HOBBLING ALONG THE FRONTIER: SKELETAL PATHOLOGY IN CATTLE FROM A LATE ROMAN SETTLEMENT ON THE DANUBIAN *LIMES*

FÉL LÁBBAL A HATÁRON: KÓROS CSONTELVÁLTOZÁSOK EGY *LIMES* MELLETTI KÉSŐ RÓMAI TELEP SZARVASMARHA ÁLLOMÁNYÁBAN•

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Abstract

Excavations conducted in 2008–2009 at Baracs (Fejér County, Hungary) yielded a large Roman-period faunal assemblage characterized by the overrepresentation of pathological specimens. This study focuses on severe skeletal lesions observed in cattle. The archaeological context comprises a multi-period settlement located near the Danubian limes.

The recorded pathologies range from advanced joint disease and traumatic injuries to inflammatory and infectious processes affecting mostly the limbs. Lesions are concentrated in the hind limbs and distal extremities. In some instances, the morphology of lesions raises the possibility of chronic infectious diseases, including bovine tuberculosis and septic arthritis. Severe traumas observed in multiple specimens indicate that affected animals were not culled immediately, likely reflecting their economic value as dairy cattle as well as the necessity to keep uninfected livestock alive for extended periods despite impairment. These findings suggest a management strategy shaped by demands of herd maintenance and limited therapeutic options.

Kivonat

A Baracs (Fejér megye, Magyarország) területén 2008–2009-ben végzett feltárások során nagy mennyiségű római kori állatcsont-anyag került elő, amelyben a kóros elváltozásokat mutató darabok szokatlanul nagy arányban fordulnak elő. Jelen tanulmány a szarvasmarhákon megfigyelhető csontvázelváltozásokra összpontosít. A lelőhely régészeti kontextusát egy több periódusú település alkotja, amely a dunai limes közelében helyezkedett el.

A szarvasmarhákon dokumentált kóros elváltozások spektruma az előrehaladott ízületi megbetegedésektől és traumás sérülésektől a gyulladásos és fertőző folyamatokig terjed, amelyek elsősorban a végtagokat érintették. Az elváltozások túlnyomórészt a hátulsó végtagokon és az alsó végtagrészeken koncentrálódnak. Egyes esetekben az elváltozások krónikus fertőző betegségek – mint a szarvasmarha-tuberkulózis és a szeptikus ízületi gyulladás – lehetőségét is felvetik. A több ízben megfigyelhető súlyos traumás elváltozások arra utalnak, hogy az állatokat komoly sérülés esetén sem feltétlenül vágták le, ami gazdasági értékükkel, igavonó vagy tejhasznú szerepükkel magyarázható, illetve potenciálisan azzal is, hogy a fertőző betegségtől mentes állatokat még sérülten is életben akarták tartani. Az eredmények olyan állattartási stratégiát körvonalaznak, amelyet az állomány fenntartásának szükségszerűségei és a korlátozott gyógyítási lehetőségek alakítottak.

KEYWORDS: CELTS, ROMAN PERIOD, TRAUMA, TRACTION, BOVINE TUBERCULOSIS, ZOONOSIS, CATTLE HUSBANDRY

KULCSSZAVAK: KELTÁK, RÓMAI KOR, TRAUMA, IGAVONÁS, SZARVASMARHA TBC, ZOONÓZIS, MARHATARTÁS

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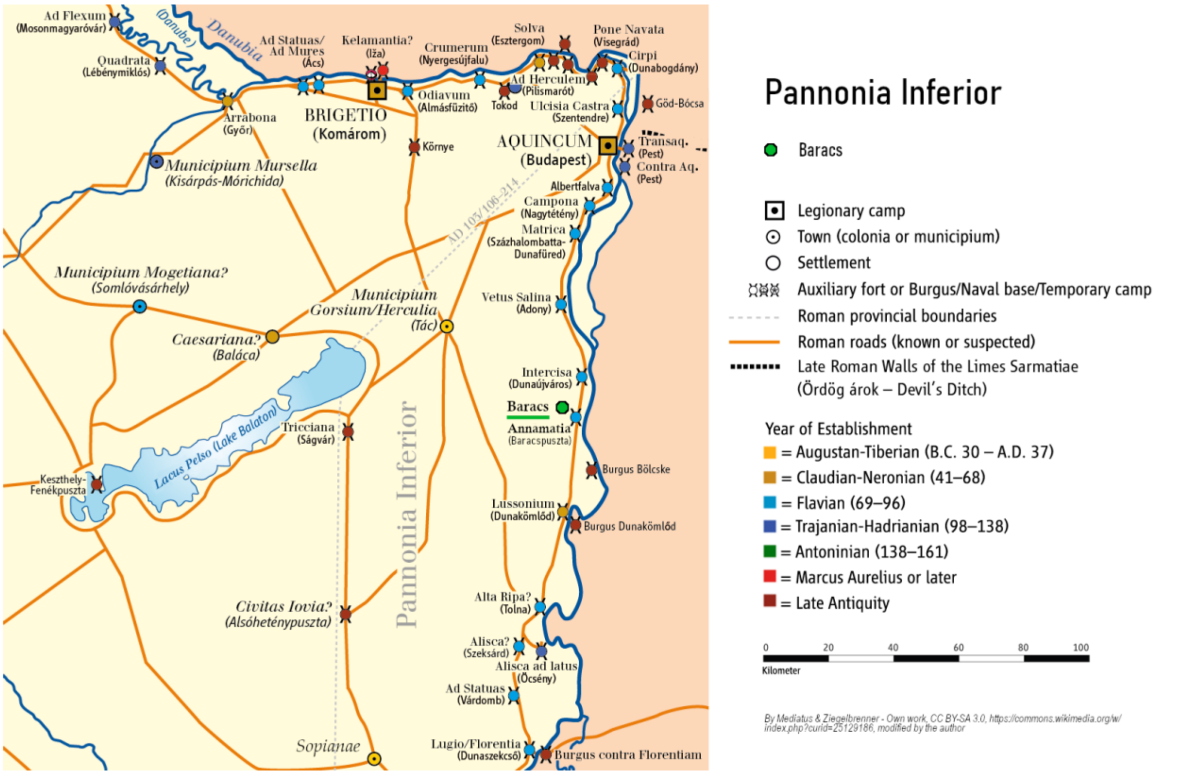

Fig. 1.: Location of the archaeological site of Baracs in Pannonia Inferior, in relation to the Roman military installations of Annamatia and Intercisa

1. ábra: Baracs lelőhely elhelyezkedése Pannonia Inferior provinciában, Annamatia és Intercisa táborának közelében

Introduction

In the Preface to Book 6 of his treatise *De re rustica*, Columella famously observes that the ox was "man's most hardworking associate in agriculture", and that among the ancients the killing of an ox was regarded as a capital crime equivalent to the killing of a fellow citizen. Cattle were indeed indispensable to Roman-period agriculture, functioning not only as primary draught animals but also as a major source of meat, milk and dairy products. Nevertheless, despite the abundance of cattle remains recovered from archaeological contexts, cattle are comparatively underrepresented in the substantial body of archaeozoological evidence documenting pathological lesions in animals from past societies. This discrepancy likely reflects the economic value of beef: injuries or impairments in cattle frequently resulted in early slaughter, thereby limiting the archaeological visibility of long-term pathological conditions.

During the 2008–2009 excavations near Baracs, Hungary, a large assemblage of animal remains was recovered, a notably high proportion of which exhibited pathological alterations, many of them affecting cattle. The site comprises a multi-period archaeological sequence, including a settlement dating to the 1st–4th centuries CE, several Avar-period features (6th–8th century CE), superimposed structures associated with an Árpád-period village (11th–13th century CE), as well as a number of undated features. This complex stratigraphic and cultural context provides an important but challenging framework for the interpretation of the pathological specimens. The significance of such lesions is often difficult to assess, as they may reflect animal care, mistreatment, or neglect, and the distinction between these interpretations remains the subject of ongoing debates. The present study focuses on severe pathological lesions observed on cattle bones from the site, offering insight into the animals' living conditions and the nature of their management and use.

Overview of the Archaeological Context and Faunal Material

The archaeological site of Baracs is situated in Fejér County, Hungary, near the Danube and the modern city of Dunaújváros, in close proximity to two major Roman-period military installations: the auxiliary forts of Annamatia, in use from approximately 70 CE onward, and Intercisa, established in the 2nd century CE (Barkóczi 1954, 52; Visy 2003, 76, 82) (**Fig. 1**). The Danubian *limes* was located approximately 6 km east of the settlement.

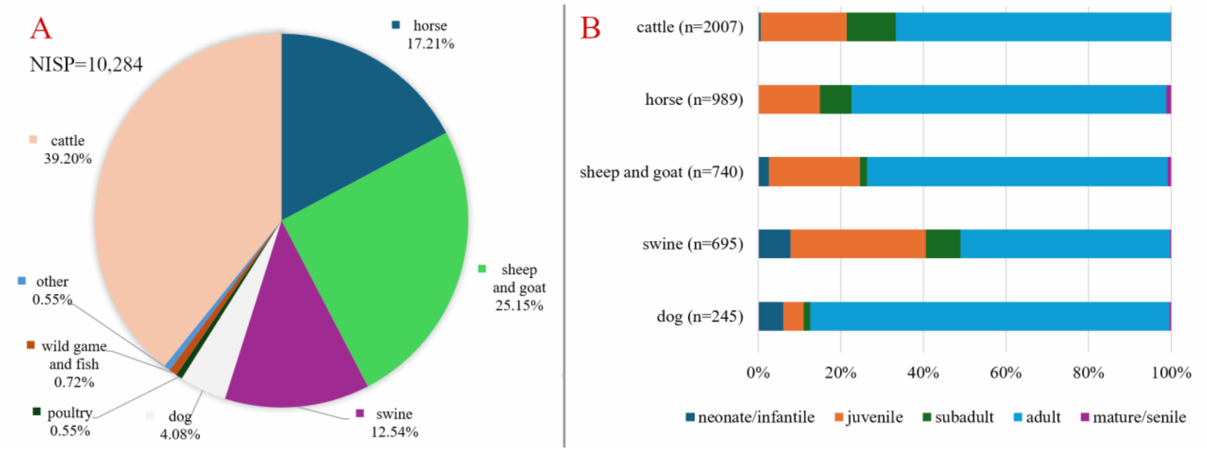

Fig. 2.: Distribution of animal taxa (A) and age-at-death (B) categories at Baracs, based on identified faunal remains; articulated specimens counted as single individuals. NISP=10,284; in graph B, only those individuals whose age at death could be determined are included

2. ábra: A leletek fajok (A) és életkor (B) szerinti eloszlása Baracs lelőhelyen, az azonosítható leleteket alapul véve; az összetartozó vázelemeket egynek számolva. NISP = 10 284. A „B" ábrán csak azok a maradványok szerepelnek, amelyek esetében az állat pusztulási életkora meghatározható volt

Archaeological investigations were conducted over two field seasons in 2008 and 2009, under the direction of Dávid Bartus and Lóránd Olivér Kovács, respectively.

