COMPARATIVE TAPHONOMY AND PALEOECOLOGICAL RECONSTRUCTION OF TWO MICROVERTEBRATE ACCUMULATIONS FROM THE LATE CRETACEOUS (MAASTRICHTIAN) HELL CREEK FORMATION, EASTERN MONTANA

by

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ABSTRACT

Although microvertebrate accumulations are commonly used for paleoecological reconstructions, the taphonomic processes affecting the final taxonomic composition of an accumulation are often ignored. To explore the correlation between taphonomic processes and taxonomic structure, one floodplain and one channel-lag deposit from the Maastrichtian Hell Creek Formation were compared. Specimens were quarried to collect high-resolution vertical and horizontal distribution data. Distribution of skeletal elements with specific physical attributes and relative abundance of taxa are shown to correlate with the hydraulic indicators (i.e., grain size, sedimentary structures) of the depositional facies.

Conor's Microsite (CM) is located within a laminated sandstone, siltstone, and mudstone facies interpreted as a fluvial overbank deposit. Just Past Celeste Microsite (JPC) is located in a massive sandstone facies and is interpreted as a channel lag deposit. Relative abundance data in conjunction with statistical test results show size, shape, abrasion, and taxonomic compositions to vary significantly between assemblages. Chi-squared tests and Correspondence Analyses of CM and JPC data sets indicate significant differences between taxonomic compositions. The CM assemblage is dominated by tabular, low density elements such as cycloid scales and fish vertebrae. Dense, equidimensional elements such as teeth and ganoid fish scales dominate the JPC assemblage. Transport distances, hydraulic equivalencies of dominant skeletal elements, amount of hydraulic sorting and reworking, and degree of time-averaging varies between deposits and significantly affect taxonomic distributions.

Chi-squared tests and rank order analysis results demonstrate that relative abundance of taxa can be determined for portions of the assemblages despite different taphonomic processes. Most notably, relative abundance of hydraulically equivalent skeletal elements from morphologically similar organisms can be compared regardless of accumulation in non-isotaphonomic deposits. Statistical comparisons were made among osteichthians using ganoid scales, caudates using vertebrae, ornithischians using teeth, and testudinates using shell fragments. Results show that portions of the assemblage analyzed using hydrodynamically equivalent elements are not significantly different.

INTRODUCTION

Microvertebrate fossil accumulations (also termed microsites) provide a wealth of data derived from the regional faunal and floral communities as well as local transport processes. Because of the abundance of vertebrate taxa, as well as invertebrates and plants included in a given assemblage, much information can be gained concerning the paleoecology of the area. Marine invertebrate accumulations (e.g., Martin et al., 1996; Meldahl et al., 1997; e.g., Best and Kidwell, 2000a; Best and Kidwell, 2000b) and bone beds of large terrestrial vertebrates (e.g., Fiorillo, 1991; Varricchio and Horner, 1993; Varricchio, 1995; Fiorillo et al., 2000; Ryan et al., 2001) have been subject to extensive paleoecological and taphonomic analysis. However, taphonomic analysis is often lacking from microsite assemblages despite their wider taxonomic sampling and larger sample sizes. The examination of taphonomic processes characterizing an assemblage exemplifies the preservation potential of an organism in a given deposit. Consequently, understanding taphonomic processes affecting a fossil accumulation is fundamental before taxonomic structures can be compared between assemblages.

Taphonomic studies have been influencing interpretations of fossil assemblages since the concept was first proposed by Efremov (1940). Continued research in more recent decades has focused on how taphonomic biases affect the deposition and preservation of organisms in the fossil record (e.g., Dodson, 1973; Behrensmeyer, 1978, 1982; Hill and Behrensmeyer, 1984; Behrensmeyer and Kidwell, 1985; Allison, 1988; 1988; Wood et al., 1988; Butterfield, 1990; Blob and Fiorillo, 1996; Kowalewski, 1996;

Cutler et al., 1999; Olszewski, 1999; Hedges, 2002; Behrensmeyer et al., 2005). Transport and preservation of microvertebrate remains have been experimentally and theoretically analyzed, (Dodson, 1973; Blob and Fiorillo, 1996; Blob, 1997), but the application of these concepts is still underutilized in microsite paleoecology. Early paleoecological studies using microsites attempted to relate relative abundances of organisms to specific environments distal and proximal to the site of deposition (Shotwell, 1955, 1958; Estes and Berberian, 1970). However, no analysis of transport and time-averaging ensued. More recent microsite analysis in the Judith River Group of Alberta, Canada (e.g., Brinkman, 1990; Eberth, 1990; Brinkman et al., 2004) combine large sample sizes and increased stratigraphic controls for statistical analysis that has yet to be applied to assemblages from other formations.

The purpose of this study is to compare the taphonomic processes affecting the faunal content preserved in microsites from distinctly different sedimentary facies. By understanding the various influences affecting deposition of vertebrate remains, researchers can more accurately interpret the usefulness of a given deposit for paleoecological reconstruction. A comprehensive study of the sediments, fossils, and depositional regime provide invaluable insight to the paleoecological analysis of multiple localities despite the facies. This thesis seeks to answer the following questions:

(1) How do assemblages from microsites deposited in different sedimentary facies vary taphonomically?

(2) How do taphonomic processes alter the taxonomic diversity and relative abundance of taxa represented in a deposit?

(3) Can any paleocommunity structure can be determined from microvertebrate assemblages in different facies?

The scope of this study obviously does not include all fossil-bearing facies, but will hopefully impress the need for more comprehensive research on this subject and its application to any assemblages from other formations.

GEOLOGIC SETTING

The study area of this thesis is located along Fort Peck Reservoir in Garfield County, eastern Montana (Figure 1). Late Cretaceous strata exposed in the area include (from oldest to youngest) the Bearpaw Formation, Fox Hills Formation, and Hell Creek Formation (Figure 2). This sequence is overlain by the Paleocene Tullock Member of the Fort Union Formation; Paleocene Tullock strata, however, have been eroded from the immediate area analyzed here.

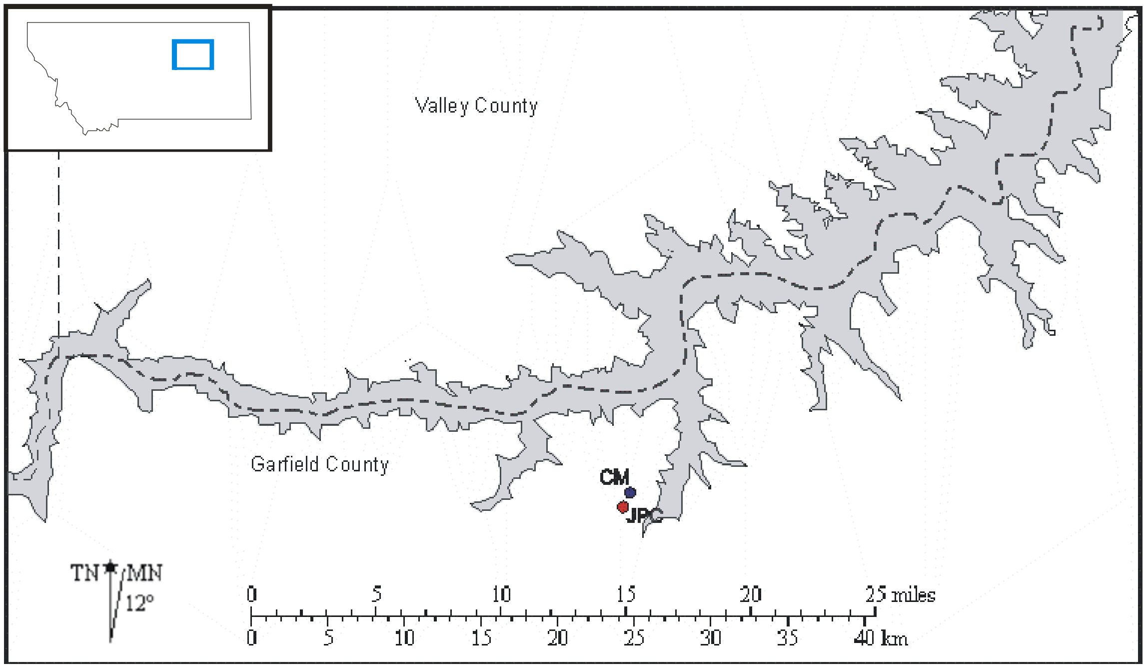

Figure 1. Map showing quarry localities along Fort Peck Reservoir in Garfield County, eastern Montana. The two localities are Conor's Microsite (CM) and Just Past Celeste Microsite (JPC).

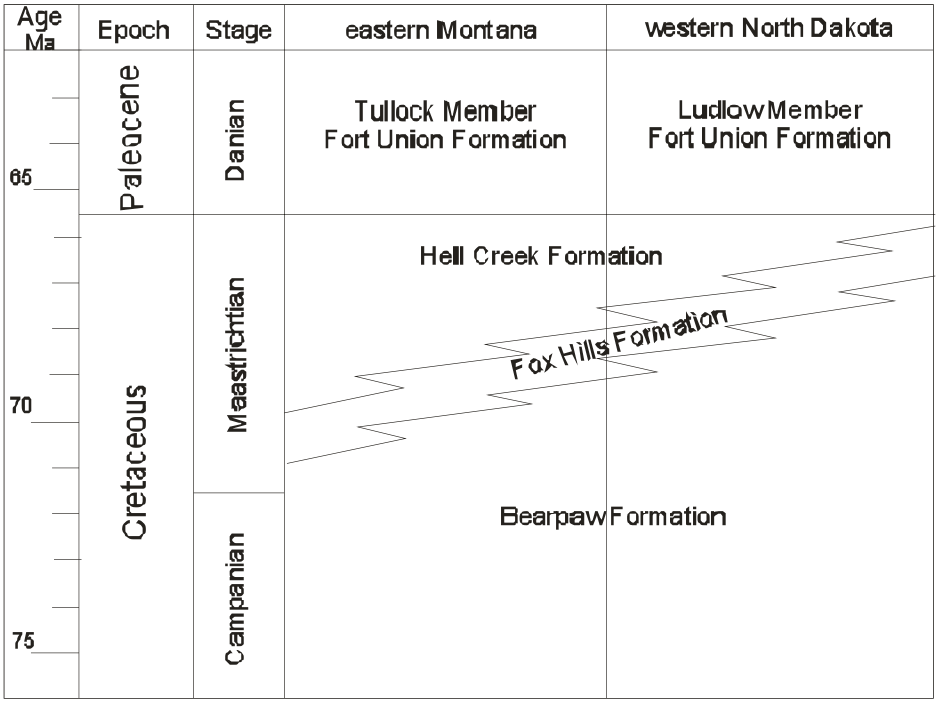

Figure 2. Stratigraphic relationship of the Late Cretaceous and Paleocene regressive strata of eastern Montana and the western Dakotas. Modified from Fastovsky (1987).

The Late Cretaceous Bearpaw, Fox Hills, and Hell Creek formations of eastern Montana and the western Dakotas were deposited during the final regression of the Western Interior Cretaceous Seaway. The Campanian-Maastrichtian Bearpaw Formation (73.5 Ma to 71.5 Ma; Macauley, 1964) is characterized by tan to dark gray shale with thin, very fine sandstone interbeds with hummocky cross-stratification deposited in a shallow marine setting of an epicontinental sea. Hummocky cross-stratified sandstone bodies most likely represent nearshore storm deposits. The Maastrichtian Fox Hills Formation (71.5 Ma to 67.5 Ma; Macauley 1964) is predominantly a tan to brown, well-sorted, very fine sandstone with thin gray mudstone sparsely interbedded. Fox Hills deposits represent a shoreface and foreshore environment.

Interbedded sandstones, mudstones, and siltstones define the more heterogeneous Hell Creek Formation (67.5 Ma to 65.5 Ma; Macauley 1964). The basal Hell Creek sandstone is distinguishable from the Fox Hills sandstone by a transition to coarser, darker sandstone with a distinct fossil content (i.e., terrestrial organisms) and large scale trough cross-bedding (Jensen and Varnes, 1964; see also Flight, 2004). While several studies have revealed unconformities along the Fox Hills-Hell Creek contact (Brown, 1907; Jensen and Varnes, 1964; Hartman, 1998), the contact remains an important datum for physical stratigraphic placement of fossil localities. Flight (2004) noted the usefulness of sequence stratigraphy to dinosaur paleontology in providing relative age groupings in an area lacking detailed chronostratigraphic framework. This methodology is not explored in depth within this thesis, but is included to note that both microvertebrate deposits are within the same highstand systems tract. Separation of stratigraphic units by sequences and systems tracts establishes a more detailed stratigraphic framework for correlating sediments (and potentially the fauna included in them) across the study area (Posamentier and Allen, 1999; Flight, 2004).

Sedimentology of the Hell Creek Formation reflects fluvial, overbank, and lacustrine deposition. Sediment provenance of the Late Cretaceous strata is considered to be the Sevier uplifts to the west and northwest (Gill and Cobban, 1973; Dickinson and Suczek, 1979; Dickinson et al., 1983; Zaleha, 1988; Hartman and Kirkland, 2002) with the Hell Creek sediments deposited as a prograding clastic wedge (Hartman and Kirkland, 2002). Contemporaneous units include the Maastrichtian Lance Formation of Wyoming and the Maastrichtian Frenchman and Scollard Formations of southwestern Alberta. The duration of sediment deposition persisted for 1.36 m.y. in North Dakota

(Hicks et al., 2002) to 2.5 m.y. in central North Dakota and easternmost Montana (Lund et al., 2002). Due to the thickening of the Hell Creek Formation from east to west (e.g., Fastovsky, 1987; Johnson et al., 2002; Figure 2), Lund et al.'s (2002) estimate is more likely a closer estimate for western Hell Creek deposits.

METHODS

The two microsites in this study were selected based on geographic and sedimentologic criteria. Both accumulations were collected from different facies of the lower half of the Hell Creek Formation exposed in Garfield County, Montana, and are in close geographic proximity to each other. Because the questions explored in this thesis address differences in taphonomic processes and faunal composition of assemblages from different facies, sampling microsite from distinctly different facies was an important criterion. Both microsites also had identifiable fossil horizons with dense fossil distribution permitting the efficient collection of spatial distribution data by quarrying. To explore the questions addressed in this study, a number of data collection methods were employed both in the field and in the laboratory.

Stratigraphic Data Collection

Stratigraphic data were collected to better understand facies associations and depositional environments of the fossil accumulation and surrounding units. Understanding the sedimentological history of a deposit is essential to fully determine and analyze taphonomic processes affecting a given deposit. One stratigraphic section was measured through each of the two microvertebrate quarries used in this study. Sections began in the upper portions of the Bearpaw Formation, and continued through the Fox Hills Formation to the uppermost Hell Creek Formation exposed above the quarry. Stratigraphic sections were measured using a Brunton compass adjusted to appropriate declination and a 1.5 meter Jacob's staff subdivided on a decimeter scale. Trenches were dug with a rock hammer or a paleontology pick-hoe to expose unweathered surfaces for description. Stratigraphic descriptions include lithology, grain size, sediment color, unit thickness, and sedimentary and biogenic structures. Detailed, small-scale stratigraphic measurements and notes were taken through the fossiliferous horizons, with attention given to small-scale lithologic changes and sedimentary and biogenic structures. Lithofacies were assigned for discrete sediment packages in the Hell Creek Formation based on Miall's (1996; Chapter 5) fluvial sedimentary facies (Table 1).

Table 1. Lithofacies of the study area, Hell Creek Formation, Garfield County, eastern Montana

Lithofacies	Description	Interpretation
Trough cross-stratified sandstone (St)	Very fine to medium sandstone with cross-bedding sets ? 5cm and usually < 1m; sometimes associated with lag deposits at the base of the sets	Deposition by migrating dune bedforms where the size of the cross-stratified sets correlates with flow depth
Massive sandstone (Sm)	Lower fine to medium sand with no or patchy traces of original sedimentary structures; possible traces of grading or lamination	Originally structureless due to rapid deposition (e.g., sediment gravity flow or bank collapse) or secondarily structureless due to postdepositional modification like dewatering and bioturbation
Laminated sand, silt, and mud (Fl)	Interlaminated sand, silt, and mud on cm to m scale with individual laminae possibly on mm scale; ripples, bioturbation, dessication cracks, and plant roots may be present	Deposition by suspension or weak currents common in overbank environments; sand beds represent greater depositional energy (crevasse splay deposits
Massive mud, silt (Fm)	Sedimentary structure-less fine grained sediments; root traces and dessication cracks may be present	Deposition by suspension settling or secondary destruction of structures by bioturbation or dewatering; common to distal floodplain environments and ponds
Root bed (Fr)	Sand, silt, or mud with sedimentary structures destroyed by bioturbation and root growth; beds often have mottled appearance	Vegetated floodplains with soil development in humid environments

Taphonomic Data Collection

Field Data

Vertebrate specimens for this research were collected during the summer field seasons of 2003 and 2004 by Museum of the Rockies field crews under the direction of the author. Vertebrate specimens used in the study were quarried, permitting collection of horizontal and vertical spatial distribution data for the assessment of depositional trends resulting from hydraulic processes. Screenwashing and surface collection are more common collection methods, and the collection of microvertebrate remains by quarrying has yet to be reported in the literature. Surface collection was undertaken before quarrying disrupted the area; discarded tailings were used for screenwashing. Mesh size was twenty openings per inch; screens were hand built by the University of California, Berkeley paleontology crews (Wilson, 2004). Only quarried specimens were used in the taphonomic and taxonomic abundance analysis. The advantage of using quarried specimens is three-fold: (1) using fossils collected by quarrying reduced the likelihood that a broken fossil would be counted multiple times (given that breakage is common during screenwashing); (2) using surface collected specimens could potentially influence taxonomic and relative abundance results biasing against small-bodied taxa (Wolff, 1975); (3) spatial distribution data were only able to be accurately collected for quarried specimens.

Horizontal and vertical distribution data were collected in the field for each specimen, allowing positioning in three-dimensional space. Horizontal distribution data were collected by the floating-grid method similar to that described by Organ et al. (2003). Each quarry was divided into 0.25 m^2 alphanumerically labeled quadrants. Rebar rods were pounded into the ground at four 90° angles around the quarry. Rebar stakes were also added at ½ meter increments along two parallel sides of the quarry with heavy wire stretched between the stakes across the face of the quarry (Figure 3). Due to the frequency of data collection, wires were permanently strung across the quarry (unlike the retractable wires described by Organ et al., 2003). A 0.50 m by 0.50 m grid was constructed from 0.25 inch PVC pipe. Hooks were added to the corners of the grid so it could hang from the 0.5 m-spaced guide wires. Each specimen found was given a number for its specific quadrant and plotted on a corresponding piece of graph paper (Appendix G).

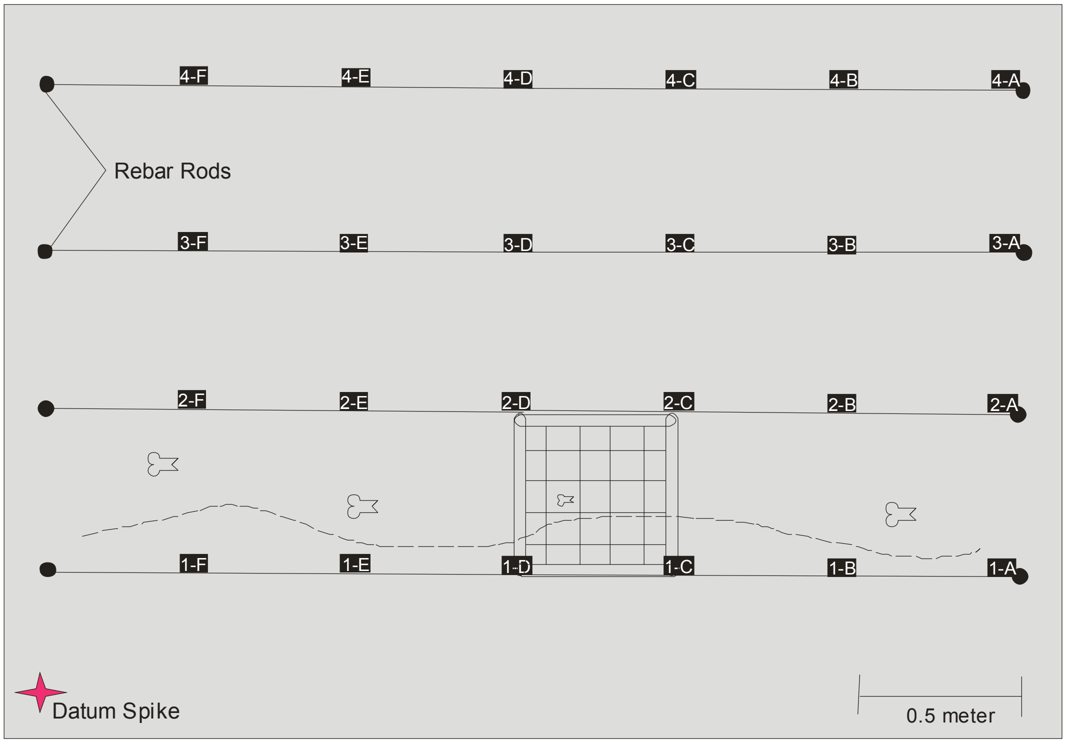

Figure 3. Diagram of the floating-grid system adapted from Organ et al. (2003) for microvertebrate data collection.

