ARCHAEOZOOLOGY OF THE NEAR EAST
V

Proceedings of the fifth international symposium on the
archaeozoology of southwestern Asia and adjacent areas

edited by

H. Buitenhuis, A.M. Choyke, M. Mashkour and A.H. Al-Shiyab

ARC-Publicaties 62
Groningen, The Netherlands, 2002

Cover illustrations:
Logo of the Yarmouk University, Jordan

This publication is sponsored by: ARCbv and Vledderhuizen Beheer bv

Printing: RCG-Groningen

Information and sales: ARCbv, Kraneweg 13, Postbus 41018, 9701 CA, Groningen, The Netherlands
Tel: +31 (0)50 3687100, fax: +31 (0)50 3687199, email: info@arcbv.nl, internet: www.arcbv.nl

ISBN 90 – 77170 – 01– 4

NUGI 680 -430

Contents

Preface

DRAUGHT CATTLE AND ITS OSTEOLOGICAL INDICATIONS: THE EXAMPLE OF SAGALASSOS.

Bea De Cupere[1] and Marc Waelkens[2]

Abstract

An osteological study undertaken on the metapodials and phalanges of modern draught oxen and young bulls led to the definition of a series of draught-related anomalies, which can be quantified using a scoring scale for each individual pathology (Bartosiewicz *et al.* 1997). The present paper describes the results of the application of this method to the cattle remains from classical Sagalassos (Burdur province, SW-Turkey). Sex distribution and the age structure of the cattle population, land use in the territory of Sagalassos and literary sources are used as additional evidence for the use of cattle as beasts of burden at the ancient site.

Résumé

Une étude ostéologique menée sur des métapodes et des phalanges de bœufs de trait et de jeunes taureaux modernes a permis de distinguer une série d'anomalie liées à la traction dont la gravité est évaluée à l'aide d'un système de scores (Bartosiewicz *et al.* 1997). Cet article décrit les résultats d'application de cette méthode aux restes de bœufs du sites romain de Sagalassos (Province de Burdur, Sud-Ouest de la Turquie). La répartition des sexes et des classes d'âge de la population bovine, l'exploitation de la terre sur le territoire de Sagalassos ainsi que les sources écrites sont utilisées comme des preuves supplémentaires de l'utilisation du bœuf pour la traction sur ce site.

Key Words: Draught cattle, palaeopathology, Turkey, Roman/Early Byzantine

Mots Clés: Bœufs de trait, paléopathologie, Turquie, Romain/début Byzantin

Indications for the draught use of cattle

Cattle have been kept since prehistoric times for different purposes, i.e. meat, dairy products, skin and physical power. Archaeological evidence for the use of cattle as draught animals, e.g. yokes, ploughs, figurines or depictions of cattle at work, are found from the Neolithic onwards, while literary sources can be used as well from the Bronze Age onwards. Archaeozoological studies emphasise the use of cattle for meat and dairy products, but their use as draught animals is rarely dealt with. Certain pathologies in the skeleton have been attributed to draught exploitation, i.e. depressions on the horn cores (Benecke 1994: 147), hip joint deformations (Armour-Chelu & Clutton-Brock 1985: 298) and deformations on feet such as exostoses on metapodials and phalanges, as well as spavin (Baker & Brothwell 1980: 117-122), mediolateral broadening of the medial throchlea of the metacarpal (Mennerich 1968: 35; von den Driesch 1975; Uerpmann & Uerpmann 1994) and asymmetry in metatarsals (Davis 1987: 162; Peters 1998: 71). A recent study on the presence of pathologies on the bones of 18 modern Rumanian draught oxen (age ranging between 6 and 19 years) and 7 young bulls (age 2 years) involved the establishment of a scoring system to quantify draught related anomalies (Bartosiewicz *et al*. 1997). The pathological deformations were defined as broadening and lipping of the articular surface, new bone formation near the articulations and osteoarthritis (grooving and eburnation) on the proximal and distal ends of metapodials and phalanges (Table 1). Other anomalies were defined for the metapodials but these could, in most cases, not be examined in the material of Sagalassos due to the incompleteness of the long bones, and were therefore omitted here. The severeness of the deformations can be analysed for each pathology separately or can be combined using a pathological index. The general formula for calculating the pathological index (PI) is 'PI= (sum of scores – number of variables)/(maximum score – number of variables)' and ranges between 0 and 1.

[1] Royal Museum of Central Africa, 3080 Tervuren, Belgium
[2] Department of Archaeology, Katholieke Universiteit Leuven, Blijde Inkomststraat 21, 3000 Leuven, Belgium

Table 1. The pathological deformations used for the cattle metapodials and phalanges of Sagalassos, and the range of scores that can be attributed to each deformation. For an explanation of the pathologies, see Bartosiewicz *et al.* (1997).

