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Taphonomy and depositional setting of Careless Creek Quarry (Judith River Formation), Wheatland County, Montana, U.S.A.

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ABSTRACT

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Careless Creek Quarry is a newly discovered, rich vertebrate locality in the Judith River Formation of south-central Montana. This site has yielded approximately 1500 specimens of various vertebrate taxa, most notable are dinosaurs, and is the most productive site yet reported from this formation in the United States, south of the international boundary with Canada.

A detailed taphonomic excavation of Careless Creek Quarry has shown that this site formed in an active river channel, approximately 6–11 m wide and approximately 1.5 m deep, and that the bones accumulated as a result of a log jam. This setting, in conjunction with the taphonomic setting of other sites in the area, suggest that trapping mechanisms may be largely responsible for the accumulation of vertebrate remains within active channel environments.

Close scrutiny of the fossil assemblage indicates that two different subsets of bone assemblages exist with widely different taphonomic histories. One assemblage consists of unassociated skeletal remains which are of a size which is hydraulically compatible with the grain sizes of the sediment within the quarry. This characteristic suggests that these bones were brought in by the ancient Careless Creek stream. The second assemblage consists of associated skeletal material which is too large to have been brought into the site as sedimentary clasts. Instead, this latter assemblage probably accumulated at the site due to carcass flotation and subsequent entrapment on the paleolog jam.

Examination of the taphonomic parameters of the Careless Creek associated skeletal assemblage indicates that there is little correlation between the taphonomic features of the assemblage and the expected features produced in a channel environment. Bone orientation for example, shows no clear preferred orientation. Similarly a bone census of this subset of bones shows that the lighter, less-dense bones such as ribs and vertebra are abundant at the locality. In addition, very little bone modification occurred on these bones either prior to or after deposition at Careless Creek Quarry.

Introduction

A newly discovered fossil vertebrate site, Careless Creek Quarry, in the Judith River Formation of south-central Montana has yielded an abundance of Late Cretaceous vertebrate remains. Approximately 1500 specimens have been recovered from Careless Creek Quarry, which was discovered in 1981 by Mr. Eddy Cole from Wall, South Dakota. Since the initial discovery, the quarry has been worked extensively by Academy of Natural Sciences of Philadelphia/University of Pennsylvania field parties.

This site has contributed significantly towards better understanding the faunas of the Judith River Formation. For example, Careless Creek Quarry has produced a new dinosaur taxon, *Avaceratops lammersi* (Dodson, 1986), as well as producing abundant juvenile dinosaur remains (Fiorillo, 1987a) which elsewhere have consistently been rare occurrences in the fossil record (Sternberg, 1955; Richmond, 1965, etc.). These juvenile remains show that not all dinosaurs were confined to nesting in upland habitats as had been previously suggested (cf. Horner, 1984a, 1987). Careless Creek Quarry has produced associated dinosaurian skele-

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tal remains of lambeosaurine and hadrosaurine hadrosaurs, and ceratopsians, an occurrence not observed at other localities in the Judith Formation south of the Canada–United States border (Sahni, 1972; Goodwin, 1988). This site also produced the second report of postcranial remains of pachycephalosaurid dinosaurs from North America (Fiorillo, 1989a). The purpose of this report is to discuss the taphonomic and sedimentologic setting of this rich bone bed and determine the factors which influenced its formation.

Detailed excavation and mapping of Careless Creek Quarry has shown that the quarry is the site of an ancient log jam in a paleoriver channel. The insight obtained on how the Careless Creek bone bed formed have implications for the origins of vertebrate fossil deposits in other channel deposits within the Judith River Formation of this region. The data from Careless Creek Quarry also provide a test for evaluating some of the faunal quantification methods used by workers analyzing Cenozoic vertebrate sites (e.g. Badgley, 1986a). Similarly, Careless Creek Quarry provides a means to evaluate some aspects of models for the modes of accumulation of vertebrate remains in channel deposits (Behrensmeyer, 1988). Further work stemming from the excavations at this quarry and surrounding quarries include assessment of paleoenvironmental contrasts within this region (Fiorillo, 1989a) as well as an assessment of the fossil faunas of this region as compared to other Judithian faunas (Fiorillo, 1988a, 1989b) and reconstructions of the fluvial systems of this region. This site, in combination with other sites in the Judith River Formation of south-central Montana (Fiorillo, 1988a, 1989a,b) should provide new insights into the evolutionary patterns that may have occurred due to the pressures of a transgressive–regressive interior seaway (cf. Horner, 1984b; Weishampel and Horner, 1987).

Methods

This study included both a field and a laboratory phase. The field aspect of this project involved approximately 21 weeks of excavation, spread out over the summers of 1984, 1985, and 1986. During this time, the author directed and participated in the excavation of Careless Creek Quarry.

Approximately 180 m^3 of overburden were removed during the excavation of the quarry, which is approximately 21 m long by 12 m wide. The overburden was removed by the use of a backhoe, shovels, picks and jackhammers. The specimens were all mapped in place and orientation measurements were made on all linear skeletal elements and tree remains. The specimens were removed from the quarry encased in standard plaster jackets. Approximately 1000 lbs. of quarry matrix were screenwashed in 1986 in order to sample the microvertebrate fauna.

The laboratory aspect of this work involved preparation of the bones using conventional means. Each specimen was examined to determine the skeletal and taxonomic identity. Any modification features, such as tooth marks, weathering cracks, etc., of the bone surfaces were also noted (Tables 1 and 2).

TABLE 1

Summary of the bone modification features observed in a randomly chosen sample of bones ($N=200$) from Careless Creek Quarry. The abbreviations under fracture pattern, TR and SP, refer to transverse and spiral patterns respectively. Since there are so few tooth marks of the sample examined no effort was made to distinguish between tooth scores and tooth punctures in this table

	Fracture pattern		Abrasion stage	Weathering stage			Tooth		Trample	
	TR	SP	0	0	0(1)	1	marks	no marks	marks	no marks
Number of specimens	167	3	200	196	3	1	3	197	1	199
Percentage of sample	98.2	1.8	100	94.5	1.5	0.5	1.5	98.5	0.5	99.5

TABLE 2

Comparison of the observed number of skeletal elements in Careless Creek Quarry with the predicted numbers. Since most of the dinosaur material from Careless Creek belongs to hadrosaurs and ceratopsians, the predicted number of bones belonging to Voorhies Group I and Voorhies Group II were derived from an average of the skeletal numbers of the respective groups from *Corythosaurus*, a Judithian hadrosaur identified from the quarry, and *Avaceratops*, a ceratopsian also recovered from the quarry. Notice that most of the lighter, less-dense elements such as ribs and vertebrae are well represented at the quarry suggesting that little hydraulic winnowing occurred at this site

	Voorhies Group I (ribs, vertebrae)	Voorhies Group II (limb bones)	Voorhies Group I/Group II
Predicted skeletal element quantities from an average of the element tally from *Corythosaurus* and *Avaceratops*	30	233	0.13
Skeletal element tally from Careless Creek Quarry	41	296	0.14

Geologic and geographic setting

Introduction

Careless Creek Quarry (CCQ) is located in easternmost Wheatland County of south-central Montana in the NE1/4NE1/4SW1/4 sec. 24, t. 8 N, R. 18 E (Fig.1) and is designated site MT:WH-1 in the site catalog of the Division of Vertebrate Paleontology at the Academy of Natural Sciences of Philadelphia.

The Judith River Formation is a major rock unit throughout much of Montana and southern Alberta. The exposures of this unit in southern Alberta has originally been referred to as the Oldman Formation (Russell, 1940) subsequent stratigraphic refinement synonymized the Oldman with the Judith River Formation of Montana (McLean, 1977). Historically, the formation is important as yielding the first dinosaur remains in North America, which consist of isolated teeth (Leidy, 1856). These specimens were collected by F. V. Hayden in 1854 in central Montana near the confluence of the Judith and Missouri rivers. Subsequent dinosaur discoveries from the Judith River Formation in this region have been fragmentary (e.g. Cope, 1876, 1889; Marsh, 1888; see Dodson, 1990, for detailed account of history), although more productive sites in southern Alberta have

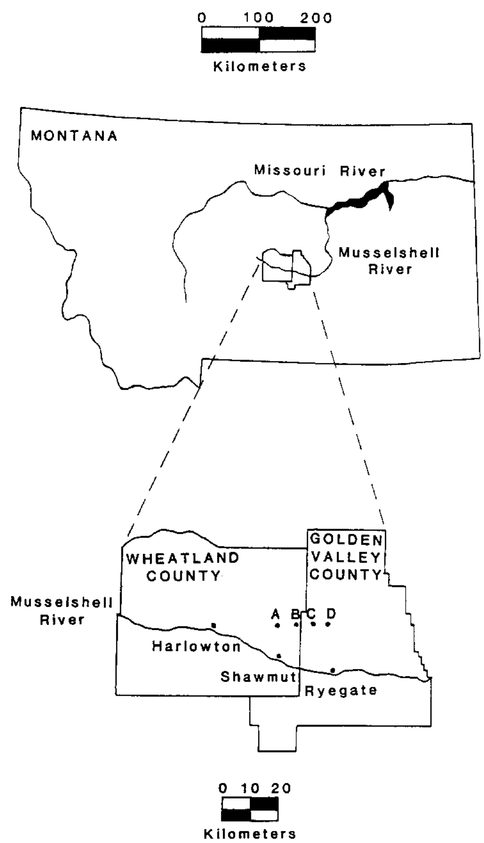


Fig.1. Location of Careless Creek Quarry and associated fossil vertebrate quarries in Wheatland and Golden Valley Counties, Montana. The letters *A*, *B*, *C*, and *D*, correspond to stratigraphic sections which are presented in Fig.2.

shown this formation in Alberta to be one of the richest dinosaur-producing rock units in the world (Dodson, 1971). Careless Creek Quarry is notable because it is the southernmost productive locality in the Judith River Formation as well as one of the most productive sites reported from the formation, south of the Canada–United States border.

The age of the Judith River Formation is currently under debate. The unit, based on ammonite zonation, had long been considered to be Campanian in age and bracketed between the underlying *Baculites asperiformis* Zone and the overlying *Baculites scotti* Zone (e.g. Gill and Cobban, 1973). Lillegraven and McKenna (1986), however, reviewed the correlations of nonmarine units temporally equivalent to, and including the Judith River Formation, and concluded that the mammal faunas of these nonmarine units must be younger in age than had previously been interpreted. Lillegraven and McKenna (1986) proposed a nonmarine chronology for the Upper Cretaceous based on species-level mammal faunas, a concept originally described for this time interval by Russell (1975).

Flynn (1986) has shown, by correlating the terrestrial sequences of the San Juan Basin of New Mexico with the paleomagnetic time scale, that the North American Late Cretaceous Land Mammal Ages defined by Lillegraven and McKenna are of variable duration. The Judithian, for example, within the San Juan Basin was of relatively long duration (6 million years) compared to the subsequent Lancian (2 million years). His correlation of biostratigraphic units with the paleomagnetic time scale supports the idea that the Judithian straddles the Campanian–Maastrichtian boundary.

Contrary to this view, Eaton (1987) argues that the correlations between the foraminiferal boundaries and the molluscan zones of Europe and North America are ambiguous. He also argues that there is no basis for considering the Judithian Land Mammal Age as other than late Campanian in age.

