# Aurochs and potential crossbreeding with domestic cattle in Central Europe in the Eneolithic period.
## A metric analysis of bones from the archaeological site of Kutná Hora-Denemark (Czech Republic)

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**ABSTRACT**
The site of Kutná Hora-Denemark (3 444 bones or bone fragments identified) shows, contrary to most of the other seventeen Early and Middle Eneolithic sites in the Bohemian basin, a high percentage of hunted animals (more than a half). Aurochs are widely represented among 918 bovine bones. Besides metrically reliably determined aurochs and domestic cattle there is a high quota (almost a half) of intermediate sized bones, which could belong to: (1) large domestic males, (2) female aurochs or to (3) cross-breeds of both forms or to locally domesticated cattle. Some proposed indications support the third hypothesis.
The theoretical aspect of the problem is discussed at first (summary of knowledge concerning aurochs; body size; variability components; domestication). The subsequent analysis is based mainly on metric evaluation of twelve width measurements on long limb bones and phalanges (in total 483 data). This study contributes to the long standing debate concerning the local domestication/crossbreeding of wild and domestic animals in Central Europe, *i.e.* outside the main domestic centre in the Near East.

**KEY WORDS**
Aurochs,
*Bos primigenius*,
*Bos taurus*,
central Europe,
Czech Republic,
Kutná Hora-Denemark,
osteometry,
intermediate form,
crossbreeding,
local domestication.

**RESUMÉ**
*L'aurochs et l'hypothèse de son croisement avec des bovins domestiques en Europe centrale pendant le Chalcolithique. Analyse ostéométrique du site archéologique de Kutná Hora-Denemark (République tchèque).*
À la différence de la plupart des autres dix-sept sites de l'époque du Chalcolithique ancien et moyen dans le bassin tchèque, Kutná Hora-Denemark (3 444 os ou fragmentes osseux déterminés) contient un taux élevé de gibier (plus de la moitié). Les restes osseux du gibier montrent la présence marquante des aurochs. À côté des aurochs et des bovins domestiques déterminés (NR = 918) de manière certaine sur la base des données métriques, on

**MOTS CLÉS**
Aurochs,
*Bos primigenius*,
*Bos taurus*,
Europe centrale,
République tchèque,
Kutná Hora-Denemark,
ostéométrie,
formes intermédiaires,
croisement,
domestication locale.

trouve un fort pourcentage (presque la moitié) d'os de taille intermédiaire qui pourraient appartenir à (1) de grands mâles domestiques, (2) des femelles d'aurochs, (3) des croisements entre bœuf et aurochs ou des bovins domestiqués localement. Quelques indices présentés appuient la troisième hypothèse. La partie théorique de la problématique (résumé des connaissances sur les aurochs, la taille du corps, les éléments variables, la domestication) est tout d'abord discutée. L'analyse qui suit est basée sur l'évaluation métrique sur douze mesures de la largeur d'os longs et de phalanges (483 données). Cette étude contribue au débat de longue date sur la domestication locale et le croisement d'animaux domestiques et sauvages en Europe centrale, région située hors du centre principal de domestication au Proche-Orient.

## INTRODUCTION

This study was initiated by the determination and archaeozoological analysis of osteological assemblage from the middle Eneolithic site at Kutná Hora-Denemark; distr. Kutná Hora, Řivnáč culture; see § *The site at Kutná Hora-Denemark* (*Kutná Hora distr.*), Fig. 1, no 12. During the initial analysis a number of intermediate sized bones were registered among reliably identified small domestic cattle and big wild cattle (aurochs). These intermediate large and not closely assigned bones (described as *Bos sp.)* form almost half of all cattle bones (the relationship of domestic, wild and unspecified cattle, according to the number of fragments, is 274: 181: 460). Differentiation among cattle (*Bos* genus) and from the wisent (*Bison bonasus* Linnaeus, 1758) were not possible in some cases, nevertheless the bones of wisent were most probably not present on the site at all or only in an insignificant percentage. Two facts support this presumption: (1) definitely classified bones from Kutná Hora-Denemark were always assigned to the *Bos*[1] genus, (2) wisent has not been reliably identified on a single Czech prehistoric site since the Neolithic (see Kyselý 2005).

The first part of the article summarises the present state of knowledge of the problem and analyses, in detail, its theoretical substance. Since an analysis of aurochs problems for the region described has not so far been published, it is emphasised. Methodology is further proposed and analysis of the data is introduced in a form of a case study.

## THEORETICAL ANALYSIS, METHODOLOGY AND MATERIAL

### AUROCHS – HISTORY, BIOLOGY, SIZE

Aurochs (*Bos primigenius* Bojanus, 1827) is the only ancestor of all domestic breeds of cattle (see Zeuner 1963, Clutton-Brock 1999, Bradley & Magee 2006). In prehistory it inhabited a wide area from India to Great Britain in the west, to south Scandinavia in the north and North Africa in the south (distribution map: *e.g.* in Murray 1970 and Clutton-Brock 1999). In Europe as well as in The Near East a subspecies *Bos primigenius primigenius* occurred, from which tauroid breeds of domestic cattle are derived (*Bos taurus*). Zeboid breeds (*Bos indicus*) are on the other hand derived from a southasian subspecies of aurochs (*Bos primigenius*

1. Determination was done by comparison with collection skeletons (in archaeozoological laboratory of the Institute of Archaeology in Prague) and with help of determinative literature (Olsen 1860; Stampfli in Boessneck *et al.* 1963, Patou-Mathis & Auguste 1994).

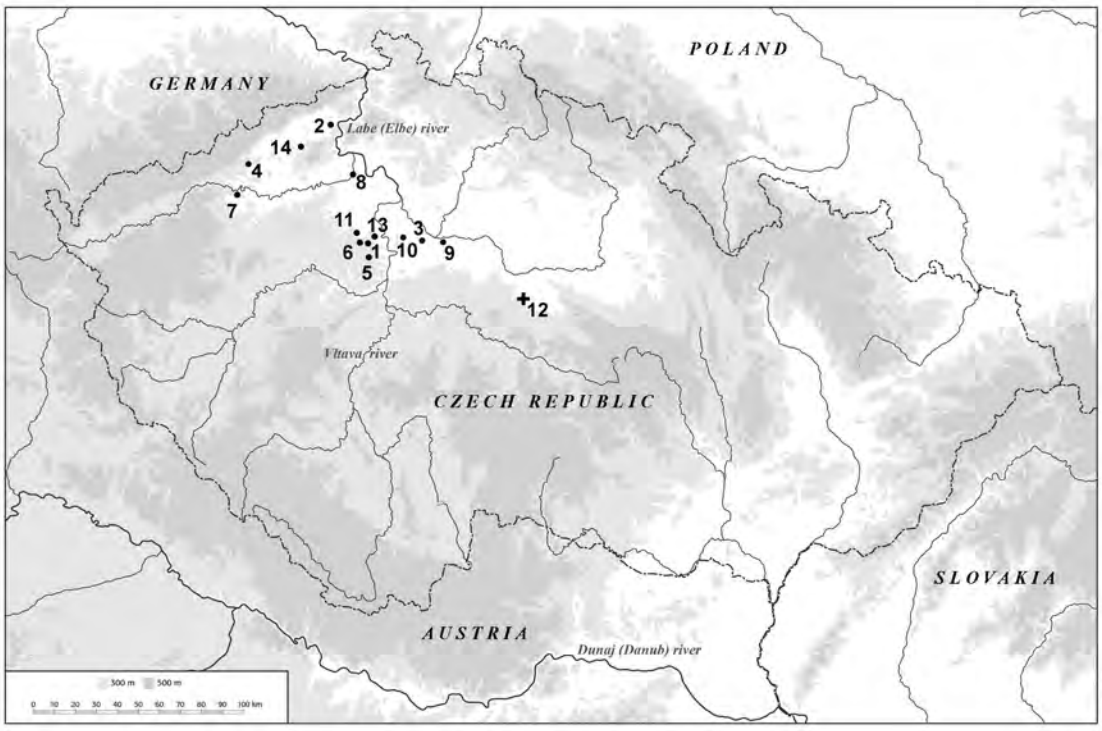


FIG. 1. — Map of the Czech Republic with the sites included in the analysis. 1: Tuchoměřice; 2: Trmice; 3: Jenštejn; 4: Droužkovice; 5: Litovice; 6: Makotřasy; 7: Vikletice; 8: Hostěnice; 9: Mochov; 10: Praha-Miškovice; 11: Stehelčeves-Homolka; 12: Kutná Hora-Denemark; 13: Velké Přílepy; 14: Radovesice. (Inforgraphists: M. Ernée & R. Kyselý).
Kutná Hora-Denemark site marked with a cross; borderline of the Czech Repubic dashed.

*namadicus*). This postulate by Zeuner (1963) was confirmed by genetic studies (see Bradley *et al.* 1996, Bradley & Magee 2006). It was a commonly hunted species in prehistory in the Central Europe. In The Czech republic there is a good evidence of aurochs both in Bohemia as well as in Moravia. The phylogenetic divergency of European aurochs (haplogroup P), *i.e.* genetic isolation from Near East aurochs (and thus later domesticants) happened, according to a study by Edwards *et al.* (2007), ca 10 000-30 200 BP.

A relatively high frequency presence on Neolithic sites indicates its abundance in nature. Significant decrease of aurochs' occurrence, probably in connection with human presence, is evident since the Neolithic to the Bronze Age (Kyselý 2005, Fig. 2). Aurochs finds occur up to Early Medieval times, the latest osteological evidence from The Czech republic being the 10$^{th}$/half of the 13$^{th}$ century AD (Kyselý 2005). Osteological evidence from the High Medieval Ages is missing. Presumably since the 13th century it lived in preserves only (Łukaszewicz 1952). Following historic sources "Europe in the beginnings of the 15$^{th}$ century did not know aurochs nor wisent" (Rokosz 2006). Nevertheless sporadic (natural?) occurrence is possible even later, as is indicated by finds from Germany dated up to the turn of the 14$^{th}$/15$^{th}$ century AD (summary of the finds in Prilloff 1994). In Poland, its last refuge, it survived till post medieval times. The last individual died in 1627 in Jaktorow near Warsaw (Łukaszewicz 1952, Clutton-Brock 1999, Guintard & Rewerski 1999, Rokosz 2006).

Biotope requirements of aurochs are not completely clear, but generally it could have been a

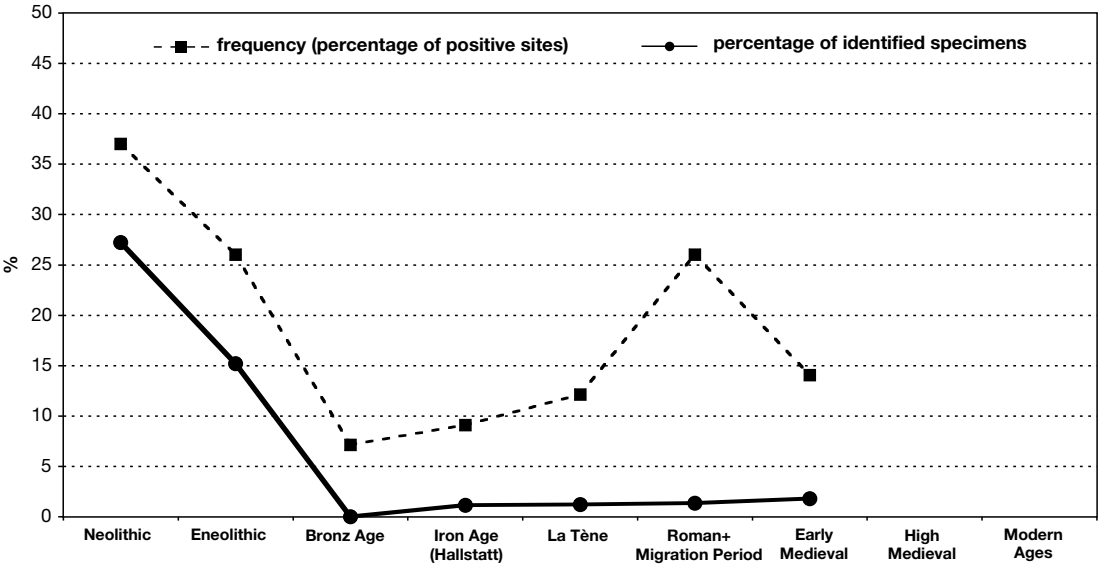


FIG. 2. — Representation of aurochs from the Neolithic to the Medieval Ages in the Czech Republic after two different quantifications (after Kyselý 2005).