A narrow, unexcavated strip separates the two excavated portions of the settlement – Kokasdi-ér partja (RM-01, the bank of the Kokasdi Stream) to the north and Boldog-dűlő (F-18/B, Boldog Field) to the south – which together form an elongated tract along the M6 motorway. (For the sake of clarity, the two parts of the settlement are referred to throughout the paper by their Hungarian names, Kokasdi-ér partja and Boldog-dűlő.) The approximately five-hectare area is only a sliver of the site's original extent. The excavations revealed the remains of a Celtic-Roman (*Eraviscus*) settlement dating to the 1st–3rd centuries CE, which may have been abandoned during the Marcomannic Wars and repopulated later. Subsequently, in the late 3rd century CE, a Roman villa was likely established at the same location (Kovács 2009; Bartus 2010; Bíró 2017, 200, 326–327).

The Celtic-Roman settlement is characterized primarily by small pit-houses measuring approximately 4 × 5 m. The only stone structure identified at the site was located in the northern sector and dates to the 3rd century CE, corresponding to the Roman villa phase of occupation. This building comprised six rooms and a portico, and yielded remains of a terrazzo floor and wall paintings (Kovács 2009). Adjacent to the eastern wall of the structure, an altar dedicated to Jupiter was recovered in secondary deposition, placed upside down. The surviving Latin inscription reads: *I(ovi) O(ptimo) M(aximo) / Aurelioru(m) Veri et Valentis / ex voto / v(otum) s(olvit) l(ibens) m(erito)* ("To Jupiter Optimus Maximus, from the pledge of Aurelius Verus and Aurelius Valens, they kept their vow"); it was dated to the middle of the 3rd century CE (Bartus 2010; Borhy et al. 2012).

Across all chronological phases, the assemblage is dominated by animal bones and handmade pottery, while only a small number of *terra sigillata* fragments were recovered, all originating from the stone building. Excavation was significantly impeded by the high groundwater table, which had caused substantial disturbance to the archaeological features. It is therefore likely that the present-day Kokasdi Stream either did not exist or was intermittent during the Roman period. The First Military Survey Map, however, clearly depicts the Kokasdi Stream; the area appears as an unbuilt landscape labelled Puszta Baracs and Puszta Kokosd, intersected only by dirt roads and lacking permanent structures.

The site yielded approximately 13,000 animal bones, of which 11,251 were attributed to the Roman-period occupation. Of these, 10,284 specimens could be identified to species level. The assemblage is dominated by domestic taxa and exhibits species ratios and age-at-death patterns consistent with those commonly observed in Roman-period contexts (**Fig. 2**).

While most of the assemblage consists of disarticulated remains interpreted as consumption waste, an unusually high number of articulated carcasses was also recovered. In total, approximately 140 complete or partial skeletons were documented, most of them canine. This pattern may indicate that the area was used as a disposal zone once the houses were abandoned. The interpretation of these deposits is, however, constrained by the limited contextual information available. Data on spatial relationships between articulated carcasses and disarticulated refuse and the relative depth are incomplete, hindering the reconstruction of depositional sequences or distinct phases of use. In most cases, photographic documentation of the carcasses *in situ* is lacking, preventing independent verification of their original position. Although a dog's head recovered from the foundation of a house may be interpreted as evidence for a construction-related ritual, this remains speculative in the absence of associated features or contextual indicators.

The number of precisely datable finds is limited, which hinders drawing up a fine-grained chronology for the associated archaeological features. As a result, it is hard to distinguish between faunal remains attributable to the Celtic-Roman settlement and those associated with the later Roman villa phase. Only 4,278 specimens could be securely dated to the century. Of these, the vast majority (92%) date to the 2nd–3rd centuries CE. Most of this material likely reflects the occupation of the Celtic-Roman settlement prior to the establishment of the Roman villa.

Although a detailed discussion of the site's broader chronological development, the effects of the Marcomannic Wars, and potential shifts in economic strategies lie beyond the scope of the present study, one pattern merits brief consideration. The proportion of adult cows appears to increase markedly during the 2nd–3rd centuries CE compared to the earlier phase. This trend may point to a growing emphasis on dairy production and thus to changes in cattle exploitation strategies. As the analysis is based on a small subset of cattle remains that could be both sexed and securely dated – 28 specimens in total – this conclusion should be regarded as a tentative hypothesis.

Overview of Recorded Pathological Lesions

Pathological specimens constitute an unusually high proportion of the faunal assemblage, accounting for 2.3% of the material (298 specimens, likely representing 247 individuals). Although the frequency of pathological remains varies considerably among assemblages, reported averages generally lie around 0.4% and only rarely exceed 1% (Bartosiewicz 2013, 33). Such high incidence observed at Baracs does not necessarily indicate an above-average incidence of disease or injury within the livestock. More plausibly, it reflects the survival of animals to ages at which pathological processes had sufficient time to produce observable changes in the skeletal elements.

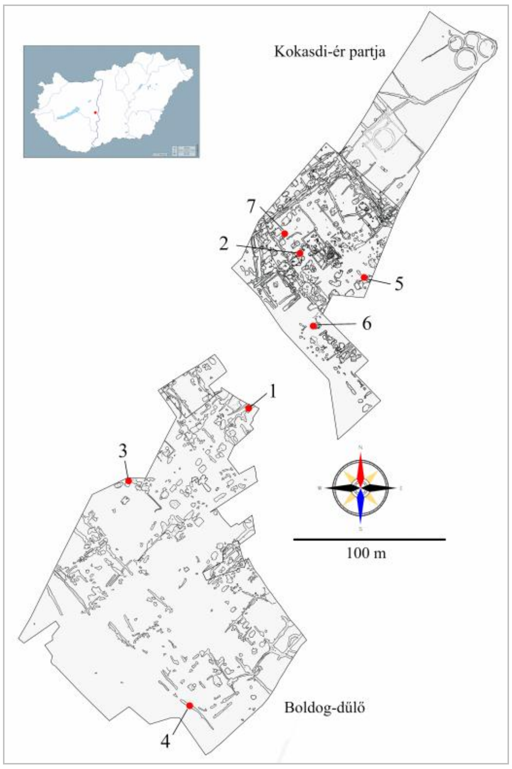

Fig. 3.:

Distribution of pathological specimens analyzed in this study: (1) humerus, (2) proximal phalanx, (3) pelvis, (4) skeleton exhibiting hip dislocation, (5) femur, (6) fused tarsal joint, (7) metatarsal with os centroquartale

3. ábra:

A cikkben elemzett patológiás leletek térbeli elhelyezkedése: (1) karcsont, (2) első ujjperc, (3) medence, (4) részleges váz csípőficammal, (5) combcsont, (6) összenőtt lábtőízület, (7) lábközépcsont és központi lábtőcsont