Radiometric ages are rare from the Judith River Formation. Presently the only radiometric dates known for this formation are argon–argon ages from the Judith River of northern Montana (Goodwin, 1988; Goodwin and Deino, 1989). These dates, $78.20 + 0.21$ Ma and $79.46 + 0.27$ Ma respectively, are from two bentonite layers low in the section, and they indicate that the lower part of the Judith River Formation is firmly in the Campanian (Goodwin, 1988; Goodwin and Deino, 1989).

The lithologic units above and below the nonmarine Judith River Formation in central Montana are marine shales; the Bearpaw Formation and the Claggett Formation, respectively.

Local geology

From the base of the Judith River Formation to the top of the formation, the Careless Creek Quarry section is approximately 130 m thick (Fig.2). Oyster beds, which can be found in the lowermost and uppermost few meters of this formation in the area around CCQ, indicate a substantial marine or brackish water influence on the depositional setting of the Judith River Formation at the beginning and at the end of the Judith River Regression. The non-marine units in the CCQ local section are dominantly mudstones and sandstones although lignitic or poorly developed bituminous grade coals or coaly units are also present. These organic-rich units comprise approximately 5% of the lower two thirds of the section. This contrasts sharply with the upper third of the section where the thicknesses of the coals or black shales comprise approximately 80% of the total thicknesses of all of the lithologies, although individual coal seams only reached thicknesses up to 3 m.

Careless Creek Quarry is located in the lower one-third of the local section (Fig.2), in an approximately 3 m thick medium to light gray sandstone. Within this unit, which is fine- to coarse-grained and has subangular to subrounded sand grains, there are numerous lenses of pebbly conglomerate, all less than 10 cm thick. The clasts of these conglomerates are intraformational mudstones which are commonly stained yellowish brown. The lower 0.35 m of this sandstone shows some discontinuous mudstone interbeds, which may be flattened clayballs, or the result of small scale ponding within the stream caused by abundance of logs at

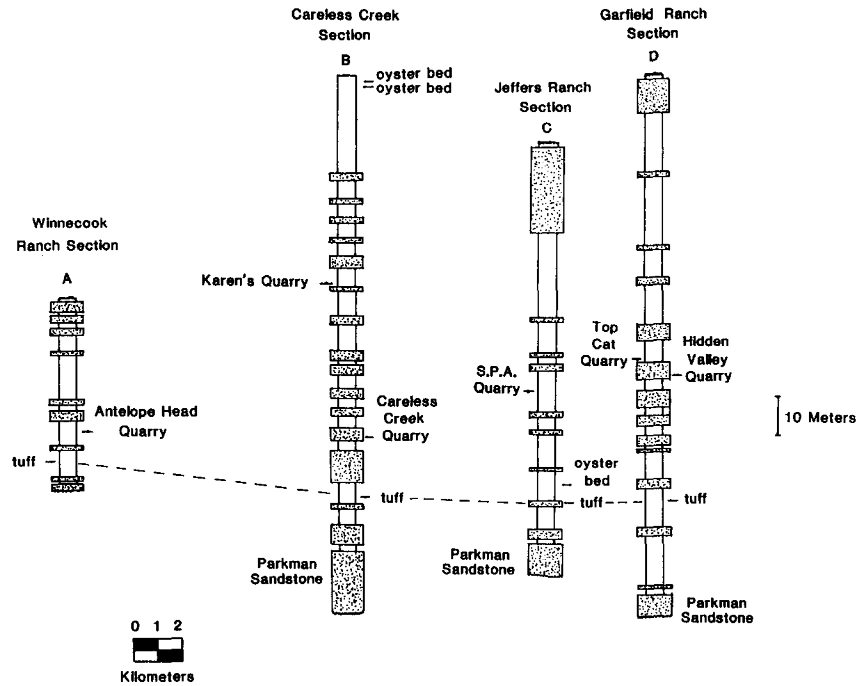


Fig.2. Stratigraphic sections showing the relative position of fossil quarries. The letters *A*, *B*, *C*, and *D*, correspond to the labeled positions in Fig.1. The sandstones are represented by the dotted regions in each section while the fine-grained units are represented by blank regions.

this site. Locally, the interbeds are continuous. Fossil bones, carbonized tree limbs and carbonized vegetative mats are contained in this interval. This sandstone has a sharp contact with the underlying medium to dark gray, organic rich shale.

Sedimentary structures are preserved locally in areas of CCQ where bone and tree limb density are minimal. Cross bedding, present in the quarry, can also be observed in numerous sandstones above and below the quarry level. These cross beds show a dominant paleocurrent flow from west to east (Fig.3). Weak horizontal laminae, approximately 4–8 cm thick, are also preserved in the quarry, while in other areas the sandstone is massive.

Depositional environment

The Judith River Formation in Alberta has been interpreted as being deposited on an aggrading coastal plain dominated by fluviatile sedimentation (Eisbacher et al., 1974). This coastal plain lay between alluvial fans in the west and the Western

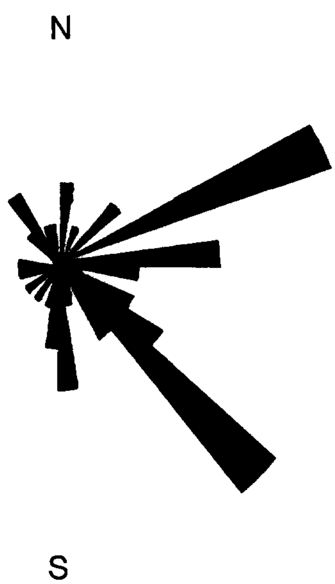


Fig.3. Paleocurrent data from cross-bedded sandstones throughout the Careless Creek section ($N=49$). Notice that the dominant flow direction was from west to east.

Interior Seaway to the east (Eisbacher et al., 1974). Although most of the detailed depositional interpretations have been made in regions several hundred kilometers north of Careless Creek Quarry, personal observations in the Careless Creek area are consistent with the general interpretation for the depositional setting of the Judith River Formation. The distribution of sediment types in the sections discussed here is typical of transgressive–regressive sedimentation sequences. The dominance of clastic sedimentation in the lower parts of the sections is likely the result of renewed uplift to the west providing an abundance of fluvial siliclastic sediments to the area.

The depositional environment for CCQ is interpreted as a stream channel. The presence of inclined heterolithic strata (IHS units, see below) in the section which are interpreted here as point bar deposits suggest that the stream was part of a meandering fluvial system. Since Careless Creek Quarry, in the regions void of fossils, is dominated by cross-beds, with either poorly developed laminae or a massive appearance, it is probable that the CCQ stream channel was perennial (cf. McKee et al., 1967; Tunbridge, 1981). The presence of amorphous vegetative mats in the quarry also suggest that the stream was perennial. These mats indicate abundant bacteria, within an aqueous environment, which served to decompose the leafy material (Gastaldo et al., 1987). The source area of the mudstone clasts was not far from the quarry since mud clasts do not survive lengthy transport (Smith, 1972). The clasts are likely to be the result of the channel reworking its banks.

Within the Careless Creek section there are a small number of units which are composed of alternating beds of sandstone and mudstone (Fig.4). These beds are inclined and conform to the definition of inclined heterolithic stratification (IHS), a descriptive rather than genetic term, recently proposed by Thomas et al. (1987). The IHS units in the Careless Creek section are thin, not laterally continuous, show sharp basal contacts and tend to grade upwards into mudstones. Based on these characters, the Careless Creek IHS units are interpreted as point bar deposits of an ancient meandering fluvial system.

The field data recorded from these point bar deposits are maximum dip angle and thickness; thickness is an estimator of the stream channel depth (Allen, 1965). Thomas et al. (1987), utilizing data derived in part from the literature, arbitrarily define small-scale channels as those with depths of less than 3 m, medium-scale channels with depths of between 3 and 10 m, and large-scale channels with depths of greater than 10 m. The thicknesses of the Careless Creek point bars indicate that stream-channel depth ranged from 1.5 to 1.75 m, and thus that they are, according to Thomas et al. (1987), small-scale channels.

Paleohydrology

Introduction

Although studies of the hydraulic parameters, such as stream depth, stream width, sediment load, sinuosity, etc., of modern rivers (e.g. Schumm, 1963; Ethbridge and Schumm, 1978) have provided a basis for estimating the paleohydraulic parameters of ancient meandering river systems (e.g. Cotter, 1971; Koster, 1984), it is doubtful that the specifics of these estimates are reliable. I am inclined (with Jackson, 1978) to regard these estimates as measures of the general magnitude of the river. For example, much of their foundation is based on sedimentary structures, and differential compaction of sediments during lithification would distort the true relationships of these structures. Also, in most studies of ancient river systems the data are derived from constrained areas and rarely provide any indication that they are derived from precisely the same time interval within a fluvial system. Lastly, as noted by Jackson (1978), variations in vegetation type and abundance can influence the overall stream morphology (Keller and Tally, 1979; Keller and Swanson, 1979) and to some degree bank stability (up to 20,000 ×, Smith, 1976). This influence intuitively seems greater as the stream size diminishes. It also is reasonable to expect the effects of variations of topography (Keller and Tally, 1979) and bedrock to increase as stream size decreases. The effects of the variations of topography, bedrock and vegetation type on small streams is particularly relevant to the interpretation of stream parameters at Careless

Fig.4. Inclined Heterolithic Stratified (IHS) unit, outlined by dotted lines, which is located a few meters up section of Careless Creek Quarry. This unit is interpreted to be a point bar deposit within a meandering stream system. View is to the northeast. Scale bar equals approximately 1.5 m.

Creek Quarry, since the streams here are interpreted as small-scale.

Using Koster's (1984, Fig.52) graphs and equations for reconstructing meandering fluvial systems, it is possible to reconstruct some of the parameters of the streams in the Judith River Formation of south-central Montana at the time the Careless Creek Quarry formed.

Koster (1984, fig.52) correlates bankful depth and point bar dip to bankful width. The maximum dip angles measured from the Careless Creek point bars ranged from 12 to 21°. By Koster's approach, the bankful widths of the streams in the Careless Creek section range from approximately 6 to 11 m.

Estimating sediment-load type for a channel can be achieved through the use of the ratio of bankful width to depth (Ethbridge and Schumm, 1978). The ratios obtained for the Careless Creek point bars are 4–6.3. In both cases this ratio is well under 10, the lower limit for mixed-load channels (Koster, 1984). Therefore, the Careless Creek channels were suspended-load channels.

In summary, the meandering streams of the Careless Creek section were small-scale streams with depths between 1.5 m and 1.75 m and widths of 6–11 m. These streams can be classified as suspended-load streams.

Taphonomic features

Introduction

A study of the taphonomic parameters (sensu Badgley and Behrensmeyer, 1980; Badgley, 1986a,b; Fiorillo, 1988c) at Careless Creek Quarry, (such as spatial distribution of fossils within the bonebed, the degree of skeletal articulation, the orientation of the fossil material at the site, the hydraulic equivalence of bones, bone modification features and a bone element census) provides a means for determining the biological and sedimentological processes that influenced the formation and preservation of the quarry. In addition, the abundance of carbonized plant debris at Careless Creek Quarry provides an opportunity to obtain insight into the processes operating at the time the site formed based on taphonomic data from a distinctly different type of organism.

