Pathologies of Medieval Horses of the Netherlands – An Analysis of the Pathologies of the Medieval Horses from De Hoge Hof

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Pathological phalanges (R. Kost)

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Master Thesis – Archaeological Science

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Leiden, 01-07-2020, Final Version

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1. Introduction

(Osteo)Pathology is the study of the origin and effects of abnormal structural and functional changes in the body, which usually result from either trauma or disease (Reitz and Wing 2008, 170). Pathologies can yield significant insight into the relation between humans and animals. Osteopathologies in particular can evidence how animals were treated, the way they were kept, or the way they were used. Bone is a dynamic material that reacts to external influences like trauma or diseases. There are two ways bone can react to trauma and disease (excluding some abnormalities in skeletal development): the forming of new bone, or the resorption of bone. In order to identify the possible cause, the spread of the pathological changes throughout the skeleton is of great importance. However, this is a difficult task for archaeozoological materials since most of the materials consist of individual or fragmented bones that are rarely articulated or associated to one single individual (Groot 2010, 92). Making a diagnosis based on a single fragment is very hard, which is why paleopathology for archaeozoological remains is still very underdeveloped (Groot 2010, 89-92).

Unlike the investigation of paleopathology in humans, literature on the analysis of paleopathology in animal remains has been rare so far (Janeczek *et al.* 2010, 331). Paleopathology, to this day, is still mainly based on the classical publication of Baker and Brothwell in 1980 based on macroscopic pathological changes in archaeozoology. There is still no definitive and detailed system or nomenclature for animal paleopathology, often leading to different terms used by different publications (Markovic *et al.* 2014, 83). There has been both optimism on the use paleopathology in archaeozoology as well as caution and pessimism. The diagnosis and interpretation of paleopathologies can be very difficult and even in modern clinical situations after a post-mortem pathologists are not always able to make a reliable diagnosis (Siegel 1976, 350). In bones from archaeological contexts, after all manner of taphonomic processes, this will be even harder and coming to a diagnosis can be problematic (Siegel 1976, 350).
From both human and animal sources, it has been stated that there are difficulties with distinguishing between pathological changes and pseudopathological changes. These are changes to the bone that are caused post-mortem by edaphic factors, physicochemical decomposition, insect action, or animal gnawing (Wells 1967 in Siegel 1976, 350).
Other issues are the possibilities of inaccurate identification of pathologies due to a general lack of knowledge of the parameters of normal variation. This is especially true for wild forms due to the

lack of knowledge regarding the occurrence and nature of diseases in wild populations (Siegel 1976, 350).
It is also important to understand that most diseases primarily leave their mark in the soft-tissue. Only in more severe cases do diseases typically leave their mark on the bones as pathological changes. One should keep in mind that pathological changes on the bones represent only the bare minimum of diseases that were present in ancient populations (Siegel 1976, 355).

However, regardless of the difficulties and possible problems with the use of paleopathology in archaeozoology, the reporting and describing of pathologies should be encouraged. Research done on pathology in human populations has built up significant amounts of literature (Siegel 1976, 350). A similar base of knowledge should be possible for pathologies in animals. The Animal Palaeopathology Working Group of the ICAZ has already made a commendable start to such a base of knowledge by managing a searchable bibliography of publications on the topic of paleopathology (www.zotero.org).
From modern day research it is clear that pathologies can be the result of a variety of factors that include malnutrition or mismanagement as a result of husbandry practices by humans. The research on paleopathologies in archaeozoological contexts could yield insight into the husbandry practices of animals in past societies and the role these animals played in said societies (Siegel 1976, 350-351).

The frequency of pathologies in a population and in an archaeozoological assemblage can be influenced by many factors. For example, a low frequency of pathologies might indicate that the population was young and fit, while a high frequency of pathologies might be explained by local inbreeding causing an increase in detrimental genetic traits or by poor husbandry practices (Siegel 1976, 357). But other variables, such as economic factors may be at work as well. For example, animals exploited for meat are often slaughtered at a young age. This could lead to an “increase” in the relative frequency of diseases that develop in young animals such as rickets or neonatal infections. On the other hand diseases that tend to occur in populations of older animals, such as degenerative, senile and infectious changes, are likely less frequent due to the composition of the population because of economic reasons (Siegel 1976, 357).

Different forms of pathology occur in differing frequencies throughout the body of different animals. In a research on a British Neolithic to Medieval site, Siegel identified 141 pathologies of which oral pathologies were most common (33%) (Siegel 1976). These were mostly found in oxen with a particularly high frequency of absence of the first lower molar. Arthropathy, here defined as non-infectious degenerative pathologies of the joint, was second in frequency with 20% and were mostly

found in the tarsals and metatarsals of horses, likely due to use of the horses as draught animals. Fractures accounted for 10% of the pathologies and were most common in dogs. Finally, hunting game, such as red deer and fowl, had no pathologies, likely due to underrepresentation in the assemblage (Siegel 1976, 357-362). Another research by Dzierzecka *et al.* regarding pathological changes in Iron Age and medieval horses showed that fractures were the most common condition (Dzierzecka *et al.* 2008, 693).
Because the occurrence and frequency of pathologies differs per species and location, for this research, the choice has been made to focus on pathologies in a single species of animal: horses.

Horses have been chosen due to the variety of roles these animals played in past societies, from riding horses to war horses, to draught horses. Horses have been used primarily to ride since the end of the Bronze Age (3500 BC) onwards (Outram *et al.* 2009, 1332). Horses are somewhat unique as a domesticated ungulate given that they are mostly used for a variety of tasks rather than just for exploitation of food. In the case of medieval horses in the Netherlands, they have typically not been consumed, hence their bones tend to be less fractured compared to food animals of similar size such as cattle. Cutting and chopping marks are also less common, although their radii and metapodia were used for the production of objects (Lauwerier 1997a, 483-484). Their role as riding or draught animals instead of food animals means that the horses should live longer and have more time to develop pathologies that could be used to indicate a particular role. The idea is that different tasks lead to different forms of pathology and to pathologies in different places. Levine *et al.* pointed out that the stresses on the horse caused by riding and traction differ from natural activities, as well as being distinguishable from each other (Levine *et al.* 2000, 125). Since most horses are typically used for one task, it would be expected that these different tasks are identifiable (Levine *et al.* 2000, 125; Markovic *et al.* 2014, 83). In this way paleopathology could give insight into the role that the horses played in their human society. In order to do this, it is important to understand the context a horse is found in to be able to relate pathologies to their use (Markovic *et al.* 2014, 77), since the range of pathological changes on the bone are limited. On the other hand however, one should also keep in mind that not every pathological change is necessarily the result of the interactions between humans and horses. Some pathologies may be caused or influenced by other factors such as genetic components, age and weight (Levine *et al.* 2010, 125).

Unfortunately, it should be noted that publications and reports of pathologies in horses are somewhat limited in general (Janeczek *et al.* 2010, 333). In particular, there are hardly any publications on the pathologies of medieval horses from the Netherlands. This research will attempt to make a start on the topic of pathological changes in medieval horses. To do so, the following research questions have been postulated.

What can pathologies tell us about the use of medieval horses in the Netherlands?

In order to answer this broader question, several sub-questioned will have to be investigated.

What forms of pathology can be found in Medieval Horses from the Netherlands?

Which skeletal elements of Medieval Horses from the Netherlands are most commonly affected by pathology?

Which different forms of pathology on Medieval Horses from the Netherlands are related to human interactions and how (activities, husbandry practices, living conditions)?

It has been established that the amount of literature on pathologies on horses is limited, especially so in the Netherlands. It is important to understand what the investigation of pathologies on horses can add to our knowledge and understanding of the Middle Ages, but also what its issues and pitfall are and if it is warranted that the amount of literature is so limited.

What are the advantages, disadvantages and difficulties of investigating the use of Medieval Horse remains based on their pathologies?

To answer these question, the archaeozoological remains from a mostly medieval site of De Hoge Hof, Tiel – Medel have been investigated. This site contains a large amount of archaeozoological remains, including a large amount of horses, and it was known that several pathologies had been found among the horse remains. Moreover, the preservation of the site was high as well making this an ideal site to investigate horse pathologies from the Middle Ages.

2. An Overview of Animal Pathology

Analysis of paleopathology in archaeozoology is to this day still mainly based on macroscopic analysis of changes to the bone as described by Baker and Brothwell. There is still no detailed and definitive systematization or nomenclature for bone pathology. This often results in different terms being used for the same pathological change (Markovic *et al.* 2014, 83) or incorrect use of terms (Baker and Brothwell 1980, 114). In order understand paleopathology, an overview of different pathologies that may occur in horses has been gathered from current available archaeozoological reports and the work of Baker and Brothwell. First off all, a general overview of pathologies found in animals is presented. This is followed by an overview of pathologies that are known in horses from current archaezoological research and publications.

2.1. General Overview of Animal Pathology

2.1.1. Abnormalities of Skeletal Development

These forms of skeletal defect fall in two types.

- Inherited: these abnormalities have an inherited genetic basis. These abnormalities can manifest at any point during life.
- Congenital: these are abnormalities that are present at birth and have no known genetic basis.

It is important to question what is abnormal. Prehistoric and even historic animals will not show as extreme variations like in the modern day domesticates (particularly visible in dogs). There is however significant variation of features within one species within its natural variety (Baker and Brothwell 1980, 32).

It is generally not easy to distinguish between inherited and non-inherited abnormalities. In addition, abnormalities of bone development are likely underrepresented in archaeological context due to the following reasons:

- Minor anomalies require detailed knowledge to be detected.
- Many lethal abnormalities result in death in perinatal period. This leads to bones being poorly mineralized and thus poorly/rarely preserved.
- Abnormalities of joints mainly affect soft tissue which will (usually) be missing in archaeological materials.

There are however abnormalities described from archaeological sites such as a horse from an 8th century Hungarian site with a supernumerary incisor from Bökönyi (1974) in Siegel (1976, 357).

2.1.2. Diseases of the Immature Skeleton

Harris's lines or lines of retarded growth are a non-specific indicator of disease or malnutrition that will show in bones. They are difficult to see in dry specimen, but can be detected radiologically. They consist of thin lines of increased radiodensity, or sometimes as radiolucency, that are parallel to the epiphyseal plate. They reflect a factor that temporarily stopped growth of the bone. There are three forms of Harris's lines, each with different causes (Baker and Brothwell 1980, 45):

- Most common form is produced when the epiphyseal cartilage formation stops, but osteoblastic ossification persists on the primary and secondary trabeculae resulting in the area becoming hypercalcified. When the animal recovers from the illness these show as radiodense lines and are carried down into the metaphysis as bone growth resumes (Baker and Brothwell 1980, 46).
- If osteoblastic bone formation and cartilage growth both cease, hypermineralization of the zone of provisional calcification occurs. This also results in increased radiodensity. However, when growth recommences this line is only very weakly persistent due to the formation of trabeculae (Baker and Brothwell 1980, 47).
- When cartilage proliferation persists and osteoblastic activity is suppressed, a wide line of hypomineralized cartilage appears and this is carried down into the shaft. When osteoblastic activity resumes, it usually does so at the correct distance from the articular side of the growth plate so that a radiolucent line persists in the metaphysis. Lines of this type may be seen in scurvy and rickets (Baker and Brothwell 1980, 47).

The most common form of disease in immature animals are osteodystrophies. These are defective bone developments attributed to the calcium and phosphorus metabolism. These diseases show particularly in the more active epiphyseal plates (Baker and Brothwell 1980, 47).
Rickets are the classic example of this type of growth disease and it is more common in herbivores. It occurs when the animal has a diet with a mineral deficiency (usually phosphorus relative to calcium) combined with a vitamin D deficiency. Generally, the most obvious pathological change is an irregular thickening of the epiphyseal plates with production of spines of cartilage extending down into the metaphysis. In conjunction with the thickening there is a flaring of the adjacent area of the metaphysis, giving it a splayed or cupped appearance. As the periosteum continues to produce bone, it becomes poorly mineralized and an osteomalacia (softening of the bone) develops. In weight

bearing bones this may lead to bowing. This is a relatively common disease in the archaeological record, but it is much more common in humans than in animals (Baker and Brothwell 1980, 49). Other osteodystrophies are not well known outside of the veterinary discipline and are rarely commented on in archaeological materials (Baker and Brothwell 1980, 52).

Osteoporotic conditions (weakening of the bone) are a problem in modern herbivores. They are the result of dietary insufficiencies and cause the production of normal bone, but with a thin cortex of regular density. This condition is rarely noted in archaeological materials. This may be due a lack of awareness of the condition or because all animals of the site are affected and thus perceived as normal. However, this may well be present as some experts have mentioned a greater cortical thickness in the bones of wild herbivores (Baker and Brothwell 1980, 53-54).

Epiphysitis or “angled legs” is a condition that occurs in all species of domestic mammals, but it is particularly prevalent in horses and pigs. It is debated whether this should be considered a pathological change and it is very hard to spot unless one would be very familiar with the condition, but it is obvious when there is marked metaphyseal lipping (Baker and Brothwell 1980, 56-58). Separation of the epiphysis can occur in young animals as a result of traumatic causes, but in horses may also be present in the femur of horses without considerable trauma. Late stages of this condition may be detected in archaeological materials as eburnation and localized sclerosis as result of a false joint between the metaphysis and epiphysis (Baker and Brothwell 1980, 59).

2.1.3. Inflammation and Infection

Inflammation is a condition that is very common in both modern and archaeological material. Inflammation is generally caused by neglect or the impossibility to reach the place and is difficult to treat. It results in lesions that can be of considerable size. Inflammation in bones can have three types of pathological origin (Baker and Brothwell 1980, 63):

- Osteomyelitis: this is when the disease originates in the marrow cavity. Osteomyelitis is commonly found in archaeological materials. Examples of causes of osteomyelitis include compound fractures combined with broken skin and laminitis (an inflammatory process affecting the feet of horses and cattle) (Baker and Brothwell 1980, 68-73).
- Osteoperiostitis: this is when the disease originates in the periosteum. This can be caused for example by recumbency, certain infections or traumatic damage (Baker and Brothwell 1980, 75-77).
- Osteitis: this is when the disease originates in the soft tissue contained within the compact tissue of the bone shaft. This is however very rare (Baker and Brothwell 1980, 63).

Each type of pathological origin may indicate a different causal agent, but it is often times difficult to impossible to distinguish in archaeological materials as the inflammation tends to spread to all three sites (Baker and Brothwell 1980, 63).

2.1.4. Traumatic Injuries

Traumatic injuries or wounds as defined as "disruptions of continuity of an external or internal surface of the body (Baker and Brothwell 1980, 82). Traumatic injuries can caused by many things and have various forms. Not all traumatic injuries leave a mark on the bones. Trauma that cause cuts, lacerations or puncture of soft tissue may result in infection, but they are not necessarily detected in the bone.

Contused wounds from blunt impact can result in pathological change in the bone. Bleeding at a sub-periosteal level can occur in the area of the impact. In this case, swelling may gradually be replaced by a smooth bone swelling. This is called an ossified haematoma. If there is rupturing of tissue insertion onto the bone, the newly developing bone may become more irregular. This is sometimes referred to as a "traumatic osteoma" (Baker and Brothwell 1980, 83).

Traumatic injuries that are sustained near the death of the animal can be problematic to identify since there has not been enough time for repair and changes to occur. It has been argued that the shape of the fractures is different in fresh bones and buried bones. Older buried bones tend to snap "cleanly"; however, there is a grey area that may occur between trauma during life and post-mortem damage to the bone. For this reason only traumatic damage with evidence of healing or inflammatory reaction is addressed (Baker and Brothwell 1980, 83-85).

