular a spavin on a tarsal/metatarsal (Helmer, 2008). According to the LSR data (fig. 12B), the seven clustered Cafer specimens present the similar proportions as the aurochs', but three of them are outside the range and present a deviation towards the bottom and to the left. The pathological phalanx CaA1 is situated further to the right and below the aurochs and is in keeping with the bone conformation of castrated animals. In conclusion, at Cafer Höyük the bovines were used for work and at least one of them was likely castrated. Most of these remains are related to domestic bovines, but the aurochs is represented by one very large horn core fragment (Helmer, 2008).

### Other PPNB sites

For Mezra-Teleilat, six MPPNB phalanxes can be analyzed. One of them is very large in terms of raw measurements and LSR, but is still within the aurochs range of variation. Regarding Akarçay tepe (7580–6080 cal. BC), the six analyzed MPPNB phalanxes do not present variations. Out of the ten available LPPNB bones, two are large and are outside the aurochs range in terms of raw measurements. The LSR of these elements are within the range of wild cattle, but their divergence with the other phalanxes suggests (but does not demonstrate) that these may be from castrated animals. When the observations made from these two projections are combined, the occurrence of castrated animals as a hypothesis appears more likely than the presence of aurochs. However, only the study of pathologies, which has not yet been carried out, could confirm or not this hypothesis. Evidence of the presence of castrated animals is available on two of the five MPPNB sites studied with the possibility of castrated animals on an additional site.