Spatial distribution

Spatial distribution of fossils refers to the three-dimensional distribution of fossils within one stratigraphic unit (Badgley, 1986a). This distribution is typically heterogeneous in terrestrial vertebrate fossil localities. Concentrations of fossils often occur in the basal portion of a rock unit, which has a sharp contact with the underlying unit, and such a distribution is typical of a mass mortality of animals (Efremov, 1940). Although the distribution of fossils at CCQ is generally consistent with Efremov's observations (1940) based on many vertebrate localities, data described below suggest that it is unlikely that all of the fossils from the CCQ bone bed can be attributed to a mass mortality.

The sandstone unit containing Careless Creek Quarry is approximately 3 m thick; and the fossils are concentrated in the lower meter. The thickness of the bone bed suggests that there was a large interval of time over which these bones accumulated. In addition to this attritional component of the bone concentration, there was also a large, sudden influx of bones, due most likely to a mass mortality event, which by comparison to the attritional component, represent an "instantaneous" accumulation. These two modes of fossil accumulation indicate that two major taphonomic histories are preserved in the quarry.

The greatest concentrations of vertebrate fossils are found with carbonized tree limbs or trunks (Fig.5). Here bone density can exceed 5 bones per m^2. On the other hand, where no tree limbs occur vertebrate remains are rare. In some areas within the quarry, bones can be found lying parallel to trees on the upstream side of the tree. This association between the bone assemblages and the carbonized trees suggests that the deposition of the trees preceded, or was penecontemporaneous with, the deposition of the bones. In addition to carbonized tree limbs, plant remains from the quarry include abundant amorphous vegetative mats. Gastropod opercula (*Viviparus*; A. Bogan, ANSP Malacology Dept., pers. comm., 1988), are also found in abundance with bones and trees.

This distribution of fossils in the Careless Creek Quarry suggests an ancient log jam in a river channel. Active stream bank erosion quite often introduce trees into a river channel by undercutting the banks (Spicer, 1989, p. 114). At CCQ, abundant intraformational mud clasts indicates that bank reworking was active within this paleoriver. I suggest that it was this process which provided the source of the trees at the quarry. The significance of the logs is that they served to trap the

Fig.5. Careless Creek Quarry bone bed showing the association of fossil bones with carbonized tree limbs.

bones as they moved downstream. Dead wood entanglements are not rare in fluvial systems and they have long been recognized as obstacles to movement of some types of materials along a river. The presence of abundant logs in the modern Missouri River, for example, posed major problems to Lewis and Clark as they navigated the river in the early 1800's (e.g. Moulton, 1987). Karl Bodmer illustrated a stretch of this same river in the 1830's, again showing an abundance of logs in the channel (Goetzmann et al., 1984). Such entanglements can be initiated with even a single large tree caught on a shallow of some type within a channel. Once one tree is immobilized, other objects presumably can be caught by the jam. Such organic debris piles can have a profound effect on the channel morphology of a low-gradient meandering stream by greatly enhancing such aspects as stream bank erosion and channel width, and can also facilitate meander cut-off development (Keller and Swanson, 1979).

Plant taphonomy

There are two major modes of occurrence for plant material at Careless Creek Quarry, carbonized tree limbs and amorphous vegetative mats. This latter mode is indicative of abundant fungal and bacterial decomposition beneath the sediment–water interface for extended periods of time (Gastaldo et al., 1987) and may be indicative of perennial stream flow at Careless Creek Quarry.

Although none of the trees excavated at the quarry were complete, the fragments preserved varied extensively in length (15–600 cm; Fig.6) and the widths ranged from 3 to 75 cm. The mixed sizes suggest that hydraulic sorting had little or no effect on this part of the fossil assemblage. The dimensions of these tree fragments may seem small for initiating blockage in a larger stream, but considering the size of the small-scale streams at Careless Creek, they are entirely appropriate.

Unfortunately the preservation of much of the plant material provides little clue to its identity. However, structure of the wood is similar to that found within this formation in the region of Dinosaur Provincial Park, Alberta, where metasequoian foliage is abundant (Koster, 1984). Also in the

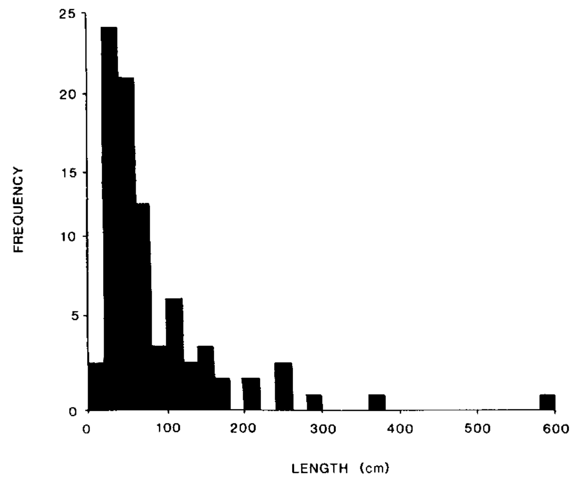


Fig.6. Distribution of tree limb lengths in Careless Creek Quarry ($N = 89$).

park area, the dominant wood found belongs to the genus *Taxodioxylon*, a coniferous tree (Koster, 1984). There is little clue as to the provenance of the plant material at Careless Creek Quarry since plant debris in channel environments is capable of transport over several kilometers (Gastaldo et al., 1987). Since channel-margin vegetation has a higher probability of transport downstream (Gastaldo et al., 1987), and that lag deposits represent near-channel floras (Spicer, 1989) it may be that the vegetation preserved at CCQ represents near-channel flora.

Skeletal articulation

The degrees of skeletal association at Careless Creek Quarry suggest two taphonomically distinct bone assemblages at this one site with each assemblage having a different burial history. Of the approximately 1500 specimens from Careless Creek, very few specimens were found articulated. Much more common were examples of associated skeletal remains for some of the herbivorous dinosaurs (e.g. *Avaceratops lammersi* Dodson 1986; juvenile and adult lambeosaurs, Fiorillo, 1987a, as well as adult hadrosaurine hadrosaurs). These associations are based on the proximity of specimens within the quarry and also the relative sizes of individual elements.

The largest percentage of vertebrate material consists of unassociated skeletal remains. This latter sample also provides the greatest diversity in the CCQ fauna (e.g. fish, crocodiles, turtles, mammals, pterosaur, dinosaur).

Since the unassociated skeletal remains are distributed throughout the 1 m fossiliferous interval, they were probably added to the quarry bone assemblage as individual sedimentary clasts over time (cf. Badgley, 1986a) and therefore represent an attritional accumulation. Examination of the skeletal elements within this unassociated component shows that this subset is comprised largely of teeth. This type of occurrence is usually interpreted to be characteristic of hydraulically accumulated lag deposits. Moreover, these specimens are equivalent, in general terms, to cobble-sized or smaller particles, and there is a marked gap in the size distribution of material between this set and the elements belonging to the associated assemblage (Fig.7). This selection towards similar sizes and shapes within this subset of material also tends to suggest a lag deposit.

The associated bone assemblage represents bones that were added to the quarry as skeletal "sets". This pattern can be derived within a channel deposit from some mode of mass mortality and subsequent transport and deposition of carcasses. Suggested means for mass mortality of vertebrates included crossing rivers in flood conditions (Orr, 1970, p. 240; Kurten, 1953, p. 69; Schaller, 1972, p. 215), mud flows (Norman, 1987), ash falls (Voorhies, 1985), drought and its effect such as disease and starvation (Carpenter, 1987; Rogers and Sampson, 1989).

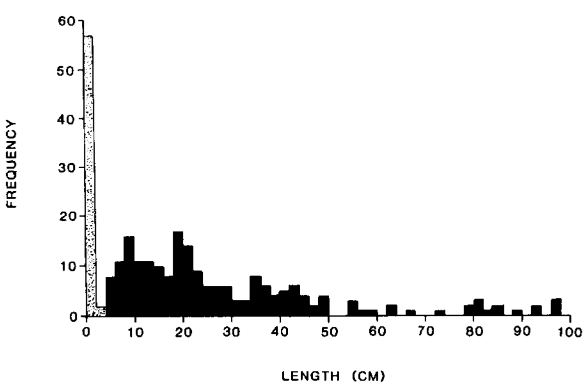


Fig.7. Distribution of two samples of bones from Careless Creek Quarry. The sample of unassociated skeletal material ($N=55$) is comprised largely of teeth and designated by the stipple pattern. The sample of associated skeletal assemblage ($N=200$) is represented by the solid pattern. Notice that there is an abundance of unassociated material less than 2 cm long. The associated material represents a bimodal distribution of lengths with a positive skew, with peaks at approximately 9 cm and 19 cm.

Since there is little sedimentologic evidence to support flood deposition, the associated dinosaur remains from Careless Creek Quarry most likely represent animals which tried to cross this ancient stream during a weakened state brought about by stressed environmental conditions. The geometry of a 10 m animal (i.e. the adult hadrosaurs) drowning in an 11 m wide channel at first seems unreasonable. This problem, however, can be addressed by examining modern herd behavior among terrestrial herding animals. With respect to wildebeests, Schaller (1973, p. 31) notes, "This immutable urge to stay with the herd, to move in the direction of others, causes them to press forward regardless of obstacles in their path ... If a river bars their way, they plunge in, disregarding all dangers, and many may drown." If hadrosaurs behaved in a similar manner, then the deaths recorded at Careless Creek Quarry may have been produced by the interaction of the herd as they crossed the river, such as the trampling of some animals under the feet of others.

The bones of the associated skeletal subset at Careless Creek Quarry are considered too large to have been brought into the deposit as part of the stream bedload as well as exhibiting very little sign of abrasion (see below). Instead these carcasses probably floated into the site as bloated carcasses sometime after death. In support of this model is the fact that the number of less dense bones (e.g. vertebrae, ribs) are present in near predicted numbers, suggesting that once disarticulation of the skeletons began the logs trapped the bones at the site.

Carcass flotation has been recognized by others as an important means for bone transport (e.g., Efremov, 1953, Dodson, 1971). The maximum amount of time between the death of these animals and their flotation downstream was probably on the order of three weeks or less, since Coe (1980) shows photographs of a comparably sized elephant corpse on the savannah of East Africa, desiccated within three weeks after death.

If the carcasses did, in fact, float downstream to this site, then disarticulation would have occurred at the log jam. No data are readily available on the rates of disarticulation for large-bodied terrestrial animals. Indirect rates of skeletal disarticulation for dinosaurs, however, may be available from the numbers of dinosaur remains from marine units. Within the coastal plain of North America there are a larger number of dinosaur skeletons found in marine rock units than terrestrial mammal skeletons, which may suggest that disarticulation rates for dinosaurs were slower than those for mammals (Fiorillo, 1990).

Additional data supporting the presence of decaying flesh at the time this site formed is the abundance of *Viviparus* operculae. Extant representatives of this genus are often found in slow moving water of modern streams and rivers, feeding on decaying organic matter (Allison, 1942; Harman and Berg, 1971).

Given that log jams can survive in the fluvial environment on the order of 10^1 years to 10^2 yr (Keller and Tally, 1979, Keller and Swanson, 1979), it can be concluded that the unassociated material accumulated at this site over many years prior to, and/or after the introduction of the associated skeletal material. Therefore, time averaging during the accumulation of fossils at Careless Creek Quarry is a significant factor, and should be considered in interpreting the paleoecology of the quarry fauna.