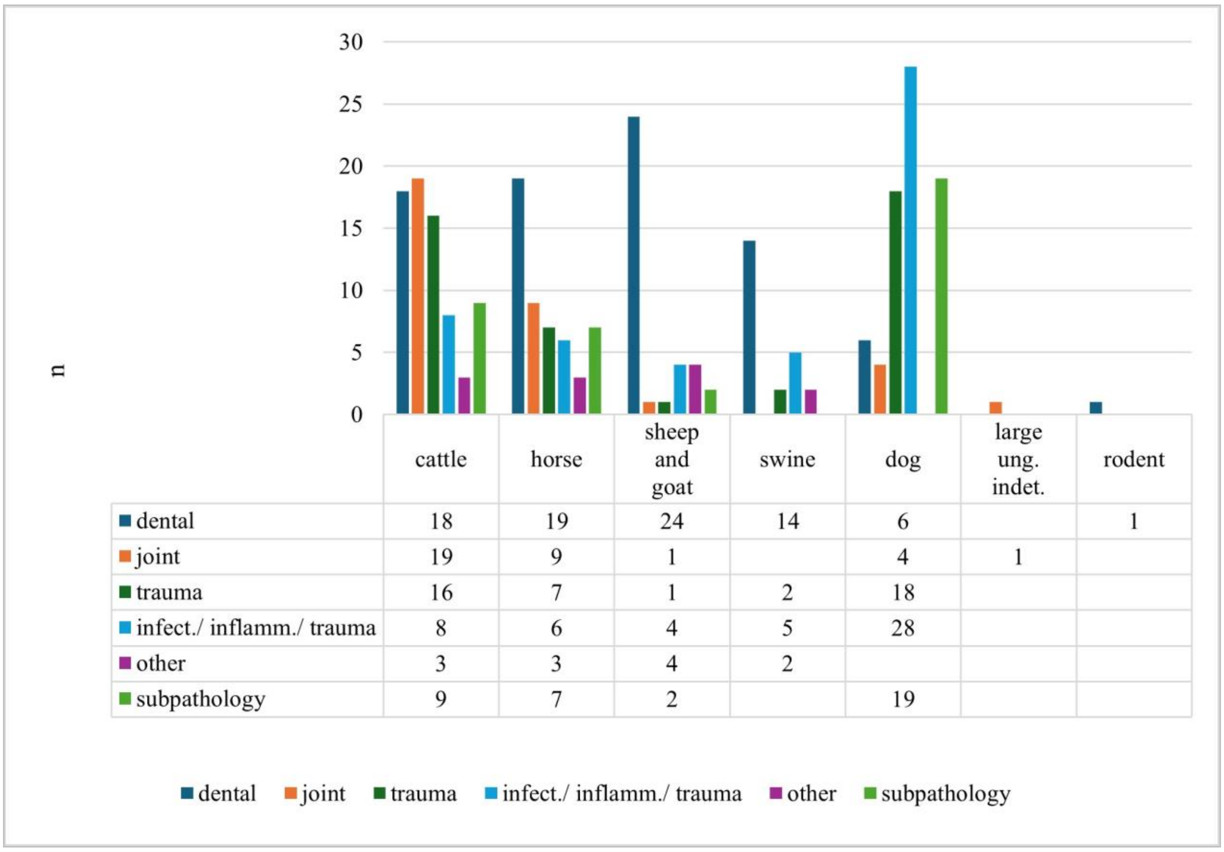

Fig. 4.: Roman-period pathological lesions documented in the Baracs assemblage

4. ábra: Kóros elváltozások a római kori baracsi leletanyagban

Pathological specimens were notably more abundant in the northern sector of the site (Kokasdi-ér partja), where 229 pathological bones were recovered, 206 of which can be confidently attributed to the Roman period. By contrast, the larger southern sector (Boldog-dűlő) yielded only 70 pathological specimens, 54 of them Roman. In total, 260 pathological bones are securely assigned to the Roman period (**Figs. 3–4**), with an additional 17 specimens considered possibly Roman. Due to chronological uncertainties, the present analysis focuses exclusively on the material securely dated to the Roman phase.

The lesions in this material encompass a wide range, from minor, age-related conditions to severe traumatic injuries. Cattle (73 bones from 67 individuals) and dogs (75 bones from 44 individuals) are the most frequently affected species, followed by horses (51 bones from 44 individuals). The distribution of pathological types varies markedly among species (**Fig. 4**). In cattle, horses, and dogs, many lesions are associated with trauma, new (woven) bone formation indicative of inflammation, and various joint deformities; in addition, dental pathologies are relatively frequent in both cattle and horses. In contrast, small ruminants and swine predominantly exhibit oral pathologies, while other lesion types are rare in comparison. Of the 43 pathological sheep and goat bones, 30 are mandibles or teeth, several of which show evidence of periodontal disease, likely reflecting poor-quality pasture (Holmes et al. 2021). Similarly, 15 of the 26 pathological swine specimens show dental abnormalities, especially excessive wear. These inter-species differences likely reflect the distinct functional roles and management practices associated with each species.

Lesions Recorded in Cattle

Severe pathologies in cattle are generally uncommon, reflecting the species' multipurpose role. At Baracs, however, several severe pathological conditions were documented in cattle, distributed across multiple areas of the settlement (**Fig. 3**). Overall, 1.7% of the cattle bones exhibited pathological alterations ranging from minor to severe, with a few additional specimens showing subpathological changes. Approximately 70% of the cattle of identifiable age at Baracs survived to adulthood, increasing the likelihood of age-related skeletal remodelling being present in the assemblage.

Table 1.: Pathological bones in cattle from Baracs. The “Other” category comprises tumor-like lesions. *: corrected sum, counting articulated bones as one. See **Appendix Table 1** for detailed list

1. táblázat: Patológiás szarvasmarha csontok Baracs lelőhelyről. Az "other" (egyéb) kategóriába tumor jellegű elváltozások kerültek. *: korrigált adat, az összetartozó vázelelemeket egynek számolva. További részletek a **Melléklet 1. táblázat**ában találhatók.

skeletal element	dental	joint disease	trauma	infect./ inflamm./ trauma	other	subpathology	total
mandible			1				**1**
upper teeth row	5						**5**
lower teeth row	13						**13**
thoracic vertebrae		1	1			2	**4**
lumbar vertebrae			1	1			**2**
costae			6				**6**
scapula		1					**1**
humerus				1			**1**
metacarpal			1	1			**2**
pelvis		3	1	3			**7**
femur			2	1		1	**4**
tibia					2	2	**4**
tarsal bones		2	3			2	**7**
metatarsal		7		1	1	1	**10**
phalanges		5				1	**6**
total	**18 (17*)**	**19 (18*)**	**16 (13*)**	**8**	**3**	**9 (8*)**	**73 (67*)**

Most observed pathologies, however, were minor, including irregular tooth wear, slight lipping or exostoses, and small areas of woven bone.

The majority of cattle pathologies at Baracs affected the hind limbs (**Table 1**). Joint lesions were most frequently observed in the distal extremity segments, particularly the hock and below. Notably, inflammation in the pelvis and femur, possibly resulting from trauma, was also recorded. In contrast, the cervical spine, radius and ulna, and carpal joints were largely unaffected by lesions. These patterns align with observations by Bartosiewicz (2008, 157-158; 2013, 150-153), who noted that in Roman and medieval contexts, cattle pathologies tend to concentrate in the hind limbs and distal extremities. This distribution likely reflects the biomechanical stress imposed by traction, as draught cattle bear greater dynamic loads on the hindquarters, whereas the forelimbs support more weight during natural locomotion. Trauma primarily involved the ribs, which have high healing potential and do not significantly impede mobility. Subpathological changes were also concentrated in the hind limbs, suggesting incipient stages of processes that could eventually lead to similar alterations.

Traumatic lesions primarily consist of healed greenstick fractures of ribs and vertebral processes. Inflammatory changes in the pelvis include woven bone on the ischiadic spine and pubis, along with lipping and minor exostoses, whereas dental pathologies are dominated by excessive wear, calculus accumulation, and periodontal disease. A few specimens represent severe, rare, or even exceptional conditions; these cases are discussed in detail below.

The forelimb: Humerus with hypertrophic osteopathy

This fragmented right humerus of an adult individual was recovered from a trench (Boldog-dűlő, Feature no. 237) in association with tegulae and an almost complete, pathological horse skeleton.

A cattle radius recovered from the same context may belong to the same individual, but the fragmentary nature of the material precludes confirmation. No evidence of butchery was observed on any of the bones. The feature can be broadly attributed to the Roman period, although more precise dating was not possible.

Fig. 5.: Cattle humerus exhibiting hypertrophic osteopathy: medial and caudal views, with close-ups of the fragmented end showing cortical bone overlain by newly formed woven bone. Baracs–Boldog-dűlő, Feature no. 237

5. ábra: Kóros szövetburjánzás karcsonton: medialis és caudalis nézet. Közeli képek: a lelet törött végén jól megfigyelhető a kéregállományra felrakódott, gyulladásos folyamatot jelző új csontszövet. Baracs–Boldog-dűlő, STR 237

Around the diaphysis, a thick, spongy accretion of woven bone-like tissue, approximately 2–5 mm in thickness, covers nearly the entire surface, sparing the distal joint surface (**Fig. 5**). This bony layer seems to be separated from the diaphysis itself; at the fracture margins, the newly formed tissue is clearly distinguishable, while the underlying cortical bone appears normal. The surface of the accretion is porous and spongy, with no visible draining sinuses. On the medial side, at the level of the greater tuberosity, the surface is notably irregular and nodular. A similarly uneven, sulcus-like texture occurs on the medial aspect above the medial condyle and laterally above the *fossa olecrani*, near the attachment of the *extensor carpi radialis* muscle, resembling fistulized abscesses. The proliferation above the distal condyle on the medial side exhibits a nodular morphology.

A ridged, uneven surface is present on the *tuberositas teres major*, the attachment site for the shoulder-flexing *m. teres major*, the *coracobrachialis*, and the *m. latissimus dorsi* (the broad back muscle), which function to elevate and retract the forelimb and, during locomotion, to pull the trunk forward in the weight-transfer phase of the stride (Budras & Habel 2003). The pronounced muscle attachment surface on the pathological accretion suggests that the limb continued to bear substantial mechanical loading – potentially from traction work – even during the inflammatory process.

The animal appears to have suffered from ossifying periostitis, an inflammation of the periosteum usually caused by repetitive strain or infection. The condition does not appear to be trauma-related, as it affects the entire diaphyseal surface rather than being localized, indicating systemic infection. Although the proximal portion of the bone is missing, the newly formed bone layer evidently extended proximally and may have covered the proximal end as well. The porous structure of the new bone indicates a rapid, acute process that was still active at the time of death; the woven bone had not yet fused with the underlying cortex or remodelled into lamellar bone.

In some areas, the newly formed layer can be detached from the cortical surface. The distal articular surface remains unaffected, showing no signs of osteoarthritis; while the extensive periosteal proliferation did not compromise the joint itself, the olecranon's movement in the *fossa olecrani* may have caused pain.

The extent of this alteration suggests an inflammation of the surrounding soft tissues, with calcium deposits turning the periosteum into an osseous mass. Such periosteal proliferation has been reported in connection with various conditions. Periostitis has been reported in a bovine humerus from Avlesbury (Baker & Brothwell 1980, 76), although in that case the bone tissue was sclerotic, which is not observed here. Compound fractures can also lead to the formation of proliferative woven bone (Bartosiewicz 2013, 93-94), but these lesions are typically localized. Osteomyelitis may cause periosteal elevation, as pus accumulating beneath the periosteum lifts it from the bone surface, prompting the formation of new, porous woven bone; this bone may then be invaded by the inflammatory process and die, triggering further cycles of new bone formation until the periosteum ruptures (Baker & Brothwell 1980, 66-67). In the present case, however, there is no evidence of necrosis in the underlying bone.

Hypertrophic osteopathy is often associated with intrathoracic lesions such as pulmonary tumors, bronchopneumonia, and tuberculosis, and often leads to bilateral hypertrophy of the limb bones without affecting the articular surfaces (Lignereux & Peters 1999, 346; Martin et al. 1971; Guyot et al. 2011). The precise pathogenic mechanism remains unclear, but it may involve reduced blood flow to the bones following the development of tumors or infectious masses in the thoracic or abdominal cavities. Although rare, this severe condition can result in irregular periosteal proliferations affecting the entire bone surface. Typically, it involves the distal extremities rather than the stylopodium, though in advanced stages, all skeletal elements may be affected, and the condition can progress rapidly if untreated (Lignereux & Peters 1999, 346; Baker & Brothwell 1980, 162). A possible underlying cause of hypertrophic osteopathy in the present case may have been tuberculosis, described as one of the most prevalent diseases by Greek and Roman authors (Meinecke 1927).