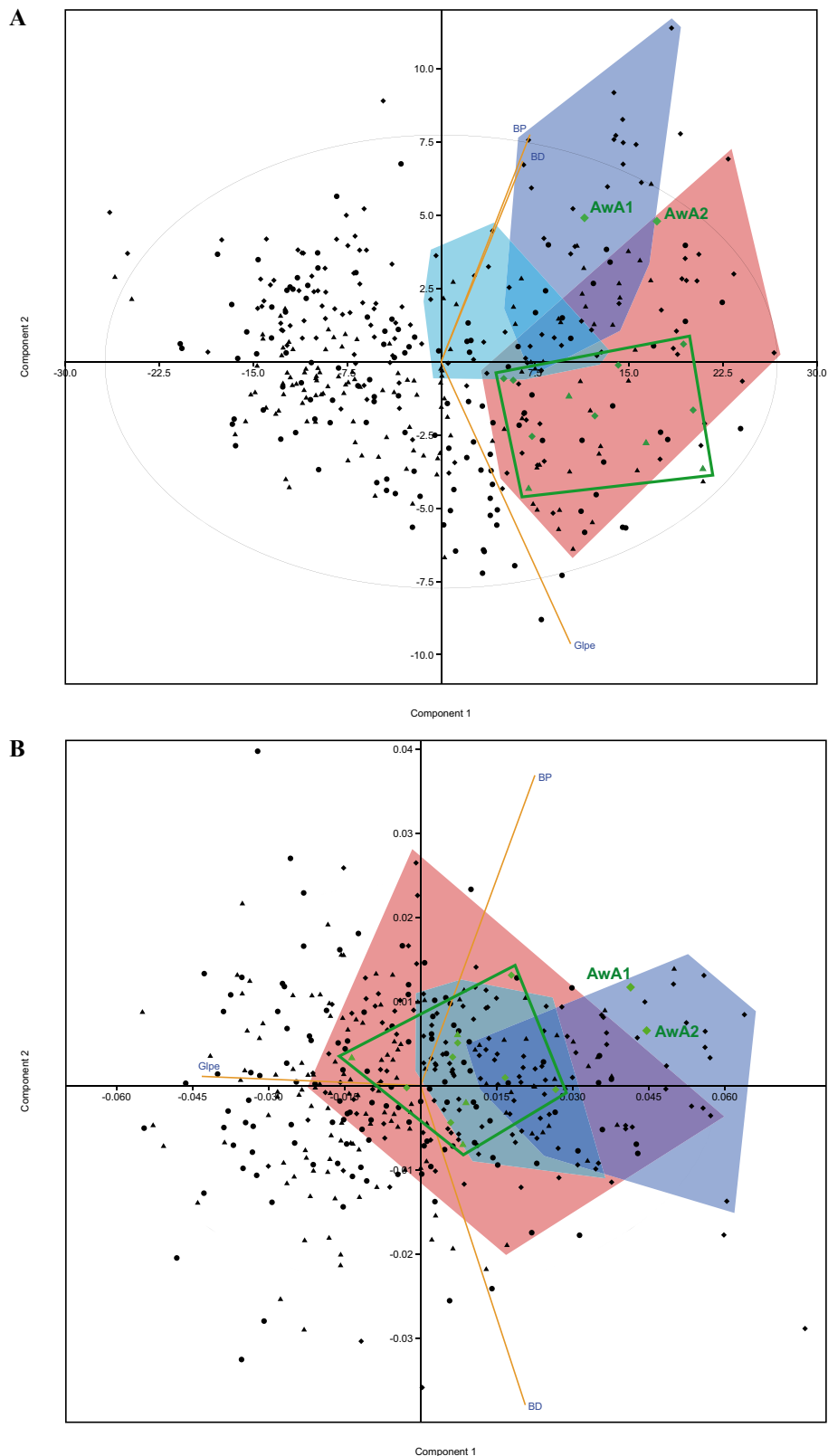
## CONCLUSIONS

The results of this morphometric study of size and shape based on the first phalanxes show that:



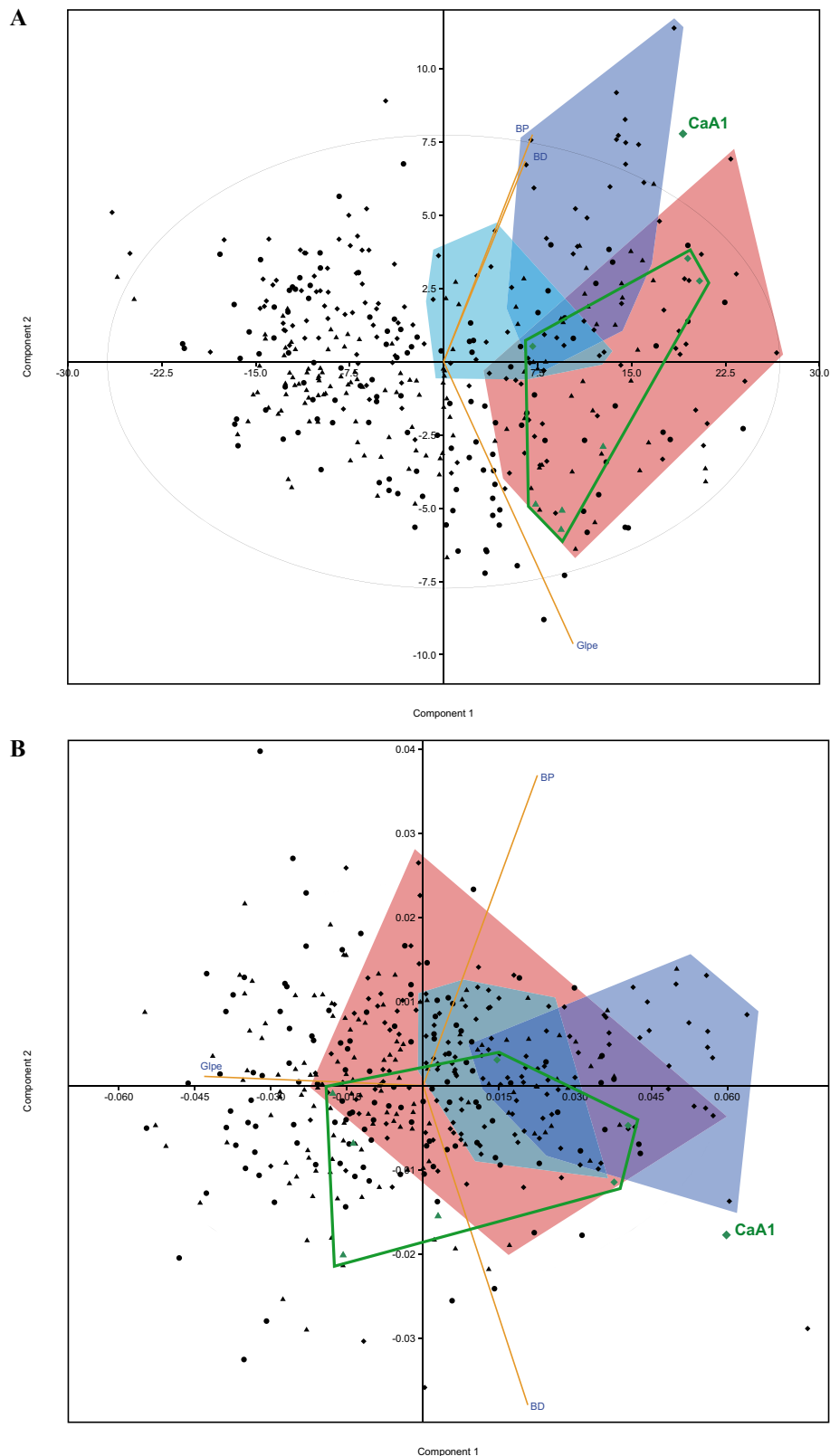
**Fig. 10** – PPNB in Syria: Tell Halula (Middle and Late PPNB levels). A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the LSR. In green symbols, specimens from Halula; red area: Near Eastern aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 10** – PPNB de Syrie : Tell Halula (niveaux PPNB moyen et récent). A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens de Halula ; zone rouge : aurochs proche-orientaux ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.