Different causes for traumatic injuries can be classified to a degree as presented by Baker and Brothwell, although one should keep in mind that, after healing, it may not always be obvious to which category they may belong (Baker and Brothwell 1980, 85):

- Greenstick/Incomplete fractures: this consists of cracking or splitting without complete separation in young animals as result of bone stress. After healing, few traces may be left except for a possible light deformity of the shaft (Baker and Brothwell 1980, 85).
- Simple fractures: this are clean breaks all the ways through in a single position. After healing, mal-union may occur as the bones heal in a different position to each other. Healing will result in the formation of callus and bone remodelling at the site of the fracture. If there is too much movement, a false joint may form with two separate callus areas. This is particularly likely in the ribs (Baker and Brothwell 1980, 85).
- Comminuted fractures: these are fractures that show crushing or multiple fragmentation. Once healed, it is hard to differentiate from simple fractures (Baker and Brothwell 1980, 85).
- Compound fractures: these are fractures with added complications from infection as parts

of the fractured bone may have come into contact with the external surface (Baker and Brothwell 1980, 85).

- Fissured/Incomplete fractures: these are incomplete fractures in adult animals. These are commonly found in flat bones in the skull as cracks. Additionally, these are also found in horse tibia as result from kicking (Baker and Brothwell 1980, 85).
- Epiphyseal fractures: these are fractures of the epiphysis. These can occur in several different forms (Fig.1) (Baker and Brothwell 1980, 87).

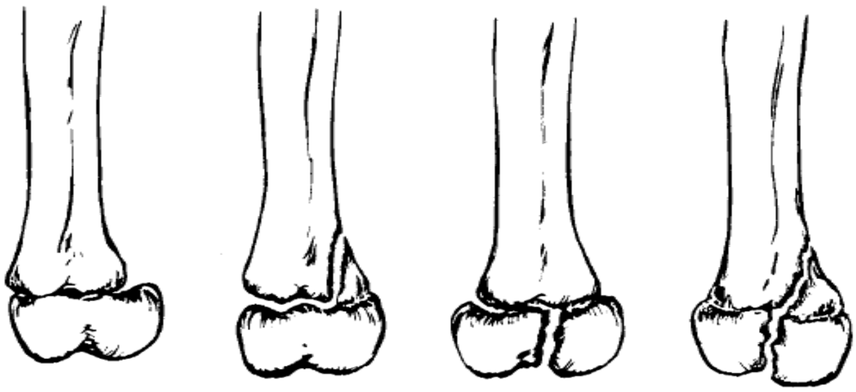

Fig.1. Different types of epiphyseal fractures (after Morgan 1972 in Baker and Brothwell 1980, 86).

2.1.5. Neoplasia

Neoplasia are abnormal growths that are uncontrolled by body mechanisms independent of the adjacent tissue. Neoplasia are particularly rare in archaeological materials. Neoplasia can be grouped in two different groups (Baker and Brothwell 1980, 96-98):

- Benign growths: benign growths are slow growing growths. They are discrete with a smooth surface and displace adjacent tissue instead of invading it. Benign growths tend to relatively small (Baker and Brothwell 1980, 96).
- Malignant growths: malignant growths are fast growing growths. They have an irregular surface due to invading surrounding tissues. They tend to spread to other parts of the body and produce secondary lesions there. These growths tend to be uncontrolled (Baker and Brothwell 1980, 96).

2.1.6. Diseases of the Joints

Joint diseases are the most common abnormalities that is found in animal skeletons. These joint diseases can be grouped together in a number of different disease processes (Baker and Brothwell 1980, 107).

Osteoarthitis is a degenerative disease that primarily affects the articular cartilage. It is generally caused by repeated trauma to the joint from for example heavy work. As such, it is often found in draught horses. Unfortunately, osteoarthritis is often misused for any conditions of the joint. Baker and Brothwell state that for a definitive diagnosis of osteoarthritis to make based on archaeological materials, at least three the following conditions should be met (Baker and Brothwell 1980, 114-115):

- Grooving of the articular surface of the bone.
- Eburnation.
- Extension of the articular surface by new bone formation.
- Exostoses around the periphery of the bone.

Spavin is a disease of the tarsus of horses, although it can also occur in other draught animals such as cattle and camel. It is a condition that affects the small bones of the medial of the joint, but it can also be found in other parts of the joint and it is called high spavin. It generally causes exostoses that limit movement, with exception of occult spavin which is when there are not significant exostoses on the small tarsals. Likely factors in developing spavin are faulty shoeing, heavy work and working on hard surfaces. Usually spavin causes a mild degree of lameness. With time and rest, the joint will ankylose and the animals will still be able to be used for slow work (Baker and Brothwell 1980, 117-119).

Ringbone is another form of exostoses. It is a disease of the fore feet of heavy draught horses. While there is no accurate definition of ringbone, it generally is described as any bony exostoses affecting the interphalangeal joint of the horse’s feet or any bone enlargement in the region. Ringbone is divided in three types. High ringbone is when the interphalangeal joint between the first and second phalange are affected. Low ringbone is when the interphalangeal joint between the second and third phalange are affected. False ringbone may occur on the shaft of the first or second phalange. It does not affect the joint, although lesions may spread along the shaft and may eventually cause ankylosis of the joint. Ringbone is caused by similar factors as spavin involving concussive effects such as heavy work and working on hard surfaces (Baker and Brothwell 1980, 120).

Bacterial infections of the joint can lead to osteomyelitis. Osteomyelitis can cause pitting of the epiphysis that is distinct from the grooving from osteoarthritis. After overcoming the infection, two exposed bone ends, may end up fusing together (Baker and Brothwell 1980, 123).
Luxation (dislocation) and subluxation (severe sprain) can cause tearing in the ligaments. This may lead to ossification of the ligaments that are detectable in archaeological materials. In chronic cases of dislocation, which is often the case in large farm animals, a false joint may form as the femur

comes into contact with the ilium. This may also cause extensive bone remodelling (Baker and Brothwell 1980, 126-127).

Spondylosis deformans or vertebral osteophytosis is a disease that causes lesions to form in the lumbar region of riding and work horses. Although, it is also found in the thoracic region of the spine of prehistoric wild horses (Baker and Brothwell 1980, 129-131).

2.2. Overview of Paleopathology of Horses

Following is an overview of pathological changes in horses described in archaeozoological literature. Specifically in the case of horses, teeth pathologies and four parts of the post-cranial skeleton bear most pathologies that are related to their use: the lower limb bones, the hip bones, the shoulder bones and the vertebral column. Shoulder and hip pathologies are typically characteristic of traction. Pathologies to the vertebrae are typically associated with riding. It has also been suggested that pathologies to the cervical vertebrae are related to confinement since horses in stables would have had their heads elevated for long period of time rather than having its head down when grazing (Levine *et al*. 2000, 125).

2.2.1. Cranial and Dental Pathology

The Byzantine horses from Theodosius harbour are an excellent example of an in-depth study on teeth pathologies in archaeological horses (Onar *et al.* 2012). In this site, 20 horse skeletons were excavated exhibiting a wide variety of teeth pathologies in both upper and lower teeth of horses. The dental pathologies consist of caries, oligodontia, abscess chambers, alveolar recession and unusual teeth wear. The teeth wear, caries and abscess chambers, were most likely caused by the use of a certain type of bit. This bit wearing probably caused the inflammation of the palate, producing lesions of varying degree and in some cases perforations (Onar *et al.* 2012, 141).
Some horses evidenced osteophytic proliferation on the *Dorsum nasi* (nasal bone). Such proliferations are thought to be caused by bridles exerting pressure on the snout (Onar *et al.* 2012, 141).

Another curious example was presented by Diedrich (2017) who described dental pathologies from 19th century mining horses from Central Bohemia, Czech Republic. From this context, almost none of the horses had normal tooth rows or straight occlusal tooth rows surfaces. Additionally, the jaw joints of the horses were non-smooth and irregular in shape and joint convexity (Diedrich 2017, 18).

Most horses had uplifted second premolars in the lower mandibular and in some cases, there was a concave abrasion in the P_2. These dental pathologies were likely caused by pressure from the snaffle bit while the horses were used for wagon pulling. Identical concave abrasions on the anterior surfaces of the P_2 are known from both from modern riding horses and archaeological horses since the Hallstatt culture (Bronze Age), Egypt Middle Kingdom and different sites from the Iron Age (Azzaroli 1985; Bökönyi 1968; Clutton-Brock 1974; Liesau 2005). In exceptional cases the snaffle bit may even slip over the P_2 after the loss of the upper premolars. In this case abrasion by the bit causes a strong concave occlusal surface on the P_2 and P_3. The P_3 was even conical as it was rubbed by the bit on the anterior side and by the upper P^4 (before tooth loss of the P^4) on the posterior side (Diedrich 2017, 18-25).
Dental pathologies in the incisors are known also from the mining horses from Central Bohemia. Several horses with unusual antero-occlusal wear on the upper and lower I1 and I2 or a broken upper I^1 with further polishing are described. These dental pathologies were explained by stressed horses in the mining stables. These horses would have moved heads up and down rapidly with their anterior teeth touching the ground at times (Diedrich 2017, 25).

2.2.2. Vertebral Pathology

Back problems are one of the most common veterinary problems in modern day horses (Janeczek *et al.* 2012, 623). However, pathologies in the spine are found in horses from archaeological contexts from all manner of periods. Since the domestication of horses, the occurrence of vertebral pathologies may have been increased in contrast to wild populations. Since horses were highly valued due to their use as riding animals, their longevity increased and the pressure of natural selection decreased. This way, domestication has introduced pathologies that would not have existed due to natural selection and increased the frequency of naturally developed pathologies. In fact, an increased in the frequency of pathological lesions through time could be regarded as a sign of domestication (Bartosiewicz & Bartosiewicz 2002, 828-829).

Vertebral fusion has been described in archaeozoological literature on multiple occasions (Janeczek *et al.* 2012, 623). Vertebral fusion is a condition that is usually found in middle aged and old riding horses as well as draught horses. In severe cases it may develop into so called “bamboo spine” which forms when the long ventral ligaments ossify and form a glaze-like spondylotic crust (Diedrich 2017, 25). The condition has typically been attributed to repetitive strain injury (RSI). However due to culling in modern veterinary practices it is a rare condition (Bartosiewicz & Bartosiewicz 2002, 819). The fusion of 2 to 4 vertebrae is not uncommon to be found in proto-historic horses, but the fusion of 10 vertebrae or more is extremely rare. The first occurrence of ankyloses of more vertebrae is known from an ancient horse from the Avar Period described by Bökönyi (Bökönyi 1964 in Bartosiewicz & Bartosiewicz 2002, 820). The condition is best known from horses from the second half of the first millennium AD from central Europe. The overrepresentation of horses with vertebral fusion might be related to the Migration Period and early medieval burial practices since horses were often entered in burial. The buried horses are well articulated and taphonomically similar to human burial leading to better palaeopathological data and thus likely overrepresented compared to other periods. Some cases are also known from Roman provincial sites and Iron Age sites; however from the Middle Ages there are few reports of the condition (Bartosiewicz & Bartosiewicz 2002, 820).

It has been stated that vertebral fusion occurred in the dorsal vertebrae for pre-Roman wild horses while in modern riding horses it occurs mainly in the lumbar vertebrae (Bartosiewicz & Bartosiewicz 2002, 824). This was tested by L. Bartosiewicz and G. Bartosiewicz and they concluded that riding is a major contributor to the development of vertebral fusion. The variation in the location of the pathology may be due to differences in saddling given that improper saddling is often pointed to as a factor of vertebral pathologies. While riding and RSI are major contributors to the vertebral fusion, severe cases such as the “bamboo spine” cannot be explained just by excessive riding. As such, riding is often overemphasized in archaeozoology (Bartosiewicz & Bartosiewicz 2002, 828). Other authors suggest that vertebral fusion is produced by the saddle and often caused by long-lasting and excessive loading. Usually the horse is overloaded at a young age before the locomotor system of the animal has fully developed producing such conditions, but other factors are at work as well such as the type of saddle and the characteristic and riding style of the rider (Janeczek *et al.* 2012, 630-631).

The severity documented in some cases of vertebral fusion usually suggests that the condition developed over a long time. Sometimes symptoms may have been limited but did not affect the animal’s use causing the condition to grow more severe. In this way, there is a proposed sequence of symptoms consists of: 1) chronic inflammation of the spine muscles, 2) lameness, 3) osseous tissue reaction, 4) rider intolerance, and 5) irreversible changes in the locomotor system (Janeczek *et al.* 2012, 631).

Within the mining horses studied by Diedrich, other vertebral column pathologies were recorded. These include the kissing spine syndrome. In this condition, only the dorsal spinous processes of some of the thoracic vertebrae are fused together (Diedrich 2017, 25).
Vertebral articular surface lipping were also found in two mining horses of 4.5 and 6 years old. In this condition a lip or spur of bone growth forms on the dorsal side between the articular surfaces of two

vertebrae. The condition is found in both the thoracic vertebrae and the lumbar vertebrae (Diedrich 2017, 25).
Synovial intervertebral inflamed line is a pathology where the bone surface around the articular process (or zygapophyses) shows inflammation dissolution and deformation structures. This condition was present in a 4 year old mining horse (Diedrich 2017, 25).
Synovial intervertebral osteoarthritis is a condition in which periarticular bone growth forms on the articular process and finally connect and fuse the vertebrae. It is found in a 4.5 year old horse on three thoracic vertebrae as well as a 16 year old horse where only the right side is fused (Diedrich 2017, 25).
Finally, bamboo spine behind the saddle is typically seen as an indicator of riding. Strongly connected spines with fusion of middle thoracic vertebrae and lumbar vertebrae are also interpreted as riding pathologies, but in the case of the mining horses, the pathology may also have been the result from constant heavy wagon pulling (Diedrich 2017, 25).

2.2.3. Pathology of the Limb Bones

It has been generally agreed that most of pathological changes in horses concern the limb bones, even though the majority of horse bones that are retrieved and identified are also limb bones. Chest and spine bones are less commonly excavated due to taphonomic biases.
An extensive research on horse pathologies in a Polish medieval sample provide very interesting insights on limb bones pathologies (Dzierzecka *et al.* 2008). They concluded in their research that fractures were the most common pathological change, the majority of which occurred in limb bones and it was attributed to overloading. The research of Dzierzecka *et al.* illustrated that pathological changes in the horse skeleton are indeed the most common in the limb bones, particularly the autopodial parts, and that taphonomical biases are not biasing that figure much.
The high amount of fractures were associated by these authors with morphophysical changes in the bone tissue as result of domestication. The bones of domesticated horses had a lower specific weight, less compact bone substance and a bigger marrow cavity compared to their wild counterparts. This may be the result of the change in nutrition driven by domestication (Dzierzecka *et al.* 2008, 693). However, they also noted that many pathological changes appear in wild ancestors and thus cannot be linked to the domestication of horses, husbandry practices or the use of horses (Dzierzecka *et al.* 2008, 693-694).

Another research on animals from the Roman city of Sirmium, Serbia, showed pathological changes to the metacarpal bones as the most common pathologies, especially in the form of exostoses and splints (Markovic et al. 2014). Other pathological changes included osteoarthritis, periostal ossification plaques, scaly bones deposits, osteophytes, sclerosis, zones of decreased bone density, and exostoses on proximal and distal parts of the bone. Fractures or metabolic diseases of bones were not observed in horses (Markovic *et al.* 2014, 81). The high frequency of splints in the front horse limbs were likely the result of great loading from riders. This is supported by the presence of a hippodrome in the city. Splints occur in young horses subjected to early sport training, but is most often seen in horses of 3 to 4 years old. It is a possible reason for lameness in horses (Markovic *et al.* 2014, 84-85).

Another study focused on the limb skeletal elements most affected by pathologies (Onar et al. 2012). These authors found that pathologies were most common in the metapodia and phalanges of both the fore and hind limbs. Pathologies included splints, sore shin, spavin, and ringbone. Several horses show degenerative lesions on the front of the distal phalange. This was interpreted as laminitis. Other phalanges showed ossification of the cartilage of the hoof (Onar *et al.* 2012, 142).