Tuberculosis (TB) is an infectious granulomatous disease caused by acid-fast bacilli of the genus *Mycobacterium*, which infects humans and other mammals (Santos 2023). Hypertrophic osteopathy resulting in periosteal bone proliferation has been linked to tuberculosis in archaeological dogs, pigs, and cattle alike (Lignereux & Peters 1999; Bathurst & Barta 2004; Bartosiewicz 2013, 99-100). TB usually spreads haematogenous from infected soft tissues to the skeleton and can involve any bone. Zooarchaeological reports of bovine tuberculosis (bTB) typically document lesions in the vertebrae and ribs, and less frequently in the distal extremities; in some cases, diagnoses have been confirmed through the aDNA identification of the pathogen (Wooding et al. 2020). The predominance of vertebral and rib lesions in the archaeological record aligns with clinical observations, as skeletal TB is most common in cancellous bone and the red marrow of spongy bone tissue (Lignereux & Peters 1999, 340-342). In the present case, however, the cortical bone was affected, suggesting a chronic pulmonary infection that had progressed to the upper extremity and likely involved other skeletal regions. The animal died while the inflammatory process was ongoing, before the newly formed woven bone on the humerus could remodel into lamellar bone; in case of a systemic infection, lesions in other skeletal elements may have been more advanced. Notably, Vegetius observed that lung disease often causes lameness in the forelimbs, indicating that such complications of chronic TB were recognized in Roman times.

> “If the illness lasts longer, [the animal] will limp on its forelegs, will expel a heavy phlegm from the nostrils, will have difficulty staying still, but will lean on the manger feverishly, and will discharge unhealthy excrement.”
> (*Si aegritudo longior fuerit, de prioribus claudicabit pedibus, gravem foetorem naribus expellet, difficile se collocat, sed febriens praesepio ineumbit, corruptum assellabitur*. Vegetius [1903], ed. Lommatzsch, 199)

It is also important to note that, although TB is generally considered a debilitating chronic disease, it can occasionally progress rapidly (Santos 2023). If this animal had bTB, the infection was likely advanced and potentially transmissible to humans.

A comparable condition has been documented in a human individual from ca. 1000 BP, who exhibited newly formed bone tissue covering both tibiae as well as the radius and ulna (González-Reimers et al. 2015); in that case, however, the woven bone had already begun remodelling into lamellar bone at the time of death. The probable diagnosis was a chronic, non-malignant pulmonary condition resulting in hypertrophic osteopathy. While a similar non-malignant etiology cannot be entirely excluded for the Baracs animal, the presence of inflammation across the entire diaphyseal surface at the time of death suggests an aggressive pathological process.

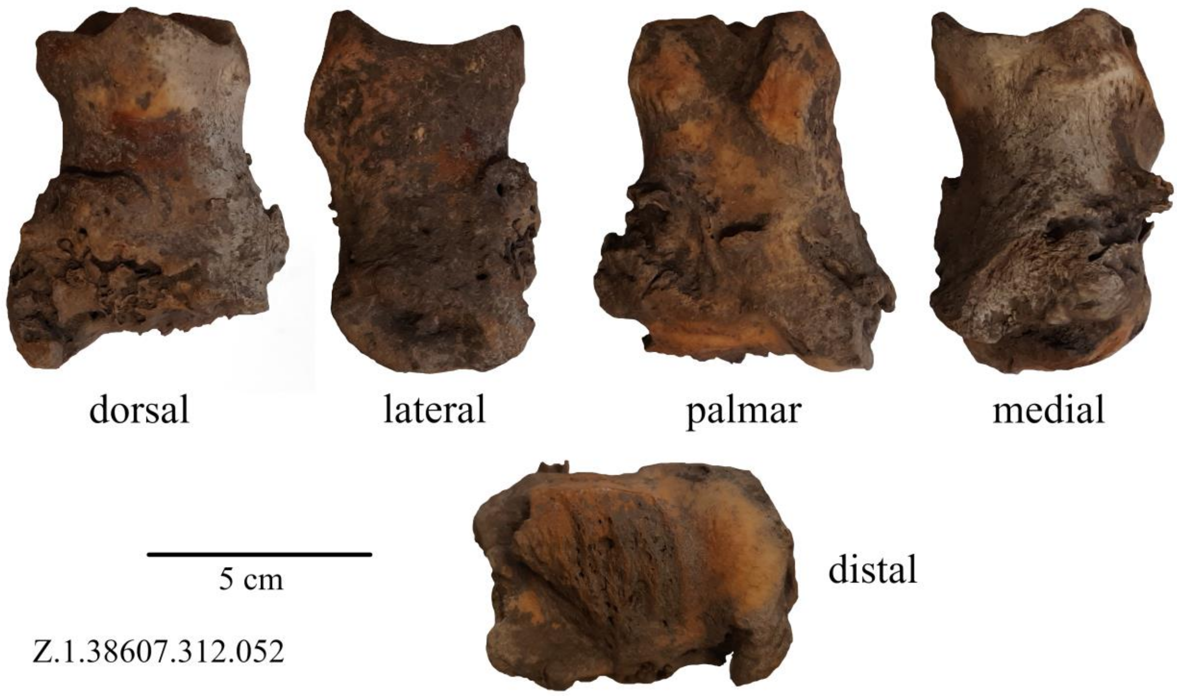

Fig. 6.: Cattle proximal phalanx exhibiting advanced arthropathy. Baracs–Kokasdi-ér partja, Feature no. 312
6. ábra: Első ujjperc, előrehaladott ízületi gyulladással. Baracs–Kokasdi-ér partja, STR 312

The forelimb: Proximal phalanx with advanced arthropathy

A pathological first phalanx was recovered as a disarticulated element from mixed refuse in another pit-house dated to the 2nd–3rd century (Kokasdi-ér partja, Feature no. 312). Due to the extent of the deformation, it is not possible to determine whether it originated from a forelimb or hind limb; however, its robust shape suggests that it is most likely an anterior phalanx.

The bone is deformed (**Fig. 6**, Pathological Index =0.45; see Bartosiewicz et al. 1997, 55-62); the proximal epiphysis is unaffected, but nearly all other parts are markedly abnormal. On the palmar surface of the diaphysis, there is a medially projecting bony spur approximately 8 mm in length. On the dorsal side, amorphous, porous, and thick compact bone proliferations form a continuous surface; these exostoses are also substantial on the medial side, terminating in a prominent ridge that rises from the shaft of the diaphysis. The articulating surface of the distal epiphysis exhibits deep, craniocaudally oriented eburnation and grooves with sharp edges, showing signs of severe osteoarthritis. The cartilage was evidently destroyed, and a displaced bone fragment must have carved out this surface, while small, cystic cavities opened up in the distal articular surface. The extent of exostoses may indicate inflammatory reaction to a joint sepsis. Although not found, the medial phalanx was obviously also affected, and as substantial exostoses are found on the medial side of the first phalanx, it can be hypothesized that the other first phalanx of the same foot was similarly involved.

This deformation suggests that the proximal interdigital and the plantar annular ligaments as well as the collateral ligament of the pastern joint were compromised by the proliferating exostoses. The tendon of the long digital extensor muscle is inserted onto the first phalanx, and therefore, the extension mobility of the foot may have been hindered. The exostoses are not clustered around the attachment points of ligaments, and the osteoarthrosis in the interphalangeal joint suggests a traumatic origin and/or possible infection rather than simple overworking.

The hind limb: Pelvis with cavitary osteolysis

This fragmented cattle pelvis was recovered from a Roman-period pit (Feature no. 193) in the southern part of the settlement (Boldog-dűlő), alongside potsherds and an iron object. The feature has been broadly dated to the Roman period without finer chronological resolution.

Fig. 7.:
Cavitary osteolysis on the medial aspect of a cattle ischium and pubis, adjacent to the obturator foramen.
Baracs–Kokasdi-ér partja, Feature no. 193

7. ábra:
A csontszövet átépülésével keletkezett üreg szarvasmarha medencéjén.
Baracs–Kokasdi-ér partja, STR 193

On the medial side of the ischial corpus, there is an elongated, oval-shaped cavity encircled by a small wreath-like ring of newly formed, though not clearly woven, bone (**Fig. 7**). The edges of the cavity are smooth; while the interior exhibits potentially necrotic remodelling with a pitted, irregular surface, resulting in marked thinning of the ischium; at the fossa acetabuli, the bone is nearly perforated. Despite this, the acetabulum itself appears normal. Observation of the interior of the cavity is hindered by limescale encrustation, and the entire surface has been damaged by taphonomic processes.

It is difficult to assess the extent to which the lesion on the medial surface affected the animal's mobility; however, the marked thinning of the bone at the acetabulum must have had some adverse impact on the hip joint. The external obturator muscle, which attaches to the inner and outer surfaces of the ischium around the obturator foramen, may also have been affected, as may the sacrosciatic ligament, which is anchored in this region (Budras & Habel 2003).

As noted above, bovine tuberculosis (bTB) frequently affects flat bones, including the vertebrae. A characteristic skeletal manifestation of bTB is rarefying osteitis, in which demineralized bone becomes increasingly porotic and is subsequently resorbed through ulcerative or cavitary osteolysis; as a result, the affected bone progressively weakens and structural collapse may occur. An osteosclerotic rim surrounding such cavities is considered typical (Lignereux & Peters 1999, 341). Although a definitive differential diagnosis is not possible given the fragmentary nature of the specimen, the co-occurrence of a humerus exhibiting hypertrophic osteopathy – potentially linked to bTB – suggests that tuberculosis may have been present at the settlement and could also account for the pelvic lesion observed here.