**Fig. 11** – PPNB in Syria: Tell Aswad (Middle PPNB). A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the LSR. In green symbols, specimens from Tell Aswad; red area: Near Eastern aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

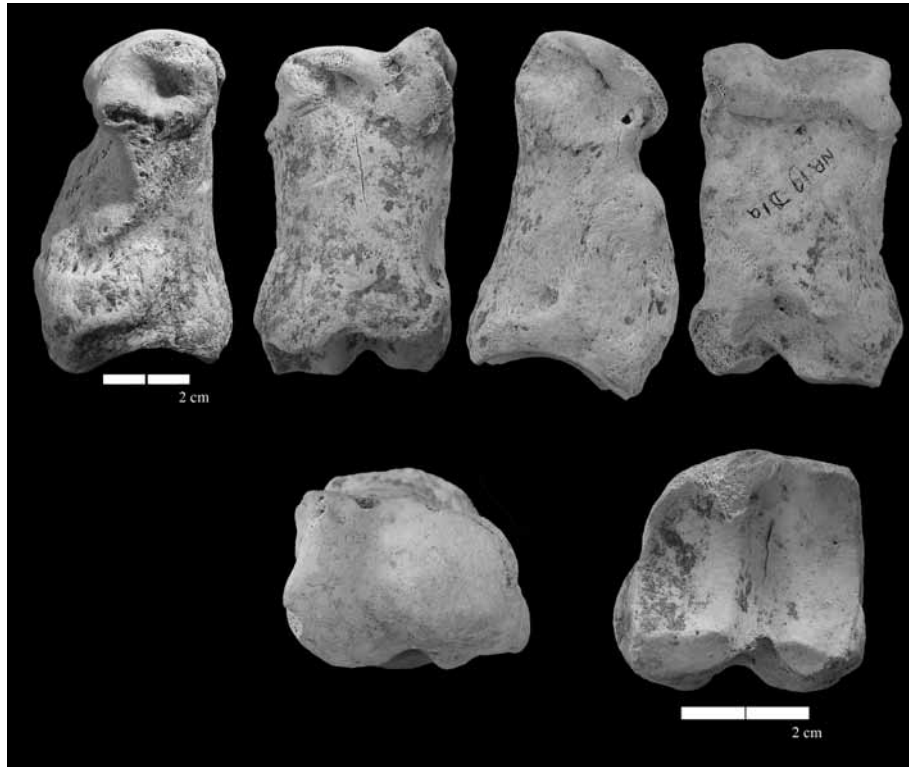
**Fig. 11** – PPNB de Syrie : Tell Aswad (PPNB moyen). A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens de Tell Aswad ; zone rouge : aurochs proche-orientaux ; zone bleu ciel : taureaux entiers roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.



**Fig. 12** – PPNB in Turkey: Cafer Höyük (Middle PPNB). A: Principal Component analysis on the raw measurements; B: Principal Component analysis on the LSR. In green symbols, specimens from Cafer; red area: Near Eastern aurochs; sky blue area: non-castrated Romanian bulls; dark blue area: castrated Romanian bulls. Diamond symbol: anterior phalanx; triangle: posterior phalanx; circle: anterior or posterior.

**Fig. 12** – PPNB de Turquie : Cafer Höyük (PPNB moyen). A : PCA mesures brutes ; B : PCA sur les indices de forme (LSR). Symboles en vert : spécimens de Cafer ; zone rouge : aurochs proche-orientaux ; zone bleu ciel : taureaux entiers Roumains ; zone bleu foncé : taureaux castrés roumains. Symbole losange : phalange antérieure ; triangle : phalange postérieure ; disque : antérieure ou postérieure.





**Fig. 13** – Proximal anterior phalanx from the Middle PPNB of Cafer Höyük (Turkey).

*Fig. 13* – *Phalange 1 antérieure du PPNB moyen de Cafer Höyük (Turquie).*

1) The large bovines considered here can be aurochs as well as large domestic cattle.