	MC	MT	Ph1	Ph2	Ph3
Proximal exostosis (PEX)	-	-	1-4	1-4	1-4
Proximal lipping (PLIP)	-	-	1-4	1-4	1-4
Distal exostosis (DEX)	1-4	1-4	1-4	1-4	-
Broadening of distal epiphysis (BRD)	1-4	1-4	-	-	-
Proximal osteoarthritis (PEBU)	-	-	1-2	1-2	1-2
Distal osteoarthritis (DEBU)	1-2	1-2	1-2	1-2	-
Total minimum score	3	3	5	5	3
Total maximum score	10	10	16	16	10
Number of variables	3	3	5	5	3

Literary sources are another possibility to indicate the use of cattle as draught animals. Although literary evidence of Greek animal husbandry is somewhat limited, Hesiod (Works and Days ll. 405, 436, 606) does mention the use of draught oxen, whereas Xenophon also refers to draught animals (hypozogia), including oxen, mules and horses, in connection with threshing (Oeconomicus 18.3). According to Aristotle as well, the main function of oxen was as draught animals, employed in strenuous labour such as ploughing and heavy transport (*Historia Animalium*). In fact, in Greece, oxen are shown more often as a plough-team than are mules (Isager & Skydsgaard 1992: 89). The Greeks also used both mules and oxen for pulling carts with smaller loads. However, for heavy loads (usually placed on wooden sleds), yoked oxen (zyga boôn) became the normal draught animal and are mentioned as such in various Greek building accounts (Raepsaet 1987; Jeskins 1998: 56 Fig. 16). Similar practices are known from pharaonic Egypt as well (Klemm 1981: 41 Fig. 42). Roman agronomist authors, such as Columella (*De re rustica* 2.2.1.5; 2.2.24; 6.22.1), Varro (*Res rusticae* 1.20.2, 4-5) and Cato (*De agricultura* 11.2.4;14.2; 62), also document the frequent use of cattle and give technical details concerning the training of working animals, their diet, breeding, harnessing and shoeing (Parain 1966: 144; Toynbee 1983: 319-327; White 1970: 221, 275-288). In general, they mention cattle, especially oxen but sometimes also sterile cows, as working animals drawing ploughs and carts (Columella 6.1.3; White 1970: 278; Flach 1990: 292). Although, asses, mules and cows could also be used as draught-animals pulling light ploughs in light soils, the strongest ploughs could only be drawn by oxen or by sterile cows (Pliny the Younger, *Epistolae* 5.6.10; Spurr 1986: 29, 32). For the heaviest loads (for instance huge marble blocks) the Romans also yoked oxen to wooden drags (trahea: Spurr 1986: 145), a system which was still in use at Carrara during the earlier part of this century (Raepsaet 1987). A representation of a pair of oxen, pulling a cart loaded with marble blocks, is for example, known for Roman Anatolia (Waelkens 1986: 196 no. 486, pl. 75), as well as various representations on votive monuments and sepulchral stelae, depicting oxen attached to ploughs (Waelkens 1977, 1986; Cremer 1992). In Imperial times, bulky goods, including grain, were sometimes carried by mules (Pliny the Younger, *Epistolae* 2.6.5). Most landowners however, purchased oxen for the special purpose of hauling wagons around their estate, or for transporting their produce and equipment to and from the market centres (Spurr 1986: 145). The ownership of draft animals eventually became a prerequisite for agricultural expansion, since only farmers with their own draught animals could become self-sufficient, while those lacking these animals had to rent them from the former or were forced to serve as labourers on other farms (Kehoe 1988: 94).

It is known from literary sources that mules and donkeys were used at Sagalassos for the transport of official goods (Mitchell 1976). This is documented in a letter sent in AD 13-15 to the city by Sextus Sotidius Strabo Libuscidianus, *legatus pro praetore* of the emperor Tiberius. It concerns the organisation of requisitioned transport within the territory of the city for the use of the Roman authorities. The letter states that the people of Sagalassos needed to provide a service of wagons for the necessary use of officials passing through their territory and even some miles beyond it. As draught animals, the letter only mentions mules and donkeys. Despite the fact that the text also refers to the transport of grain by individuals, no mention is made of oxen or cattle. The osteological evidence presented below, however, shows that those animals were used as well.

The application of the scoring system to the material of Sagalassos

The scoring system of Bartosiewicz *et al*. (1997) has been applied to all cattle phalanges and distal ends of the metapodials collected during the excavations of Sagalassos. A detailed analysis of the results was carried out for the material of the 1990-1994 campaigns and will be discussed here. This material comprises 70 metacarpals, 93 metatarsals, 571 first phalanges (Ph1), 386 second phalanges (Ph2) and 226 third phalanges (Ph3) (Table 2). The location of the Ph1 and Ph2 in the limbs, i.e. anterior, posterior, medial and lateral for the Ph1 and anterior and posterior for the Ph2, was established using Dottrens (1964).

Table 2. Scores given to distal ends of metapodials and phalanges (A: anterior; P: posterior, M: medial, L: lateral) and their calculated pathological index (PI).