Orientation of fossils

Introduction

The significance of the distributions of fossil orientations was thoroughly discussed several years ago by Toots (1965), who modelled four idealized distributions of orientation data which were based in part on petrofabric studies. Experimental work with fossils expanded on Toots' work (e.g., Voorhies, 1969) and brought about further review of orientation data from fossils (Fiorillo, 1987b, 1988b). Since Careless Creek Quarry consists largely of bones and carbonized tree limbs, the bones orientation study by Voorhies (1969) and the study of waterlogged tree trunks and limbs by MacDonald and Jefferson (1985) are particularly interesting. In his study, Voorhies noticed the tendency of linear elements to align parallel to current if the elements are submergent. If, however, the elements are partially emergent, then the elements align perpendicular to flow direction. MacDonald and Jefferson also noticed a tendency for waterlogged tree trunks to align preferentially in a current. This degree of alignment was dependent on stream velocity, particle size and shape.

Methods

Data were obtained from both carbonized tree limbs ($N=89$) and linear bone elements ($N=152$) excavated in the Careless Creek Quarry. Trend and plunge measurements were made in situ using a Brunton compass. Trend was measured in the direction of the plunge allowing the use of a full 360° arc. Since it has been demonstrated that stereographic projections are the best way to graphically present orientation data (Fiorillo, 1987b, 1988b), the data from Careless Creek Quarry are presented as a lower hemisphere stereographic projection. Each projection was contoured since contouring is a quick and simple method for visualizing patterns (Fiorillo, 1987b, 1988b).

Results and discussion

The orientation data for the trees are presented in Fig.8, while the orientation data for the bones are presented in Fig.9. No strong preferred orientation is observed in either the trees or the bones, indicating that fluvial currents were not responsible for the orientations. Whereas preferred distributions of orientation data have been reasonably thought of as the stable end product of transportation, non-preferred or random orientations of fossils have been interpreted to indicate a sudden end to transport before this stability can be reached (Toots, 1965). This latter distribution can also result from a secondary "randomization" of a preferential alignment (Fiorillo, 1987b, 1988b). Orientation distributions in elongated pebbles are related to pebble concentrations (Rust, 1972). Low density concentrations of large pebbles show the strongest preference in orientation on sandy beds,

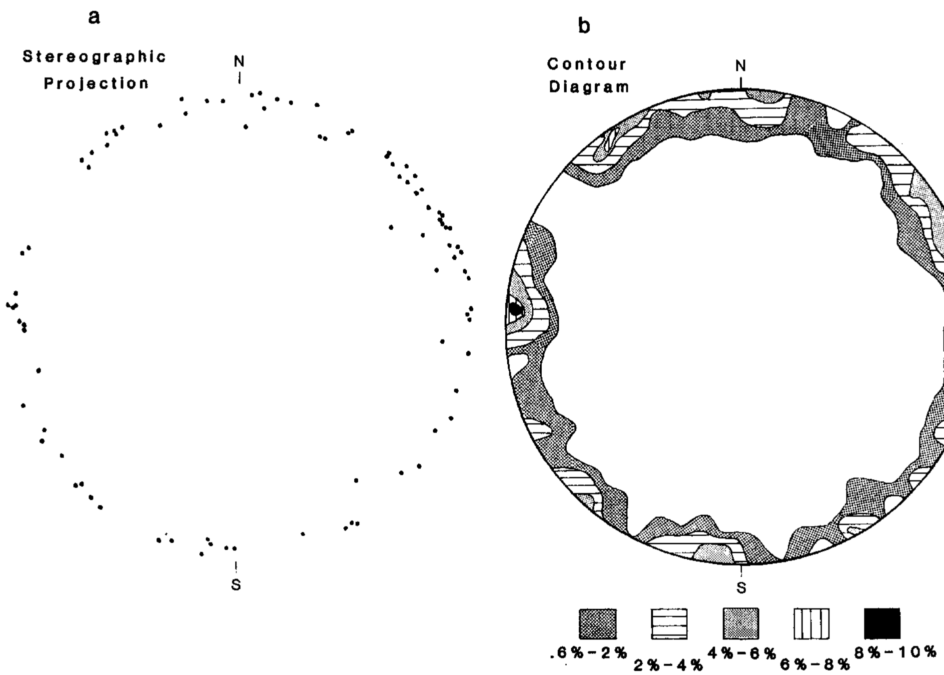


Fig.8. Synoptic projection and contour diagram for orientation data collected in Careless Creek Quarry from carbonized tree limbs ($N=89$). Note that all of the points appear to be essentially randomly distributed within a peripheral girdle representing nearly horizontal specimens. No indication of paleocurrent direction is evident.

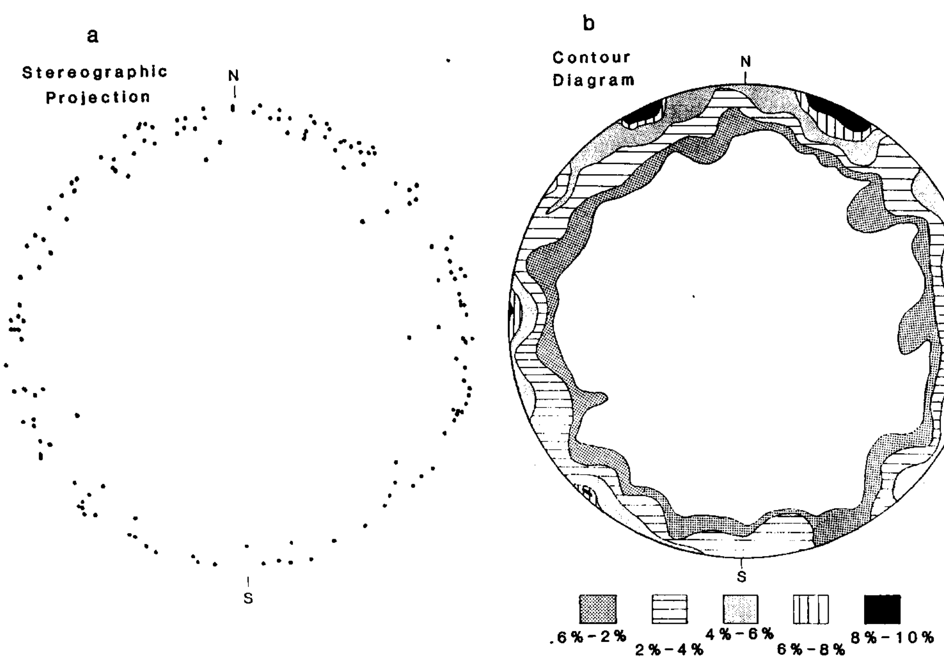


Fig.9. Synoptic projection and contour diagram for orientation data collected in Careless Creek Quarry from long bones and bone fragments ($N=152$). Note that all of the points appear to be essentially randomly distributed within a peripheral girdle representing nearly horizontal specimens. No indication of paleocurrent direction is evident.

while increased pebble densities show less preference in pebble orientation (Rust, 1972). Variation in the density, or packing, of fossil wood within a site can yield similar patterns to those observed in pebble orientation distributions (MacDonald and Jefferson, 1985). Random orientations can be diagnostic of many transported log assemblages (Wnuk and Pfefferkorn, 1987), presumably the result of interference patterns due to the high density of elements. The pattern of orientations for the fossil trees observed at CCQ, then, is expected. Since it is improbable that a secondary "randomizing' process such as trampling (Fiorillo, 1987b) affected the bone orientations at the Careless Creek Quarry log jam, during the time the quarry formed, a phenomenon similar to that described for the large pebbles may also have occurred with the fossil bones. Alternatively the absence of a preferred orientation of these linear elements may have been the result of insufficient current velocities at the time this site was forming.

Whereas previous experimental studies showed bones align preferentially due to uninterrupted current flow, the logs probably disrupted the flow pattern. Disruption of the fluvial flow patterns would probably allow deposition of individual skeletal elements. The inference provided at Careless Creek then, is that the trees served as a trapping mechanism for bones as they were brought down stream.

Hydraulic equivalence

Behrensmeyer (1975) and Korth (1979) devised an interesting method for determining the hydraulic compatibility of bones and the surrounding sediment by measuring the settling velocities of bones and comparing them to the settling velocities of spheroidal quartz grains. Through comparison with these data, it is possible to determine if the bones from Careless Creek Quarry are hydraulically compatible with the surrounding sediment.

Except for isolated fish teeth and other fish remains, most of the vertebrates from Careless Creek Quarry are regarded as either terrestrial (e.g., hadrosaurs) or semi-aquatic (e.g. soft-shelled turtles, crocodiles). Most of these non-fish remains belong to animals the size of small sheep (*Ovis*) or larger. The sandstone within the quarry is fine- to coarse-grained sand which corresponds to grain diameters of 0.25 mm–1.0 mm.

Of the sheep elements tested by Korth, the element with the slowest settling velocity is the atlas at 21.4 cm/s (Korth, 1979). Using fig.8 of Behrensmeyer (1975, p. 496) which provides the theoretical transport velocities of bones, this settling velocity indicates that the sheep atlas would equilibrate with quartz grains with approximately 9 mm diameter. Also, Behrensmeyer (1975, table 3) provides data for a centrum, an *Ovis* patella, and a crocodile scute which equilibrate with quartz grains with diameters of 2.6 mm, 3.0 mm, and 3.1 mm respectively. Since these specimens by Korth and Behrensmeyer are comparable to the minimum bone sizes at CCQ, it is clear from the grain sizes preserved at the site that the vast majority of bones from Careless Creek Quarry, particularly the dinosaur bones, were too large to have been transported into the quarry by the currents which transported the sediments (Fig.10). The presence of mammal, small crocodile and dinosaur teeth, all of which are approximately pebble-sized, suggests however that some of the teeth may have been brought into the site as part of the bed-load of the ancient stream (Fig.10).

Since many of the bones from the quarry are fragmentary, a second approach is necessary to evaluate the hydraulic equivalents of the fossil material at the site. Bone fragments are generally denser than the original whole bone, since fragmentation tends to break open the inner cavities of bones (the exception to this would be teeth). Behrensmeyer's fig.8 (1975, p. 496), provides a means by which to accommodate the densities of teeth, compact bone and porous bone. Estimates of hydraulic equivalence, then, can be made for bone fragments.