2) The observed pathologies are mainly due to work.

3) The large domesticated animals, often affected by bone deformations, were likely castrated.

4) In Western Europe, the first evidence of use of cattle for work is observed during the Early Neolithic of La Draga (as was previously shown by Bosch et al., 2000).

5) This use—for draught and transport—begins during the early stages of domestication during the Early PPNB (8700–8200 cal. BC), at least for transport, and castration is practiced from the Middle PPNB in Syria (at Tell Aswad) and in Turkey (at Cafer Höyük).

Bovine work and castration are thus older practices than previously thought and were probably, along with the production of milk, one of the prime motivations for the domestication of these animals. The animals could also be used for plowing and accessing new lands for farming. Bovines thus pulled and transported loads during the Neolithic, they were the 'large vehicles' of the time. Some of the sites considered here, where work is attested and castration is highly probable, are characterized by the presence of specific raw materials. At Cafer Höyük, most of the stone tools are made in obsidian, the source outcrops of which are located 200 km away (Cauvin et al., 1999; Cauvin, 2000). The same situation can be observed at Tell Maghzaliyah in the north of Iraq (7500–7000 cal. BC: Bader, 1989). At Tell Halula, the presence of objects in native copper from the Middle PPNB layers demonstrates links with

Anatolia. At Tell Aswad, distant links are evidenced for instance with shell beads originated from the Red Sea and the Mediterranean (Alarashi, 2010), and the occurrence of cedar wood might come from the Anti-Lebanon Mountains.

Lastly, the possession of these “large vehicles” must have greatly facilitated Neolithic diffusion and settlement from the earliest Neolithization centre to the Western Mediterranean. Regarding the other Neolithic cases studied in this paper, some cultural and economic contexts can shed light on the use of domestic cattle for work. During the Final Neolithic of Provence, La Fare is located near to the Oligocene flint deposits that supplied the large blades found all over the Southeast of France (Renault, 1998). It is also a perched enclosed site (with ditch and fences) where the use of tribulum is attested (Khedhaier et al., 2003). Bovines could have been used for agricultural activities, for thrashing straw and cereals. In southeastern France, during earliest Neolithic periods, pathologies on cattle bones are rarely observed and consist in deformed phalanxes with an incipient lipping on the proximal articular surface (Blaise et al., 2010; Bréhard, 2011). Different animals may have been used from time to time for transport or low intensity activities. The presence of large domestic specimens might correspond to bulls (breeding stock) or some possible castrated animals, for meat production for example (Bréhard, 2011), but this practice is not necessarily linked to transport. In the Late Neolithic, the high frequency of pathologies and the important deformations on the first and second phalanxes (Blaise,

2010) of these small-sized bovines (less than 1.20 m withers height) suggest intensive traction type activities (ploughing and perhaps log hauling) and castration occurring once the animal's growth was achieved. Other Final Neolithic sites in the same region—La Brémonde, Le Plan Saint-Jean, Le Mourre du Tendre, Ponteau-Gare, Collet-Redon, etc.—all contain bovines with pathologies (clear deformations and anteriorization; *Ibid.*). They provide evidence of the generalized use of animals for hauling and transport (animals were kept until an old age and probably worked all their lives) with the probable intensification of farm labour (shown by use of bovines for ploughing). These last sites, located near the sea, may also have used cattle for the transport of salt, for example at Le Mourre du Tendre (Vaucluse), which is located in the plain of Comtat (Vaucluse) near a salt lagoon, more than 150 km from the Mediterranean. On Bell Beaker sites, the presence of both domestic bovines and aurochs is attested and confirms the particular role of hunting in this culture, which is very different to Neolithic regional sites where this practice is nearly non-existent (Blaise et al., 2014).

This study attests the presence of castrated animals during the Neolithic period in Western Mediterranean as well as in the Near East at the beginning of cattle husbandry. Though evidence of castration could not be found on all sites, among the other faunal assemblages integrated in the database, the occurrence of such animals is some-

times observable, for example at Mezraa Teleilat MPPNB, at Tell Halula during the Late PPNB, but not at the sites of Gürcütepe and Ras Shamra during the same period. This does not mean that castrated cattle was absent at these sites. Let us recall that in a domestic population, not all the animals work and only a fraction of them are used for heavy work, which requires strong and calm animals. The selection and rearing of these animals requires a long term effort and training. Transport is less traumatizing for the animals and can be detected through the presence of anteriorized phalanges, which is relatively frequent (as is the case at Ras Shamra and Tell Halula). Out of the 18 samples considered here, 14 yielded sufficient measurements for analysis and castrated cattle were identified for five of them. This high frequency points to a considerable economic role. When linked to the production of milk (consumption and libation), these results highlight the importance of domestic cattle in the economy of Neolithic societies, in line with the high symbolic value of the aurochs attested well before its domestication (Cauvin, 2000; Helmer et al., 2004).

