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A vertebrate microsite from a marine-terrestrial transition in the Foremost Formation (Campanian) of Alberta, Canada, and the use of faunal assemblage data as a palaeoenvironmental indicator

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Abstract:

Vertebrate microfossil assemblages contain abundant fossil material of small and large bodied animals recruited from the local palaeocommunity that can provide important information for reconstructing regional palaeoecology. The Foremost Formation is the oldest unit of the Belly River Group, and records the transition from the fully marine shales of the Pakowki Formation to the non-marine strata of the relatively well-sampled Oldman and Dinosaur Park formations. Although the Foremost Formation has relatively limited exposure and vertebrate fossil material is not abundant, it does contain some important early records of major vertebrate clades from Laramidia (e.g. ceratopsids, pachycephalosaurids).

Here we document a new microfossil locality from the upper part of the formation that shows a transitional assemblage containing an abundance of terrestrial forms such as

dinosaurs and other sauropsids, while still showing considerable marine influence. The proportion of marine taxa at this site is reduced relative to most sites known from the Foremost Formation, though much higher than more terrestrial sites of the overlying Oldman Formation. In addition to filling a gap in our understanding of this palaeoenvironmental transition, this new site preserves two particularly significant specimens: a large, complete, cephalic spine of the hybodont shark *Hybodus*, and jaw fragments from the ratfish *Elasmodus*. This represents the first known complete cephalic spine of a hybodont shark from the Cretaceous of Alberta. The ratfish jaw fragments represent the first published record of this group from the Foremost Formation, further increasing our knowledge of chondrichthyan diversity in the Western Interior Seaway. Comparisons of this site to other microsites from the Campanian of Alberta demonstrate the utility of certain key groups, such as lissamphibians and chondrichthyans, in determining palaeoenvironments from Mesozoic and Cenozoic vertebrate microsite assemblage data.

1. Introduction

Vertebrate microfossil sites play an important role in understanding Late Cretaceous palaeoecology, community structure, and faunal turnover across palaeoenvironmental transitions (Baszio 1997; Brinkman 1990; Brinkman et al. 2004; Peng et al. 2001; Rogers and Brady 2010). These sites (often abbreviated ‘microsites’) typically preserve rich concentrations of small teeth, bones, and scales of numerous taxa,

in which more than 75% of the component fossils are less than 5 cm in maximum dimension (Eberth et al. 2007). These fossil concentrations can be formed in a number of ways, with most representing in-channel deposits, crevasse splays, or low energy ponds (Brinkman et al. 2004; Eberth 1990; Rogers and Brady 2010). Recent work has suggested that these sites represent reliable, high fidelity samples of the local vertebrate biodiversity that are largely independent of small-scale differences in depositional environment (Rogers and Brady 2010). These microsite conditions also aid in the preservation of rare taxa and skeletal elements otherwise unknown from other depositional settings in the region (Rogers and Kidwell 2007). These unique deposits provide a broad snapshot of diversity and palaeocommunity structure that is vital for understanding the relationship between larger scale environmental changes and faunal composition, and by extension may be an important palaeoenvironmental indicator where detailed geological data and other proxies are lacking (Rogers and Brady 2010).

The Late Cretaceous terrestrial vertebrate record of Alberta, Canada, is characterized by a series of taxonomically diverse assemblages, with much of these data coming from vertebrate microfossil bonebeds, and the addition of accurate stratigraphic information has facilitated comparisons between assemblages that provide insights into palaeocommunity evolution through time (Brinkman 1990; Brinkman et al. 2004; Eberth 2015; Evans et al. 2006; Fanti and Miyashita 2009; Mallon et al. 2012; Ryan and Evans 2005). The Campanian deposits of the Belly River Group in central and southern Alberta - including, in ascending order, the Foremost, Oldman, and Dinosaur Park formations - have yielded a number of rich microsites, although the best documented interval is the

transition from the terrestrial to marine palaeocommunities in the upper Dinosaur Park Formation (Baszio 1997; Beavan and Russell 1999; Brinkman 1990; Brinkman et al. 2004; Brinkman et al. 1998; Dodson 1987; Eberth 1990; Frampton 2005; Mallon et al. 2012; Peng et al. 2001). In fact, the number of sites in the Dinosaur Park Formation is double the amount of microsites in the entire Foremost and Oldman formations combined, with only four localities reported in the Foremost beds (Brinkman 1990; Brinkman et al. 2004; Eberth 2015).

In southernmost Alberta, the Foremost Formation represents lower coastal plain deposits that accumulated behind prograding shorelines: the MacKay and Taber coal zones mark the lower and upper limit of this unit, respectively (Eberth and Hamblin 1993; Ogunyomi and Hills 1977), which overall consists of alternating progradational and aggrading parasequences with common back-barrier coal seams and brackish- to fresh-water beds (Brinkman et al. 2004; Eberth et al. 2007; Eberth 2015; Ogunyomi and Hills 1977). Recently, the Herronton sandstone zone, an informal unit that occurs immediately above the Taber Coal Zone and considered a basal unit within the Oldman formation (Eberth and Hamblin 1993; Ogunyomi and Hills 1977), has been suggested to represent the uppermost unit of the Foremost succession (Eberth 2005, 2015). In this paper, we use the Taber Coal Zone to demarcate the formational boundary simply to facilitate stratigraphic comparisons with the published microsite literature where this marker is also used (e.g. Brinkman et al. 2004; Peng et al. 2001). We understand that this boundary is likely to change with further revisions to the stratigraphy. Overall, the Foremost Formation reflects an early Campanian shift from marine to coastal, and finally fluvial facies: therefore, vertebrate microfossil bonebeds in the Foremost Formation may

document the evolution of vertebrate faunas toward the terrestrial-dominated assemblages of the overlying Oldman Formation. The fossil record of the Foremost Formation is poorly documented (Brinkman et al. 2004; Ryan et al. 2012; Schott et al. 2009) and consequently studies on the fossil community structure are largely incomplete (Beavan 1995; Frampton 2005), but document a primarily marine faunal assemblage dominated by chondrichthyans in the lowermost deposits. Sampling of the more terrestrial, upper part of the Foremost Formation is relatively poor, which limits our understanding of the palaeoecological transition into these environments. The regressive deposits in this interval are of additional importance as they represent the oldest terrestrial late Campanian deposits exposed in southern Alberta, and are therefore critical in understanding the first terrestrial components of the palaeoecological communities that would come to dominate later in the Belly River Group (i.e. Oldman and Dinosaur Park formations; (i.e. Oldman and Dinosaur Park formations; Ryan et al. 2012).

This study reports on a new vertebrate microsite from the uppermost deposits of the Foremost Formation that records a more terrestrial fauna than most previously described material from the unit, while still displaying strong marine influences. Quantitative comparisons to known microsites in earlier and later periods of the regressive sequence facilitates increased understanding of the associated changes in the faunal assemblage, and their relation to palaeoenvironmental changes. In addition, the site has produced a number of rare specimens, including ratfish jaws and a complete hybodont cephalic spine, which are described here.

2. Materials and Methods

2.1 Institutional and locality abbreviations

EZ, ‘EZ’ site; HoS, Hoodoo site; LSD–S–T–R–W, legal subdivision – Section – Township – Range – west of Meridian; PHR-1, Pinhorn Range #1 site; PHR-2, Pinhorn Range #2 site; PHR93-2, Pinhorn Ranch #93-2; PHRN, Pinhorn Ranch North site; PHS, Pinhorn South site; PK, Phil’s Knob site; SPS, Suffield Pumping Station site; TCZ, Taber Coal Zone; TMP, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada; WS, Wendy’s Site.

2.2 Geological and stratigraphic setting

The new Foremost Formation locality described in this study is known as the Phil’s Knob vertebrate microfossil bonebed site (hereafter referred to as the PK microsite) and was originally discovered in 2009 by Phil Bell, while working with the Southern Alberta Dinosaur Project field crew. The site is part of the Chin Coulee system near Foremost, Alberta, Canada (LSD06-S29-T06-R10-W4) (see Figure 1), with precise locality information on file with the Royal Tyrrell Museum of Palaeontology. At the locality, shoreface sands grade into lower and upper coastal plain deposits capped by three coal seams referred to the Taber Coal Zone (TCZ); this regressive trend culminates with the alluvial Herronton deposits at the top (Figure 2). The interval that in which the PK is located consists of crossbedded fine sandstone, with the specific microvertebrate producing horizon consisting of sandy siltstone, thought to represent a graded

splay/palaeochannel deposit, and is located stratigraphically approximately 6 m below the lowermost coal referable to the TCZ. An additional vertebrate microfossil producing horizon can be found approximately 1-1.5 m below the PK site (Figure 2).

2.3 Collection techniques and specimen identification

Initial surface collection of the site was performed in 2009, which was followed by the collection of bulk sediments in 2009, 2011, and 2013 taken from a 2 m² area on the side of the outcrop (to a depth of approximately 30 cm). Additional surface collections occurred during 2015, from the area nearby the bulk collection site. All bulk sediment was collected from the same stratigraphic horizon ('PK' in Figure 2B), as were the majority of surface collected materials. A small component of the surface collected samples may derive from the vertebrate microfossil-bearing horizon immediately below the main PK layer (Figure 2). All excavations were undertaken by the authors, and by members of the field crew of the Southern Alberta Dinosaur Project (SADP). The collected material was screen-washed at the Royal Tyrrell Museum of Palaeontology in Drumheller, Alberta, using sieves with ~1mm openings (measured diagonally). After screen washing, the material was sent to Carleton University, Ottawa, and later the Royal Ontario Museum, for sorting and identification. Two hundred and eighty identifiable specimens were recovered from the site. These specimens were identified following comparisons with previously described Campanian vertebrate microfossil assemblages in southern Alberta, in particular the 'PHRN' (Frampton 2005), 'PHR-1', 'PHR-2', and 'SPS' sites (Brinkman et al. 2004; Peng et al. 2001) of the Foremost Formation, and the

‘EZ’, ‘PHR93-2’, ‘WS’, ‘PHS’, and ‘HoS’ sites of the Oldman Formation (Brinkman et al. 2004; Peng et al. 2001).

