

# Prey bone utilization by predatory dinosaurs

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## ABSTRACT

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Many mammalian predators chew and crush bone to various degrees during their utilization of a prey carcass, leaving tooth marks on the prey bones as evidence of their activity. Recognition of similar types of tooth marks on dinosaur bones provides a means to evaluate the degree to which predatory dinosaurs were capable of prey bone utilization.

A survey of 858 dinosaur prey bones from six dinosaur localities in Wyoming, Utah and Montana, has shown the frequencies of tooth-damaged bone range from 0.0% to 4.0%. Compared to bone assemblages in which there is a strong inference of mammalian scavenging, the frequencies of tooth-marked bone from the dinosaur localities are decidedly less common. Theropod dinosaur feeding behaviors were probably more similar to Komodo monitor behavior observed in the monitor communities of Indonesia, than for mammalian-based communities.

The results of this survey indicate that bone crushing was not employed by predatory dinosaurs during their utilization of prey carcasses. The routine crushing of bone, then, as a means of obtaining further nutrients contained within a prey carcass was not an ecological or functional phenomenon present in the Mesozoic and was only developed later by mammalian predators in the Cenozoic.

## Introduction

Utilization of bone from a carcass by mammals is a common phenomenon in modern terrestrial ecosystems. This pattern is not surprising since bone represents a nutritional source of some elements, such as calcium and phosphorus, which are available both to carnivores (e.g. hyenas; Kruuk, 1972) and herbivores (e.g. camels; Gauthier-Pilters and Dagg, 1981). Quite often mammalian carnivores consume portions of prey bones, such as the proximal ends of femora or humeri, which contain an abundance of grease and fat as well as other nutrients (cf. Haynes, 1980).

Alternatively, bones can be utilized for non-nutritive purposes. Rodents, for example, chew bone to wear down their incisors (e.g., porcupines; Brain, 1981), and typically they gnaw the same grooves on a bone, deepening the grooves rather than lengthening them (Farlow et al., 1986). These teeth grow throughout the life of the rodent and need to be worn continuously, which is accom-

plished during mastication. Due to the curvature of the incisors, continued growth would allow these teeth to curve back into the animal's mouth, perhaps penetrating the braincase and leading to obvious pain and eventual death. Bones of dead animals provide a useful medium for this necessary wear of rodent teeth.

Since the chewing of bone for either of these purposes is a common occurrence in mammal-dominated ecosystems today, the question raised here is, did dinosaurs similarly utilize bone in Mesozoic terrestrial ecosystems? No dinosaur is known to have had continually growing teeth like those of rodents, and therefore it is unlikely that any dinosaurs utilized bone for the purpose of wearing down their teeth. The rest of this discussion, then, will address the issue of whether or not carnivorous dinosaurs routinely crushed bone in a manner similar to that of many mammalian carnivores.

A survey of bone-modification features on potential dinosaur prey provides insight into the

behavior of predatory dinosaurs. Bone-modification features can be defined as the result of any post-mortem, prediagenetic process (e.g., trampling, scavenging, weathering) which alters the original morphology of bone in a living animal. Excluded from this definition are pathological processes (e.g., arthritis) that affect the living animal. Also excluded are those processes which operate independent of those responsible for the formation of a particular site (e.g., compaction of surrounding sediment during lithification which can crush bone, stress due to tectonic forces which can shear bones). Fossilization processes such as the "explosion" of bone cavities due to excessive mineral growth within the bone or bone dissolution are also excluded from this definition. Studies of the types and frequencies of bone modification features, such as tooth marks and trample marks, as well as some types of paleopathological features, have been shown to be reasonable indicators for inferring various aspects of vertebrate activity at fossil localities (e.g. Fiorillo, 1984, 1987, 1988a; Tanke, 1989a, b).