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## APPENDIX

### RAW MEASUREMENTS OF THE PROXIMAL PHALANXES OF BOVINES USED FOR THE MORPHOMETRIC ANALYSES

(for the modern Romanian cattle, see Bartosiewicz et al., 1997).

#### *Bos primigenius* from Europe

##### Danish sites - Mesolithic

	GLpe	Bp	Bd	Notes
	77	45	41	male
	81	43	40	male
	77	40	37	male
	69	41	38	male
	69	39	34	male
	72	35,5	35	female
	68	34	33	female
	68	35	31	female
	74	34	30	female
	63	34	31	female

##### La Montagne (France) - Mesolithic

	GLpe	Bp	Bd	Notes
	68.7	32.9	28.4	female
	68.8	30.0	29.0	female

### *Bos taurus* + *Bos primigenius* from Neolithic Catalunya

#### La Draga - Early Neolithic

Position	GLpe	Bp	Bd	Notes
anterior	52.5	34.5	32.6	designed as DrA1 in the text
anterior	59.0	31.5	27.2	
anterior	62.4	32.6	30.2	
anterior	62.1	29.5	27.9	
posterior	60.8	35.0	31.0	
posterior	60.4	30.7	28.4	
posterior	59.9	29.4	28.3	
posterior	56.5	29.0	27.7	
posterior	63.1	29.7	28.0	
posterior	63.6	29.8	25.2	
	57.64	27.66	27.51	
	57.97	31.19	27.82	
	58.20	29.07	27.13	
	58.20	30.05	28.51	
	58.86	28.61	27.38	
	58.97	28.85	26.92	
	59.14	31.21	27.59	
	59.62	30.35	29.57	
	59.74	31.60	28.75	
	59.84	31.84	29.30	
	60.25	29.36	28.55	
	61.73	25.48	28.36	
	62.36	28.69	25.39	
	62.93	29.49	26.86	
	63.29	31.62	29.73	
	63.83	26.91	29.28	
	64.13	28.01	26.28	
	66.09	35.18	33.65	designed as DrU in the text

***Bos taurus + Bos primigenius***  
**from Neolithic in southeastern France**

La Brémonde - Late Neolithic

Position	GLpe	Bp	Bd	Notes
anterior	48.9	27.7	25.5	with pathologies/deformation
anterior	46.3	25.3	24.5	
posterior	61.6	28.2	29.6	with pathologies/deformation
posterior	53.2	24.8	24.7	with pathologies/deformation
posterior	58.8	27.3	25.6	with pathologies/deformation

Claparouse - Late Neolithic

	GLpe	Bp	Bd
	51.5	26.1	24.0
	56.5	26.5	26.2

La Citadelle - Late Neolithic

	GLpe	Bp	Bd	Notes
	52.2	28.6	28.2	
	51.6	26.7	26.9	
	52.6	27.9	26.3	
	51.6	27.5	26.8	with pathologies/deformation
	49.9	24.4	24.1	
	51.0	25.2	23.2	with pathologies/deformation
	56.1	27.3	27.0	with pathologies/deformation
	55.9	25.2	25.5	
	51.7	26.2	26.0	
	51.2	22.8	21.6	
	46.5	21.8	21.1	
	51.2	21.6	22.6	

La Fare 1 - Late Neolithic

	GLpe	Bp	Bd	Notes
	46.4	25.5	23.4	
	48.4	25.3	22.9	
	48.9	27.3	24.5	with pathologies/deformation
	58.7	30.9	29.3	with pathologies/deformation
	55.0	33.6	32.7	designed as LF1D1, with pathologies
	52.0	30.5	29.7	designed as LF1D2, with pathologies
	54.9	29.8	29.2	with pathologies/deformation
	56.6	29.5	28.8	with pathologies/deformation
	51.3	28.2	24.7	with pathologies/deformation
	61.5	30.0	27.0	with pathologies/deformation
	61.5	27.1	27.0	with pathologies/deformation
	55.2	25.8	25.2	
	55.1	24.6	24.1	
	52.7	24.7	22.2	
	54.4	27.2	25.1	
	56.9	27.1	24.5	with pathologies/deformation
	51.9	22.1	21.5	
	50.0	24.2	22.6	
	52.7	26.4	24.3	
	58.1	31.5	28.5	with pathologies/deformation
	52.4	28.9	25.8	with pathologies/deformation