The Bohemian mining horses reported by Diedrich evidenced also several forms of pathology in the limbs. On the pelvic bone and proximal end of the femur, exostoses were formed around the joints and surrounding areas at several locations. This condition is known as coxofemoral osteoarthritis (Diedrich 2017, 25). It is likely that they were the result of stress by the pulling of heavy wagons (Diedrich 2017, 31).
Osteoarthritic lipping is another condition found in the limbs of mining horses. This condition consists generally of a combination of conditions in the third metapodium with the following characteristics: 1) marginal exostoses, 2) fusion of the carpalia/tarsalia, 3) necrosis of the joint surfaces, and 4) lipping in the final stage of fusion. In the most severe cases, all tarsalia are fused to each other, to the metatarsus and severe exostoses are present. These pathologies involving lipping are attributed to standing on hard surfaces and at wrong angles or general stress on the joints (Diedrich 2017, 25). Finally, fusion of the splint bones to the third metapodia has been also described, often in combination with lipping pathologies. In this context it is also attributed to standing on hard surfaces and at wrong angles and general stress on the joints, but the practice of bandaging of the legs for protection may have been a factor as well (Diedrich 2017, 25).

3. Archaeological background of De Hoge Hof

The materials investigated for this thesis derives from the excavation at the site of De Hoge Hof near Tiel, the Netherlands. Tiel is situated in the riverine area of the Netherlands. The excavation was performed for the expansion of the business park Medel to the northeast of Tiel. Previous research identified several sites deemed worthy of preservation. The site of De Hoge Hof, site 9, monument number: 3641, is one the locations identified for preservation by the RCE (Rijksdienst voor Cultureel Erfgoed) (Dijkstra and Mousch 2016, 1).

The site contains archaeological evidence from the Roman period, but most material derives from the Early Medieval to Late Medieval periods. Previous research showed the presence of intensive habitation from the Roman Period to the Late Medieval period with a hiatus between the Late Roman Period and the 8th century A.D. Roman occupation was mainly situating in the southern part of the site. From the Medieval period, a settlement was located on the site bordered by a residual channel of the Echteldse stroomgordel (Dijkstra *et al.* 2016, 5-6). While the southern part of the site was able to be preserved, the northern part had to be excavated for preservation ex situ (Dijkstra & Mousch 2016, 1). The contexts were at ca. 30 to 40 cm below the surface and mostly above the groundwater level (Dijkstra *et al.* 2016, 1).

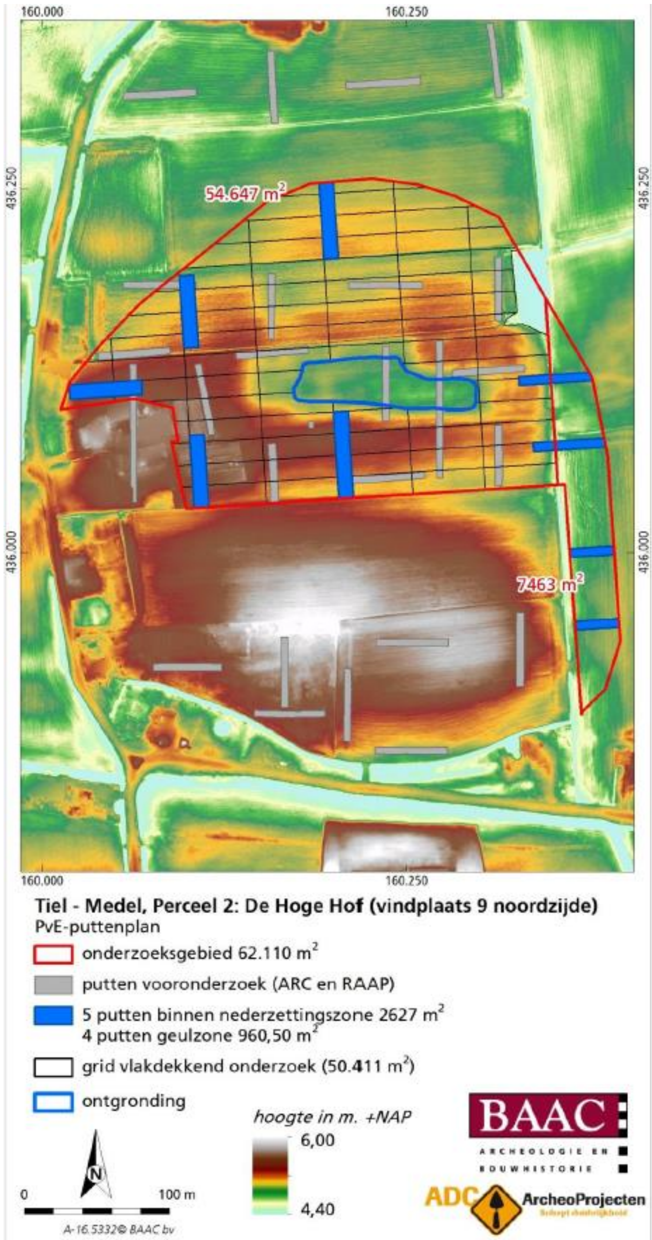

Fig.2. Plan of trenches of the first phase of the excavation (Dijkstra and Mousch 2016, 27).

The excavation was performed in two phases. The first phase consisted of the excavation of 9 trenches (2627m^2) (Fig.2), 4 of which were placed in the channel area and 5 placed in the settlement area, and was aimed at understanding the following: evaluating the potential for investigating the eastern channel area and whether it is contemporary with settlement, understanding the composition of the soil of the western part of the site, identifying possible channels in the southern area of the site, and investigating the possible presence of archaeology in the northern flank of the site (Dijkstra and Mousch 2016, 6).

The second phase of the excavation excavated areas within the site based on the results of the first phase. These areas consist of: the eastern channel area, the settlement area and its periphery, and the area between the northern and southern preserved are of the site. The settlement area was excavated using a checkers pattern with trenches of 15m x 50m. In the northern part of the site, the periphery and the transition of the settlement to the periphery were investigated as well. This was carried out due the small amount of sites with inclusion of the periphery in the rivers area. Structures were first uncovered as completely as possible after which they were cut vertically. During the excavation special attention was given to traces of crafting processes. Possible locations of crafting were gathered and sieved in order to better understand the special relationships between crafting spots (Dijkstra and Mousch 2016, 7-8).

3.1. Preliminary Results

The results of the excavation are still a work in progress and are yet to be published. There are however preliminary results available. These preliminary results regarding the site that are relevant to this research will be presented here.

The large system of ditches was one of the most remarkable structures found at the site. The systems of ditches have repeatedly been emptied and moved throughout time. This allowed for the system of ditches to be used as a basis for identifying the different phases at the site and to link the settlement finds to the different phases. Five different phases were able to be identified (ADC and BAAC 2020, 8).

The ditches associated with the first phase of the site was constructed during the Roman period. The second phase largely continues to maintain the same system and last until the end of the Early Middle Ages. During the end of the Early Middle Ages, the third phase of the site started in which a drastic redesigning of the site occurred. The ditch systems IIIa and IIIb are associated with this redesign of the period. By the end of the Late Middle Ages there is another change to the design of the site, although this change is not as drastic and likely occurred more gradually. Phase 4 is associated with the combining of plots of land to larger fields, the construction of so-called “moated sites”, and ditch system IVa. The fifth phase is associated with the ditch systems of the Modern Age and the farms from the 19th century and onwards (ADC and BAAC 2020, 30).

The structures and complexes that were identified during excavation have been associated to one or more phases (Tab.1). Some structures were hard to date and others have been in used for an extended period. For these reasons, these structures have been assigned to multiple phases. The dating has been determined based on a combination of pottery, metal finds, ^{14}C-dating, dendrochronology and the stratigraphic relation of the structures (ADC and BAAC 2020, 30-31).

Tab.1. Overview of structures and complexes per phase

Time Period	**Phase**	**Dating**	**Types of complex**
Roman Period	1	ROM	Plot, house, outbuilding, animals burial, burial, water well, several pits
Middle Ages	2	MEV	Plot, house, outbuilding, water well, possible pier
	2 or 3	MEV/MEL	Water well
	3	MELA	Plot, house, outbuilding, water well
	3 or 4	MELA/MELB	Hay storage, ditch, water well, sand extraction
Middle Ages and Modern Age	4	MELB/NTV	Plot, moated site, possible sand extraction
Modern Age	5	NT	Plot, house, outbuilding, hay storage, water well, animal burial, sand extraction

3.1.1. Roman Period

The river bank in the eastern part of the site originated around the start of the calendar and was part of the river system. During the Early Roman period, this turned into a residual channel that was sailable up into the Middle Ages. Any building located near the residual channel and are dated to the 1st and 2nd centuries A.D. while the western part of the site was mostly used for agricultural practices. From the 2nd century onwards occupation seems to decline, though there is still evidence for human activity during the 3th and 4th centuries. Three burials have found dating to the 4th and 5th centuries. There have only been a small amount of structures found at the site compared to the number of finds and traces. This may be due to the intensive use during the Medieval Period causing the upper layer to be lost and have only the deepest traces to be preserved. The number of structures at the site may have been higher than has been found (ADC and BAAC 2020, 57).

In the north-east, a large outbuilding (structure 102) and three smaller outbuildings (structures 101, 105 and 146) have been found. The buildings are expected to be of the type Alphen-Ekeren, although only evidence of the central posts have been found. Structure 146 seems to have been a type

horreum building and is likely part of a younger phase of occupation around the late 1st or early 2nd century (ADC and BAAC 2020, 58).
Several pits have been dated to the Roman Period. Finds from these pits indicate these were used as waste pits. The pits seem to have been in used for an extended period of time including pottery of the whole 1st century and early 2nd centuries A.D. One pit also contained several melon beads (ADC and BAAC 2020, 59).
An animal burial has been found between outbuilding 101 and 146. The remains belong to a medium to large mammal, but could not be determined to species level. Pottery included in the burial indicates a date during the Late Iron Age or Early Roman Period. Due to its relation with the outbuildings it seems likely to be part of the 1st century occupation (ADC and BAAC 2020, 59).
Despite ^{14}C-dating on wood and seed, none of the water wells have been definitively dated to the Roman Period since Roman Period wood does not guarantee the well was constructed during that time (ADC and BAAC 2020, 61-63).
From the Late Roman Period, three burials have been found, structures 901, 902 and 903. Structure 901 has been found in relation to ditch system Ib. It is oriented in northwest-southeast direction similar to the ditch. It is likely the burial and the ditch are related and constructed around the same time. It could not be established which of them is older. Structures 902 and 903 are located to the northeast of the residual channel and oriented in a north-south direction. Structures 901 and 902 are of similar size while structure 903 is significantly larger (ADC and BAAC 2020, 64). The three individual seem to date to the 5th century. One individual is clearly male, the other two are less clear but seem closer to male in posture. The first individual was aged 41 years old and showed traces of arthrosis on the spine. The other two individuals were aged 22-24 years old and 30-40 years old (ADC and BAAC 2020, 276).
Roughly 5000 pieces (1100 kg) of stone artefacts have been found at the site. The stone artefacts bear the typology and rock-type signature of the Roman Period. The vast majority of stone artefacts fits typologically in the Roman Period rather than the Medieval Period, roughly 80% to 20% respectively. The majority of the Roman material consists of roof tiles. Other finds consist of building materials and grindstones and a small minority of grinding tools and other tools. The composition of the stone materials deviates strongly from that of the average local Roman settlement. Roof tiles amount to almost 300 kg, contain over a 100 fully or mostly complete tiles and relatively thick (2 – 3 cm). Building materials consist primarily tuff and white chalkstone. Grauwacke type stones, typically used in Roman foundations, are limited but present. There is also a surprisingly large amount of large, flattened stray stones. Majority of these stones have been found in the Roman ditch system, though a small amount has been found in Late Roman and Medieval contexts. These have likely been reused, but it is unclear in what manner. Another well represented category are grindstones. One

complete grindstone has been found that belongs to a hand mill. The other grindstones consist of smaller fragments from hand mill grindstones, mostly vesicular lava and some fragments of conglomerated sandstone. These grindstones can typologically be attributed to the first half of the Mid-Roman Period, although the small diameters and concave surfaces on some grindstones indicate a relatively early dating. At least one grindstone comes from a larger hand mill with evidence that it was powered from underneath like a watermill, however there is no knowledge of watermills during the Roman Period in the Netherlands. The channel was deep enough for a watermill but would have had a very slow current. An animal powered mill might be a possibility too. One special find consists of a sandstone bowl of which only one other example is known. The combination of building materials, mill stones and the sandstone bowl indicate the presence of the Roman villa with multiple building phases. The grauwacke foundations date to ca. 100 A.D. while the tuff and chalkstone belong to a later phase. The types of roof tiles indicate three building phases. The Roman villa likely lasted to the second half of the Mid-Roman Period (ADC and BAAC 2020, 230-231).

3.1.2. Medieval Period

After the Roman period there seems to be a continuation of human activity in the area, albeit to varying degrees through time. There is peak in pottery finds from the 6th century followed by a period of settlement growth from the late 9th century to the first half of the 11th century, although there is evidence of human activity up to the end of the Middle Ages. The oldest structure is a house dating to the 10th century and houses last until the 12th to 13th century. During the medieval period there is a reorganization of the area with the construction of moated plots that later are combined to larger plots. There is evidence of farming activities including the processing of flax and hemp as well as evidence of sand extraction (ADC and BAAC 2020, 66).

A total of eight house structures have been identified, structures 118, 119, 121, 124, 128, 132, 138 and 148. The houses are mostly oriented in an east-west orientation. The structures 118, 119, 121, 128 and 132 seem to be the oldest buildings, dating to the 10th and 11th centuries, and are located in the eastern part of the levee. Structures 124, 138 and 148 are located on the western part of the levee. Based on typological characteristics, these structures are dated to the 12th and 13th century (ADC and BAAC 2020, 67-69).

A total of 29 structures have been interpreted as outbuildings. 20 of these building are of MDS-typology B1, multi-corner buildings typically interpreted as storage rooms. Attributing these structures to a specific phase is problematics, but most of these can attributed to the Middle Ages, either phase 3 or phase 4. The remaining outbuildings are smaller versions of the main buildings and are interpreted as sheds and stables. These outbuildings have been attributed to phase 2 and phase 3 (ADC and BAAC 2020, 69-72).

In total, 40 water wells have been excavated that date to the Middle Ages. The medieval water wells consist of wickerwork, barrels, hollow out tree trunks, and planks. An exact dating for these water wells is difficult. They have been assigned to one or multiple phases based on their *terminus post quem* dating and their position within the site. Most water wells have been assigned to phases 2 and 3, although some water wells can be assigned to phase 3 or phase 4. There is also a small group of water wells that that may date to the Roman Period or Early Medieval Period, though their location likely puts them in the Early Middle Ages (ADC and BAAC 2020, 72-77).

There is evidence of a moated site at the site during the 14th and 15th century that possibly contained a residence. Possibly a nobleman resided here and controlled the surrounding agricultural and crafts area (ADC and BAAC 2020, 86).

229 pieces of stone artefacts (182 kg) from the Middle Ages and Modern Ages have been analysed. This is significantly less than that of the Roman Period. On top of that, there is 95 kg of Roman building materials found in medieval context. Roughly two-thirds of the material is dateable and consists primarily of grindstones and import stones. Majority of these stones date to the High Middle Ages. Roughly 90% of the medieval stone consists of grindstones and stray stones. Building materials from the Medieval Period are more or less absent, apart from Roman spolia. The grindstones consist mostly of flat types, both from hand mills as well as larger mills. These date mostly to the High Middle Ages. A second type of grindstones consists of types with an inward slope of both hand mills and larger mills. These date more towards the Late Middle Ages. Both types bear characteristics that would put the latest date to the 13th century. Several fragments of grindstones bear a slit parallel to the edge and next to a conic hole. These are thought to be characteristic of animal powered mills. These date to the High Middle Ages. The amount of grindstones indicates personal use by the local farms rather than surplus production. Other that grindstones, a number of weights have been found that point to fishing activities. These date from the Early Middle Ages to the Modern age. There seems to have been a limited amount of fishing indicating personal consumption. Only a small amount of sharpening tools have been found, and only five of which are imports. Ten whetstones and sharpening stones date to the Late Middle Ages to Early Modern Ages and most were found in the ditch of the moated site. These bear mostly traces of sharpening of knives and polishing. Other finds are very limited. The imported stones are limited to grindstones and whetstones. These were likely traded through Tiel from both the Rhineland area and Scandinavia. Other than that, most of the stone used at the site consists of Roman spolia. There was a selection for large and hard stone types as well as rough chalkstones and flat quarry stones. The finds at the site indicate a rural settlement with contact with trade centres. Habitation seems to have been primarily during the High Middle Ages (ADC and BAAC 2020, 257-259).

