Histories written in (cattle) bone – an archaeozoological and osteological perspective

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Abstract

Cattle are not designed for carrying loads or pulling weights. Their wild ancestor, the aurochs (*Bos primigenius*) evolved to be excellent at grazing and browsing in herds, but since their interactions with humans some 10.000 years ago, domestic cattle (*Bos taurus and Bos indicus*) have been exploited, in life, for milk and power. This paper investigates the effects of one aspect of domestication on the skeleton of cattle – that of draught work. We combine approaches, using observations taken from modern animals through the lens of veterinary science, and paleopathologies recorded on archaeological material. The stories presented show how loading can affect the skeleton of draught animals, problems in diagnosis in the living, and problems in determining a cause in the dead. In either case, it is shown that when cattle are used for draught work it affects their skeleton, sometimes with extreme consequences.

Résumé

Les bovins ne sont pas faits pour porter des charges ou tirer des poids. Leur ancêtre sauvage, l'aurochs (*Bos primigenius*), a évolué pour être efficace dans le pâturage et le broutage en troupeaux, mais depuis leur interaction avec les humains il y a environ 10 000 ans, les bovins domestiques (*Bos taurus* et *Bos indicus*) ont été exploités, de leur vivant, pour leur lait et leur force. Cet article examine les effets d'un aspect de la domestication sur le squelette des bovins : le travail de traction. Nous combinons plusieurs approches, en utilisant des observations faites sur des animaux modernes à travers le prisme de la science vétérinaire et des paléopathologies enregistrées sur du matériel archéologique. Les résultats présentés montrent comment l'effort de traction peut affecter le squelette des animaux de trait, les problèmes de diagnostic chez les animaux vivants et les problèmes de détermination de la cause chez les animaux morts. Dans les deux cas, il est démontré que lorsque les bovins sont utilisés pour le travail de traction, cela affecte leur squelette, parfois avec des conséquences extrêmes.

Kurzfassung

Rinder sind nicht dafür geschaffen, Lasten zu tragen oder Gewichte zu ziehen. Ihre wilden Vorfahren, die Auerochsen (*Bos primigenius*), entwikkelten sich zu hervorragenden Weidetieren, die in Herden grasten und Blätter fraßen. Seit ihrer Begegnung mit dem Menschen vor etwa 10.000 Jahren werden domestizierte Rinder (*Bos taurus* und *Bos indicus*) jedoch zu Lebzeiten für die Milchproduktion und als Zugtiere genutzt. Dieser Artikel untersucht die Auswirkungen eines Aspekts der Domestizierung auf das Skelett von Rindern – nämlich die Zugarbeit. Wir kombinieren verschiedene Ansätze und stützen uns dabei auf Beobachtungen moderner Tiere aus veterinärmedizinischer Sicht sowie auf paläopathologische Befunde aus archäologischen Fundstücken. Die vorgestellten Fälle zeigen, wie sich Belastungen auf das Skelett von Zugtieren auswirken können, welche Probleme bei der Diagnose bei lebenden Tieren auftreten und welche Schwierigkeiten es gibt, die Ursache bei toten Tieren zu bestimmen. In beiden Fällen zeigt sich, dass sich der Einsatz von Rindern als Zugtiere auf ihr Skelett auswirkt, manchmal mit extremen Folgen.

Resumen

El ganado vacuno no está diseñado para transportar cargas ni tirar de pesos. Sus ancestros salvajes, los uros (Bos primigenius), se convirtieron en excelentes animales de pastoreo que pastaban en manadas y se alimentaban de hojas. Pero desde su encuentro con el hombre hace unos 10 000 años, el ganado doméstico (Bos taurus y Bos indicus) se ha utilizado durante su vida para la producción de leche y como animal de tiro. Este artículo investiga los efectos de un aspecto de la domesticación en el esqueleto del ganado: el trabajo de tiro. Combinamos diferentes enfoques, utilizando observaciones tomadas de animales modernos a través de la lente de la ciencia veterinaria y paleopatologías registradas en material arqueológico. Los casos presentados muestran cómo la carga puede afectar al esqueleto del ganado de tiro, qué problemas surgen al diagnosticar a animales vivos y los problemas para determinar la causa en animales muertos. En ambos casos se demuestra que cuando el ganado se utiliza para el trabajo de tiro, esto afecta a su esqueleto, a veces con consecuencias extremas.