Grotte du Hasard - Late Neolithic

Position	GLpe	Bp	Bd	Notes
anterior	58.4	32.2	29.0	designed as HsA1 in the text
anterior	52.4	27.8	27.7	
anterior	54.0	30.6	29.6	
posterior	55.1	26.7	26.0	
posterior	51.0	25.2	24.3	
posterior	54.0	25.5	25.0	
posterior	54.8	25.3	25.0	
posterior	55.6	23.5	22.8	
posterior	58.5	29.8	29.3	designed as HsP1, with pathologies
posterior	56.3	28.2	25.7	
posterior	55.8	28.2	27.1	
posterior	53.5	24.6	23.2	
posterior	55.7	28.5	27.5	
posterior	59.2	29.8	27.0	
posterior	53.8	25.7	24.4	
posterior	54.6	27.6	27.3	
anterior	53.7	28.0	27.2	

Grotte de Chazelles - Late Neolithic

Position	GLpe	Bp	Bd	Notes
anterior	50.2	26.9	25.0	
anterior	51.4	29.4	26.1	
anterior	54.1	27.3	26.3	
anterior	53.0	29.3	27.4	
anterior	53.1	28.2	27.2	
anterior	54.2	28.9	26.0	
anterior	53.3	27.0	25.5	
anterior	49.5	27.1	24.2	designed as ChA1, with pathologies
anterior	52.0	27.9	26.0	
anterior	52.9	28.6	26.4	
anterior	53.0	30.4	28.2	
anterior	50.2	26.7	24.1	
anterior	51.9	27.1	24.0	
anterior	50.3	27.4	24.9	
anterior	51.3	29.2	26.2	
anterior	52.0	27.0	24.2	
anterior	50.0	25.9	24.2	
anterior	53.0	30.3	30.0	designed as ChA2, with pathologies
anterior	52.6	27.8	23.1	
anterior	53.0	27.8	25.4	
anterior	53.9	32.0	29.8	designed as ChA3 in the text
anterior	51.0	29.1	26.1	
anterior	50.2	26.1	24.4	
anterior	51.7	27.0	24.3	
anterior	48.1	22.5	22.3	
anterior	41.1	20.2	22.0	
anterior	39.1	20.0	22.3	
posterior	40.9	19.4	21.0	
posterior	42.4	19.8	21.1	
posterior	55.9	27.0	25.8	



posterior	52.4	27.0	23.6	
posterior	53.5	25.2	23.9	
posterior	52.5	27.0	23.2	
posterior	51.6	27.2	25.0	
posterior	53.6	25.1	23.0	
posterior	50.9	26.4	23.1	
posterior	52.8	25.0	22.2	
posterior	55.1	28.0	27.0	
posterior	51.5	26.8	24.8	
posterior	55.7	26.6	25.4	
posterior	51.3	25.3	22.7	
posterior	51.6	24.5	22.0	
posterior	51.9	22.5	22.8	
posterior	51.6	22.2	21.8	
posterior	54.9	27.6	25.0	
posterior	53.0	26.5	24.9	
posterior	52.6	26.9	24.4	
posterior	55.1	26.2	26.0	
posterior	54.2	25.8	26.0	
posterior	55.0	27.4	24.8	
posterior	53.5	25.9	24.3	
posterior	54.9	26.2	24.5	
posterior	53.2	25.2	25.0	
posterior	55.0	26.3	25.9	
posterior	54.2	25.4	26.2	
posterior	54.9	27.0	27.0	
posterior	51.8	24.8	22.1	
posterior	54.6	26.3	24.5	
posterior	55.5	26.0	23.9	

## Grotte Murée - Bell Beaker

	GLpe	Bp	Bd	Notes
	66.0	32.5	25.0	designed as Mur1 in the text
	61.0	26.7	26.5	
	52.6	30.5	25.5	
	51.4	28.0	25.3	
	53.3	26.0	23.2	
	57.3	24.5	24.7	
	54.3	27.5	23.2	
	54.4	25.0	22.2	
	46.3	22.1	20.8	
	50.8	26.8	24.4	