3.1.3. Modern Age

At the end of the Middle Ages the site was mostly abandoned, with the exception of the moated site. During the Modern Age this trend continues and the moated site is abandoned as well until the 19th century. In the 19th a farm is known from historical sources. The main building was located at structure 115, but only two small walls were found. At the property four more outbuildings have been found. Structure 112 is hexagonal building known as to be hay storage. Structures 113 and 114 are square constructions, with 114 being more recent and overlap with structures 112 and 113. Structure 147 was likely part of a larger outbuilding with a shallow foundation (ADC and BAAC 2020, 93).

Two water wells, structure 536 and structure 563, have been dated to the Modern Age. Both wells have been constructed from bricks. Ditch system IVc has been attributed to the Modern Ages, although it is hard to determine due to the small amount of finds and mixture of older materials. It contains materials from the Roman Period, Medieval Period all the way to the 20th century. A possible dating of 16th or 17th century is guessed (ADC and BAAC 2020, 93-94).

3.1.4. Archaeozoological Remains

Regarding the archaeozoological material, 21113 finds have been analysed thus far, 18116 of these were investigated in further detail and judged on preservation and fragmentation. Roughly 80% has been classified as well preserved, 16% as good to medium preservation and 4% as medium preservation. There is hardly any material that were classified as poorly preserved. The average weight of large skeletal elements that have been investigated in detail is 40.1g while the average weight of the remaining material is 24.8g (Brouwer and Mousch 2020, 59). The animal remains date from the Roman Period to the Modern Age, but the majority of animal remains derive from the High Middle Ages, the 10th to 13th centuries (Brouwer and Mousch 2020, 57).

During excavation, two animal burials were recorded. A scan of the material revealed more relatively complete skeletons that had not been recognized as such in the field. These are mostly (partial) skeletons of cattle, horse, pig, and dog (Brouwer and Mousch 2020, 59).

The scan of the material revealed there is a low presence of bird remains, mostly duck and goose, but no chicken. No fish remains have been observed. There is a small presence of game in the form of deer and beaver. There have also been some finds that have included remains of small rodents and insectivores (Brouwer and Mousch 2020, 60).

An estimated 99% of the animal remains consist of domesticated species, especially cattle and horse, the latter being at an unusual high frequency in the region at that time period. Even when disregarding the impact of partial skeletons, the presence of horse still is higher than that of sheep/goat or pig. This is unusual since horse is not a common animal used for consumption. There is

also a relatively high amount of complete skulls, mostly of cattle and horse, but also relatively large dog skulls (Brouwer and Mousch 2020, 60).
Any bias on the skeletal distribution of elements was not observed, suggesting that carcasses alongside with consumption remains as well as butchery remains are present at the site. However, there is a high presence of (mostly) complete bones of meat-bearing elements and a low presence of butchery marks, 7% on cattle remains and none on the remains of sheep/goat or pig (Brouwer and Mousch 2020, 61).
The animal remains of the Roman Period show a noteworthy amount of complete elements. Half of the material originated from the ditch while the other more-fragmented half originates from pits. The Roman material shows a high amount of horse bones, some of which bear butchery marks (Brouwer and Mousch 2020, 61).
The majority of the pathologies were detected during the initial scan of the material are attributed to the Medieval Period. The presence of milling stones might indicate these pathologies are related with the use of the horses in the mill. The medieval material also contained 8 medieval ice skates made of cattle and horse bones. The medieval ditches and sand-extraction-pits contained a large amount of animal remains. These contained mostly cattle and a relatively high amount of bird remains (Brouwer and Mousch 2020, 62).
There is only a small amount of animal remains that can be correlated to the moated site. This material contains no noteworthy remains. The Modern Age material is similarly unremarkable (Brouwer and Mousch 2020, 63).

4. Materials and Methods

The horse remains analysed in this thesis derive from 59 boxes of archaeozoological materials provided by Archeoplan Eco, the company handling the archaeozoological data for the excavation (Dijkstra and Mousch 2016, 2-3).

In order to investigate the horse remains macroscopic visual analysis of the material has been performed. Macroscopic analysis is inexpensive and relatively easy to perform (Markovic *et al.* 2014, 83). This allows analysis to be applied to a large assemblage of bones by a single analyst. Part of the material had already been determined taxonomically by staff of Archeoplan Eco, but a large fraction of the material has been investigated by the author. Only skeletal elements that were identified as horse were recorded. This data was then combined with the data recorded by Archeoplan Eco.

For the determination of the skeletal elements the collection of the Laboratory for Archaeozoological Studies (LAS-Leiden) of the faculty Archaeology of Leiden University was used as a reference collection for comparison.

The data of the identified horse bones were recorded into an Access database provided by Archeoplan Eco (Fig.3). The following data was recorded: box number, find number, degree of fragmentation, degree of weathering, species, type of skeletal element, symmetry, number of elements, number of fragments, the part of the skeletal element, percentage of the element, the fusion of the epiphyses, sex if applicable, and special marks (i.e. cut marks, chop marks, pathologies, etc.). The database would assign a unique ZOO_ID number to each individual record. Whenever

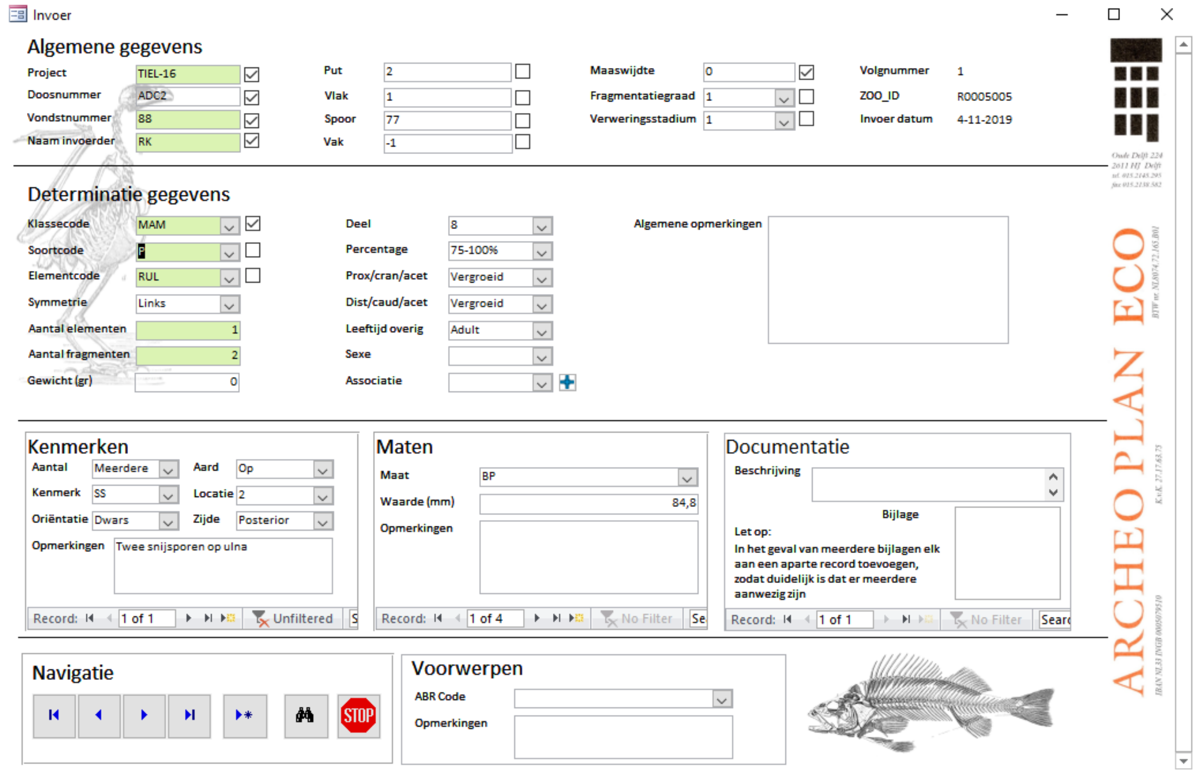

Fig.3. Example of the input sheet for the access database.

possible measurements were taken as well by Femke Warnar, a Bachelor's student focusing on equid morphology and size at the size. Primarily the greatest length, proximal width, distal width and smallest width were recorded following the method of von den Driesch (1976). Weight was not recorded since weights had already been taken during the processing at the excavation and were not deemed necessary.

The degree of fragmentation represents the state of the structural integrity of the bone and is graded and recorded by Archeoplan Eco using the following criteria:

1. Strong, complete bone or bone fragment.
2. Fragile but complete bone or bone fragment.
3. Disintegrated, fragmented bone or bone fragment.
4. Completely decayed bone in the form of a soil feature and possibly dental enamel.

The degree of weathering represents the state of the surface of the bone and is graded and recorded by Archeoplan Eco using the following criteria:

0. Bone shows no traces of cracking or flaking.
1. Bone displays cracks parallel to the fibre structure or in mosaic pattern on the surfaces of joints.
2. Early stages of flaking in outermost concentric bone layers.
3. Surface shows rough weathered patches where all the outermost concentric bone layers have disappeared.
4. Bone surface is coarsely fibrous and rough, small and large splinters have (almost) flaked off.
5. Bone disintegrates in situ such that its shape is difficult to determine.

Recording of the species and skeletal elements was done in line with the codes prescribed by Laboratorium protocol archeozoölogie – ROB (Lauwerier 1997b, 5-10). Similarly, the zone of the skeletal element was determined using the codes used by the ROB (Lauwerier 1997b, 12). This is a system that ascribes numerical codes to each part of a bone per type of skeletal element. Percentages of the element are ascribed using the following categories for ease of comparison: 0 – 10%, 10 – 25%, 25 – 50%, 50 – 75%, 75 – 100%, and 100%.
Age was determined primarily based on the fusion of the epiphyses. Both the state of the proximal and distal epiphyses of long bones were recorded. For vertebrae, the fusing of the cranial and caudal epiphyses were recorded and for the pelvis the fusing of the acetabulum was recorded. Fusion calendars follow the estimations provided in Silver (1969 in Groot 2010, 65). In addition, age

estimations based on the emergence of teeth were applied when possible following the charts by Habermehl (1975 in Groot 2010, 50).
Sex was only determined on the basis of the teeth. Canine teeth are mostly commonly present in male horses, or if canine teeth are present in both sexes, they are larger in males compared to females (Groot 2010, 69). The presence of canine teeth in some animals likely indicates a male animal. The sex of horses can also be determined based of the morphology of the pelvic bone. However this was method was not applied for this investigation.
Bone surface marks were recorded using their separate characteristics and the frequency of the marks. This was recorded either as a single or multiple marks and the type of mark, i.e. cut mark, chop mark, pathology, etc., according to the codes prescribed by the ROB (Lauwerier 1997b, 14). The orientation of the mark was recorded as either lengthwise, transverse or all around as well as whether the mark was either located on the surface of the bone or went through the bone. The location of the mark was recorded using the codes of the ROB (Lauwerier 1997b, 12). The side of the bone which contained the mark was recorded (i.e. posterior, lateral, etc.). Finally a description of the mark was added in the remarks.

In the case of marks that were identified as possible pathologies, photographs were taken. These photographs were used for further investigation and comparison of the material since access to the material was limited due to space and time. To take the pictures, the photography setup of the Laboratory for Archaeozoological Studies at the faculty Archaeology of Leiden University was used. This photography setup consists of a Canon EOS 80D camera with an 18-135mm IS USM lens and was mounted on a height adjustable standard with the camera pointed downwards and perpendicular. The skeletal element was placed on a white plane with a measureable reference scale. Lighting was applied to ensure each side of the bone was fully illuminated. A photograph of the complete element was made followed by several close up photos of the pathology.

Regarding the quantification of skeletal elements, the NISP values will be presented. This has been chosen since this thesis is focused on a single species, so problems due intertaxonomical variation of NISP are not an issue, its ease of use and the fact that parts of the assemblage have been determined by multiple researchers, making the determinations of MNI difficult (Lyman 2008, 29-30). NISP values will generally be presented per skeletal element for comparison between skeletal elements.

5. Results

5.1. General Results

The total archaeozoological remains excavated at De Hoge Hof site consisted of 21,111 animal bone fragments of which 10126 skeletal elements were identified. In total 3519 fragments from 1786 skeletal elements were identified as horse (Tab.2), a 16.7% of the total assemblage. The MNI for horse is 59 attending to the 59 left tibia elements, the most frequent skeletal element after dividing the number of elements in the body in order to take in account the number of each element in the body.

Tab.2. NISP and number of fragments of horses per skeletal element

Element Code	Element	NISP	NISP as % of total	Number of fragments	$N_{fragments}$ as % of total
	Head	**459**	**25.7%**	**1342**	**38.1%**
CR	Cranium	62	3.5%	652	18.5%
MAN	Mandibula	106	5.9%	278	7.9%
MAX	Maxilla	41	2.3%	145	4.1%
DES	Dentes Superior	139	7.8%	154	4.4%
DEI	Dentes Inferior	80	4.5%	81	2.3%
DE	Dentes Indet	31	1.7%	32	0.9%
	Vertebrae	**381**	**21.3%**	**862**	**24.5%**
AT	Atlas	9	0.5%	10	0.3%
AX	Axis	11	0.6%	12	0.3%
VCE	Vertebrae Cervicales	49	2.7%	69	2.0%
VTH	Vertebrae Thoracales	71	4.0%	149	4.2%
CO	Costas	90	5.0%	352	10.0%
CC	Cartilagines Costales	5	0.3%	5	0.1%
VLU	Vertebrae Lumbales	33	1.8%	87	2.5%
SA	Sacrum	9	0.5%	11	0.3%
PE	Pelvis	95	5.3%	156	4.4%
VCA	Vertebra Caudales	1	0.1%	1	0.0%
V	Vertebra	8	0.4%	10	0.3%
	Fore Limbs	**348**	**19.5%**	**527**	**15.0%**
SC	Scapula	49	2.7%	89	2.5%
HU	Humerus	84	4.7%	146	4.1%
RA	Radius	86	4.8%	132	3.8%

RUL	Radio-Ulna	8	0.4%	12	0.3%
UL	Ulna	27	1.5%	32	0.9%
CAR	Carpalia	23	1.3%	23	0.7%
MCP	Perifere Metacarpal	1	0.1%	1	0.0%
MC	Metacarpus	64	3.6%	85	2.4%
MC2	2nd Metacarpal	2	0.1%	3	0.1%
MC4	4th Metacarpal	4	0.2%	4	0.1%
	Hind Limbs	**342**	**19.1%**	**522**	**14.8%**
FE	Femur	93	5.2%	163	4.6%
PA	Patella	7	0.4%	7	0.2%
TI	Tibia	117	6.6%	179	5.1%
AS	Astralagus	16	0.9%	16	0.5%
CA	Calcaneum	16	0.9%	17	0.5%
TAR	Tarsalia	10	0.6%	10	0.3%
MTP	Perifere Metatarsal	2	0.1%	2	0.1%
MT	Metatarsus	76	4.3%	121	3.4%
MT2	2nd Metatarsal	1	0.1%	1	0.0%
MT4	4th Metatarsal	4	0.2%	6	0.2%
	Other	**256**	**14.3%**	**266**	**7.6%**
PB	Os longum	12	0.7%	12	0.3%
MP	Metapodia	13	0.7%	15	0.4%
MPP	Perifere Metapodia	9	0.5%	9	0.3%
SE	Sesomoidea	4	0.2%	4	0.1%
P	Phalanx	1	0.1%	1	0.0%
P1	Phalanx 1	63	3.5%	68	1.9%
P2	Phalanx 2	16	0.9%	19	0.5%
P3	Phalanx 3	19	1.1%	19	0.5%
IND	Indeterminate	119	6.7%	119	3.4%
	Total	**1786**	**100.0%**	**3519**	**100.0%**

A total of 732 (41.0%) skeletal elements of horses were able to be assigned to one of the phases of the site (Tab.3). The vast majority (81.3%) of the horse bones are associated with phases 3 and 4, thus the Early to Late Middle Ages.