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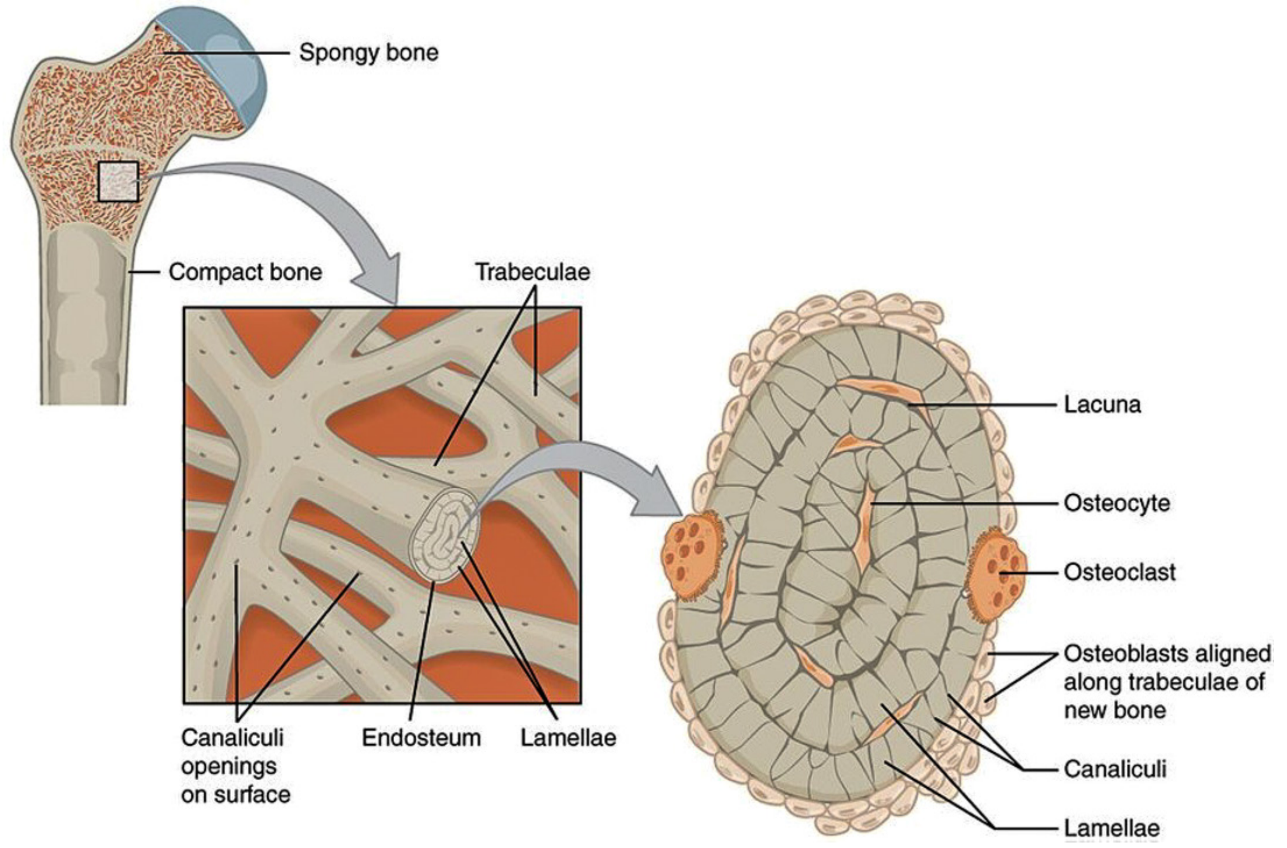

Fig 1 *Schematic illustration of bone structure (Graph: OpenStax College - Anatomy & Physiology, Connexions; Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC BY 3.0, taken from https://commons.wikimedia.org/w/index.php?curid=30131413).*

Introduction[1]

Bone is important in vertebrate animals for support and movement, and for controlling the balance of minerals like calcium and phosphorous, which are essential for metabolic functions. Bones also serve as a site where blood cells are produced, so although it can appear that bones are static and unchanging, in the living animal they are in a constant state of change.