forest animal. Lengerken (1955) mentions its occurrence in alluvial forest, Lehman (1949) states, that it lived on the border of both sparse and dense forests. Also recent publications (Clutton-Brock 1999) suggest that aurochs lived in forest environments or, if necessary in open bushy scrub landscapes. Other authors (Łukaszewicz 1952, Legge & Rowley-Conwy 1988, Van Vuure 2005) describe aurochs as an inhabitant of both types of environment: forest as well as open landscape. Otherwise a special relationship with sedge marshes and marshy forests is suggested (Van Vuure 2005). Last group of aurochs in Polish Jaktorow lived in a woody, wet terrain, which is likely to be a refuge, therefore not completely corresponding with a typical and original biotope. Degerbøl (in Degerbøl & Fredskild 1970) considers aurochs as a forest animal, although he describes it also from the late dryas. In general, aurochs is believed to have been a grazer (Grigson 1978, Van Vuure 2005). However Schneeberger (ex Gesner 1602) mentions the importance of acorns in autumnal diet and branches of bushes and trees in the winter diet. New information deduced from isotope analyses of southern Scandinavia aurochsen show changes in a diet during the time corresponding with environmental changes, specifically a change from an open to forested ecosystem (Noe-Nygaard *et al.* 2005). According to this work, in the Neolithic period aurochsen were feeding in forests while domestic cattle grazing on more open areas. To the same conclusion came Balasse *et al.* (1997) in work based on isotope analysis from Neolithic contexts in the Paris Basin. The evidence indicates a wide ecological valence and potentially. It could most probably inhabit various types of environment (depending among other things on geographical position, period, climate, human presence, etc.) nevertheless some boundaries of aurochs' ecological valence have to be taken into account though. For example it was not adapted to rough northern conditions as is indicated by the dying of aurochsen and feral cattle in hard winters (Łukaszewicze 1952, Tankerville 1994) and by the position of the northern boundary of its areal (roughly up to 58$^{th}$ northern latitude).

Life of aurochs is outlined in a publication by Łukaszewicz (1952) describing the last herd in Poland (Jaktorow) at the turn of the 17th century, based mainly on information from Schneeberger (ex Gesner 1602): Aurochs moved in herds-females with the young ones, while old bulls lived separately. They lived to 15 years, but the last female was about 30 years old. They mated in September and at this time conflict amongst the males was often very aggressive, sometimes ended in death. The youngsters were born in May. Some individuals did not survive hard winters. Aurochs are not afraid of man and is not so shy compared to wisent. Aurochs may be classed as a dangerous animal at all times.

The herd life style of cattle female with the young ones is mentioned also in the text by Rokosz (2006) and in the works by Guintard (1996) and by Bouissou *et al.* (2001). Also the herds of feral populations of Chillingham cattle are divided into groups of females with youngsters and males, either solitarily or in groups (2-3) (Hall 1986). Aurochs were hunted: the Germans were trapping them in pits — see Caesar's sixth book of *De bello Gallico* (Bureš 1972), it was hunted by Polish princes and the nobility (Rokosz 2006) and allegedly also by Charles The Great (see Balbuli 1959: 60). The privilege of hunting aurochs by the ruling classes had a symbolic meaning. A symbolic status of aurochs has been in existence since the Neolithic period (see *e.g.* finds at Çatal Hüyük and publication by Cauvin 2000).

The height of aurochs males reached, according to some of the more general publications, around 200 cm (*e.g.* Brink 1973, Clutton-Brock 1999, Guintard 1999). This height is relevant for Pleistocene populations since a sudden warm period at the turn of Würm/Holocene period caused a rapid reduction in size, which according to evidence from the various regions affected many mammal species (*e.g.* Degerbøl & Fredskild 1970, Davis 1981, Vörös 1987, Lasota-Moskalewska & Kobryń 1990). More specialised publications give concrete size values for Holocene finds. Significant sex dimorphism is apparent in the case of aurochs, showing in a larger size of males. According to Benecke (1994) the wither height of aurochs from Danmark is 154-176 cm for males (in average 160 cm), for females 139-153 cm (average 145 cm). Van Vuure (2005) calculated wither height of "Degerbøl's" aurochsen to 160-180 cm in the case of bulls and ca. 150 cm in the case of cows. Similarly wide size range (135-170 cm) of postglacial aurochsen is presented also by Guintard (1999). Lehmkuhl (1988) counted the height of a male 154 cm, a female 133.5 cm (Germany). Teichert (1999) counted for two males 163.9 and 156.1 cm, and one female 154.9 cm (Germany). After Vörös (1987) average height of two aurochsen from Hungarian sites is 156.5 and 158.7 cm. After Łukaszewicz (1952), height of males is 170-185 cm and height of females is 165 cm (Poland). These values give information about the size of Central European aurochs in the Eneolithic. Average sizes of females and males are different however the span of their variability merges (see Degerbøl & Fredskild 1970). Sex dimorphism is significant even at domestic species. For more concerning size and variability of aurochs see also § *Size boundaries domestic cattle/aurochs and allometry*.

As already mentioned, there is a high percentage of hunted animals at the site of Kutná Hora-Denemark (see Fig. 3). Aurochs is more widely represented there than on sites inside the oikumenon (showed by comparison with stag as another large wild ungulate; Fig. 4). Aurochsen, being large and dangerous beasts, offered more of a challenge than other wild game to the human hunters and were therefore probably over-hunted in areas close to human activity and occupation. Probably in the Eneolithic period aurochs survived in much greater abundance in such marginal woody areas as represented by the described site (it's marginal position in the oikumenon is obvious from Zápotocký 2000, Zápotocký & Zápotocká 2008).

The size of aurochs does not significantly change during Holocene (Lasota-Moskalewska & Kobryń 1990), but the population, however, is not totally uniform. The morphometric heterogenity of Holocene aurochs is shown for example

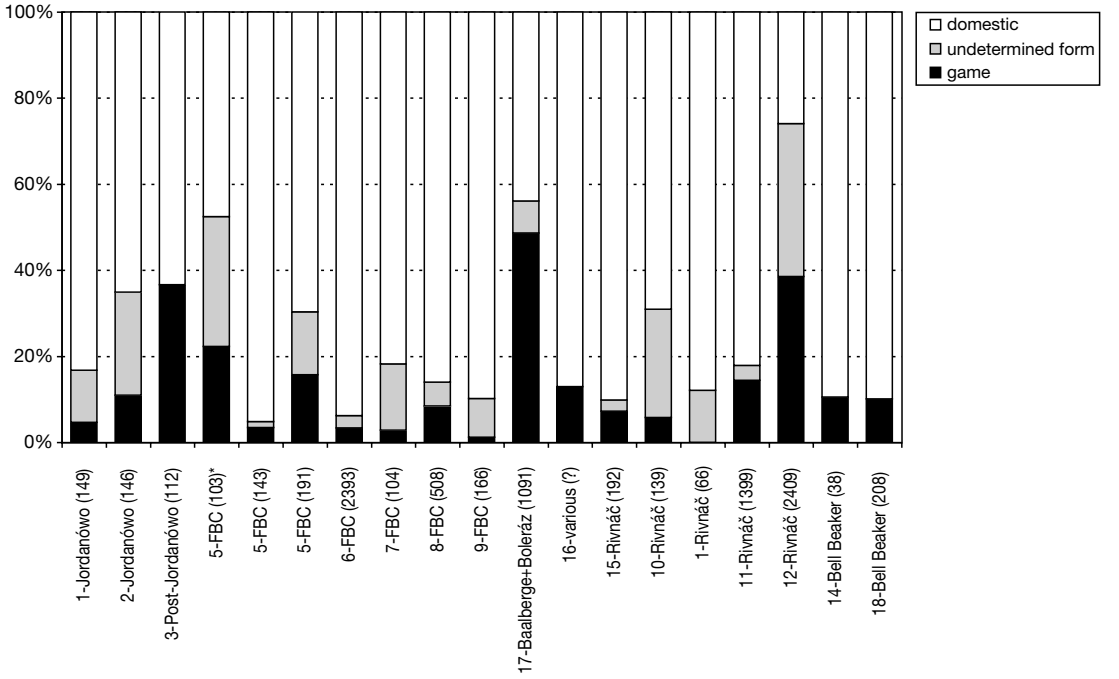


FIG. 3. — Rate of domestic and wild animals on Eneolithic sites in the Czech Republic classed periodically if possible.
Numbers in brackets after abbreviations of cultures = number of determined material (NISP). 15 — Soběsuky (according to Peške 1991a, b), 16 — Lysolaje (various Eneolithic cultures, mostly FBC and Řivnáč C., quantified by MNI; according to Zikmundová 1959); 17 — Cimburk (mixed data of Baalberg and Boleraz stratum; according to Peške 2000); 18 — Liptice (according to Beech 1993b); rest of the sites — see codes in Table 1. * data according to Peške (1972) and (1978). For abbreviations of cultures see Table 1. Y axis = % NISP.

in the work of Chaix & Arbogast (1999). In our analysis geographic variability has mainly to be considered: according to results of Lasota-Moskalewska & Kobryń (1990) the size of aurochs decreases from east to west; after analysis by Grigson (1969) and Vörös (1987) Hungarian aurochsen are smaller than those from rest of the Europe to the north, *i.e.* mainly from Danmark and North Germany (represented mostly by Degerbøl data). Despite having rich sources of detail, discussion and references on aurochs size in time and European space at our disposal in Lasota-Moskalewska & Kobryń (1990), a more detailed metric evaluation of aurochs from Bohemia is unfortunately not available. Bohemia lies almost centrally between the two regions mentioned (*i.e.* Hungary south-east and Danmark north-west, both well represented), which could lead to the conclusion, that the size of aurochs will be somewhere in the values from these regions. Nevertheless Bohemia is surrounded by mountains, which could cause a certain isolation of local population and specific phenotype characteristics. Despite the fact, that aurochs are presumed to mostly inhabit lowlands (see Bökönyi 1972 and compare altimetrical distribution of aurochs with altimetrical distribution of *Bison* in Bauer 2001a, b), it can sometimes occur at higher attitudes, sporadically even over 1 000 m above see level: see for example finds from hilly/mountainous areas around Zürich lake (Schibler *et al.* 1997), in Austria (Bauer 2001a) and in the mountainous region along France - Switzerland borderline (Chaix & Arbogast 1999). The relatively low, not steep and in some places intermittent mountains surrounding Bohemia were therefore probably not such a large obstruction to isolate populations and allow minor differences to evolve.

## Domestication question

Domestication process is manifested in archaeozoological material mainly by the shape and relative size of horns (Guintard 2005) and by absolute size of animals (and therefore also the bones; Bökönyi & Bartosiewicz 1987, Bartosiewicz *et al.* 2006, Tekkouk & Guintard 2007). The first domesticated cattle (*Bos taurus* Linnaeus 1758) to appear in Europe came with the first agriculturists as a part of so called Neolithic package ca 6500-6800 BC (see Bradley & Magee 1996, Edwards *et al.* 2007), *i.e.* about a thousand years before the onset of the Neolithic and the introduction of domestic cattle into Central Europe. Among the earliest osteological evidence of domestic cattle in Europe are finds from the site of Argissa-Magula in Thessaly in north Greece (Boessneck 1961). Even earlier examples are described from the Near East (Peters *et al.* 1999, Helmer *et al.* 2005) and Africa (Wendorf & Schild 1994, 2003). Also in the oldest agricultural settlements in Bohemia domestic cattle clearly display smaller sizes than aurochs. From the Neolithic onwards to the Middle Ages the size gets gradually smaller as is shown in the work by Peške (1994), summarising sizes of cattle in the Czech Republic from the Neolithic to the Middle Ages. Reduction of sizes from the Neolithic to the Eneolithic is apparently a common pan-regional feature as indicated in the work by Benecke (1994) and results of the ECONET project[2]. Concerning osteometric changes during domestication see § *Size boundaries domestic cattle/aurochs and allometry*.