Vertical distribution data were taken for each specimen using a transit and meter stick, with the transit erected and leveled atop a tripod at the edge of the quarry. A datum spike was hammered into the ground and remained undisturbed for the duration of the data-taking processes. Each day, the height of the transit above the datum spike was measured and recorded. For each specimen found, the height of the fossil below the transit was measured using a meter stick. The height of the fossil is subtracted from the height of the datum to get the height of the fossil above the datum spike. This allows for the vertical distribution of all fossils found in the quarry to be plotted relative to the datum, making daily variations in transit height insignificant.

Laboratory Data

All vertebrate fossil specimens collected in the field were returned to the laboratory for further research and data collection regardless of taxonomic resolution. Each fossil was assigned to as low a taxonomic level possible. Additional data collected from each fossil included size, shape, degree of abrasion, and degree of weathering. Size was measured with an electronic digital caliper to 0.01mm for all specimens. Each fossil was placed into one of four shape classes following the shape descriptions given by Blob and Fiorillo (1996). The categories include plate-shaped (or tabular; class 1), elongate (class 2), equidimensional (class 3), and conical (class 4) specimens (Figure 4). Degree of abrasion was measured on a 0 to 3 scale with 0 being no abrasion, and 3 representing well rounded fossils no longer anatomically identifiable. Weathering was also noted on a scale of 0 to 3 (Fiorillo, 1988; modified from Behrensmeyer, 1978) where 0 corresponds to no cracking or breaking, 1 to minor (shallow) cracking, 2 to flaking and deeper cracking, and 3 to loss of external bone.

Statistical Analysis

Four statistical tests, chi-squared test, powers test, correspondence analysis, and Spearman's rank order analysis, were used to compare taxonomic abundances and

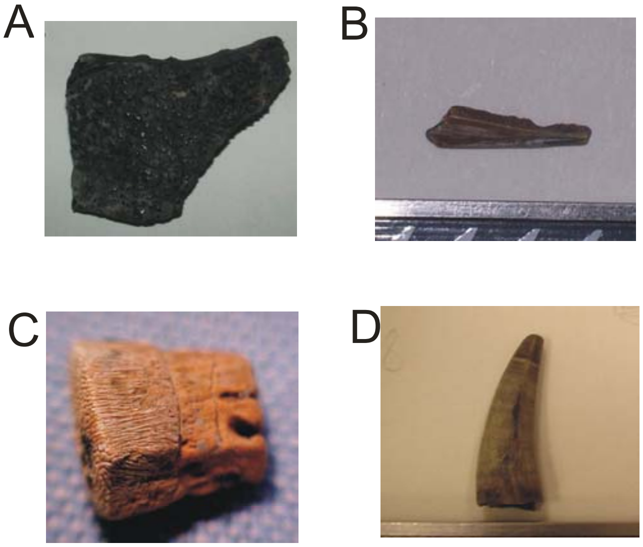

Figure 4. Shape classification is an important parameter for considering hydrodynamic transport, and all skeletal elements collected were assigned to a shape category. Plate-shaped elements (A) include fish scales and skull fragments; elongate elements (B) include jaw fragments and fish ribs; equidimensional elements (C) include ornithischain teeth, ray teeth, and vertebrate; conical elements (D) include crocodilian teeth, theropod teeth, and fish teeth.

distribution of specimens with specific physical attributes between assemblages (Table 1). Chi-squared tests were used to determine whether variance between datasets from the two assemblages was statistically significant, and were used to analyze the distribution of taxa and physical attributes of fossil remains between assemblages. Results from chi-squared analyses demonstrate the degree to which hydraulic processes have influenced the distribution of physical attributes (e.g., shape) and the relative abundance and distribution of taxa. Assumptions of the chi-squared test include sample sizes greater than 4. This assumption is not met by many of the samples used in the comparisons.

Table 2. Statistical tests used to explore the relationship between taphonomic processes and relative abundance of taxa

Statistical Test	Purpose	Problems with test
Chi-squared Test	Tests for differences between data sets	Assumes minimum sample size of 4
Powers Test	Tests the power of the data sets to determine differences between statistical samples (based on sample sizes)	No quantification of significant differences between samples
Correspondence Analysis	Test identifies the most difference portions of the assemblages	Graphical results rather than quantificantion of differences
Spearman's Rank Order Analysis	Test compares rank orders between assemblages	Loses power because rank orders are compared rather than abundance data

To negate the sample size problems in chi-squared tests, power tests were run on chi-squared data sets to determine the potential of a dataset for determining differences between two statistical samples given the sample size. Power tests were run at three levels where w=0.5 indicates the ability of the sample to determine large differences, w=0.3 indicates potential for determining medium-sized differences, and w=0.1 represents small differences.

Correspondence analysis was used to determine the most different taxa between assemblages based on relative abundance data. Differences in physical attributes and the affects of taphonomic processes of these taxa were then considered in further qualitative analysis.

Lastly, Spearman rank order analyses were used in support of chi-squared results for determining the level of correlation between assemblages based on rank orders. Rank order analysis does not make assumption about sample sizes. However, because the test compares rank order and not the numbers of specimens, the power of the test to determine differences is reduced.

Curation

Curation of the specimens collected for this research ensures that as much taphonomic data is preserved as possible. Each specimen was individually labeled with a Museum of the Rockies specimen number including the alphanumeric quadrant identification and specimen number from that quadrant (e.g., MOR 2559.1G.9). Specimens from the same quadrant were grouped together. Spreadsheets including taxonomic identification, spatial distribution, size, shape, and abrasion data are attached to the Museum of the Rockies collections database so future researchers can access all previous collected data for each specimen.

SITE DESCRIPTIONS

Conor's Microsite (CM) – HC 285

Sedimentology and Stratigraphy

Conor's Microsite, Museum of the Rockies locality HC 285, is in a mudstone bed 31.4 m above the Fox Hills – Hell Creek Formational contact (Figure 5). The quarried unit is located within a sequence of interbedded sandstone, siltstone, and mudstone units. The fossiliferous mudstone was deposited atop a mottled clay with abundant *in situ* plant stems and root traces. A minor erosion surface identified by small-scale, local scouring is preserved between the fossil-bearing mudstone and underlying clay. The quarried mudstone is capped by a thin layer of carbonized wood fragments and a coarsening upwards mud-rich siltstone containing plant stem traces. The fossiliferous horizon is roughly 60 cm thick, thins to the east, and contains clay clasts and plant stem traces concentrated towards the base of the deposit. Millimeter-scale silt and less frequent sandstone lenses are interbedded in the fossil-bearing mudstone and concentrated towards the base of the deposit. Fossils are rarely associated with the coarser sediment lenses. Vertebrate, invertebrate (bivalve and gastropod), and plant remains (leaf impressions and seeds) are common within the fossil assemblage, as well as gypsum and amber nodules. Shell hash is confined to the western 1.2 m of the quarry.

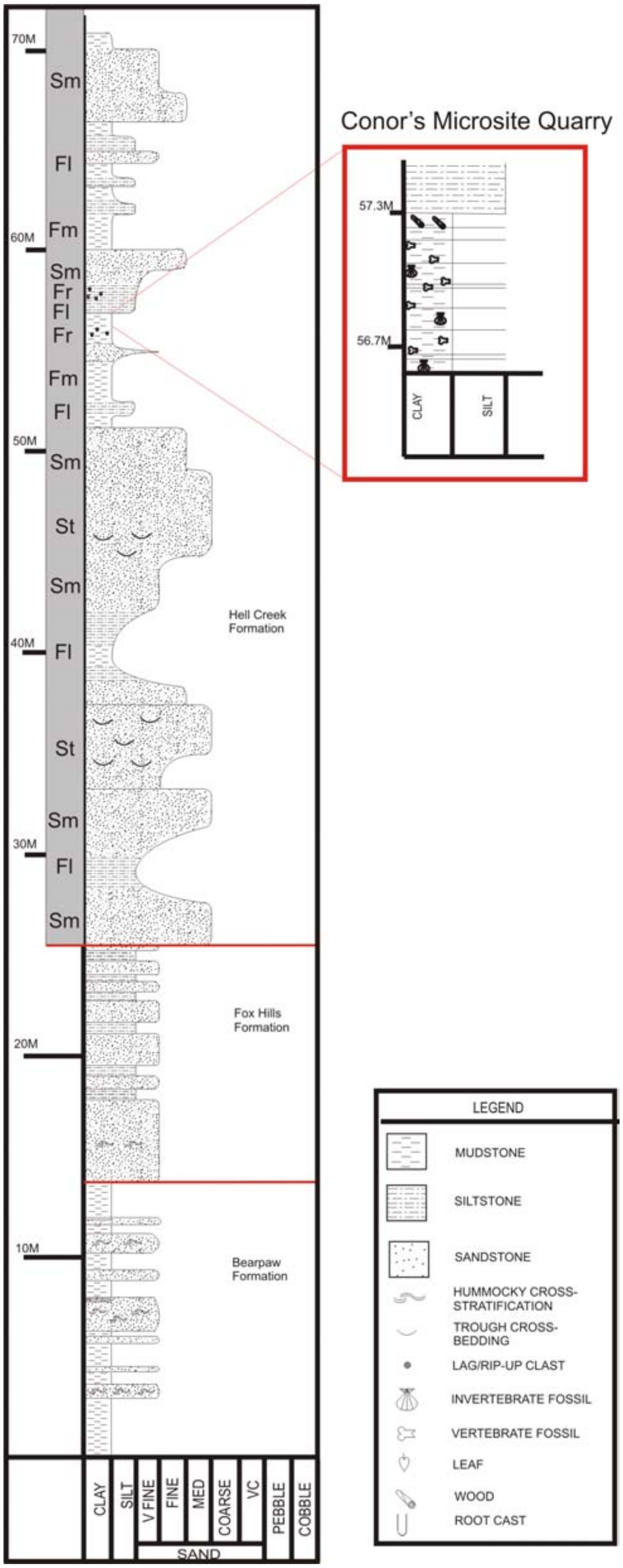

Figure 5. Stratigraphic section measured from the upper portions of the Bearpaw Formation through CM Microsite

Interpretation. The alternating massive sandstone facies (Sm) and massive and laminated mudstone facies (Fm and Fl) containing the fossiliferous unit are interpreted as isolated channel and overbank deposits, and the trough cross-stratified sandstones (St) are also interpreted as channel deposits (Table 1). The fossiliferous unit falls within the laminated fine-grained facies (Fl), signifying deposition under lower current velocities or by suspension settling. Fossil-bearing sediments could be interpreted as either floodplain or lake deposits. However, the mudstone unit lacks the thin laminations characteristic of lacustrine deposits (Fastovsky and Dott, 1986; Blair, 1987). Rip-up clasts and the small lenses of coarser sediments indicate minimal fluid movement during the onset of fossil deposition with waning velocities towards the top of the deposit as grain size becomes more homogenous. Mud clasts in fluvial deposits can represent either locally derived rip-up (see Smith, 1972 for experimental results) or bank-collapse features under high flow regime. The clasts are very well-rounded and composed of mottled clay matching the underlying clay paleosol deposit, indicating that the mud pebbles most likely represent rip-up clasts derived from the underlying sediments.

Despite evidence of deposition by moving water rather than settling, the unit lacks the fining upwards sequence typical of subaqueous turbidity flows (Bouma et al., 1985), which have been previously identified in the Hell Creek Formation (Shoup, 2001). Rather, the presence of bivalves and gastropods suggests local erosion by relatively calm waters (Eberth, 1990). The abundance of *in situ* plant stems and root traces combined with slickensides, small-scale fractures, and gypsum nodules present within and/or directly below the fossil horizon indicate paleosol development with possible wet-dry cycles (Fastovsky, 1987; Fastovsky and McSweeney, 1987; McSweeney and Fastovsky, 1987; Retallack, 1994). Root traces, plant stems, and plant fossils overlying the fossiliferous horizon also signify an abundantly vegetated floodplain.

Paleosol development overlying and directly underlying the fossiliferous unit suggests that the fossil layer was laid down in one event. Erosion patterns in the immediate area of the fossil bed prevent lateral tracing of beds, making proximity to the paleochannel unknown. However, the influx of mud, silt, and sand sediments, as well as rip-up clasts, on a paleosol could indicate a nearby crevasse splay. Despite the dominance of mud-sized sediment, presence of rip-up clasts and coarser silt and sand lenses indicate higher energy (not suspension settling).

Taxonomic Description

Table 3. Number of specimens from and rank order of each taxon in the CM assemblage. Refer to Appendix A for complete taxa list and Appendix J for skeletal elements represented in each taxon.

Conor's Microsite

Taxon	Number of Specimens	Rank Order
Teleostei	726	1
Amiidae	224	2
L. occidentalis	130	3
Holostean	94	4
Ornithischia	76	5
Testudines	17	6
Caudata	16	7
M. bipartitus	13	8
Acipenser	10	9
Lepidosauria	9	10
Crocodilia	8	11.5
Small Theropod	8	11.5
Choristodera	2	13
Elasmobranchii	1	15
Large Theropod	1	15
Mammalia	1	15
Anura	0	17
Total (N)	1336	

The CM assemblage is dominated by osteichthian remains, predominantly teleostei scales and amiidae vertebrae and teeth (Table 3). *Lepisosteus occidentalis* scales are also common. Ornithischians are the most common terrestrial vertebrates in the assemblage, and are represented only by teeth. Turtle shell fragments, amphibian jaws and vertebrae, lizard jaws, crocodilian teeth and scutes, and theropod dinosaur teeth are present in low abundances.

Just Past Celeste Microsite (JPC) – HC 377

Sedimentology and Stratigraphy

The JPC fossil bed is located slightly lower in stratigraphic section than CM (22.4 m above the Hell Creek – Fox Hills contact), approximately 0.5 km southwest of Conor's Microsite. Lithofacies of the Hell Creek Formation at HC 377 are dominated by massive mudstone (Fm) with interbedded siltstone units (Figure 7). Basal Hell Creek deposits in this section consist of massive (Sm) and trough cross-stratified (St) sandstones. The fossiliferous unit is in a medium-grained sandstone deposit that fines upward to a fine grained sandstone. The fossil horizon is underlain by a clay-dominated mudstone, and capped by a medium-grained sandstone unit. Mudstone clasts, iron concretions, vertebrate fossils, and well-rounded, pebble-sized bone fragments are interbedded within the 40cm thick fossil-bearing sandstone. Shell hash is deposited throughout the unit.

Interpretation. Like Conor's Microsite, sandstone (Sm and St) facies and fine-grained (Fm and Fl) facies bounding the JPC quarry are interpreted as fluvial channel and overbank deposits, respectively. The fossiliferous horizon is in the massive sandstone

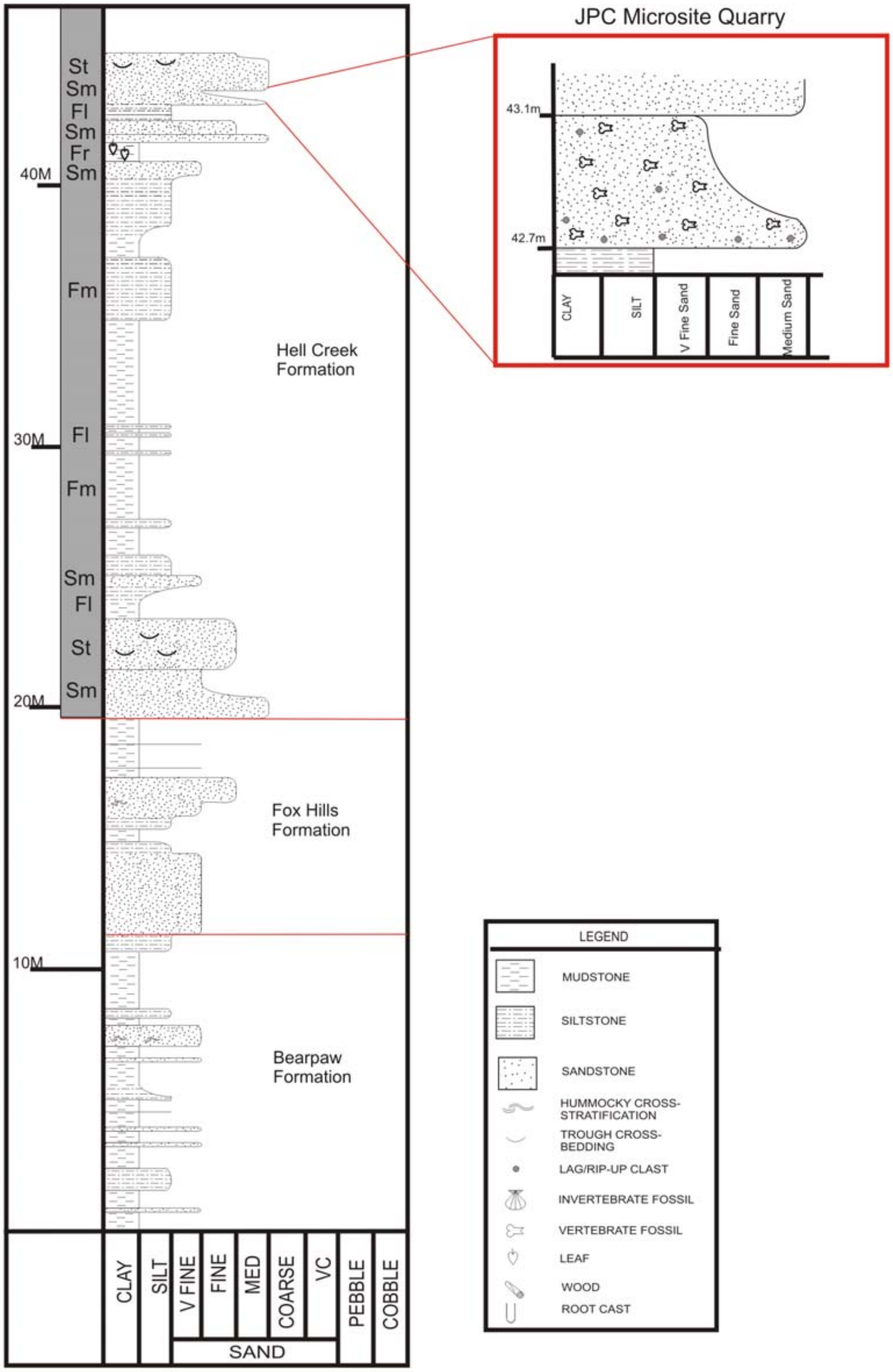

Figure 6. Stratigraphic section measured from the upper portions of the Bearpaw Formation through JPC Microsite.

facies (Sm), indicating that the sandstone was either primarily structureless due to rapid deposition or structures were obliterated by later currents and bioturbation. The stratigraphy of the JPC quarry is interpreted to represent accumulation of microvertebrate remains as a channel lag. Channel lag deposits are found in association with coarse clastic material in channel thalwegs, and are often deposited upon fine-grained facies or stacked sandstones (Behrensmeyer, 1988). Sorting and abrasion are common taphonomic signals of prolonged contact between skeletal remains and clasts in subaqueous transport (Behrensmeyer, 1982). Eberth (1990) found similar deposits in the Judith River Formation of Alberta, and interpreted them as plane-bed deposits the accumulated under upper flow-regime conditions. Like the fossil-bearing sandstone of the JPC Microsite, the sediments fine upward and are matrix-supported accumulations, but unlike the Judith River facies, the sandstone unit analyzed here has no preserved sedimentary structures.

Taxonomic Description

The JPC assemblage consists of considerably fewer teleostei remains (50 scales in the JPC assemblage versus over 700 in the CM assemblage) than the CM assemblage, as well as a larger proportion of terrestrial taxa. Amiidae and *L. occidentalis* are still common, but Ornithischian teeth, *Myledaphus bipartitus* (a freshwater ray) teeth, and turtle shell fragments are found in significantly higher abundance (Table 4). Amphibians, Lizards, and crocodilians are also more abundant in the JPC assemblage.

Table 4. Number of specimens from and rank order of each taxon in the JPC assemblage. Refer to Appendix A for complete taxa list and Appendix J for skeletal elements represented in each taxon.

JPC Microsite

Taxon	Number of Specimens	Rank Order
Amiidae	149	1
Ornithischia	135	2
M. bipartitus	88	3
L. occidentalis	75	4
Teleostei	66	5
Testudines	64	6
Holostean	60	7
Crocodilia	23	8
Caudata	22	9
Lepidosauria	16	10
Mammalia	12	11
Acipenser	9	12
Large Theropod	8	13
Choristodera	7	14
Small Theropod	5	15
Anura	2	16
Elasmobranchii	0	17
Total (N)	741	

HOW DO ASSEMBLAGES FROM MICROSITES DEPOSITED IN DIFFERENT SEDIMENTARY FACIES VARY TAPHONOMICALLY?

Variance in abrasion, shape, size, and relative density distributions characterizing specimens in the assemblages indicate non-isotaphonomic deposits (*sensu* Brinkman et al., 2004). Distribution of elements in specific abrasion categories (Figure 7) and shape classes (Figure 8) varies greatly between assemblages. Specimens in the sandstone (JPC) assemblage have a more limited average size range than the mudstone (Figure 9) and a larger percentage of equidimensional clasts (50.2% vs. 17.88%). The higher degree of abrasion indicated by the specimens in the JPC assemblage also correlates to the transport energy and grain size of the depositional system. The higher proportion of weathered fossils in the sandstone assemblage (>1% of the CM assemblage compared to 3.4% of the JPC assemblage) suggests many specimens underwent reworking cycles before final deposition and burial.