How bones do all these things is complex, but there is a simple way of starting to explain it: "form is function." In the physical world, the shape of something determines what it can do, and vice versa. For example: a ball can roll because it is round, and conversely, round objects roll, but cuboid objects do not. The shape of a bone depends on—and determines-- it's function in the body.

Understanding bones starts with learning how they are shaped on the macroscopic level (with the naked eye), and continues with understanding the microscopic level and molecular level. At the microscopic level, all animal tissues are made up of two components:

- cells that are characteristic of the tissue
- the "stuff-between-the-cells", generically called the interstitium or the matrix.

To visualize the three-dimensional microscopic structure of bone, it may help to think of a loaf of raisin bread. The raisins in the bread are analogous to cells, and the bread or dough is equivalent to the matrix.

But a loaf of bread is *not* a good analogy for how bone tissues works, or functions. In living bone tissue, there is constant interaction between the cells and the matrix, so a better analogy for bone function is a bee hive that is being built and maintained by the bees that are living there. Like a hive of bees, the living cells constantly monitor each other, the environment, as well as the structures they are building.

All tissues have cells and interstitium, but the unique hallmark of bone tissue is the fact that the interstitium or matrix is mineralized and made rigid by precipitates of calcium and phosphorous. The mineral precipitate is what makes bones hard and stiff, so that they can function for support. Long bones like those in the legs act like levers to allow animals to move. As mentioned, the mineral deposits also act as a storage depot for calcium, phosphorus and other minerals that are essential for metabolism in vertebrate animals.

For the paleozoologist, the mineralization is important for another reason: it is why bones don't decay. Even after an animal has been dead for years, you can often see evidence of (at least some of) the things that were going on while it was still alive. It's a little like looking at the ruins of Pompei.

But the mineralization also means that it's harder to look at bone under the microscope. To look at the kidney or liver under the microscope, you cut very thin slices, but bone is difficult to cut because it shatters. On the other

1 This and the following chapter (A story told by a bone) are based on a written transcript presented by co-author Barbara Corson during the World Draft Cattle Symposium in 2024.

hand, you can use x-rays to study bone because of the mineral, but the lack of mineral means that soft tissues don't show up on radiographs.

Bone structure and function is complex and a involves a lot of biochemistry, but it's still possible to make a few useful generalizations[2]:

1. Like any living tissue, bone needs oxygen and energy to keep working. These necessities are carried in the blood, and bones have lots of blood vessels. Anything that affects the blood supply to a particular area will affect the bone quickly, for example a blood clot that plugs a blood vessel, or a fracture of the bone that tears the vessels apart.
2. Because they function as levers, being stressed (subjected to forces) is part of daily life for the long bones of animals (like those in the legs and feet). Bone tissue that is subjected to forces tries to get stronger by making more bone and repairing damage. Bone tissue that isn't stressed tries to save resources by removing bone from areas where it isn't needed. The process of adding bone where it's needed, and removing it where it's not is called "remodeling".
3. In an immature (growing) animal, bones lengthen is specific areas called growth plates. In these areas, cartilage tissue is produced which is gradually mineralized and turned into bone. Growth plates are visible with the naked eye as well as microscopically, which allows rough age determination.
4. Like other tissues, bone can be injured in various ways, including infection, physical trauma, neoplasia (tumors), nutritional imbalances and degenerative conditions. Practitioners of modern western medicine diagnose diseases by trying to determine which of these processes are or were involved.
5. Any living tissue, (including bone) responds to injury by becoming inflamed. Inflammation is a complex subject, but its signs can be summed up in four words: redness, heat, swelling, pain. Inflammation is the first step in tissue healing, but if it gets out of balance or goes on too long, it can become a problem in its own right.

Using these general rules, you can often piece together a kind of picture of what was going on in the animal's body when it was alive by looking at its bones with your naked eyes and/ or using x-ray or microscopic technology if that's available to you.