Figure 7 is a graph of the lengths of a sample of bones from Careless Creek Quarry. Cursory examination of this graph shows the presence of three peaks. One peak is the spike of unassociated skeletal material 2 cm or less in length, while the remaining two peaks occur within the associated skeletal assemblage at bones and bone fragments between 8 and 10 cm long, and bones and bone fragments 18–20 cm in length. Figure 10 is an

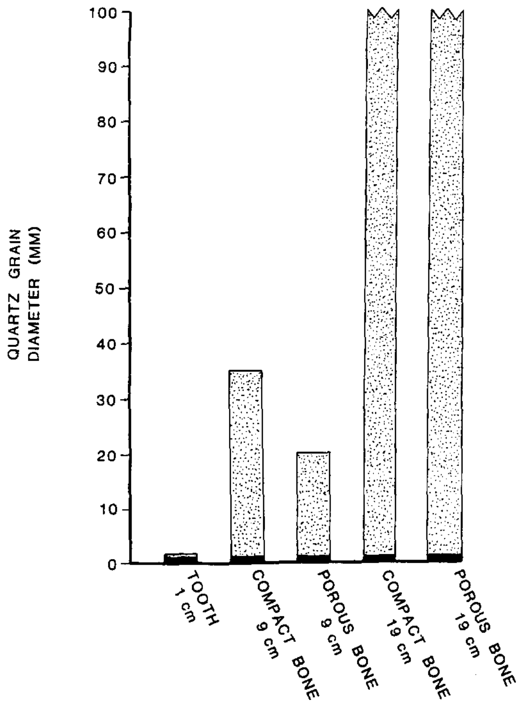


Fig.10. Comparison of the predicted quartz grain diameters for Careless Creek Quarry (stippled pattern) with the observed quartz grain diameters (solid pattern) within the quarry. Three points were chosen for this graph based on the three dominant bone lengths in Fig.7. The shortest length, 1 cm, was considered to be comprised of tooth material while the other two peaks (9 cm and 19 cm) were considered to be either compact bone or porous bone. Predicted values are based on data from Behrensmeyer (1975, p. 496). Notice that only the predicted quartz diameters for the sample of the smallest bones, the teeth, show any reasonable correspondence to the observed quartz grain diameters from the quarry. The larger material, rather than being part of the stream bedload, was probably brought in by carcass flotation.

illustration of the predicted quartz equivalents for these three peaks compared to the observed quartz diameters in the quarry. The three peaks were considered, for this exercise, as occurring at 1, 9, and 19 cm, respectively. The predicted value for the 1 cm spike, assumed to be composed of teeth, was quartz spheres with approximately 1.5 mm diameters, while the remaining two spikes, if assumed to be compact bone, would equate to quartz spheres 35 mm and greater than 100 mm in diameter. Since not all of the bone in this sample was compact bone but also included porous bone, the quartz equivalents for porous bone of these sizes would be 20 mm and also greater than 100 mm. Clearly, only the 1 cm spike produced a predicted quartz diameter close to that observed in the Careless Creek Quarry sediment.

The associated skeletal material is likely to have instead been brought in as bloated carcasses. The isolated remains of semi-aquatic crocodiles and turtles, which are also too large to have been transported, such as large crocodile vertebrae, turtle shell fragments and turtle limb bones, may reflect animals which died nearby or at the site and whose lighter skeletal elements (e.g. small vertebrae, ribs, etc.) were carried off by the stream.

Bone modification

Introduction

Bone modification can be loosely defined as features on bones which were the result of any post-mortem, prediagenetic process (e.g. trampling, scavenging, weathering) which alters the morphology of a once-living bone (Fiorillo, in press a). Excluded from this definition are features which are the result of pathological processes (e.g. arthritis) that affect the living animal. Also excluded are features resulting from those geologic processes which operate independently 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 within the region 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.

These processes can be divided into two groups. One group includes those processes which are active in a fluvial environment (e.g. abrasion), while a second group includes processes which are active on the land surface (perthotaxic processes of Clark et al., 1967). This latter group can be further subdivided into biological processes (e.g. trampling, scavenging) and physical processes (e.g. weathering). Much is now known about these features (e.g., Binford, 1981; Fiorillo, 1987b, 1988c, 1989c) so they can provide valuable clues to the taphonomic history of the bones at a fossil site.

Methods and results

A sample of non-tooth skeletal specimens ($N=$ 200) from the quarry were closely examined for specific modification features. Teeth are unlikely to show evidence of gnawing since they offer little nutritional value to a predator, and they are unlikely to be separated from the skull or jaw for ingestion, therefore teeth were excluded from the survey of Careless Creek specimens. These bones were inspected with regard to the fracture pattern (if present), abrasion stage, weathering stage, the presence of tooth marks and trample marks. The fracture pattern was designated as transverse if the fracture occurred perpendicular to the direction of bone fiber or spiral if the fracture occurred at some oblique angle to bone fiber (cf. Myers et al., 1980). The abrasion stage determination is outlined elsewhere (Fiorillo, 1987b, 1988c), but essentially follows the degree of rounding described by sedimentologists for inorganic grains. For bone abrasion, the lowest abrasion stage, or the stage showing no abrasion, is stage 0. Similarly, the stages of bone weathering for fossil bones have been outlined elsewhere (Fiorillo, 1987b, 1988c) and these stages are based on empirical observations on modern bones in East Africa by Behrensmeyer (1978) and modern bones in western Nebraska (Fiorillo, 1989c). Since bone weathering represents a continuum, some of the bones used in this study show a transitional stage between two consecutive stages. In these example, both the weathering stages are recorded. Tooth marks are recorded if they are present in this sample either as grooves left by teeth along the bone surface or as punctures and gnaws (cf. Fiorillo, 1987b, 1988c). Trample marks are shallow sub-parallel scratch marks left on the surfaces of bones (Behrensmeyer et al., 1986; Fiorillo, 1984, 1987b, c, 1988c, 1989c). Results of this bone by bone survey are presented in the appendix and summarized in Table 1.

Discussion

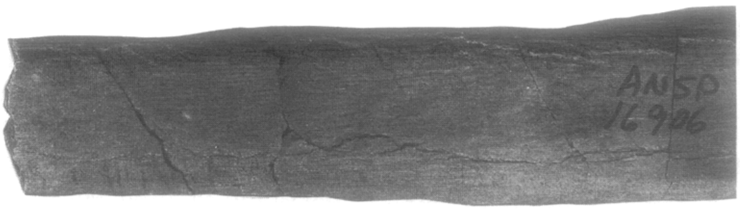
Very few modification features are observable on the Careless Creek assemblage. Those features represented are fracture patterns, tooth marks, subaerial weathering cracks and trample marks, but these fractures are present only in minimal numbers.

Most of the bones examined exhibited breakage transverse to the bone fiber (Fig.11a), which is indicative of breakage after significant alteration of the bone has occurred (e.g. mineralization), whereas less than 2% of the sample showed any indication of fresh bone breakage, exhibited by spiral fractures (Fig.11b, cf. Myers et al., 1980).

Very few of the bones inspected during this survey exhibited weathering features (2%) and those observed are indicative of very early stage weathering indicating short subaerial exposure times for the bones (Fig.12). By far most of the bones in the sample show that they were not exposed subaerially for any significant length of time (Fig.12a).

Less than 2% of the sample of fossils from Careless Creek Quarry showed any tooth marks. Most of the gnaw marks observed were isolated tooth scores (Fig.13) which are similar in morphology to those attributed by Dodson (1971, fig.9), to carnosaurs, and those attributed by Fiorillo (1987b, 1988c, fig.23), which are attributed to mammalian amphicyonid carnivores. The gnaw marks on the bones from CCQ are attributed to dinosaurs. One caudal vertebra (ANSP 16764) showed evidence of a scalloped surface at the end of the neural spine (Fig.14). Such features, when found on mammalian bones in Cenozoic deposits, have been interpreted to result from scavenging by carnivores (e.g. Fiorillo, 1987b, 1988c, figs.24 and 25). Since mammalian carnivores have only limited tooth replacement and are unlikely to risk tooth damage by attacking the bony aspects of the prey skeleton, these marks are not considered the result of the killing process. Dinosaur predators, however, have continual tooth replacement, hence tooth damage in dinosaurian predators would not have been as potentially deadly to the carnosaur. However, dinosaur teeth are not as well rooted as are those of mammalian carnivores and are more likely to be dislodged during excessive contact between tooth and bone (Fiorillo, in prep.). Therefore, toothmarks such as those found on the bones at Careless Creek Quarry are also attributed to scavenging and prey carcass utilization.

One bone in this sample had shallow, subparallel scratch marks on it, indicative of tramping activity by other animals whose feet pressed the bone



a

b

Fig.11a. Hadrosaur rib (ANSP 16906) as an example of bone breakage transverse to bone fiber direction. b. Bone fragment exhibiting a fracture pattern which is at an oblique angle to the direction of bone fiber. Scale bars each equal 2 cm.

against a sandy substrate (Fiorillo, 1984, 1987b, 1989c). This record of trample marks is the second occurrence of such a feature from a dinosaur locality. The first occurrence is from another locality in the Judith River Formation in the Shawmut region, Antelope Head Quarry (Figs.1 and 2) where the scratch marks have been found on nearly one third of the sample (Fiorillo, 1987c; Fig.15).

None of the Careless Creek bones showed any rounding due to abrasion. This lack of significant abrasion on the bones is somewhat anomalous given that the depositional environment is a channel. This feature, or lack thereof, may be the result of minimal transportation distances or the specimens were transported to the site by carcass flotation (see above). Certainly the former can explain the lack of abrasion on the semi-aquatic and aquatic vertebrate remains from CCQ, while the lack of abrasion in bones of the associated skeletons can be accommodated by both possibilities.

The relative lack of perthotaxic features on the Careless Creek fossil assemblage contrasts sharply with a similar study of bone modification features from a floodplain assemblage of Miocene age in Nebraska (Hazard Homestead Quarry, Fiorillo 1987b, 1988c). In that bone assemblage perthotaxic features are abundant, with some features (trample marks) represented on 41% of a similarly sized sample. These differences in relative abundances of features at each site are due largely to the depositional setting of the respective localities. Hazard Homestead Quarry has been interpreted as a waterhole on a floodplain, a scenario which allows for an abundance of perthotaxic activity. Conversely, at Careless Creek Quarry the bones were in a channel environment and did not experience the degenerative modification processes active on a floodplain. From this examination, it is clear that the Careless Creek bone assemblage accumulated in an area where bone modification was minimal, due presumably to the fact that much of the material was brought to the quarry as part of floating carcasses. Badgley (1986a) similarly recognized that the correlation between depositional environ-

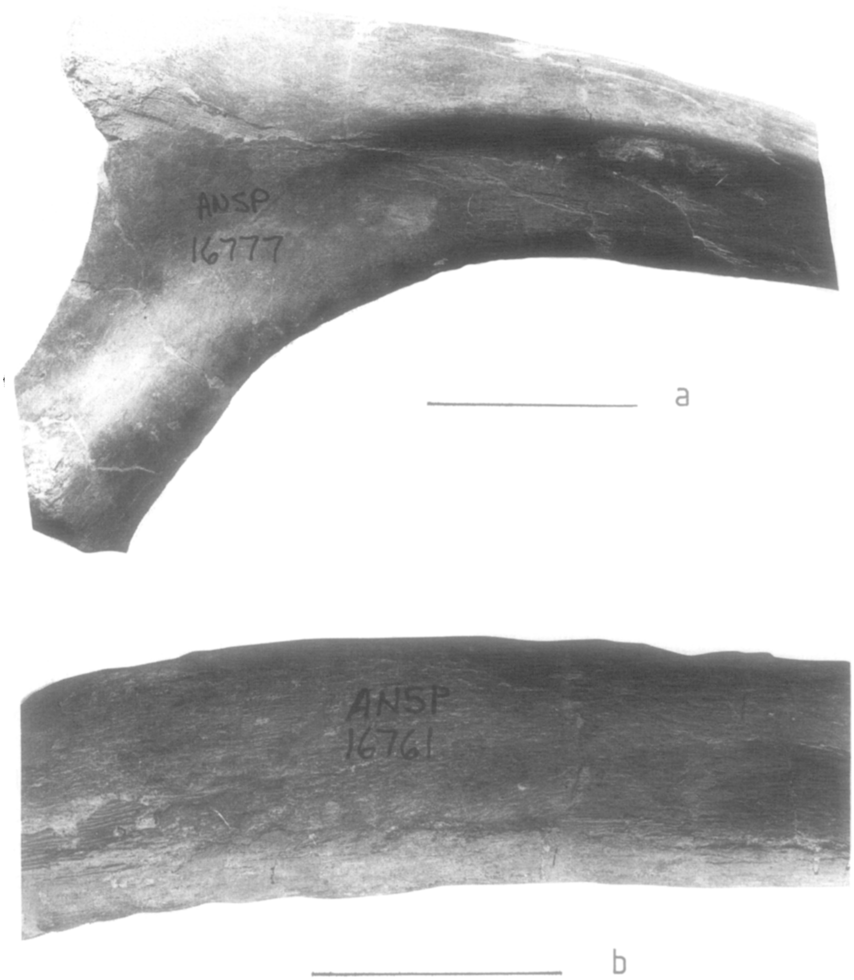


Fig.12a. Hadrosaur rib (ANSP 16777) which the characteristics of weathering stage 0. Other than the post fossilization cracks on its surface this bone shows no cracking or flaking which can be attributed to prolonged periods of subaerial exposure prior to burial. This weathering stage is the dominant stage in the sample examined. b. Bone fragment (ANSP 16761) which exhibits characteristics of weathering stage 1. Notice that the cortical bone has started to crack and flake which indicates potential subaerial exposure of up to 6 yr (Behrensmeyer, 1978; Fiorillo, in press a). The scale bar for both photos equals 5 cm.

ment and taphonomic features is weak when the bones accumulate due to carcass flotation.