Grain size differences between the two deposits predict a difference in hydraulic equivalences of bioclasts and provide insight into transport histories. The distinct variation in fossil shape, density, and abrasion directly corresponds to the depositional system, indicated by facies characteristics. Size, shape, and density are all important factors influencing which elements are perserved in a deposit (i.e., Stokes' Law). Settling velocity increases with density and size, with shape also an important factor (Behrensmeyer, 1975) – a plate-shaped clast will fall slower than a spherical one because of viscous resistance distributed across a larger surface area. Hydraulically significant characteristics of common fossils are shown in Table 3. Cycloid scales, ganoid scales,

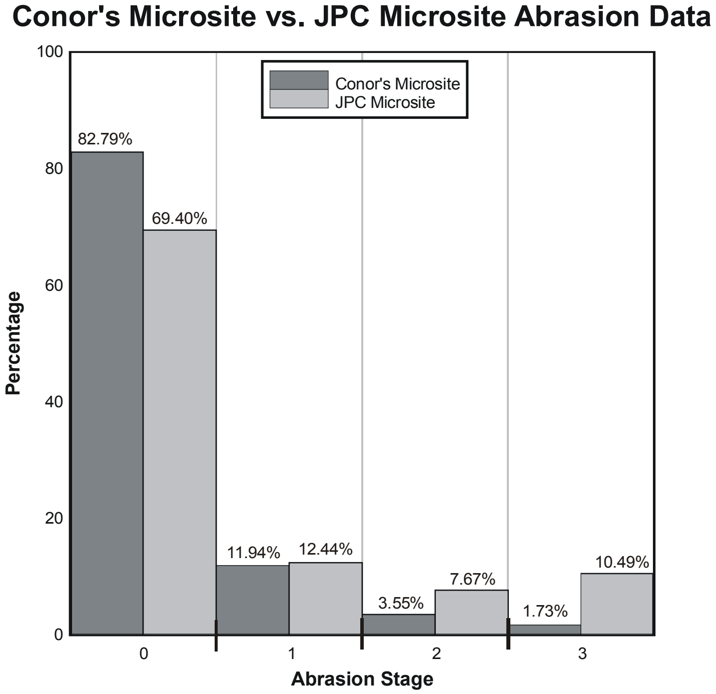

Figure 7. Comparison of percentage of specimens in abrasion stages 0-3 between CM and JPC assemblages.

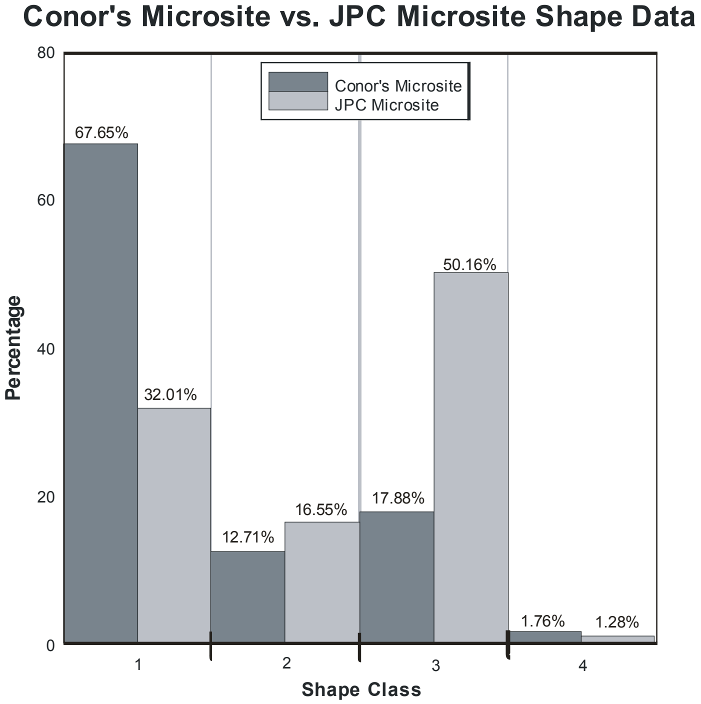

Figure 8. Comparison of the percent of specimens in shape classes 1-4 between the CM and JPC assemblages. Class 1 = tabular elements; Class 2 = elongate elements; Class 3 = equidimensional elements; Class 4 = concial elements

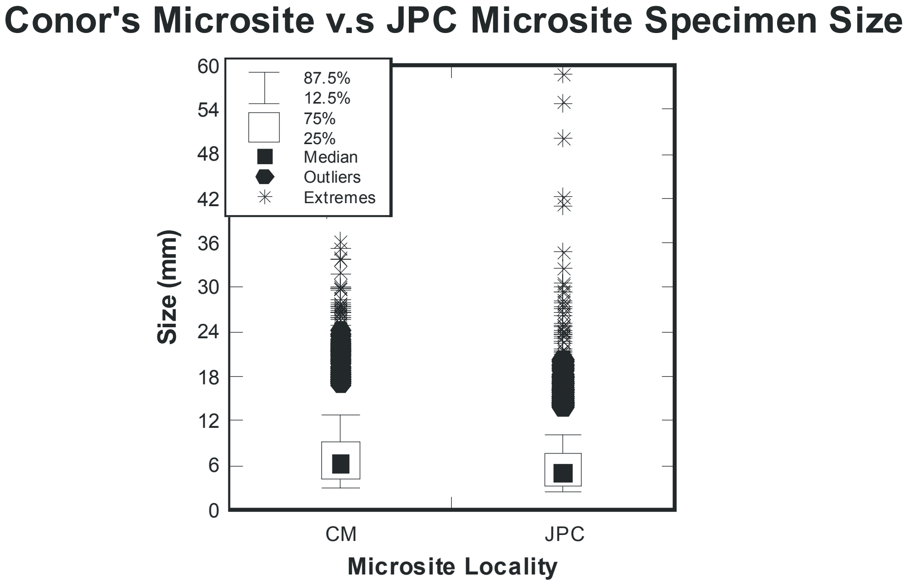

Figure 9. Box and whisker plot comparing average specimen size from the Conor's Microsite quarry and JPC Microsite quarry. The limits of the box represent the median 50% of specimens (distance between is the IQR, interquartile range). The whisker limits represent the non-outlier minimum and maximum (the median 75% of specimens). Outliers are the specimens that's sizes are greater than 1.5 times the IQR, and the extremes have size values 3 times the IQR. Note that the box of CM specimen sizes is larger and the whiskers are longer, illustrating the greater average variability in specimen size within the CM assemblage. JPC, however, has a larger overall size range with larger maximum extremes.

vertebrae (especially flatter amiid vertebrae), and smaller jaws are more common in the CM assemblage. Teeth, shells/scutes, ganoid scales, larger jaws (especially those with teeth), and round amiid vertebrae are elements that are more common in the JPC assemblage. Despite the shape classification, the abundance of palatal teeth in the JPC assemblage most likely reflects their small size, higher relative density, and high number per individual. The tabular higher density and tabular shape of ganoid scales accounts for their high preservation potential in both assemblages. The concentration of teeth, reduced number of vertebrae, and more constrained average size range of specimens indicates a pre-burial history of winnowing and sorting of the JPC assemblage.

Table 5. Physical attributes relating to the hydraulic characteristics of common skeletal elements in the CM and JPC assemblages

Element	Relative Density	Shape	Relative Size
Ganoid Scale	high	tabular	small-medium
Amiid Vertebra	low	tabular-round	large
Amiid Palatal Tooth	high	round	small
Cycloid Scale	low	tabular	small-medium
Teleost Vertebra	low	round	small
Turtle Shell	high	tabular-round	large
Jaw	high	tabular	small-medium
Dinosaur Tooth	high	round	medium-large

Analyzing hydraulic equivalencies of skeletal elements found within a deposit is useful in unraveling transport histories of deposits. Behrensmeyer (1975) measured the hydraulic equivalences of several bones common to the Plio-Pleistocene deposits from Africa (Figure 10). While the skeletal elements used in her comparison are not directly comparable to those of Cretaceous microsites, her results emphasize the affect of size, shape, and density on settling velocities. Ideally, hydrodynamic analysis of skeletal elements indicates the likelihood of bones and sediments to be transported together to the site of final deposition (Behrensmeyer, 1975). Within the JPC assemblage most bones and teeth fall within the size range dictated by the average grain size of the deposit. Based on Behrensmeyer's (1975; Figure 10) hydrodynamic equivalency measurements, the flat shaped elements (which have the most variation in quartz equivalencies) correspond with the medium-sized sand of the deposit. The larger ornithischian and theropod teeth are smaller than any of the teeth in Behrenmeyer's (1975) analysis, and could possible be equivalent to a medium sand. Bones and teeth with equivalencies higher than a medium-sized sand grain could have been deposited by disarticulation of a floating carcass or reworking of immediately adjacent bank/floodplain deposits. Dense bones and teeth have a greater likelihood of preservation after reworking (Behrensmeyer, 1975). In the fine-grained deposit, the larger teeth, turtle scutes, and bone fragments mostly likely fall outside the mud and silt equivalency. This suggests that the floodplain deposit is a mix of allochthonous and more locally-derived authochthonous assemblages. If fluid density increased because of suspended load, which would not be surprising during flood stage, then larger and denser elements could have been transported with the sediment. Disarticulation of floating carcasses could also lead to deposition of elements with larger hydrodynamic equivalencies.

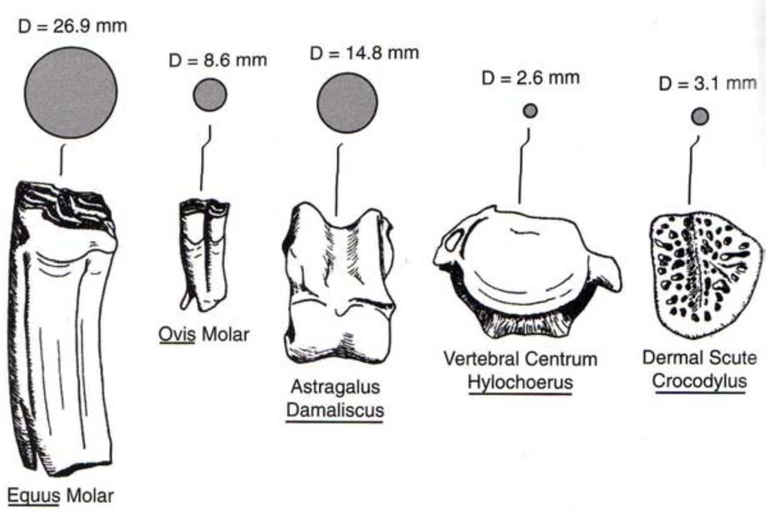

Figure 10. Hydrodynamics equivalences of skeletal elements from the Plio-Pleistocene of Africa to quartz grains. (From Behrensmeyer, 1975)

Transport and depositional processes determines the amount of time represented and the paleoecological conclusions that can be drawn from a given deposit. Behrensmeyer (1982) identified three pathways for fossils to be introduced into channel assemblages: (1) reworking of floodplain deposits, (2) overland transport, and (3) death of an organism within the channel. As a result, channel deposits are allochthonous over wide spans of time and space and channel-lag concentrations can represent $\leq 10^2$ to $>10^5$ years of time-averaging (Rogers, 1993). Floodplain deposits are considered to be either autochthonous (Behrensmeyer, 1982) or at least contain a less time-averaged assemblage (Rogers, 1993). However, because the floodplain deposit used in this study was probably deposited in one flooding event, many of skeletal elements were likely derived from the channel and the floodplain surface, mixing autochthonous and allochthonous assemblages. Resultantly, the amount of time-averaging within the CM assemblage occupies the upper limits of time averaging designated by Rogers's (1993) model, but perhaps does not represent as much time as the JPC lag deposit. The long interval of time potentially represented in these deposits is better suited to evaluating long term evolutionary and paleoecology trends (Behrensmeyer, 1982; Rogers, 1993), and must be kept in consideration when using attritional microfossil accumulations for paleoecological research.

Overall, many studies have been published analyzing transport of large skeletons (e.g., Voorhies, 1969; Behrensmeyer, 1975, 1982; e.g., Behrensmeyer, 1988; Zaleha, 1988; White et al., 1998), with few transport studies focusing on microvertebrate remains (Dodson, 1973; Blob and Fiorillo, 1996; Blob, 1997). Voorhies (1969) studied the affects of hydrodynamic sorting on bone assemblages of large mammals. His methods and results have been readily applied to large dinosaur assemblages (e.g., Alberdi et al., 2001; Ryan et al., 2001), but hydrodynamic effects on sorting of small bones have not been as thoroughly explored. Dodson (1973) concluded that bones from small animals had such large transport potential that microvertebrate accumulations in channel deposits better reflection transport mechanisms rather than paleoecology. After testing transportability of turtle elements, Blob (1997) concluded that elements from each clade represented in an assemblage have different transport potentials, all of which need to be explored before taphonomic affects on an assemblage as a whole are fully understood. Though important hydrodynamic characters are highlighted by the characteristics of the fossils in the accumulation, high transport potential does not necessarily forego paleoecological usefulness.

As the results of this study emphasize, strong correlation is evident between facies, physical attributes of fossils, and taphonomic processes (e.g., transport, time-averaging, sorting, winnowing). Collection biases often associated with microsites include unequal sampling among sedimentary facies and unequal sampling from upper or lower portions of a formation. Rogers (1993) emphasizes the taphonomic and time-averaging differences between proximal and distal environments in the Campanian of Montana. The research presented in this thesis also illustrates taphonomic differences in assemblages from different facies (i.e., taphofacies; *sensu* Brett and Speyer, 1990). Focusing collection on sandstone units because of denser fossil deposition, collecting from a lag deposit because of higher concentration of mammal teeth, or disproportionately collecting from upper portions of a formation because of easy access, mars accurate reconstruction of the paleoecology in question. Consequently, taxa can be underrepresented or even perceived as absent from the community because sedimentary processes are not favorable for the deposition of skeletal elements of a specific organism. For example, the lower portion of the Hell Creek Formation is dominated by large sandstone packages and fine-grained facies increase up-section as the stratigraphic record reflects increasingly inland environments and basin subsidence rates. Similar trends were also noted in the Two Medicine – Judith River sequence of central Montana (Rogers, 1993). It is important to note that factors other than evolutionary change prove important when sampling across geological time.

HOW DO TAPHONOMIC PROCESSES ALTER THE TAXONOMIC DIVERSITY AND RELATIVE ABUNDANCE OF TAXA REPRESENTED IN A DEPOSIT?

The two microsites included in this study accumulated under distinctly different hydrodynamic and taphonomic processes over varying amounts of time, producing distinctly different faunal assemblages (Figure 11). Chi-squared analysis of taxa identified to class or order show the two assemblages to be significantly different (Table 6). Correspondence analysis indicates that Osteichthyes, Chondrichthyes, Testudines, Ornithischia have the most variance between assemblages (Figure 12).

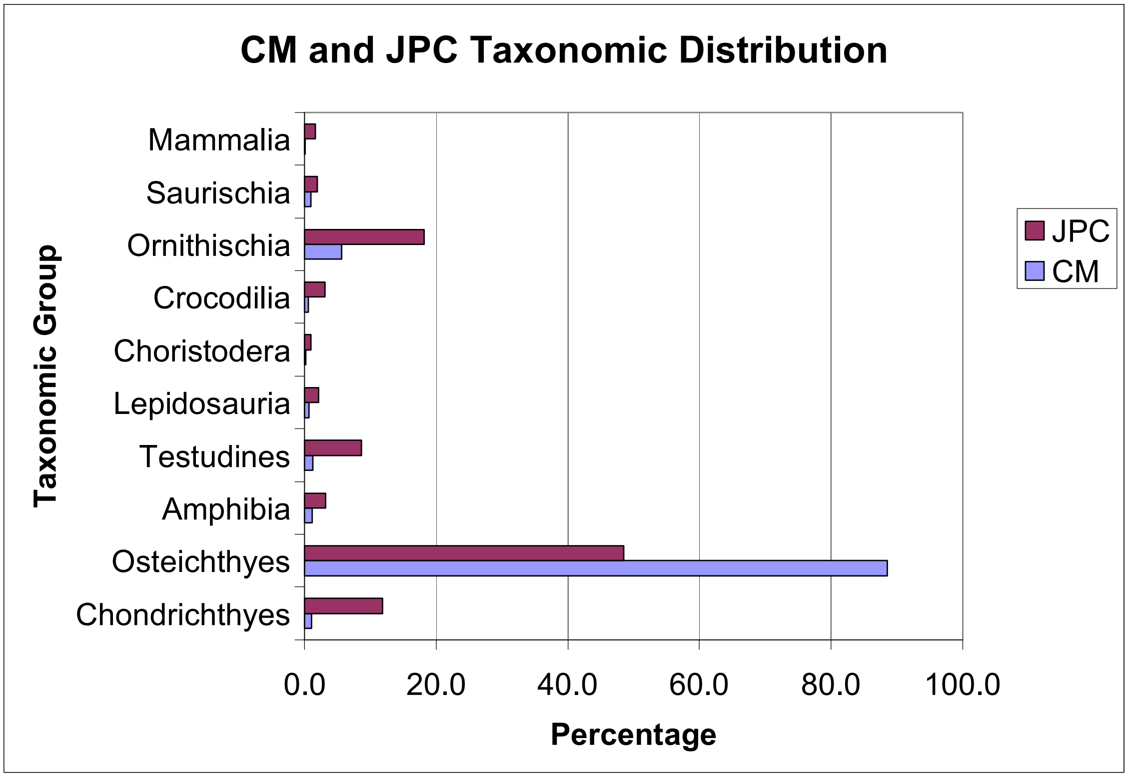

Figure 11. Percent relative abundances of specimens from major taxonomic groups within the CM and JPC microsite assemblages. Refer to Appendix C from complete fauna lists and Appendix J for rank orders and number of specimens used in the comparison.

Table 6. Results of chi-squared and power tests on taxonomic compositions between CM and JPC assemblages. Test B includes only taxa with sample sizes larger than 4. Refer to Appedix C for taxa and sample sizes used in each comparison.

Taxonomic Composition	X^2	p	Powers w = 0.5	w = 0.3	w = 0.1
A	431.09	<<0.001	1	1	0.9195
B	408.16	<<0.001	1	1	0.9387

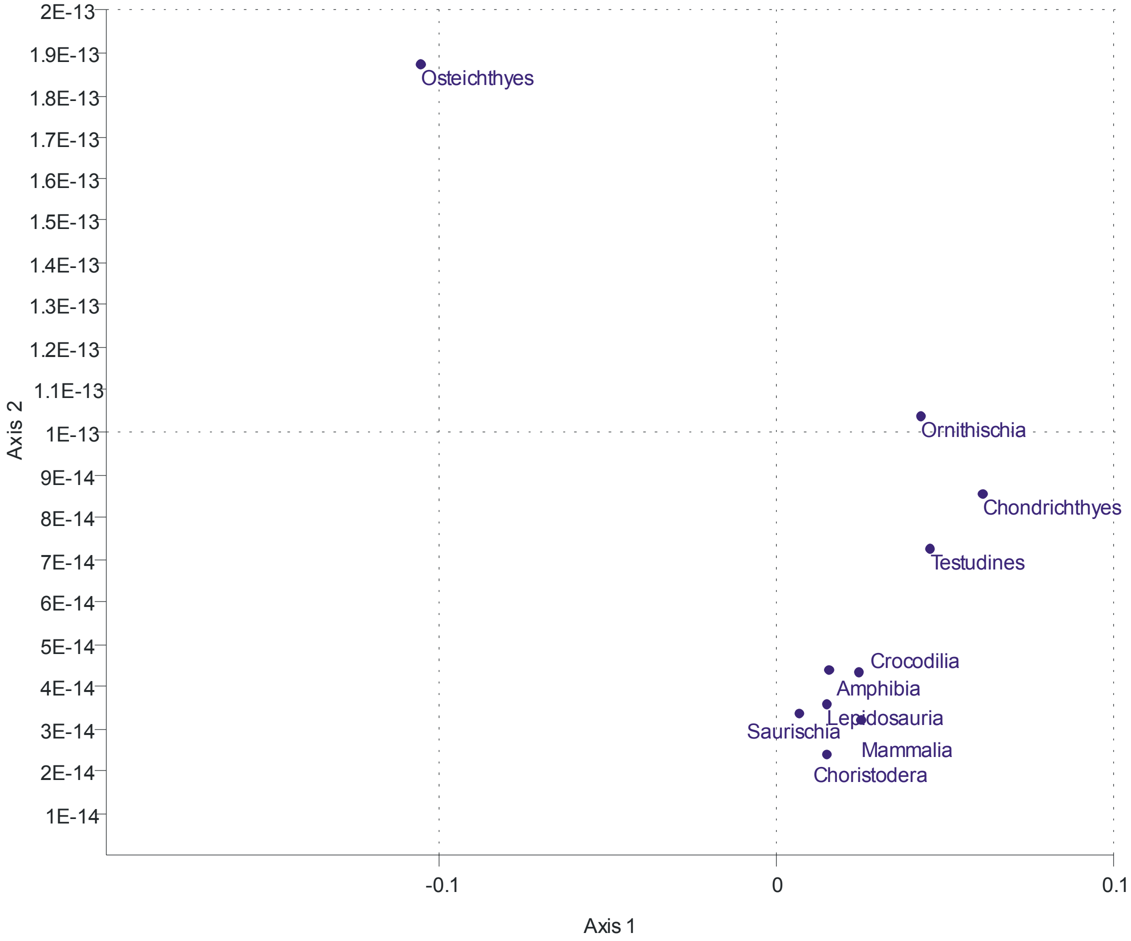

Figure 12. Correspondence Analysis of taxonomic distribution between CM and JPC assemblages based on relative abundances. Clustered taxa have similar relative abundances between assemblages and outlying taxa show differences in relative abundances between assemblages. Refer to appendix C for taxonomic comparisons between assemblages.