This can be both fun and useful, but disease processes are complex, it's a mistake to be too sure that you can know everything about an animal from its tissues alone. Sometimes the bones match the rest of the story:

A 10-year-old ox showed signs of severe arthritis, including lameness and swollen stifle joints when he was alive. After death, his bones definitely confirmed the clinical impression. The rough irregular surfaces of the affected femur (thigh bone) show how bone responds to long term inflammation, compared to the smooth surfaces of the normal femur.

But the bones can also tell stories that you didn't expect. For example, I performed a post-mortem on a normal-looking thoroughbred broodmare that had died suddenly. I diagnosed intestinal Salmonellosis as the cause of death. There was no history of muscle or skeletal problems, and since I wanted a set of horse bones for teaching purposes, I collected hers and cleaned them, assuming that they would be normal. But to my surprise, she had deformed lumbar vertebrae consistent with a diagnosis of spina bifida occulta. If I had been presented with only that vertebra, it would have been logical to conclude that the mare had suffered from neurologic issues during her life, but she apparently did not, at least none that anyone noticed. One of the pathologist's mottoes is: *Mortui vivos docent* (the dead teach the living). But they don't teach us everything we want to know! Sometimes they leave us with even more questions.

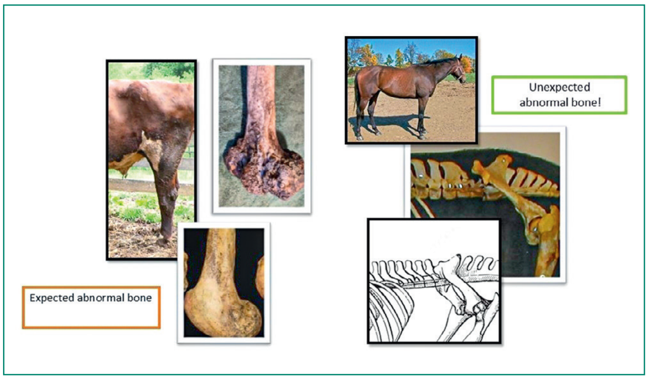

Fig. 2 *Bones provide information. Sometimes the information confirms the expected diagnosis, and sometimes the information is a surprise! (Photos and Drawing: B. Corson)*

A story told by a bone

A year or two ago, I was honored to participate in the examination of a particular bovine bone from an archeologic site in Mannheim (Vogelstang "Hinter der Nachtweide"), Germany[3].

It was the lower leg bone of an adult bovine, what we would call the "shinbone" in English. The shinbones are actually analogous to the long bones of the human hand and foot, which generates some confusion: should they be called 'leg bones' or 'foot bones'? A good way to avoid the issue is to call them 'metapodials' which roughly translated means 'after the foot' in Latin. Normal metapodials are smooth, dense, and symmetrical.

Fig. 3 *Normal metatarsal bone from adult cattle (Photo: M. Holmes).*

2 For general info, also see: https://ohiostate.pressbooks.pub/vethisto/chapter/5-bone-microanatomy/ (last accessed June 27th 2025).

3 The osteological material was kindly provided by the State Office for Cultural Heritage Management Baden-Wuerttemberg. For context of the excavation see Damminger / Gross 2009.

Compared to the normal bone, the Mannheim bone is rough and porous along the mid-shaft. The roughening does not, however extend to the joint surfaces. The bone is also deformed/ bent along its long axis. There is a clearly defined hole visible in one view of the bone.

***Fig. 4** Photographs of the Mannheim metatarsal; plantar view (**top**), lateral view (**bottom**) (Photo: C. Kropp).*

There are a number of disease processes that could cause a bone to be deformed and disorganized, including

- a nutritional disease like rickets
- a neoplastic disease (a bone tumor)
- a bacterial infection of the bone with subsequent inflammation resulting in fracture;
- an open fracture with a resulting infection and inflammation, prolonging healing

To decide which of these processes was involved, it would help to see inside the bone macroscopically and microscopically, but cutting slices of this artifact is not really an option. Instead the bone was radiographed. To evaluate pathology, the lesions have to be compared to normal. Figure five illustrates how normal bones appear on x-ray, using a human foot. Humans have five metapodial bones in each limb; the second metatarsal is indicated. Notice that the outline of the bones is smooth and discrete and there is a well-defined hollow space in the middle: the marrow cavity.