Application of genetic methods on archaeological material is expected to be a great contribution into the discussed problem, but during an everyday practise the main practical criteria for distinguishing domestic and wild cattle are still metric data taken from bones. Immeasurable fragments are often evaluated intuitively mainly according to the robustness of bones, thickness of compacta and muscle attachment areas. Finds of intermediate sized forms in Central Europe lead scientists to a conclusion, that even in this area local domestication of aurochs or crossbreeding of introduced domestic form with the wild one did happen. This possibility was suggested mainly by Bökönyi (1962, 1969, 1974) on the basis of a large evaluated assemblage from Hungary (cultures: Herpály, Theiss, Lengyel). Local domestication is also described from central Germany by Müller (1964) and by Döhle (1990), in both cases from Linear Band Ceramic. And the question so far is being mentioned in many works spanning the Neolithic-Eneolithic period (*e.g.* Steppan 2001) and mesolithic/neolithic boundary (Noe-Nygaard *et al.* 2005). The main argument for local domestication is finds of intermediate sized bones, but other indications are also supportive (see Bökönyi 1969). After Bogucki (1989) indications for local domestication are missing (with certain exceptions) in the

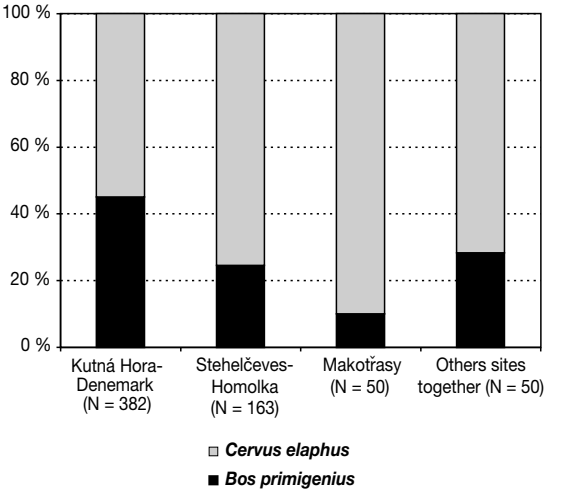


FIG. 4. – Comparison of aurochs representation with stag in Kutná Hora-Denemark and on other Tczech Eneolithic sites. Finds of uncertain morphological determination of form (*Bos* sp.) not included. Y axis = % NISP.

2. ECONET n° 12676 VE (Egide egency). *Des bœufs, des souris et des hommes : premiers animaux domestiques et premiers commensaux en Europe continentale tempérée (fin du 7e mill.- 3e mill. a. J.-C.) : Éclairages centre-européens (Moldavie, Muntenie, Doubroudja, Moravie, Bohème) et ouest-européens (Bassin parisien, Ouest de la France).* A. Tresset (head) *et al.* 2006-2007.

northern part of Europe. Argument against local domestication based on individuals of intermediate form is that the sizes of local bulls (or castrates) and aurochs females overlap. Benecke (1994) comes to a conclusion, that arguments by Bökönyi for autochthonous domestication of cattle in Central Europe is little persuasive and that the overlap in size can be a result of domestic and wild form living together in one space without becoming crossbred. Data from the Czech Republic have yet not been evaluated from this point of view.

For the solution of our question one has to distinguish between (1) local domestication (*i.e.* domestication of wild cattle, which is difficult with regards to their size and belligerence) and (2) crossbreeding of domestic and wild form. Crossbreeding (2) seems easier than domestication from the very beginning. This version will therefore be analysed with higher priority. Easier and therefore more probable seems to be insemination of domestic females by wild males, but even the opposite is possible. The insemination could have happened intentionally or by chance. Advantages of such crossbreeding are larger size and resistance of the crossbreds and animation of blood (prevention from inbreeding, heterosis effect). Therefore even the Romans in northern Italy possibly practised this method (after Vergil ex Bökönyi 1984). The influence of domestic and wild crossbreeding on the sizes of the crossbreds can not be determined by experiment, analogies however from other hoofed mammals and practical observation from the current breeding of domestic cattle stock along with numerous studies indicate a very high inter-breed heritability ($h^2$) of sizes and body weight (*e.g.* Brown *et al.* 1989, Jenkins *et al.* 1991). According to Jenkins *et al.* (1991) the between-breed heritability for weight 91% ± 27% and height 94% ± 28%. The size of possible crossbreds was therefore very probably between a smaller domestic and larger wild form.

The discussed period (Řivnáč C.) is several thousand years from introduction of the first domesticated cattle and far from presumptive genetical divergency (see § *Aurochs – history, biology, size*). But the crossbreeding possibility of domestic and wild forms is very high during this period (and in prehistory in general) as indicated by the mention of the last aurochs in Poland (Łukaszewicz 1952, s. 21-22) at the end of the 16th and beginning of the 17th century AD.

According to the information from Herberstein and mainly Antoni Schneeberger (in Łukaszewicz 1952), the aurochs bulls from the last herd preserved in Jaktorow (Poland) crossbred successfully with domestic cows. That might have been followed by complications: the youngsters were miscarried or died shortly after birth, they were born in different period than calves of aurochsen, which caused survival problems during the winter period. That period however was five thousand years distant from our material, so the domestic stock was more primitive in the Eneolithic. On the other hand, in the case of the 16th century cattle, thanks to isolation, further genetic, morphologic, physiologic and ethologic divergence developed. The crossbreeding problems mentioned above might have not affected more primitive or less derived stock of domestic cattle in the Eneolithic or they could have been smaller, which accords well with the texts of Vergilius.

This article is focused on osteometric analysis, but the fundamental results of molecular genetic studies have to be mentioned. Mitochondrial DNA analysis of an extensive sample assemblage of recent and ancient DNA shows Near East origin of domestic cattle (haplotype T) and does not indicate a domestication of European aurochs (Loftus *et al.* 1999, Troy *et al.* 2001, Bollongino *et al.* 2006, Edwards *et al.* 2007, Scheu *et al.* 2008). Mitochondrial DNA is not however quite successful in detecting the contribution of aurochs males (insemination of domestic females). Y chromosome study of recent stock and prehistoric aurochs (Götherstrom *et al.* 2005) indicates genetic influence by the DNA of male aurochs on European stock (major in the north than in the south). Therefore wild males probably did selectively (intentionally or incidentally) inseminate domestic females. Moreover also new mtDNA analyses based on Italian aurochs (Beja-Pereira *et al.* 2006) and modern

cattle (Achilli *et al.* 2008) show that domesticated cattle of Near East origin intermixed, at least in some regions, with local wild animals. A contribution of European aurochs to domestic cattle breeds is sometimes valued as little or none in North Europe, but significant in South Europe (Caramelli 2006).

### Consideration of size – theoretical analysis

Total body size is usually deduced from the height of the withers or weight:

– (A) Height. Counting the height of the withers is usually achieved on the basis of long bone lengths. The length of bones depends on speed of growth and its termination (fusion of epiphysis with diaphysis). Since these processes are strongly influenced by hormones, the lengths of long bones can differ between males and females (for example the metapodia lengths do not differ but humerus lengths do). Resulting effect, among others, is that the rate of lengths of individual long bones is different for males and females (for more details see Bartosiewicz 1984, 1985). The calculation of withers height is therefore done with different indexes for females and males (see Driesch & Boessneck 1974). In practice different indexes depending on sexes are used at the metapodia (Thomas 1988, Berteaux & Guintard 1995, Guintard 1998b), especially the metacarpals, where sex can be determined most reliably. These allometric regularities can complicate and confuse results of size analysis.

– (B) Weight. Another method used to calculate the size of an individual is by body weight. Widths of bones correlate positively with weight (Higham 1969, Noddle 1973), which corresponds with a logical presumption that: the heavier the animal the wider the bones should be to cope with the greater stresses involved. Inter species allometric analysis within the *Bovidae* family (Scott 1985, 1990) shows a good correlation (corr. coefficient between 0.8-0.9). Within the *Bos primigenius* species limited amount of correlation analysis is to disposition. Usable analysis (Higham 1969, Noddle 1973) show, that correlation is not too high and "estimates of body weight from bone dimension is not feasible (for example) due to high seasonal fluctuation in weight, which would have occurred" (Higham 1969). Nevertheless "some dimensions might be a functuation of body weight" (Higham 1969) and estimation of weight from widths of archaeozoological finds is sometimes used practically (Ijzerev 1981). The fact that males have some bones wider (most evident at metacarpus) is again a result of higher weight effect which corresponds with the outlined scheme. In a paleontological practise cross-sectional measurements of major limb bones, especially proximal ones such as humerus and femur, are believed to be the best for a body mass estimation of mammals (Mendoza *et al.* 2006). That breadth measurements largely depends on weight is indicated also in methodological recommendations in Uerpmann & Uerpmann (1994) and Meadow (1999).

– (C) Dimensions on the skull. As brain (and thus braincase) dimensions also the dimensions of teeth are influenced by different evolutionary pressures than the dimensions of the postcranial skeleton (Uerpmann & Uerpmann 1994, Mendoza *et al.* 2006). Due to possible allometries (*e.g.* skull of domesticants, incl. cattle, gets relatively smaller during domestication – Zeuner 1963, O'Regan & Kitchener 2005, Guintard 2005; size of horns depends strongly on stock, sex and diet), skull fragments are not the most suitable scale for the calculation of animal height or body mass (also Mendoza *et al.* 2006). According to Bökönyi (1984) "limb bones are much more plastic and, therefore, react more sharply to environmental and genetic changes than skull elements and horns". This fact also leads to allometric relationships between postcranial and skull. Another disadvantage is that many dimensions of single teeth depend on the age of the individual.

### Variability and its components

In this case we shall concentrate on width dimensions, which presumably reflect relatively well the total weight of relative category of individuals. Width variability depends on: (1) sex dimorphism, (2) age, (3) breed relevance (wild/domestic

form), (4) (residual) individual variability (for analysis of these components see Payne & Bull 1988). The influence of pathologies must not be neglected either (Albarella 1997). Geographic variability should not play a role within the relatively small Bohemian basin area and sympatric coexistence of two different subspecies or populations is highly improbable, in accordance with zoogeographical rules, but it can have great significance in interregional comparisons (Bökönyi 1995). Since our task is to analyse the size of domestic cattle and their relation to aurochs, ideally the influence of sex dimorphism, age and pathologies should be eliminated.

(1) Fragmentary material does not usually allow sex determination therefore it will appear on our graphic analysis without a division between the male, female and castrate groups. Studies describing sexual morphometric differences on limb bones are summarised by Thomas (1988). Sexual dimorphism is evident more on front limb bones than hind bones. Measurements of breadth are more sex dimorphic than those of length, among them mainly the widths of metapodia and phalanges, which show a high sexual dimorphism (Higham 1969). Lowest sex dimorphism among limb bones is apparent on the talus according to Higham. Albarella (1997) states that the influence of sex on morphometrics is overemphasized and of greater influence even among domestic cattle could be for example stock relevance (however that analysis mostly concerns medieval and post-medieval material, when several domestic breeds already existed).

(2) As known, bones can continue growing in width after lengthwise growth had finished, *i.e.* after the fusion of epiphysis (Koch 1932, Davis 1996). There are also inter-sex differences in this phenomenon (see Legge & Rowley-Conwy 1988). Nevertheless finds, which according to surface character indicate adult age, would not have a large extra growth. During the selection of bones for analysis the bones with non fused epiphysis and bones with fused epiphysis, but not "adult-like" (porous) surface character were excluded. Thus an assemblage of adult individuals was gained, however individuals on the border of subadultus/adultus may be included and also very rarely non-recognised subadult individuals. Such selection limited influence of age on the analysis to a maximum possible degree. Pathologies, which theoretically could influence the results of the presented material, were observed on finger bones only (Kyselý 2008). The amount, character and intensity of these pathologies are however so small that it will not affect the results of the analysis.