Taphonomic processes specific to the JPC accumulation strongly influenced the relative abundance of taxa found in the assemblage. Contact with large clasts during transport in a higher velocity fluid and increased likelihood that many of the fossils underwent exhumation and redeposition cycles before final burial, led to a lower abundance of many of the thin, fragile specimens abundant in the CM assemblage. The higher energy of the channel environment allowed for hydrodynamic sorting of clasts with distinctive size, shape, and density characteristics and winnowing of lighter elements. The high tooth to vertebrae ratio (see Appendix J) also suggests winnowing of the final deposits (Behrensmeyer, 1975). As a result, the sandstone assemblage not only contains fewer osteichthian scales and skull fragments, but contains more non-osteichthian teeth and scutes – equidimensional elements and bones with higher densities. Fish elements that are present in the JPC assemblage include mostly teeth and ganoid scales.

Hydrodynamic influences were explored by comparing taxa distribution within specific shape classes (Table 7) and shape class distribution within specific taxa (Table 8) between assemblages. Significant differences were found when analyzing the relative abundance of the plate-shaped taxa from the CM assemblage versus the JPC assemblage (X^2_8=320.93, p»0.001 ; Table 7a). Aggregating the least abundant taxonomic groups still produced significant differences between assemblages (X^2_4=296.88, p»0.001). The large number of teleosts with thin, light scales in Conor's Microsite and concentration of testudinates with dense shell fragments in JPC Microsite contribute most significantly to taxonomic differences in tabular-shaped taxa. Taxonomic comparisons of equidimensional-shaped taxa between the two sites are significantly different (X^2_8=107.73, p»0.001; Table 7b) with amiids, ornithischians, and chondrichthians the most variable between assemblages. Aggregation of taxa with low sample sizes still results in significant differences between the samples (X^2_4=102.40, p»0.001). The high number of porous amiid vertebrae in the CM assemblage and the number of dense ornithischian and chondrichthian teeth in the JPC assemblage (despite size, and shape similarities) constitute these distinctions.

Table 7. Results of chi-squared and power tests of the distribution of taxonomic groups of (A) tabular taxa and (B) equidimensional taxa. Test B in both shape analyses includes only taxa with sample sizes larger than 4. Refer to Appendix D for taxa and samples sizes used in comparisons.

A

			Powers		
Tabular Taxa	X^2	p	w = 0.5	w = 0.3	w = 0.1
A	320.93	<<0.001	1	1	0.703
B	296.88	<<0.001	1	1	0.8165

B

Equidimensional Taxa	X^2	p	w = 0.5	w = 0.3	w = 0.1
A	107.73	<<0.001	1	1	0.4373
B	102.4	<<0.001	1	1	0.5821

Table 8. Chi-squared and power test results analyzing the distribution of shape classes in each taxonomic group. Teleost B excludes shape class 4 which is not present in either assemblage. Refer to Appendix E for sample sizes used in comparison.

			Powers		
Group	X^2	p	w = 0.5	w = 0.3	w = 0.1
Osteichthyes	101.34	<<0.001	1	1	0.9832
Teleostei A	18.511	0.00249	1	1	0.6511
Teleostei B	18.511	<<0.001	1	1	0.7147
Non-teleostei	14.332	0.00249	1	1	0.6362
Lepidosauria	4.332	0.2277	0.5366	0.2125	0.0651
Caudata	7.9948	0.00469	0.7371	0.3099	0.0733

Significant differences in the number of specimens in each shape class for a given taxon also highlights the affects abiotic taphonomic factors on an assemblage (Table 8).

Only lepidosaur samples are not significantly different between assemblages, but these data sets have exceptionally low sample sizes and contain only jaw elements. Large taxonomic groups like Osteichthyes that contain a wide variety of skeletal elements with various sizes, shapes, and densities are significantly different between accumulations. Because of differences in these physical attributes, comparisons of hydraulically equivalent elements within specific taxa (e.g., caudates, osteichthians with ganoid scales, ornithischian teeth) are more accurate reflections of paleoecological relationships (see discussion in the next section).

Although the relative abundance of taxa is significantly skewed between the two assemblages, taxonomic diversity is similar within each deposit (Appendix A). Forty-seven taxa are identified when taxa lists are combined and the majority of these taxa are found in both assemblages. This suggests that similar original paleocommunities with similar organisms were sampled. Taxa appearing in markedly low abundance or (especially) at only one assemblage can be attributed to (1) taphonomic biases selecting against preservation at one site, (2) being members of a distal community, and (3) being rare members of the proximal community. Whether organisms are rare to the final time-averaged paleocommunity sampled or not, hydrodynamic explanations can be offered for most taxa found only in one assemblage. The most prominent example is the abundance of mammal teeth in the JPC assemblage. Mammal remains are relative rare in Cretaceous deposits and are most commonly represented by teeth. Equidimensional and relatively dense, mammal teeth fall into the same general shape, size, and density classifications. They also have a higher concentration in the sandstone deposit, which favors the concentration and preservation of equidimensional and dense skeletal elements. Thus, sampling different facies (with the understanding of the time represented in the assemblage) to determine the extent of taxonomic diversity in a time-averaged paleocommunity is important, especially when a taxon can be identified by numerous skeletal elements with different hydrodynamic equivalence.

CAN ANY PALEOCOMMUNITY STRUCTURE BE DETERMINED FROM MICROVERTEBRATE ASSEMBLAGES IN DIFFERENT FACIES?

Assemblages with different depositional histories and time-averaging emphasize the problems correlating abundance data with original ecological population trends. As shown (Blob and Fiorillo, 1996; this study), problems arise when attempting to interpret relative abundance of taxa between non-isotaphonomic deposits. Taxonomic discrepancies resulting from selective preservation of element size, shape, and density may inhibit reliable results. Also, attritional and reworked deposits representing varying degrees of time-averaging permit taxonomic analysis only within the time represented by the deposit. The amount of time-averaging represented in the two deposits is on the order of 10^2-10^5 yr (Rogers, 1993) and undoubtedly varies between the two assemblages due to differences in attritional and reworking processes. Rogers (1993) states that deposits with coarse time resolution are still useful for recognizing long-term ecological shifts. Resultantly, only reconstructions of a *time-averaged* paleocommunity can be determined. Faunal analyses in the light of taphonomic constraints and understanding can aid in drawing conclusions even amongst assemblages with differences. Conclusions are unsupportable without a stratigraphic framework and a firm understanding of the taphonomic processes affecting of the accumulations.

Although this study focuses on abiotic taphonomic processes, it should be noted that inherent biological biases derived from the original skeletons affect microvertebrate accumulation regardless of facies and hydrodynamic processes. Differential ossification of elements, the number of bones per animal, number of easily preservable parts (e.g., teeth, scales, dermal armor), and tooth replacement rates can affect the preservation potential of a given taxon. Examples include: (1) chondricthians are rarely represented by elements other than teeth due to the nature of skeleton ossification; (2) animals with dermal ossifications, such as scales on fish or scutes on crocodilians, have more skeletal elements per individual potentially entering the system than animals without dermal ossifications; (3) mammals produce fewer number of teeth per individual than lower vertebrates as they only replace their teeth once through ontogeny. A comprehensive study on the affects of these biological factors has yet to be conducted and is outside the focus of this thesis. Until actualistic experiments and/or statistical analyses have been performed exploring these considerations, potential biological biases cannot be directly applied to statistical tests analyzing entire assemblages. However, biotic variations still need to be kept in mind when making conclusions. This study does assume that organisms within morphologically similar clades have similar skeletal features with comparable preservation potentials. Thus, it can be assumed that all caudates have the same preservation potential (biologically speaking) if equally abundant in the original paleocommunity. The same assumption is made for turtle, lizard, crocodilian, and mammal groups. Differences are known and taken into consideration for the number of teeth per jaw in various dinosaur taxa.

In this study, many taxonomic groups are represented by the same elements (e.g., vertebrae and jaws in caudates, teeth in dinosaurs) with the same hydrodynamic properties, permitting analysis between sites despite different depositional histories. It is proposed that comparing elements with similar shape, density, and/or size classification of morphologically similar organisms produces reliable reconstructions of portions of the time-averaged paleocommunity. This permits assemblages from different facies, geographic regions, and stratigraphic sections to be accurately compared. Comparing taxonomic abundance across broad taxonomic groups is problematic. Relative abundances of chondrichthian and osteichthian remains are not directly comparable because of extreme differences in size, shape, and density characteristics as well as differences in preservable skeletal remains per individual organism. Even taxa within Osteichthyes cannot be directly compared due to the variety of skeletal elements with different taphonomic classifications (e.g., teeth, cycloid scales, ganoid scales, vertebrae, jaw fragments). However, comparisons under the proposed guidelines at lower taxonomic resolution (family, genus, and/or species level) are valid. Although data sets used in statistical analyses are small, trends are consistent between tests and are further supported by powers test and rank order analysis.

Comparison of similar skeletal elements within portions of the taxonomic composition reduces the affects of biotic and abiotic taphonomic processes. Several groups of organisms are represented by hydrodynamically similar elements in the Hell Creek Formation microsites. Caudates are predominantly represented by vertebrae and jaws (none of which contain teeth) that vary in size by only one or two mm; ganoid fish scales (of non-teleost fish) fall into the same shape, density, and size categories; ornithiscian teeth are equidimensional and similar in size and density; turtle shell fragments are similar in size, shape and density. Relative abundance of the caudates *Opisthotriton kayi*, *Scapherpeton tectum*, *Habrosaurus dilatus*, and *Prodesmodon copei* is similar in both assemblages and rank order is preserved (Table 9b; Table 10a); *O. kayi* is the most abundant and *P. copei* is the least. Chi-square analysis of caudates does not indicate that data sets from the two sites are significantly different (X^2_3=0.792, p=0.8514; Table 9a). The caudate sample size is particularly low and power tests show that data

Table 9. (A) Chi-squared and power tests results of hydrodynamically similar elements in given taxonomic groups and (B) results of Spearman's rank order analysis. Ornithischia B data set excluded Euornithopoda, which is only present in the JPC assemblage. Refer to Appendix F for taxa and sample sizes used in each comparison.

A

Group	X^2	p	w = 0.5	w = 0.3	w = 0.1
Ganoid	1.5633	0.6678	1	0.9971	0.2839
Caudata	0.792	0.8514	0.6541	0.2646	0.0695
Testudines	14.32	0.00634	0.9541	0.5042	0.0887
Ornithischia	2.9711	0.5627	0.968	0.5653	0.0946
Ornithischia B	2.2462	0.5229	0.9766	0.609	0.1022
Theropoda	12.118	0.03321	0.398	0.1577	0.0597
Dinosauria	15.055	0.13008	0.9614	0.5041	0.083

B

Group	r_s	p	Correlation
Ganoid	0.8	0.2	good
Caudata	1	0	good
Testudines	0.41039	0.36754	poor
Ornithischia	1	0	good
Ornithischia B	1	0	good
Theropoda	-0.6364	0.17431	ok
Dinosauria	0.42991	0.18693	poor

sets are not good for detecting even large changes. However the results match the trends show by the other tests using hydrodynamically similar elements. Acipenser, Holostean (A and B morphotypes), and *Lepisosteus occidentalis* scales (X^2_3=1.5633, p=0.6678; Table 9a) are not significantly different between assemblages. (Note: there are two unnamed holostean fishes in these assemblages identifies mostly by scales, hereafter they will be referred to as "holostean", not to be confused with amiids, gars, and acipensers which are also considered holostean-grade fishes.) *L. occidentalis* is the most abundant "primitive" (i.e., non-teleost) fish in both assemblages, and Holostean A is the second most abundant (Table 9b; Table 10b). Specimens from Holostean morphotype B and acipensers are less common and vary in abundance between localities. Low sample size of these two taxa reduces their effect on statistical comparisons and makes conclusions regarding relative abundance of these two taxa (Holostean B morphotype and Acipenser) tenuous.

Ornithischian teeth (Ceratopsidae, Hadrosauridae, Euornithopoda, Ankylosauridae, and Pachycephalosauridae) frequencies are not shown to be significantly different between assemblages (X^2_4=2.9711; p=0.5627; Table 9a). With the exception of one euornithopoda tooth in the JPC assemblage, ornithischian teeth hold the same rank between localities as well (Table 9b; Table 10c). Ceratopsians are the most abundant, followed by hadrosaurs, pachycephalosaurs, and ankylosaurs. Although the number of tooth families per jaw correlates with skull size in both hadrosaurs and ceratopsians (i.e., changes through ontogeny; Dodson et al., 2004; Horner et al., 2004), hadrosaurs consistently have more teeth per individual than ceratopsians. The higher abundance in both assemblages of ceratopsian teeth, despite taxonomic differences in teeth per individual, strongly indicates that ceratopsians (such as *Triceratops* and *Torosaurus*) were the most abundant ornithischians in the time-averaged paleocommunity.

Theropod tooth distribution between the CM and JPC assemblages are statistically different (X^2_5=12.118, p=0.03321; Table 9a). It should also be noted that the theropod dataset is the smallest of those compared in these analyses, and results are therefore the least reliable as a potential reflection of the time-averaged paleocommunity. Rank order is inconsistent between CM and JPC assemblages (Table 9b; Table 10d); when theropod data from both sites are combined, tyrannosaurids are most abundant despite low frequency in the CM assemblage. In the Theropoda, small, tabular *Saurornitholestes*,

Table 10. Rank order analysis and number of all elements from taxonomic groups used in chi-squared analysis of specific taxonomic groups in the CM and JPC assemblages.

		Conor's Microsite		**JPC Microsite**	
	Taxon	Number of Specimens	Rank Order	Number of Specimens	Rank Order
A	**Caudata**				
	O. kayi	5	1	8	1
	S. tectum	4	2	5	2
	H. dilatus	3	3	4	3
	P. copei	2	4	1	4
	Total (N)	14		18	
B	**Ganoid Fishes**				
	L. occidentalis	124	1	65	1
	Holostean A	75	2	30	2
	Holostean B	7	3	2	4
	Acipenser	5	4	3	3
	Total (N)	211		100	
C	**Ornithischia**				
	Ceratopsidae	20	1	22	1
	Hadrosauridae	8	2	18	2
	Pachycephalosauridae	5	3	5	3
	Ankylosauridae	1	4	2	4
	Euornithopoda	0	5	1	5
	Total (N)	34		48	
D	**Theropoda**				
	R. gilmorei	3	1	0	5.5
	S. langstoni	2	2	0	5.5
	P. lacustris	2	3	2	2.5
	R. isosceles	1	4	1	4
	Tyrannosauridae	1	5	8	1
	D. albertensis	0	6	2	2.5
	Total (N)	9		13	
E	**Dinosauria**				
	Ceratopsidae	20	1	22	1
	Hadrosauridae	8	2	18	2
	Pachycephalosauridae	5	3	5	4
	R. gilmorei	3	4	0	10.5
	S. langstoni	2	5.5	0	10.5
	P. lacustris	2	5.5	2	5.5
	Ankylosauridae	1	8	2	5.5
	Tyrannosauridae	1	8	8	3
	R. isosceles	1	8	1	8.5
	D. albertensis	0	9.5	2	6
	Euornithopoda	0	9.5	1	8.5
	Total (N)	43		61	
F	**Testudines**				
	Trionychidae	7	1	24	1
	Chelydridae	4	2	11	3
	Basilemys sp.	3	3	0	5
	Baenidae	1	4.5	19	2
	Adocus sp.	1	4.5	2	4
	Total (N)	16		56	

Paronychodon, and *Richardoestesia* teeth are analyzed alongside the more robust *Dromaeosaurus* teeth and tyrannosaurid fragments, mixing different shape and size categories. Given different taphonomic characteristics between theropod taxa, it remains in question whether a larger sample size would permit more certainty regarding theropod abundances. Interestingly, when ornithischian and saurischian data are analyzed as a single dataset for each assemblage, the two assemblages are not found to be statistically different (X^2_{10}=15.055; p=0.13008; Table 9a) despite low rank order correlation (Table 9b; Table 10e). While this suggests that data from taphonomically different deposits can be combined and preservational biases due to different taphonomic processes eliminated, there is not enough data from this study to draw any firm conclusions. Differences in relative abundances potentially related to hydrodynamic differences of elements are minimized in larger data sets. Tabular teeth of small theropods are neither in the same shape class nor size range as tyrannosaurid and ornithischain teeth. Because saurischians are represented by low sample size (yet have high abundance variability), their affect on statistical results decreases overall.

Relative abundance and number of teeth per individual is more difficult to decipher in theropods as well. Most of the theropod taxa present have similar numbers of teeth per individual that, at least in some cases, change through ontogeny (J. Horner, personal communication, 2006). Tooth replacement rates also vary inter- and intra-specifically and correlate with tooth size (Erickson, 1996). The genera *Richardoestesia* and *Paronychodon* were described based on teeth and/or partial jaw fragments, prohibiting total tooth row counts or even confident phylogenetic placement. *Dromaeosaurus* is only known by teeth in the Hell Creek Formaiton and teeth previously assigned to *D. albertensis* could potentially represent juvenile tyrannosaurids (J. Horner, personal communication, 2006). The case of theropod teeth emphasizes the restriction taphonomic differences (i.e., size and shape) impose upon taxonomic reconstruction. Further analysis with multiple large datasets is needed to fully explore possibilities to test for relative abundance of taxa, and whether combining data from taphonomically different assemblages produces valid results.

Relative abundances of crocodilians can be determined within the time-averaged paleocommunity using teeth. *Borealosuchus sternbergi* and *Brachychampsa montana* have similar dental morphology with anterior caniniform teeth and tabular, crushing posterior teeth. Only the posterior teeth can be identified to species; the posterior teeth of *B. sternbergi* are oval in occlusial view and *B.montana* more circular. *B. sternbergi* may have a few more teeth than the smaller *B. montana*, but the two are similar overall in tooth number, size, and density. The dominance of *B. sternbergi* teeth with assemblages are combined is, therefore, a likely representation of true relative abundances among crocodilians. Given similar dental, cranial, and post-cranial morphologies, different abundances can indicate either biotic trends characteristic of similar organisms sharing the same environment, or the occasional introduction of an individual from a different habitat, rather than taphonomic biases. Another example of one species being distinctly less common than another with similar ecology, morphology, and diet are the two crocodilians from the Judith River Formation; *Albertochampsa* (an alligatorine closely related phylogenetically and morphologically to *Brachychamps*) skeletons are distinctly less common than the crocodyline *Leidyosuchus* (Brinkman, 2004). Champsosaurs have more teeth per individual than crocodilians, but teeth were rarely present in the assemblages. Because the majority of *Champsosaurus* remains in the assemblages are vertebrae, the choristoderian and crocodilian assemblages are not directly comparable.

Some of the first researchers to explore statistical paleoecology used relative abundance data to differentiate communities distal and proximal to the site of deposition (Shotwell, 1955, 1958; Estes and Berberian, 1970). More recent taphonomic studies criticize the application of Shotwell's (1955) statistical paleoecology methods (Voorhies, 1969; Dodson, 1973; Behrensmeyer, 1975; e.g., Behrensmeyer, 1978; Grayson, 1978; Behrensmeyer, 1982; Brinkman, 1990) and take a more taphonomically-minded approach. Taphonomic processes (transport, reworking, sorting, winnowing) and other depositional factors (including sedimentation rate) associated with fluvial deposits produce variation in the geographic range sampled (Behrensmeyer, 1988), time-averaging (Behrensmeyer, 1982; Rogers, 1993), and hydrodynamic transport (Voorhies, 1969; Behrensmeyer, 1975; Hanson, 1980). These processes also confuse trends in preferential preservation of taxa in specific depositional environments. Regardless, within any attritional assemblage, more than one community will be sampled (Shotwell, 1958; Behrensmeyer, 1982) as members of more distal communities are introduced by predators/scavengers, stream action, or random occurrences of an organism outside its home community. It remains unclear if species present only in floodplain deposits are those most likely to be destroyed in channels, and if species only found in channels have an increased likelihood of representing members of distal communities.

Turtle remains are limited to shell fragments of similar size and density, and based on trends preserved in caudate, ornithischian, and fish samples, turtles present another ideal assemblage of taphonomically similar elements for abundance analysis.

However, baenids, chelydrids, *Basilemys* sp., *Adocus* sp., and trionychids are significantly different between Conor's Microsite and JPC Microsite (X^2_4=14.320, p=0.00634; Table 11a). Baenids and *Basilemys* cause the most significant divergence between the two assemblages, and *Basilemys* is the only turtle taxon present at only one locality (Table 9b; Table 10f). Taxonomic analysis excluding *Basilemys* sp. specimens does not indicate significant difference between the assemblages (Table 11b), and sample size is still sufficient for indicating large changes between datasets. Of all testudinate taxa represented in the fauna, *Basilemys* is the only diagnosed terrestrial turtle (based on jaw morphology, limb robustness, and toe length; Brinkman, 1998). The JPC assemblage has a higher overall concentration of turtles due to hydrodynamic sorting of turtle shell and possibly the aquatic ecology of the remaining turtle taxa, yet does not include any *Basilemys* specimens. *Basilemys* is found only in the CM assemblage, which would be more likely to sample organisms inhabiting the floodplain.

Table 11. Results from (A) chi-squared and power test and (B) Spearman's rank order analysis of the turtle assemblage excluding *Basilemys* sp. specimens. Refer to Appendix F for taxa and number of specimens from each assemblage.