For example, the high percentage of bones exhibiting shallow, subparallel scratch marks at a Miocene mammal locality in southwestern Nebraska indicates an abundance of trampling at the time the bone bed formed (Fiorillo, 1984, 1988a). Marks similar to these were also reported from a Late Cretaceous dinosaur quarry in south-central Montana and were interpreted as the results of similar processes (Fiorillo, 1987). In addition to trample marks, the frequency of rehealed bone among hadrosaurs and ceratopsians have been used to gain insight into the intraspecific combat behavior of these animals (Tanke, 1989a, b).

Tooth marks attributable to mammalian activity have been documented several times on modern and Recent bones (e.g., Haynes, 1980, figs. 1–6 and 8–9; 1983, figs. 3–6; Binford, 1981, figs. 3.01–3.06), as well as on fossil bones (e.g., Fiorillo, 1988a, figs. 19, 21–25). Reports of tooth marks on bones attributed to dinosaurs, however, are rare (e.g., Dodson 1971; Fiorillo, 1991). In these reports, tooth marks are interpreted as indicators of carcass utilization during either predation or scavenging. Recognition of tooth marks on bones from Mesozoic bone beds, as well as being a census

of the relative abundances of these features, should provide a reasonable measure of the method by which theropod dinosaurs routinely chewed the bones of their prey.

### Materials and methods

A total of eleven bone assemblages were chosen for this study. Four of these assemblages were composed of modern mammal bones, while a fifth was made up of bones from fossil mammals from a mid-Tertiary locality in southwestern Nebraska. The remaining six bone assemblages were comprised of dinosaur bones from the Late Jurassic of Utah and Wyoming, and the Late Cretaceous of Montana (Fig. 1).

All bones were surveyed for modification features of the bone surfaces, such as tooth marks, weathering cracks (e.g., Behrensmeyer, 1978; Fiorillo, 1988a), trample marks (e.g., Fiorillo, 1984, 1987, 1988a), etc. Tooth marks on bone surfaces were identified either as grooves, often several millimeters deep, with a U-shaped cross-section (Fig. 2), or isolated punctures (e.g., Binford, 1981;

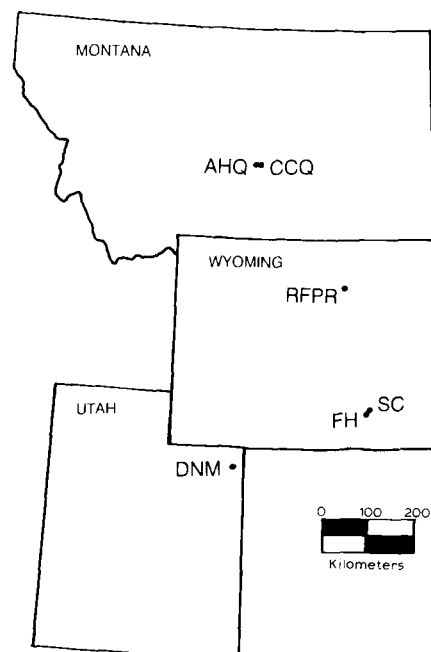


Fig. 1. Locality map showing the geographic location of the six dinosaur bonebeds used in this report. For explanation see Table 1.

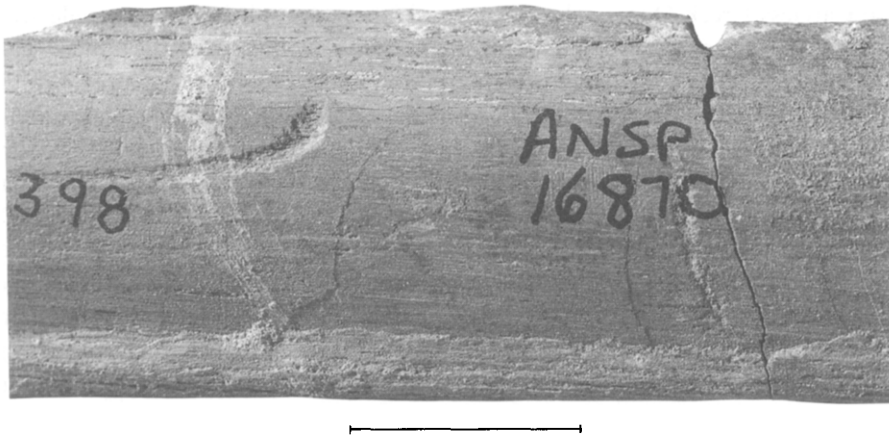


Fig. 2. Hadrosaur rib (Academy of Natural Sciences of Philadelphia specimen number 16870) from Careless Creek Quarry (Judith River Formation, south-central Montana) which exhibits an isolated tooth score. This scoring is attributed to predation by a carnosaur. Scale bar equals 2 cm.