***Fig. 5** X-ray image of a human foot (Source: https://commons.wikimedia.org/wiki/Category:X-rays_of_normal_feet_by_dorsoplantar_projection#/media/File:Fu%C3%9F_re_r%C3%B6ntgen.png).*

Compare the normal radiographs with these of the Mannheim bone: you can see that the internal structure of the matrix is disorganized and 'chaotic', instead of being uniform in density. You can see the hole in one of the views; unlike the rest of the tissue, the margins of the hole are dense and clear-cut.

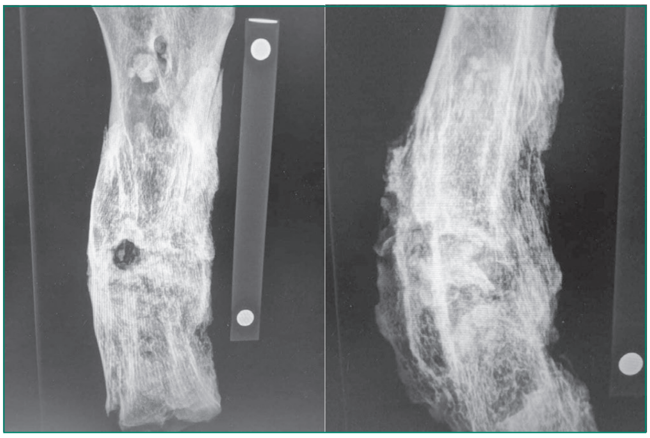

***Fig. 6** Radiographic details of the Mannheim metatarsal (Source: C. Kropp).*

Adding the radiographic information to the macroscopic examination gives us enough information to rule out two of the possible diagnoses listed above; i.e., neoplasia and rickets show different internal patterns of bony remodeling than those seen here, and neither of those diseases is common in adult cattle. It's logical to conclude that the changes were most likely caused by a combination of bacterial infection and traumatic injury (fracture), but can we determine which problem happened first? Was there an infection that caused inflammation, weakening the bone and resulting in a pathologic fracture? Or was there an open fracture in which bone fragments pierced the skin, exposing them to contamination and allowing an infection to take hold?

There are various clues that can help us decide which is most likely. Fractures heal by creating new bone, which takes time. Radiographs (x-rays) therefore can give you an idea of how old the fracture is. Figure seven shows a recently broken human collar bone. The ends of the broken bones are clear cut, with no bony tissue connecting them at all, because there hasn't been time for the bone tissue to respond to the injury

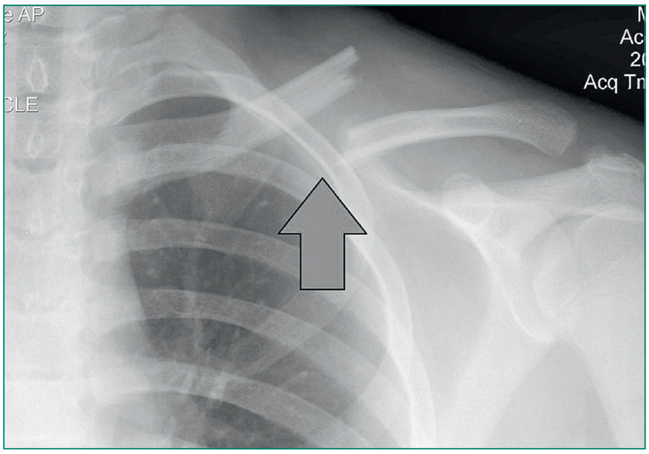

Fig. 7 *Acute clavicle fracture (Source: Majorkev at English Wikipedia, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=59569959).*