	MC	MT		Ph1				Ph2			Ph3
	dist	dist		AL	AM	PL	PM	A	P		
DEX	N=70	N=90	**PEX**	N=85	N=177	N=129	N=161	N=168	N=196	**EX**	N=226
1	47	56	1	29	65	43	54	57	153	1	76
2	22	34	2	55	115	82	105	108	43	2	148
3	1	0	3	1	0	3	2	2	0	3	2
4	0	0	4	0	0	1	0	1	0	4	0
DEBU	N=70	N=92	**PLIP**	N=84	N=177	N=128	N=160	N=165	N=195	**LIP**	N=222
1	68	90	1	17	44	19	47	33	57	1	57
2	2	2	2	49	109	99	104	110	116	2	156
			3	18	24	7	9	19	22	3	9
BRD	N=68	N=87	4	0	0	3	0	3	0	4	0
1	35	60									
2	29	26	**PEBU**	N=86	N=177	N=129	N=161	N=169	N=197	**EBU**	N=226
3	3	0	1	86	177	126	161	168	197	1	226
4	1	1	2	0	0	3	0	1	0	2	0
			DEX	N=86	N=174	N=128	N=158	N=167	N=196		
			1	19	50	15	16	89	161		
			2	65	120	110	138	73	35		
			3	1	4	3	4	4	0		
			4	1	0	0	0	0	0		
			DEBU	N=86	N=177	N=129	N=161	N=169	N=197		
			1	85	177	129	161	169	197		
			2	1	0	0	0	0	0		
PI	N=68	N=85	**PI**	N=84	N=174	N=127	N=157	N=164	N=194	**PI**	N=222
0	31	41	0	10	23	9	10	13	48	0	41
0.143	18	29	0.091	10	28	12	23	46	86	0.143	51
0.286	15	15	0.182	15	30	26	34	40	34	0.286	121
0.429	3	0	0.273	31	71	68	79	48	22	0.429	7
0.571	0	0	0.364	16	21	8	8	12	4	0.571	2
0.714	1	0	0.455	1	1	2	2	3	0	0.714	0
0.857	0	0	0.545	0	0	1	1	0	0	0.857	0
1	0	0	0.636	0	0	1	0	1	0	1	0
			0.727	1	0	1	0	1	0		
			0.878	0	0	0	0	0	0		
			0.909	0	0	0	0	0	0		
			1	0	0	0	0	0	0		

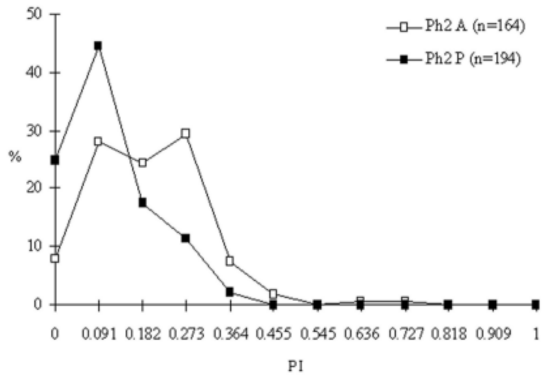

Fig. 1. Pathological indices (PI) calculated for metapodials and phalanges, indicating higher values in the fore limb than in the hind limb (A: anterior; P: posterior, M: medial, L: lateral).

A certain degree of exostosis and lipping is observed on many phalanges: 60 to 90% of the Ph1 and the Ph3 received a score of 2 or more for these anomalies. Proximal and distal exostoses in the anterior Ph2 were noticed in 66% and 46% of the finds respectively; in the case of the posterior Ph2 the incidence of exostosis is lower, respectively 22 and 18%. Lipping is frequently present in both anterior and posterior Ph2. About one third of the metapodials showed distal exostosis while the broadening of the trochlea was observed in less than 50% of the cases. When a score higher than 1 was given, most were 2 scores, seldom 3. Score 4 was, with the exception of one metacarpal, only given to specimens that also displayed osteoarthritis. The presence of eburnation and grooving is very restricted and was noticed in only a few cases, i.e. in 2 metacarpals, 2 metatarsals, 4 posterior Ph1, 1 anterior Ph1 and 1 anterior Ph2. In the case of the first and second phalanges, the relation between size and score was examined by plotting the length (GL) to the smallest breadth of the diaphysis (SD), in relation to the given scores of the individual pathologies. Scores 3 and 4 were observed in the larger, heavily built bones, whereas score 1 was given to the smaller and slender specimens. Score 2 was observed on both smaller and larger sized bones. Well-developed pathologies are thus related to the larger animals, i.e. most probably the males.

The pathological index was calculated for metapodials and phalanges, following the formula given above. Although the mean pathological index does not display large differences between the anterior and posterior limbs (Table 3), higher values are more frequently observed for elements of the fore limb when the calculated indices are displayed graphically (Fig. 1). Development of pathological deformations are thus, slightly higher in the fore limb than in the hind limb. This was also the case for the Rumanian oxen. Indeed, the fore limbs carry a greater part of the live weight than the hind limbs and wither-harnessed cattle exert an additional load on the fore limbs which might lead to more severe pathological deformations in the anterior skeletal elements (Bartosiewicz *et al.* 1997: 61). Differences between lateral and medial sides are negligible for the material of Sagalassos (Table 3, Fig. 1).

The data from the Sagalassos material were compared with those of the Rumanian draught oxen and young bulls. The pathologies were considered here individually (Fig. 2). As expected, the pathological deformations of the Sagalassos material were generally scored lower than the modern oxen but higher than the young bulls. The collection from Sagalassos differs from the modern oxen sample in that it

Table 3. Mean and standard deviation of the pathological indices (PI) calculated for the cattle phalanges and distal metapodials of Sagalassos.