2.4 Taphonomic assessment and comparison

Several tests were performed to assess taphonomic controls on the PK assemblage, based primarily on the methods of Blob and Fiorillo (1996) and Brinkman et al (2004). Identified (N=280, Appendix 2) and unidentified (N=508, Appendix 3) vertebrate specimens were measured using digital callipers. Specimen size distribution curves were then produced for both unidentified and identified specimens using functions contained in the ‘ggplot2’ package in R (Wickham 2009). Additionally, each identified specimen was assessed as enamel-covered or non-enamel-covered. The taphonomic data for the PK site were compared with similar data from sites from the Foremost and Oldman formations, as described in Brinkman et al (2004).

2.5 Analytical techniques and ordinations

An R-mode vs. Q-mode cluster analysis comparison was made for the relative species abundance of the PK site and nine other sites from the Foremost and Oldman formations using data obtained from the literature (Brinkman et al. 2004; Frampton 2005). Prior to this analysis, the data matrices of each site were modified, with some entries combined into higher-order taxonomic groups in order to allow for comparability between sites (as some studies used less precise taxonomic identifications, or could not

be directly assessed for recent taxonomic sub-divisions). Included in this was the merging of indeterminate testudine (three fragmentary post-cranial elements) and mosasaur (one partial phalanx) material from the PK site into other testudine and squamate categories, respectively, given the absence of such categories in other microsite data tables.

Additional minor modifications (e.g. *Atractosteus* to *Lepisosteus*) to the data matrices were made to adjust for taxonomic revisions that have occurred since the publication of the literature datasets used for comparison. Once the data matrix was prepared, it was imported into R, and rarefied using the functions ‘rarefy’ and ‘rarecurve’ in the ‘vegan’ package to account for potential sample size issues (Oksanen et al. 2013). This alleviated most sample issues between sites, though the PK site remains somewhat undersampled (Appendix 1). The rarefied data were converted to relative abundances and ‘Double Wisconsin’ standardized using the ‘decostand’ function, again in the ‘vegan’ package (Oksanen et al. 2013). Using the ‘vegdist’ and ‘hclust’ functions in the ‘Vegan’ package, R- and Q-mode cluster analyses, using the percentage difference index (also known as Bray-Curtis), were performed and then compared using the ‘tabasco’ function (De Cáceres et al. 2013; Oksanen et al. 2013).

3. Results

3.1 Systematic Palaeontology

Class CHONDRICHTHYES Huxley, 1880

Subclass HOLOCEPHALI Bonaparte, 1832

Order CHIMAERIFORMES Obruchev, 1953

Genus ELASMODUS Egerton, 1843

Elasmodus sp.

Material. Jaw fragments likely representing a partial palatine tooth-plate. See Figure 3B.

Description & Diagnosis. TMP 2013.019.0076 is assigned to chimaeriformes and *Elasmodus* due to the presence and relative size of the four tooth-plate tritors (Hoganson and Erickson 2005).

Previous researchers have referred similar fragments from the Judith River Formation of Montana (Case 1979) and the Dinosaur Park Formation of Alberta (Beavan and Russell 1999) to *Elasmodus*, a convention we follow here. Given the fragmentary nature of these specimens, it is possible that it could also belong to *Ischyodus*, another similar chimaeriform taxon reported from the Judith River Formation along with other late Cretaceous localities in North America and Europe (Case 1978, 1979; Cicimurri and Ebersole 2014; Hoganson and Erickson 2005). Additionally, it is possible that this material represents a previously undescribed chimaeriform taxon, given that all examples of *Elasmodus*, besides those noted above, are of European origin (Case 1979). These jaw fragments represent the first published record of a chimaeriform in the Foremost Formation (though some material is also listed, though not described, in Beavan 1995, an unpublished Masters thesis), and the oldest record of *Elasmodus* in North America (Beavan and Russell 1999; Case 1978).

Subclass ELASMOBRANCHII Bonaparte, 1838

Cohort: EUSELACHII Hay, 1902

Order HYBODONTIFORMES Maisey, 1989

Family HYBODONTIDAE Owen, 1845

Genus HYBODUS Agassiz, 1837

cf. *Hybodus* sp.

Material. One nearly complete cephalic spine. See Figure 4.

Description & Diagnosis. The basal plate of the spine (TMP 2009.037.0078) has three complete lobes: a lateral, mesial, and posterior lobe (Figure 4). The basal plate is asymmetrical from dorsal view with the lateral lobe being placed more anterolaterally than the mesial lobe (Maisey 1982). The lateral lobe is very asymmetrical in comparison to the mesial lobe and is extremely raised anteriorly (Figure 4B). The base of the basal plate is convex anteroposteriorly and concave bilaterally.

The crown curves posteriorly and extends past the end of the posterior lobe of the basal plate (Figure 4C, D). Striations are present near the base of the crown on lateral and mesial sides, however, they are much more distinct on the lateral side (Figure 4D). The crown has a sigmoidal shape, with the apex curving towards the mesial side (Figure 4B). Near the apex on the ventral side of the crown an incomplete single barb is present (Figure 4D). Part of the mesial side of the barb is missing, however, the shape of the barb is still distinguishable by the complete lateral side. The apex of the crown is complete with some wear of the enamel on the dorsomesial side.

Cephalic shark spines are found exclusively within the Hybodontoidae (Maisey 1982). Male hybodonts are the only ones known to have cephalic spines, and it is unclear whether females had them, as there is no female specimen where cephalic spines and claspers are present (Rees 2002). Many hybodonts are known from their cephalic spines,

and unless they are found in association with teeth they will likely remain nomina dubia (Rees 2002).

Order LAMNIFORMES Berg, 1958

Family ODONTASPIDIDAE Muller and Henle, 1839

Material. Tooth. Central cusp tall, narrow, straight and sigmoidal in lateral view.

Evidence of accessory cusps present on both side of cusp. Accessory cusp one-quarter the size of the cusp. Nutrient groove preserved on lingual surface of base. See Figure 3D.

Description & Diagnosis. TMP 2009.037.0081, tooth referred to odontaspimid based on tall, central cusp, with single pair of accessory cusps, as discussed by Frampton (2005).

Family ARCHAEOLAMNIDAE Underwood and Cumbaa, 2010

Genus ARCHAEOLAMNA Siverson, 1992

Archaeolamna sp.

Material. Teeth with broad, triangular central cusps, low and curved in lateral view.

Accessory cusps present on both sides of central cusp. No prominent nutrient groove. See Figure 3C.

Description & Diagnosis. TMP 2011.053.0077 distinguishable from odontaspimids based on the low, broad central cusp, as noted in Peng et al (2001). Comparisons with material described in Cook et al (2011) suggest that TMP 2011.053.0077 may be a tenth upper lateral tooth, or possibly a more distal position in the tooth row (as the comparative material is incomplete after that tooth position).

Order RAJIFORMES Berg, 1940

Suborder RHINOBATOIDEI Fowler, 1941

Family incertae sedis

Genus PSEUDOMYLEDAPHUS Kirkland et al, 2013

Pseudomyledaphus sp.

Material. Teeth and fragmentary vertebral centrum. Tooth crown hexagonal, flat. Root bifurcated, straight, short, more heavily abraded than crown. Occlusal surface smooth. See Figure 3A. Vertebral centrum is circular and cone-like, with concentric rings on centrum surface See Figure 3E.

Description & Diagnosis. Teeth, TMP 2009.037.0079 referred to *Pseudomyledaphus* due to hexagonal shape of crown, short, straight, bifurcated root, and smooth occlusal surface. The presence of a *Myledaphus*-like taxon in the Foremost Formation that differs from *M. bipartitus* through the lack of a ridge along the occlusal surface was previously noted by Frampton (2005). Given the similarity of this material to a similarly smooth-toothed guitarfish taxon, *Pseudomyledaphus madseni*, known from the Santonian of Utah, a referral of the Foremost material seemed appropriate, pending more detailed future taxonomic assessments (Kirkland et al. 2013). Referral of the centrum, TMP 2011.053.0076, based on circular surface, cone-like later shape, and lack of basidorsal/basiventral foramina (Wilson et al. 2013).

Class ACTINOPTERYGII Cope, 1887

Subclass NEOPTERYGII Regan, 1923

ORDER SEMIONOTIFORMES Arambourg and Bertini 1958

Family incertae sedis

Gen. et sp. indet. (Holostean B)

Material. Scales are small, thin, and elongate. The scale surface is composed of a ganoid layer. See Figure 3G.

Description & Diagnosis. TMP 2013.019.0077, scales referred to 'Holostean B' based on the peg-and-socket articulation along the scale margins, elongate scale shape, and presence of tuberulate external surface (Brinkman 1990; Peng et al. 2001).

ORDER LEPISOSTEIFORMES Hay 1929

Family LEPISOSTEIDAE Cuvier, 1825

Genus LEPISOSTEUS Linnaeus, 1758

Lepisosteus sp.

Material. Teeth, ganoid covered scales, and fragmentary skull element. See Figure 3F.

Description & Diagnosis. Teeth are elongate and conical, with longitudinal striations present across the surface. Scales are thick and relatively rectangular, with a surface ganoid layer. Skull element is indeterminate, possessing a ganoid surface layer. TMP 2009.037.0082 is referred to *Lepisosteus* sp. given their similarity in morphology to that of extant gar, following similar referrals made by previous authors (Neuman and Brinkman 2005).

TELEOSTEI Müller, 1846

Superorder CLUPEOMORPHA Greenwood et al, 1966

Order ELLIMMICHTHIFORMES Grande, 1985

Genus HORSESHOEICHTHYS Newbrey et al, 2010

Horseshoeichthys sp.

Material. Vertebral centrum. See Figure 3H.

Description & Diagnosis. TMP 2011.053.0102, precaudal centrum possessing a mid-dorsal bar and short, ventrally directed, transverse processes. Referred to ‘teleost morphoserries IIA-2’ (sensu Neuman and Brinkman 2005), which had been tentatively assigned to *Cretophareodus*. More recent revisions have referred this morphotype to *Horseshoeichthys*, which we follow here (Newbrey et al. 2010).

Clade LISSAMPHIBIA Haeckel, 1866

ORDER ANURA Duméril, 1806

Family incertae sedis

Gen. et sp. indet.