The result of the dimension distribution will therefore be explained only by components (1), (3) and (4) (residual variability cannot be eliminated – it is a natural feature of every population sample). Theoretically up to five size categories can be appointed: domestic female, domestic male, domestic castrates, wild female, wild male. Since the boundaries of some of these categories strongly overlap or merge, distribution of graphically depicted sizes of cattle from archaeological sites will never reach the shape of ideally separated groups. The differentiation between female aurochs and domesticated males is especially problematical, as is the distinction of castrates with higher absolute lengths of long bones. The influence of castration on size and osteometric values is evident in the Bovid group and castration is the causation of many skeletal allometries (Hatting 1975, Davis 2000, Pöllath & Peters 2005). Castrates of some domestic cattle can sometimes have some body and bone measurements smaller than bulls, while others have larger (also depending on the period of castration; see *e.g.* Witt & Andreae 1965, Ijzerev 1981). Their length-width indexes of long bones strongly overlap with females as well as males (Higham 1969). Considering the problems with data combining various sexes and various forms in a single graph, determination of average and maximum size of domestic cattle is difficult (Guintard 1998a). However minimum size values for domestic cattle can be determined – they are not influenced by the problems described above. Supposing that females are present (which is highly probable on every prehistoric site with enough material) and that the sample is representative, we gain a value, which characterises the local stock: *i.e.* minimum

size of domestic cattle females. Therefore during the analysis I suggest the use of this minimum value as a characteristic of domestic stock as opposed to average. But, in this case, one must be sure that evaluated material comes just from adult individuals. However we know that in practice this identification and separation of subadult individuals can be problematic in some cases, which require a carefully considered approach and interpretation.

### The site at Kutná Hora-Denemark (Kutná Hora distr.)

The site is situated in the eastern part of central Bohemia on the edge of central Bohemian lowland area about 10 km south from the Labe (Elbe) river and about 1 km south from Kutná Hora, not far from the Neolithic site at Bylany (Fig. 1, no 12). The site of Kutná Hora-Denemark is a promontory fortified settlement of an earlier phase of Řivnáč culture (Middle Eneolithic, 3000-2800 BC). For more information about the site, archaeological situation and absolute dating see Zápotocký & Zápotocká (2008).

The low promontory is bounded by the Vrchlice stream (ca 2-6 m wide) at 290-300 m above sea level. The site lies at the fringe of the Bohemian settlement area: to the higher latitudes to the southeast and to the south no Eneolithic settlements have been discovered (Zápotocký 2000: fig. 61). There is, however, evidence of a trade route leading to Moravia in the east (Zápotocký 2000).

The excavation in Kutná Hora-Denemark yielded 15 611 osteozoological finds, which was the subject of a detailed study (Kyselý 2008). Because of high fragmentation only 3 444 fragments were identified to species or genus. Due to the position of the site at the edge of the main settlement area the inhabitants had greater opportunities to interact with "wild" nature than those in the settlements within the oikumenon and consequently greater access to wild beasts. There is a high percentage of hunted mammals in the osteozoological material – more than a half of the bones – confirming the use of such resources. Wild cattle forms 40% (NISP) or 71% (weight method) of identifiable *Bos* finds in Kutná Hora-Denemark (Kyselý 2008: Tab. 11). A very high ratio of wild cattle is also evident from comparisons with other Bohemian sites (see Fig. 4 and Kyselý 2008). A similar high percentage of wild species on the Eneolithic site at Cimburk (Peške 2000) within the distance of only 300 m accords well with this hypothesis. Otherwise such high rate of hunted animals is rare in the earlier and middle Eneolithic in the Bohemian basin in general (see Fig. 3).

### Comparative sites

The author has so far analysed more than 20 smaller and larger assemblages dated to earlier and middle Eneolithic; 14 of them supplied metric data for the discussed analysis. Although analysis of some sites have already been published so far metric data have been published from the sites at Litovice and Kutná Hora-Denemark only (Kyselý 2002a, 2008). An evaluation of Eneolithic archaeozoological assemblages is the theme of the dissertation of the author. Primary data and evaluation of osteozoological material from all the sites will be published in detail in the future.

Besides which numerous rich data from the Stehelčeves-Homolka site (Řivnáč Culture) will be used for comparison (published by Ambrose 1968 and Bogucki 1979) and data from Makotřasy site (Funnel Beaker Culture; Clason 1985).

The summary of Eneolithic sites included in the analysis is stated in Table 1 and Fig. 1. Centre of interest is the Kutná Hora-Denemark site.

### Selection of dimensions for the analyses

The site at Kutná Hora-Denemark did not supply any horn spurs or complete skulls (Kyselý 2008). Complete teeth rows are very rare and unfortunately even long bones were not preserved complete (only two lengths of metatarsus are to disposition). Only in the case of phalanges there is a relatively large number of complete bones and thus length dimensions. The reason for concentrating on width dimensions was (1) lack of length dimensions of long bones and skull dimensions,

TABLE 1. – Summary of sites, material and data included in log-ratio analysis.
See also Table 2 (proximal humerus breadth and proximal phalanx I breadth in log-ratio transformation not included).
Ordered by time (by cultures). FBC = Funnel Beaker Culture.
Cultural determination taken from Zápotocký 1996 (Trmice), Zápotocký 2002 (Vikletice), Ernée *et al.* 2007 (Praha-Miškovice), I. Pleinerová pers. com. (Litovice), L. Šůlová pers. com. (Velké Přílepy), M. Zápotocký pers. com. (Mochov and Tuchoměřice) and M. Dobeš pers. com. (Droužkovice and Hostěnice).

| Site | Code (see FIG. 1) | Culture | Total NISP | *Bos* NISP | Number of available metric data | | | | Source |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | foreleg long bones | hindleg long bones | phalanges | total | |
| Tuchoměřice | 1 | Jordanówo Culture | 826 | 124 | 8 | 4 | | 12 | unpublished |
| Trmice | 2 | Late Jordanówo Group | 430 | 87 | 1 | | 4 | 5 | unpublished |
| Jenštejn | 3 | Post-Jordanówo Group | 124 | 48 | 1 | | | 1 | Beech, 1995 |
| Droužkovice | 4 | Schussenried Culture | 30 | 8 | | 13 | | 13 | unpublished |
| Litovice* 1997/98 | 5 | FBC - Baalberge Group | 1628 | 975 | 3 | 4 | 1 | 8 | Kyselý, 2002a |
| Litovice* 2003 | 5 | FBC - Baalberge Group | 606 | 76 | 4 | 1 | 3 | 8 | unpublished |
| Makotřasy | 6 | FBC - Siřem Group | 3492 | 1704 | 89 | 79 | | 168 | Clason, 1985 |
| Vikletice | 7 | FBC - Siřem Group | 383 | 68 | 1 | 5 | 3 | 9 | unpublished |
| Hostěnice | 8 | FBC - Salzmünde Group | 1695 | 249 | 12 | 13 | 10 | 35 | unpublished |
| Mochov | 9 | FBC - late | 256 | 46 | 4 | 3 | 4 | 11 | unpublished |
| Praha-Miškovice | 10 | Řivnáč Culture | 3034 | 5 | | | 4 | 4 | unpublished |
| Tuchoměřice | 1 | Řivnáč Culture | 429 | 28 | 2 | 1 | | 3 | unpublished |
| Stehelčeves-Homolka | 11 | Řivnáč Culture | 1149 | 769 | 26 | 27 | 55 | 108 | Ambros, 1968 |
| Kutná Hora-Denemark | 12 | Řivnáč Culture | 14709 | 918 | 16 | 13 | 41 | 70 | Kyselý, 2005b |
| Tuchoměřice | 1 | Eneolithic middle-late Eneolithic | 290 | 21 | 4 | 2 | | 6 | unpublished |
| Velké Přílepy | 13 | (Řivnáč C.?) | 74 | 7 | | | 1 | 1 | unpublished |
| Radovesice | 14 | Bell Beaker Culture | 562 | 125 | | 2 | | 2 | Beech, 1993a |
| skeleton: Litovice* 1997/98 | 5 | FBC - Baalberge Group | | | 6 | 4 | 9 | 19 | Kyselý, 2002a |
| **TOTAL** | | | | | **177** | **173** | **135** | **483** | |
| Reference data: | | | | | | | | | |
| Aurochs (Denmark) | | | | | 90 | 88 | 13 | 191 | Degerbøl & Fredskild, 1970 |

* In Kyselý (2002a) and Pleinerová (2002) presented as Hostivice-Litovice or Hostivice.

(2) presumption that width dimensions are a suitable scale of individual size and (3) presumption that allometries between width dimensions used in log-ratio transformation are small within one group of dimensions (see below). They usually have a higher degree of sexual dimorphism between (smaller and lighter) cows and (bigger and heavier) bulls than length dimensions, but osteometrical detecting of castrates is extremely difficult or impossible. One advantage of usage of width measurements is that allometrical dissimilarities caused by castration seem to be smaller within the breadth measurements then within the length ones (Pöllath & Peters 2005). A suitable anatomic unit for size analysis would be the sexually little dimorphic talus. However paucity of

talus data from the sites presented (graph: Fig. 6) does not allow closer conclusions.

Forelimbs carry about 55% of body weight (Fock 1966). Due to non linear relationship between weight and single sized characteristics should the ratio between weight on forelimb and hindlimb change. Therefore ratio of widths of forelimb and hindlimb should change theoretically with growing size of the body. Therefore long bones of forelimbs will be evaluated separately from the hind limbs (see § *Log-ratio transformation*). On phalanges again the width dimensions will be evaluated, which presumably also reflect the body weight. Distinguishing phalanges on proximal (phalanx I), medial (phalanx II) and distal (phalanx III) is without problem, phalanges however were not distinguished to fore and hind ones, inner (axial) and outer (abaxial) ones. According to statistic analysis based on twenty four recent individuals (bulls and oxen) done by Bartosiewicz (1993) there are dimensions, which are independent on exact anatomical position: on phalanx I it is Bd (distal breadth), on phalanx II it is Bp (proximal breadth) and GLpe (abaxial or peripheral maximum length; all dimensions defined by Driesch 1976). With this information we can analyse these dimensions without knowledge of the position (fore – hind, inner – outer).

On the basis of the analyses described in § *Consideration of size – theoretical analysis; Variability and its components* and *Selection of dimensions for the analyses* and with regard to studies with similar theoretical analyses (overview of analyses in Meadow 1999) breadth dimensions stated in Table 2 were selected from our sites (Table 1) for analyses, considering that some dimensions from Table 2 were not included in the log-ratio transformation (§ *Log-ratio transformation*). Tables 1 and 2 indicate that there is enough data for such analyses.

### Size boundaries domestic cattle/aurochs and allometry

The knowledge of absolute size of individuals is important for characterization of any population. In the case of *Bos* genus ascribing particular size to one of two forms (domestic cattle/aurochs) can be highly problematic (Bartosiewicz *et al.* 2006) and can strongly influence the domestic/wild ratio of the whole archaeozoological sample (see also Steppan 2001). Considering that sizes of Pleistocene aurochs are larger than Holocene aurochs, the Holocene ones are best for comparative purposes. Especially Mesolithic finds which cannot be confused with domestic forms (largest metrically evaluated assemblage: Degerbøl & Fredskild 1970). In the Neolithic and later periods both forms live in close proximity. The metric boundary between both forms is defined in various ways by various authors, so the defined boundary is in fact an

Table 2. – Summary of metric width data from the sites (Table 1) which are available for metric evaluation (Figs 5 to 10).

| Anatomy | Dimension * | Dimension description | Number of dates available |
|---|---|---|---|
| humerus | BT | trochlea breadth | 48 |
| radius | Bp | proximal breadth | 12 |
| metacarpus | Bp and Bd | proximal and distal breadth | 49 and 70 |
| femur | Bp and Bd | proximal and distal breadth | 2 and 7 |
| tibia | Bp and Bd | proximal and distal breadth | 5 and 59 |
| talus | Bd | distal breadth | 31 |
| metatarsus | Bp and Bd | proximal and distal breadth | 37 and 61 |
| phalanx I | Bp and Bd | proximal and distal breadth | 63 and 77 |
| phalanx II | Bp | proximal breadth | 67 |
| **Total** | | | **588** |

* After Driesch (1976).

interpretation. This artificial definition is a weak point of all studies specialised on metric differences between domestic and wild cattle, and on intermediate form of cattle (this could not be avoided also in a very useful publications such as Kobryń & Lasota-Moskalewska 1989; Lasota-Moskalewska & Kobryń 1989, 1990; Bökönyi 1995). Completely reliable determination will hopefully be mastered in the future by genetic methods. According to one of the quoted studies (Lasota-Moskalewska & Kobryń 1989) the long bone dimensions react on the process of domestication in different ways; for example in comparison with the wild ancestor the distal widths of long bones of domesticated cattle usually show relatively larger values than proximal widths. In praxis might happen that a bone determined after one dimension as aurochs, is after another domestic cattle. Therefore a bone is if possible determined on the basis of all accessible criteria and not only a single dimension. Lasota-Moskalewska & Kobryń (1989) analyse in detail the zone of transgression (*i.e.* values, which can belong to domestic as well as wild cattle with overlapping dimensions). According to them all width dimensions of long bones of domestic and wild cattle overlap, one has to point out however, that they analyse mixed data from several geographically different populations.