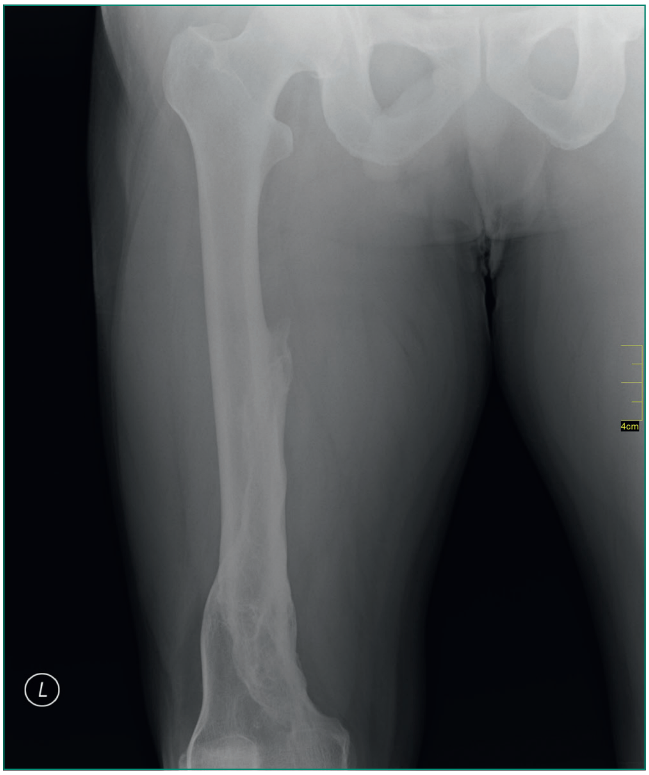

Fig. 8 *Healing spiral fracture of the femur (Source: https://commons.wikimedia.org/wiki/File:Medical_X-Ray_imaging_DPV03_nevit.jpg).*

Figure eight shows a healing fracture of the human thigh bone. There are no sharp edges; everything is "fuzzy" because of the mineralizing matrix that is being laid down to re-create the original shape of the bone.

As we saw (***Figure 6***) in the Mannheim metapodial, there is a lot of unorganized bone that connects the two pieces of misaligned bone. This is evidence that the fracture is not recent. Based on the amount of mineralization present, the bone must have been trying to heal for months. But the lack of organization is evidence that inflammation was preventing the bone from completely remodeling the original structure (You could say it's analagous to people in a termite-infested house trying to make repairs without being able to get rid of the termites first!)

Taken together the observations support the conclusion that the bony injury (fracture) was the initial problem, and that inflammation from wound infection was secondary and ongoing.

And what about the discrete hole? Is that part of the disease process? Or could it be evidence of some kind of puncture, possibly an attempted treatment of the animal, or a post-mortem artifact (something that happened after death) ? The most likely scenario is that the hole formed as part of the disease process, as a sequestrum.

Fig 9 *Sequestrum in a child's thighbone (Source: https://commons.wikimedia.org/wiki/File:Bony_sequestrum_in_a_child_femur.jpg).*