Material. A partial ilium, identified by the elongate, curved shaft, which expands out ventrally to support a large acetabular fossa. In this case, the shaft is present but the majority of the acetabular fossa is missing. See Figure 3I.

Description & Diagnosis. TMP 2013.019.0085 is referred to Anura based on comparisons to anuran ilia in Peng et al (2001), though given its fragmentary nature cannot be further identified.

ORDER CAUDATA Oppel, 1811

Family SCAPHERPETONTIDAE Auffenberg and Goin, 1959

Genus SCAPHERPETON Cope, 1876

Scapherpeton sp

Material. Trunk vertebra. See Figure 3J.

Description & Diagnosis. TMP 2015.044.0117 is referred to *Scapherpeton* due to the vertebra being amphicoelous, lack of basapophyses, tear-drop shaped cotyles, and subcentral keel (Peng et al. 2001).

Clade SAUROPSIDA Goodrich, 1916

Order TESTUDINES Batsch, 1788

Family CHELYDRIDAE Agassiz, 1857

Gen. et sp. indet.

Material.. Peripheral shell fragment. See Figure 3K

Description & Diagnosis. TMP 2015.044.0136 is identified as chelydrid based on the deep sulci on the shell surface and the prominent ‘stepped’ ridge (Peng et al. 2001).

Family SOLEMYDIDAE Lapparent and Murelaga, 1997

GENUS NAOMICHELYS Hay, 1908

Naomichelys sp.

Material. Shell fragments possessing cylindrical tubercles on dorsal surface. See Figure 3L

Description & Diagnosis. TMP 2009.037.0093 is identified as solemydid, and more particularly as likely belonging to *Naomichelys*, based on the presence of tubercles on the shell surface and on the distinctive surface scar left when tubercles are broken, which

distinguishes this taxon from other turtle material known from the Belly River Group (Peng et al. 2001).

Family TRIONYCHIDAE Gray, 1870

Gen. et sp. indet.

Material. Shell fragments possessing a surface sculpting composed of pronounced wavy ridges and deep pits. See Figure 3M

Description & Diagnosis. TMP 2009.037.0098, has sculpted shell surface, a feature characteristic of trionychids, though are of more questionable use in more specific taxonomic identifications (Peng et al. 2001).

Family ADOCIDAE Cope, 1870

Genus ADOCUS Cope, 1868

Adocus sp.

Material. Shell fragments with surface ornamentation consisting of low ridging organized into a series of semi-regular lines.

Description & Diagnosis. The low ridging on TMP 2013.019.0094 is characteristic of *Adocus*, and can be easily distinguished from the heavier ridging of trionychids (Peng et al. 2001).

Family BAENIDAE

Gen. et sp. indet.

Material. Shell fragments with smooth surfaces, lacking in any notable structures.

Description & Diagnosis. TMP 2013.019.0095 is referred to Baenidae based on the lack of surface ornamentations (Peng et al. 2001).

Family NANHSIUNGCHELYIDAE Yeh, 1966

Genus BASILEMYS Hay, 1902

Basilemys sp.

Material. Shell fragments with coarse surfaces and large pits.

Description & Diagnosis. TMP 2015.044.0134 is referred to *Basilemys* based on the considerable thickness of the shell fragments, coarse sculpture, and low to moderate density of surface pitting (Brinkman 1990; Peng et al. 2001).

Order CHORISTODERA Cope, 1876

Family CHAMPSOSAURIDAE Cope, 1876

Genus CHAMPSOSAURUS Cope, 1876

Champsosaurus sp.

Material. Dorsal and cervical vertebrae, moderately fragmented, with centra present, but neural arch bases and transverse processes variably preserved. See Figure 3N for example of posterior cervical vertebra.

Description & Diagnosis. TMP 2009.037.0100 referred to *Champsosaurus* sp. based upon the hourglass shaped ridge located on the dorsal surface of the centrum, along with the centrum being amphiplatyan. (Peng et al. 2001).

Clade ARCHOSAURIA Cope, 1869

Clade EUSUCHIA Huxley, 1875

Gen. et sp. indet.

Material. Teeth and scutes/osteoderms. See Figure 3O.

Description & Diagnosis. A combination of tall, cone-shaped (TMP 2009.037.0101), and low, ovoid, isolated teeth. All teeth bear fine striations. In addition to teeth, scutes/osteoderms are also preserved. These scutes are generally deeply pitted, thickening slightly towards the centre. Some previous studies have referred eusuchian teeth to *Leidyosuchus*, with others assigning similar teeth as indeterminate alligatorine (Brinkman et al. 2004; Peng et al. 2001). For the purpose of greater comparability between sites, the more conservative assignment as indeterminate eusuchian was made for this material.

Clade DINOSAURIA Owen, 1842

Order ORNITHISCHIA Seeley, 1888

Suborder ANKYLOSAURIA Osborn, 1923

Family ANKYLOSAURIDAE Brown, 1908

Gen. et sp. indet.

Material. Isolated tooth. See Figure 3Q.

Description & Diagnosis. The tooth, TMP 2011.053.0148, is leaf-shaped with accessory cusps running both margins of the tooth, from the base to the central primary cusp. A peg-like root is present at the base of the tooth, and vertical grooves are present along the sides of the crowns. Tooth similar in appearance to those of nodosaurids, though generally rounder in shape, rather than displaying labiolingual compression, and with no distinctive cingulum present.

Family NODOSAURIDAE Marsh, 1890

Gen. et sp. indet.

Material. Isolated tooth. See Figure 3R.

Description & Diagnosis. TMP 2011.053.0149, tooth generally similar in appearance to ankylosaurids, though more highly compressed labiolingually and possessing a pronounced cingulum. Additionally, the ridges of this tooth are less strictly vertical and more in line with the spacing between the accessory cusps. This tooth is moderately weathered, with some of the surface obscured.

Clade NEOORNITHISCHIA Cooper, 1985

Suborder ORNITHOPODA Marsh 1881

Family HADROSAURIDAE Cope, 1870

Gen. et sp. indet.

Material. Isolated tooth crowns. Roots not preserved. See Figure 3S.

Description & Diagnosis. TMP 2011.053.0150, and other such teeth, has a straight median ridge on the crown surface. Teeth are tall and relatively short antero-posteriorly. The median ridge allows identification as hadrosaurid. However, the absence of preserved roots prevents more definitive identification, though the straightness of the median ridge suggests it may be hadrosaurine (Larson et al. 2010; Peng et al. 2001).

Suborder PACHYCEPHALOSAURIA Maryanska and Osmolska, 1974

Family PACHYCEPHALOSAURIDAE Sternberg, 1945

Gen. et. sp. indet.

Material. Fragment of frontoparietal dome.

Description & Diagnosis. Through textural characteristics and comparisons to specimens of *Colepiocephale lambei* from the Foremost Formation discussed in Schott et al (2009), TMP 2015.044.0215 is identified as a fragment of pachycephalosaurid frontoparietal dome.

Suborder CERATOPSIA Marsh, 1890

Family CERATOPSIDAE Marsh, 1890

Gen. et sp. indet.

Material. Isolated tooth crown possessing dorso-ventral ridge and developed secondary ridges. See Figure 3T.

Description & Diagnosis. Though possibly mistaken for a hadrosaurid tooth, the presence of secondary ridges on TMP 2011.053.0146, along with a cingulum near the base of the enamel (not preserved here), allow it to be distinguished and this specimen identified as ceratopsid (Peng et al. 2001).

Order SAURISCHIA Seeley, 1888

Suborder THEROPODA Marsh, 1881

Clade MANIRAPTORA Gauthier, 1986

Family DROMAEOSAURIDAE Colbert and Russell, 1969

Gen. et sp. indet.

Material. Isolated tooth crowns. See Figure 3P.

Description & Diagnosis. Tooth crown, TMP 2009.037.0109, is recurved and labiolingually compressed. Denticles are large and apically directed. Potentially representative of Saurnitholestinae (sensu Larson and Currie 2013), as this group is known from the Belly River Group and Velociraptorinae (sensu Longrich and Currie 2009) is not currently known from North America until the Maastrichtian (Evans et al. 2013).

3.2 Unusual/rare material preserved at site

The PK microsite contains two noteworthy taxa that represent rare occurrences in the Late Cretaceous of North America and the first published records from the Foremost Formation. First, the chimaeriform tooth plates are the first diagnosed record of such material from the Foremost Formation, the earliest record of *Elasmodus* in North America, and one of the few records of chimaeriform material in the fossil record of Alberta (Beavan and Russell 1999; Case 1978). Secondly, the complete hybodont cephalic spine recovered from the PK site represents the only such instance known in the fossil record of Alberta (Beavan 1995; Kirkland et al. 2013; Neuman and Brinkman 2005).

3.3 Taphonomic comparisons and size distributions

Analyses performed by Blob and Fiorillo (1996) suggested size distributions of fossils derived from screen-washed microsite material should be compared, using 1 cm

bins, to determine if sites can be considered taphonomically equivalent. Size distributions for the PK site (Figure 5A, Appendix 3) show that the majority of unidentified screen-washed vertebrate material is less than 1 cm (~87%) in size, which is similar to the microsites analyzed in Brinkman et al (2004)

When those data are subdivided and compared using the non-linear size categories of Brinkman et al (2004), the distribution of the PK site (Figure 5B) is broadly similar to that seen in the other microsites examined in this study, though with a considerably larger component of material preserved in the range of 5-10 mm. This suggests that the PK site is somewhat biased towards the preservation of larger specimens than other sites in the Foremost and Oldman formations, and may explain some differences in their overall assemblages. Similarly, the proportion of enamel-covered to non-enamel-covered identified specimens is roughly equal (45% to 55%, respectively). The slightly higher proportion of larger material in the PK site relates to the proportion of enamel to non-enamel material, as the largest single component of the non-enamel-covered specimens are turtle shell fragments (53% of total non-enamel-covered material).

Additionally, the size distribution of the identified vertebrate specimens described from the PK were plotted (Figure 5C, Appendix 2) and compared to size distribution curves of the same data subdivided based on being screen-washed (Figure 5D) or surface-collected (Figure 5E). Vertebrate specimens were considerably larger, on average, in the identified vertebrate material than in the unidentified, though the size distribution curve

of the identified material did not differ markedly from either the screen-washed or surface-collected size distribution curves.