For orientation a table of spans of selected dimensions was created (Table 3) and the overlaps were also depicted graphically (Figs 5-7). The table shows maximum values for width dimensions of domestic cattle and minimum values of the same dimensions for aurochs as interpreted by various authors. The overlap of the values is specially emphasized in the table. Boundary values were selected according to:

(1) Ambros (1968): Stehelčeves-Homolka – together with Kutná Hora-Denemark, it is the only osteometrically evaluated and published site of the same period from the Bohemian basin area;

(2) Degerbøl (in Degerbøl & Fredskild 1970): so far the largest assemblage of metric data for aurochs used as a comparative material and a standard (location: Denmark);

(3) Bökönyi (1995): one of largest data assemblages for domestic cattle and aurochs (location: Hungary), see also Bökönyi 1962;

(4) Stampfli (in Boessneck *et al.* 1963) – their boundaries are very low, the use of them for cattle in Bohemia is not realistic in most cases, the finds were later reinterpreted in a different way (*e.g.* Grigson 1969);

(5) Grigson (1969) – suggests alternative boundaries aurochs/domestic cattle; states only some dimensions;

(6) Lasota-Moskalewska & Kobryń (1989) – summarise data from several sites in different regions. Considering the geographical (*e.g.* clinal) variability of aurochs, the regional and periodic variability of domestic cattle and the vast material, larger size spans were registered and therefore an even larger overlap. In Table 3 just domestic cattle from the Neolithic-Eneolithic period (= f2 in Lasota-Moskalewska & Kobryń 1989).

Comparison with "the north data" from Denmark and "the south data" from Hungary will allow the dimensions from Bohemia to be placed into the geographical framework of Central Europe. The boundaries, according to interpretations of various authors, are marked with arrows in the graphs (Figs 5-7).

### LOG-RATIO TRANSFORMATION

In the first step each of width dimensions will be evaluated separately (Figs 5-7). But since this scatters data into relatively not very numerous subfolders, it is more advantageous to evaluate data in a more complete form. This will be realised by log-ratio transformation. While using log-ratio transformation Uerpmann & Uerpmann (1994) and Meadow (1999) concordantly suggest to evaluate breadth leg bones measurements separately from length leg bones measurements. In the presented study just breadth measurements are used, but three groups of dimensions will be evaluated separately:

1. from the forelimb (united dimensions: humerus – BT, radius – Bp, metacarpus – Bp, Bd);
2. from hindlimb (united dimensions: femur – Bp, Bd, Tibia – Bp, Bd, metatarsus – Bp, Bd);

TABLE 3. – Breadth dimensions: maximum values for domestic cattle and minimum values for aurochs (female) after various authors (in mm). Abbreviations and definitions of dimensions after Driesch (1976).

| Anatomy: dimension | After ** | Domestic cattle up to | Aurochs from | Overlap? |
|---|---|---|---|---|
| humerus: BT | Degerbøl | 90 | 81 | YES |
| | Ambros | 81 | ? | |
| | Stampfli | 71 | 79 | |
| radius: Bp | Degerbøl | 99 | 91 | YES |
| | Bökönyi | 92 | 91 | YES |
| | Stampfli | 74 | 84 | |
| | Lasota-M. & Kobryń | 112 | 84 | YES |
| metacarpus: Bp | Degerbøl | 75 | 63 | YES |
| | Bökönyi | 67 | 66 | YES |
| | Ambros | 63 | 70 | |
| | Stampfli | 56.5 | 66 | |
| | Lasota-M. & Kobryń | 80 | 64 | YES |
| metacarpus: Bd | Degerbøl | 73 | 66 | YES |
| | Bökönyi | 71 | 68.5 | YES |
| | Ambros | 61.5 | unsure | |
| | Stampfli | 56 | 62 | |
| | Lasota-M. & Kobryń | 84 | 64 | YES |
| tibia: Bp | Degerbøl | 120 | 110 | YES |
| | Bökönyi | | 116 | |
| | Ambros | | not present | |
| | Lasota-M. & Kobryń | 122 | 104 | YES |
| tibia: Bd | Degerbøl | 76 | 73 | YES |
| | Bökönyi | 76.5 | 68.5 | YES |
| | Ambros | 68 | 70 | |
| | Stampfli | 56 | 70 | |
| | Lasota-M. & Kobryń | 80 | 64 | YES |
| talus: Bd | Degerbøl | 49 | 47 | YES |
| | Bökönyi | | 51 | |
| | Ambros | 49 | 51 | |
| | Stampfli | 40 | 45 | |
| | Lasota-M. & Kobryń | 66 | 38 | YES |
| metatarsus: Bp | Degerbøl | 59 | 50 | YES |
| | Bökönyi | 66 | 55 | YES |
| | Ambros | 54.5 | not present | |
| | Stampfli | 42 | 48 | |
| | Lasota-M. & Kobryń | 66 | 46 | YES |
| metatarsus: Bd | Degerbøl | 68 | 62 | YES |
| | Bökönyi | 63.5 | 62.5 | YES |
| | Ambros | 65.5 | 68 | |
| | Stampfli | 51 | 59 | |
| | Grigson* | 55 | 59 | |
| | Lasota-M. & Kobryń | 74 | 58 | YES |
| phalanx I: Bp | Degerbøl | 39 | 34 | YES |
| | Ambros | 33.5 | 31.5 | YES |
| | Stmpfli | 29 | 29 | |
| | Grigson* | 29 | 33 | |
| | Lasota-M. & Kobryń | 46 | 32 | YES |
| phalanx I: Bd | Degerbøl | 36 | 30 | YES |
| | Ambros | 31.5 | 32 | |
| | Stampfli | 28 | 29 | |
| | Lasota-M. & Kobryń | 40 | 28 | YES |
| phalanx II: Bp | Degerbøl | 33.5 | 32 | YES |
| | Ambros | 34 | 29 | YES |
| | Stampfli | 28 | 30 | |
| | Lasota-M. & Kobryń | 42 | 28 | YES |

* Grigson (1969) – boundaries suggested as "possible alternative".
** see text, § *Size boundaries domestic cattle/aurochs and allometry*.

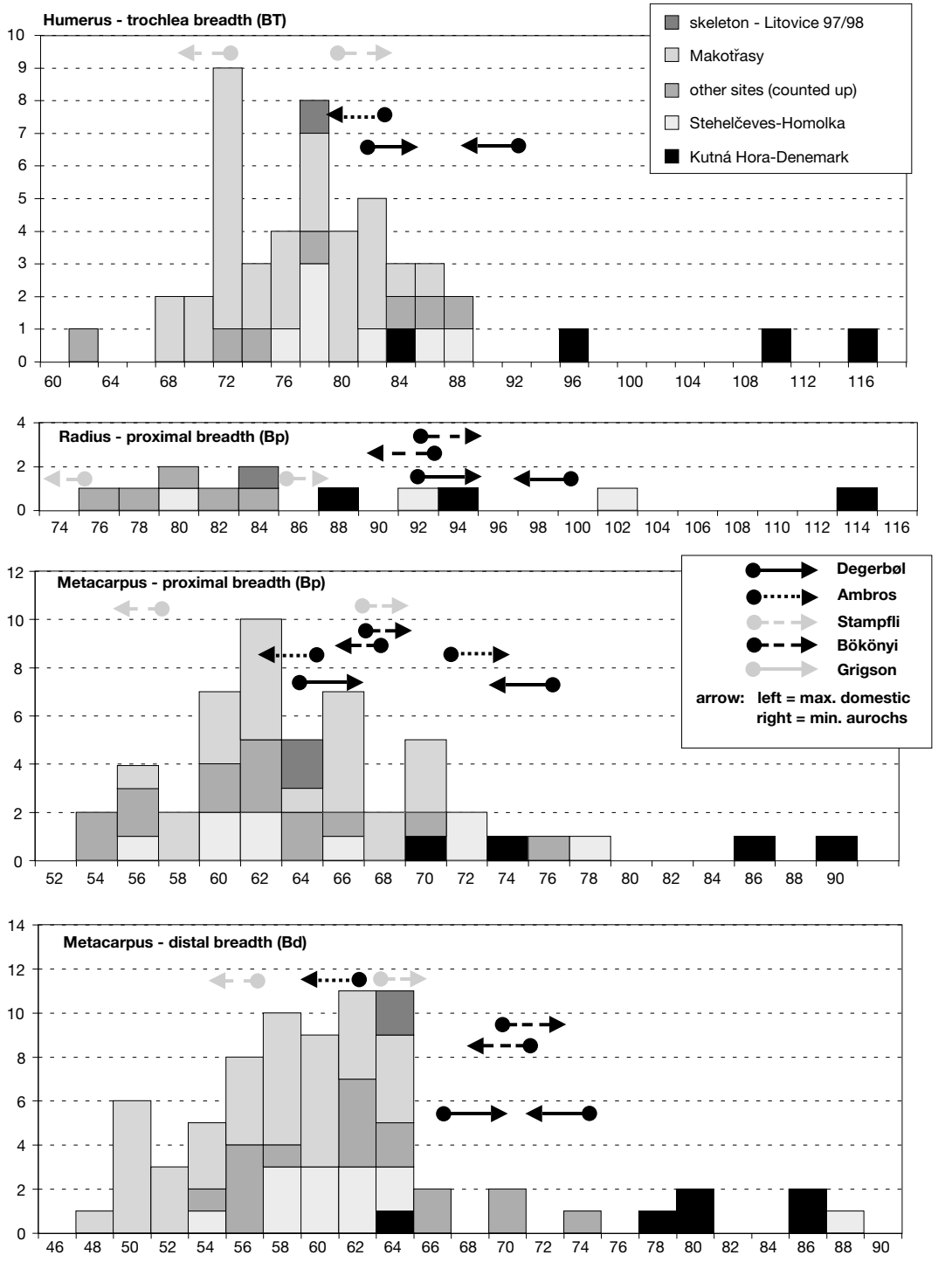


FIG. 5. – *Bos*: metric distribution: humerus, radius and metacarpus.
X axis = size in mm (values indicate maximum of particular interval), Y axis = number of cases.