A

			Powers		
Group	X^2	p	w = 0.5	w = 0.3	w = 0.1
Testudines*	3.8021	0.2837	0.9509	0.5336	0.0939

*Does not include *Basilemys*

B

Group	r_s	p	Correlation
Testudines*	0.63246	0.36745	ok

The trend demonstrated in the turtle assemblage correlating depositional environment and abundance is not shared across all taxa. The four caudate species identified in this Hell Creek fauna are all considered aquatic to semi-aquatic based on post-cranial adaptations favoring undulatory movement and phylogenetic relationships with extant taxa (Estes, 1964). *S. tectum* has dubious phylogenetic relationship to modern taxa and no apparent morphological adaptations towards strong undulatory movement, but is considered aquatic based on abundance in aquatic deposits (Estes, 1964). The dataset from this study cannot falsify this reasoning, however circular. Though remains are more common in the channel deposit, the relative abundances are not shown to be significantly different. It is likely that these organisms, being semi-aquatic, would inhabit both environments alternately throughout life. Few lepidosaurs have post-cranial adaptations diagnostic of ecology or easily deciphered phylogenetic relationships (Estes, 1964), but most likely characterize greater ecological diversity. Modern teiid lizards inhabit niches from semi-aquatic to fully terrestrial (including arboreal and subterranean) habitats. The JPC assemblage contains more lepidosaur remains, but Conor's Microsite contains higher taxonomic diversity. Many of the JPC specimens are not taxonomically diagnosable due to breakage and abrasion resulting from transport and reworking. Lepidosaurs are among the least common members of the community in both accumulations, making patterns between abundance and depositional environment unclear. Low sample sizes limit the confidence of conclusions, but pose interesting questions for future research.

CONCLUSION

It has been established here and elsewhere (Behrensmeyer, 1975, 1988; Brett and Speyer, 1990; Blob and Fiorillo, 1996) that major taphonomic differences directly related to the hydrodynamic characteristics of the depositional system exist between assemblages from different facies. Distribution of skeletal elements with specific physical attributes in conjunction with sedimentological data and statistical results indicate that the two assemblages in this study have been strongly affected by taphonomic processes including transport, sorting, winnowing, reworking, and time-averaging. While the taphofacies concept is not new to paleontological studies (see Brett and Speyer, 1990; Rogers, 1993), results presented in this study provide a quantification of the variability between assemblages cause by hydrodynamic forces.

The taphonomic and hydrodynamic differences explored in this project have a striking affect on taxonomic compositions between accumulations, as indicated by relative abundance data and statistical test results. Specific tests focus on the distribution of elements based on physical attributes, which directly correlates with transport, sorting/winnowing, and reworking processes. Analysis of the hydrodynamic equivalences of skeletal elements within each deposit reveals patterns in the distribution of taxa. The mudstone deposit is dominated by flat, low-density elements (e.g., cycloid scales, fish skull, fish vertebrae) and the sandstone deposit is dominated by spherical, higher-density elements (e.g., teeth, turtle shell).

Given the taphonomic differences between assemblages and variations in hydrodynamic equivalence of skeletal elements within taxonomic groups, using physically similar elements is the most reliable way of comparing taxonomic abundances between deposits. While sample sizes do become problematic as the assemblages are divided into hydraulic and taxonomic groups, relative abundance data and statistical test results indicate similar trends among the taxonomic groups analyzed. Despite low sample sizes, the similar taxonomic trends from the analyses of hydraulically similar elements are interpreted as significant. In this study, results indicate that within the time-averaged Hell Creek paleocommunity (1) *O. kayi* is the most abundant caudate based on vertebrate, followed by *S. tectum*; (2) the gar *L. occidentalis* is the most abundant ganoid scale-bearing fish, followed by the Holostean A morphotype; (3) Ceratopsians are the most abundant ornithischian dinosaur based on teeth, followed by hadrosaurs; and (4) Trionychids are the most abundant turtle based on analysis of turtle shells. Results from taxonomic groups with significant differences between assemblages can be explained by hydrodynamic analysis. Theropod data sets combine small, flat teeth and larger, equidimensional teeth, thus not limited to hydrodynamically equivalent elements.

Transport energy, sorting/winnowing processes, and the amount of reworking influence the taxonomic assemblage preserved in a specific deposit. Because sedimentary facies strongly correlate with faunal representation, it is important to sample a variety of facies to better understand the taphonomic biases within each assemblage and more accurately reconstruct the paleoecology. When comparing accumulations, whether across time or space, the distribution and comparison of various facies must be taken into account. Comparing hyrodynamically equivalent skeletal elements, despite the taphonomic processes affecting the assemblage, can still produce statistically reliable paleoecological conclusions. As shown, comparing different sets of data from isotaphonomic localities is not a requirement for analyzing taxonomic assemblages. In fact collecting from different facies is important for recovering taxa that may be preservationally selected against in a given facies.

More statistical research needs to be pursued on the accuracy of comparing non-isotaphonomic assemblages and biases within specific isotaphonomic assemblages. Larger sample sizes of both specimens and localities will produce more complete results. This research will hopefully act as a platform for future taphonomically-minded paleoecological studies using microvertebrate assemblages.

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APPENDICES

APPENDIX A

FAUNA LISTS

CM FAUNAL ASSEMBLAGE

Class	Order	Family	Genus/Species (Lowest Taxon)
CHONDRICTHYES			
	Batoidea		
		Anacoracidea	
			Myledaphus bipartitus
	Elasmobranchii		
		Elasmobrachii indeterminate	
OSTEICHTHYES			
	Acipenseriformes		
		Acipenseridae	
			Acipenser indeterminate
	Amiiformes		
		Amiidae	
			Amiidae indeterminate
	Order indeterminate		
		Holostean A	
		Holostean B	
		Holostean indeterminate	
	Lepisosteiformes		
		Lepisosteidae	
			Lepisosteus occidentalis
	Teleostei		
		Asperidorhynchidae	
			Belonostomus longirostris
		Elopidae	
			Paratarpon apogerontus?
		Albulidae	
			Coriops amnicolus
		Esocidae	
			Estesesox sp.
		Teleost indeterminate	
AMPHIBIA			
	Caudata		
		Batrachosaurididae	
			Opisthotriton kayi
		Scapherpetodontidae	
			Scapherpeton tectum
		Sirenidae	
			Habrosaurus dilatus
		Plethodontidae	
			Prodesmodon copei
		Caudata indeterminate	
REPTILIA			
	Testudines		
		Baenidae	
			Baenidae indeterminate
		Chelydridae	
			Chelydridae indeterminate
		Dermatemydidae	
			Adocus sp.
			Basilemys sp.
		Trionychoidae	
			Trionychoidae indeterminate
REPTILIA (continued)			
	Lepidosauria		
		Teiidae	
			Chamops segnis
			Leptochamops denticulatus
			Teiidae indeterminate
		Anguidae	
			cf. *Odaxosaurus piger*
		Anguimorpha	
			?*Litakis gilmorei*
		Helodermatidae	
			Helodermatidae indeterminate
		Lepidosauria indeterminate	
	Choristodera		
		Champsosauridae	
			Champsosaurus sp.
	Crocodilia		
		Crocodylidae	
		Alligatorinae	
			Brachychampsa montana
		Crocodylinae	
			Leidyosuchus sternbergi
	Ornithischia		
		Ceratopsidae	
			Ceratopsidae indeterminate
		Hadrosauridae	
			Hadrosauridae indeterminate
		Ankylosauridae	
			Ankylosauridae indeterminate
		Pachycephalosauridae	
			Pachycephalosauridae indeterminate
	Saurischia		
		Velociraptorinae	
			Saurornitholestes langstoni
		Tyrannosauridae	
			c.f. *Tyrannosaurus rex*
		Incertae sedis	
			Paronychodon lacustris
			Richardoestesia isosceles
			Richardoestesia gilmorei
		Theropoda indeterminate	
MAMMALIA			
		Therian indeterminate	

JPC FAUNAL ASSEMBLAGE

Class	Order	Family	Genus/Species (Lowest Taxon)
CHONDRICTHYES			
	Batoidea		
		Anacoracidea	
			Myledaphus bipartitus
OSTEICHTHYES			
	Acipenseriformes		
		Acipenseridae	
			Acipenser indeterminate
	Amiiformes		
		Amiidae	
			Amiidae indeterminate
	Order indeterminate		
		Holostean A	
		Holostean B	
		Holostean indeterminate	
	Lepisosteiformes		
		Lepisosteidae	
			Lepisosteus occidentalis
	Teleostei		
		Asperidorhynchidae	
			Belonostomus longirostris
		Elopidae	
			?*Paratarpon apogerontus*
			Parabula sp.
			Elopomorph indeterminate
		Albulidae	
			Coriops amnicolus
		Teleost indeterminate	
AMPHIBIA			
	Anura		
		Anura indeterminate	
	Caudata		
		Batrachosaurididae	
			Opisthotriton kayi
		Scapherpetodontidae	
			Scapherpeton tectum
		Sirenidae	
			Habrosaurus dilatus
		Plethodontidae	
			Prodesmodon copei
		Caudata indeterminate	
REPTILIA			
	Testudines		
		Baenidae	
			Baenidae indeterminate
		Chelydridae	
			Chelydridae indeterminate
		Dermatemydidae	
			Adocus sp.
		Trionychoidae	
			Aspideretoides sp.
			Trionychoidae indeterminate
REPTILIA (continued)			
	Lepidosauria		
		Teiidae	
			Leptochamops denticulatus
			Teiid indeterminate
		Anguidae	
			Odaxosaurus piger
		Parasaniwaidae	
			Parasaniwa wyomingensis
		Lepidosauria indeterminate	
	Choristodera		
		Champsosauridae	
			Champsosaurus sp.
	Crocodilia		
		Crocodylidae	
		Alligatorinae	
			Brachychampsa montana
		Crocodylinae	
			Leidyosuchus sternbergi
	Ornithischia		
		Ceratopsidae	
			Ceratopsidae indeterminate
		Hadrosauridae	
			Hadrosauridae indeterminate
		Euornithopoda	
			Euornithopoda indeterminate
		Ankylosauridae	
			Ankylosauridae indeterminate
		Pachycephalosauridae	
			Pachycephalosauridae indeterminate
	Saurischia		
		Velociraptorinae	
			Dromaeosaurus albertensis
		Tyrannosauridae	
			c.f. *Tyrannosaurus rex*
		Incertae sedis	
			Paronychodon lacustris
			Richardoestesia isosceles
		Theropoda indeterminate	
MAMMALIA			
	Multituberculata		
		Cimolodontidae	
			Cimolodon sp.
		Cimolomyidae	
			Cimolomys gracilis
		Neoplagiaulacidae	
			Mesodma sp.
		Multituberculata indeterminate	
	Marsupialia		
		Pediomyidae	
			Pediomys ?*florencae*
	Eutheria		
		Lepictoidae	
			Gyponictop ?*illuminatus*
	Mammalia indeterminate		

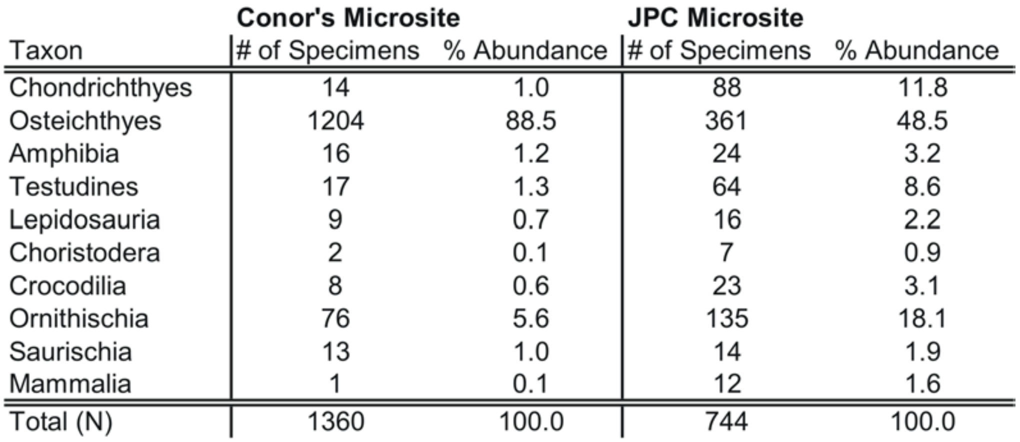
APPENDIX B

RANK ORDER

Conor's Microsite			**JPC Microsite**		
Taxon	Number of Specimens	Rank Order	Taxon	Number of Specimens	Rank Order
Teleostei	726	1	Amiidae	149	1
Amiidae	224	2	Ornithischia	135	2
L. occidentalis	130	3	*M. bipartitus*	88	3
Holostean	94	4	*L. occidentalis*	75	4
Ornithischia	76	5	Teleostei	66	5
Testudines	17	6	Testudines	64	6
Caudata	16	7	Holostean	60	7
M. bipartitus	13	8	Crocodilia	23	8
Acipenser	10	9	Caudata	22	9
Lepidosauria	9	10	Lepidosauria	16	10
Crocodilia	8	11.5	Mammalia	12	11
Small Theropod	8	11.5	Acipenser	9	12
Choristodera	2	13	Large Theropod	8	13
Elasmobranchii	1	15	Choristodera	7	14
Large Theropod	1	15	Small Theropod	5	15
Mammalia	1	15	Anura	2	16
Anura	0	17	Elasmobranchii	0	17
Total (N)	1336		Total (N)	741	

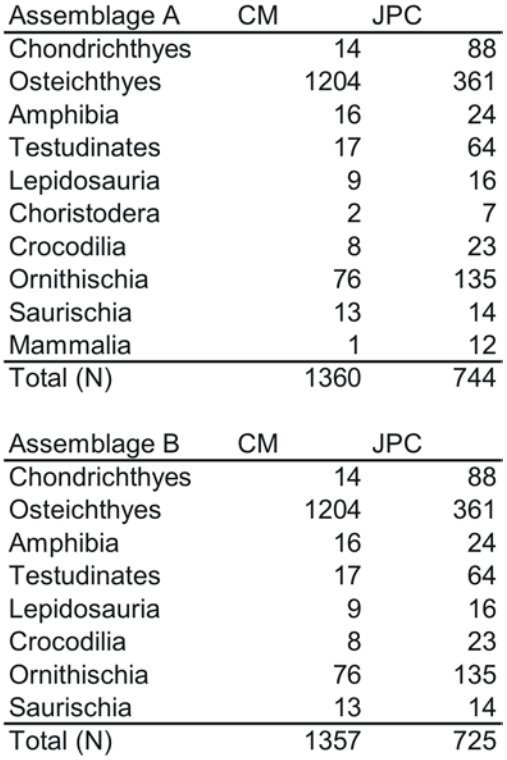
APPENDIX C

RELATIVE ABUNDANCE DATA SETS



	Conor's Microsite		JPC Microsite	
Taxon	# of Specimens	% Abundance	# of Specimens	% Abundance
Chondrichthyes	14	1.0	88	11.8
Osteichthyes	1204	88.5	361	48.5
Amphibia	16	1.2	24	3.2
Testudines	17	1.3	64	8.6
Lepidosauria	9	0.7	16	2.2
Choristodera	2	0.1	7	0.9
Crocodilia	8	0.6	23	3.1
Ornithischia	76	5.6	135	18.1
Saurischia	13	1.0	14	1.9
Mammalia	1	0.1	12	1.6
Total (N)	1360	100.0	744	100.0

Total number and percent relative abundance of specimens used in relative abundance bar chart (Figure 11).



Assemblage A	CM	JPC
Chondrichthyes	14	88
Osteichthyes	1204	361
Amphibia	16	24
Testudinates	17	64
Lepidosauria	9	16
Choristodera	2	7
Crocodilia	8	23
Ornithischia	76	135
Saurischia	13	14
Mammalia	1	12
Total (N)	1360	744

Assemblage B	CM	JPC
Chondrichthyes	14	88
Osteichthyes	1204	361
Amphibia	16	24
Testudinates	17	64
Lepidosauria	9	16
Crocodilia	8	23
Ornithischia	76	135
Saurischia	13	14
Total (N)	1357	725

Total number of specimens used in chi-squared of taxonomic compositions (Table 4). Assemblage A corresponds to the first (A) analysis and Assemblage B corresponds to the second (B) analysis where taxa with sample sizes lower than 4 (Choristodera and Mammalia) were removed.

APPENDIX D

SAMPLES USED IN SHAPE-TAXON CHI-SQUARED TESTS

Tabular Taxa A	CM	JPC
Acipenser	9	7
Amiidae	3	0
Holostean	94	60
L. occidentalis	128	70
Teleostei	705	59
Testudines	17	64
Lepidosauria	4	2
Crocodilian	4	11
Theropoda	5	0
Total (N)	969	273

Tabular Taxa B	CM	JPC
Acipenser	9	7
Holostean	94	60
L. occidentalis	128	70
Teleostei	705	59
Reptilia	30	77
Total (N)	966	273

Number of plate-shaped elements per taxon used in chi-squared analysis and power tests in Table 5a. Taxonomic assemblage B corresponds to the second test in which taxa with small sample sizes are removed (Amiidae) or aggregated (Reptilia).

Equidimensional Taxa A	CM	JPC
Chondrichthyes	14	88
Amiidae	221	137
L. occidentalis	1	5
Teleostei	19	8
Caudata	8	19
Lepidosauria	0	3
Choristodera	2	6
Crocodilian	4	9
Ornithischia	76	135
Saurischia	3	12
Total (N)	348	422

Equidimensional Taxa B	CM	JPC
Chondrichthyes	14	88
Amiidae	221	137
Teleostei	19	8
Caudata	8	19
Reptilia	85	165
Total (N)	347	417

Number of equidimensional-shaped elements per taxon used in chi-squared analysis and power tests in Table 5b. Taxonomic assemblage B corresponds to the second test in which taxa with small sample sizes are removed (*L. occidentalis*) or aggregated (Reptilia).

APPENDIX E

SAMPLES USED IN TAXON-SHAPE CHI-SQUARED TESTS

Osteichthyes	CM	JPC
Shape 1	1414	311
Shape 2	12	6
Shape 3	221	158
Shape 4	25	8
Total (N)	1672	483

Teleostei A	CM	JPC
Shape 1	705	60
Shape 2	9	3
Shape 3	12	6
Shape 4	0	0
Total (N)	726	69

Teleostei B	CM	JPC
Shape 1	705	60
Shape 2	9	3
Shape 3	12	6
Total (N)	726	69

Non-Teleost Fish	CM	JPC
Shape 1	256	139
Shape 2	1	0
Shape 3	200	152
Shape 4	21	2
Total (N)	478	293

Lepidosauria	CM	JPC
Shape 1	4	2
Shape 2	3	6
Shape 3	0	3
Shape 4	2	5
Total (N)	9	16

Caudata	CM	JPC
Shape 1	0	0
Shape 2	8	2
Shape 3	8	20
Shape 4	0	0
Total (N)	16	22

Sample sizes of the number of elements in shape classes 1-4 within specific taxa used in Table 6. The Teleost B assemblage does not include shape class 4 because of low sample sizes in both assemblages. Also note the low sample sizes in both the Lepidosauria and Caudata data sets (which correspond to low powers in Table 6).

APPENDIX F

SAMPLES USED IN CHI-SQUARED TESTS OF HYDRODYNAMICALLY EQUIVALENT ELEMENTS

Ganoid Scales

	CM	JPC
Acipenser	5	3
Holostean A	75	30
Holostean B	7	2
L. occidentalis	124	65
Total (N)	211	100

Caudata

	CM	JPC
O. kayi	5	8
S. tectum	4	5
H. dilatus	3	4
P. copei	2	1
Total (N)	14	18

Testudines

	CM	JPC
Baenidae	1	19
Chelydridae	4	11
Basilmys sp.	3	0
Adocus sp.	1	2
Trionychidae	7	24
Total (N)	16	56

Testudines*

	CM	JPC
Baenidae	1	19
Chelydridae	4	11
Adocus sp.	1	2
Trionychidae	7	24
Total (N)	13	56

*Does not include *Basilemys* sp.