3.4 Community assemblage present at the PK microsite

The site contains a broad assortment of vertebrate taxa, with tetrapods and ‘fish’ (elasmobranchs + actinopterygians) representing approximately one third and two thirds of the total number of identified specimens, respectively, collected from this assemblage (N=91, or ~32.5%, vs. N=189, or ~67.5%). Identified elements consist of teeth, scales, shell or bone fragments, and, occasionally, complete elements (see Figure 6 for a detailed breakdown of identified material and abundances, and Figure 3 for photographs of representative samples of site materials). Within the tetrapods, the majority of identified specimens are turtle shell and post-cranial fragments (N=82, ~29% of total assemblage). The remaining tetrapod material is of eusuchian (N=51, ~18% of total assemblage), choristodere (N=28, ~10% total assemblage), dinosaur (N=20, ~7% of total assemblage), and squamate (N=6, ~2% of total assemblage) origin, with lissamphibian (N=2, <1% of total assemblage) material being extremely rare. Of the ‘fish’, semionotiforms and lepisosteiforms (included together in some literature under semionotiforms, and in others under the broader, and possibly non-monophyletic, term 'Holostei'; Cavin 2010; Inoue et al. 2003) make up the largest component (N=43, ~15% of total assemblage), with elasmobranchs as the next largest group (N=37, ~13% of total assemblage). Among the elasmobranchs, rajiforms are the best-represented group (N=29, ~10% of total assemblage), with the remainder of the abundant material belonging to sharks (N=8, ~3%

of total assemblage). The remaining ‘fish’ are represented by the holocephalian *Elasmodus* (N=4, ~1% of total assemblage), and the teleost *Horseshoeichthys* (N=1, <1% of total assemblage).

The ‘fish’ assemblage, as noted above, is primarily composed of semionotiforms and elasmobranchs, being represented particularly by *Lepisosteus* and *Pseudomyledaphus*, respectively. The shark material is represented by three identifiable taxonomic groups, namely odontaspids, *Archaeolamna*, and *Hybodus*. The only other chondrichthyan known from the site is a holocephalian, cf. *Elasmodus*, represented by jaw fragments. Besides *Lepisosteus*, the actinopterygian material preserves taxa such as ‘Holostean B’, and Teleost morphotype IIA-2 (*Horseshoeichthys*). While semionotiform material is generally common in microsites throughout southern Alberta, the shark and holocephalian material is not, except in sites with considerable marine influence (Beavan and Russell 1999; Brinkman 1990; Brinkman et al. 2005; Brinkman et al. 2004).

Turtles, eusuchians, choristoderes, and dinosaurs represent the majority of taxonomic diversity among the tetrapods preserved at the PK site. Six testudine families are present, including the Solemydidae (*Naomichelys*), Trionychidae, Baenidae, Adocidae (*Adocus*), Chelydridae, and Nanhsiungchelyidae (*Basilemys*). Ornithischian dinosaurs identified at the site include ceratopsids, ankylosaurids, nodosaurids, pachycephalosaurids, and hadrosaurids. Theropods are more sparsely preserved, and represented by dromaeosaurid and tyrannosaurid teeth. The least abundant tetrapod group at the site are lissamphibians

– which are represented only by an anuran ilium fragment (Figure 2I) and a *Scapherpeton* vertebra (Figure 2J).

3.5 Stratigraphic changes in taxonomic composition of sites

Detailed comparisons were made between the PK site and other Belly River Group microsites previously described in the literature (Table 1; data modified from Brinkman et al. 2004; Frampton 2005; Peng et al. 2001). When compared to other localities using R- vs. Q-mode cluster analyses, the PK microsite closely groups with other sites from the Foremost Formation (Figure 7). The exception to this is represented by the SPS microsite, which: 1. clusters with Oldman Formation sites, 2. is fully non-marine in its faunal assemblage, and 3. is geographically separate from the other sites in this study. The stratigraphically lowest site discussed here, PHRN, refers to a sandstone unit closely associated with marine shales, and is thought to represent the shore-face of a barrier island or similarly restricted brackish-water setting (Frampton 2005). The faunal assemblage at PHRN shows evidence of marine influence, with sharks (*Archaeolamna*, *Hybodus*, odontaspids, *Squatina*, *Cretorectolobus*, *Synechodus*, *Centrophoroides*, *Cretolamna*), rajiforms ('*Myledaphus*', *Ischyrrhiza*, *Rhinobatos*), the euryhaline teleost *Paralbula*, and the solemydid turtle *Naomichelys* being the most commonly preserved taxa. Both PHR-1 and PHR-2 are thought to represent shore-face deposits, with the former being hosted in fine-grained sandstone juxtaposing marine shales, and the latter being in silty sandstone with fine shale laminations that sharply overlies marine shales

(Peng et al. 2001). The PHR-1 and PHR-2 sites have faunal assemblages similar to PHRN in the strong association with sharks (*Hybodus*, odontaspidids), rajiforms ('*Myledaphus*', *Ischyrhiza*), and *Paralbula*, and also preserve coastal taxa such as *Belonostomus* and 'Holostean B'. However, the PHR-1 site preserves taxa that are not strictly found in marine settings, such as *Adocus*, baenid turtles, and *Lepisosteus*. The SPS site occurs in fine-grained, silty sandstone and is thought to represent an in-channel deposit (Peng et al. 2001). The SPS shows a somewhat transitional faunal assemblage, though it is predominately composed of taxa considered terrestrial or inland in habitat preference (Brinkman et al. 2004). The taxa that most discriminate the SPS site are esocids, 'Holostean A', *Chiloscyllium*, acipenserids, lissamphibians (*Opisthotriton*, *Scapherpeton*), cf. Aves, and mammals.

The PK site is similar in faunal composition to the other Foremost formation sites, and is interpreted as an organic rich, graded splay/palaeochannel deposit. Specifically, the PK site displays a mix of marine/coastal taxa including sharks (*Hybodus*, *Archaeolamna*, odontaspidids), *Pseudomyledaphus*, *Elasmodus*, 'Holostean B', and *Naomichelys*, and by taxa that are not strongly associated in our analyses with either marine or terrestrial communities, such as ankylosaurs, hadrosaurids, ceratopsids, eusuchians, baenids, *Champsosaurus*, dromaeosaurids, *Basilemys*, *Adocus*, and trionychids. Sites from the Oldman Formation are a mix of silty sandstone in-channel deposits (HoS, PHR93-2) and silty to clayey sandstone crevasse splay deposits (PHS, WS, EZ). These sites were most distinguished from stratigraphically lower sites by the presence of teleost fish, *Coriops*, lissamphibians (*Opisthotriton*, *Scapherpeton*, *Albanerpeton*, anurans), *Lepisosteus*, and amiids, while also possessing a large diversity of dinosaur taxa.

4. Discussion

The relative abundance of brackish and marine taxa (such as odontaspimid sharks, *Archaeolamna*, *Hybodus*, and the guitarfish *Myledaphus* and *Pseudomyledaphus*) in the microsites representative of the lower Foremost Formation drives the clustering of these more marine sites, with the PK site assemblage closely related to them. However, in other respects, the PK fauna has relevant similarities with terrestrial/fluvial sites of the Oldman Formation and with the SPS site, which represents the most terrestrial and stratigraphically highest assemblage described from the Foremost Formation. Microsites from such alluvial deposits have large abundances of teleost fish, lissamphibians, dinosaurs, and generally lack chondrichthyans. The PK site shares an abundance of sauropsid material and a high diversity of dinosaurs with these terrestrial sites, along with a reduction in the relative abundance of chondrichthyan material. Notably, lissamphibians are found at the stratigraphically higher sites, whereas they are extremely rare in the PK material. Consequently, the shift towards more terrestrial faunal assemblages throughout the Foremost and lower Oldman formations is notably consistent with the marine to non-marine facies transition documented for this interval (Figure 7), with the PK microsite exhibiting an intermediate faunal composition consistent with its palaeoenvironmental context.

The PK site is also significant in that it preserves rare taxa and elements such as the chimaeriform *Elasmodus*, and a complete hybodont cephalic spine suggesting further sampling at the site may reveal unusual and informative specimens. Furthermore, the PK

assemblage contains proportionally more sauropsid material than the PHRN or other marine Foremost sites, while containing less chondrichthyan material (Table 1). The proportional difference mainly reflects the lower amount of guitarfish material recovered in the PK microsite, and the larger amount of turtle, eusuchian, and dinosaur elements. A possible explanation for the more terrestrial signal in the PK and SPS when compared with the closely-aged PHR-1 and PHR-2 sites is their relative position with respect to the palaeo-shoreline, as the former sites occur approximately 40 km to the west with respect to PHR localities (Brinkman et al. 2004; Gates et al. 2010, see also Figure 1).

The taphonomy of the site must also be accounted for as a possible explanation of differences between the PK and other sites. In particular, the bias of the PK site towards the preservation of larger elements (5-10 mm, vs 1-2 mm; see Figure 5) may be related to the higher proportion of large sauropsid material (e.g. turtle shell fragments, *Champsosaurus* vertebrae, and eusuchian scutes), and may explain the dearth of smaller material (e.g. small fish vertebrae and teeth, mammal teeth, lissamphibian material, small shark teeth). Interestingly, although nearly half (45%) of the identified PK fauna is represented by surface-collected elements, the size classes of identified screen-washed and surface-collected specimens are comparable, suggesting very minor biases related to collection method (Figure 5D-E). Furthermore, better-sampled lower Foremost Formation sites share a proportional scarcity of lissamphibians with PK (Table 1, Figure 6), including PHR-1 and PHR-2, which are taphonomically equivalent to the SPS and Oldman Formation sites. Previously reported Foremost Formation marine-influenced sites preserve rare lissamphibian elements at very low relative abundance (0.4% – 1.9%),

and are thus comparable with the percentile documented at the PK site (0.7%). This suggests that the relative scarcity of lissamphibians in the identified PK material is not primarily a reflection of sample size or taphonomic biases, but is best interpreted as a biological signal related to ecological influences on the site. In contrast, non-marine sites, including the SPS site, all have greater than 10% (up to 36%) of relative assemblage abundance made up of lissamphibian material. The lissamphibians generally show an inverse pattern of abundance with chondrichthyans (particularly sharks) (Figure 7, Table 1, Appendix 4), with low-abundance co-occurrence observed in transitional sites. Lissamphibians do not typically thrive in coastal or normal salinity conditions (Christman 1974; Rios-López 2008), and, conversely, chondrichthyans (with the exception of freshwater rajiforms) rarely thrive in non-marine conditions (Smith 1932).