Bone census

The variation in the size and shape of vertebral skeletal elements is reflected in the manner in which these bones behave in a stream environment (Voorhies, 1969; Dodson, 1973). The lighter, less dense elements tend to be carried away sooner than heavier, more dense elements. Counting skeletal parts at a site can give some indication of the degree of alteration the fossil asemblage. Straightforward tallying of skeletal elements is sometimes not the optimal method since mammalian carnivores can selectively remove parts of the prey skeleton (Haynes, 1981). Behrensmeyer and Dechant Boaz (1980) provide a means for estimating the degree of fluvial sorting using tooth/vertebrae (T/V) ratios. Vertebrae tend to be among the first skeletal elements removed by stream action, while teeth tend to be among the last. Such a measure may be inappropriate in dinosaur assemblages, however, since there is such a large disparity

Fig.13. Hadrosaur rib (ANSP 16870) exhibiting an isolated tooth score, attributed to a carnosaur. This bone also is indicative of weathering stage 0. Scale bar equals 2 cm.

Fig.14. Neural spine of a hadrosaur caudal vertebra (ANSP 16764) exhibiting gnaw marks. These gnaw marks are attributed to scavenging activity by a carnosaur. This specimen is also indicative of weathering stage 0. Scale bar equals 2 cm.

between vertebrae size and tooth size in most dinosaur skeletons in which the length of a vertebra may be 15× the length of a tooth.

Since there was little carnivore damage on the bones from Careless Creek Quarry the most appropriate census technique for this site is an overall tally of skeletal elements. Censuses were taken of all skeletal elements in each of the two taphonomic subsets of bones. For the unassociated skeletal material, the census is a straightforward tally of elements. For the associated skeletons a slightly different approach was applied. While isolated teeth are typically included in Voorhies Group III (e.g. Behrensmeyer, 1975), considering the size disparity between dinosaur teeth and dinosaur bones, dinosaur teeth are not considered as members of Voorhies Group III. Dinosaur teeth, being such small elements in relation to the rest of the skeleton, are more likely to have been among the first elements to be removed due to hydraulic winnowing, rather than being among the last skeletal elements to be removed as in mammal skeletons. The method employed here will, instead, compare the number of representatives of Voorhies Group I and Voorhies Group II and be presented as the ratio Voorhies Group II/Voorhies Group I (VGII/VGI). Since most of the dinosaur remains at Careless Creek Quarry can be attributed to ornithischians, this ratio can then be compared to a similar ratio for an "average" skeleton of an ornithischian for an estimate of the winnowing effects of fluvial activity. The data compiled for the average ornithischian skeleton are derived from averaging the skeletal element counts of *Corythosaurus* and *Avaceratops* (Table 2).

Table 3 shows that the VGII/VGI ratio obtained for an average ornithischian skeleton is 0.13, while the VGII/VGI ratio from the actual ornithischian specimen count from CCQ is 0.14. These data from Careless Creek Quarry show that although some of the lighter, less-dense ornithischian skeletal material has been removed virtually all of these elements are still present at the quarry in near predicted quantities. This anomaly may be

Fig.15. Dinosaur bone fragment (ANSP 15935) from Antelope Head Quarry (Figs.1 and 2) which exhibits numerous sets of shallow subparallel sets of scratch marks which are attributed to trampling (Fiorillo, 1987c). Scale bar equals 2 cm.

explained by the presence of logs at the quarry. If the associated skeletons floated downstream and got caught on the CCQ log jam, then shed bones once deterioration began, in all likelihood the trees prevented the stream currents from removing the bones by acting as obstacles. Additional data supporting the trapping mechanism model is the abundance of ossified dinosaur tendons at the quarry ($N=48$). These tendons are lightweight and small with an average length of 11 cm. One tendon uncovered at the quarry ended in a series of delicate bifurcations, which would surely have been abraded off the tendon if it was transported over long distances. It is reasonable to have expected these elements to have been winnowed away in an unobstructed stream environment.

Discussion

To summarize, there is a strong association between the occurrence of fossil bones and carbonized trees, suggesting this quarry was the site of an ancient log jam where bones were trapped as they were transported downstream. Although no bones were articulated, there is one subset of associated skeletal remains which were added to the assemblage by carcass flotation. A second taphonomically distinct subset of bones can also be identified. These are the crocodile, mammal and small theropod teeth, and the unassociated skeletal remains of turtles, fish, pterosaurs and ornithischian dinosaurs. Comparisons between the sizes of these unassociated elements and the quartz grains within the quarry indicate hydraulic compatibility, suggesting the fossils were brought into the site as part of the stream bedload.

Although the depositional setting of Careless Creek Quarry is a stream channel, many expected features of a channel assemblage are not present. For example, bones and tree fragments are not preferentially aligned although stream flow as documented by cross-beddig was unimodal. In addition, a bone census shows that the easily winnowed small, light, less-dense skeletal elements (Voorhies Group I) are all well represented. Thirdly, the vast majority of bones experienced very little alteration before final burial.

TABLE 3

Tally, at the family level, of unassociated skeletal remains from Careless Creek Quarry. The number of identifiable specimens (NISP) at this locality corresponds to the number of individuals estimated for the ancient ecosystem which was sampled by this channel (cf. Badgley, 1988a). "Carnosaur A" corresponds to a primitive carnosaur known only from teeth (Fiorillo, 1989a; Currie and Fiorillo, in prep.)

	Number of identifiable specimens (NISP)	Number of individuals
Class Chondrichthyes		
Family Chimaridae	82	82
Class Osteichthyes		
Family Acipenseridae	3	3
Lepisosteidae	13	13
Aspidorhynchidae	2	2
Phyllodontidae	4	4
Class Reptilia		
Family Neurankylidae	3	3
Baenidae	14	14
Trionychidae	45	45
Family Champsosauridae	6	6
Family Goniopholidae	1	1
Crocodylidae		
Crocodylinae	83	83
Alligatorinae	5	5
Family Dromaeosuaridae/ Saurornithoidae	32	32
Ornithomimidae	1	1
Family "Carnosaur A"	2	2
Tryrannosauridae	4	4
Hadrosauridae	2	2
Pachycephalosauridae	5	5
Nodosauridae	9	9
Ceratopsidae	12	12
Family Azhdarchidae	1	1
Class Mammalia		
Family Neoplagiaulacidae	2	2

Faunal analysis

Introduction

A more detailed description of the fauna and paleoecology of the vertebrates from Careless Creek Quarry has been presented elsewhere (Fiorillo, 1989a,b).

Recently, Badgley (1986a) reviewed the methods of quantifying fossil faunas which are typically applied to fossil mammalian assemblages (e.g. Shotwell, 1955, 1958, 1963; Grayson, 1984). She applied some of these methods to the mammal assemblages found in the Siwaliks of Pakistan and found that multiple quantification methods are needed to compare fossil assemblages from different taphonomic and sedimentologic settings in the Siwaliks. Careless Creek Quarry shows, in addition, that multiple methods for faunal quantification are also advisable within a single faunal assemblage if it contains two distinct taphonomic assemblages. Since CCQ is a channel deposit, NISP values were tallied for the unassociated taphonomic assemblage (Table 3). However, MNI values are clearly the preferred method for counting the associated skeletal remains (Table 4) found in the quarry. MNI values for juvenile dinosaurs are noted in Table 4 also.

Although the sample sizes of the two tables are reasonably similar ($N = 390$ for Table 3, $N = 531$

TABLE 4

Tally, at the family level, of associated skeletal remains from Careless Creek Quarry. The minimum number of individuals (MNI) for each family was derived from the criteria, consideration of similarly sized identifiable specimens (NISP) and proximity of specimens within the quarry. Notice the dramatic decrease in faunal diversity between the associated skeletal assemblage tallied here, and the unassociated skeletal assemblage which is tallied in Table 4

	Number of identifiable specimens (NISP)	Minimum number of individuals
Hadrosauridae	439	5
Ceratopsidae	89	1
Baenidae	15	1
Trionychidae	45	8

for Table 4), faunal diversity at the family level is strikingly different ($N=22$ families for Table 3, $N=4$ families for Table 4).

Discussion

There is a clear pattern of a greater faunal diversity in the unassociated skeletal (or lag) assemblage of the Careless Creek Quarry compared to the associated skeletal assemblage. A similar pattern has been observed in Siwalik mammal assemblages by Badgley (1986a). This dramatic difference can be accounted for by recognizing the processes responsible for forming each of the two subsets of bone assemblages.

An active channel environment provides a means for a continual influx of fossil material with the deposition of inorganic clasts. At Careless Creek Quarry the concentration of unassociated bones occurs over a vertical distance of approximately 1 m, and this bone assemblage is assumed to represent a relatively long time span for accumulation.

Since lag deposits are typically considered to represent fossil deposits formed in the absence of, or at reduced rate of, accompanying sedimentation, or to be the result of winnowing of associated sediment, lag deposits may in fact represent more time than the surrounding sediment (Behrensmeyer and Kidwell, 1985). Although this is probably also true for the Careless Creek Quarry lag component of the fossil assemblage, the simple test described below shows that the discrepancy in time represented by the fossils and the sediments was not of significant length.

To test this concept at CCQ an estimate of the length of time for the formation of the lag component within the thickness of the bonebed must be obtained, in turn this estimate must then be compared to a predicted sediment thickness corresponding to an equal length of time. In bone assemblages which exhibit an abundance of bone modification features sensitive to sedimentation rates, such as the distinctive crack patterns due to weathering (e.g. Fiorillo, 1987b, 1988c), a means for determining a rate of sedimentation, and the subsequent duration of the formation of the site is obtainable by considering bone thicknesses compared to the thickness of the bonebed (cf. Fiorillo, 1988d). Determining a length of time for the formation of Careless Creek Quarry, a site without such modification features, and in a channel environment, must be approached differently.