Sagalassos	mean PI	standard deviation	confidence level
MC	0.131	0.150	95%
MT	0.099	0.108	95%
Ph1 anterior lateral	0.227	0.130	95%
Ph1 anterior medial	0.205	0.116	95%
Ph1 posterior lateral	0.237	0.112	95%
Ph1 posterior medial	0.218	0.099	95%
Ph2 anterior	0.193	0.119	95%
Ph2 posterior	0.111	0.092	95%
Ph3	0.207	0.123	95%

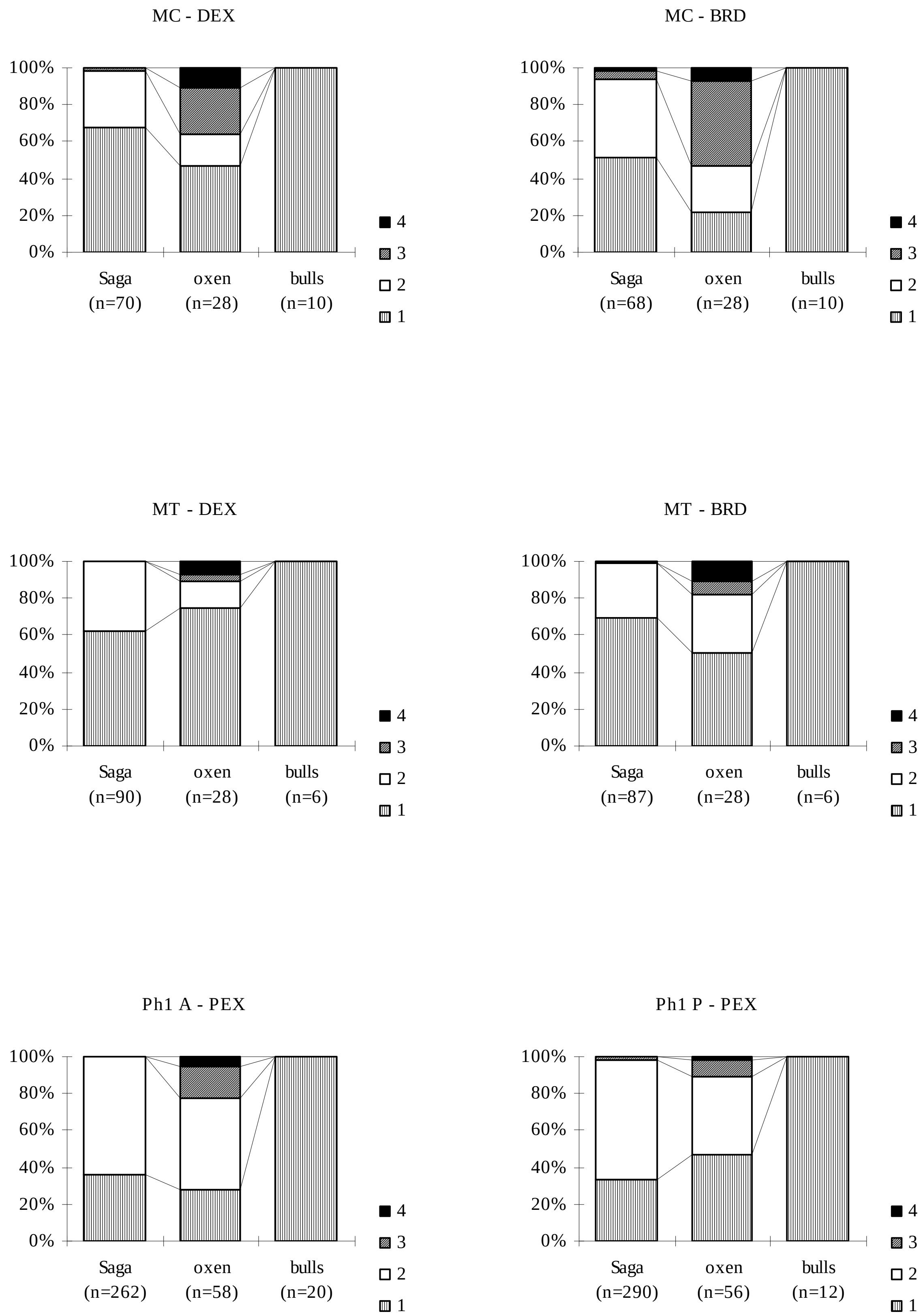

Fig. 2. Scores given to the metapodials and phalanges of Sagalassos (Saga), compared to the data on the modern oxen and young bulls (A: anterior; P: posterior).