5. Conclusions

Previous research on the microsites of the late Campanian of Southern Alberta by Brinkman (1990) and Brinkman et al (2004) focused on understanding the changes in community assemblage throughout the Belly River Group, and across the geographic range of sampled sites in Dinosaur Provincial Park and the Milk River area. One of the main results of these studies is the discrimination of coastal and inland palaeocommunities in both northern and southern sites (with some small differences thought to be related to endemism or differences in dispersal over time). Our results are generally consistent with the coastal and inland assignment of taxa (Figure 7), though a number of differences exist. These differences are here related to specific taxa assigned in

the earlier studies to coastal palaeocommunities, specifically ceratopsids, *Champsosaurus*, eusuchians, *Lepisosteus*, *Adocus*, and acipenserids. In the new analysis presented here, these taxa are found to be associated with a mix of terrestrial and coastal assemblages, lacking selective association towards one palaeoenvironmental setting or the other. This result is consistent with the modern environmental preferences of the aforementioned taxa that have close extant relatives (e.g. eusuchians, *Lepisosteus*, acipenserids), which can be found in coastal or near-coastal settings, as well as inland fluvial environments. A less dependent association between ceratopsids and coastal sites further discriminate southern Alberta and northern exposures of the upper Belly River Group (i.e. Dinosaur Park Formation) where an increase in ceratopsid abundances has been documented. As such, additional factors including time-related variations in diversity, habitat preferences, or geographic distribution, may play into the environmental preferences of this group (Brinkman et al. 1998).

Faunal assemblage data from the upper Foremost Formation PK microsite is consistent with its intermediate stratigraphic position and palaeoenvironmental context within the regressive, lower Belly River sequence. A comparison with other microsites from the Foremost and Oldman formations also indicates that the PK site represents a transitional assemblage more terrestrially influenced than most Foremost sites, yet which still received enough coastal or saline input as to prohibit any considerable niche occupation by lissamphibian taxa. This pattern underscores the importance of these key taxonomic groups- notably lissamphibians and sharks-as useful markers for determining palaeoenvironments from late Mesozoic and Cenozoic microsite assemblage data.

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Tables:

Table 1: Taxon abundance table for each site analyzed in this study.

Broad Taxonomic Descriptor #1	Broad Taxonomic Descriptor #2	Taxon	PHS(O1)	EZ(O1)	PHR93-2(O1)	WS(O1)	HOS(O1)	SPS(For)	PHR-1(For)	PHR-2(For)	PK(For)	PHRN (For)
Chondrichthyes	Elasmobranchii	<i>Myledaphus/Pseudomyledaphus</i>	19	8	24	9	15	235	1952	2164	29	3780
Chondrichthyes	Elasmobranchii	<i>Hybodus</i>	0	0	0	0	0	0	10	15	1	18
Chondrichthyes	Elasmobranchii	<i>Centrophoroides</i>	0	0	0	0	0	0	0	0	0	15
Chondrichthyes	Elasmobranchii	Odontaspidae	0	0	0	0	0	0	23	79	2	50
Chondrichthyes	Elasmobranchii	<i>Cretolamna</i>	0	0	0	0	0	0	0	0	0	4
Chondrichthyes	Elasmobranchii	<i>Archaeolamna</i>	0	0	0	0	0	0	0	10	3	27
Chondrichthyes	Elasmobranchii	<i>Cretorectolobus</i>	0	0	0	0	0	0	0	1	0	5
Chondrichthyes	Elasmobranchii	<i>Synechodus</i>	0	0	0	0	0	0	0	1	0	10
Chondrichthyes	Elasmobranchii	<i>Rhinobatos</i>	0	0	0	0	0	0	0	9	0	3
Chondrichthyes	Elasmobranchii	<i>Ischyrrhiza</i>	0	0	0	0	0	8	16	0	20	
Chondrichthyes	Elasmobranchii	<i>Chiloscyllium</i>	0	0	1	1	0	5	0	6	0	0
Chondrichthyes	Elasmobranchii	<i>Squatina</i>	0	0	0	0	0	0	1	8	0	34
Chondrichthyes	Elasmobranchii	Selachimorpha indet.	0	0	0	0	0	0	0	0	2	690
Chondrichthyes	Holocephali	<i>Elasmodus sp.</i>	0	0	0	0	0	0	0	0	4	0
Actinopterygii	Holostei	Holostean A	1	1	31	138	54	229	94	22	0	8
Actinopterygii	Holostei	Holostean B	0	4	5	25	0	45	355	166	6	56
Actinopterygii	Chondrostei	Acipenseridae indet.	6	0	4	0	6	14	90	25	0	2
Actinopterygii	Teleostei	<i>Belonostomus</i>	0	0	0	11	0	0	185	160	0	0
Actinopterygii	Holostei	<i>Lepisosteus</i>	339	147	126	404	1001	204	2463	834	43	143
Actinopterygii	Teleostei	<i>Coriops</i>	19	26	16	35	26	16	3	5	0	0
Actinopterygii	Holostei	Amiidae indet.	0	18	14	11	10	5	9	17	0	0
Actinopterygii	Teleostei	Phyllodontidae indet.	2	4	5	11	6	3	31	29	0	0
Actinopterygii	Teleostei	<i>Paralbulia</i>	43	4	14	5	6	136	1125	1987	0	2281
Actinopterygii	Teleostei	Esocidae	1	4	6	15	7	29	4	7	0	0
Actinopterygii	Teleostei	Teleost D	16	16	27	28	41	6	7	25	0	0
Actinopterygii	Teleostei	Teleost indet.	148	150	101	225	100	46	89	265	1	305
Tetrapoda	Lissamphibia	<i>Scapherpeton</i>	44	36	138	216	166	202	12	30	1	17
Tetrapoda	Lissamphibia	<i>Opisthotriton</i>	14	30	68	38	78	199	29	66	0	4
Tetrapoda	Lissamphibia	<i>Albanerpeton</i>	15	16	17	63	6	8	0	7	0	0
Tetrapoda	Lissamphibia	Anura indet.	29	43	70	75	47	24	33	31	1	10
Sauropsida	Squamata	Squamata indet.	25	60	11	45	8	7	12	11	5	0
Sauropsida	Squamata	Mosasauroidea indet.	0	0	0	0	0	0	0	0	1	0
Sauropsida	Testudines	Solemydidae indet.	0	0	0	0	0	0	1	0	35	272
Sauropsida	Testudines	Trionychidae indet.	24	6	2	14	2	1	106	7	24	21
Sauropsida	Testudines	<i>Adocus</i>	15	4	0	8	13	0	129	3	9	15
Sauropsida	Testudines	Chelydridae indet.	0	2	0	5	14	4	21	1	1	0
Sauropsida	Testudines	Baenidae indet.	13	1	4	11	2	18	93	2	8	2
Sauropsida	Testudines	<i>Basilemys</i>	0	0	0	2	0	0	0	0	2	0
Sauropsida	Testudines	Testudines indet.	0	0	0	0	0	0	0	0	3	0
Sauropsida	Choristodera	<i>Champsosaurus</i>	27	6	18	214	17	50	97	213	28	64
Sauropsida	Crocodylomorpha	Eusuchia indet.	51	13	20	82	31	38	122	205	51	45
Sauropsida	Dinosauria	Ceratopsidae indet.	2	11	10	8	3	2	52	12	2	4
Sauropsida	Dinosauria	Ankylosauria indet.	2	1	0	0	2	2	8	8	6	8
Sauropsida	Dinosauria	Pachycephalosauridae indet.	0	1	0	1	0	2	2	0	1	0
Sauropsida	Dinosauria	Hadrosauridae indet.	93	101	65	61	83	162	178	263	6	6
Sauropsida	Dinosauria	Sauromitholestinae indet.	7	1	11	7	6	2	7	18	4	0
Sauropsida	Dinosauria	<i>Richardoestesia</i>	0	0	0	0	2	0	3	3	0	1
Sauropsida	Dinosauria	<i>Paranychodon</i>	1	0	1	2	0	2	0	1	0	0
Sauropsida	Dinosauria	Aves indet.	0	1	1	3	0	3	3	0	0	1
Sauropsida	Dinosauria	Tyrannosauridae indet.	2	1	0	3	2	1	7	9	1	1
Mammalia	Mammalia	Multituberculata indet.	5	2	3	3	6	29	7	6	0	1
Mammalia	Mammalia	Metatheria indet.	4	2	0	4	1	0	4	2	0	1
Mammalia	Mammalia	Eutheria indet.	0	0	0	1	0	9	0	1	0	0
TOTAL			967	720	813	1784	1761	1738	7375	6750	280	7924

Figures:

Figure 1: Location of PK microsite and other sites of Foremost and lower Oldman formations analyzed in this study. A, geographic location in Alberta, in context to regional landmarks; B, Relative stratigraphic positions; C, Photograph of outcrop containing PK microsite, with sampling location indicated.

Figure 2: Lithostratigraphy of the Phil's Knob locality. A, field log showing the stratigraphic occurrence of reference units in the study area, specifically the Taber Coal Zone and the overlying Herronton sandstone. B, detailed field log of the PK microsite: microvertebrate are collected in silty and sandy deposits interpreted to represent upper coastal plain facies. Grey lithologies indicate organic-rich mudstones and immature coaly soils.