Ornithischians

	CM	JPC
Ceratopsidae	20	22
Hadrosauridae	8	18
Euornithopoda	0	1
Ankylosauridae	1	2
Pachycephalosauridae	5	5
Total (N)	34	48

Theropoda

	CM	JPC
D. albertensis	0	2
Tyrannosauridae	1	8
S. langstoni	2	0
P. lacustris	2	2
R. isosceles	1	1
R. gilmorei	3	0
Total (N)	9	13

Dinosauria

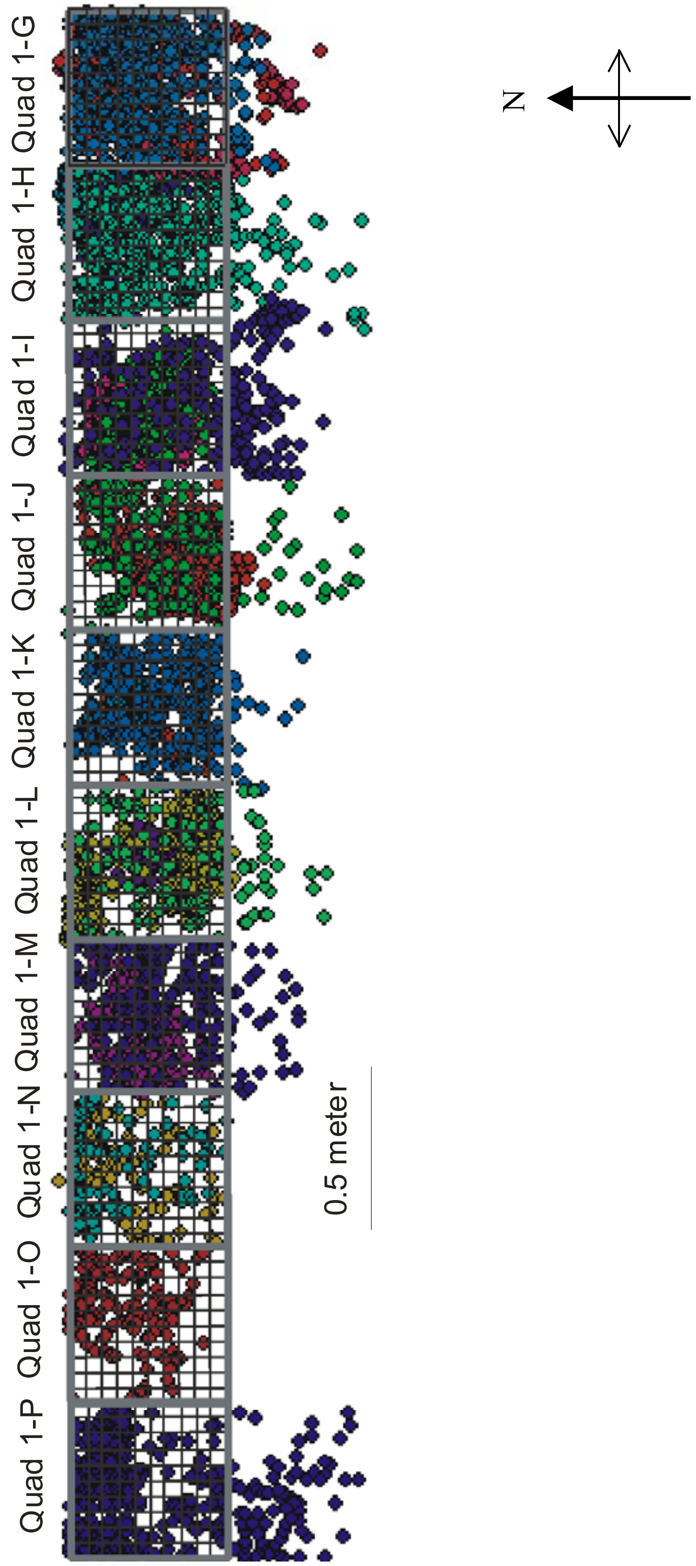
	CM	JPC
Ceratopsidae	20	22
Hadrosauridae	8	18
Euornithopoda	0	1
Ankylosauria	1	2
Pachycephalosauridae	5	5
D. albertensis	0	2
Tyrannosauridae	1	8
S. langstoni	2	0
P. lacustris	2	2
R. isosceles	1	1
R. gilmorei	3	0
Total (N)	43	61

Taxa and sample sizes used in chi-squared analysis, power tests, and Spearman's rank order analysis of hydrodynamically equivalent specimens between the CM and JPC assemblages (Table 7a, b). The Testudines* assemblage does not include the terrestrial turtle *Basilemys* sp. Ornithischia B assemblage in Table 7a and 7b does not include the Euornithopoda specimen.

APPENDIX G

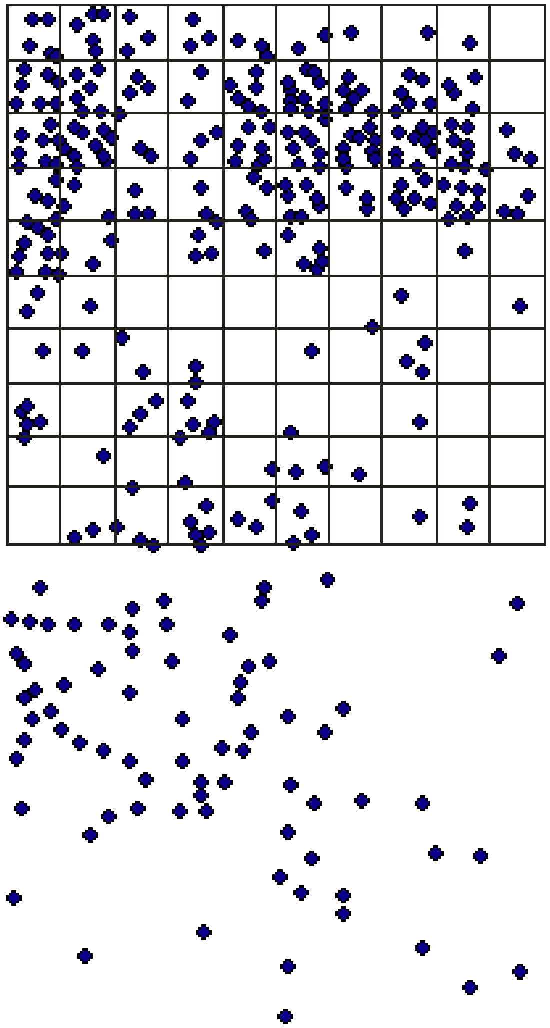
QUARRY MAPS FOR CM AND JPC MICROSITES

CM QUARRY MAP



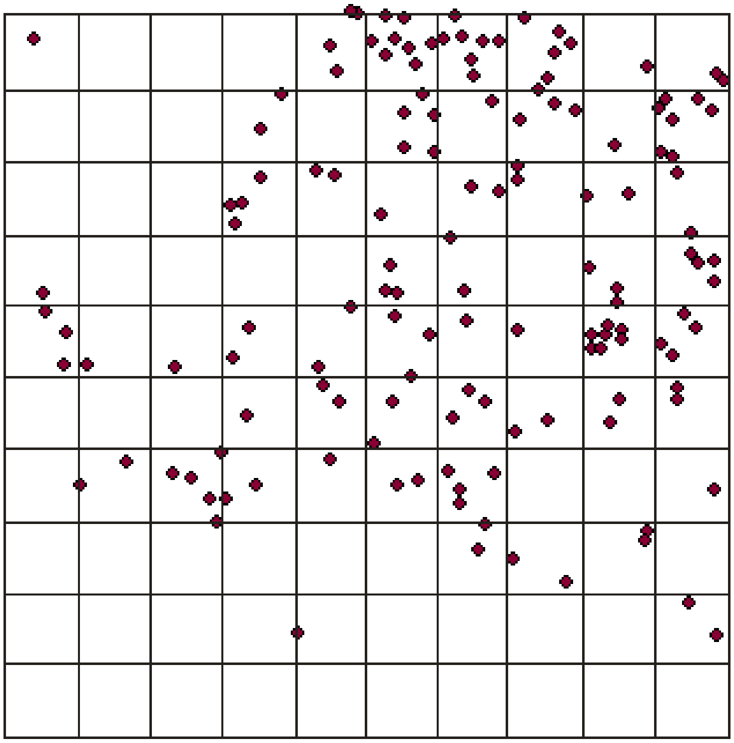
CM QUARRY MAPS (Continued)

Quadrant 1-G



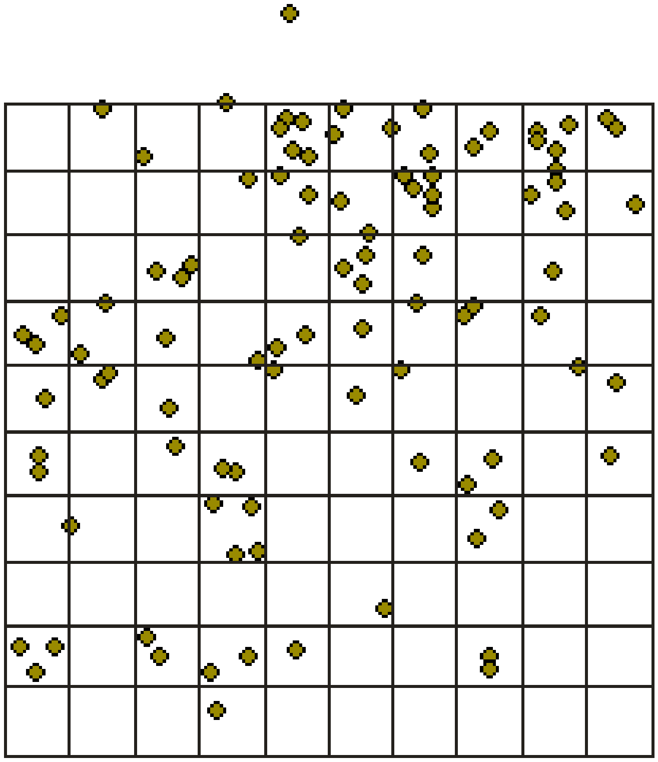
CM QUARRY MAPS (Continued)

Quadrant 1-H



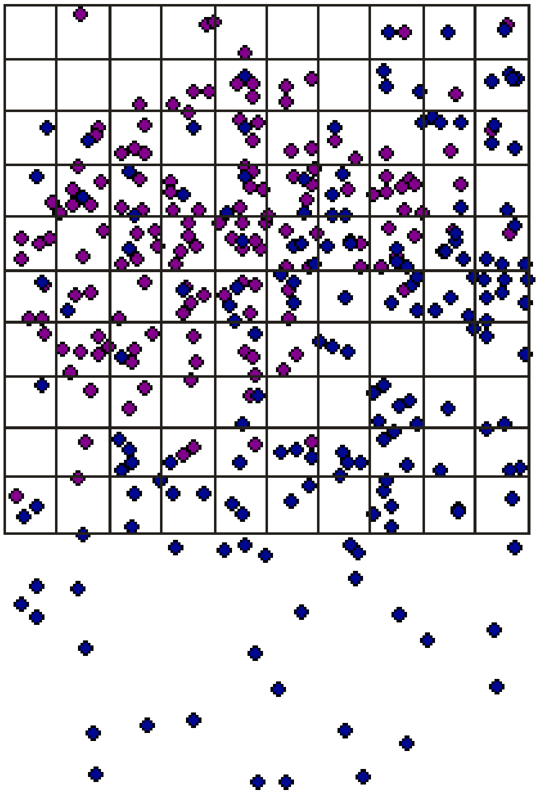
CM QUARRY MAPS (Continued)

Quadrant 1-I



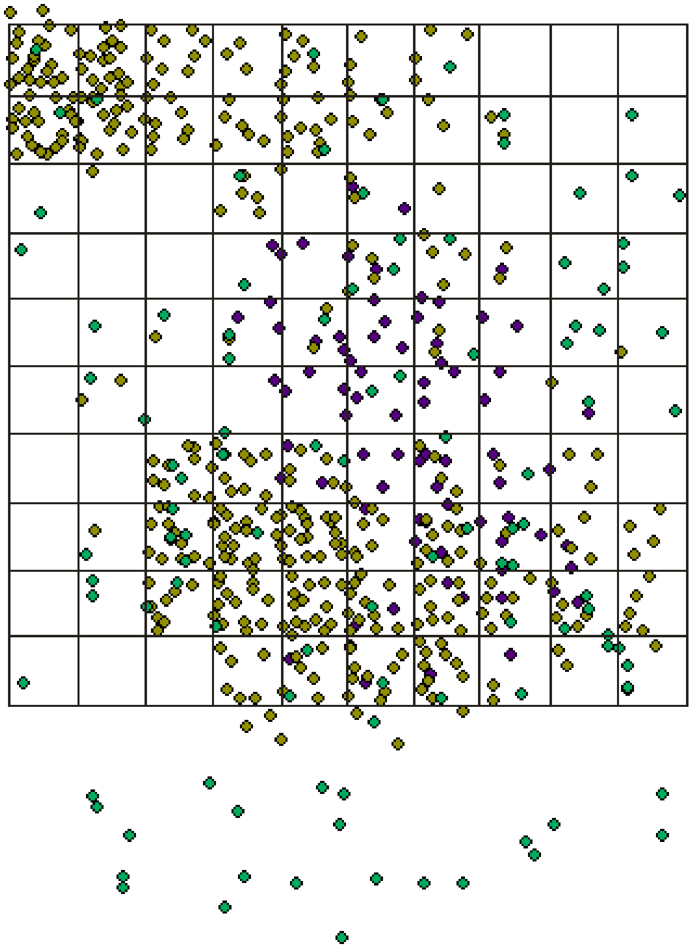
CM QUARRY MAPS (Continued)

Quadrant 1-J



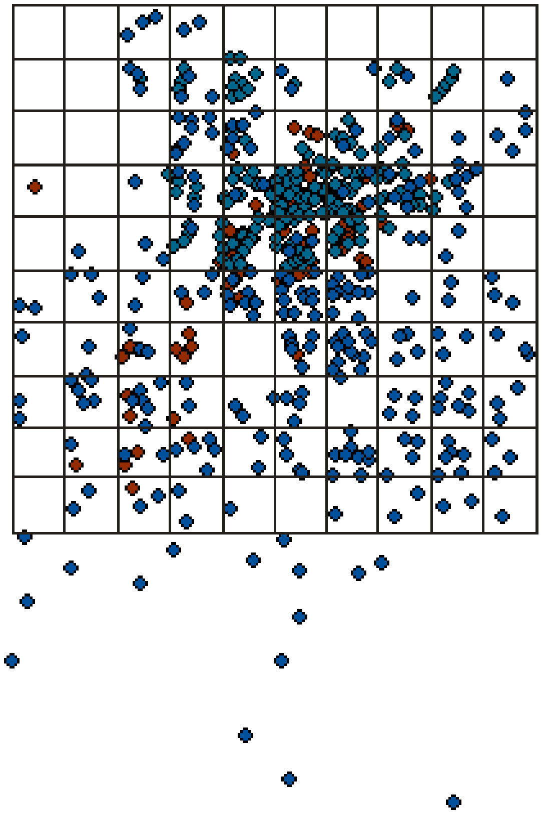
CM QUARRY MAPS (Continued)

Quadrant 1-K



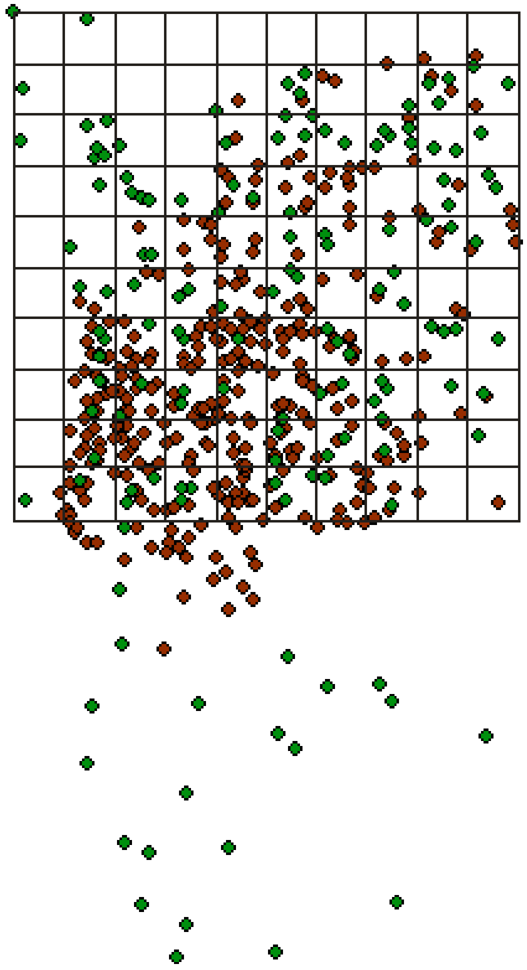
CM QUARRY MAPS (Continued)

Quadrant 1-L



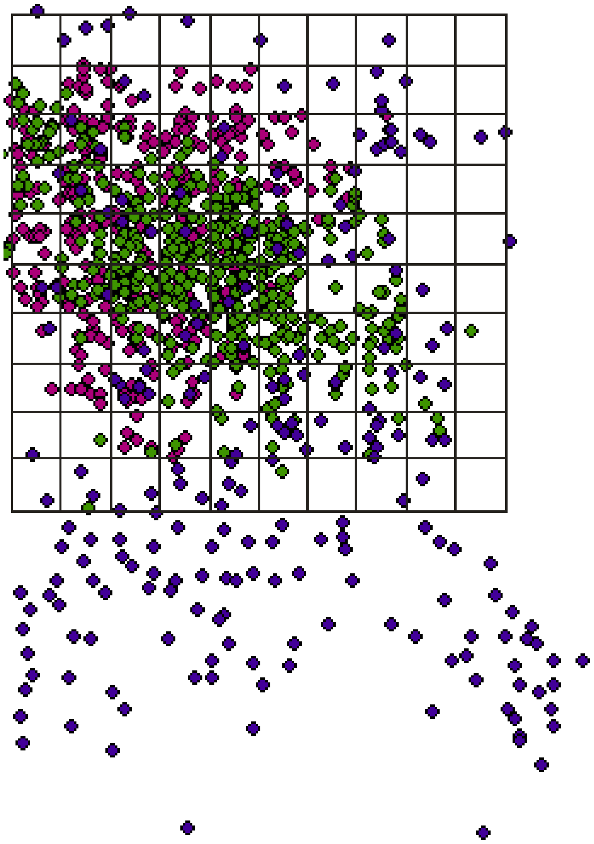
CM QUARRY MAPS (Continued)

Quadrant 1-M



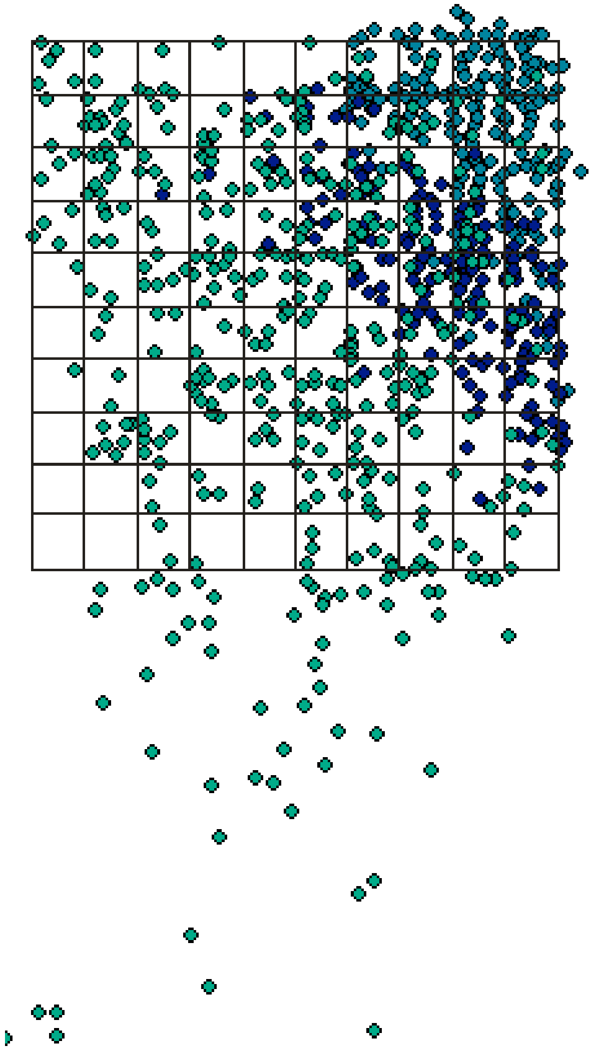
CM QUARRY MAPS (Continued)

Quadrant 1-N



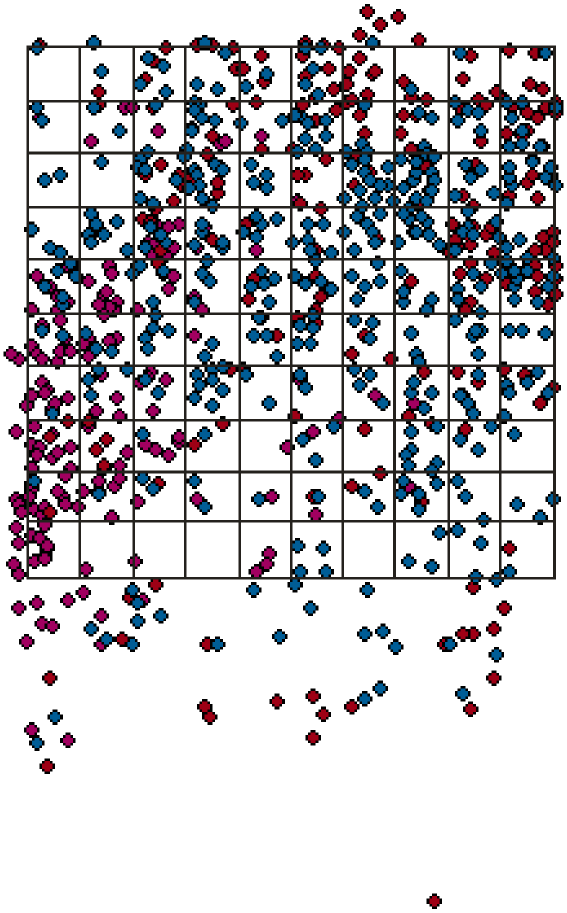
CM QUARRY MAPS (Continued)