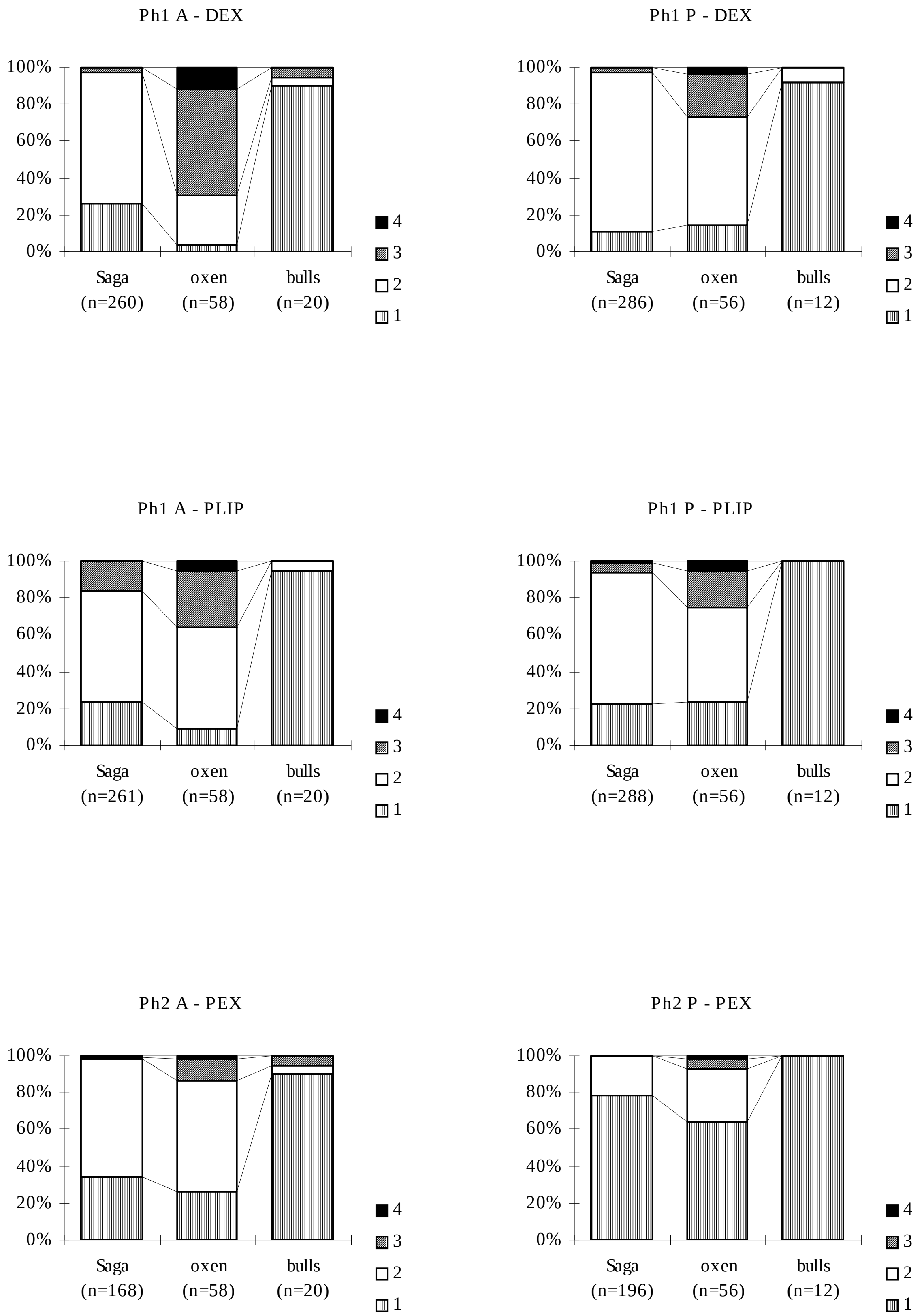

Fig. 2. continued

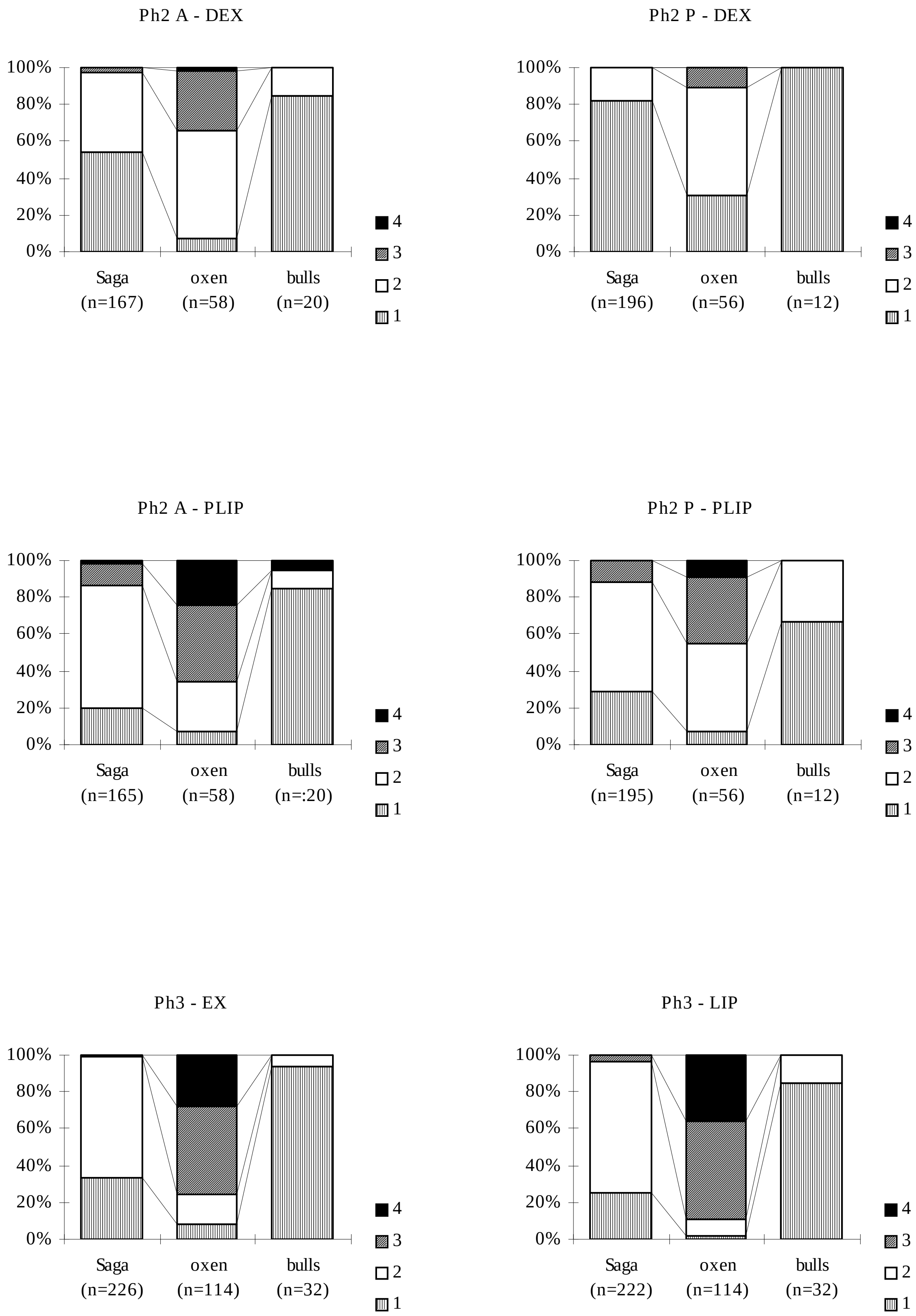

Fig. 2. continued

comprise bones from both females and males and it is likely that in this archaeozoological assemblage remains occur of animals that were never put to work. The presence of non-draught cattle tempers the relative frequency of the higher scores. Some exceptions are the distal exostosis on the metatarsals and proximal and distal exostosis on the posterior Ph1: relatively more bones in the Sagalassos material were given a score higher than 1 for these pathologies than was the case for the bones of draught oxen. This discrepancy might be related to the fact that not all pathologies defined by Bartosiewicz *et al*. (1997) are the result of draught but may be (partially) caused by other factors, such as age, weight, sex and substrate.

Complementary indications for draught use of cattle

The age and sex distribution of the slaughtered cattle can also be used to indicate the exploitation for animal power. Animals kept until an older age indicate that dairy products or physical power were important, whereas the occurrence of oxen can illustrate the keeping of draught-purpose cattle. Bulls castrated at an older age, however, do not display the typical slender stature of oxen and are therefore not easily distinguished from bulls. A more or less even distribution of mature females and males (i.e. bulls and/or oxen) might suggest that young males were not systematically removed from the herd as an exclusive source of meat.

The slaughtering pattern of cattle at Sagalassos indicated the consumption of mainly old animals and the study of the complete metapodials tells us that males and females were equally abundant (De Cupere & Waelkens 1998; De Cupere 2000.). Therefore, it was assumed that cattle at Sagalassos were primarily kept for their dairy products and power. With respect to the latter use, the ceramic industry at Sagalassos must be mentioned. The important potter's industry, which was located in the western part of the town, required a lot of raw material. The clays for this local ceramic production were partially derived from the quaternary sediments in the valley of Çanaklı, 8 km to the south of Sagalassos (Poblome *et al*. 1997), with a difference in altitude of about 400 metres. Not only the transport of the clays, but also that of the end-products, had to be secured: Sagalassos ware was mainly produced for the regional market of Pisidia (Poblome, 1996). It is, however, not excluded that equids (donkeys and mules) were partially used for this task as well, since their remains are also represented at the site.