Figure 3: Representative specimens from PK microsite. Specimens are: A, *Pseudomyledaphus* tooth; B, *Elasmodus* sp. tooth plate; C, *Archaeolamna* sp. tooth; D, Odontaspidid tooth; E, cf. *Pseudomyledaphus* vertebral centrum; F, *Lepisosteus* scale; G, ‘Holostean B’ scale; H, *Horseshoeichthys* sp. vertebra; I, Anura indet. ilium; J, *Scapherpeton* trunk vertebra; K, Chelydridae peripheral shell fragment; L, *Naomichelys* sp. carapace fragment; M, Trionychid carapace fragment; N, *Champsosaurus* sp. posterior cervical vertebra; O, Eusuchia indet. tooth crown; P, Dromaeosaurid tooth crown; Q, Ankylosaurid tooth crown; R, Nodosaurid tooth crown; S, Hadrosaurid tooth crown; T, Ceratopsid tooth crown. Scale bars equal 2 mm.

Figure 4: Right cephalic spine of cf. *Hybodus* sp. (TMP 2009.037.0078). Specimen represents the first hybodont cephalic spine from the region, and one of the few representatives of the group in the Cretaceous of North America. A, anterior view; B, dorsal view; C, mesial view; D, right lateral view. Anatomical abbreviations are: ba, barb; bp, basal plate; cr, crown; ll, lateral lobe; ml, mesial lobe; pl, posterior lobe. Scale bar equals 5 mm.

Figure 5: Size distributions of material at PK microsite. A, unidentified vertebrate material using 1 mm bin linear scale; B, unidentified vertebrate material using non-linear size categories from Brinkman et al (2004); C, all identified vertebrate material using 1 mm bin linear scale; D, screen-washed identified vertebrate material using 1 mm bin linear scale; E, surface-collected identified vertebrate material using 1 mm bin linear scale.

Figure 6: List of taxa identified from PK microsite, with element type, number of specimens identified, and proportion of total sample represented by each taxon.

Taxa	Element(s)	N (% total)
Chondrichthyes		
Elasmobranchii		
Selachimorpha		
family incertae sedis		
Selachimorpha indet.	tooth fragment	2 (0.71%)
Hybodontiformes		
Hybodontidae		
<i>Hybodus</i> sp.	cephalic spine*	1 (0.36%)
Lamniformes		
Archaeolamnidae		
<i>Archaeolamna</i> sp.	teeth	3 (1.07%)
Odontaspidae indet.	teeth	2 (0.71%)
Rajiformes		
Rhinobatoidei		
family incertae sedis		
<i>Pseudomyledaphus</i> sp.	teeth, vertebrae	29 (10.36%)
Holocephali		
Chimaeriformes		
<i>Elasmodus</i> sp.	jaw fragment*	4 (1.43%)
Osteichthyes		
Actinopterygii		
Holostei		
Lepisosteiformes		
Lepisosteidae		
<i>Lepisosteus</i> sp.	teeth, scales	43 (15.36%)
'Holostean B'	scales	6 (2.14%)
Teleostei		
Clupeomorpha		
<i>Horseshoeichthys</i> sp.	vertebra	1 (0.36%)
Lissamphibia		
Anura		
family incertae sedis		
Anura indet.	ilium	1 (0.36%)
Caudata		
<i>Scapherpeton</i> sp.	vertebra	1 (0.36%)
Sauropsida		
Squamata		
family incertae sedis		
Squamata indet.	rib, vertebral fragments.	5 (1.79%)
Mosasauridae indet.	phalanx	1 (0.36%)
Testudines		
family incertae sedis		
Testudines indet.	rib, pectoral, metatarsal fragments	3 (1.07%)
Solemydidae		
<i>Naomichelys</i> sp.	scute, carapace fragments	35 (12.50%)
Baenidae indet.	costal, carapace fragments	8 (2.86%)
Nanhsiungchelyidae		
<i>Basilemys</i> sp.	carapace fragments	2 (0.71%)
Chelydridae indet.	carapace fragments	1 (0.36%)
Trionychidae indet.	neural, carapace fragments	24 (8.57%)
Adocidae		
<i>Adocus</i> sp.	carapace fragments	9 (3.21%)
Archosauromorpha		
Choristodera		
Champsosauridae		
<i>Champsosaurus</i> sp.	vertebrae, teeth, ilium & rib fragments	28 (10.00%)
Eusuchia		
Family incertae sedis		
Eusuchia indet.	osteoderms, teeth, vertebrae, skull frag.	51 (18.21%)
Dinosauria		
Ornithischia		
Ankylosauria	scute fragment	1 (0.36%)
Ankylosauridae indet.	teeth	3 (1.07%)
Nodosauridae indet.	teeth	2 (0.71%)
Ornithopoda		
Hadrosauridae indet.	teeth	6 (2.14%)
Marginocephalia		
Ceratopsidae indet.	teeth	2 (0.71%)
Pachycephalosauridae indet.	dome fragment	1 (0.36%)
Saurischia		
Theropoda		
Dromaeosauridae indet.	teeth	4 (1.43%)
Tyrannosauridae indet.	teeth	1 (0.36%)

* Indicates first record in Foremost Formation

N total = 280

Figure 7: R vs. Q mode cluster analysis of PK and other Foremost and lower Oldman microsites. Sites listed at bottom, taxa at right. Bold or grey taxon names indicates member of coastal or inland palaeocommunities of Brinkman et al 2004, respectively. Circle or triangle indicates member of coastal or inland palaeocommunities, respectively, as identified in this study.

Appendices:

Appendix 1: Rarefaction curves for microsites analyzed in this study. Green lines indicate Foremost Formation sites. Blue lines indicate Oldman Formation sites. PK site denoted by red line.

A

B

Appendix 2: Specimen information, size data, and taphonomic characteristics for identified vertebrate material at PK microsite

TMP #	Field #	Broad Taxonomic Descriptor	Taxon	Element	Long axis measurement (mm)	Collection type	Specimen type
tmp2009.0 37.0078	SADP2009 -13	Elasmobran chii	<i>Hybodus</i>	cephalic spine	45.00	surface	enamel(oid)-covered
tmp2009.0 37.0079	SADP2009 -PK-01	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	6.05	screened	enamel(oid)-covered
tmp2009.0 37.0080	SADP2009 -PK-02	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.48	screened	enamel(oid)-covered
tmp2009.0 37.0081	SADP2009 -PK-03	Elasmobran chii	Odontaspidae	tooth	11.16	screened	enamel(oid)-covered
tmp2009.0 37.0082	SADP2009 -PK-04	Holostei	<i>Lepisosteus</i>	scale	13.54	screened	enamel(oid)-covered
tmp2009.0 37.0083	SADP2009 -PK-05	Holostei	<i>Lepisosteus</i>	scale	10.32	screened	enamel(oid)-covered
tmp2009.0 37.0084	SADP2009 -PK-06	Holostei	<i>Lepisosteus</i>	scale	10.97	screened	enamel(oid)-covered
tmp2009.0 37.0085	SADP2009 -PK-07	Holostei	<i>Lepisosteus</i>	scale	8.93	screened	enamel(oid)-covered
tmp2009.0 37.0086	SADP2009 -PK-08	Holostei	<i>Lepisosteus</i>	scale	11.36	screened	enamel(oid)-covered
tmp2009.0 37.0087	SADP2009 -PK-09	Holostei	<i>Lepisosteus</i>	scale	11.11	screened	enamel(oid)-covered
tmp2009.0 37.0088	SADP2009 -PK-10	Holostei	<i>Lepisosteus</i>	scale	7.05	screened	enamel(oid)-covered
tmp2009.0 37.0089	SADP2009 -PK-11	Holostei	<i>Lepisosteus</i>	scale	10.95	screened	enamel(oid)-covered
tmp2009.0 37.0090	SADP2009 -PK-12	Holostei	<i>Lepisosteus</i>	scale	8.91	screened	enamel(oid)-covered
tmp2009.0 37.0091	SADP2009 -PK-13	Squamata	Squamata indet.	vertebral fragment	10.09	screened	non-enamel(oid)-covered
tmp2009.0 37.0092	SADP2009 -PK-14	Squamata	Squamata indet.	vertebral fragment	15.07	screened	non-enamel(oid)-covered
tmp2009.0 37.0093	SADP2009 -PK-15	Testudines	Solemydidae	carapace fragment	12.92	screened	non-enamel(oid)-covered
tmp2009.0 37.0094	SADP2009 -PK-16	Testudines	Solemydidae	carapace fragment	2.82	screened	non-enamel(oid)-covered
tmp2009.0 37.0095	SADP2009 -PK-17	Testudines	Solemydidae	carapace fragment	3.33	screened	non-enamel(oid)-covered
tmp2009.0 37.0096	SADP2009 -PK-18	Testudines	Solemydidae	carapace fragment	13.51	screened	non-enamel(oid)

							)-covered
tmp2009.0 37.0097	SADP2009 -PK-19	Testudines	Solemydid ae	carapace fragment	15.28	screened	non- enamel(oid)-covered
tmp2009.0 37.0098	SADP2009 -PK-20	Testudines	Trionychid ae indet.	carapace fragment	11.54	screened	non- enamel(oid)-covered
tmp2009.0 37.0099	SADP2009 -PK-21	Testudines	Testudines indet.	pectoral fragment	20.34	screened	non- enamel(oid)-covered
tmp2009.0 37.0100	SADP2009 -PK-22	Choristoder a	<i>Champsosa urus</i>	vertebra	13.06	screened	non- enamel(oid)-covered
tmp2009.0 37.0101	SADP2009 -PK-23	Crocodylo morpha	Eusuchia indet.	tooth	12.30	screened	enamel(oid)-covered
tmp2009.0 37.0102	SADP2009 -PK-24	Crocodylo morpha	Eusuchia indet.	tooth	9.48	screened	enamel(oid)-covered
tmp2009.0 37.0103	SADP2009 -PK-25	Crocodylo morpha	Eusuchia indet.	scute	14.65	screened	non- enamel(oid)-covered
tmp2009.0 37.0104	SADP2009 -PK-26	Crocodylo morpha	Eusuchia indet.	scute	12.93	screened	non- enamel(oid)-covered
tmp2009.0 37.0105	SADP2009 -PK-27	Crocodylo morpha	Eusuchia indet.	scute	16.29	screened	non- enamel(oid)-covered
tmp2009.0 37.0106	SADP2009 -PK-28	Crocodylo morpha	Eusuchia indet.	scute	7.47	screened	non- enamel(oid)-covered
tmp2009.0 37.0107	SADP2009 -PK-29	Crocodylo morpha	Eusuchia indet.	scute	6.35	screened	non- enamel(oid)-covered
tmp2009.0 37.0108	SADP2009 -PK-30	Crocodylo morpha	Eusuchia indet.	scute	6.04	screened	non- enamel(oid)-covered
tmp2009.0 37.0109	SADP2009 -PK-31	Dinosauria	Dromaeosa uridae indet.	tooth	5.23	screened	enamel(oid)-covered
tmp2009.0 37.0110	SADP2009 -PK-32	Dinosauria	Dromaeosa uridae indet.	premaxil lary tooth	5.12	screened	enamel(oid)-covered
tmp2011.0 53.0064	SADP2011 -PK-01	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	1.72	screened	enamel(oid)-covered
tmp2011.0 53.0065	SADP2011 -PK-02	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	2.52	screened	enamel(oid)-covered
tmp2011.0 53.0066	SADP2011 -PK-03	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.09	screened	enamel(oid)-covered
tmp2011.0 53.0067	SADP2011 -PK-04	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	2.79	screened	enamel(oid)-covered
tmp2011.0 53.0068	SADP2011 -PK-05	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	4.92	screened	enamel(oid)-covered
tmp2011.0 53.0069	SADP2011 -PK-06	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	2.11	screened	enamel(oid)-covered
tmp2011.0 53.0070	SADP2011 -PK-07	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	1.17	screened	enamel(oid)-covered