The hind limb: Dislocated hip with pseudojoint

The articulated partial skeleton of a cow with dislocated hip has already been published (Lyublyanovics 2023), a brief summary of the findings should suffice here. A partially articulated thoracic–lumbar spine, pelvic girdle, and hind limbs of an adult cow were recovered from a trench in the southern part of the excavation area (Boldog-dűlő, Feature no. 394). The feature was broadly dated to the Roman period. The animal, approximately 12–14 years old with a withers height of 122 cm, falls within the expected size range of contemporary Pannonian cattle.

The right pelvis and femur were found to exhibit severe pathological deformation (**Figs. 8–9**). The femoral head had detached from the acetabulum, and the diaphysis rearticulated with the pelvis at the lesser trochanter, producing a pseudojoint and marked limb shortening. Both the pseudo-articulation and adjacent bone surfaces show sclerosis, eburnation, and exostoses. The pelvic bone is substantially remodelled, with external depressions and osteophytes and an uneven, cavernous internal surface. A rib fragment presents a healed fracture, further indicating trauma.

Coxofemoral luxation in cattle is typically trauma-induced, often resulting from falls, mating or calving (Hull 1996, 48; Marchionatti et al. 2014, 247, 250). The Baracs specimen displays craniodorsal luxation, consistent with muscular contraction drawing the femoral head anteriorly and superiorly. Such injuries damage the joint capsule and femoral ligament and result in an extended, stiff limb, impaired mobility, and chronic lameness

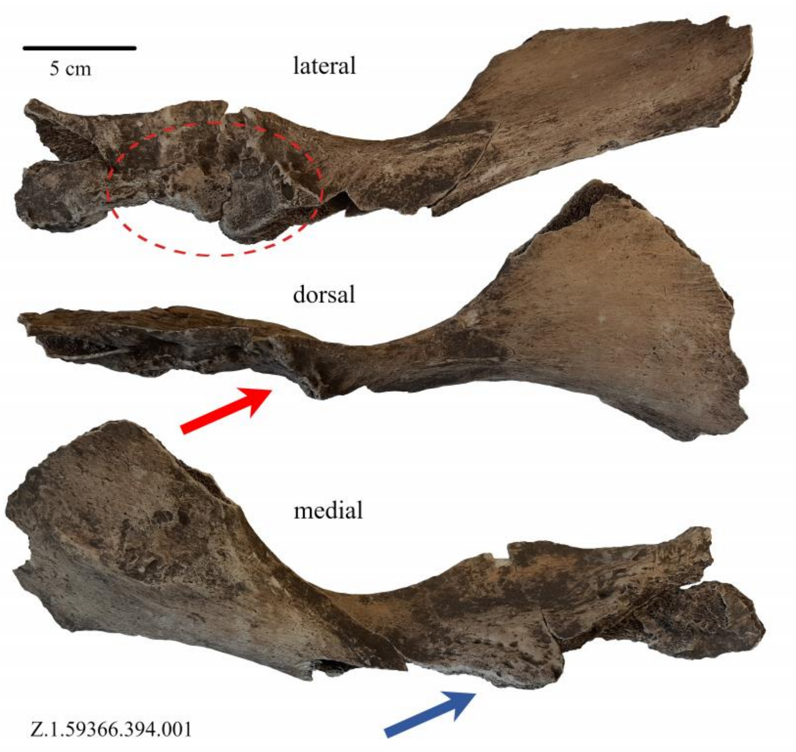

Fig. 8.: Dislocated hip from Baracs–Boldog-dűlő (Feature no. 394): lateral, dorsal, and medial views of the pelvis. The red arrow and dotted line indicate the location of the pseudojoint and associated eburnation, while the blue arrow marks remodelled bone tissue on the medial surface (after Lyublyanovics 2023)

8. ábra: Csípőficamos tehén, Baracs–Boldog-dűlő, STR 394; a medence lateralis, dorsalis és medialis képe. A piros nyíl és a szaggatott vonal az álízület helyét és az ehhez kapcsolódó eburnációt, a kék nyíl a medialis oldalon átépült csontszövetet jelzi (Lyubyanovics 2023 nyomán)

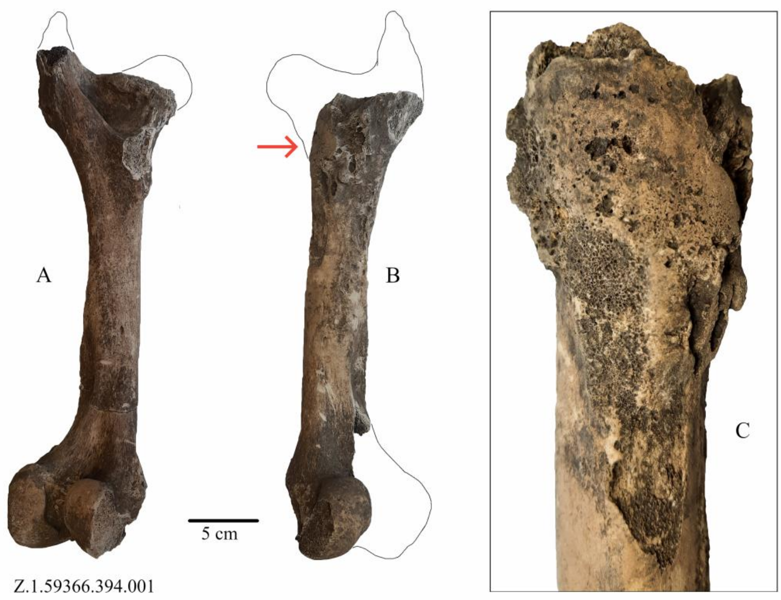

Fig. 9.: Dislocated hip from Baracs–Boldog-dűlő (Feature no. 394): caudal view of the animal's healthy left (A) and deformed right femur (B), and medial view of the eburnated articular surface (C) (after Lyublyanovics 2023)

9. ábra: Csípőficamos tehén, Baracs–Boldog-dűlő, STR 394; az állat egészséges bal (A) és deformált jobb (B) combcsontja caudalis nézetből, és az eburnálódott új ízesülési felszín medialis képe (C) (Lyublyanovics 2023 nyomán)

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(Reynolds 1996, 46; Tamás 1987, 336). Prognosis in large livestock is poor, as reduction is difficult and stabilization impossible. Untreated cases commonly lead to the development of pseudojoints, as observed here, with lameness persisting for months or becoming permanent (Tamás 1987, 337-338). The advanced eburnation and mature periosteal growths indicate long-term survival and a non-acute inflammatory state at death; a healed rib fracture also points to a long interval – possibly years – between injury and death.

Vegetius's *Digesta artis mulomedicinae* (5th c. CE) describes a "Barbarian" technique for treating hip dislocations involving traction by ropes and animal force (Vegetius [1748], 276-277, trans. A. Millar), but no evidence suggests a successful intervention here. On the other hand, the carcass shows no signs of butchery or processing, implying that the animal – likely a dairy cow – was kept alive despite chronic impairment and was ultimately discarded intact into the trench.

The hind limb: Femur with necrotic cavity

This fragment of a cattle's right femur was brought to light from a 2nd–3rd-century pit-house (Kokasdi-ér partja, Feature no. 490) along with kitchen refuse; no sign of butchery was observed. The ossification stage of the epiphysis suggests that the animal died around 3.5 years of age.

Most of the trochanteric fossa is filled with dense, nodular, remodelled bone containing multiple, small, possibly necrotic cavities of varying size (**Fig. 10**). The trochanteric fossa is perforated toward the medullary cavity at several points, which may indicate sinus openings. On the internal aspect facing the medullary cavity, the surface is also irregular and shows signs of resorption, although this is difficult to assess due to limescale deposits. A small island-like osteophyte is visible on the cranial side of the proximal diaphysis; it is not woven but lamellar in structure, and is clearly isolated.

The fragmentary nature of this specimen precludes a definitive diagnosis, as it is unknown whether lesions were present on the articular surface, along the remainder of the diaphysis, or on other skeletal elements. Bone diseases of diverse etiologies may create pathways for pyogenic bacteria, allowing secondary infection of pre-existing skeletal lesions (Bartosiewicz 2013, 95). In the present case, the necrotic surface and associated openings suggest involvement of either the cancellous bone containing red marrow or the medullary cavity, raising the possibility of osteomyelitis accompanied by inflammation of the surrounding soft tissues. In light of the pathological humerus and pelvis discussed above, it is significant that osteomyelitis affecting red marrow and the formation of necrotic cavities in long bones may also occur in tuberculosis, when abscess formation leads to bone necrosis (Lignereux & Peters 1999, 345; Bartosiewicz 2013, 100).

Fig. 10.: Fragment of a femur exhibiting necrosis in the trochanteric fossa. Baracs–Kokasdi-ér partja, Feature no. 490

10. ábra: Combcsont töredék nekrózis jeleivel a nagy forgató mögötti árokban. Baracs–Kokasdi-ér partja, STR 490

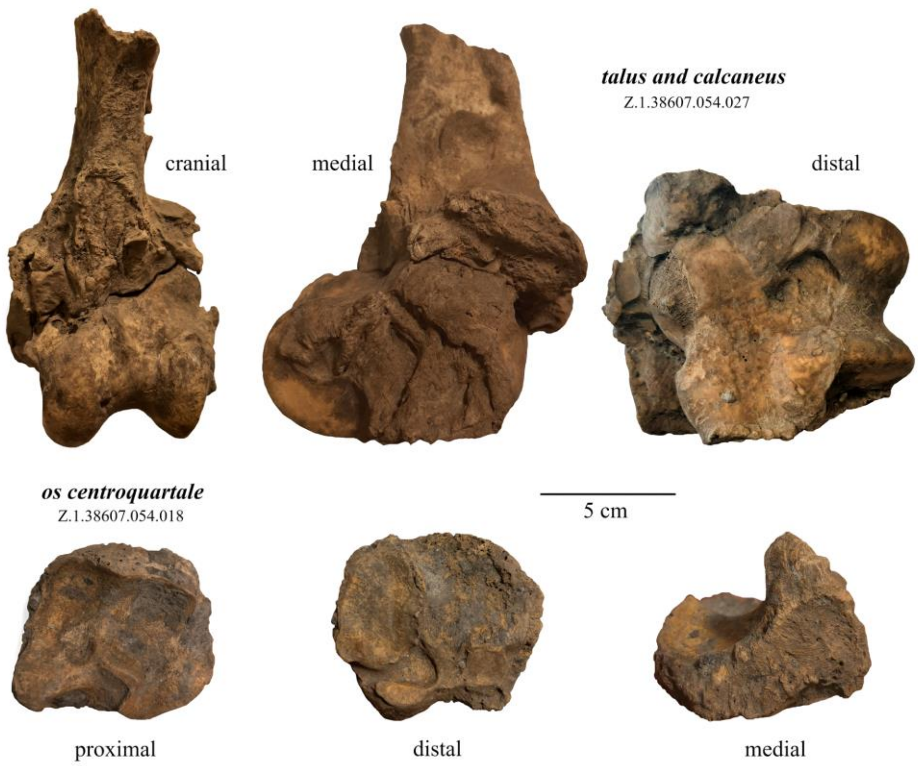

Fig. 11.: Fused talo-calcaneal joint exhibiting abnormal alignment following multiple luxations. Baracs–Kokasdi-ér partja, Feature no. 54