Haynes, 1980; Fiorillo, 1988a). The grooves were quite distinct from the V-shaped, shallow, subparallel scratch marks associated with trampling (Fiorillo, 1984, 1988a, 1989a). Special attention was paid to the proximal ends of the dinosaur bones in order to determine if crushing and gnawing of these ends occurred as it did in mammalian assemblages. No paired sets of broad, rodent-like gnaw marks were observed on any of the mammal bones. Since some multituberculates had incisors similar to those of rodents, it seems likely that some multituberculates would have left this same type of mark on the surfaces of bones. No tooth marks of this predicted type were observed on any of the dinosaur bones, although a few Morrison bones exhibited preparation tool marks which approached this morphology. All of the observed tooth marks on the bone assemblages are attributable to predatory activity.

No effort was made to quantify the amount of the bone that was chewed, only to note the presence or absence of tooth marks. In all examples where tooth marks occurred on dinosaur bones they consisted of a group of only a few grooves (typically fewer than three). Only one of the tooth-marked bones, a vertebra from Careless Creek Quarry, exhibited scalloped edges (e.g. Fiorillo, 1988a, fig. 24) indicative of chewing on the bone by a predator.

The five assemblages of bones from faunas in

which the most abundant carnivores were mammals, were included to indicate the potential for tooth marks on prey bones and the relative degree of bone utilization by mammalian carnivores. One assemblage is a Miocene fossil locality (Hazard Homestead Quarry: HK 104) in southwest Nebraska (Fiorillo, 1988a). A second assemblage represents a survey of modern bones of cattle (*Bos taurus*) and a pig (*Sus scrofa*), which were collected on the farm where Hazard Homestead Quarry was located (Fiorillo, 1988a, 1989a). Throughout the field season at this locality, several coyotes (*Canis latrans*) were observed, and all tooth-mark damage on these modern bones was attributed to these animals. A third assemblage, from south-central Montana, was obtained at an entrance to a fox den. The final two assemblages represent a scavenged sheep carcass from eastern Montana and a scavenged cow carcass from northern Wyoming. Canids were the only scavengers of the sheep carcass, while scavenging by canids or large felids may have been responsible for the tooth-damaged bone of the cow carcass. These assemblages were chosen because each had an association with a bone-crushing or gnawing carnivore, and were considered sites of scavenging activity.

In addition, six assemblages of bones from dinosaur localities were also inspected for tooth marks (Fig. 1). Two of the assemblages are from sites in the Judith River Formation (Upper Cretaceous)

of Montana, the Careless Creek Quarry (Fiorillo, 1989b,c, 1991), and the Antelope Head Quarry (Fiorillo, 1987). The remaining four assemblages are from sites in the Morrison Formation (Upper Jurassic) of Utah and Wyoming: Carnegie Museum Quarry of Dinosaur National Monument in Utah, Quarry D of Sheep Creek (Wyoming), Quarry N of Freezeout Hills (Wyoming), and Quarry B of the Red Fork of the Powder River (Wyoming). The collections used for the Morrison localities are housed at the Carnegie Museum of Natural History (CM), while those used for the Judith River localities are housed at the Academy of Natural Sciences of Philadelphia (ANSP).