tmp2011.0 53.0071	SADP2011 -PK-08	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.52	screened	enamel(oid)covered
tmp2011.0 53.0072	SADP2011 -PK-09	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	4.35	screened	enamel(oid)covered
tmp2011.0 53.0073	SADP2011 -PK-10	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	2.47	screened	enamel(oid)covered
tmp2011.0 53.0074	SADP2011 -PK-11	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	1.12	screened	enamel(oid)covered
tmp2011.0 53.0075	SADP2011 -PK-12	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	3.24	screened	enamel(oid)covered
tmp2011.0 53.0076	SADP2011 -PK-13	Elasmobran chii	<i>Pseudomyl edaphus</i>	vertebral fragment	13.26	screened	non- enamel(oid)covered
tmp2011.0 53.0077	SADP2011 -PK-14	Elasmobran chii	<i>Archaeola mna</i>	tooth	6.80	screened	enamel(oid)covered
tmp2011.0 53.0078	SADP2011 -PK-15	Elasmobran chii	<i>Archaeola mna</i>	tooth	3.69	screened	enamel(oid)covered
tmp2011.0 53.0079	SADP2011 -PK-16	Elasmobran chii	<i>Archaeola mna</i>	tooth	5.53	screened	enamel(oid)covered
tmp2011.0 53.0080	SADP2011 -PK-17	Elasmobran chii	Selachimor pha indet.	tooth fragment	18.51	screened	enamel(oid)covered
tmp2011.0 53.0081	SADP2011 -PK-18	Elasmobran chii	Selachimor pha indet.	tooth fragment	12.74	screened	enamel(oid)covered
tmp2011.0 53.0082	SADP2011 -PK-19	Holostei	Holostean B	scale	3.21	screened	enamel(oid)covered
tmp2011.0 53.0083	SADP2011 -PK-20	Holostei	Holostean B	scale	4.84	screened	enamel(oid)covered
tmp2011.0 53.0084	SADP2011 -PK-21	Holostei	Holostean B	scale	8.31	screened	enamel(oid)covered
tmp2011.0 53.0085	SADP2011 -PK-22	Holostei	<i>Lepisosteus</i>	scale	10.29	screened	enamel(oid)covered
tmp2011.0 53.0086	SADP2011 -PK-23	Holostei	<i>Lepisosteus</i>	scale	7.36	screened	enamel(oid)covered
tmp2011.0 53.0087	SADP2011 -PK-24	Holostei	<i>Lepisosteus</i>	scale	11.41	screened	enamel(oid)covered
tmp2011.0 53.0088	SADP2011 -PK-25	Holostei	<i>Lepisosteus</i>	scale	9.28	screened	enamel(oid)covered
tmp2011.0 53.0089	SADP2011 -PK-26	Holostei	<i>Lepisosteus</i>	scale	4.68	screened	enamel(oid)covered
tmp2011.0 53.0090	SADP2011 -PK-27	Holostei	<i>Lepisosteus</i>	scale	3.77	screened	enamel(oid)covered
tmp2011.0 53.0091	SADP2011 -PK-28	Holostei	<i>Lepisosteus</i>	scale	9.12	screened	enamel(oid)covered
tmp2011.0 53.0092	SADP2011 -PK-29	Holostei	<i>Lepisosteus</i>	scale	11.07	screened	enamel(oid)covered
tmp2011.0 53.0093	SADP2011 -PK-30	Holostei	<i>Lepisosteus</i>	scale	9.86	screened	enamel(oid)covered
tmp2011.0 53.0094	SADP2011 -PK-31	Holostei	<i>Lepisosteus</i>	scale	9.41	screened	enamel(oid)covered
tmp2011.0 53.0095	SADP2011 -PK-32	Holostei	<i>Lepisosteus</i>	scale	7.75	screened	enamel(oid)covered
tmp2011.0 53.0096	SADP2011 -PK-33	Holostei	<i>Lepisosteus</i>	tooth	3.31	screened	enamel(oid)covered
tmp2011.0 53.0097	SADP2011 -PK-34	Holostei	<i>Lepisosteus</i>	tooth	3.01	screened	enamel(oid)covered

tmp2011.0 53.0098	SADP2011 -PK-35	Holostei	<i>Lepisosteus</i>	tooth	3.11	screened	enamel(oid)-covered
tmp2011.0 53.0099	SADP2011 -PK-36	Holostei	<i>Lepisosteus</i>	tooth	3.95	screened	enamel(oid)-covered
tmp2011.0 53.0100	SADP2011 -PK-37	Holostei	<i>Lepisosteus</i>	tooth	6.60	screened	enamel(oid)-covered
tmp2011.0 53.0101	SADP2011 -PK-38	Holostei	<i>Lepisosteus</i>	skull fragment	8.82	screened	non- enamel(oid)-covered
tmp2011.0 53.0102	SADP2011 -PK-39	Teleostei	<i>Horseshoei chthyes</i>	vertebra	2.18	screened	non- enamel(oid)-covered
tmp2011.0 53.0103	SADP2011 -PK-40	Testudines	Solemydid ae	carapace fragment	11.78	screened	non- enamel(oid)-covered
tmp2011.0 53.0104	SADP2011 -PK-41	Testudines	Solemydid ae	carapace fragment	13.80	screened	non- enamel(oid)-covered
tmp2011.0 53.0105	SADP2011 -PK-42	Testudines	Solemydid ae	carapace fragment	16.02	screened	non- enamel(oid)-covered
tmp2011.0 53.0106	SADP2011 -PK-43	Testudines	Solemydid ae	carapace fragment	11.52	screened	non- enamel(oid)-covered
tmp2011.0 53.0107	SADP2011 -PK-44	Testudines	Solemydid ae	carapace fragment	8.52	screened	non- enamel(oid)-covered
tmp2011.0 53.0108	SADP2011 -PK-45	Testudines	Solemydid ae	carapace fragment	6.00	screened	non- enamel(oid)-covered
tmp2011.0 53.0109	SADP2011 -PK-46	Testudines	Solemydid ae	carapace fragment	7.43	screened	non- enamel(oid)-covered
tmp2011.0 53.0110	SADP2011 -PK-47	Testudines	Solemydid ae	carapace fragment	8.77	screened	non- enamel(oid)-covered
tmp2011.0 53.0111	SADP2011 -PK-48	Testudines	Trionychid ae indet.	carapace fragment	16.33	screened	non- enamel(oid)-covered
tmp2011.0 53.0112	SADP2011 -PK-49	Testudines	Trionychid ae indet.	carapace fragment	31.63	screened	non- enamel(oid)-covered
tmp2011.0 53.0113	SADP2011 -PK-50	Testudines	Trionychid ae indet.	carapace fragment	20.46	screened	non- enamel(oid)-covered
tmp2011.0 53.0114	SADP2011 -PK-51	Testudines	Trionychid ae indet.	carapace fragment	12.86	screened	non- enamel(oid)-covered
tmp2011.0 53.0115	SADP2011 -PK-52	Testudines	Trionychid ae indet.	carapace fragment	10.51	screened	non- enamel(oid)-covered
tmp2011.0 53.0116	SADP2011 -PK-53	Testudines	Trionychid ae indet.	carapace fragment	24.66	screened	non- enamel(oid)-covered
tmp2011.0 53.0117	SADP2011 -PK-54	Testudines	Trionychid ae indet.	carapace fragment	16.90	screened	non- enamel(oid