Pollen analysis from a drilling core taken about 15 km south-west of Sagalassos, illustrated the vegetation history in the environment of the site (Vermoere *et al*. 1999, 2000). An important cultivation phase was recognised within the pollen diagram which covers the Imperial/Early Byzantine period. Already in Hellenistic times, the inhabitants of Sagalassos had to pay tribute in the form of enormous amounts of grain to Vulso (189 BC) and the region around Sagalassos was described as very fertile by Livy (38,15.9). According to literary sources, grain became the most important crop of Roman Anatolia and in the territory of Sagalassos, increasing farming activities are witnessed by an explosion of farming sites and settlements (Waelkens *et al.* 1997). Growing rural production demands, one can assume, an increase in the number of draught animals. Indeed, the study of the animal remains indicated that the relative abundance of cattle remains increased during the Imperial period (until the 4th century AD) (De Cupere & Waelkens 1998; De Cupere 2000.).

Discussion and conclusion

The incidence of osteoarthritis has been related to age, with higher incidence in old age, and can be explained by a tendency for articular cartilage to undergo degeneration with age as a result of which, it is less able to withstand injury (Vaughan 1960). Although no relation between age and pathological anomalies could be established for the modern draught oxen (Bartosiewicz, *et al.* 1997: 64), the study of the first phalanges from late medieval Koekelare (Belgium), where animal power is believed to have been provided mainly by horses and the cattle phalanges are interpreted as probably coming from non-draught cattle, appeared to score generally higher than the phalanges of the young Rumanian bulls (De Cupere *et al* 2000). The cattle at this site was mostly kept until old age and the higher values of the pathological index of the Koekelare site, in comparison with the young bulls, was related to the presence of old individuals. Despite the fact that cattle at Sagalassos were also slaughtered at an old age (see above), the mean pathological index of the Ph1 was higher than the mean at the Koekelare site (De Cupere *et al* 2000). Factors other than age are thus, responsible for the pathological deformations in the Sagalassos cattle.