Disarticulated specimens, associated specimens, and partially articulated skeletons tend to record a more complex taphonomic history than do completely, or nearly completely articulated skeletons. Skeletons from the famed fossil fields of the Judith River Formation of southern Alberta (e.g., Dodson, 1971), for example, were considered to be unsuitable for this study due to the high degree of articulation exhibited. This degree of articulation indicates that these carcasses were subjected to little postmortem alteration, including disarticulation due to scavenging, probably as a result of rapid sediment accumulation rates in this area. In contrast, disarticulated or associated specimens from bone beds typically exhibit effects of multiple taphonomic processes, which include tooth marks due to predation and scavenging.

The taphonomic and sedimentologic settings for the dinosaur assemblages are relevant, since it is of prime interest to determine whether or not predation or scavenging could have occurred at each locality. The taphonomic history of Careless Creek Quarry has been discussed in detail (Fiorillo, 1991). This locality was interpreted as the site of a paleolog-jam which served as a trapping mechanism for vertebrate carcasses floating downstream. The maximum duration of the site was on the order of hundreds of years; and at some point in the history of this site, there was plentiful decaying dinosaur flesh, as indicated by the abundance of remains of the gastropod *Viviparus* sp. (Fiorillo, 1991). Antelope Head Quarry has been described as an overbank deposit with a large percentage (31%) of trampled dinosaur bone (Fiorillo, 1987).

If these trampled bones are reflective of vertebrate activity in this area, then there was probably an abundance of potential prey for theropods. The four Morrison assemblages are from sedimentologically diverse settings, ranging from channels to overbank deposits, each including partial skeletons of large herbivorous dinosaurs (Dodson et al., 1980). The presence of these skeletons suggests that food for scavengers was available. These six dinosaur assemblages, therefore, are appropriate for this study, since each assemblage had at least the potential for scavenging as a major taphonomic process. The majority of the dinosaur bones examined in this study belonged to sauropods, stegosaurs, hadrosaurs, and ceratopsians.

## Results

The results of the surveys of tooth marks in bone assemblages are presented in Table 1. The percentages of tooth-marked bones from all of the surveys ranged from 0.0 to 37.5%. The mammalian assemblages ranged from 13.1 to 37.5%, while the dinosaur assemblages ranged from 0.0 to 4.0%.

The few records of tooth marks observed on the dinosaur bones showed a slightly higher frequency of U-shaped grooves on the bone surfaces than tooth punctures, which typically were isolated occurrences. In the few cases of multiple punctures, no group of punctures exceeded two in number on any one bone surface. No pattern of gnawing or bone crushing of the proximal ends of bones was observed on any of the dinosaur bones. One vertebra exhibited gnaw marks on the end of the neural spine; these have been attributed to scavenging activity (Fiorillo, 1991, fig. 14). The only specimen which exhibited any indication of pronounced tooth damage was the symphyseal region of the ischia of the mounted skeleton of *Diplodocus* from Sheep Creek (CM 84). This damage, thought not extensive, consisted of a small group of tooth punctures combined with a small group of U-shaped grooves.

## Discussion

In all dinosaurian assemblages, the frequencies of tooth-marked bones are decidedly lower than

TABLE 1

Summary of the frequency of tooth marks, attributed to predator activity, on bones from selected bone assemblages. Data for the Hazard Homestead Quarry (HK 104) assemblage, Cow-Pig assemblage, and the Careless Creek Quarry (CCQ) assemblage are presented elsewhere (Fiorillo, 1988a, 1989a, 1991). The Antelope Head Quarry (AHQ) data were collected as part of the survey of trample marks within this assemblage (Fiorillo, 1987). The data for the remaining three modern assemblages (Fox Den, Sheep, Cow) are recorded as field notes. The data for the remaining four quarries (SC, FH, RFPR, DNM; Sheep Creek Quarry D, Freezeout Hills Quarry N, Red Fork of the Powder River Quarry B, and Dinosaur National Monument Carnegie Quarry, respectively) were, similarly, collected as part of this report. Notice the reduced numbers of tooth-marked bones in the dinosaur assemblages (CCQ, AHQ, SC, FH, RFPR, DNM) compared to the mammal assemblages (HK 104, Cow-Pig, Fox Den, Sheep, Cow).