11. ábra: Többszörös ficam után rossz szögben rögzült lábtőízület (csiga- és sarokcsont). Baracs–Kokasdi-ér partja, STR 54

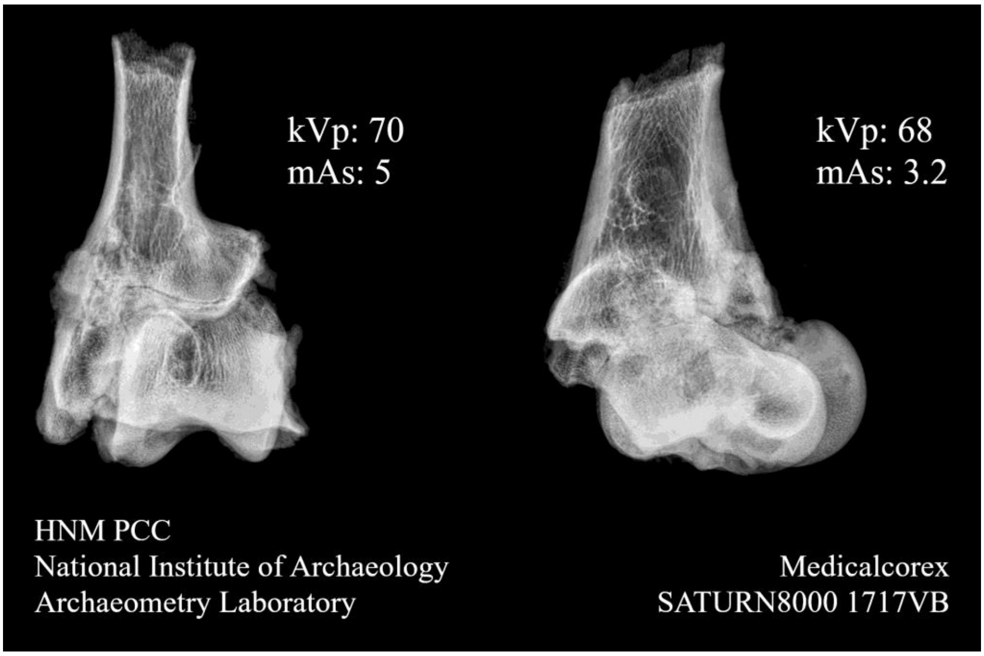

Fig. 12.: Mediolateral and craniocaudal radiographs of the fused talus and calcaneus, showing altered joint morphology

12. ábra: Az összenőtt és torzult csiga- és sarokcsont mediolateralis és craniocaudalis röntgenképe

The deep musculature of the hip joint must have been affected – most notably the *gemelli* and the external obturator muscles, which insert into the trochanteric fossa, as well as the *gluteus medius* and *gluteus accessorius* muscles, which insert around the greater trochanter. These muscles are primarily responsible for lateral rotation, supination, and abduction of the limb. The newly formed bone on the cranial surface is located approximately at the origin of the *vastus intermedius*, a component of the *quadriceps femoris* group that contributes to hip flexion and stabilization of the stifle joint (Budras & Habel 2003, 107). Together, these alterations indicate a complex impairment of mobility and call into question the animal's ability to perform traction work.

The hind limb: Dislocated and fused tarsal joint

This specimen was recovered from a 2nd-century pit-house in the northern sector of the settlement (Kokasdi-ér partja, Feature no. 54) as a disarticulated element within a deposit of mixed refuse. An *os centroquartale*, likely originating from the same joint, was also recovered from this context. However, it cannot be established whether the elements were originally articulated or deposited separately, as the pathological condition was not identified during excavation and the bones were neither photographed in situ nor separated from the surrounding refuse deposit. Consequently, the fused talus and calcaneus and the *os centroquartale* were assigned separate ID numbers.

The tuber calcanei was not preserved, most likely as a result of gnawing. Nevertheless, the overall dimensions of the elements and the thickness of the cortical bone indicate that the individual was fully adult. The sex of the animal could not be determined.

The talus and calcaneus are ankylosed in an abnormal orientation, displaying distorted articular surfaces and extensive exostoses (**Figs. 11–12**). The two bones are fused at an angle of approximately 90°, with the *facies articularis calcanei* oriented dorsally. The originally cranial surface of the talus is rotated ventrally and broadened, forming an abnormal articulation with the *os centroquartale*. The medial surface of the astragalus is deformed by exostoses, while the (originally) laterodorsal condyle shows slight eburnation, likely resulting from contact with the displaced *os malleolare*. The cranial portion of the calcaneus is markedly deformed and bears numerous exostoses. On the dorsal surface of the *sustentaculum tali*, a pseudo-articulation is evident, indicating abnormal contact with the tibia. This likely resulted in an atypical angulation of the tibia relative to the metatarsal, with the tibia and *processus calcanei* positioned nearly parallel to one another, thereby restricting hock mobility (**Fig. 13**). Notably, there is no evidence of woven bone or other indicators of acute inflammation at the time of death, and the amount of newly formed bone is minimal relative to the severity of the injury.

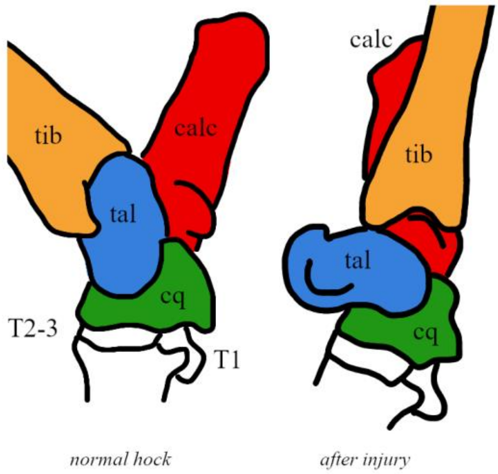

Fig. 13.: Schematic reconstruction of the hock bones' position post-luxation, illustrating the abnormal angulation and restricted mobility

13. ábra: A csánk csontjainak rekonstruált pozíciója a ficam után. Jól megfigyelhető a végtag abnormális szöge és az ízület csökkent mobilitása

The ventral articular surface of the *os centroquartale*, which articulates with the fused second and third tarsal bones, exhibits exostoses, accompanied by osteophyte formation along the cranial margin. Assessment is, however, limited by damage to the specimen and limescale deposition. On the ventral aspect, along the medial margin of the articular surface for the metatarsal, a narrow strip of eburnation is present, indicating that the distal elements of the limb were also involved, although these have not been recovered.

This clearly represents a case of multiple luxations, involving the talo-tibial, talo-centroquartal, and talo-calcaneal joints. Such an injury could only have occurred if the bones of the tarsal joint were displaced far enough from one another to allow the talus to rotate within the joint capsule. The most plausible scenario is that the animal panicked and struggled violently when its leg became trapped, causing sufficient separation of the bones to disrupt the joint. Modern examples of similar injuries suggest a traumatic origin; reported cases include getting a leg caught in the manger and being shoved around by other cattle, as well as slipping in the gutter (Arighi et al. 1987). The fixation of the joint in this position must have resulted in a post-legged or straight-hocked animal with considerably impaired mobility, and the position of the hock must have impacted the position and weight-bearing of the phalanges and hooves, as well as the position of the hip. Post-legged cattle are more prone to develop joint, tendon and hoof diseases

(Wolfe 2018, 155), and they often have a short, uneven stride resulting from restricted mobility and are at a greater risk of injury (e.g. lameness, bone fractures) (Sitz et al. 2023). Problems with the weight-bearing of hooves, either in the injured leg or in the ones compensating for it, could lead to further complications, such as sole ulcers.

Although luxation of the hock joint is rarely documented in the contemporary veterinary literature, a closely comparable case was reported in an 18-month-old Holstein heifer presented with non-weight-bearing lameness (Constant et al. 2015). In this case, the affected hind limb was fixed in a flexed position and exhibited marked swelling and pain at the level of the hock. Radiographic examination detected rotation of the talus with entrapment of the calcaneal coracoid process beneath the lateral ridge of the plantar trochlea of the talus, while the talo-tibial joint remained mostly unaffected. Multiple bony fragments consistent with medial and lateral ligament avulsions were also identified. The heifer was unable to stand, and despite several partially successful attempts to reduce the luxation – including mechanical traction under anesthesia, external coaptation using a cast, and the use of a standing aid (sling) – the joint repeatedly reluxated, and the animal subsequently developed clinical signs of bilateral radial nerve paralysis. Because the owner declined surgical intervention, the heifer was euthanized. Necropsy revealed a comminuted plantaromedial fracture of the centroquartal bone at the attachment site of the medial collateral ligaments.

A comparison of the published photographs of the above-mentioned luxation (Constant et al. 2015, Fig. 4) with the Baracs specimen shows clear parallels. In the Baracs individual, however, the degree of displacement appears to have been more pronounced: the coracoid process seems not to have been entrapped, but the tibia eventually moved on top of the *sustentaculum tali* of the calcaneus, creating a pseudo-joint there. This advanced (re?)luxation may have been the result of attempts at mechanical reduction undertaken by the animal's owners, potentially employing a traction technique analogous to that described by Vegetius, or of the animal's own movements.