Tab.3. Number of skeletal elements per phase

Phase	**Number of elements**
1	41
2	57
3	247
3/4	183
4	165
5	39
Total	732

5.1.1. Preservation condition of the material

To determine the preservation condition of the material two characteristics were recorded, the degree of fragmentation and the degree of weathering. The degree of fragmentation is very good. Overall, 91.4% of elements have been described as strong or complete bones and bone fragments (Tab.4). Similarly the degree of weathering is also very good with 73.4% described as showing no traces of cracking or flaking and 0.7% showing a coarsely fibrous and rough bone surface with small and large splinters flaked off (Tab.5). With 93.9% of skeletal elements showing no traces of flaking the degree of preservation in exceedingly good.

Tab.4. Fragmentation of skeletal elements

Category	Number of elements	% of elements
1	1589	91.4%
2	67	3.9%
3	82	4.7%
Total	**1738**	**100.0%**

Tab.5. Weathering of skeletal elements

Category	Number of elements	% of elements
0	1274	73.4%
1	356	20.5%
2	68	3.9%
3	26	1.5%
4	12	0.7%
Total	**1736**	**100.0%**

5.1.2. Age

The age of the horses have been determined for 630 epiphyses based on the fusion of the epiphyses (Tab.6). 21.1% of all epiphyses are unfused. Based the scapula and second phalanx only 9.3% of horses are below the age of 12 months and 69.2% of horses show epiphyseal fusion indicating an age of 36 months or older. The low presence of young animals, high presence of older animals and the steady decline of fused epiphyses indicates that animals were kept for a long period of time. The only skeletal element that differs from this trend is the calcaneum which fuses at 36 months. However, this only represented by a small sample size (7) and can be ignored.

5.1.3. Anthropic and Biological Marks

A total of 162 marks have been identified and recorded in the assemblage. Out of the total marks 51 were identified as cut marks, 37 marks were identified as chop marks, 64 have been identified as marks of gnawing, and 9 as other marks such as scrape marks and polishing.

Tab.6. Overview of epiphyseal fusion per element					
Element	**Unfused**	**Fused**	**Total**	**% unfused**	**% fused**
scapula	3	26	29	10.3%	89.7%
phalanx 2 p.	1	13	14	7.1%	92.9%
humerus d.	6	56	62	9.7%	90.3%
radius p.	10	38	48	20.8%	79.2%
metacarpus d.	1	40	41	2.4%	97.6%
phalanx 1 p.	3	42	45	6.7%	93.3%
metatarsus d.	12	43	55	21.8%	78.2%
pelvis acetabulum	3	37	40	7.5%	92.5%
tibia d.	25	56	81	30.9%	69.1%
calcaneum	5	2	7	71.4%	28.6%
humerus p.	5	15	20	25.0%	75.0%
radius d.	13	34	47	27.7%	72.3%
ulna p.	3	11	14	21.4%	78.6%
femur p.	13	18	31	41.9%	58.1%
femur d.	11	29	40	27.5%	72.5%
tibia p.	19	37	56	33.9%	66.1%
Total	**133**	**497**	**630**	**21.1%**	**78.9%**

Most of the anthropic marks are found on the limbs with a small amount of cut marks in the skull and mandible. The frequency of cut marks seems to be more frequent in the lower limbs, particularly in the radius and tibia (Tab.7). Similarly, the chop marks are identified primarily on the limbs with a small amount in the skull and neck area. The chop marks are even more so frequent in the lower limbs, primarily identified in the metapodia and radius (Tab.7).

Gnawing marks are exclusively found in the limbs of the horses. However these marks are more frequent on the humerus and femur as well as the metatarsus and tibia. Gnawing marks are significantly less frequent in the metacarpus compared to the other long bones (Tab.7).

Tab.7. Number of cut, chop, gnaw and other marks per skeletal element								
Skeletal Element	**Cut Marks**		**Chop Marks**		**Gnaw Marks**		**Other Marks**	
	Number of elements	**% of Elements**	**Number of elements**	**% of Elements**	**Number of elements**	**% of Elements**	**Number of elements**	**% of Elements**
Astralagus	1	6.3%	1	6.3%	0	0.0%	0	0.0%
Atlas	0	0.0%	1	11.1%	0	0.0%	0	0.0%
Calcaneum	0	0.0%	2	12.5%	5	31.3%	0	0.0%
Cranium	3	4.8%	1	1.6%	0	0.0%	0	0.0%
Femur	4	4.3%	2	2.2%	9	9.7%	2	2.2%
Humerus	5	6.0%	1	1.2%	10	11.9%	0	0.0%
Mandibula	3	2.8%	0	0.0%	0	0.0%	0	0.0%
Maxilla	1	2.4%	0	0.0%	0	0.0%	0	0.0%
Metacarpus	5	7.8%	5	7.8%	2	3.1%	3	4.7%
Metapodia	0	0.0%	0	0.0%	1	7.7%	0	0.0%
Metatarsus	5	6.6%	6	7.9%	8	10.5%	1	1.3%
Phalange 1	1	1.6%	0	0.0%	1	1.6%	0	0.0%
Phalange 2	0	0.0%	0	0.0%	1	6.3%	0	0.0%
Phalange 3	0	0.0%	0	0.0%	0	0.0%	1	5.3%
Pelvis	2	2.1%	3	3.2%	5	5.3%	0	0.0%
Radius	8	9.3%	8	9.3%	4	4.7%	0	0.0%
Radio-ulna	1	12.5%	0	0.0%	1	12.5%	0	0.0%
Scapula	3	6.1%	4	8.2%	2	4.1%	0	0.0%
Tibia	8	6.8%	3	2.6%	9	7.7%	2	1.7%
Ulna	1	3.7%	0	0.0%	6	22.2%	0	0.0%
Total	**51**		**37**		**64**		**9**	

5.2. Pathologies

A total of 54 (3.0%) skeletal elements exhibited some form of pathology of varying degrees of severity. The most common skeletal elements identified with pathology are the pelvis, the metatarsus and the first phalange (Tab.8).

Regarding the dating of the materials, only a limited amount of finds with pathologies have been attributed to a specific habitation phase of the site, but they are all from the Middle Ages. Five of the specimens with pathologies have been attributed to phase 3, another four specimens to phase 3 or 4, and two more have been attributed to phase 4. None have been attributed to earlier or later phases. This is in line with the fact that most of the horse bones (81.3%) belong to either phases 3 or 4. This way, it seems safe to assume that at least the vast majority, if not all, of the pathologies can attributed to these phases of occupation that date to the High and Late Middle Ages.

Tab.8. Number of horse pathologies per skeletal element

Skeletal Element	Number of pathologies identified	% of given element identified with pathology	Number of pathologies identified by author	Number of pathologies identified by Archeoplan Eco
Axis	2	18.2%	1	1
Calcalneum	1	6.3%	0	1
Costas	1	1.1%	0	1
Cranium	2	3.2%	0	2
Dentes Superior	2	1.4%	1	1
Humerus	1	1.2%	0	2
Mandibula	6	5.7%	3	3
Maxilla	1	2.4%	1	0
Metacarpus	3	4.7%	3	0
Metatarsus	8	10.5%	1	7
Phalanx	1	100.0%	0	1
Phalanx 1	8	12.7%	1	7
Phalanx 2	2	12.5%	1	1
Phalanx 3	1	5.3%	1	0
Pelvis	8	8.4%	0	8
Scapula	1	2.0%	0	1
Tibia	1	0.9%	0	2
Vertebra Cervicales	1	2.0%	0	1
Vertebra Lumbales	2	6.1%	1	1
Vertebra Thoracales	2	2.8%	0	2
Total	**56**	**3.1%**	**14**	**42**

First the different pathologies identified by the author will be described. They are described either individually per find number or grouped together if the pathologies are particularly similar. A few special pathologies are described separately and in further detail. Finally, the pathologies described by staff from Archeoplan Eco are presented.

5.2.1. Exostoses

A total of three elements presented exostoses in very different parts of the skeleton. All three of these are from different pits and do not seem related to eachother.

V7015

V7015 contains a mostly complete right-side scapula (ZOOID_5132). On the medial side of the flat of the bone near the end of the bone three exostoses are present (Fig.4). These exostoses are not in a location that is typically associated with physical stress, nor is there any other evidence for disease. The most likely diagnosis would be a benign neoplasia.

V2258

V2258 contains a right side mandibula (ZOOID_5501). The mandibula is mostly complete and contains all premolars and molars. On the lateral side of the corpus a small exostosis is situated near the underside of the mandibula roughly under the second premolar (Fig.5). The exostosis is shaped like a round knob with a depression in the centre. The small size, nature, and unusual location not typically associated with stress as well as lack of any other pathological indicators suggest this is no more than a benign neoplasia.

V6715

V6715 contains a left-sided metatarsus (ZOOID_5097). The metatarsus is mostly complete. On the diaphysis of the bone, three small exostoses are located on the medial side. The exostoses are relatively smooth and hard to observe. There is no other evidence of pathological change to the bone. These seem to be most likely benign neoplasia.

Fig.4. Scapula from V7015 with three exostoses in medial view (above) and close-up (below) (R. Kost).

Fig.5. Mandibula from V2258 with small exostosis on the corpus in lateral view (above) and close-up (below) (R. Kost).

5.2.2. Lesions

V7586

V7586 contains a large complete skull of a young horse (ZOOID_5066). The animal has several periosteal lesions of lighter coloured porous bone along the nasals (Fig.6, above), right parietal (Fig.6, above and below) and left maxilla (Fig.6, middle picture). The maxilla on the left side also shows the same discolouration and porosity along the second and third premolars which are still emerging. The lesions are similar to those described by Bendrey *et al.* of two horse skeletons suspected to have been subject of bacterial infection (Bendrey *et al.* 2008, 1581). The combination of periosteal lesions and the pitted maxilla strongly indicate a form of disease. The possibility of it being a bacterial infection seem likely.

Based on Habermehl (1975), the second and third premolar emerge around 2.5 years old. The presence of the fourth deciduous premolar indicates an age below 3.5 years old. The first and second molar emerge around 1 and 2 years respectively. The absence of the third molar indicates an age below 4 years of age. This data combined suggests to an age of between 2.5 and 3.5 years old, a subadult horse.

Fig.6. Cranium from V7586 with periosteal lesions in doral view (above), lateral view (middle) and close up of periosteal lesion from dorsal view (below) (R. Kost).

V8098

V8098 contains part of the symphysis and diastema of a mandibula of a young horse (ZOOID_5235) with lesions of porous bone similar to ZOOID_5066. The lesions are located on the basal corpus of the mandibular at the diastema level close to where the premolars would be situated (Fig.7).

The first and second permanent incisors are present which emerge around 2.5 and 3.5 years old respectively (Habermehl 1975). On the left side of the mandibula the third incisor and canine tooth are present, but they have not yet fully emerged yet. The third incisor emerges between the age of 4 and 4.5 years old while the canine tooth emerges around 4 years old. This would place the age of the animal between 3.5 and 4 years old. The presence of the canine indicates that the animal was likely a male.

The periosteal lesions seem similar to those seen on ZOOID_5066. However, the two elements come from different contexts. Though there is an overlap in age, the two elements are not likely to be associated with each other. Regardless, a form of infection seems the most likely cause. Possibly the same form of disease that affected ZOOID_5066.

V4063

V4063 contains a left humerus (ZOOID_5514). The caudal part of the proximal end of the bone is covered with a layer of smooth bone with some porosity and irregularity near the edge of the pathology (Fig.8). This points to a periosteal lesion which is a result of inflammation that might have been caused by a disease. However, the lesion is present around the attachment point of the muscle suggesting that this inflammation could be the result of some form of stress on the front limb as an alternative explanation.

V6474

V6474 contains a complete left metatarsus (ZOOID_5278) of excellent preservation condition allowing for the identification of this possible pathology. The distal end of the bone, above the epiphysis, shows a thin layer of irregular and porous bone on the surface (Fig.9). This may be an early stage of a lesion and thus indicating some minor inflammation. However, the fact that the pathology is so minor makes it difficult to assign a clear diagnosis.

V7015

V7015 contains a right tibia from a young horse (ZOOID_5141). The tibia has a triangular spot of irregular bone and proliferations on the backside of the diaphysis disrupting the usual striations typically found on the tibia (Fig.10). Both the proximal and distal epiphyses are not fused and missing. This means the horse was younger than 1.5 – 2 years old.

Fig.7. Left mandibula from V8098 with periosteal lesions on a lateral (above) and latero-basal (close-up below) views (R.Kost).

Fig.8. Left humerus general view and close up from V4063 with lesions around the proximal muscle attachment area (R. Kost).

Fig.9. Left metatarsus (dorsal/anterior view) from V6474 with possible early state lesion above the distal epiphysis (R. Kost).

Fig.10. Left Tibia of young horse (plantar/posterior view) from V7015 with proliferations on the diaphysis (R. Kost).

5.2.3. Ossified Haematoma

V6728

V6728 contains part of the left side of a mandibula (ZOOID_5263). The basal side of the corpus of this mandibula has a thickening of the bone roughly under where the third premolar would have been (Fig.11). The bone of the corpus above the thickening and the premolar are no longer present, so a dental origin cannot be excluded. However, the thickening would fit an ossified haematoma.

V6641

V6641 contains a complete right side metatarsus (ZOOID_5348). On the lateral side of the diaphysis, roughly on the distal shaft, the bone shows a smooth thickening of the bone (Fig.12). This pathological change is similar to the description of an ossified haematoma, although of a smaller size. Since the pathology is on the lateral side of the lower limb, it seems not unlikely that is the result of kicking.

V4078

V4078 contains an associated set of bones of a young horse. One of the ribs of the animal (ZOOID_5535) shows a lump on the bone with a small amount of porosity on the medial part of the pathology (Fig.13). There is no evidence of a fracture. This rib is the only rib associated with this animal that shows this pathological change. An ossified haematoma seems the most likely aetiology.

Fig.11. Left mandibula (latero-basal view) from V6728 with possible ossified haematoma (R. Kost).

Fig.12. Right metatarsus (dorsal/anterior view) from V6641 with ossified haematoma on the distal diaphysis (R. Kost).

Fig.13. Rib (antero/medial view) from V4078 with possible ossified haematoma (R. Kost).

5.2.4. Vertebrae

V2974

V2974 contains an axis (ZOOID_5197). On the ventral side of the corpus, there is an elongated ridge of bone along the right side on the bone (Fig.14). This axis has been found associated with a sand extraction context and has been attributed to phase 3 or 4. Pathological changes to the cervical vertebrae are hardly mentioned in archaeozoological literature. Levine *et al.* have proposed that pathological changes to the cervical vertebrae are related to confinement in the stables, having to keep its head elevated for longer periods of time (Levine *et al.* 2000, 125).

Fig.14. Axis (lateral view) from V2974 with ridge along the corpus (R. Kost).

V4860

V4860 contains three thoracic vertebrae (all +4 years old). Two of these vertebrae showed a small amount of pathological change (ZOOID_5113, ZOOID_5114). Both of these vertebrae show bone proliferations on the inferior articular processus (Fig.15). The proliferations are irregular and pitted. The proliferations are slightly larger on the left side of the vertebrae. These proliferations seem to be the early stages of the fusion of the inferior articular process to the superior articular process of the next vertebra. The pathology looks similar to synovial intervertebral osteoarthritis as presented by Diedrich (2017, 27) and are located in a similar location.

Fig.15. General caudal view (above) of thoracic vertebrae from V4860 with proliferations on the inferior articular processus (close-up below) (R.Kost).

V3744

V3744 contains a single lumbar vertebra of a +4 year-old horse (ZOOID_5612). This is the fifth lumbar vertebra and it shows a spur of bone on the right side of the cranial end of the corpus (Fig.16). The pathology extends slightly past the corpus and the articular surface forming a lip or spur. This is an indicator of spondylosis where the vertebrae start to fuse (Diedrich 2017, 27). While this condition is related to the natural aging process and with congenital defects, it is generally accepted that overriding contributes to the condition (Levine *et al.* 2005, 98-99).