Bone assemblage	Number of tooth-marked bones	Percentage of sample
HK 104 ( <i>N</i> = 196)	59	30.1
Cow-Pig ( <i>N</i> = 84)	11	13.1
Fox Den ( <i>N</i> = 50)	16	32.0
Sheep ( <i>N</i> = 56)	13	23.2
Cow ( <i>N</i> = 24)	9	37.5
CCQ ( <i>N</i> = 200)	3	1.5
AHQ ( <i>N</i> = 131)	0	0.0
SC ( <i>N</i> = 150)	6	4.0
FH ( <i>N</i> = 100)	2	2.0
RFPR ( <i>N</i> = 77)	3	3.9
DNM ( <i>N</i> = 200)	4	2.0

those frequencies observed in the mammalian assemblages. This, however, is not surprising considering the patterns of dentition of theropod dinosaurs compared to mammalian predators (Fig. 3). Comparison of the maxilla of a typical theropod and that of a bone-crushing mammalian carnivore shows that the latter is better suited for crushing bones by having a much more precise tooth-to-tooth occlusal pattern and more bulbous teeth. From a similar comparison, Hunt (1987) predicted that the frequency of tooth marks on bones from Mesozoic localities would be lower than that from Cenozoic localities. With his observations of the occlusion of teeth in theropod dinosaurs, Farlow (1976) estimated the amount of a tyrannosaur prey carcass which was not utilized as being close to the upper limit of unutilized prey

observed for large mammalian carnivores. He concluded that tyrannosaurs were likely to have higher "wastage factors" than mammalian predators. The low frequency of tooth-marked bone from this study, then, substantiates the predictions of Hunt (1987) and Farlow (1976) by indicating that dinosaurian predators did not utilize prey bone in a manner similar to that of mammalian carnivores that routinely crush bone.

However, not all mammalian assemblages contain frequencies of tooth-marked bone as high as the ones used in this study. The taphonomic history of a particular assemblage of bone may preclude the possibility of predation or scavenging. For example, during catastrophic events which are responsible for mass deaths and which are also accompanied by rapid burial, exposure to predation or scavenging of the carcasses is unlikely. The mammalian bone assemblages used in this study were chosen specifically because scavenging by carnivores could be documented, and it was this general level of scavenging that was needed as a basis for comparison with the dinosaurian assemblages.

It might also be argued that the frequency of tooth-marked bones in an assemblage of bones is not an accurate gage in determining levels of carnivore bone modification, since these levels are related to the environment and the differences in the available prey. For example, the wolves of northern Minnesota have been observed to kill deer excessively during severe winters and only lightly utilize the carcass, whereas in subsequent years, with less deer available, the wolves extensively utilized the carcasses of the deer killed (Haynes, 1981, and references therein).

Remains at most fossil localities are the result of time-averaging and all remains of the fossil assemblage may not be contemporaneous. As a result, frequencies of taphonomic features at a locality are the result of the average effect of a particular process over a given increment of time. For example, at the mid-Miocene mammal locality, Hazard Homestead Quarry, in southwestern Nebraska, which has been interpreted as a water-hole locality, an abundance of tooth-marked bone (30%) was attributed to the canid *Aelurodon* (Fiorillo, 1988a). From this occurrence it was concluded