Even in the modern praxis, tibiotarsal joint luxation is often difficult to reduce due to the rapid development of haematoma, soft-tissue swelling, and contraction of the periarticular musculature. However, once in place, external support and immobilization during the healing period is usually sufficient to prevent reluxation, and no splint or bandage is required in the postoperative period, but the animal must be confined in a stall for one or two months (Nichols & Lardé 2014, 214). In Roman times, only conservative management was available. Even today, the prognosis remains poor in the absence of surgical intervention, although successful outcomes have been documented in which cattle regained ambulatory function shortly after conservative treatment (Arighi et al. 1987). Comparable cases of bilateral dorsal rotation of the talus accompanied by subluxation of the tibio-tarsal, talo-calcaneal, and proximal intertarsal joints have been reported in camelids as well, including a 14-month-old female alpaca treated surgically with screws (Duesterdieck-Zellmer 2022) and a five-month-old male llama managed without surgery (Peavey et al. 2000). The alpaca recovered full mobility, whereas the untreated llama remained lame eight months post-injury. In these camelids, however, the mechanical load borne by the hind limb is considerably smaller than in cattle.

The present case is significant because it indicates that the animal survived long enough for osseous fusion and sclerosis to develop – processes that require several months at least. Whether the individual remained ambulatory during this period remains uncertain, though modern analogies strongly suggest that this would have been unlikely without some human intervention. The condition is certainly painful, even if this is not necessarily evident. The aforementioned alpaca displayed no overt pain during manual manipulation of the lesion, but its elevated rectal temperature, heart rate, and respiratory rate indicated substantial physiological stress (Duesterdieck-Zellmer 2022). In the remaining published cases, the animals exhibited unmistakable signs of severe pain and were unable to stand or ambulate normally, if at all. It is unlikely that an animal in this condition would have gone unnoticed in Roman times. In the Baracs specimen, the presence of a pseudojoint on the dorsal aspect of the *sustentaculum tali* indicates that the altered hock joint had regained a limited degree of mobility: the fused talus–calcaneus complex could articulate, to some extent, against the tibia. The formation of this pseudojoint further implies that the animal was not continuously confined; repetitive movement and sustained pressure from the distal tibia produced the eburnated surface observed on the *sustentaculum tali*. However, as the calcaneal tuberosity serves as the insertion point of a number of tendons, such as that of the large *gastrocnemius* muscle, the abnormal placement of the calcaneus must have had a detrimental effect on the movement of the hind limb in general.

The hind limb: Tarsal arthropathy

A deformed tarso-metatarsal joint, involving a proximal metatarsus and an *os centroquartale*, came to light from a 2nd-century pit house (Kokasdi-ér partja, Feature no. 147). The finds are partially burnt. The structure yielded considerable amounts of pottery, grinding stones, iron and bronze tools, glass vessels, blast-furnace slag, and burnt animal bones.

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The joint exhibits deformation accompanied by severe arthritis, although no fusion is evident (**Fig. 14**). The articular surface of the proximal metatarsus is altered, displaying a porous, irregular, necrotic morphology and subchondral pitting, with minor perforations. The proximal epiphysis is markedly expanded mediolaterally, with especially pronounced lateral broadening. The surface articulating with the large cuneiform is less severely affected. Caudally, the surface articulating with the sesamoid also shows signs of inflammation, with evidence of resorptive bone remodelling. On the corresponding *os centroquartale*, the articular surface with the metatarsus displays a similarly porous, pitted and deformed bone structure, whereas the surface adjoining the large cuneiform bone presents pathological alteration only along its margin, otherwise it seems normal. The Pathological Index (after Bartosiewicz et al. 1997) is 0.42.

Such deformations are typical of infected chronic injuries characterized by soft tissue degradation. The main symptom, the extensive remodelling, the substantial destruction of the articular surface and the underlying cancellous bone, along with the pitted, necrotic character of these surfaces suggest infectious arthropathy (O'Connor 2008, 178-179), which is a common condition in cattle (Verschooten & Demoor 1974, 60). Spavin, the fusion of the tarsals and the proximal metatarsal, is often reported in large domesticates in the zooarchaeological record. In typical spavin, the marginal osteophytes create a "bridge" but the articular surfaces are not affected. In this case, however, the presence of lipping and marginal osteophytes may suggest secondary osteoarthrosis indicative of an early stage of spavin, which can result from necrosis, fractures, septic arthritis, or metabolic joint disorders (Stevanovic et al. 2025, iii).

A number of agents including bacteria, viruses and fungi can cause septic arthritis, but it is most often caused by bacteria in large domesticates as a sequel of septicemia (Stevanovic et al. 2025, v). Tuberculosis and brucellosis can result in similar lesions on the skeleton in cattle; brucellosis can cause chronic arthritis, polyarthrithis and ankylosis, as well as granulous lesions on the vertebrae (Lignereux and Peters 1999, 345; Bartosiewicz 2013, 102). Brucellosis hardly goes unnoticed in a reproductive herd, as the main symptoms include abortion and giving birth to weak calves (Rehman et al. 2025, 1523). This disease often targets joints, bursae and tendon sheaths, and may manifest on the adjacent bones as focally extensive periosteal responses; however, no definitive archaeological cases are known in animals, although in humans, a

Fig. 14.: Tarsal arthropathy. Baracs–Kokasdi-ér partja, Feature no. 147

14. ábra: Lábtőízület gyulladása. Baracs–Kokasdi-ér partja, STR 147

few cases have been published (Bendrey et al. 2019, 102-104).

Septic arthritis may develop due to trauma as well, most often in the interphalangeal joints and the fetlock, with fetlock and tarsal joints more frequently involved in adults than in calves (Desrochers & Francoz 2014). In the present case, radiological examination did not indicate trauma, bearing in mind that the bones are fragmented and the affected part may be missing. When the cartilage is destroyed, the bone itself may be infected and osteomyelitis develops (Verschooten & Demoor 1974, 60). The condition presents in the live animal as weight-bearing lameness, joint swelling, as well as pain and heat on joint palpation and manipulation, indicating a significant impairment of mobility and work capacity.

The porous tissue of the affected area suggests that the inflammation was ongoing at the time of death. It is important to note, however, that the condition must have been present for some time for this extent of bone remodelling to occur; in the case of septic arthritis in the interphalangeal joint – where this type of lesion has been extensively studied – bone changes may occur no earlier than 14 days after the onset of the inflammation (Heppelmann et al. 2009, 408).

This form of lameness probably did not go unnoticed. In terms of contemporary treatment, Vegetius has a number of propositions in connection with swollen and injured joints in horses; these involve wrapping the leg with wool, clay, nettles, salt, cumin, vinegar and dung (*Mulomedicina*, Book I, Chapter 13), which probably proved ineffective in treating severe bacterial infections.

Discussion

Pathologies in cattle have mostly been studied in terms of traction. The identification of work-related pathologies presents a persistent challenge, particularly when only disarticulated bone fragments are available, as work-related trauma or repetitive strain may lead to secondary inflammation or infection as well. Definitive attribution of traumatic lesions to activities such as traction is possible only in exceptionally rare cases, and joint pathologies or inflammation caused by excessive physical strain may arise from a variety of etiologies.

In their analysis of cattle remains from Bronze and Iron Age Anatolia, Crabbé et al. (2025) demonstrated a strong correlation between traction-related skeletal stress, large body size, and a high proportion of adult animals during periods of economic expansion. They further noted that in regions characterized by increased agricultural output, the prevalence of traction-related pathologies rose accordingly. The historical context suggests that this framework may also be applicable to Baracs.

In peacetime, the Roman army drew its provisions from multiple sources, primarily through subjecting the civilian population of the provinces to requisitioning or compulsory sale at fixed prices (Davies 1971, 128). Nearby Roman military installations, including the forts of Annamatia and Intercisa, would have relied on surrounding rural settlements for the production of food to sustain the stationed troops, as has been observed at other sites in the immediate hinterland of the *limes* (Bíró 2017, 184-191). In her comprehensive analysis, Sz. Bíró identifies Baracs as one of the hinterland settlements that played a role in provisioning Roman military establishments with agricultural products (Bíró 2017, 185, Abb. 183, 188, Tab. 12). This assumption is supported by the close proximity of the auxiliary fort of Annamatia, situated approximately 5 km from the settlement, which was already in existence at the time of the fort's construction. However, no direct evidence of army procurement has been identified at Baracs. By contrast, at Levél and Mosonszentmiklós the supply of the forts of Ad Flexum and Quadrata is indicated by the large quantities of skeletal remains left after slaughter and the sale of meat, particularly distal limb elements and fragments of the skull (Bíró 2017, 187). Such a pattern is not observed at Baracs, where most of the faunal assemblage derives from the trunk and the meat-bearing portions of the limbs. However, animals sold live and slaughtered off-site would not normally leave archaeologically detectable remains within the settlement. Cattle raised specifically for market supply and traded on the hoof would be more likely to appear in the faunal assemblages of the military sites, whereas the remains of meat-bearing body parts recovered from the settlement most plausibly derive from animals exploited locally for meat, dairy production and traction. Ditch systems interpreted as animal enclosures may likewise provide evidence for livestock breeding, as demonstrated at Mosonszentmiklós, Ács and Dunaföldvár (Bíró 2017, 173); no such features have been identified at Baracs. Nevertheless, the quantity of faunal remains may reflect the scale of animal husbandry and indirectly suggest the exchange or trade of animal products.

However, there is little material evidence to suggest the accumulation of wealth at Baracs that might be expected from a profitable trade in beef or dairy products. The artefactual assemblage is dominated by simple household ceramics, while the architectural evidence – primarily pit-houses – indicates a modest rural settlement associated with the local Celtic-Roman population. It is more likely that beef and dairy production was oriented mainly toward household consumption rather than market exchange, and that animals kept for milk production were simultaneously employed for traction and reproduction.