Quadrant 1-O

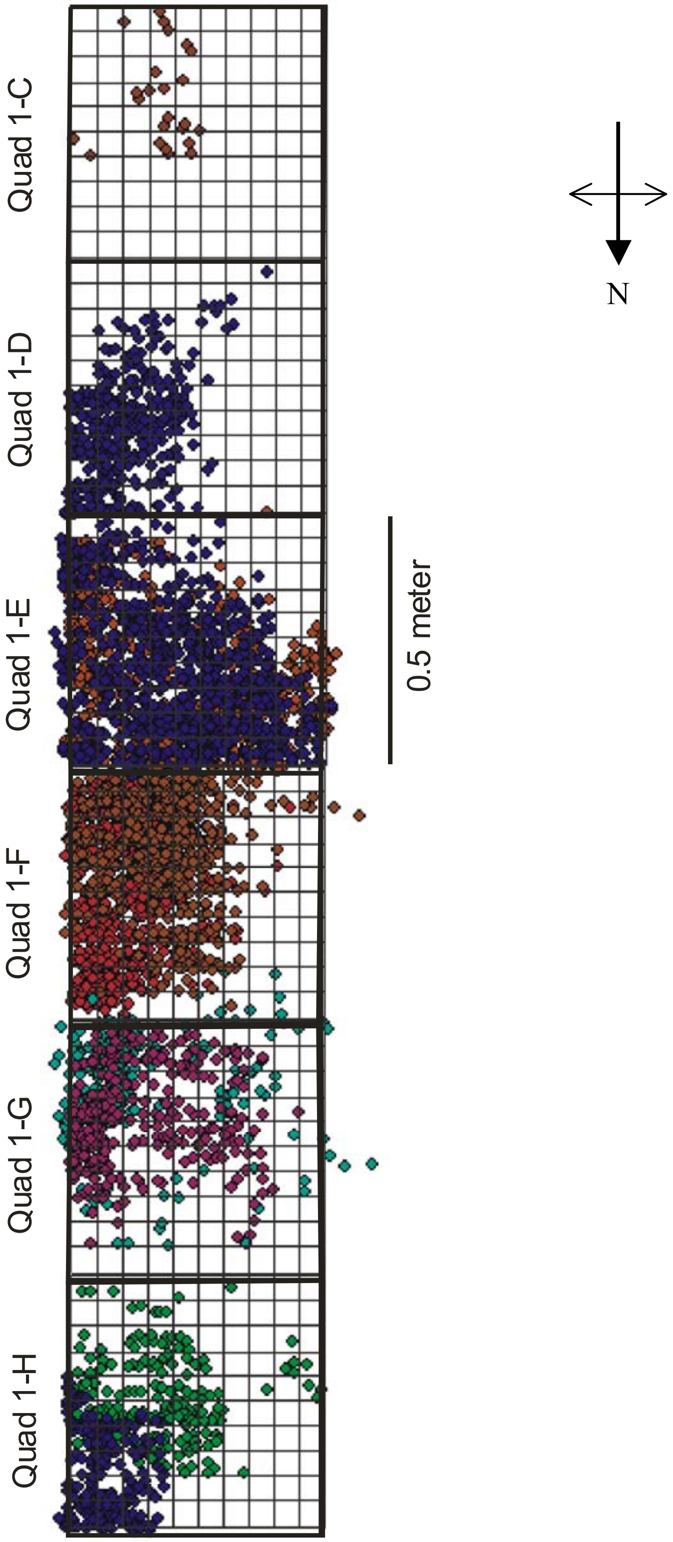


CM QUARRY MAPS (Continued)

Quadrant 1-P

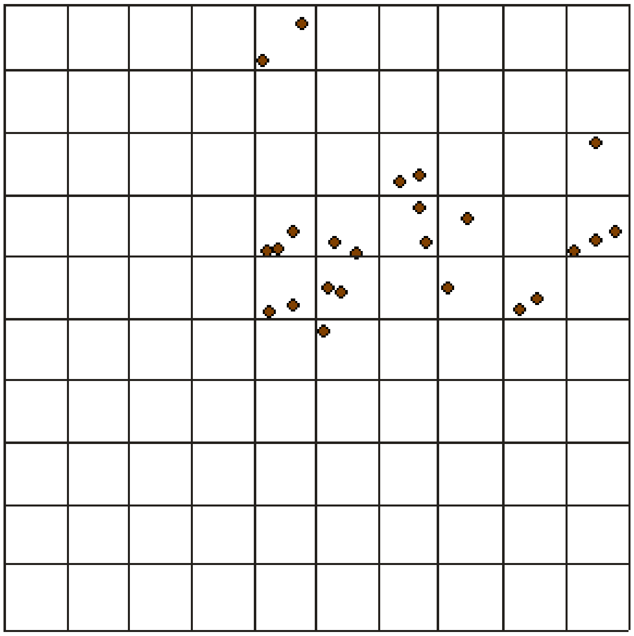


JPC QUARRY MAP



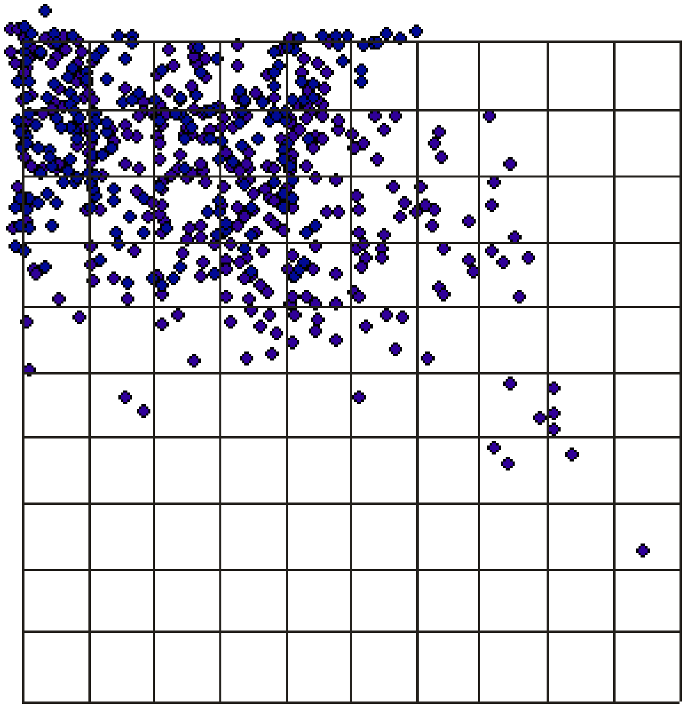
JPC QUARRY MAPS (Continued)

Quadrant 1-C



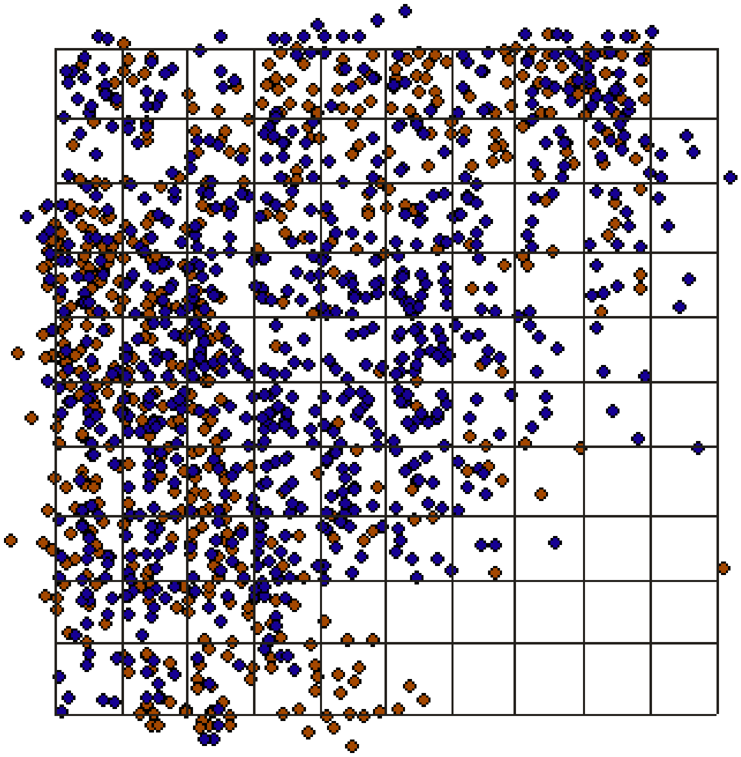
JPC QUARRY MAPS (Continued)

Quadrant 1-D



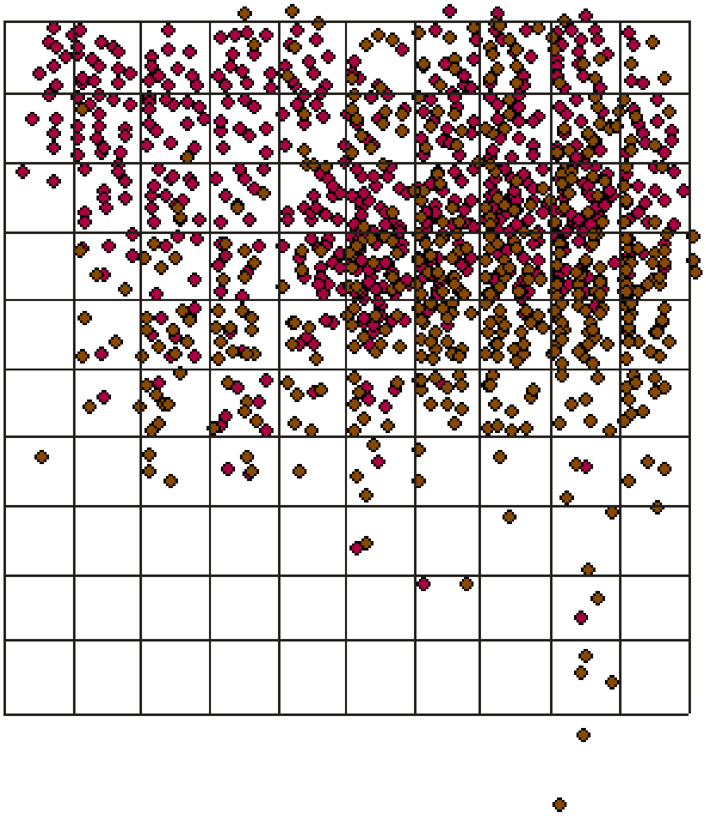
JPC QUARRY MAPS (Continued)

Quadrant 1-E



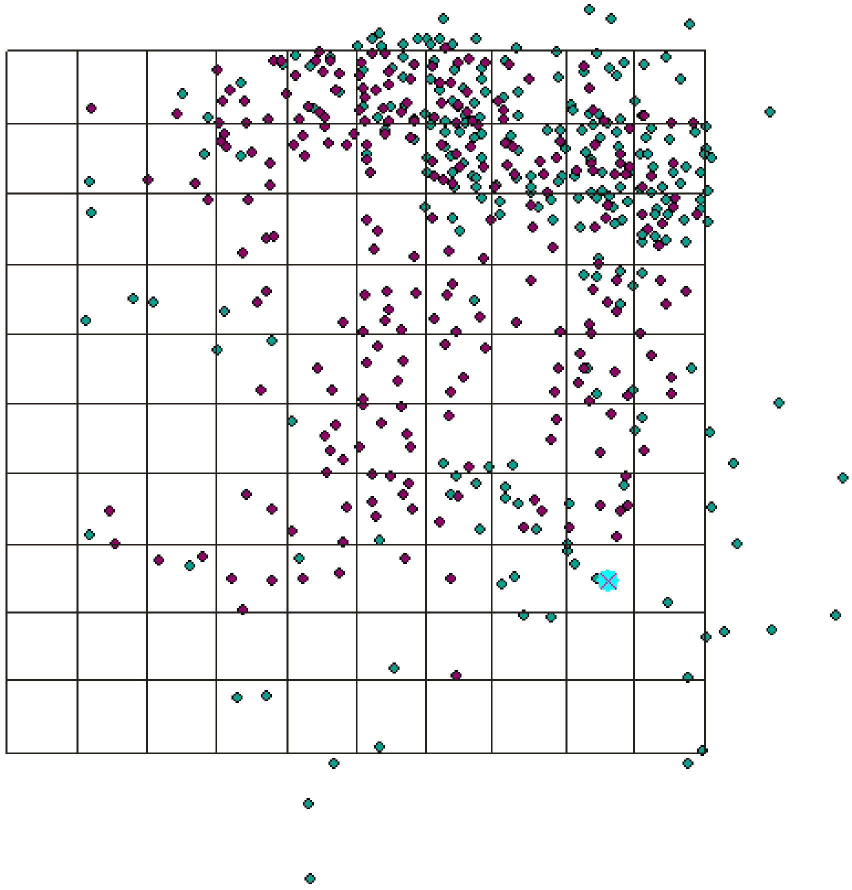
JPC QUARRY MAPS (Continued)

Quadrant 1-F



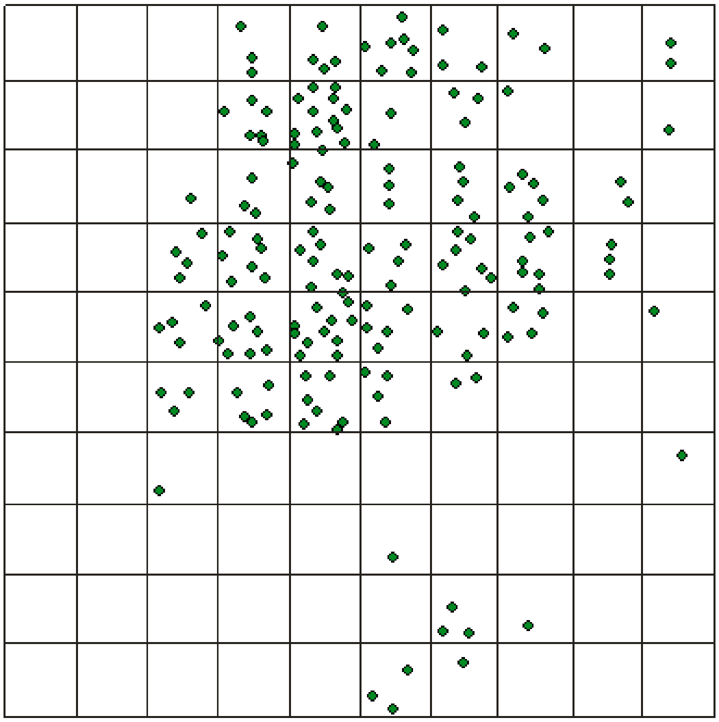
JPC QUARRY MAPS (Continued)

Quadrant 1-G



JPC QUARRY MAPS (Continued)

Quadrant 1-H



APPENDIX H

TAXONOMIC DISTRIBUTION AND SAMPLE SIZE BY QUADRANT

CM QUADRANTS

QUAD 1-G

Veretbrata indeterminate	95
Myledaphus bipartitus	2
Osteichthyes indeterminate	49
Amiidae indeterminate	44
Holostean A	6
Holostean B	2
Holostean indeterminate	1
Lepisosteus occidentalis	32
Teleost indeterminate	52
Amphibia indeterminate	1
Opisthotriton kayi	2
Habrosaurus dilatus	1
Testudines indeterminate	1
Chelydridae indeterminate	2
Leptochamops denticulatus	1
Champsosaurus sp.	1
Ornithischia indeterminate	8
Ceratopsidae indeterminate	3
Hadrosauridae indeterminate	1
Richardoestesia gilmorei	2
Total Specimens	**306**

QUAD 1-H

Vertebrata indeterminate	26
Osteichthyes indeterminate	22
Amiidae indetermiante	7
Holostean A	3
Holostean indeterminate	2
Teleostei indetermiante	57
Belonostomus longirostris	1
Paratarpon apogerontus	1
Amphibia indeterminate	1
Prodesmodon copei	1
Crocodilia indeterminate	1
Ornithischia indeterminate	2
Ceratopsidae indeterminate	1
Total Specimens	**125**

QUAD 1-I

Vertebrata indeterminate	28
Myledaphus bipartitus	2
Osteichthyes indeterminate	19
Amiidae indeterminate	17
Holostean A	3
Holostean B	2
Lepisosteus occidentalis	8
Teleostei indeterminate	15
Trionychidae indeterminate	1
Chamops segnis	1
Odaxosaurus piger	1
Total Specimens	**97**

QUAD 1-J

Vertebrata indeterminate	31
Osteichthyes indeterminate	18
Acipenser indeterminate	1
Amiidae indeterminate	17
Holostean A	7
Holostean indeterminate	2
Lepisosteus occidentalis	10
Teleostei indeterminate	68
Caudata indeterminate	1
Helodermatidae indeterminate	1
Ornithischian indeterminate	1
Ceratopsidae indeterminate	1
Hadrosauridae indeterminate	1
Pachycephalosauridae indeterminate	1
Theropoda indeterminate	1
Saurornitholestes langstoni	1
Total Specimens	**162**

QUAD 1-K

Vertebrata indeterminate	17
Osteichthyes indeterminate	31
Acipenser indeterminate	1
Amiidae indeterminate	11
Holostean A	1
Holostean B	1
Holostean indeterminate	2
Lepisosteus occidentalis	11
Teleostei indeterminate	20
Belonostomus longirostris	2
Trionychidae indeterminate	1
Litakis gilmorei	1
Crocodilia indeterminate	1
Brachychampsa montana	1
Ornithischia indeterminate	4
Ceratopsidae indeterminate	1
Pachycephalosauridae indeterminate	1
Total Specimens	**107**

QUAD 1-L

Vertebrata indeterminate	32
Myledaphus bipartitus	1
Elasmobranchii indeterminate	1
Osteichthyes indeterminate	58
Amiidae indeterminate	16
Holostean A	11
Lepisosteus occidentalis	13
Teleostei indeterminate	101
Coriops amnicolus	1
Brachychampsa montana	1
Borealosuchus sternbergi	1
Ornithischia indeterminate	1
Ceratopsidae indeterminate	2
Hadrosauridae indeterminate	1
Total Specimens	**240**

CM QUADRANTS (Continued)

QUAD 1-M

Vertebrata indeterminate	32
Myledaphus bipartitus	1
Osteichthyes indeterminate	31
Acipenser indeterminate	1
Amiidae indeterminate	17
Holostean A	3
Holostean indeterminate	1
Lepisosteus occidentalis	8
Teleostei indeterminate	23
Prodesmodon copei	1
Chelydridae indeterminate	1
Basilemys sp.	1
Adocus sp.	1
Trionychidae indeterminate	1
Champsosaurus sp.	1
Ornithischian indeterminate	6
Ceratopsidae indeterminate	2
Hadrosauridae indeterminate	3
Pachycephalosauridae indeterminate	1
Saurornitholestes langstoni	1
Total Specimens	**136**

QUAD 1-N

Vertebrata indeterminate	37
Myledaphus bipartitus	1
Osteichthyes indeterminate	53
Acipenser indeterminate	1
Amiidae indeterminate	13
Holostean A	9
Lepisosteus occidentalis	8
Teleostei indeterminate	62
Belonostomus longirostris	2
Coriops amnicolus	1
Opisthotriton kayi	1
Reptilia indeterminate	1
Baenidae indeterminate	1
Basilemys sp.	1
Trionychidae indeterminate	1
Ornithischia indeterminate	9
Ceratopsidae indeterminate	4
Theropoda indeterminate	2
Paronychodon lacustris	1
Richardoestesia gilmorei	1
Total Specimens	**209**

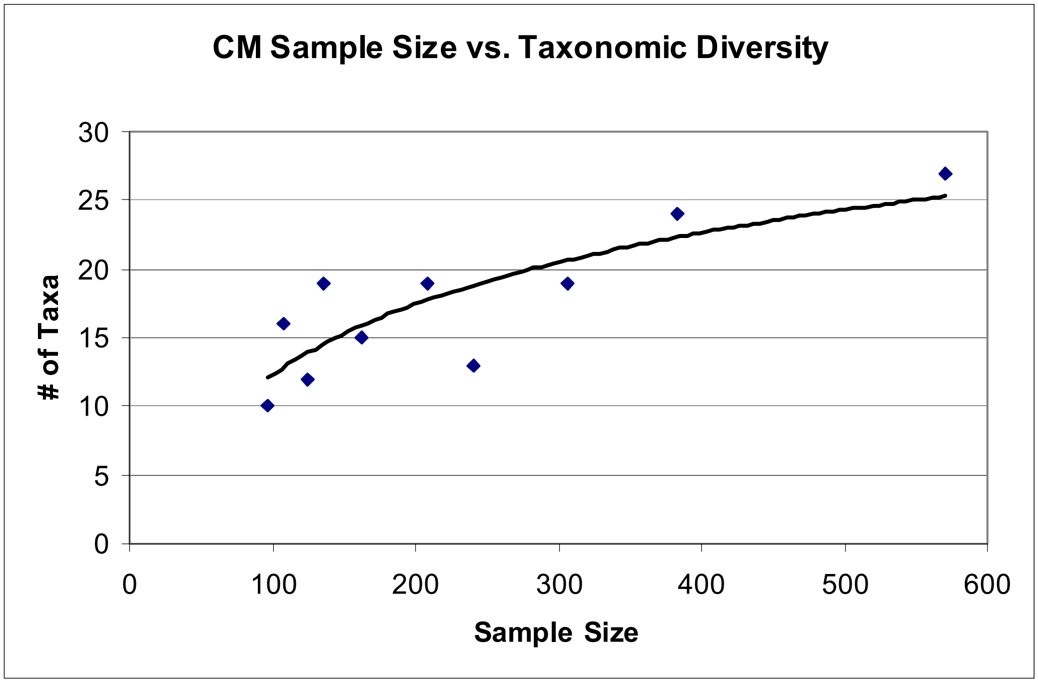
QUAD 1-O

Vertebrata indeterminate	81
Osteichthyes indeterminate	74
Acipenser indeterminate	2
Amiidae indeterminate	33
Holostean A	9
Holostean B	2
Holostean indeterminate	1
Lepisosteus occidentalis	19
Teleostei indeterminate	135
Belonostomus longirostris	2
Caudata indeterminate	2
Opisthotriton kayi	2
Scapherpeton tectum	2
Habrosaurus dilatus	1
Reptilia indeterminate	3
Trionychidae indeterminate	2
Teiidae indeterminate	1
Leptochamops denticulatus	1
Helodermatidae indeterminate	1
Borealosuchus sternbergi	1
Ornithischia indeterminate	3
Ceratopsidae indeterminate	3
Hadrosauridae indeterminate	1
Pachycephalosauridae indeterminate	1
Theropoda indeterminate	1
Total Specimens	**383**

QUAD 1-P

Vertebrata indeterminate	128
Myledaphus bipartitus	5
Osteichthyes indeterminate	106
Acipenser indeterminate	3
Amiidae indeterminate	60
Holostean A	23
Holostean indeterminate	2
Lepisosteus occidentalis	17
Teleostei indeterminate	196
Belonostomus longirostris	1
Estesesox sp.	1
Caudata indeterminate	1
Scapherpeton tectum	1
Habrosaurus dilatus	1
Reptilia indeterminate	3
Chelydridae indeterminate	2
Basilemys sp.	1
Trionychidae indeterminate	1
Lepidosauria indeterminate	1
Crocodilia indeterminate	1
Ornithischia indeterminate	7
Ceratopsidae indeterminate	3
Hadrosauridae indeterminate	2
Ankylosauridae indeterminate	1
Pachycephalosauridae indeterminate	1
Theropoda indeterminate	1
Paronychodon lacustris	1
Richardoestesia isosceles	1
Total Specimens	**571**

Boxes show the number of specimens in each taxon from quarried quadrants in the CM assemblage.