## La Balance rue Ferruce - Bell Beaker

Position	GLpe	Bp	Bd	Notes
anterior	80.0	44.0	40.8	designed as BfA1, with pathologies
anterior	72.0	33.0	32.7	designed as BfA2, with pathologies
posterior	56.9	28.0	26.2	designed as BfP1, with pathologies

## Les Calades - Bell Beaker

	GLpe	Bp	Bd	
	59.0	28.4	26.0	

*Bos primigenius* from northern Near East

## Mureybet - PPNA

Position	GLpe	Bp	Bd	
anterior	81.2	46.2	42.0	
anterior	78.8	42.7	37.6	
anterior	68.3	35.7	31.0	
anterior	70.3	35.0	31.7	
anterior	68.4	33.4	30.0	
posterior	71.8	38.2	33.8	
posterior	73.3	37.5	38.8	
posterior	67.2	33.8	31.0	
posterior	71.0	33.5	31.0	

## Jerf el Ahmar - PPNA

Position	GLpe	Bp	Bd	
anterior	74.1	44.1	39.6	
anterior	68.0	35.4	34.4	
anterior	74.4	44.1	39.9	
anterior	68.0	35.4	34.4	
anterior	69.2	37.2	30.3	
anterior	64.9	34.2	31.2	
posterior	72.3	42.5	38.8	

## Göbekli Tepe - PPNA

Position	GLpe	Bp	Bd	
anterior	74	47.1	44.5	
anterior	77	38.6	37.2	
posterior	73	40.2	37.5	
posterior	74	34.0	31.9	

***Bos taurus + Bos primigenius***  
**from Neolithic Syria**

## Tell Aswad - Middle PPNB

Position	GLpe	Bp	Bd	Notes
anterior	67.0	41.8	36.5	designed as AwA1 in the text
anterior	71.3	44.2	39.6	designed as AwA2 in the text
anterior	72.4	40.5	35.2	
anterior	75.7	42.2	39.4	
anterior	77.8	41.5	38.5	
anterior	66.6	35.0	32.2	
anterior	72.2	37.8	34.4	
anterior	66.0	34.0	32.6	
anterior	69.0	34.4	32.3	
posterior	70.0	33.6	31.0	
posterior	79.7	40.0	38.8	
posterior	70.2	36.5	34.5	
posterior	75.8	39.5	35.7	

## Assouad - Late PPNB

Position	GLpe	Bp	Bd
anterior	75,2	41,4	39,3
anterior	75,0	43,2	38,2
posterior	74,5	34,6	33,8

## Dja'de el Mughara - Early PPNB

Position	GLpe	Bp	Bd
anterior	65.0	30.5	28.5
anterior	79.1	42.5	36.7
posterior	64.3	28.6	29.6
posterior	73.3	36.4	34.9
posterior	75.9	36.3	37.5

## Tell Halula - Middle PPNB

Position	GLpe	Bp	Bd
anterior	68.8	33.2	32.2
anterior	68.0	35.0	31.8
anterior	70.0	35.0	31.0
anterior	68.6	37.0	35.2
anterior	65.1	31.1	28.7
anterior	63.8	33.6	31.3
anterior	69.2	38.2	36.4
anterior	73.6	41.0	40.2
anterior	64.0	35.2	31.0
anterior	75.6	42.5	38.2
posterior	64.0	30.0	29.1
posterior	62.3	31.2	30.8
posterior	62.4	31.6	30.0
posterior	64.2	30.2	30.4
posterior	64.0	31.0	27.6
posterior	63.6	31.4	29.5
posterior	66.8	33.8	29.6
posterior	72.0	35.0	33.4

posterior	70.5	35.4	37.2
posterior	70.1	35.0	31.2
	73.0	38.0	36.0
	63.2	33.6	31.8
	68.0	31.6	29.7
	68.0	37.0	36.3
	76.4	39.0	37.8

## Tell Halula - Late PPNB

Position	GLpe	Bp	Bd
	67.2	29.0	27.8
	67.0	33.8	28.9
	69.5	40.3	38.6
	69.7	34.4	33.0
	66.0	35.0	32.3
	74.0	41.3	37.9
	69.0	38.0	39.0
	68.4	31.3	29.4
	66.8	31.6	30.0
	69.0	31.0	29.9
	63.4	34.0	30.8
	67.8	31.6	30.4
	75.3	44.0	38.4
	62.6	32.0	34.0
	67.4	31.6	30.8
	73.8	31.0	30.0
	71.0	31.4	29.4