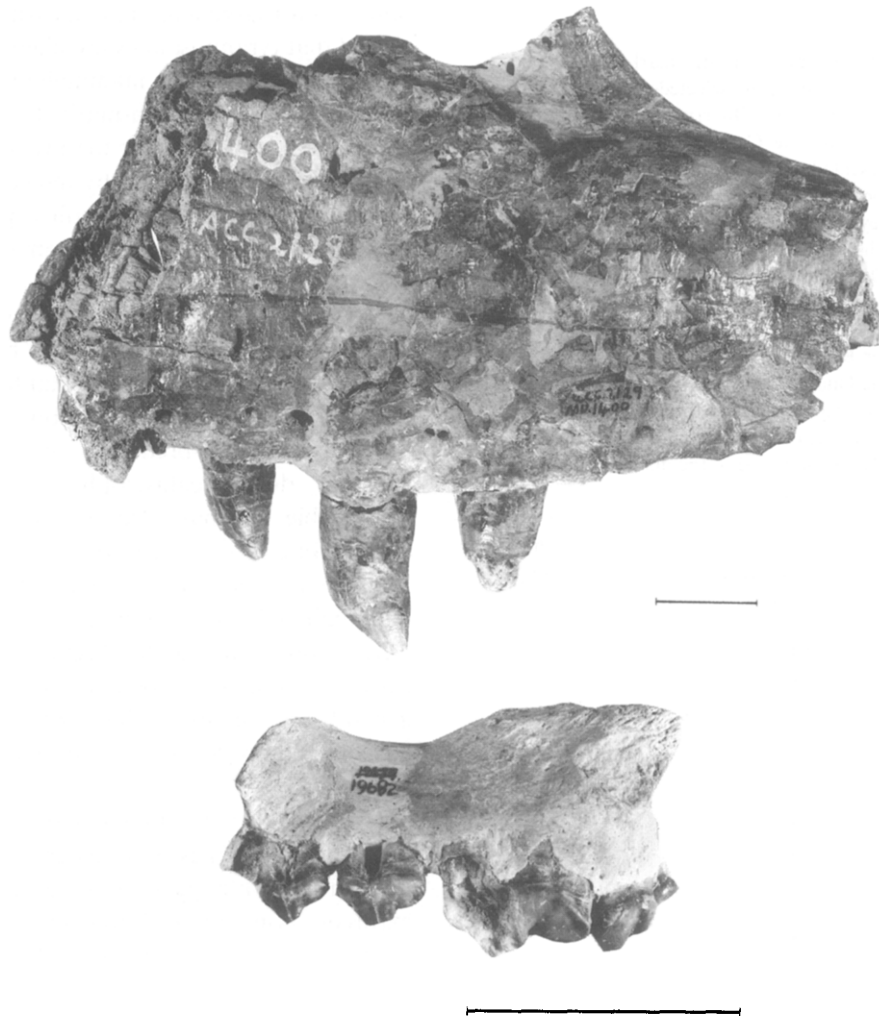


Fig. 3. Comparison between a generalized theropod maxilla typified in *Tyrannosaurus rex* (CM 1400) and the maxilla of *Aelurodon* (CM 19682), a bone-crushing canid (e.g., Fiorillo 1988a, fig. 21). Notice the specialization of the individual teeth of *Aelurodon* as well as the extreme proximity of adjacent teeth compared to the teeth in the maxilla of *Tyrannosaurus*. Each scale bar equals 5 cm.

that carnivore activity was common at the time this bone assemblage formed. Estimates of the time it took for the bonebed to form at this locality vary from two years to 750 years (Fiorillo, 1988b), which indicates that this site is indeed a time-averaged sample. Although there may have been changes in the intensity of carnivore activity around this water-hole from year to year, the percentage of tooth-marked bone at this locality represents an average of carnivore activity over the time interval during which the site was formed. The percentages of tooth marks on the bones of

the various assemblages used in this study should be viewed as representing a time-averaged sample of the relative levels of carnivorous vertebrate activity. In this context the fewer tooth marks on dinosaur bones the mammalian assemblages suggests a different pattern of prey-bone utilization between mammalian carnivores and carnivorous dinosaurs.

Another issue of concern is that studies based on tooth morphology indicate a varying ability among mammalian carnivore taxa to crush bone (Van Valkenburg 1988; Van Valkenburg and Ruff