Alternatively an estimate of the length of time for the formation of the Careless Creek Quarry is obtainable by understanding the reason for the accumulation of the bonebed. As discussed earlier, the bones at this site were trapped as they moved downstream by a log jam present in the channel. In studies of the residence times of logs in log jams in modern streams with widths generally less than 15 m, it can be shown that these logs can exist for up to several hundred years (Keller and Swanson, 1979, Keller and Tally, 1979). This residence time is inversely proportional to the size of the stream (Keller and Swanson, 1979; Keller and Tally, 1979). From these data it is reasonable to suggest that the CCQ log jam existed for 100 years.

Sadler (1981) compiled nearly 25,000 sediment accumulation rates for various sedimentary environments, including fluvial environments. From this data base, one can estimate the expected sediment thickness given a unit of time, based on the median accumulation thicknesses of a specific depositional environment. For Careless Creek Quarry, if the duration of the formation of the site was on the order of 100 years, then based on the median accumulation thickness obtainable in a fluvial environment for this time interval (Sadler, 1981, fig.1), the expected sediment thickness for Careless Creek Quarry was on the order of 1 m. Clearly this thickness closely approximates the actual thickness of the sediment preserved at the quarry, therefore the discrepancy between the time represented by the lag deposit and the sediment is minimal.

The inference from this type of accumulation is that a number of time planes are preserved at Careless Creek. Thus the site could preserve faunal changes which occurred in the local environmental setting during an interval of approximately 100 yr. This component of the bone assemblage obviously then represents a time averaged sample. In addition, since material from the floodplain environment can be introduced into the channel by either reworking of the channel banks (i.e. exhumed bones) or by surface runoff transporting material into the channel (cf. Hanson, 1980), the assemblage of isolated bones at Careless Creek Quarry may represent a sampling of different depositional environments as well as different time planes. The unassociated bone assemblage thus is dramatically more diverse than the associated skeletal assemblage.

The most parsimonious explanation for the deposition of associated skeletal remains is that they represent an essentially instantaneous event (e.g. Voorhies, 1969; Currie and Dodson, 1984). Such an occurrence of bones seems likely in the case of animals which had a herding lifestyle, and hadrosaurs are considered to have been herd animals (e.g. Weishampel and Horner, 1990). Burial of virtually whole vertebrate skeletons together at Careless Creek Quarry must certainly represent a common death and path of transport to deposition among the individuals represented by this taphonomic subset of bones. If this is true, this set of bones represents a sample of a single environment and time plane.

A closer look at the MNI values for the associated remains in Table 4 provides a basis for an interesting speculation. The typical age class distribution in catastrophic death assemblages is for the adults to outnumber the juveniles (e.g. Voorhies, 1969). Although the sample size of associated hadrosaur remains is very small ($MNI = 5$), it may seem odd that at Careless Creek Quarry the minimum number of adult individuals ($MNI = 2$) is less than that for the juveniles ($MNI = 3$). These data provide a basis for a speculative assessment of the susceptibility of juvenile hadrosaurs towards high accidental mortality rates.

Some modern animals which spend their lives in herds, such as the wildebeest, have been shown to have high juvenile mortality rates (Schaller, 1973). Disproportionately large numbers of dead juvenile wildebeests have been observed after a herd of wildebeests had made a river crossing (Schaller, 1973). Perhaps the occurrence of a larger number of juvenile hadrosaurs than adult hadrosaurs at Careless Creek Quarry is an indication that hadrosaurs also had high levels of juvenile mortality among their populations.

Discussion

Numerous other workers have dealt with taphonomic studies on a site-specific basis in fossil deposits from the Cenozoic (e.g. Voorhies, 1969; Hunt, 1978; Saunders, 1977; Behrensmeyer, 1975; Fiorillo, 1987a). These studies all dealt with Cenozoic mammal sites.

Site-specific studies of dinosaur-producing quarries, in contrast to those of mammal-producing quarries, are few. Lawton (1977) examined bone orientations in the bone bed at Dinosaur National Monument in Utah and concluded that the site had three distinct fluvial phases. More recently, Currie and Dodson (1984) discussed the taphonomic setting of a ceratopsian bone bed in the Judith River Formation of Alberta. They showed the bone bed was the result of a catastrophic death assemblage. A second ceratopsian bone-bed from the Judith River Formation of Alberta had also been described recently (Visser, 1986) and has similarly been shown to be the result of a mass mortality of ceratopsians. Visser showed that this site was a point bar within a Judith River stream.

Most taphonomic work on Mesozoic aged vertebrate fossil deposits is by region or formation. Dodson (1971), for example, studied the taphonomy of the Judith River Formation in the vicinity of Dinosaur Provincial Park in southern Alberta. Based on the rich dinosaur quarries in the Morrison Formation of western North America, Dodson et al. (1980) discussed the taphonomic setting of the entire Morrison Formation of western North America. A third example of a regional taphonomic study is by Grigorescu (1983) in which the taphonomy of a number of small fossil sites in the Sinpetru beds of Romania is briefly discussed. However, this report is the first published application of the taphonomic parameters established in site-specific studies of mammal sites in the Cenozoic, to a major dinosaur quarry.

Results of this study show that the Careless Creek Quarry formed largely due to an abundance of logs in an ancient river channel trapping the bones as they moved downstream. Similarly, two other quarries in the area around CCQ, Top Cat Quarry and Karen's Quarry (Figs.1 and 2) appear to have formed due to log jams. A cursory examination of the literature shows that other vertebrate fossil localities may, in fact, also be attributed to similar causes. Jain (1980), for example, recognized the similarity of a vertebrate fossil site, with fossilized logs, in the Kota Formation (Jurassic) of India to a log jam. These data suggest that in an active channel environment a quarry concentration of bones is most likely to form in the presence of a trapping mechanism, which in the examples above are log jams. Further, personal observations on some of the quarry concentrations of bones in the Judith River Formation in the vicinity of Dinosaur Provincial Park in Alberta suggests that this trapping mechanism is by no means restricted to only log jams. These trapping mechanisms may also include sedimentological traps, such as depositional low spots of scours, within a channel environment, or large bones themselves, such as the carcasses of dinosaurs at the Carnegie Quarry in Dinosaur National Monument.

Reconstruction of the fauna from this site shows that although one bone assemblage is preserved, at least two taphonomic assemblages exist at the site. One taphonomic assemblage consists of unassociated skeletal remains and is the result of an attritional accumulation of bones and teeth. The second taphonomic assemblage consists of associated skeletal material which is likely to have been added to the fossil assemblage as the result of bloated carcasses floating into the site. Because there are bones within the Careless Creek Quarry assemblage with such obviously different taphonomic histories, different methods for accessing the relative abundances of the taxa represented are necessary. For the unassociated skeletal material, which has a low probability for skeletal association, NISP values are used to approximate the minimum number of individuals (MNI), as suggested by Badgley (1986a) from her work in the Siwaliks of Pakistan. The associated skeletons, however, clearly need to be tallied using a straightforward MNI method.

Behrensmeyer (1988) points out that two modes, in her case channel-lag and channel-fill, can coexist as separate entities within a larger scheme. Careless Creek Quarry, in addition, clearly shows that multiple modes of bone accumulation can also coexist in a single fossil assemblage. These points are conceptually distinct. Behrensmeyer shows that fossil accumulations can have different taphonomic and sedimentologic histories yet remain discrete entities within a single channel complex. Careless Creek Quarry, alternatively, shows that separate fossil assemblages can have different taphonomic histories but be buried together within the same sedimentologic complex, thereby producing a mixed assemblage. At Careless Creek Quarry this scenario was brought about by the presence of the log jam acting as a trapping mechanism for bones.

Conclusions

Careless Creek Quarry is a newly discovered, rich fossil site in the Judith River Formation of south-central Montana which has yielded approximately 1500 specimens of various vertebrate taxa, most notable being an abundance of dinosaur remains. This site is the most productive site yet reported from this formation in the United States, south of the international boundary with Canada.

The sedimentologic and taphonomic settings of the Careless Creek Quarry show that this site formed in a channel environment and that the bones accumulated due to an ancient log jam. In relation to similar taphonomic settings of other sites in the Judith River Formation, the data from Careless Creek Quarry suggests that trapping mechanisms may be important for the formation of quarry concentrations of vertebrate remains within active channel environments.

Close examination of the fauna shows that the quarry sample consists of two sets of bones with different taphonomic histories. One set of fossils represents a lag deposit, which accumulated over a period of many years while the other set of fossils represents a more "instantaneous" accumulation of material. This second set of bones represents animals brought into the site as bloated, floating carcasses. This quarry is a good example of time averaging within a fossil assemblage.

Within the set of associated bones, details of the taphonomic features provide clues to the history of this assemblage. Orientation data from the trees and long bones at the site show no preferred orientation, a seemingly anomalous feature of the bones, but not the trees, given the depositional setting of the site. Censusing of skeletal elements within the set of bones which are associated skeletal remains shows that there is an abundance of lighter, less-dense skeletal elements present, another anomalous feature given the depositional setting of the site. This feature suggests that very little alteration of the carcasses of the animals took place after they floated downstream to the site. There is little evidence of any bone modification features present on the bones from this site suggesting that these bones were buried before significant alteration, due to subaerial exposure, took place. Based on these parameters, it is clear that the associated skeletal material is not heavily overprinted by taphonomic processes.

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Appendix — Bone surface survey of a randomly selected sample ($n = 200$) of fossil bones from Careless Creek Quarry, Wheatland County, Montana. The bones are listed in the approximate order of increasing density. Bone fragments are the last entries

ANSP specimen number	Element (ns = neural spine; bf = bone fragment)	Maximum length (cm)	% complete	Fracture pattern (SP = spiral; TR = transverse; – = complete bone)	Abrasion stage (0 = none; 1 = slight)	Weathering stage (parentheses indicate traces of a stage)	Tooth marks (X = present; 0 = none present)	Trample marks (X = present; 0 = none present)
16856	rib	40	80	TR	0	0	0	0
16803	rib	12.5	20	TR	0	0	0	0
16855	rib	20	90	TR	0	0	0	0
16858	rib	34	60	TR	0	0	0	0
16859	rib	49.5	95+	TR	0	0(1)	0	0
16811	rib	19	80	TR	0	1	0	0
16843a	rib	43.5	80	TR	0	0	0	0
16843b	rib	63.5	95+	–	0	0(1)	0	0
16841	rib	20	90	TR	0	0	0	0
16760	rib	44	80	TR	0	0	0	0