V4078

All of the cervical vertebrae were present of a single animal in V4078. A single cervical vertebra shows bony ridges and proliferation near the base of the processus spinoidus (Fig.17). Pathological changes to the cervical vertebrae are not commonly described in archaeozoological literature, though, it has been mentioned pathological changes to the cervical vertebrae may be related to prolonged stabling (Levine *et al.* 2000, 125).

5.2.5. Pelvic Bones

Eight pelvic bones were identified with a mixture of exostoses and an irregular surfaces along the dorso-lateral surface above the acetabulum. The pelvic bones with this pathology are ZOOID_5202, ZOOID_5226, ZOOID_5252, ZOOID_5421, and ZOOID_5482 for the left side, ZOOID_5251, ZOOID_5350 for the right side and ZOOID_5227 consists of both sides of the same pelvis. The most common form of pathology is the ridge of irregular bone along the dorso-lateral surface of the acetabulum. Three of the pelvises have exostoses along the corpus ossis ilii of the bone located between the ilium and acetabulum (Fig.18; Fig.19). The shape of both form of the pathologies as well as their location looks very similar to the examples of coxofemoral osteoarthritis as described by Diedrich (2017, 29). This is a condition that is typically the result of stress on the hind limbs such as the mining horses described there (Diedrich 2017, 31).

ZOOID_5226 and ZOOID_5227 are associated with structure 807, a ditch dated to phase 3 or 4.
ZOOID_5350 is associated with structure 360 and is dated to phase 3.

Fig.16. Lumbar vertebra from V3744 with spondylotic spur in cranial view (above) and latero cranial view (close-up below) (R. Kost).

Fig.17. Cervical vertebra from V4078 with proliferations around the base of the processus spinoidus (dorso-caudal view above, caudal close up below) (R. Kost).

Fig.18. Pelvis ZOOID_5350 with exostoses and irregular surface along the dorso-lateral surface close to the acetabulum (R. Kost).

Fig.19. mediodorsal view (above) of pelvis ZOOID_5226 with exostoses on dorsol-lateral surface (close up below) (R. Kost).

5.2.6. Phalanges

Seven first phalanges and a second phalanx presented pathologies (Fig.20 to 22). These include ZOOID_5028, ZOOID_5107, ZOOID_5358, ZOOID_5471, ZOOID_5498, ZOOID_5513, and ZOOID_5613. The first phalanges have an irregular and pitted layers of bone on the lateral and medial sides of the phalanges, from barely visible as on ZOOID_5613 (Fig.20) to more pronounced on ZOOID_5358 (Fig.22 upper picture). The most severe case is ZOOID_5471 where this condition covers both sides of the diaphysis and most of the proximal half on the posterior side (Fig.20; Fig.21). In one case (ZOOID_5028) there is a similarly irregular and pitted bone ridge along the posterior side. The ridge runs from the middle along towards the proximal end (Fig.22). The second phalanx has two bony ridges along the posterior sides similar to ZOOID_5028 (Fig.22).

These pathologies are very similar in appearance to the bilateral osteophytosis as seen in Bendrey (2007a). The condition has been found naturally in equids in the fossil record, but work related stress may exacerbate the development of bilateral osteophytes (Bendrey 2007a, 100-103). ZOOID_5498 is associated a homestead dated to phase 4.

Fig.20. Phalange ZOOID_5613 with light amount of bilateral osteophytosis (caucal view) (R. Kost).

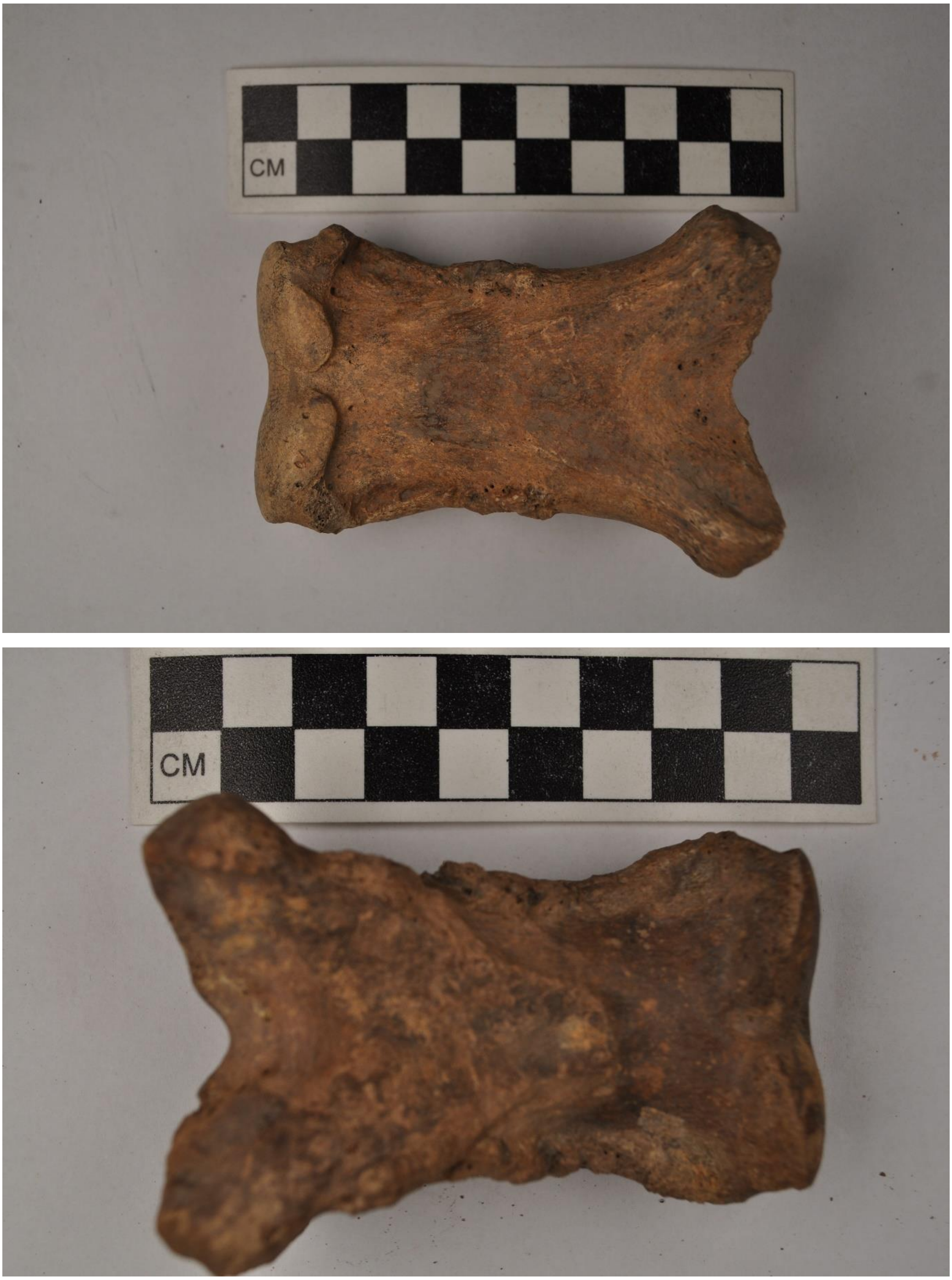

Fig.21. Phalanges with bilateral osteophytosis (caudal views). Above ZOOID_5358, ZOOID_5471 below (R. Kost).

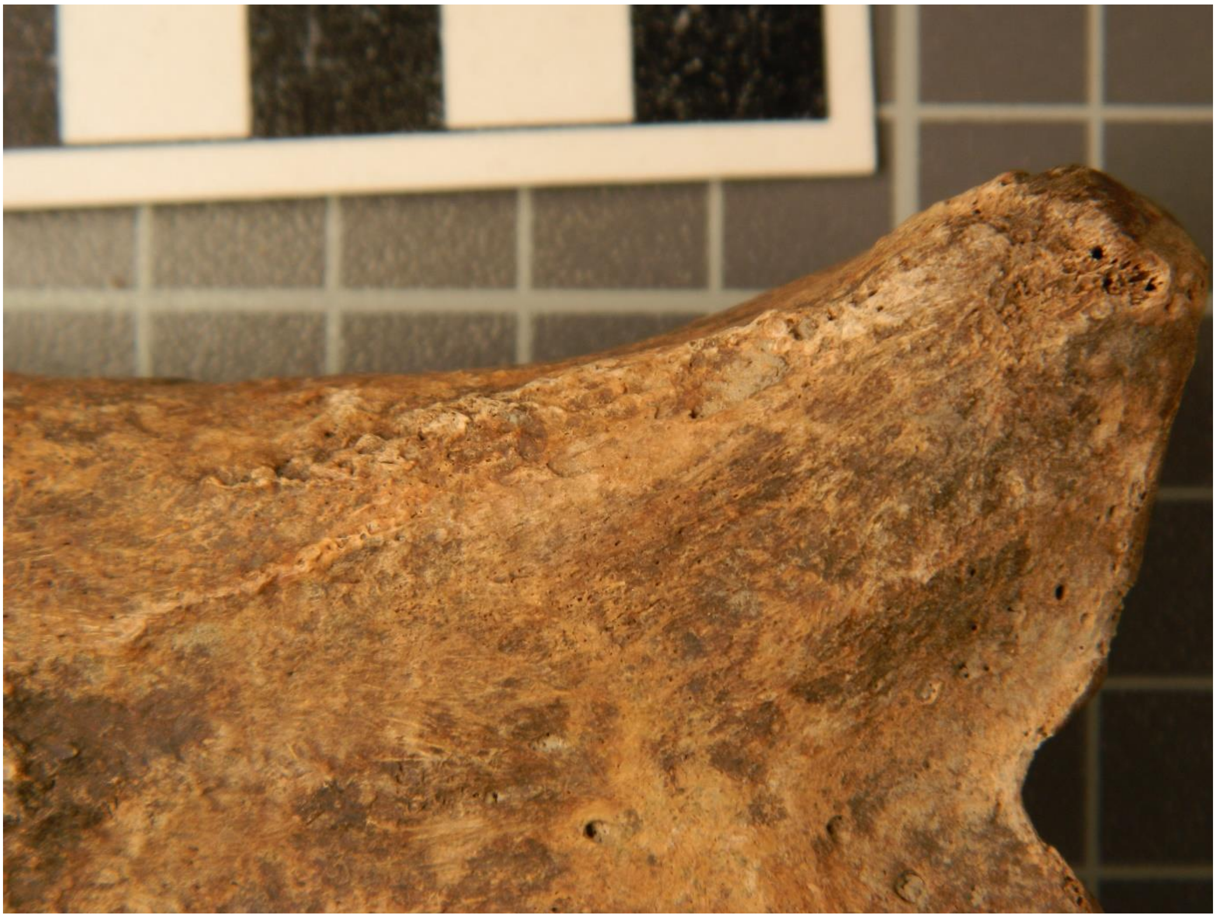

Fig.22. Above, proximo-caudal view of phalange ZOOID_5028 with pitted ridge. Below, second phalange ZOOID_5498 with bilateral proliferations (caudal view) (R. Kost).

5.2.7. Splints

Two third metatarsals evidence fusing of the second or fourth metatarsals (Fig.23). The metatarsals in question are ZOOID_5026 and ZOOID_5458. Splints are a common pathology seen in horses (Markovic *et al.* 2014, 81). In the metatarsals, this condition is typically seen in 3 – 4 year old horses and often as the result of heavy loads (Markovic *et al*. 2014, 84-85).

ZOOID_5458 is associated with structure 404, a plot dated to phase 3.

Fig.23. Metatarsus ZOOID_5458 with splints (caudal view) (R. Kost).

5.2.8. Other

V192

V192 contained a left-sided calcaneum with a possible pathology (ZOOID_5013). The lateral side of the bone shows an irregularly shaped hole in the bone (Fig.24). The hole does not reach all the way through the bone and the irregular shape of the hole make it seem unlikely that it is the result of human activity. A pathological origin could be a possible aetiology, though a tooth-pit might also be a possibility. Unfortunately the surface of the bone is pretty weathered and irregular.

Fig.24. Calcaneum from V192 with irregular hole (close-up on the right) of unclear origin (lateral view) (R. Kost).

5.2.9. Special Finds

V4078

V4078 contains a partial skeleton of a horse. It consists of the following elements: fragments of the cranium, both side of the mandibula, all vertebrae from the atlas to the sacrum, both scapulae, many fragmented ribs, both sides of the pelvis, both femurs and the left tibia (Fig.27). Both the cranial and caudal epiphyses of the vertebrae, as well as the proximal and distal epiphyses of the femur and tibia have not yet fused what would indicate an age of <4 years old which would suggest an age older than >1.5 - 2 years. The second molars that have not fully emerged indicate an age of around 2 years. This would indicate a young animal between 1.5 and 2 years old.

Exceptional are the two second molars that exhibit a strange pathological condition that might have influenced their development and emergence (ZOOID_5517). These second upper molars on both sides are severely "swollen" near the roots of the teeth (Fig.25; Fig.26). The left molar was identified separated from the maxilla, while the right molar was still present within the maxilla. Both upper second molars of this animal were still emerging. The swelling in the teeth was within the maxilla while the crown of the molar appears normal.

In archaeozoological literature there is no mention of a similar condition. It seems similar in appearance as hypercementosis or cementomas as seen in the veterinary literature (Grier-Lowe and Anthony 2015, 858). Hypercementosis is a result of the condition equine odontoclastic tooth resorption and hypercementosis (EORTH). In horses however, it is a condition that occurs in older horses of >15 years old as well as typically affecting the incisors and canine teeth. On the other

Fig.25. Right maxilla from V4078 with swollen molar (lateral view) (R. Kost).

Fig.26. Left swollen second molar from V4078 (lateral view on the left, anterior view on the right) (R. Kost).

Fig.27. Overview of associated skeleton v4078 (R. Kost).

hand, in humans cementomas primarily occur in the premolars and molars of children and young adults (Grier-Lowe and Anthony 2015, 861). This may be a similar condition, but there is a lack of literature on this condition in horses.

V850

V850 contained a set of first, second and third phalanges (ZOOID_5542) fused together and covered in pitted and spongy bone material (Fig.28). The proximal end of the first phalange and the distal end of the third phalange are visible at either end. The second phalange is not visible due to the pathological bone covering it, though it is likely present underneath it. The pathological condition was probably present at distal end of the metapodia judging the development of bone at the proximal end of the first phalanx. Although at first glance the pathology seem more severe in the medial side of the bone, part of the pathological bone has broken off from the lateral side as well as from the posterior side, likely during excavation and/or transport. It is difficult to tell whether these phalanges are from the front or hind limb and they seem to be the left, but due to the pathological bone this is our interpretation.

While phalangeal fusion is a typical result of stress on the limbs seen in horses, due to the severity of the pathology, it seems unlikely it could have advanced to this state while the animals was still used. A pathology of this form and severity may rather be the result of an infection (Baker and Brothwell 1980, 123).

Fig.28. Severe pathology surrounding phalanges I, II and III from V850 (anterior view) (R. Kost).

V2959

V2959 contained a right metatarsus (ZOOID_5026) with multiple pathologies (Fig.29). The metatarsus has a ridge of bone along the length of the lateral side of the diaphysis. This is a typical pathology found in horses in which the fourth metacarpus fuses to the third metacarpus. There is a Similar ridge along medial side of the caudal part of the bone, where the second metacarpus started to fuse to the third metacarpus. The fusion of these bones is a pathology common in horses called "splints". The metacarpus also has a distal epiphysis that is oriented at an angle of ca. 30° compared to the diaphysis rather than being perpendicular to the diaphysis. This fits with the condition of epiphysitis or "angled legs". This is a condition where the legs develop incorrectly and the legs become angled inwards. It is a condition that typically develops in young animals as a result of malnutrition.

Fig.29. Metacarpus from V2959 with splints and epiphysitis (caudal view) (R. Kost).

V82

V82 contains a first phalange (ZOOID_5008) with significant exostoses covering the distal end and joint with the second phalanx to which it seems to have fused, although the second phalange does not seem to be complete (Fig.30). There is also some pitting along the posterior side of the diaphysis. Regarding the size of the bone it seems that the first phalanx is relatively short and wide.