Under conditions of intensified agricultural cultivation or increased transport distances to meet military demand, skeletal pathologies associated with overwork would be expected to occur more frequently in animals used in traction. Phalanges are particularly prone to skeletal remodelling due to their role in transmitting force and absorbing mechanical stress during locomotion and are therefore frequently examined in studies of traction and draught use in cattle. Morphological alterations may also occur in the phalanges of modern non-draught cattle, as factors such as age, body mass, and stalling conditions can affect joint morphology (Rassadnikov 2021); however, these changes are generally limited in severity. At Baracs, lesions typically associated with traction work – such as exostoses and eburnation on phalanges, as well as metapodial asymmetry – were sporadically observed. Although the majority of pathological changes affected the hind limbs, suggesting some impact of traction, the overall frequency of such lesions remains low. Of the 162 identified cattle phalanges, only eight exhibited pathological alterations, while 15 of the 256 metapodia showed signs of pathology. In total, traction-related lesions (including exostoses and lipping on phalanges and metapodia, and metapodial asymmetry) were recorded in 21 cases, representing 0.6% of the total cattle assemblage. The mean Pathological Index value (after Bartosiewicz et al. 1997) is 0.16 (minimum 0.05, maximum 0.45; standard deviation 0.14), indicating that skeletal deformations commonly associated with sustained traction use are not pronounced in this assemblage.

Relatively little is known about the agricultural practices of Celtic-Roman villages in the *limes* zone, it is nonetheless worth noting that in the Carpathian Basin between the 1st and 5th centuries CE, cultivation was primarily carried out using the symmetrical, simple ard plough (Balassi 1973, 94). Although a heavy moldboard plough capable of deeper tillage over larger areas was developed during the 3rd–4th centuries CE, its use in the Baracs area is unlikely, as this technology emerged in response to environmental conditions characteristic of regions north of the Alps (Margaritis & Jones 2008, 170). The area surrounding Baracs is dominated by loam, sandy loam, and silty loam soils with a moderate clay content, comparable to the western, Danube-adjacent zone of the Great Hungarian Plain; these soil properties are considered temporally stable and largely independent of land use (Tóth et al. 2015). Such soils are well suited to agricultural production and are relatively easy to cultivate compared to clay-rich substrates. Consequently, local soil conditions alone would not have required unusually high traction forces during ploughing that might otherwise be expected to result in pathological skeletal changes, unless draught animals were subjected to sustained or intensified workloads. The use of cows for both dairy and traction is a well-known phenomenon, and such dual-purpose exploitation has been shown to be less likely to result in pronounced work-related osteomorphological changes (Bartosiewicz et al. 1997, 119). It is important to add that, in addition to traction work, pregnancy also alters the weight distribution on the limbs: the growth of body mass and the shift in the center of gravity may have contributed to physiological stress in dairy cows that were repeatedly bred.

As demonstrated in the case studies, cattle that became lame – or even temporarily recumbent – were not immediately slaughtered for consumption. Instead, they appear to have been afforded rest, fodder, and possibly rudimentary forms of treatment, enabling at least partial recovery of mobility. This is also reflected in the kill-off patterns, which are overwhelmingly dominated by adult individuals. Owing to the fragmented nature of the assemblage and the lack of butchering marks, it is not possible to determine whether these animals were ultimately culled, died of natural causes, or were subsequently consumed. Interpretation is further hampered by the lack of a refined internal chronology. Notably, 36.1% of all Roman-period faunal remains – including 106 pathological/subpathological specimens, representing 40.8% of all Roman-period pathological finds – derive from building-related contexts, suggesting secondary deposition following the abandonment of these structures. An average of 60 animal bones was recovered from features associated with buildings (minimum 1, maximum 392 specimens; standard deviation 80.55; median 28). The substantial variability in the volume of material deposited in these contexts likely reflects differing depositional processes, thereby further complicating taphonomic and behavioral interpretations.

In addition to beef, demand for dairy products may have increased as a consequence of the military presence in the region, given that cheese constituted a staple component of the soldiers' diet (Davies 1971, 125). Among the sexed Roman-period cattle remains, 62 specimens were identified as cows, compared to 10 bulls and 13 oxen. This distribution may indicate an emphasis on dairy production and is consistent with the selective removal (possibly selling) of young males for meat. Such a strategy would also account for the continued maintenance of cows that were no longer suitable for traction but remained reproductive.

Systemic bacterial infections can result in widespread skeletal alterations. These changes can be effectively investigated when complete skeletons are recovered and when osteological observations are complemented by biomolecular analyses aimed at identifying the causative pathogens (see e.g. Bendrey et al. 2008). The pathological finds discussed above suggest that inflammation-inducing diseases, such as tuberculosis and brucellosis, may have been present within the livestock population at levels sufficient to produce skeletal manifestations in at least a limited number of individuals. As zoonoses can be transmitted to humans through the consumption of contaminated, unpasteurized dairy products, some form of herd management or selective culling must have been practiced. In situations where replacement animals were scarce, the removal of infected individuals must have increased the likelihood of survival for non-infected members of the herd. Comparable dynamics are observed in modern dairy herds, where elevated culling rates due to *Mycobacterium* infection may necessitate the retention of cows affected by lameness or chronic mastitis – animals that would otherwise be culled – in order to maintain herd structure and productivity (Breen et al. 2012, 39). While this reflects contemporary management strategies aimed at maximizing milk yield, similar considerations are likely to have been operative in Roman-period contexts, regardless of whether dairy production was a primary objective or part of a broader multipurpose exploitation strategy. Disease-driven culling pressures may have influenced herd-management decisions, encouraging the retention of injured or chronically ill animals during periods of zoonotic outbreaks, while infected individuals – removed pre-emptively and lacking diagnostic skeletal alterations – remain archaeologically invisible. These observations are consistent with the low Pathological Index values recorded for the metapodials and phalanges, as well as with the presence of possible infection-related lesions on other skeletal elements. Nevertheless, this interpretation remains tentative in the absence of direct biomolecular evidence of pathogens and given the uncertainties of deposition. Furthermore, the assemblage may have accumulated over the course of one or two centuries, and it is unclear whether these patterns reflect herd-management decisions made in response to a discrete epidemic episode or rather a long-term condition intermittently affecting the livestock population.

Decisions concerning the retention or removal of diseased animals would have been strongly conditioned by both the economic circumstances of individual communities and their awareness of livestock diseases and their consequences. Classical authors indicate that respiratory conditions were recognized in antiquity as affecting cattle. Columella, for example, notes that "ulceration of the lungs is also a source of great destruction to cattle," while Pliny and Vegetius likewise refer to this condition, emphasizing its severity and zoonotic potential, and proposing treatments that seem ineffective from a modern perspective (Meinecke 1927, 395-399). At the same time, some ancient sources provide plausible recommendations for disease management through segregation. Columella explicitly advocates the separation of affected animals, stating that when disease strikes a herd, the cattle should be divided into groups, infected individuals isolated from healthy stock, and relocated to areas where no other herds are pastured, in order to prevent further contagion (*De re rustica* 6.5.2). Despite these prescriptive accounts, there is no direct evidence for how such diseases were perceived or managed in the frontier regions of the Roman Empire, including the rural settlements of Pannonia. In contexts where beef and dairy production entered broader exchange networks, it is plausible that some degree of disease control was exercised by the Roman administration over livestock supplying the military. Nevertheless, in the absence of documentary evidence, the existence and nature of such regulatory practices remain speculative.

Little is known about the prevalence of zoonotic diseases in Roman-period Pannonia. Nevertheless, a limited number of human skeletal remains displaying lesions consistent with tuberculosis have been reported, and the mobility of the Roman army has been proposed as a factor contributing to the spread of the disease across Europe (Hajdu et al. 2012). The extent to which tuberculosis affected animal populations in Roman Pannonia, or the degree to which transmission occurred between livestock and humans, is uncertain. Bovine tuberculosis may remain undetected for prolonged periods, as the early stages are typically asymptomatic and the disease may persist in a subclinical state for months or even years until organ involvement becomes sufficiently advanced to cause functional impairment (Domingo et al. 2014). In more advanced stages, clinical signs may include general weakness, low-grade fluctuating fever, progressive emaciation, and reduced appetite; respiratory symptoms such as dyspnoea, cough, or tachypnoea may develop when pulmonary involvement is present (Khairullah et al. 2024).

In this context, the high number of articulated animal remains recovered from the site is noteworthy, as such deposits may represent animals that collapsed or were culled due to infectious disease and subsequently buried after being deemed unsuitable for use. The majority of these articulated carcasses belong to dogs, a species known to be susceptible to *Mycobacterium* infection through contact with infected cattle. In contrast, whole or partial skeletons of livestock from the Roman period are rare, comprising only two cattle (including the individual with a dislocated hip discussed here), three horses, one sheep, and two pigs. None of these specimens exhibited skeletal lesions diagnostic of tuberculosis. A definitive diagnosis would require biomolecular confirmation, such as ancient DNA analysis demonstrating the presence of the *Mycobacterium* complex or the identification of mycolic acids.

Conclusions

The pathologies recorded at Baracs present a coherent picture of prolonged survival under conditions of repeated mechanical stress, trauma, and chronic disease within a Celtic-Roman rural community integrated into the economic zone of the military forts along the Danubian *limes*. The unusually high proportion and character of skeletal lesions point to a multipurpose use, with cattle often kept alive well beyond the onset of debilitating conditions. Several cases demonstrate advanced remodelling, pseudo-joint formation, ankylosis, and chronic infection, all of which require months or years to develop, indicating tolerance of long-term lameness rather than immediate culling. At the same time, the presence of inflammatory, probably infectious diseases highlights the health risks inherent in close human–animal cohabitation and limited veterinary intervention. Taken together, these findings suggest a management strategy shaped by economic necessity, in which impaired animals were maintained as long as they retained residual utility or value in dairy production, possibly due to the lack of resources to replace the infected and culled livestock. The Baracs assemblage thus contributes evidence to ongoing debates about animal welfare, exploitation, and disease ecology in Roman-period provincial settlements, underscoring the value of detailed paleopathological analyses for reconstructing human–animal relationships in the past.

Contribution of the author

Lyublyanovics Kyra Writing – original draft.

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