The influence of the substrate on the development of pathologies was not examined in the Rumanian oxen, nor was sex (Bartosiewicz, *et al*. 1997). The substrate in the region around the site of Sagalassos is very uneven: the erosion of the underlying limestone results in loose stones and sharp edges on which the animals might injure their feet. The rather steep slopes around the town of Sagalassos created another obstacle. One can therefore assume that the substrate played a certain role in the development of pathologies in the feet of animals. Indeed, pathologies have not only been observed in cattle but also in ovicaprines (non-draught animals), albeit in very low numbers (De Cupere 2000). The following anomaly should also be mentioned here, i.e. depressions on the volar side of metapodials, more or less symmetrically above the distal epiphysis. This pathology was described by Bartosiewicz *et al*. (1997) for the modern oxen but not discussed in detail above. It results from a chronic inflammation of the articulary capsule. The capsules have extensions on the shaft in the shape of small pockets. When the pockets are constantly inflamed and swollen, the underlying bone can become remodelled and displays depressions (Van Neer & De Cupere 1993). In the case of Sagalasssos, depressions on metacarpals could be scored in half of the finds only, due to the incompleteness of the material and therefore this pathology was initially omitted from the present study. However, from the examined material it appeared that depressions were observed in 69% of the cases at Sagalassos, while only 44% of the Rumanian oxen showed this anomaly. The high incidence of depressions on the shaft of the Sagalassos metacarpals can thus not be interpreted as a result of draught work but seems rather to be inflicted by the irregular substrate.

Considering agricultural activities on the territory of Sagalassos and the potters' industry in the town, draught oxen must have been indispensable, both for farmers and craftsmen. Although the literary evidence regarding the town of Sagalassos does not specifically mention draught oxen, it is known from other sources that during classical times these animals were in general used for ploughing and pulling heavy loads (see above). Their presence on the site seems thus self-evident.

The applied methodology was initially established to determine the presence of draught animals at individual sites, based solely on cattle remains. It remains, however, quite difficult to unequivocally explain the pathological anomalies that are observed on the cattle metapodials and phalanges of Sagalassos. The rather low incidence of severe developed pathologies is probably due to the nature of the analysed collection, which consists of both males and females, some of which were never put to work. Slight deformations may occur in animals that were only put to work for a relatively short period of time or which were subjected to a milder work regime over a longer period. On the other hand, as light anomalies can also be related to age, substrate or other possible factors, individual finds with a poor development of pathologies should not necessarily be interpreted as the result of draught work. Only the various kinds of archaeozoological data combined with information from other disciplines, can lead to a correct understanding of the observed anomalies. Therefore, taking all facts under consideration – i.e. the frequency of the pathological deformations, their degree of development, the environment, the age at slaughtering, the sex distribution and the economical background of the site – the pathological deformations observed on the cattle metapodials and phalanges can be interpreted as, at least partially, the result of heavy labour.

Acknowledgements

This text presents research results from the Belgian Programme on Interuniversity Poles of Attraction initiated by the Belgian State, Prime Minister's Office, Science Policy Programming. The text also presents the results from the Conserted Action of the Flemish Government (GOA 97/2). Scientific responsibility is assumed by its authors.

References

Armour-Chelou M. and Clutton-Brock J., 1985. Notes on the evidence for the use of cattle as draught animals at Etton. In: F. Pryor, C. French and M. Taylor (eds), An interim report on excavations at Etton, Maxey, Cambridgeshire, 1982-1984, *The Antiquaries Journal*, 65: 297-302.

Baker J. and Brothwell D., 1980. *Animal diseases in Archaeology*. London, Academic Press.

Bartosiewicz L., Van Neer W. and Lentacker A., 1997. *Draught cattle: their osteological identification and history*. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 281. Tervuren.

Benecke N., 1994. *Der Mensch und seine Haustiere. Die Geschichte einer jahrtausendalten Beziehung*. Stuttgart, Theiss Verlag.

Cremer M., 1992. Hellenistisch-römische Grabstelen im nordwestlichen Kleinasien. 2: Bithynien. *Asia Minor Studien* 4. Bonn, Habelt.

Davis S.J.M., 1987. *The archaeology of animals*. London, B.T. Batsford Ltd.

De Cupere B. and Waelkens M., 1998. The antique site of Sagalassos (Turkey): faunal results from the 1990-1994 excavation seasons. In: H. Buitenhuis, L. Bartosiewicz and A.M. Choyke (eds), *Archaeozoology of the Near East III. Proceedings of the third international symposium on the archaeozoology of southwestern Asia and adjacent areas.* ARC publication 18, Groningen. pp. 276-284.

De Cupere B., Lentacker A., Van Neer W., Waelkens M. and Verslype L., 2000. Osteological Evidence for the Draught Exploitation of Cattle: first Applications of a new Methodology. *International Journal of Osteoarchaeology.*

De Cupere B., 2000. *Animals at ancient Sagalassos. Evidence of the faunal remains.* (Studies in Eastern Mediterranean Archaeolgy), Turnhout, Brepols.