***Bos taurus + Bos primigenius***  
**from Neolithic eastern Turkey**

## Cafer Höyük - Middle PPNB

Position	GLpe	Bp	Bd	Notes
anterior	66.8	36.3	33.4	
anterior	73.8	43.4	41.4	
anterior	75.0	42.7	42.3	
anterior	70.6	44.0	45.0	designed as CaA1 in the text
posterior	73.2	35.6	36.2	
posterior	72.3	33.6	32.7	
posterior	72.7	33.7	31.8	
posterior	70.6	31.6	33.0	

## Gürcütepe - Late PPNB

Position	GLpe	Bp	Bd
anterior	67	35	32.5
anterior	68.5	33	29.5
anterior	70	39	36
anterior	71	41	37
anterior	74.5	44	42
anterior	77	45	43
posterior	70	34	32
posterior	70	38.5	37
posterior	80	38.5	40

## Mezraa Teleilat - Middle PPNB

	GLpe	Bp	Bd	Notes
	73.5	43.4	41.9	designed as Mez1 in the text
	65.7	32.2	26.4	
	66.4	32.9	31.3	
	63.3	30.3	29.0	
	65.7	31.1	31.0	
	74.1	35.7	33.9	

## Akarçay IV - Late PPNB

	GLpe	Bp	Bd	Notes
	61.56	32.3	30.23	designed as Mez1 in the text
	64.4	29.8	30.2	
	64.5	33.8	29.1	
	65.4	33.4	30.5	
	65.5	38.7	36.0	
	65.7	32.6	28.2	
	65.9	29.1	27.7	
	66.4	37.4	35.5	
	69.3	30.5	27.5	
	76.6	36.3	34.4	

## Akarçay V - Middle PPNB

	GLpe	Bp	Bd
	68.88	29.78	29.25
	73.6	34.55	33.33
	73.77	35.87	35.54
	76.4	36.00	34.5
	74.3	34.4	33.0

***Bos taurus + Bos primigenius***  
**from Neolithic Iraq**

## Tell Sotto - Pottery Neolithic

Position	GLpe	Bp	Bd
anterior	67.0	38.5	37.7
anterior	59.3	31.4	29.9
anterior	64.0	32.3	31.2
posterior	68.0	33.0	35.4
posterior	66.3	35.3	36.2

*Bos taurus + Bos primigenius*  
from Neolithic of northeastern Greece

## Dikili Tash - Late Neolithic

Position	GLpe	Bp	Bd
	66.7	28.9	26.8
	56.0	24.2	22.0
anterior	52.3	26.8	25.2
anterior	53.6	29.0	26.9
anterior	54.8	30.7	28.0
anterior	56.8	30.0	29.1
anterior	56.8	31.1	31.0
anterior	56.8	31.3	28.0
anterior	57.0	28.7	27.0
anterior	57.5	31.5	26.4
anterior	58.4	31.2	29.0
anterior	58.5	28.5	26.8
anterior	58.7	30.6	29.0
anterior	59.0	30.8	27.5
anterior	60.0	30.6	27.7
anterior	60.4	31.5	30.0
anterior	53.8	30.2	29.1
anterior	54.5	28.2	27.9
anterior	54.6	31.0	29.0
anterior	55.0	31.5	29.0
anterior	55.1	29.3	27.1
anterior	55.4	30.6	28.2
anterior	55.5	30.0	27.0
anterior	56.0	30.0	28.4
anterior	56.7	28.0	28.0
anterior	57.0	30.2	28.0
anterior	57.2	27.0	26.0
anterior	58.0	28.4	27.2
anterior	60.6	29.5	28.0
anterior	65.0	35.3	33.0
posterior	61.5	34.3	31.2
posterior	55.4	26.0	25.6
posterior	57.8	28.0	27.3
posterior	58.8	26.7	25.0
posterior	59.7	30.6	28.0
posterior	60.5	27.8	26.4
posterior	60.5	27.7	27.9
posterior	62.4	28.0	28.0
posterior	63.0	31.1	29.7
posterior	63.0	32.6	28.6
posterior	68.0	35.2	31.3
posterior	55.8	27.5	24.6
posterior	56.0	25.8	24.8
posterior	57.0	28.2	27.0
posterior	57.0	28.3	25.4
posterior	57.0	28.0	26.5
posterior	57.3	28.3	26.8

posterior	58.2	27.5	26.0
posterior	59.5	27.7	25.2
posterior	60.8	30.8	28.8
posterior	61.2	26.6	26.0
posterior	61.3	30.8	28.5
posterior	62.4	29.5	27.6
posterior	65.4	35.8	33.6