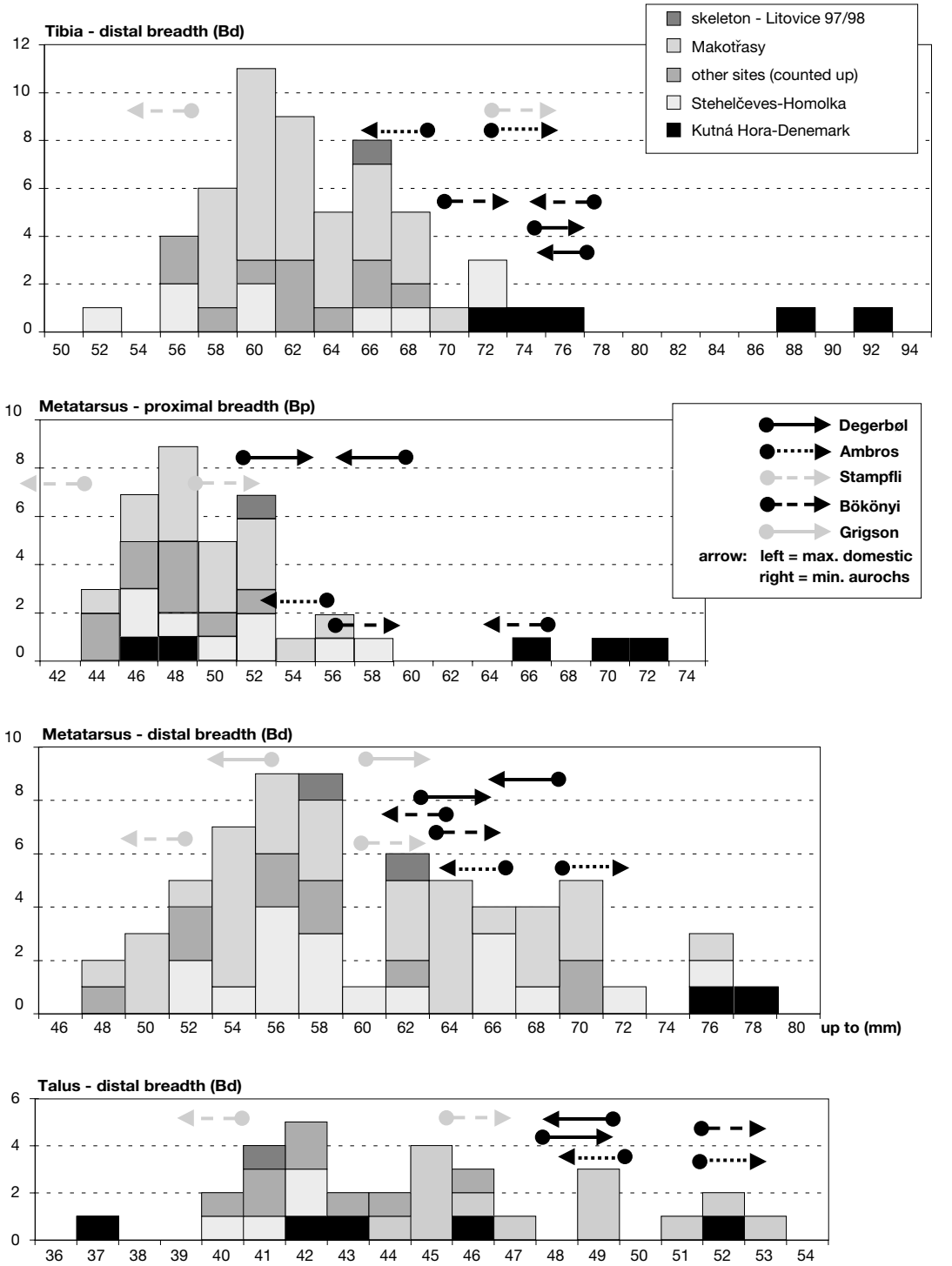


FIG. 6. – *Bos*: metric distribution: tibia, talus and metatarsus.
X axis = size in mm (values indicate maximum of particular interval), Y axis = number of cases.

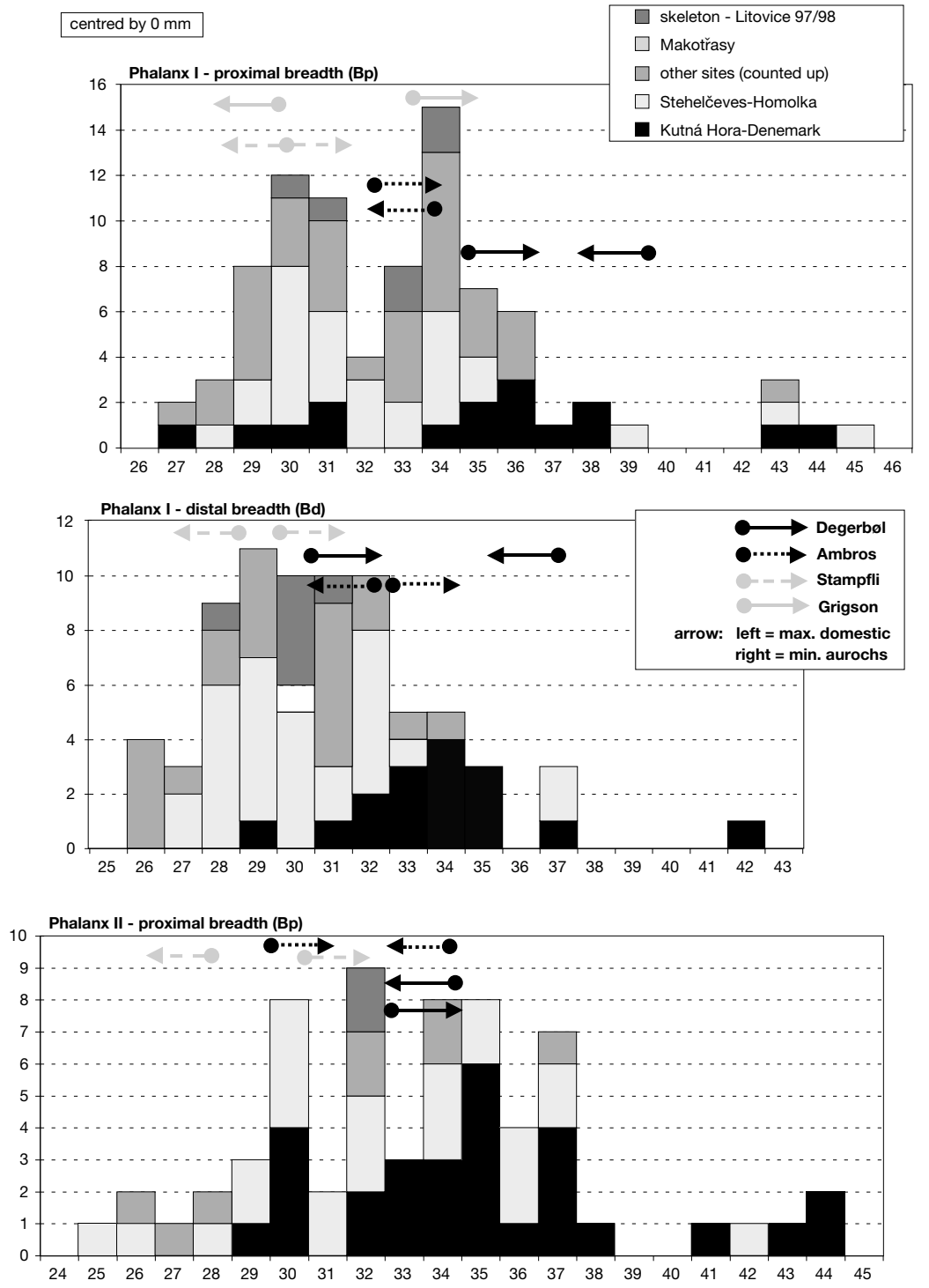


FIG. 7. – *Bos*: metric distribution: phalanges.
X axis = size in mm (values indicate maximum of particular interval), Y axis = number of cases.

3. phalanges (united dimensions: phalanx I – Bd, phalanx II – Bd).

The reasons for separate evaluation of fore- and hindlimb are, as mentioned above, the different regularities in the weight on the fore and hind limb (§ *Selection of dimensions for the analyses*). The bones of one limb are subjected to the same weight therefore the dimensions of one limb will react on a change of size (weight) in a similar way. In this study, the angles between limb bones, sizes of muscle attachment tuberosities and other factors, which can also affect the width dimensions, will not be considered for simplicity. Phalanges are evaluated separately from long bones, since they are of different character and they were not separated to hind and fore limbs. In general, phalanges are considered less useful for size analyses, but Pöllath and Peters (2005) and Russell *et al.* (2005) show their usability even in log-ratio inter-sites comparisons (even without identification of phalanx position in body).

Thanks to taphonomic processes which degrade skeletons on archaeological sites the original material becomes greatly reduced. In cases of the analysed sites it is probable that one bone means one individual. The possibility, that there will be more bones from one individual preserved in the assemblage can not be eliminated but is very little probable. One complete bone (within the selected dimensions, Table 2) gives in maximum two dimensions. In case of complete phalanges only one width dimension will always be used (see § *Log-ratio transformation*, (3)) and long bones are preserved just in fragments. Therefore one individual will be probable represented by only one measured width value. Of course from a find of a skeleton or its part we have more dimensions from a single individual. Such cases however are very rare. The only skeleton (cattle 1 from the pit 3 in Litovice[3]) included in our data will be extra marked in the graphs.

To enable the complex evaluation of the various dimensions it was necessary to transform the data. Log-ratio methodology was used (Simpson *et al.* 1960), which is based on the difference between logarithmic values of archaeological and reference material: LOG (arch. value)-LOG (ref.). Log-ratio transformation or similar procedures are used especially for the comparison of various sites or time horizons (see Meadow's (1999) article who calls the same index "log size index", LSI) and for the evaluation and interpretation of the distribution of body size in population (see Bartosiewicz *et al.* 2006). In consensus with a procedure used by Tresset (1996) and project ECONET[2] as a reference material the average values of dimensions of aurochs from Denmark were chosen (Table 4; Degerbøl & Fredskild 1970), these stand in the graphs as null (beginning of the scale). In the Figs 8-10 there is distribution of female aurochs sizes (again after Degerbøl in Degerbøl & Fredskild 1970), because comparison of female sizes of the wild form with our material will be pivotal. That is to say that the possible crossbreds of the domestic and the wild form may be expected to reach approximately the size of the female aurochs (smaller than the aurochs males and larger then domestic cattle) – § *Domestication question*.

As results from some studies (*e.g.* Lasota-Moskalewska & Kobryń 1989, see also § *Size boundaries domestic cattle/aurochs and allometry*) suggest, there are certain allometries between width dimensions (*i.e.* their averages are changing) even within the framework of a single limb of adult individuals. That could complicate the use of log-ratio methods. For our rough orientation however will the given method, including separation of dimensions into three categories (see above) with relatively widely chosen length of the interval (0.03 for long bones and 0.02 for phalanges[4]; see Figs 5-7), be fit. Also the fact that

3. In original description in Kyselý (2002a) and Pleinerová (2002) as Hostivice-Litovice or Hostivice; here the skeleton is actually assigned to female as suggested in original determination (Kyselý 2002a).

4. Because in one source of compared material (Makotřasy; Clason 1985) are not published primary data (just size pattern in a form of histogram) I had to slightly adapt the procedure (*e.g.* interval boundaries) of presented transformation to possibilities.

TABLE 4. – Reference data: aurochs males (from Degerbøl & Fredskild 1970); and metrics from domestic cattle female skeleton from Litovice (see Table 1 and note 3); some original measurements not corrected in the last proofs (dist. femur, prox. metacarpus sinistra and some phalanges) and published in Kyselý (2002a) presented in revised form here. In mm.

| Anatomy | Dimension | Aurochs males | | | | | Litovice - skeleton |
|---|---|---|---|---|---|---|---|
| | | Number of data | Min. | Max. | Average | Log (average) | |
| humerus | BT | 22 | 95 | 108 | 103.2 | 2.01 | 77.8 |
| radius | Bp | 22 | 104 | 122 | 115.6 | 2.06 | 83.7 |
| metacarpus | Bp | 22 | 77 | 90 | 84.2 | 1.92 | 60.1 and 60.8 |
| metacarpus | Bd | 21 | 80 | 88 | 83.7 | 1.92 | 62.3 and 62.3 |
| femur | Bp | 8 | 157 | 183 | 171.6 | 2.23 | (114.8) |
| femur | Bd | 17 | 122 | 146 | 135.4 | 2.13 | 100.5 |
| tibia | Bp | 13 | 129 | 145 | 139 | 2.14 | 99.3 |
| tibia | Bd | 16 | 83 | 93 | 87.9 | 1.94 | 64.4 |
| metatarsus | Bp | 17 | 64 | 73 | 68.9 | 1.84 | 51 |
| metatarsus | Bd | 18 | 73 | 82 | 77.1 | 1.89 | 56.7 |
| phalanx 1 | Bd | 4 | 37 | 41 | 39 | 1.59 | 27; 29.2; 29.3; 29.4; 29.6 and 30.7 |
| phalanx 2 | Bp | 7 | 39 | 43 | 40.9 | 1.59 | 31.4 and 31.6 |

the metric data of a single individual including six phalanges (posterior and anterior, axial and abaxial), *i.e.* skeleton from Litovice (data in Table 4) are mostly concentrated in the graphs into a relatively narrow area (Figs 8-10) indicates, that the graphically depicted variability within the sites by applied methodology is not overly affected by using the log-ratio methodology. There are only two exceptions of compact pattern: femur Bp which could not be measured accurately (therefore marked with?) and one phalanx Bd (suspected being an admixture to the skeleton, also marked with?).