1987). Could this also be true for dinosaurs? Preliminary data on the morphology of carnivorous dinosaur teeth indicates that gross variation in shape is minimal (Farlow et al., 1989), suggesting that the variability in bone crushing ability was minimal among carnivorous dinosaurs. However, skeletons of larger animals are a larger fraction of the total mass of an animal than are the skeletons of small animals (Anderson et al., 1979; Hokkanen, 1986). Presumably *Tyrannosaurus* ate prey bigger than the prey of a small carnivorous dinosaur like *Coelophysis*; if so, *Tyrannosaurus* fed upon animals with more massive skeletons. The prey bones may have been too robust to have been effectively broken and chewed by large theropods. If *Tyrannosaurus* also fed on smaller prey the small bones may have been destroyed during ingestion, leaving no trace of this aspect of prey-bone utilization. The routine crushing of bone may have been more likely to have occurred among the small predatory dinosaurs. *Coelophysis* specimens from the Triassic locality at Ghost Ranch, New Mexico exhibit the disarticulated remains of juvenile *Coelophysis* specimens within the rib cage of articulated adult *Coelophysis* skeletons (American Museum of Natural History 7223, 7224). Given the disarticulated state of the juvenile within the abdominal cavity of the articulated adult, these specimens are interpreted as indications of cannibalism by the adults (Colbert 1989). Examination of the cast of AMNH 7224 at the Carnegie Museum of Natural History and figs. 99–102 of Colbert (1989) reveal no sign of tooth marks on the bones of these juveniles, suggesting that bone crushing was not employed by *Coelophysis*. If these specimens are regarded as a basis for a model for all small theropods, then it can be inferred that small theropods utilized prey bones in a manner similar to that of the large theropods, where small bones were ingested whole while large bones were not chewed. In applying interpretation based on these two specimens to all small theropods caution should be exercised, however, since the sample size is small and both specimens are from only one locality.

Although the results of this study indicate that carnivorous dinosaurs did not routinely crush bone as part of their utilization of prey carcasses, incidences of tooth damage on prey bones are docu-

mented. In addition to the marks recorded in this study, other examples of tooth damage on dinosaur bones have also been reported but remain rare (e.g. Beasley, 1907; Dodson, 1971; Matthew, 1908; Fiorillo, 1991). The results of this study suggest that these occurrences were incidental, and that routine bone chewing was not an intentional part of carcass utilization.

This conclusion seems anomalous, considering the caniniform shape of the theropod tooth. Mammalian carnivores have similarly shaped canines which have a specific function. The initial point of contact in the bite of a mammalian carnivore is at the canine. The robustness of these teeth has been shown to be significant in the ability of a carnivore to break bone and can vary among taxa (Van Valkenburgh, 1988; Van Valkenburgh and Ruff, 1987). Since theropod teeth have a gross similarity to mammalian carnivore canines, it may seem surprising that tooth marks on dinosaur prey bones are not more common. This apparent anomaly may be explained by recognizing that dinosaurs continually shed teeth and that these teeth were not as firmly socketed as mammalian carnivore teeth. Consequently, contact with bone probably resulted in the dislodging of teeth from the jaw, rather than sustaining a tooth–bone contact long enough to create either a tooth score or puncture on the bone surface. Indeed, isolated theropod teeth are commonly found in association with potential prey carcasses (e.g., Buffetaut and Suteetham, 1989; Gallup, 1989; Horner, 1987; Ostrom, 1969).

### Implications for the ecological role of theropods

What is the ecological significance of the scarcity of tooth-marked bones, and does this pattern have implications for how large theropods obtained their food? This issue was alluded to by Lambe (1917) in his description of the type specimen of “*Gorgosaurus*” (= *Albertosaurus*), when he noted that the teeth showed no appreciable wear. He concluded that *Gorgosaurus* ate easily obtained soft foods, such as partially rancid flesh, and filled the role of a scavenger in Cretaceous ecosystems. The rancid meat would have separated more easily from the bones than fresh meat, thereby reducing

the possibility of predator tooth–prey bone contact.

Variations for cutting meat with reptile teeth are limited (Farlow et al., 1989), suggesting that specialized scavengers were likely absent from dinosaur-dominated ecosystems. Theropods, in general then, may have incorporated a significant amount of carrion into their diet, as Lambe initially suggested for *Gorgosaurus* (= *Albertosaurus*).