The exostoses are characteristics of ring bone (Dzierzecka *et al.* 2008, 690-691). Although the condition lacks a precise definition, it is described as bony exostoses affecting the interphalangeal joint. This would be a case of high ring bone since it affects the first interphalangeal joint. In severe cases it can also cause ankyloses as seems to be the case in this instance with the fusion with the second phalange. Ring bone is typically a disease affecting the fore feet of heavy draught horses (Baker and Brothwell 1980, 120-122).

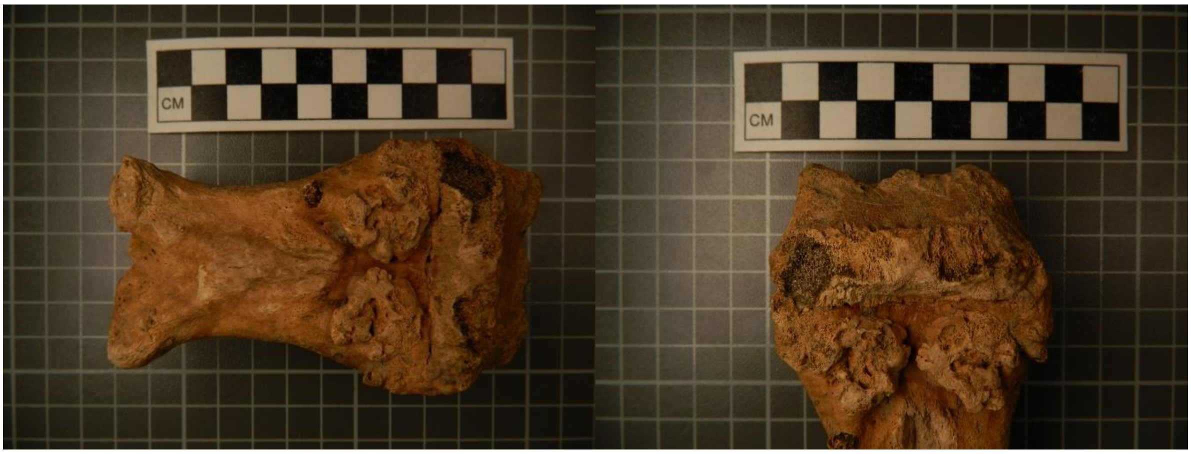

Fig.30: Phalange from V82 with ringbone (caudal view on the left, dorso-caudal view on the right) (R. Kost).

V4787

Find number 4787 contained a tibia and part of the fibula of a dog. While outside of the scope of this research, it contained a severe pathology worth reporting. The tibia shows evidence of a fracture halfway down the shaft of the diaphysis. The fracture has subsequently healed with a large amount of bone around the fracture fusing the fibula to the diaphysis of the tibia as well (Fig.31).

Fig.31. Dog bone from V4787 with healed fracture (R. Kost).

5.2.10. Pathologies described by Archeoplan Eco

Below all pathologies that have been recorded and described by staff from Archeoplan Eco will be presented.

V8789

Find number 8789 contains a right mandibula (ZOOID_669). The mandibula is described as having a second premolar with a hole in the tooth. This description is somewhat lacking, but this description does not point to a concave wearing of the tooth that is typically associated with a bit. Rather, this seems to indicate a hole in the tooth as seen with caries. The mandibula is associated with structure 662, a ditch dated to phase 3 or 4.

V758

Find number 758 contains a left-sided metacarpus (ZOOID_1590). On the edge of the peripheral metacarpals a light amount of thickening of the bone was identified as well as exostoses. The articular surface however does not seem to be affected in any way. Since the articular surface is unaffected, a joint condition is unlikely. Exostoses along the peripheral metacarpals point to the development of splints. The light amount thickening of the bone could also fit with splints as seen in ZOOID_5458 (Fig.23).

V3067

Find number 3067 contains four upper premolars and molars (ZOOID_1692), the P3, P4, M1 and M2. The fourth premolar has a chewing surface that differs from the other teeth. The chewing surface has a concave hole where the tooth has worn away. The location of the concave wearing on the upper P4 is somewhat unusual, since there is no mention of wearing of the P3. Tooth wear as result of the wearing of a bit or bridle typically occurs in the first premolars (Baker and Brothwell 1980, 147; Siegel 1976, 363). While tooth wear on the later premolars does occur as seen in Diedrich (2017, 18-25), this does not seem to happen independently, but rather in combination with previous wear or tooth loss in the previous premolars. The teeth are associated with structure 398, a plot dated to phase 3.

V5553

Find number 5553 contains a right-sided metacarpus (ZOOID_1738). The bone has light bone proliferations with a porous but even surface along the diaphysis. The even but porous surface indicates a periosteal lesion, so some form of periosteal inflammation seems likely. The presence of proliferation along the diaphysis of the metacarpus have also been observed by Markovic *et al.* in riding horses (2014, 81). This metacarpus is associated with structure 407, a plot dated to phase 3.

V7535

Find number 7535 contains a right-sided mandibula (ZOOID_1944) and left-sided mandibula (ZOOID_1946). The mandibulae both show hyperdontia in the form an extra incisor/canine, likely a wolfstooth. The mandibulae also shows a significant amount of distance between the fourth premolar and the first molar and the bone between the teeth has withdrawn. The retraction of bone between teeth and the presence of a gap between two teeth are typical indicators of periodontal disease (Baker and Brothwell 1980, 148-153).

Find number 7535 also contains a maxilla (ZOOID_1947). The canines on both sides are severely worn down to the point where the canines are very flat. This is not a pathological change that is described in archaeozoological literature.

V7584

Find number 7584 contains a third phalange (ZOOID_1953). This phalange shows bone proliferations on the proximal side alongside the articular surface. Bony proliferations along the articular surface indicate it affected the interphalangeal joint of the second and third phalanges. This fits with the general description of ringbone, particularly low ringbone (Baker and Brothwell 1980, 120).

Additionally, find number 7584 contains an axis (ZOOID_1954). The axis has a “hook” shaped edge along the backside of the processus transversus. Pathological changes to the cervical vertebrae are uncommon and rarely described. It may be related to confinement in stables as the horse would have had to keep its head elevated as proposed by Levine *et al.* (2000, 125), causing the development of such an hook shaped proliferation, this is however highly speculative since not much is known.

V3379

Find number 3379 contains a right-sided metatarsus (ZOOID_2220). The metatarsus is fused with the central tarsal bone. Around the fusing of the bones there is a significant amount of the bone proliferations. The presence of proliferations and fusion of the tarsal bone to the metatarsus is seen in spavin. Spavin can cause a mild lameness and is typically the result of heavy work and working on hard surfaces (Baker and Brothwell 1980, 117-119). This metatarsus is associated with a plot dated to phase 3.

V6313

Find number 6313 contains three lumbar vertebrae (ZOOID_3529). One of the lumbar vertebrae shows bone proliferation along the sides of the corpus. The vertebral joints are unaffected however.

Since there is no evidence of pathological change along the vertebral joint, it seems it is not part of the process of vertebral fusion. Since it affects only a single vertebra it seems a very minor pathology or perhaps a very early stage in the development of a condition. These vertebrae are associated with structure 398, a plot dated to phase 3.

V7015

Find number 7015 contains a first and second phalange (ZOOID_4381 and ZOOID_4382). The two phalanges are fused to each other. Around the phalangeal joint there are bone proliferations. The fusion of the first and second phalange with proliferations and exostosis are typical characteristics of ringbone, in particular high ringbone (Baker and Brothwell 1980 120).

5.3. Overview of the typology and skeletal distribution of pathologies

Absolutely, the most commonly affected skeletal elements among the horses from De Hoge Hof are the mandibulae, metatarsals, the first phalanges and the pelvis. The number pathologies on these skeletal elements range from 6 – 10 whereas all other elements that show pathologies range from 1 – 3. The metatarsus and pelvis are all part of the hind legs. While no distinction has been made between front and hind leg for the phalanges, but it seems likely that at least part of these pathologies are part of the hind legs. These are also all skeletal elements that are well represented in the total assemblage, with total numbers of 95 pelvises, 76 metatarsals and 63 first phalanges. If we look at the presence of pathologies percentagewise these elements are also well represented compared to other elements with 8.4% for the pelvis, 10.5% for the metatarsus and 12.7% for the first phalange. This would point towards activities that influence the hind legs.
The mandibula shows a higher number pathologies as well compared to the other skeletal elements with 6 instances of pathology. The mandibula is also well represented with 106 elements. Percentagewise this is significantly lower than the hind leg bones with a percentage of only 5.7%.
If we look at the other skeletal elements with only a few instances of pathology, we see a great variety of skeletal elements. The tibia is also part of the hind leg, however, this bone has only yielded two instances of pathology while this is one on the most common skeletal element in the assemblage. It accounts for only 1.7% of the total number of tibia. Whatever factors may have been of influence on development of pathologies on the hind legs, the tibia seems mostly unaffected.
Some other skeletal elements worth noting are the axis, calcaneum, metacarpus, second phalange, and lumbar vertebrae. These are all elements that have low numbers of pathologies but relatively high ratios of pathologies. There is not much in common regarding the location of these elements.

This is obviously due to their low presence in the assemblage as a whole, so any pathology will seem overrepresented such as is the case for the axis. The axis is not a very common skeletal element in the assemblage with 11 entries, but two instances of pathology has a high presence percentagewise with 18.2%. It is noteworthy that the second phalange, while not as numerous as the first phalange, shows a similar presence of pathological changes percentagewise as 12.5%.
There is also one instance of a 100% of ratio of affected elements, however, this is the phalange category. This is V850, a single instance of three phalanges that are fused together with severe proliferation surrounding it. This has been recorded as a single entry under the category phalange. This seems to be a unique form of pathology compared to the rest of the phalanges. The 100% pathology-ratio is uninformative and can thus be ignored.

6. Discussion

6.1. The unique horse assemblage at the De Hoge Hof

There is an unusually high presence of horse at De Hoge Hof, accounting for 16.7% of the assemblage. In the Netherlands, such frequency of horse has only been documented in the Early Middle Ages at Wierum (Groningen) (Cakirlar *et al.* 2019, supplementary table 20), but not in the riverine area. It should be highlighted though that the 17% horse frequency at Wierum is only based on 7 horse remains (NISP = 41) whereas the horse NISP at De Hoge Hof is 1786 (Tab.2). Although the excellent preservation of the archaeozoological material at the Hoge Hof might have influenced such frequency, it still makes this assemblage unique for the whole of the archaeozoological record of the Netherlands and suitable for an investigation of horse pathologies.

De Hoge Hof is also an interesting period to address horse pathologies because based on other find categories, there is mainly evidence of farming activities and evidence of milling (ADC and BAAC 2020). In the Hoge Hof, grinding stones have been used to suggest that some of the mills may have been animal powered. If this is indeed the case, pathologies related to such activities would be expected in the assemblage, but given that cattle, not horse, have been reported more often to be related with all sort of traction activities since Roman times (Groot 2005), such hypothesis requires a well based series of empirical data.

There is evidence of light traction activities by horses from early medieval Ireland (McCormick 2007, 93) and with the introduction of the horse collar in Europe during the tenth century horses were usable for heavier traction activities such as ploughing (Raepsaet 1997, 55-57). Pathologies related with horse traction have been reported in Bendrey (2007a) and Diedrich (2017) and include particularly pathological changes to shoulder and hip (such as coxofemoral osteoarthritis) (Diedrich 2017; Levine 2000), but may also include lower limb pathologies (particularly joint diseases such as spavin and ringbone) (Baker and Brothwell 1980, Levine 2000), vertebral pathologies (such as kissing spine syndrome, articular surface lipping, synovial intervertebral osteoarthritis) (Diedrich 2017).

Because these horse pathologies have never been recorded in the Netherlands one goal of this thesis has been to develop a first categorization of the most common pathologies in order to detect whether such traction pathologies are indeed frequent to suggest horse traction.

6.2. De Hoge Hof horse pathologies as a case study: a first insight into typological categorization present in the early medieval period in the Netherlands

The range of pathologies found on the horse bones from De Hoge Hof are very diverse. For ease of analysing, the pathologies will be grouped into the following categories: 1) minor pathologies, 2) pathological changes as result of disease, 3) pathological change as result of trauma, 4) pathological change as result of stress, 5) developmental pathological changes, and 6) pathological changes of unclear origin.

Minor Pathologies

These are small pathological changes that are generally of no consequence to the health of the animal and are generally benign neoplasia. This category consists of a scapula (ZOOID_5132), mandibula (ZOOID_5501), metatarsus (ZOOID_5097) and lumbar vertebra (ZOOID_3529). These minor pathologies are not caused by any outside factors and not particularly informative. Minor pathologies account for 7.4% of the total amount of pathologies. Minor pathologies are spread out across the body and do not seem to have an overly large presence in any skeletal element.

Pathological change as result of disease

These are pathological changes that are most likely the result of an infection or other disease. These include a cranium (ZOOID_5066), mandibula (ZOOID_5235), the ankylosed phalanges (ZOOID_5542), a premolar (ZOOID_669), two mandibulae (ZOOID_1944; ZOODI_1946).

The number of disease-related pathologies are low in De Hoge Hof (13.0%) and all, except for one, affect the head area and consist of either oral pathologies (caries and periodontal disease) or lesions on the head. The disease-related pathologies can be divided in two group, infection related pathologies and dental pathologies. The dental pathologies observed are both pathological changes seen in relation to nutrition. The other disease-related pathologies seem infectious in nature, with the two cranial pathologies appearing similar, but due to the nature of infection-related pathological changes an exact diagnosis is impossible.

Dental pathologies reported by Onar *et al.* (2012) from a Byzantine harbour consisting primarily of caries, oligondontia, abscess chambers, alveolar recession and abnormal teeth wear (amounting to (38.1%) related to bit wearing and those reported by Diedrich (2017) from 19th century mining horses show caries and on almost all horses abnormal tooth rows as result of bit pressure. This is in stark contrast dental pathologies from De Hoge Hof consisting mainly of periodontal disease that are more commonly associated by malnutrition (Baker and Brothwell 1980). It seems that the horses of De

Hoge Hof did not show similar evidence of bit wear and these dental pathologies are likely related to nutrition instead.

Pathological change as result of trauma

These are pathological changes that have been attributed to trauma. There are no instances of fractures in the assemblage. Several skeletal elements, a mandibula (ZOOID_5263), a metatarsus (ZOOID_5348) and a rib (ZOOID_5535), have been identified with what likely are ossified haematomas. Ossified haematomas are the result of blunt force trauma (Baker and Brothwell 1980). The ossified haematomas in this assemblage are of a small size suggesting lighter trauma. Then again, more severe blunt impact would likely have led to fracturing rather than a haematoma. Trauma related pathologies account for 5.6% of pathologies (0.17% of the total assemblage) in the assemblage and do not seem to be more abundant in any skeletal element or part of the body in particular. Trauma related pathologies are also reported by Diedrich (2017) in mining horses, but these were located in the scapula and ischium and are thought to be the result of mining accidents. Vertebral trauma has been reported related to riding have been reported by L. Bartosiewicz and G. Bartosiewicz (2002) and Pluskowski *et al.* (2010). Slightly lower amounts (<0.1% of the total assemblage) of trauma related pathologies in similar skeletal elements are reported by Onar *et al.* (2012), but these consist mainly of healed fractures in the ribs and metatarsus. These traumas have been attributed to kicking by other animals. While this assemblage does not include healed fractures, the trauma related pathologies are mostly located in the same skeletal elements and the slightly higher frequency may be related to the low sample size and inclusion of less severe traumas. The trauma related pathologies of this assemblage do not indicate riding.