## THE RESULTS OF THE STUDY

The resulted distribution of measured absolute data (in mm) separately for every width dimension is shown on the Figs 5-7 (a femur with only few values to disposition was not evaluated separately).

We will aim at general evaluation of more dimensions (Figs 8-10). For simplicity we shall compare mainly these groups of *Bos* material:

(1) aurochs males from Denmark
(2) aurochs females from Denmark
(3) Kutná Hora-Denemark (czech)
(4) other Czech Eneolithic sites together

The resulted span of individual dimension values of the finds from Kutná Hora-Denemark cannot be a result of variability within a single population. Minimum values of some dimensions are only 60% of the maximum values of the given dimension. Minimum and maximum values for the material show, that domestic cattle as well as aurochs are reliably present. It also ensues from comparison with the aurochs values from Denmark and Hungary (Table 3, Figs 5-10). On other Czech sites mostly domestic cattle are present but the largest values are assigned to aurochs also on that sites (see *e.g.* Stehelčeves-Homolka; Ambros 1968).

The site of Kutná Hora-Denemark is special among other Czech sites due to:

(a) Containing a relatively large number of bones with large dimensions, which correspond in size with male aurochs and are classified as reliably wild form (*Bos primigenius*);

(b) Intermediate sizes bones are strongly represented here – roughly in the size of female aurochs. That is most apparent among phalanges (Fig. 10). This "critical" area is in Figs 8-10

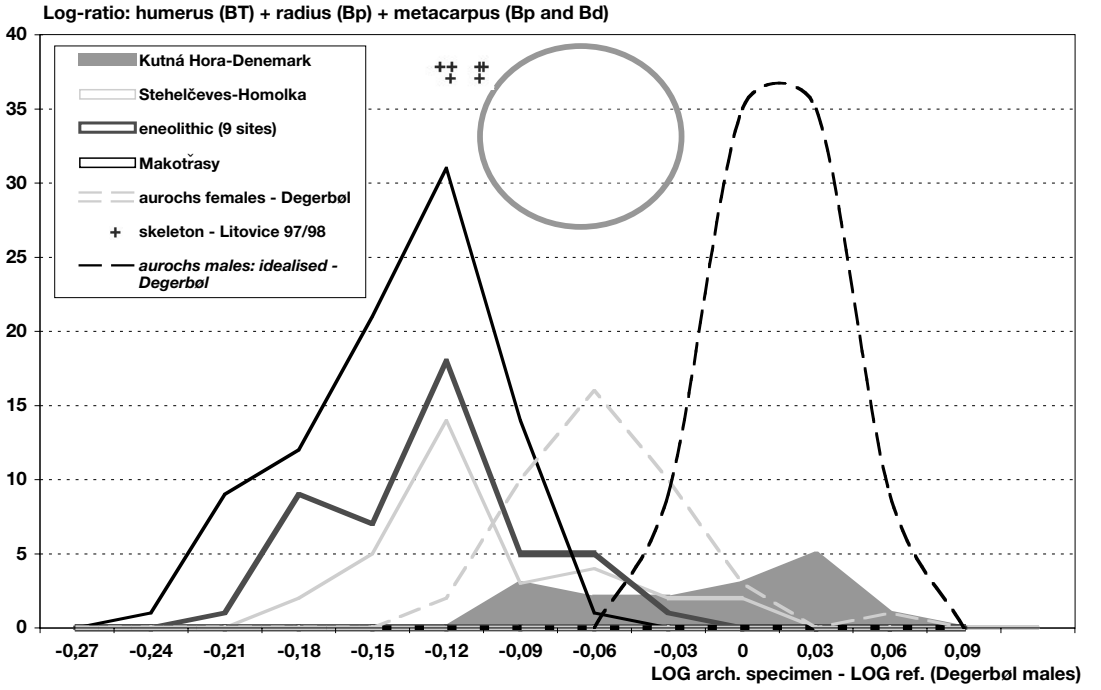


FIG. 8. – *Bos*: log-ratio transformation: front limb long bones - total data of breadth dimensions of humerus (BT), radius (Bp) and metacarpus (Bp and Bd).
Gray circle = transitional interval (intermediate size forms). X axis = Log-ratio index (values indicate maximum of particular interval), Y axis = number of cases. Plus marks represent values for the skeleton (X axis), plus marks distribution in Y axis orientation has no meaning.

marked with a question mark and a circle. Data from other Czech sites coincidently show only low representation in the circled area of overlap;
(c) The smallest sizes of cattle observed in Kutná Hora-Denemark are recognisably larger than on other Czech Eneolithic sites (Figs 5-10).

## INTERPRETATION AND DISCUSSION

Presence of intermediate large forms is not surprising (that is common even on most of the other Czech Eneolithic sites) but their strong representation and domination visible in the case of phalanges is (Fig. 10). The percentage of wild cattle in the measurable set can be increased by butchery techniques and by age pattern (Bartosiewicz *et al.* 2006). In the case of Kutná Hora-Denemark fragmentation of wild and domestic cattle bones is the same (unpubl.) and the age pattern different (Kyselý 2008). Howbeit this biasing factor can influence the shape of the distribution pattern by reduction in the right part of the graphs, logically it cannot selectively reduce the central part of the graphs.
Presence of these intermediate forms cannot be explained by the reduction of average size of wild cattle in the region[5], since even male aurochs were recognised with maximum size reaching the size boundary of this species in Holocene (compare values in the graphs, Figs 5-10, with dimensions published by Degerbøl & Fredskild 1970).

5. For explanation problems of the aurochs body becoming smaller in first stages of domestication see Helmer *et al.* (2005).

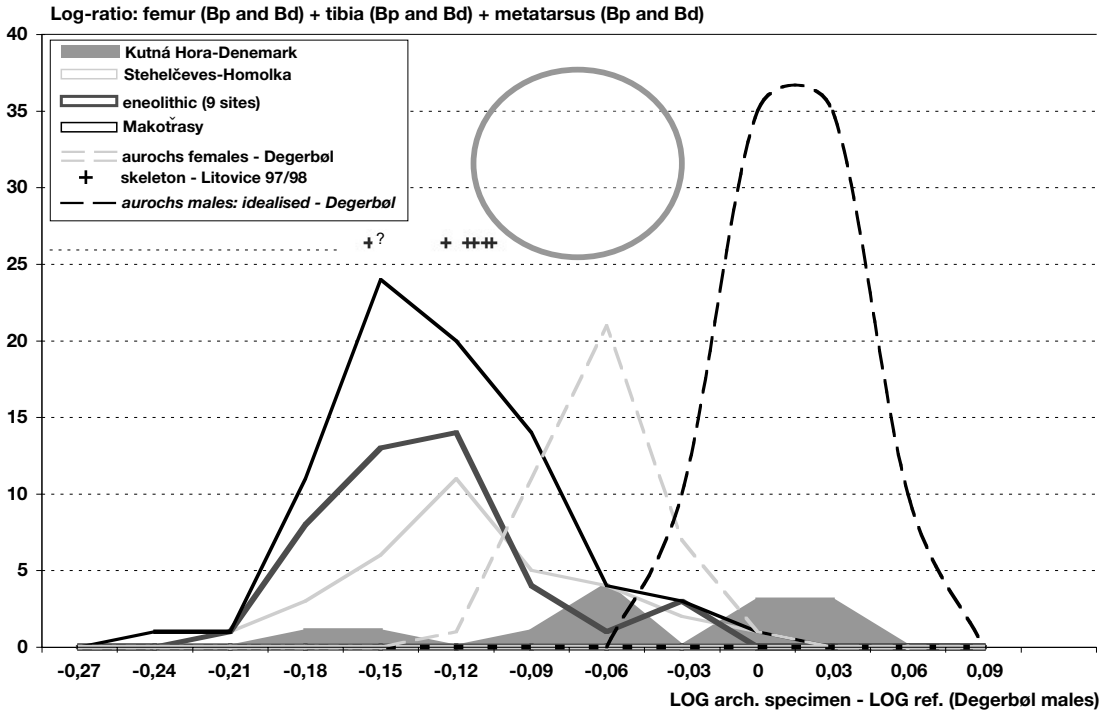


FIG. 9. – *Bos*: log-ratio transformation: hind limb long bones - total data of breadth dimensions of femur (Bp and Bd), tibia (Bp and Bd) and metatarsus (Bp and Bd).
Gray circle = transitional interval (intermediate size forms). X axis = Log-ratio index (values indicate maximum of particular interval), Y axis = number of cases. Plus marks represent values for the skeleton (X axis), plus marks distribution in Y axis orientation has no meaning.

The influencing of the result by an intrusion of wisent bones was eliminated in the introduction (Chap. *Introduction*) and also the influence of age was reduced to minimum (§ *Variability and its components*). Thus bones of intermediate size can be:
(1) large domestic cattle: males (or castrates) or larger stock;
(2) aurochs (females);
(3) crossbreds of domestic and wild form/locally domesticated cattle.

(1) Other Czech sites with large analysed assemblages (Makotřasy and Stehelčeves-Homolka) do not show double peaked data distribution, which could indicate females and males of domestic cattle. On the contrary they are significantly single peaked with the peak being far left from the critical area marked with a circle and question mark (Figs 8-10). However in Kutná Hora-Denemark the cattle are strongly represented just in this area. The assigning of all the intermediate individuals to domestic males would not correspond with the situation at other sites.
Presence of more morphometrically different stocks in the Eneolithic is hardly probable, but not impossible since it could have originated as adaptation on various living conditions (differentiated use of cattle or differentiated conditions of breeding - sheds, pasture) or by intentional or unconsciousness artificial selection; for discussion see Clason 1984. Nevertheless excessive husbandry specialisation is not presumed and two or more stock of various size were not described on a single Neolithic or Eneolithic site. Such evidence in continental Europe is much later, for

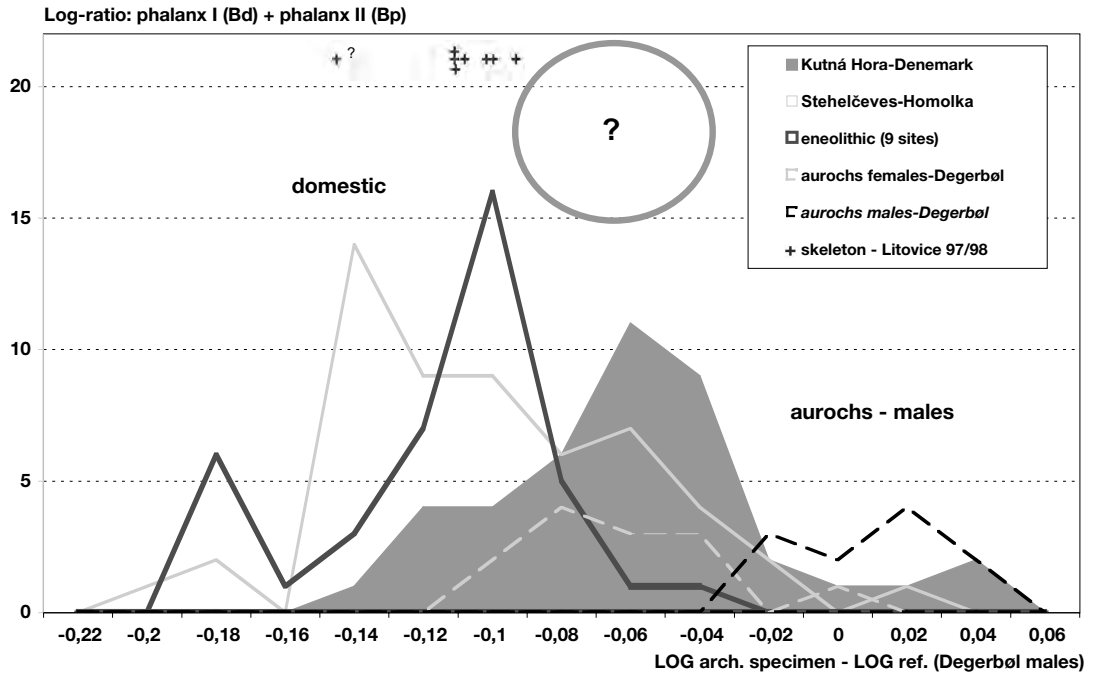


FIG. 10. – *Bos*: log-ratio transformation: phalanges - total data of breadth dimensions of phalanx I (Bd) and phalanx II (Bp). Gray circle = transitional interval (intermediate size forms). X axis = Log-ratio index (values indicate maximum of particular interval); Y axis = number of cases. Plus marks represent values for the skeleton (X axis), plus marks distribution in Y axis orientation has no meaning.

example under the conditions of Roman invasion (Peters 1998), in the Medieval/Postmedieval Ages (*e.g.* Albarella 1997). But in the Neolithic the size variability getting wider can be reflected upon, which can also be a result from factors mentioned above (adaptation on different concrete conditions, selection).