Isolated theropod teeth are commonly found at dinosaur fossil localities, and many, although by no means all, of these teeth show a pristine form similar to the teeth of *Gorgosaurus* (= *Albertosaurus*) described by Lambe (Fig. 4). This pattern corroborates the results of this study which suggest that dinosaurs did not routinely chew the bones of their prey. It must be concluded, then, that bone crushing was not a significant process employed by predatory dinosaurs during the utilization of a prey carcass. The ecological and functional role of routine bone crushing in terrestrial ecosystems was, therefore, unoccupied during the Mesozoic but later occupied by mammalian carnivores during the Cenozoic.



Fig. 4. A representative sample of isolated tyrannosaur teeth (CM 30749). Notice that the number of teeth which are pristine and those exhibiting wear facets is essentially the same. Wear facets are highlighted by the arrows. Scale bar equals 1 cm.

### Implications for predatory dinosaur nutrient intake

Were there alternative means by which a theropod may have obtained the nutrients contained within prey bones? Fisher (1981) showed that in crocodiles, ingested small bones of mice and rats were demineralized. Conversely, Weigelt (1989, p. 92) noted that crocodiles regurgitate the “residue” of their food, which includes the bones, rather than digest it. Similar to Fisher’s findings on crocodiles, Komodo monitors typically digest the small bones and cartilage of their prey (Auffenberg 1981). If feeding is heavy, however, the fecal material of these monitors will include undigested bone (Auffenberg 1981). Although Fisher and Auffenberg report the complete digestion of small bones by these reptiles, these reports suggest that crocodiles and komodo monitors only passively consumed the small bones as part of their utilization of a prey carcass, that is the bones were not sought after for consumption. In the case of ingestion of larger prey items by Komodo monitors, the bones are swallowed whole with no gnawing or crushing of the prey bones first (Auffenberg, written comm. 1989). Presumably during the ingestion of these larger bones, a few scratches from the teeth of these reptiles could be left on the bone surfaces (Auffenberg, pers. comm., 1989). This pattern of little or no modification of prey bones by the Komodo monitor appears similar to the patterns of tooth-marked bone observed in the dinosaur assemblages. If theropod digestive systems were similar to those of Komodo monitors or crocodiles, then theropods may have obtained the nutrients within bones by ingesting whole some of the smaller bones of their prey. Evidence that theropods may have at least partially digested bone can be obtained at the Cleveland-Lloyd Quarry, famous for its abundance of *Allosaurus* remains. At this quarry, a large number of bones have had the outer cortical layers removed, suggestive of partial digestion (Petersen et al., 1972; Madsen, 1976, p. 8).

Further speculation pertaining to small theropods is possible. The presence of the juvenile bones in the *Coelophysis* specimens mentioned above suggests that bone was not demineralized by small theropods as has been shown for crocodiles



(Fisher, 1981). Instead, digestion of bone in the *Coelophysis* specimens was largely incomplete and may have resembled the pattern of partial bone dissolution observed for predatory birds (e.g. Mayhew 1977; Dodson and Wexlar 1979). Alternatively, these *Coelophysis* individuals may have died before digestion was completed.

## Conclusions

Utilization of prey bone in modern terrestrial ecosystems which are dominated by mammalian carnivores is common. Typically the resulting damage from mammalian carnivores utilizing prey carcasses is that many of the prey bones are tooth-marked. Studies of the surfaces of bones from dinosaur-dominated terrestrial ecosystems indicate that similar patterns in bone utilization did not exist for theropods. Tooth-marked prey bones are decidedly uncommon in dinosaur bone assemblages. The few reports of theropod tooth-prey bone contact are instead attributed to incidental contact, and forced contact between teeth and bone may have instead dislodged theropod teeth from the jaw.

Theropods may have utilized prey bones more like modern Komodo monitors and crocodiles than mammalian carnivores, that is by passive consumption rather than by actively seeking out the bones for nutrient intake. The absence of bone crushing in dinosaur prey bones suggests that routine bone crushing as an ecological and functional phenomenon was not present in Mesozoic terrestrial ecosystems.

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