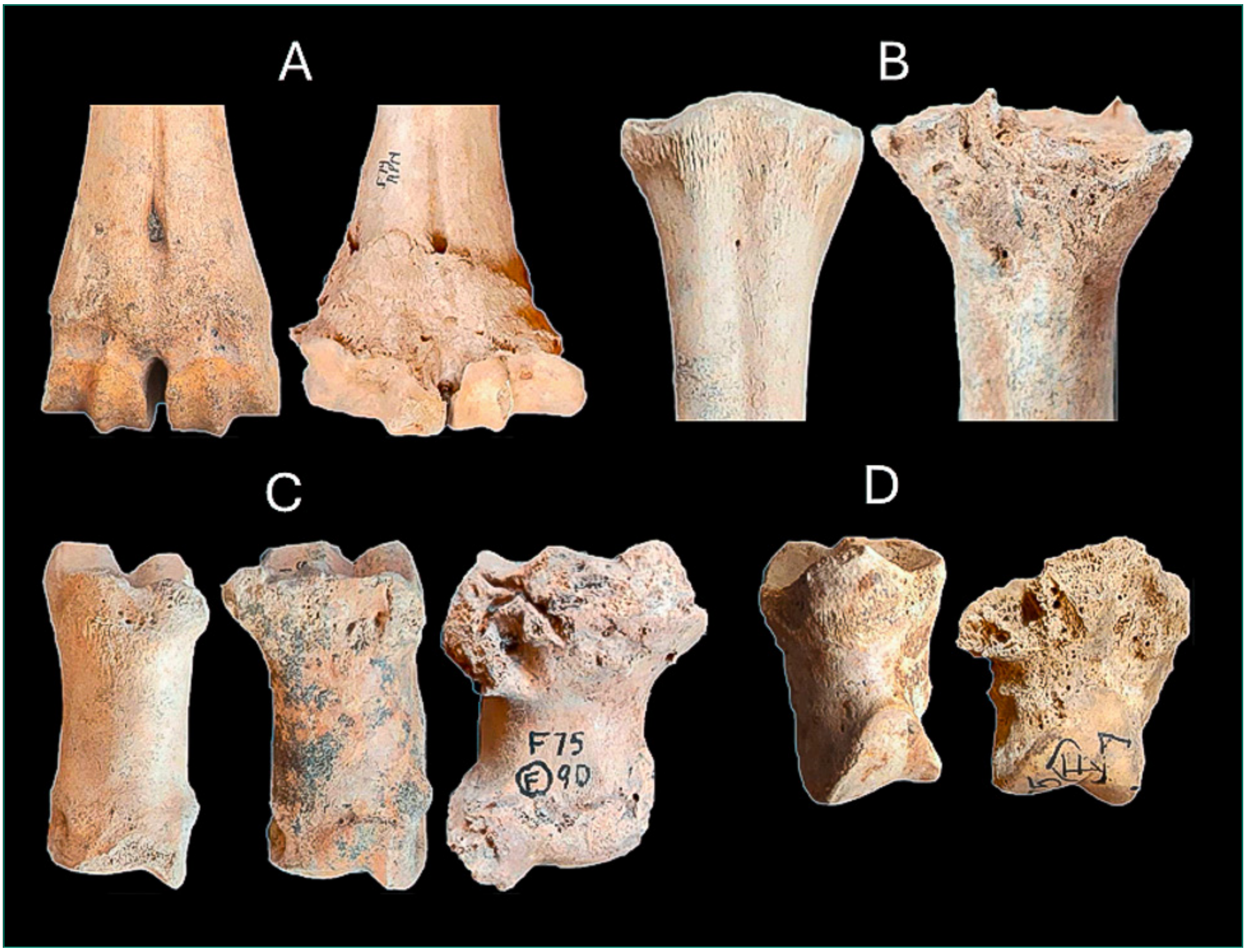

Fig. 10 *Examples of deformations affecting cattle lower leg bones. Unaffected, healthy bones are pictured on the left. A: distal metapodial; B: proximal metapodial; C: first phalanx; D: second phalanx (Image: M Holmes).*

If a piece of bone loses its blood supply (because of either a fracture or a blood clot), that portion of bone will die, and the surrounding tissues try to clean up the debris. The dead fragment is called a sequestrum. If it's small enough, clean- up can be completed inside (like a small home repair where you can burn the debris in your fireplace) and there is no external evidence. If the sequestrum is larger, the clean-up process can only proceed through an opening in the surface, called a draining tract or fistula. The fistula is something that the bone tissue builds deliberately, like a chute to funnel debris outside and it is typically lined with dense bone to help channel all the debris to the outside. The lining of the fistula shows up on x-ray as a cuff of radiodense material.

Findings from a pathological examination are formulated as a "pathological anatomic diagnosis", which includes:

- The process causing the disease (e.g., inflammation),
- The time-frame (how long the process has been going on),
- An assessment of distribution (one spot in the body, vs many spots in the body) and
- The severity of the process (i.e., how much did it affect the animal's function).

Even if you can see all the animal's tissues and know the animal's history, it can be hard to get consensus among pathologists regarding diagnoses, leading to the joke that 'if you ask five different pathologists, you will get 6 different opinions'. In spite of the general truth in that little joke, all five of the US veterinary pathologists who considered this bone agreed that the most likely sequence of events in this case was:

An open fracture with contamination of the wound, followed by prolonged inflammation (months to years in duration!) and the development of a fistula. During this time the animal would have been three-legged lame, making it likely that humans were caring for it during its disability.