Dottrens E., 1946. Etude préliminaire: Les phalanges ossueses de *Bos taurus domesticus*. *Revue Suisse de Zoologie* 53(33): 739-774.

Flach D., 1990. *Römische Agrargeschichte (Handbuch der Altertumswissenschaft III.9)*. München.

Isagher S. and Skydsgaard J.E., 1992. *Ancient Greek Agriculture*. London & New York, Routledge.

Jeskins P., 1998. *The Environment and the Classical World*. Bristol Classical Press.

Kehoe D.P., 1988. *The Economics of Agriculture on Roman Imperial Estates in North Africa (Hyponemata. Untersuchungen zur Antike und zu ihrem Nachleben 89)*. Göttingen.

Klemm R., 1981. *Die Steine der Pharaonen*. München.

Mennerich G., 1968. *Römerzeitliche Tierknochen aus drei Fundorten des Niederrheingebietes*. Unpublished dissertation, Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin, University of München.

Mitchell S., 1976. Requisitioned transport in the Roman Empire: A new inscription from Pisidia. *Journal of Roman Studies* 66: 106-131.

Parain C., 1966. Roman and medieval agriculture in the Mediterranean area. In: M.M. Postan (ed), *The agrarian life of the Middle Ages The Cambridge Economic History of Europe* 1: 126-179.

Peters J., 1998. *Römische Tierhaltung und Tierzucht*. Passauer Universitäts Schriften zur Archäologie 5. Rahden/Westf., Verlag Marie Leidorf GmbH.

Poblome J., 1996. Production and distribution of Sagalassos red slip ware. A dialogue with the Roman economy. In: M. Herfort-Koch, U. Mandel and U. Schüdler (ed), *Hellenistische und kaiserzeitliche Keramik des östlichen Mittelmeergebietes.* Frankfurt am Mainz. pp.75-103.

Poblome J., Viaene W., Kucha H., Waelkens M., Laduron D. and Depuydt F., 1997. The clay raw materials of Sagalassos red slip ware. A chronological evaluation. In: M. Waelkens and J. Poblome (ed), Sagalassos IV. Report on the survey and excavation campaigns of 1994 and 1995. *Acta Archaeologica Lovaniensia Monographiae*, 9: 507-518.

Raepsaet G., 1987. Transport de pierres en Grèce ancienne. De la carrière au chantier. In: *Marbres helléniques. De la carrière au chef-d'oeuvre*. Bruxelles, Crédit Communal. pp. 34-45.

Spurr M.S., 1986. *Arable Cultivation in Roman Italy c. 200 B.C.- c. A.D. 100 (Journal of Roman Studies Monographs 3)*. London.

Toynbee J.M.C., 1983. *Tierwelt der Antike*. Mainz, Verlag Philip von Zabern.

Uerpmann M. and Uerpmann H.-P., 1994. Animal bone finds from excavation 520 at Qala'at al-Bahrain. In: F. Højlund and H.H. Andersen (ed), *Qala'at al-Bahrain. The Northern City Wall and* *the Islamic Fortress*. Jutland Archaeological Society Publications 301. Aarhus, Aarhus University Press. pp. 417-444.

Vaughan L.C., 1960. Osteoarthritis in cattle. *The Veterinary Record* 72: 534-538.

Van Neer W. and De Cupere B., 1993. First archaeozoological results from the Hellinistic-Roman site of Sagalassos (Burdur Province; Turkey). In: M. Waelkens (ed), *Sagalassos I 1986-1991). First report on the surveys and the excavations*. Acta Archaeologica Lovaniensia Monographiae 5, Leuven, University Press, pp. 225-238.

Vermoere M., Degryse P., Paulissen E., Vanhecke L., Waelkens M. and Smets E., 1999. Pollen analysis of two travertine sections in Bağköy (southwestern Turkey): implications for environmental conditions during the Early Holocen. *Review of Palaeobotany and Palynology*.

Vermoere M., Waelkens M., Vanhaverbeke H., Librecht I., Paulissen E. and Smets E., 2000. Late Holocene environmental change and the record of human impact at Gravgaz near Sagalassos, Southwest Turkey. *Journal of Archaeological Science.*

Von den Driesch A., 1975. Die Bewertung pathologisch-anatomischer Veränderungen an vor- und frühgeschichtlichen Tierknochen. In: A.T. Clason (ed), *Archaeozoological studies*: Amsterdam, North Holland Publishing Company. pp. 413-425.

Waelkens M., 1977. Phrygian votive and tombstones as sources of the social and economic life in Roman antiquity. *Ancient Society* 8: 277-315.

Waelkens M., 1986. *Die Kleinasiatische Tursteine: typologische und epigrafische Untersuchungen der Kleinasiatischen Grabreliefs mit Scheintur*. Mainz am Rhein, von Zabern,.

Waelkens M., Paulissen E., Van Haverbeke H., Öztürk I., De Cupere B., Ekinci H.A., Vermeersch P.-M., Poblome J. & Degeest R. 1997.The 1994 and 1995 surveys on the territory of Sagalassos. In: Waelkens, M. and Poblome, J. (eds), *Sagalassos IV. Report on the Survey and Excavation Campaigns of 1994 and 1995 (Acta Archaeologica Lovaniensia Monographiae 9).* Leuven, University Press, pp. 11-102.

White K.D., 1970. *Roman farming*. London, Thames and Hudson.