Pathological change as result of stress

These are pathologies that are most likely the result of some form of stress on the body, typically from certain physical activities. Two thoracic vertebrae (ZOOID_5113; ZOOID_5114), a lumbar vertebra (ZOOID_5612), a humerus (ZOOID_5514), eight pelvic bones (ZOOID_5202; ZOOID_5226; ZOOID_5252; ZOOID_5421; ZOOID_5482; ZOOID_5251; ZOOID_5350; ZOOID_5227), eleven phalanges (ZOOID_1953; ZOOID_4381; ZOOID_4382; ZOOID_5008; ZOOID_5028; ZOOID_5107; ZOOID_5358; ZOOID_5471; ZOOID_5498; ZOOID_5513; ZOOID_5613), three metatarsals (ZOOID_2220; ZOOID_5026; ZOOID_5458), and two metacarpals (ZOOID_1590; ZOOID_1738) have been assigned as stress related pathologies accounting for 53.7% of all pathologies. These are the pathologies that are more often related to the use of the animal either as the result of riding or draught activities rather than related to natural causes (Levine *et al.* 2000). The vast majority of these stress-related pathologies affected the limbs, with a small amount affecting the vertebrae. Many of the common limb-affecting pathologies found in horses have been found in the assemblage such as spavin, splints, and ringbone. These are generally agreed to be the most common pathological changes (Dzierzecka *et al.* 2008) and often reported from archaeozoological assemblages (Markovic *et al.* 2014; Onar *et al.* 2012; Diedrich 2017). These are pathologies that are generally attributed to heavy work and loadings (Baker and Brothwell 1980; Markovic *et al.* 2014; Onar *et al.* 2012). Looking further at the ratio between front and hind limbs, 3 pathologies are located in the fore limb whereas 12 are located in the hind limb. The ratio is significantly in favour of the hind limb. This is in contrast to riding horses reported by Markovic *et al.* (2014), where the front limbs were more often affected due to greater loading under the rider. This would indicate the horses of the Hoge Hof were not primarily used for riding, but rather activities that put stress primarily on the hind limbs.

A large part (11) of the stress related pathologies are phalangeal, particularly bilateral osteophytosis. Due to the difficulty and unreliability of designating phalanges to either front or hind leg, these have not been assigned to either. This does leave a large part of stress related pathologies as unknown in terms of the fore limb or hind limb. It seems more likely that the majority phalangeal pathologies were related to the hind legs due to the higher frequency of the other pathologies in these limbs. While some of the limb bone pathologies are seen in riding horses, most all of the pathologies are common in draught horses.

Pelvic pathologies make up a significant part of pathologies in the assemblage (14.8%). These are similar to pelvic pathologies described by Diedrich (2017) where they are related to heavy wagon pulling. It would be expected that the pelvic pathologies from De Hoge Hof are related to similar draught activities.

Vertebral fusion is found in middle ages and old riding horses as well as draught horses (Diedrich 2017), but in riding horses these pathologies tend to be much more advanced to severe cases as “bamboo spine” (Bartosiewicz & Bartosoewicz 2002; Onar *et al.* 2012; Pluskowski *et al.* 2010). As seen, pathological changes to the thoracic vertebrae can also occur as the result of draught activities (Diedrich 2017). The single pathological change to the lumbar vertebra is also seen as result of the natural aging process. The low presence of vertebral pathologies and their relatively minor degree of these pathologies suggests that these animals were not likely riding animals. It is still possible that some animals on occasion have been used for riding, but if so, not to a degree where typical riding related pathologies have developed.

Developmental pathological changes

These are pathological changes that are the result of developmental issues. There is only a single instance of a pathology that has been assigned as a developmental pathology. This pathology is an epiphysitis or “angled legs” in the metacarpus ZOOID_5026 and displays an angled articular surface of the distal epiphysis. It is a condition that is typically seen in young animals and are common in malnutred horses (Baker and Brothwell 1980).

Pathological changes of unclear origin

These are pathological changes that are not known from archaeozoological literature and for which no clear aetiology has been identified. A metatarsus (ZOOID_5278), two axis (ZOOID_1954; ZOOID_5197), a cervical vertebra (ZOOID_5530), two second upper premolars (ZOOID_5517), and a fourth upper premolar (ZOOID_1692) have been assigned to this category. These account for 18.5% of pathologies and have been recorded in the head area, neck area, and both front and hind limbs. Two axis and a cervical vertebra have been identified with bony ridges along the corpus and proliferations at the base of the processus spinoidus. A hypothesis for some cervical pathologies has been suggested in relation to confinement (Levine *et al.* 2000). Several outbuildings from the early and late Middle Ages (phases 2 and 3) have been interpreted as possible stables (ADC and BAAC 2020), potentially supporting this hypothesis.

The fourth upper premolar of ZOOID_1692 shows a concave hole. At first glance it might be attributed to bit wear, but bit wear is normally seen in the lower second premolar (Bendrey 2007b). If bit wear is seen the fourth premolar, the second and third molar would normally be affected as well (Diedrich 2017), but there is no bit wear present on the third premolar. As such it is unclear what exactly may have caused this pathology.

6.3. De Hoge Hof pathologies and anthropic activities: a related matter?

Categorizing the different forms of pathologies has allowed us to confirm that the majority of pathologies are related to stress. These stress-related pathologies are present in the vertebrae and limbs, particularly affecting the latter.

Out of the pathologies identified, 29 of these have been identified as work-related pathologies and mostly located in the limb bones. The small amount of vertebral pathologies and their relatively mild state compared to other riding horses such as seen the bamboo spine in Bartosiewicz & Bartosiewicz (2002) or vertebral fusion seen in Onar *et al.* (2012), suggest that the horses at De Hoge Hof site were not used as riding horses. The small amount of vertebral pathologies can very well be explained by use as working horses as seen in mining horse described by Diedrich (2017). Other material finds suggest that animals may have been used in mills based on certain types of milling stones. The pelvic pathologies and higher frequency of pathologies in the hind limbs support the hypothesis that the horses of De Hoge Hof were used for draught activities (Diedrich 2017) and may have been used in animal powered mills. This would be uncommon since cattle have been reported to be more commonly related to traction activities (Groot 2005). Comparison to the cattle assemblage of De Hoge Hof could provide a better understanding whether horses were used for heavy traction activities.

There is some pathological evidence related to husbandry practices. First of all, there is some evidence of malnutrition. An instance of caries, an instance of periodontal disease and an instance of epiphysitis may all be related to malnutrition or at least feeding activities of horses. Furthermore, there are three instances of pathologies likely related to infection, two cranial and one phalangeal. Pathological changes from bacterial infection in two horses described by Bendrey *et al.* (2008) are found spread throughout the body. The cranial and phalangeal pathologies from this site seem unliky to be related and seem more local infections. Although these are some instances of pathology that may be related to poor husbandry practices, these are uncommon in the assemblage. The phalangeal infection may very well be related to work activities.

Related to husbandry practices, are two instances of pathological changes to the axis. Although this is not a commonly described pathology and not well understood, it has been suggested that such pathologies may indicate the animals have been stabled for a prolonged period of time with their heads elevated (Levine *et al.* 2000). There is evidence of outbuildings that may be potential stables. If these pathologies are indeed related to stabling, it would indicate these horses would have spent a lot of time stabled rather than grazing outside.

Finally, most of the pathologies in the unclear origin category are due to a lack of representation in palaeopathological literature.

6.4. Horse pathologies: advantages and challenges of study

Having discussed the results of the analysis of the assemblage, it is also important to discuss the advantages, disadvantages, and difficulties in the use paleopathology. First of all, there is the difference in frequency of pathologies between observers. Out of the pathologies identified, 42 pathologies (Tab.8) were recorded by the author out of 472 identified horse bones. The 14 remaining pathologies recorded by others (Tab.8), were so out of 1098 identified horse bones. There is a vast difference in frequency of pathologies between observers. There are two possible explanations for this difference in frequency of pathologies. First off, there is the difference in research goals. Due to the focus of this investigation being on pathologies, the author is much more focussed on identifying any pathological changes that can be observed. This likely leads to closer scrutiny of the bones as well smaller changes being recorded compared to a normal analysis of the material that is focused on recording and determining the assemblage, in which case one may only record very obvious pathological changes or may disregard minor pathological changes. A second explanation might be a difference in knowledge regarding pathologies. As mentioned by Janeczek *et al.*, literature regarding paleopathology in animals is limited and as Markovic *et al.* noted, there is no definitive and detailed system or nomenclature for paleopathology. A deeper investigation into paleopathology in horses likely leads to a better ability to identify pathological changes.

This leads into a second difficulty of paleopathology. There seems to be a clear difference in the description of pathological changes, not only between observers but also between authors of palaeopathological literature. The use of different description leads to difficulties of recognizing conditions, uncertainties and could lead to incorrect diagnoses that would be required to identify the archaeological role of animals. All this stems from the lack of a defined system and nomenclature of paleopathology of animals. The inclusion of visual data such as pictures can alleviate the problem of differing descriptions to some extent, and are definitely a necessity in paleopathology.

From the result of this investigation, a variety of pathologies has been observed in the assemblage, but often in small amounts. In some cases, pathologies can be difficult to interpret on individual basis. For example, there is an instance of splints in one of the metacarpi. On the front limbs this condition is often seen in riding horses, while splints in the hind limbs are often attributed to working horses, but from literature is becomes apparent that splint in the front leg can occur in working horses. On individual basis, this instance of splints might suggest that the animal was a riding horse, but the high presence of pathologies in the hind legs as seen in working horses, and a very small amount of vertebral pathologies (again typically seen in riding horses but can occur in working horses), on top of evidence from the other find categories strongly indicate the horses were working horses. Without the understanding of the full assemblage it may be hard to correctly interpret these pathologies. This site with its large assemblage of well-preserved skeletal elements of horses lend itself ideally for such palaeopathological investigation, but in general horse remains and horse pathologies less common or may not be so well preserved. In the case of small amounts of material or severely fragmented and weathered remains, paleopathology may be hard to identify and interpret. Sites with large assemblages, good preservation or remains with multiple instance of associated pathologies would lend themselves well for palaeopathological investigation. As such, paleopathology may reveal valuable insight in the relation between humans and animals or confirm hypotheses regarding these relations, but the situations where it can be properly applied, may be limited and should be kept in mind.

7. Conclusion

De Hoge Hof is an interesting site for the study of pathologies in horses, showing a high frequency of horse pathologies only seen in one other site in the Netherlands. Pathologies observed in the horses from the De Hoge Hof, show a large variety of pathologies that can be found in medieval horses from the Netherlands. Pathologies found include: minor pathologies such as benign neoplasia, disease related pathologies such as periosteal lesions, caries and periodontal disease, trauma related pathologies including ossified haematomas, stress related pathologies including synovial intervertebral osteoarthritis, spondylosis, coxofemoral osteoarthritis, bilateral osteophytosis, spavin, splints and ringbone, and the developmental pathology epiphysitis. There are also several pathological changes of unclear origin. Majority of pathologies are observed in the limbs, particularly in the hind limbs. Particularly the pelvis, metatarsus and phalanges are affected. The observed pathologies indicate that the horses of De Hoge Hof were likely used as work horses. There is little evidence to support the use as riding horses and what little evidence there is, may still fit with a use as work horses. These findings are supported by other evidence pointing to a farming communities with possible animal powered mills. Periodontal disease and epiphysitis are conditions that may indicate instances of malnutrition, but these conditions are few in the assemblage. The periosteal lesions on the head indicate some form of disease or infection, but an exact diagnoses has not been established. Similarly, this pathology in uncommon in the assemblage. It has shown that at the medieval farming community of the Hoge Hof, horses were primarily used as work animals. Pathologies have been able to identify a role of the horses primarily as working animals. However, in order to get a further understanding of what activities this might have involved, this data has to be combined with evidence from other disciplines highlighting the importance of combining of data. These are however the result of a single agricultural site in the Netherlands. This is a start regarding the palaeopathological knowledge of medieval horses in the Netherlands, but cannot be taken as representative of medieval horses. To this end, paleopathology would have to be applied to archaeozoological remains from different types of sites as well as more similar sites throughout the Netherlands.

While paleopathology has been able to identify the likely use of the horses, it has also highlighted some of the issues and limitations of paleopathology. There are issues regarding differences in frequency of recognized pathologies between observers as well as difference of describing certain pathologies. For a large part, this issues stem from a lack of a clear system or nomenclature as well as a limited amount of the literature regarding the pathologies of horses. To combat this, the inclusion of visual data is mandatory for the use in future research.

In conclusion, paleopathology can be a useful tool for understanding the role of medieval horses in archaeological contexts, but its limitations should be kept in mind. It can identify general categories of horses, but should not be used without supporting evidence from other disciplines. Furthermore, there is a need for a proper system and nomenclature. This could help alleviate many of the issues regarding the implementation of paleopathology.

8. Abstract

Paleopathology is the study of pathological changes in ancient remains. It is not often employed in the investigation of archaeozoological remains. Palaeopathological publications of horses are even rarer and almost unknown from the Netherlands. In this research paleopathology is applied to horse remains from a Dutch medieval site, De Hoge Hof, Tiel, in order to understand which forms of pathology occur in medieval horses from the Netherlands and what information can be gained from paleopathology on horses regarding their use, role and relation to humans. Furthermore the advantages, disadvantages and difficulties of applying paleopathology to medieval horse remains are explored based on this investigation.

A general overview of animal pathology is presented based on the works of Baker and Brothwell and further supplemented with an overview of results of pathological studies on archaeozoological horse remains.

The materials used for this investigation are from an excavation of the site De Hoge Hof near Tiel in the riverine area of the Netherlands. This is a site that showed human presence from the Roman period up to the Modern Age, with the strongest human presence in the High and Late Middle Ages. The site boasted a large amount of horse remains in its assemblage, particularly during the Early and Late Middle Ages. Further find categories indicate that the site was an agricultural site with a presence of both smaller hand mills and larger mills, possibly animal powered.

The vast majority of horse remains are associated with the Early to Late Middle Ages in which an unusual number of pathological changes were detected by the preliminary study. These pathological changes have all been described, presented and interpreted in order to have a first approach to horse pathology in the Netherlands, in general, and their relation to human activities during the Middle Ages, in particular. In order to achieve this, a typological categorization of horse pathologies is attempted and the relation between pathologies and anthropic activities are discussed.

Samenvatting

Paleopathologie is de studie van pathologische veranderingen in oud botmateriaal. Het wordt niet vaak toegepast in onderzoek naar archeozoologische resten. Paleopathologische publicaties over paarden zijn nog zeldzamer en vrijwel onbekend uit Nederland. In dit onderzoek wordt paleopathologie toegepast op de paarden de resten van de Nederlandse middeleeuwse site, De Hoge Hof, Tiel, om te begrijpen welke vormen van pathologie voorkomen in Nederlandse middeleeuwse paarden en welke informatie kan worden verkregen betreffende het gebruik, de rol en relatie van de paarden tot de mensen. Eveneens worden de voordelen, nadelen en moeilijkheden van het toepassen van paleopathologie op middeleeuwse paardenresten onderzocht.

Een algemeen overzicht van dierenpathologie verzamelt gebaseerd op het werk van Baker en Brothwell en verder aangevuld met een overzicht van resultaten van pathologische studies van archeozoologische paardenresten.

Het materiaal dat gebruikt is voor dit onderzoek komen van een opgraving van de site De Hoge Hof nabij Tiel, gelegen in het revierengebied van Nederland. Deze site bevat sporen van menselijke bewoning vanaf de Romeinse Tijd tot de Nieuwe Tijd, met de sterkste menselijke aanwezigheid gedurende de Hoge en Late Middeleeuwen. De site bevat een groot aantal paardenbotten in de assemblage, in het bijzonder gedurende de Hoge en Late Middeleeuwen. Andere vondstcategorieën wijzen erop dat deze site een agrarische nederzetting was met de aanwezigheid van zowel kleinere handmolens tot grotere mogelijke rosmolens.

Het overgrote merendeel van de paardenresten is toegeschreven aan de Vroege en Late Middeleeuwen waarin een ongebruikelijke hoeveelheid pathologische veranderingen zijn aangetroffen uit een vooronderzoek. Deze pathologische veranderingen zijn allemaal beschreven, gepresenteerd en geïnterpreteerd om een eerste aanpak te verkrijgen tot paardenpathologie uit Nederland, in het algemeen en, in het bijzonder, de relatie tot menselijke activiteiten gedurende de Middeleeuwen. Om dit te bereiken is een typologische categorisatie van paardenpathologieën geprobeerd en is de relatie tussen de pathologieën en menselijke activiteiten besproken.

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10. Figures and Tables

Figures

Tables