ANSP specimen number	Element (ns = neural spine; bf = bone fragment)	Maximum length (cm)	% complete	Fracture pattern (SP = spiral; TR = transverse; – = complete bone)	Abrasion stage (0 = none; 1 = slight)	Weathering stage (parentheses indicate traces of a stage)	Tooth marks (X = present; 0 = none present)	Trample marks (X = present; 0 = none present)
16759	rib	19	50	TR	0	0	0	0
16781	rib	55	75	TR	0	0	0	0
16779	rib	37	95	–	0	0(1)	0	0
16780	rib	36	50	TR	0	0	0	0
16782	rib	43	75	TR	0	0	0	0
16787	rib	54	95+	–	0	0	0	0
16786	rib	48	90	TR	0	0	0	0
16783	rib	47	95+	–	0	0	0	0
16785	rib	23	75	TR	0	0	0	0
16784	rib	39	90	TR	0	0	0	0
16788	rib	97	90	TR	0	0	0	0
16777	rib	88.5	90	TR	0	0	0	0
16775	rib	93	95	TR	0	0	0	0
16774	rib	37	90	TR	0	0	0	0
16776	rib	59.5	80	TR	0	0	0	0
16769	rib	92.5	90	TR	0	0	0	0
16772	rib	79.5	90	TR	0	0	0	0
16771	rib	35	90	TR	0	0	0	0
16768	rib	97	95	TR	0	0	0	0
16773	rib	46	50	TR	0	0	0	0
16848	rib	17.5	40	TR	0	0	0	0
16850	rib	19.5	35	TR	0	0	0	0
16849	rib	30.5	40	TR	0	0	0	0
16851	rib	40	40	TR	0	0	0	0
16852	rib	13	10	TR	0	0	0	0
16846	rib	42	60	TR	0	0	0	0
16845	rib	81	90	TR	0	0	0	0
16857	rib	35.5	60	TR	0	0	0	0
16847	rib	80	80	TR	0	0	0	0
16872	rib	20	30	TR	0	0	0	0
16869	rib	19	30	TR	0	0	0	0
16870	rib	21	30	TR	0	0	X	0
16881	rib	38.5	80	TR	0	0	0	0
16589	rib	26	50	TR	0	0	0	0
16880	rib	7	40	TR	0	0	0	0
16891	rib	20	60	TR	0	0	0	0
16883	rib	11.5	20	TR	0	0	0	0
16886	rib	24	60	TR	0	0	0	0
16882	rib	21	60	TR	0	0	0	0
16884	rib	19	30	TR	0	0	0	0
16888	rib	15.5	40	TR	0	0	0	0
16905	rib	30.5	60	TR	0	0	0	0
16906	rib	26	35	TR	0	0	0	0
16903	rib	14	20	TR	0	0	0	0
16916	rib	44	75	TR	0	0	0	0
16907	rib	19.5	50	TR	0	0	0	0
16909	rib	25	60	TR	0	0	0	0
16920	rib	15	80	TR	0	0	0	0
16921	rib	21.5	80	TR	0	0	0	0
16922	rib	11.5	80	TR	0	0	0	0
16918	rib	36	80	TR	0	0	0	0
16788	vertebra	14.5	45	TR	0	0	0	0

ANSP specimen number	Element (ns = neural spine; bf = bone fragment)	Maximum length (cm)	% complete	Fracture pattern (SP = spiral; TR = transverse; – = complete bone)	Abrasion stage (0 = none; 1 = slight)	Weathering stage (parentheses indicate traces of a stage)	Tooth marks (X = present; 0 = none present)	Trample marks (X = present; 0 = none present)
16791	vertebra	24.5	80	TR	0	0	0	0
16790	vertebra	34	90	TR	0	0	0	0
16789	vertebra	44	90	TR	0	0	0	0
16861	vertebra	9	95+	TR	0	0	0	0
16860	vertebra	4	95+	–	0	0	0	0
16799	vertebra	15	80	TR	0	0	0	0
16798	vertebra	18	80	TR	0	0	0	0
16801	vertebra	15.5	95+	TR	0	0	0	0
16800	vertebra	15.5	50	TR	0	0	0	0
16809	vertebra	40	95	TR	0	0	0	0
16805	vertebra	17.5	50	TR	0	0	0	0
16821	vertebra	12.5	50	TR	0	0	0	0
16820	vertebra	11.5	40	TR	0	0	0	0
16812	vertebra	13	90	TR	0	0	0	0
16819	vertebra	23.5	50	TR	0	0	0	0
16825	vertebra	12	95+	–	0	0	X	0
16823	vertebra	42.5	95+	–	0	0	0	0
16824	vertebra	39.5	90	TR	0	0	0	0
16827	vertebra	37	90	TR	0	0	0	0
16826	vertebra	41	95+	–	0	0	0	0
16839	vertebra	7.5	50	TR	0	0	0	0
16838	vertebra	5	95+	–	0	0	0	0
16837	vertebra	9	80	TR	0	0	0	0
16836	vertebra	10.5	75	TR	0	0	0	0
16757	vertebra	23.5	90	TR	0	0	0	0
16764	vertebra	19	95+	–	0	0	X	0
16765	vertebra	11	95+	–	0	0	0	0
16767	vertebra	23	95	TR	0	0	0	0
16766	vertebra	5.5	95	TR	0	0	0	0
16763	vertebra	25	95+	–	0	0	0	0
16762	vertebra	40	95	TR	0	0	0	0
16726	vertebra	48	95+	–	0	0	0	0
16727	vertebra	43.5	90	TR	0	0	0	0
16728	vertebra	44.5	90	TR	0	0	0	0
16729	vertebra	13.5	50	TR	0	0	0	0
16735	vertebra	8	40	TR	0	0	0	0
16730	vertebra	9	35	TR	0	0	0	0
16732	vertebra	11.5	95	TR	0	0	0	0
16731	vertebra	7	35	TR	0	0	0	0
16739	vertebra	11	75	TR	0	0	0	0
16738	vertebra	20.5	40	TR	0	0	0	0
16741	vertebra	23	90	TR	0	0	0	0
16742	vertebra	20.5	90	TR	0	0	0	0
16746	vertebra	33	90	TR	0	0	0	0
16745	vertebra	16	80	TR	0	0	0	0
16743	vertebra	34.5	90	TR	0	0	0	0
16756	vertebra	32.5	90	TR	0	0	0	0
16751	vertebra	39	95	TR	0	0	0	0
16755	vertebra	29	95	TR	0	0	0	0
16754	vertebra	14.5	80	TR	0	0	0	0
16749	vertebra	7.5	40	TR	0	0	0	0
16748	vertebra	7.5	95+	–	0	0	0	0

ANSP specimen number	Element (ns = neural spine; bf = bone fragment)	Maximum length (cm)	% complete	Fracture pattern (SP = spiral; TR = transverse; – = complete bone)	Abrasion stage (0 = none; 1 = slight)	Weathering stage (parentheses indicate traces of a stage)	Tooth marks (X = present; 0 = none present)	Trample marks (X = present; 0 = none present)
16747	vertebra	9	25	TR	0	0	0	0
16750	vertebra	42	95+	–	0	0	0	0
16866	vertebra	7	45	TR	0	0	0	0
16865	vertebra	10	45	TR	0	0	0	0
16864	vertebra	48.5	95+	–	0	0	0	0
16868	vertebra	18.5	90	TR	0	0	0	0
16894	vertebra	9.5	50	TR	0	0	0	0
16895	vertebra	8	50	TR	0	0	0	0
16902	vertebra	9	95+	–	0	0	0	0
16901	vertebra	5	60	TR	0	0	0	0
16899	vertebra	9	40	TR	0	0	0	0
16897	vertebra	19	40	TR	0	0	0	0
16900	vertebra	4.5	40	TR	0	0	0	0
16893	vertebra	8.5	40	TR	0	0	0	0
16890	vertebra	14	30	TR	0	0	0	0
16889	vertebra	17.5	40	TR	0	0	0	0
16913	vertebra	7	40	TR	0	0	0	0
16911	vertebra	23	75	TR	0	0	0	0
16808	ns	18.5	95+	–	0	0	0	0
16807	ns	19	95+	–	0	0	0	0
16806	ns	14.5	50	SP	0	0	0	0
16802	ns	13	40	TR	0	0	0	0
16842	ns	17	90	TR	0	0	0	0
16734	ns	8	40	TR	0	0	0	0
16736	ns	28.5	80	TR	0	0	0	0
16740	ns	18	95+	–	0	0	0	0
16752	ns	26	90	TR	0	0	0	0
16873	ns	21	80	TR	0	0	0	0
16875	ns	18	70	TR	0	0	0	0
16896	ns	20.5	70	TR	0	0	0	0
16804	ns	13	40	TR	0	0	0	0
16792	chevron	27.5	95+	TR	0	0	0	0
16794	chevron	34	95+	–	0	0	0	0
16793	chevron	28.5	95+	TR	0	0	0	0
16795	chevron	32.5	95+	TR	0	0	0	0
16796	chevron	28	95+	TR	0	0(1)	0	0
16797	chevron	25	80	TR	0	0(1)	0	0
16830	chevron	37	95+	–	0	0	0	0
16831	chevron	34	95+	–	0	0	0	0
16832	chevron	21	95+	–	0	0	0	0
16833	chevron	26.5	95+	–	0	0	0	0
16871	chevron	20	90	TR	0	0	0	0
16877	chevron	23	90	TR	0	0	0	0
16878	chevron	13	90	TR	0	0	0	0
16874	chevron	28	80	TR	0	0	0	0
16892	chevron	17.5	80	TR	0	0	0	0
16885	chevron	22.5	80	TR	0	0	0	0
16917	chevron	16	90	TR	0	0	0	0
16908	chevron	25	90	TR	0	0	0	0
15979	scapula	18.5	80	TR	0	0	0	0
15981	scapula	62.5	90	TR	0	0	0	0
15979	tibia	27	90	TR	0	0	0	0

ANSP specimen number	Element (ns = neural spine; bf = bone fragment)	Maximum length (cm)	% complete	Fracture pattern (SP = spiral; TR = transverse; – = complete bone)	Abrasion stage (0 = none; 1 = slight)	Weathering stage (parentheses indicate traces of a stage)	Tooth marks (X = present; 0 = none present)	Trample marks (X = present; 0 = none present)
15978	tibia	30	90	TR	0	0	0	0
15981	tibia	85	90	TR	0	0	0	0
15981	tibia-c	85	95+	–	0	0	0	0
15980	illium	18.5	80	TR	0	0	0	0
15979	humerus	17.5	90	TR	0	0	0	0
15981	humerus	57	90	TR	0	0	0	0
17073	fibula	66	95+	–	0	0	0	0
17074	fibula	97.5	95+	–	0	0	0	0
15981	fibula	82	95+	–	0	0	0	0
15981	fibula-c	81	95+	–	0	0	0	0
15981	femur	78	90	TR	0	0	0	0
15981	femur	73	90	TR	0	0	0	0
16975	metapod.	22	90	TR	0	0	0	0
16978	metapod.	19.5	95+	–	0	0	0	0
16813	bf	8	–	TR	0	0(1)	0	0
16814	bf	7	–	TR	0	0	0	0
16817	bf	29.5	–	TR/SP	0	0	0	0
16822	bf	11	–	TR	0	0	0	0
16835	bf	54	–	TR	0	0	0	0
16761	bf	35	–	TR/SP	0	1	0	0
16770	bf	9	–	TR	0	0	0	0
16744	bf	6	–	TR	0	0	0	0
16733	bf	4.5	–	TR	0	0	0	0
16737	bf	8.5	–	TR	0	0	0	0
16753	bf	10.5	–	TR	0	0	0	0
16854	bf	10	–	TR	0	0	0	0
16853	bf	8	–	TR	0	0	0	0
16867	bf	21	–	TR	0	0	0	0
16876	bf	5	–	TR	0	0	0	0
16887	bf	12	–	TR	0	0	0	0
16912	bf	4.5	–	TR	0	0	0	0
16904	bf	12.5	–	TR	0	0	0	0
16910	bf	9	–	TR	0	0	0	0
16919	bf	7.5	–	TR	0	0	0	0

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