Graph shows the correlation between the number of taxa and number of quarried specimens collected from each quadrant in the CM assemblage.

JPC QUADRANTS

QUAD 1-C

Vertebrata indeterminate	5
Myledaphus bipartitus	1
Osteichthyes indeterminate	9
Amiidae indeterminate	3
Holostean indeterminate	1
Lepisosteus occidentalis	3
Belonostomus longirostris	1
Theropoda indeterminate	1
Total Specimens	**24**

QUAD 1-D

Vertebrata indeterminate	234
Myledaphus bipartitus	31
Osteichthyes indeterminate	32
Acipenser indeterminate	2
Amiidae indeterminate	41
Holostean A	8
Holostean B	1
Lepisosteus occidentalis	25
Paratarpon apogerontus	1
Elopomorph indeterminate	1
Caudata indeterminate	1
Opisthotriton kayi	3
Scapherpeton tectum	2
Habrosaurus dilatus	1
Reptilia indeterminate	5
Testudines indeterminate	2
Baenidae indeterminate	3
Trionychidae indeterminate	2
Lepidosauria indeterminate	1
Champsosaurus sp.	2
Borealosuchus sternbergi	3
Dinosauria indeterminate	1
Ornithischia indeterminate	14
Ceratopsidae indeterminate	7
Hadrosauridae indeterminate	3
Ankylosauridae indeterminate	2
Pachycephalosauridae indeterminate	4
Euornithopoda indeterminate	1
Theropoda indeterminate	2
Mammalia indeterminate	2
Gyponictop illuminatus	1
Total Specimens	**438**

QUAD 1-E

Vertebrata indeterminate	335
Myledaphus bipartitus	24
Osteichthyes indeterminate	44
Acipenser indeterminate	5
Amiidae indeterminate	34
Holostean A	10
Holostean B	1
Holostean indeterminate	9
Lepisosteus occidentalis	20
Teleostei indeterminate	1
Paratarpon apogerontus	1
Coriops amnicolus	2
Caudata indeterminate	1
Opisthotriton kayi	2
Scapherpeton tectum	1
Habrosaurus dilatus	3
Reptilia indeterminate	4
Testudines indeterminate	1
Baenidae indeterminate	2
Chelydridae indetermiante	5
Trionychidae indeterminate	7
Lepidosauria indeterminate	4
Teiidae indeterminate	1
Odaxosaurus piger	2
Champsosaurus sp.	3
Crocodilia indeterminate	2
Borealosuchus sternbergi	2
Ornithischia indeterminate	23
Ceratopsidae indeterminate	8
Hadrosauridae indeterminate	9
Pachycephalosauridae indeterminate	1
Dromaeosaurus albertensis	1
Richardoestesia isosceles	1
Mammalia indeterminate	2
Multituberculata indeterminate	1
Cimolodon sp.	1
Cimolomys gracilis	1
Total Specimens	**574**

JPC QUADRANTS (Continued)

QUAD 1-F

Vertebrata indeterminate	611
Myledaphus bipartitus	20
Osteichthyes indeterminate	59
Amiidae indeterminate	58
Holostean A	10
Holostean indeterminate	11
Lepisosteus occidentalis	15
Teleostei indeterminate	3
Parabula sp.	1
Anura indeterminate	2
Caudata indeterminate	7
Opisthotriton kayi	2
Prodesmodon copei	1
Reptilia indeterminate	6
Testudines indeterminate	2
Baenidae indeterminate	5
Chelydridae indetermiante	5
Trionychidae indeterminate	7
Lepidosauria indeterminate	3
Teiidae indeterminate	1
Leptochamops denticulatus	1
Parasaniwa wyomingensis	1
Champsosaurus sp.	1
Crocodilia indeterminate	9
Brachychampsa montana	1
Borealosuchus sternbergi	1
Dinosauria indeterminate	11
Ornithischia indeterminate	21
Ceratopsidae indeterminate	4
Hadrosauridae indeterminate	5
Theropoda indeterminate	2
Tryannosauridae indeterminate	1
Paronychodon lacustris	1
Multituberculata indeterminate	1
Mesodma sp.	1
Total Specimens	**890**

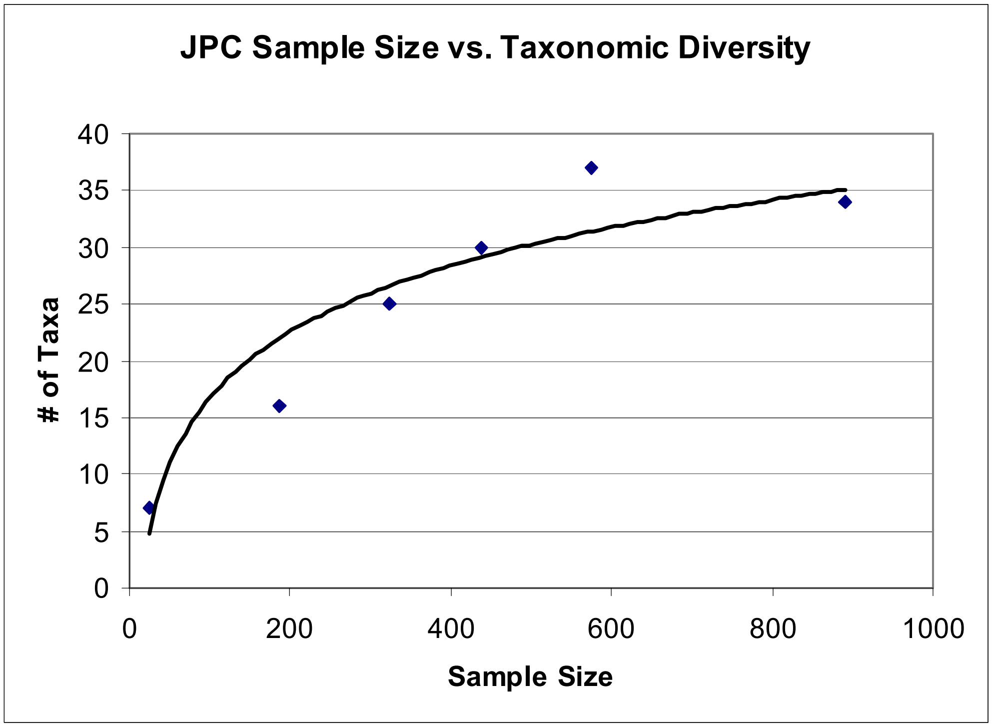
QUAD 1-G

Vertebrata indeterminate	174
Myledaphus bipartitus	8
Osteichthyes indeterminate	31
Acipenser indeterminate	1
Amiidae indeterminate	21
Holostean A	4
Holostean indeterminate	2
Lepisosteus occidentalis	10
Caudata indeterminate	2
Opisthotriton kayi	1
Scapherpeton tectum	2
Reptilia indeterminate	7
Testudines indeterminate	2
Baenidae indeterminate	10
Adocus sp.	2
Asperitoides sp.	1
Trionychidae indeterminate	5
Lepidosauria indeterminate	3
Teiidae indeterminate	1
Champsosaurus sp.	1
Crocodilia indeterminate	2
Dinosauria indeterminate	9
Ornithischia indeterminate	20
Ceratopsidae indeterminate	3
Dromaeosaurus albertensis	1
Tyrannosauridae indeterminate	1
Total Specimens	**324**

QUAD 1-H

Vertebrata indeterminate	122
Myledaphus bipartitus	5
Osteichthyes indeterminate	22
Acipenser indeterminate	1
Amiidae indeterminate	5
Holostean indeterminate	4
Lepisosteus occidentalis	1
Testudines indeterminate	1
Chelydridae indetermiante	1
Trionychidae indeterminate	2
Crocodilia indeterminate	2
Borealosuchus sternbergi	2
Dinosauria indeterminate	2
Ornithischia indeterminate	13
Hadrosauridae indeterminate	1
Paronychodon lacustris	1
Mammalia indeterminate	1
Total Specimens	**186**

Boxes show the number of specimens in each taxon from quarried quadrants in the JPC assemblage.



Graph shows the correlation between the number of taxa and number of quarried specimens collected from each quadrant in the JPC assemblage

APPENDIX I

QUADRANT-BY-QUADRANT ANALYSIS OF QUARRIED SPECIMENS

A

CM Abrasion

QUAD	% Stage 0	% Stage 1	% Stage 2	% Stage 3	N
1G	75.1	15.7	5.6	3.6	305
1H	76.4	18.1	2.4	3.1	127
1I	62.6	26.3	7.1	4.0	99
1J	74.5	20.5	2.5	2.5	161
1K	77.6	17.8	1.9	2.8	107
1L	91.1	8.5	0.4	0.0	235
1M	80.0	15.4	4.6	0.0	130
1N	83.3	8.4	6.4	2.0	203
1O	87.3	7.4	5.3	0.0	377
1P	89.3	7.4	1.6	1.8	568

CM Shape

QUAD	% Class 1	% Class 2	% Class 3	% Class 4	N
1G	57.2	13.8	26.1	2.8	318
1H	73.7	12.4	12.4	1.5	137
1I	60.6	11.5	26.0	1.9	104
1J	75.3	7.8	16.3	0.6	166
1K	69.2	10.3	18.8	1.7	117
1L	77.4	10.5	10.1	2.0	248
1M	60.3	17.8	18.5	3.4	146
1N	68.0	15.1	14.6	2.3	219
1O	71.1	14.3	13.6	1.0	398
1P	65.9	11.9	20.8	1.4	586

B

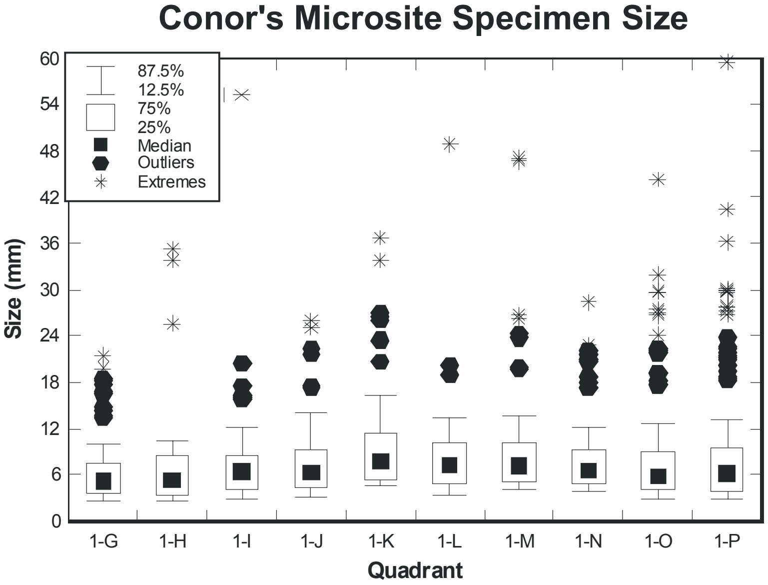
JPC Abrasion

QUAD	% Stage 0	% Stage 1	% Stage 2	% Stage 3	N
1C	66.7	19.0	14.3	0.0	21
1D	49.6	12.0	11.2	27.2	474
1E	64.1	12.7	10.3	12.9	590
1F	80.1	11.7	4.8	3.4	880
1G	71.3	16.5	6.2	5.9	321
1H	84.8	7.9	5.5	1.8	165

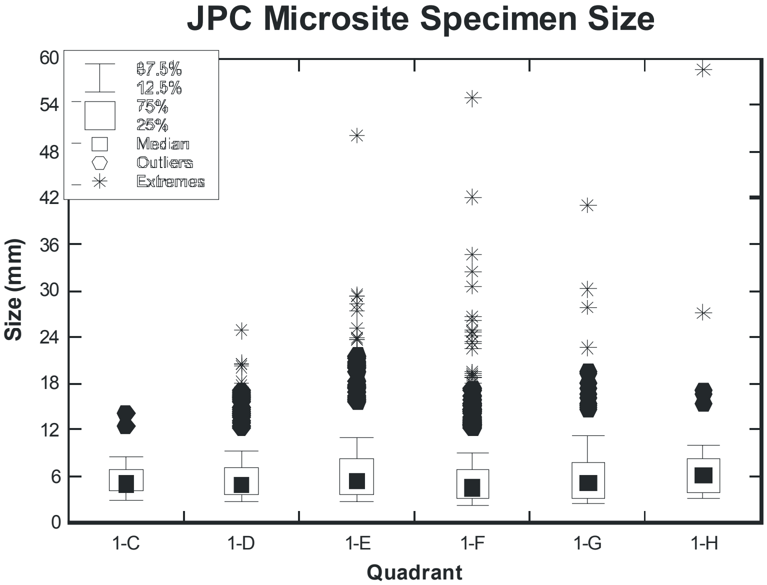
JPC Shape

QUAD	% Class 1	% Class 2	% Class 3	% Class 4	N
1C	54.2	8.3	33.3	4.2	24
1D	25.9	11.9	60.2	2.0	495
1E	35.0	15.4	48.4	1.2	597
1F	32.9	21.4	45.0	0.7	893
1G	29.2	9.9	59.3	1.6	165
1H	37.0	22.4	38.8	1.8	165

Analysis of shape class and abrasion category distribution by quadrant of quarried specimens from the CM (A) and JPC (B) assemblages. Note the skewed percentages from quadrants with low sample sizes (e.g., 1-I in the CM assemblage and 1-C in the JPC assemblage).



Box and whisker plot showing the size range of specimens collected from the Conor's Microsite quarry displayed by ¼ m^2 quadrant. The limits of the box represent the median 50% of specimens (distance between is the IQR, interquartile range). The whisker limits represent the non-outlier minimum and maximum (the median 75% of specimens). Outliers are the specimens with sizes are greater than 1.5 times the IQR, and the extremes have size values 3 times the IQR.



Box and whisker plot showing the size range of specimens collected from the JPC Microsite quarry displayed by ¼ m^2 quadrant. The limits of the box represent the median 50% of specimens (distance between is the IQR, interquartile range). The whisker limits represent the non-outlier minimum and maximum (the median 75% of specimens. Outliers are the specimens with sizes greater than 1.5 times the IQR, and the extremes have size values 3 times the IQR.

APPENDIX J

NUMBER OF SPECIMENS PER SKELETAL ELEMENT PER TAXON

Skeletal Elements and Taxa From Conor's Microsite and JPC Microsite

Taxon	Skeletal Element	CM	JPC	Dominant Shape(s)
Vertebrata	indeterminate bone	508	1491	1,2,3
Myledaphus bipartitus	tooth	13	88	3
Elasmobranchii	dermal scale	1	0	3
Osteichthyes	indeterminate bone	41	25	1,2,3
Osteichthyes	scale (cycloid)	697	55	1
Osteichthyes	skull	450	113	1
Osteichthyes	spine	3	3	2
Osteichthyes	tooth	4	4	4
Acipenser	skull	4	6	1
Acipenser	scale	3	0	1
Acipenser	osteoderm	2	3	1
Acipenser	spine	1	0	2
Amiidae	palate (usually with teeth)	39	12	3
Amiidae	mandible (sometimes with teeth)	6	7	2,3
Amiidae	palatal tooth	110	114	3
Amiidae	mandibular tooth	20	2	4
Amiidae	skull	3	0	1
Amiidae	vertebra	66	14	1,3
Holostean A	scale	75	30	1
Holostean B	scale	7	2	1
Holostean indeterminate	scale	11	22	1
Holostean indeterminate	skull	1	6	1
Lepisosteus occidentalis	scale	124	65	1
Lepisosteus occidentalis	skull	4	5	1
Lepisosteus occidentalis	tooth	1	0	4
Lepisosteus occidentalis	vertebra	1	3	3
Lepisosteus occidentalis	jaw	0	2	3
Teleostei indeterminate	vertebra	12	2	3
Teleostei indeterminate	mandible	5	2	1,2,3
Teleostei indeterminate	skull	0	2	1
Belonostomus longirostris	scale	8	1	1,2
Paratarpon apogerontus	maxilla	1	1	2
Paratarpon apogerontus	vertebra	0	1	3
Elopomorpha	vertebra	0	1	3
Parabula sp.	vertebra	0	1	3
Coriops amnicolus	mandible	2	0	2,3
Coriops amnicolus	palate	0	1	3
Coriops amnicolus	vomer	0	1	1
Estesesox sp.	mandible	1	0	2
Amphibia	ilium	1	0	2
Amphibia	indeterminate bone	1	0	3
Amphibia	vertebra	2	2	2,3
Amphibia	jaw	0	2	1,2
Amphibia	tooth	0	2	2,3
Anura	vertebra	0	2	3
Caudata	indeterminate bone	0	1	3
Caudata	vertebra	2	2	2,3
Caudata	tooth	0	1	3
Opisthotriton kayi	vertebra	5	7	2,3
Opisthotriton kayi	dentary	0	1	3
Scapherpeton tectum	mandible	4	1	1,2
Scapherpeton tectum	vertebra	0	4	3
Habrosaurus dilatus	mandible	2	0	1,2
Habrosaurus dilatus	vomer	1	0	2
Habrosaurus dilatus	palate	0	1	3
Habrosaurus dilatus	tooth	0	2	3
Habrosaurus dilatus	vertebra	0	1	3
Prodesmodon copei	vertebra	1	0	3
Prodesmodon copei	mandible	1	1	2
Reptilia	indeterminate bone	5	16	1,2,3
Reptilia	scute	1	0	1
Reptilia	phalange	1	2	2,3
Reptilia	tooth	1	4	4
Testudines	indeterminate shell	1	8	1,3
Baenidae	shell	1	19	1,3
Chelydridae	shell	4	11	1,3
Adocus sp.	shell	1	2	1,3
Basilemys sp.	shell	3	0	1,3
Trionychoidae	shell	7	24	1,3
Lepidosauria	tooth	1	5	4
Lepidosauria	jaw	0	5	2
Lepidosauria	vertebra	0	1	3
Teiidae	jaw	0	1	3
Teiidae	tooth	1	0	4
Champos segnis	partietal	1	0	1
Leptochampos denticulatus	jaw	2	1	2
Odaxosaurus piger	osteoscute	1	2	1
?Litakis gilmorei	mandible	1	0	2
Helodermatidae	osteoscute	2	0	1
Parasaniwa wyomingensis	jaw	0	1	3
Champsosaurus sp.	tooth	0	1	4
Champsosaurus sp.	vertebra	2	6	3
Crocodilia	scute	3	10	1
Crocodilia	skull	1	1	1
Crocodilia	tooth	0	3	2,4
Brachychampsa montana	tooth	2	1	3
Borealosuchus sternbergi	tooth	2	8	3,4
Dinosauria	indeterminate bone	0	22	3
Omithischia	tooth	42	87	3
Ceratopsidae	tooth	20	22	3
Hadrosauridae	tooth	8	18	3
Euornithopoda	tooth	0	1	3
Ankylosauridae	tooth	1	2	3
Pachycephalosauridae	tooth	5	5	3
Theropoda	phalange	2	0	2
Theropoda	indeterminate bone	2	1	2
Dromaeosaurus albertensis	tooth	0	2	4
Saurornitholestes langstoni	tooth	2	0	1,4
Tyrannosauridae	tooth	1	8	3
Paronychodon lacustris	tooth	2	2	4
Richardoestesia isosceles	tooth	1	1	4
Richardoestesia gilmorei	tooth	3	0	1,4
Mammalia	tooth	1	5	3
Multituberculata	tooth	0	2	3
Cimolodon sp.	tooth	0	1	3
Cimolomys gracilis	tooth	0	1	3
Mesodma sp.	tooth	0	1	3
Pediomys florencae	tooth	0	1	3
Gyponictop illuminatus	tooth	0	1	3
Total Number		**2378**	**2430**	

Table shows the sample size of each skeletal element collect for each taxon, along with the dominant shape class(es) of the skeletal element. These number were used when compiling data for analysis of taxa in each shape class (Table 5), analysis of shape class distribution in each taxon (Table 6), and analysis of hydrodynamically equivalent elements (Table 7, 8, 9) between the CM and JPC assemblages.