Zooarchaeology

Zooarchaeology has been a distinct sub-discipline of archaeology since the 1960s and from the beginning bones exhibiting pathologies (changes caused by disease) and sub-pathologies (deformations that may not be related to disease) have been recorded and their origin a matter of speculation. One of the areas of palaeopathology (the study of bone disease in ancient specimens) that has created a large body of work concerns the use of animals for draught work. Archaeologically it is important to be able to understand developments in animal power, having inferences for domestication, agriculture, economy and human-animal relationships.

As described above, bone has a very structured response to trauma, resulting in loss or addition, depending on the nature and location of that trauma. Groundbreaking research using the lower limbs of cattle with known life histories found a correlation between these changes and cattle used for draught work[4]. Archaeological examples of the types of changes to the bones of cattle lower legs and feet are provided in Figure 10, which illustrates how severe these effects can be. Subsequent studies have built on this work making it more applicable to archaeological material, taking into account the effect of sex, age and weight[5]. Some deformations are more common in older animals, related to diseases such as osteoarthritis, while larger, heavier, male cattle are also more likely to be affected by these pathological changes. Conversely, younger animals are less likely to exhibit deformations that may take months or years to develop.

The results of research into draught related skeletal changes are useful for answering specific questions, but if considered on a broader scale it raises several observations that should be taken into account by those working with draught animals and zooarchaeological material alike:

- Younger animals rarely exhibit bone deformations linked to draught work. It is notable that none of the studies recorded draught animals less than six years of age.
- Older and larger animals are more likely to develop bone changes linked to draught work.
- Animals with moderate to heavy workloads will potentially exhibit pathological or sub-pathological changes to a greater extent than those with light workloads even if the latter work for several years.
- Animals with heavy workloads used for one season are less likely to exhibit pathological or sub-pathological changes.
- It is hard to tell how severely an animal has been affected by bone changes, but the potential for deformations to limit joint flexibility and cause pain has implications for the welfare of draught animals.

In summary, we have well-established methods for recording changes to cattle bones that can result from draught work. We can compare the severity and take age and size into consideration but cannot say with any certainty how that animal may have been affected, or how much work the animal was asked to do, the nature of that work, or how long the animal was working for. Similarly, animals that were worked when young, with minimal workloads or over a short period of time will be invisible in the archaeological record.

Bibliography

Bartosiewicz et al. 1997 L. Bartosiewicz, W. Van Neer and A. Lentacker, Draught Cattle: Their Osteological Identification and History. Musee Royal de L'Afrique Centrale Belgique, Annales Sciences Zoologiques 281 (Tervuren 1997).

Carlson Dietmeier 2018 J. K. Carlson Dietmeier, The oxen of Oxon Hill Manor: pathological analyses and cattle husbandry in eighteenth-century Maryland. International Journal of Osteoarchaeology 28(4) (2018), 419-427.

Damminger / Gross 2009 F. Damminger, U. Gross, Zur Ausgrabung und Erforschung einer Wüstung in Mannheim-Vogelstang. Ein Beitrag zur früh- bis hochmittelalterlichen Siedlungsgeschichte am unteren Neckar, in: J. Biel (Ed.), Landesarchäologie. Festschrift für Dieter Planck zum 65. Geburtstag (Stuttgart 2009), 557-584.

Holmes et al. 2021 M. Holmes, R. Thomas, H. Hamerow, Identifying draught cattle in the past: lessons from large-scale analysis of archaeological datasets. International Journal of Paleopathology 33 (2021), 258-269.

Thomas et al. 2021 R. Thomas, L. Bellis, R. Gordon, M. Holmes, N. Johannsen, M. Mahoney, D. Smith, Refining the methods for identifying draught cattle in the archaeological record: lessons from the semi-feral herd at Chillingham Park. International Journal of Paleopathology 33 (2021), 84-93.

4 Bartosiewicz et al. 1997.

5 Carlson Dietmeier 2018; Holmes et al. 2021; Thomas et al. 2021.

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