As a new stock also a population originated by crossbreeding of domestic and wild cattle could be considered, if this population lasted longer and was genetically isolated but that corresponds with the hypothesis (3).

High representation of non castrated males is highly improbable since it is not economical (compare the rate of females and males in present-day breeding with primitive character; *e.g.* Dahl & Hjort 1976).

The role of trade routes coming from Moravia in the period can not be judged due to current knowledge but they probably did not play any role since domestic cattle was presumably of the same size in Bohemia as well as in close and ecologically and geographically not very distant Moravia.

(2) The centre of finds gravity from Kutná Hora-Denmark really lays in the area of sizes of female aurochs. Explanation could be specialisation in hunting the females, for example groups of females with the young ones (see Helmer *et al.* 2005). Common life of female together with the youngsters in groups is presumed within social behaviour of aurochs (see § *Aurochs – history, biology, size*). Nevertheless some indications are against this hypothesis: Fig. 11 shows (in the middle) the humerus bones of aurochs of the same size. Considerable size of these aurochs finds clearly shows that they are males. Dimensions of this find (Bd = 126.8 mm, BT = 109.7 mm) even strikingly exceed maximum data from Denmark stated by Degerbøl (in Degerbøl & Fredskild 1970), *i.e.* max. Bd = 116 mm, max. BT = 108 mm. That suggests that aurochs in Bohemian basin was not

FIG. 11. – The visual illustration of size differences: photograph comparing three humerus bones of *Bos* from Kutná Hora-Denemark with recent female of wisent (left). The two finds in the centre belong reliably to aurochs. Scale: 1 piece = 1 cm. (Photograph: R. Kyselý).

"a stock reduced in size" as it potentially could seem from the partial geographic isolation. The find depicted to the right on the photograph is approximately of the size of a female wisent and in the graph (Fig. 8) it shows in the circle centre of the complete distribution (and so in the area of potential female aurochs). At the same time it is quite improbable that the size difference of male and female aurochs was so considerable in a single region (compare finds in the centre and to the right on the Fig. 11). The occurrence of more genetically different wild forms within Europe is possible, as reveald by the evidence for P and E haplotypes within genofond of European aurochsen (from archaeogenetical investigations by Edwards *et al.* 2007). But the coexistence of two wild forms differing in size in a single space is improbable. The find to the right on the Fig. 11 therefore seems to belong to a domestic form or a form genetically influenced by domestic cattle.

(3) This hypothesis is supported by:
a) Some results (phalanges) indicate a high representation of individuals of intermediate size (in the area with crossbreds expected), which is not common on the other sites of the same period in Bohemia.
b) In the material from Kutná Hora-Denemark where there was an expressive difference in representation of domestic and wild form according to teeth and postcranial skeleton: that is to say that teeth were usually interpreted as domestic form due to the small size, while other parts equally to both forms (see Kyselý 2008). This non-uniformity is confirmed also by comparison of sizes gained from phalanges and teeth (molar 3) from two richest Řivnáč sites Kutná Hora-Denemark and Stehelčeves-Homolka (Fig. 12). Centre of dimension gravity is in the case of phalanges from Kutná Hora-Denemark more to the right while in the case of teeth it is more to the left than in data from Stehelčeves-Homolka. Hypothetically, this difference can be a result of crossbreeding when teeth react on the mixing of genes in a different way (they keep the size of domestic form) than the rest of the skeleton, which presumably reached a middle size between both forms.
However this difference can also be a result of taphonomic processes. Selective transport of some anatomical parts of hunted cattle into the settlement may occur. For example, if the skulls were not brought, in the dimensions of aurochs teeth will not appear in the graph. Such a taphonomic case cannot be completely eliminated; especially with consideration of the higher quantity of skull fragments of domestic form compared to wild one occuring in Kutná Hora-Denemark (by weight method; Graph 6 in Kyselý 2008).
c) Higher minimum value in the span of size variability of cattle in Kutná Hora-Denemark could also be a result of the fact, that the material represents a population originating from the genetic mixing of domestic and wild cattle (or potentially even a population at the beginnings of the domestication process). The consequence could be that the size span (*i.e.* also minimum) of such population would theoretically be shifted in the graphs more to the right from domestic cattle since the crossbreds would be of middle size.
Nevertheless another potential explanation of this feature has to be mentioned: presence of larger domestic stock than on other Czech sites (hypothesis 1); absence of domestic females, which are osteometrically smaller than males

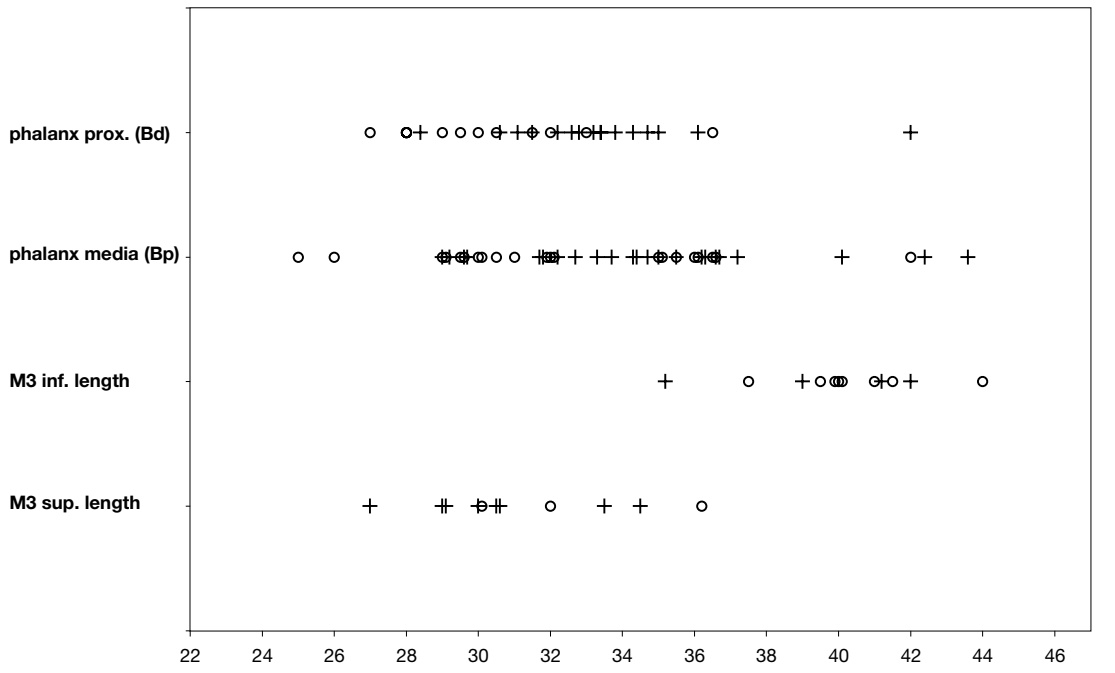


FIG. 12. – *Bos*: comparison of metric data from Řivnáč Culture sites Kutná Hora-Denemark (crosses) and Stehelčeves-Homolka (circles). M3 inf. = molar 3 inferior, M3 sup. = molar 3 superior; X axis = values in mm.

(that however has little probability). Another cause can also be the small amount of data for domestic cattle in Kutná Hora-Denemark, and therefore a smaller chance of recognising the size span.

Although many arguments support the crossbreeding of domestic and wild cattle, we cannot exclude any of the hypotheses. Also possible is a combination of suggested explanations: for example: the size intermediate group can be formed together by large domestic males, wild females and crossbreds.
The solution of this question is not possible only on the basis of osteometry. Of great help would be some information about the sex of the finds and their assigning to a metric value representing the size. Determination of sex, with the help of genetic methods, is planned for the future[6], as well as the analysis of haplotypes (which are already known for wild and domestic form; Edwards *et al.* 2007) of individual fragments. The consequent combination of both data (similarly as in Scheu *et al.* 2008) can be of significant help in resolving the problem.

## CONCLUSION

In the osteozoological material from the Řivnáč hillfort at Kutná Hora-Denemark (distr. Kutná Hora), which is situated on the edge of contemporaneously settled area, (1) significant rate of aurochs representation was proved, which indicates its abundant occurrence in the vicinity of the site in a larger amount than was observed

6. Kyselý R. & Hájek M.: The Grant Agency of the Academy of Sciences of the Czech Republic - GAAV, identif. code KJB800020801 (submission); The Czech Science Foundation - GAČR, identif. code 206/09/2038.

within the oikumenon. This state was suitable for the local domestication of aurochs or (more probably) for the crossbreeding of the domestic and wild cattle form. The small dimensions of some individuals certainly proved the presence of domestic cattle, (2) the smallest values however are slightly larger than the minimum for domestic cattle on other Czech Eneolithic sites (*e.g.* Makotřasy, Stehelčeves-Homolka). (3) Comparison of width metric data of cattle limbs with other Czech Eneolithic sites points to a significantly different distribution of *Bos* sizes in Kutná Hora-Denemark. That could be a result of crossbreeding of domestic and wild cattle. This hypothesis is possibly supported also by other circumstantial evidence. The work on recent DNA by Götherstöm *et al.* (2005) suggests occasional mating of domestic females with wild males. Occasional transmitting of DNA from aurochsen to domesticated taurine is supported also by works on mtDNA (Beja-Pereira *et al.* 2006, Achilli *et al.* 2008). The presented site could be such a place, possibly with an intentional management. However alternative hypotheses explaining the unusual distribution were suggested, for example "specialisation" by hunting aurochs females.

Since osteometric analysis does not provide a reliable explanation of the recognised distribution, other methods have to be sought, of which the most promising appears to be molecularly (genetically) aimed research on the bones. Such a project has been already suggested[6]. This case study showed that finds from the analysed site are an interesting and suitable material for such a study. Metric analysis remains an equivalent source of information, which gives, for example, a good perception of the size and robustness of the body and other characteristics of animals from the past. This in the future will enable us to compare genotype with phenotype features.

This study works with central Bohemian Eneolithic sites, but its theme touches a question, which extends beyond this period and area. The question of crosssbreeding/local domestication is just as topical either in the Neolithic or later periods.

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Material from Kutná Hora-Denemark is stored in the Institute of Archaeology of the Academy of Sciences in Prague.

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- on page 20 (right) should be always „Kobryń & Lasota-Moskalewska (1989)“ instead of „Lasota-Moskalewska & Kobryń (1989)“
- in Tab. 3 should be always „Kobryń & Lasota-M.“ instead of „Lasota-M. & Kobryń“
- in caption to Fig. 4 should be Czech insted of Tczech