							)-covered
tmp2011.0 53.0118	SADP2011 -PK-55	Testudines	Trionychid ae indet.	carapace fragment	18.32	screened	non- enamel(oid)-covered
tmp2011.0 53.0119	SADP2011 -PK-56	Testudines	Trionychid ae indet.	carapace fragment	15.20	screened	non- enamel(oid)-covered
tmp2011.0 53.0120	SADP2011 -PK-57	Testudines	Trionychid ae indet.	carapace fragment	23.02	screened	non- enamel(oid)-covered
tmp2011.0 53.0121	SADP2011 -PK-58	Testudines	Trionychid ae indet.	carapace fragment	20.44	screened	non- enamel(oid)-covered
tmp2011.0 53.0122	SADP2011 -PK-59	Testudines	Trionychid ae indet.	carapace fragment	13.61	screened	non- enamel(oid)-covered
tmp2011.0 53.0123	SADP2011 -PK-60	Testudines	Trionychid ae indet.	carapace fragment	15.70	screened	non- enamel(oid)-covered
tmp2011.0 53.0124	SADP2011 -PK-61	Testudines	Trionychid ae indet.	carapace fragment	12.62	screened	non- enamel(oid)-covered
tmp2011.0 53.0125	SADP2011 -PK-62	Testudines	Testudines indet.	rib fragment	17.95	screened	non- enamel(oid)-covered
tmp2011.0 53.0126	SADP2011 -PK-63	Testudines	Testudines indet.	partial metatars al	10.64	screened	non- enamel(oid)-covered
tmp2011.0 53.0127	SADP2011 -PK-64	Choristoder a	<i>Champsosa urus</i>	vertebra	16.38	screened	non- enamel(oid)-covered
tmp2011.0 53.0128	SADP2011 -PK-65	Choristoder a	<i>Champsosa urus</i>	vertebra	8.76	screened	non- enamel(oid)-covered
tmp2011.0 53.0129	SADP2011 -PK-66	Choristoder a	<i>Champsosa urus</i>	vertebra	12.26	screened	non- enamel(oid)-covered
tmp2011.0 53.0130	SADP2011 -PK-67	Choristoder a	<i>Champsosa urus</i>	vertebra	12.78	screened	non- enamel(oid)-covered
tmp2011.0 53.0131	SADP2011 -PK-68	Choristoder a	<i>Champsosa urus</i>	vertebra	9.85	screened	non- enamel(oid)-covered
tmp2011.0 53.0132	SADP2011 -PK-69	Crocodylo morpha	Eusuchia indet.	tooth	4.08	screened	enamel(oid)-covered
tmp2011.0 53.0133	SADP2011 -PK-70	Crocodylo morpha	Eusuchia indet.	tooth	2.57	screened	enamel(oid)-covered
tmp2011.0 53.0134	SADP2011 -PK-71	Crocodylo morpha	Eusuchia indet.	tooth	3.68	screened	enamel(oid)-covered
tmp2011.0 53.0135	SADP2011 -PK-72	Crocodylo morpha	Eusuchia indet.	tooth	2.30	screened	enamel(oid)-covered
tmp2011.0 53.0136	SADP2011 -PK-73	Crocodylo morpha	Eusuchia indet.	tooth	2.93	screened	enamel(oid)-covered
tmp2011.0 53.0137	SADP2011 -PK-74	Crocodylo morpha	Eusuchia indet.	tooth	14.80	screened	enamel(oid)-covered

tmp2011.0 53.0138	SADP2011 -PK-75	Crocodylo morpha	Eusuchia indet.	tooth	13.26	screened	enamel(oid)covered
tmp2011.0 53.0139	SADP2011 -PK-76	Crocodylo morpha	Eusuchia indet.	partial dentary	27.08	screened	non- enamel(oid)covered
tmp2011.0 53.0140	SADP2011 -PK-77	Crocodylo morpha	Eusuchia indet.	partial vertebra	16.68	screened	non- enamel(oid)covered
tmp2011.0 53.0141	SADP2011 -PK-78	Crocodylo morpha	Eusuchia indet.	scute	16.18	screened	non- enamel(oid)covered
tmp2011.0 53.0142	SADP2011 -PK-79	Crocodylo morpha	Eusuchia indet.	scute	14.00	screened	non- enamel(oid)covered
tmp2011.0 53.0143	SADP2011 -PK-80	Crocodylo morpha	Eusuchia indet.	scute	11.92	screened	non- enamel(oid)covered
tmp2011.0 53.0144	SADP2011 -PK-81	Crocodylo morpha	Eusuchia indet.	scute	15.75	screened	non- enamel(oid)covered
tmp2011.0 53.0145	SADP2011 -PK-82	Crocodylo morpha	Eusuchia indet.	scute	14.67	screened	non- enamel(oid)covered
tmp2011.0 53.0146	SADP2011 -PK-83	Dinosauria	Ceratopsid ae indet.	tooth fragment	12.30	screened	enamel(oid)covered
tmp2011.0 53.0147	SADP2011 -PK-84	Dinosauria	Ceratopsid ae indet.	tooth fragment	11.45	screened	enamel(oid)covered
tmp2011.0 53.0148	SADP2011 -PK-85	Dinosauria	Ankylosaur idae indet.	tooth	9.39	screened	enamel(oid)covered
tmp2011.0 53.0149	SADP2011 -PK-86	Dinosauria	Nodosaurid ae indet.	tooth	10.83	screened	enamel(oid)covered
tmp2011.0 53.0150	SADP2011 -PK-87	Dinosauria	Hadrosauri dae indet.	tooth	15.25	screened	enamel(oid)covered
tmp2011.0 53.0151	SADP2011 -PK-88	Dinosauria	Dromaeosa uridae indet.	tooth	5.84	screened	enamel(oid)covered
tmp2011.0 53.0152	SADP2011 -PK-89	Dinosauria	Dromaeosa uridae indet.	tooth	3.74	screened	enamel(oid)covered
tmp2013.0 19.0072	SADP2013 -PK-01	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.36	screened	enamel(oid)covered
tmp2013.0 19.0073	SADP2013 -PK-02	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	1.92	screened	enamel(oid)covered
tmp2013.0 19.0074	SADP2013 -PK-03	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	3.62	screened	enamel(oid)covered
tmp2013.0 19.0075	SADP2013 -PK-04	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	2.78	screened	enamel(oid)covered
tmp2013.0 19.0076	SADP2013 -PK-05	Holocephal i	<i>Elasmodus sp.</i>	jaw	18.12	screened	non- enamel(oid)covered
tmp2013.0 19.0077	SADP2013 -PK-06	Holostei	Holostean B	scale	6.23	screened	enamel(oid)covered
tmp2013.0 19.0078	SADP2013 -PK-07	Holostei	<i>Lepisosteus</i>	scale	5.39	screened	enamel(oid)covered
tmp2013.0 19.0079	SADP2013 -PK-08	Holostei	<i>Lepisosteus</i>	scale	4.85	screened	enamel(oid)covered

tmp2013.0 19.0080	SADP2013 -PK-09	Holostei	<i>Lepisosteus</i>	scale	8.23	screened	enamel(oid)-covered
tmp2013.0 19.0081	SADP2013 -PK-10	Holostei	<i>Lepisosteus</i>	scale	8.89	screened	enamel(oid)-covered
tmp2013.0 19.0082	SADP2013 -PK-11	Holostei	<i>Lepisosteus</i>	scale	7.57	screened	enamel(oid)-covered
tmp2013.0 19.0083	SADP2013 -PK-12	Holostei	<i>Lepisosteus</i>	scale	4.91	screened	enamel(oid)-covered
tmp2013.0 19.0084	SADP2013 -PK-13	Holostei	<i>Lepisosteus</i>	scale	7.42	screened	enamel(oid)-covered
tmp2013.0 19.0085	SADP2013 -PK-14	Lissamphib ia	Anura indet.	ilium	5.96	screened	non- enamel(oid)-covered
tmp2013.0 19.0086	SADP2013 -PK-15	Squamata	Squamata indet.	rib fragment	21.73	screened	non- enamel(oid)-covered
tmp2013.0 19.0087	SADP2013 -PK-16	Squamata	Squamata indet.	rib fragment	11.57	screened	non- enamel(oid)-covered
tmp2013.0 19.0088	SADP2013 -PK-17	Testudines	Solemydid ae	carapace fragment	4.01	screened	non- enamel(oid)-covered
tmp2013.0 19.0089	SADP2013 -PK-18	Testudines	Solemydid ae	carapace fragment	8.94	screened	non- enamel(oid)-covered
tmp2013.0 19.0090	SADP2013 -PK-19	Testudines	Solemydid ae	carapace fragment	11.54	screened	non- enamel(oid)-covered
tmp2013.0 19.0091	SADP2013 -PK-20	Testudines	Solemydid ae	carapace fragment	15.83	screened	non- enamel(oid)-covered
tmp2013.0 19.0092	SADP2013 -PK-21	Testudines	Solemydid ae	carapace fragment	8.98	screened	non- enamel(oid)-covered
tmp2013.0 19.0093	SADP2013 -PK-22	Testudines	Solemydid ae	carapace fragment	20.33	screened	non- enamel(oid)-covered
tmp2013.0 19.0094	SADP2013 -PK-23	Testudines	<i>Adocus</i>	carapace fragment	22.86	screened	non- enamel(oid)-covered
tmp2013.0 19.0095	SADP2013 -PK-24	Testudines	Baenidae indet.	carapace fragment	22.56	screened	non- enamel(oid)-covered
tmp2013.0 19.0096	SADP2013 -PK-25	Testudines	Baenidae indet.	carapace fragment	21.50	screened	non- enamel(oid)-covered
tmp2013.0 19.0097	SADP2013 -PK-26	Choristoder a	<i>Champsosa urus</i>	rib fragment	26.35	screened	non- enamel(oid)-covered
tmp2013.0 19.0098	SADP2013 -PK-27	Crocodylo morpha	Eusuchia indet.	tooth	7.79	screened	enamel(oid)-covered
tmp2013.0 19.0099	SADP2013 -PK-28	Crocodylo morpha	Eusuchia indet.	tooth	5.94	screened	enamel(oid)-covered
tmp2013.0 19.0100	SADP2013 -PK-29	Crocodylo morpha	Eusuchia indet.	tooth	2.79	screened	enamel(oid)-covered

tmp2013.0 19.0101	SADP2013 -PK-30	Crocodylo morpha	Eusuchia indet.	tooth	5.12	screened	enamel(oid)covered
tmp2013.0 19.0102	SADP2013 -PK-31	Dinosauria	Hadrosauri dae indet.	tooth	8.84	screened	enamel(oid)covered
tmp2013.0 19.0103	SADP2013 -PK-32	Dinosauria	Hadrosauri dae indet.	tooth	5.20	screened	enamel(oid)covered
tmp2015.0 44.0092	SADP2015 -PK-01	Elasmobran chii	Odontaspid idae	tooth	12.11	surface	enamel(oid)covered
tmp2015.0 44.0093	SADP2015 -PK-02	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	4.22	surface	enamel(oid)covered
tmp2015.0 44.0094	SADP2015 -PK-03	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	7.08	surface	enamel(oid)covered
tmp2015.0 44.0095	SADP2015 -PK-04	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	6.01	surface	enamel(oid)covered
tmp2015.0 44.0096	SADP2015 -PK-05	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.35	surface	enamel(oid)covered
tmp2015.0 44.0097	SADP2015 -PK-06	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	6.08	surface	enamel(oid)covered
tmp2015.0 44.0098	SADP2015 -PK-07	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	5.39	surface	enamel(oid)covered
tmp2015.0 44.0099	SADP2015 -PK-08	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	4.98	surface	enamel(oid)covered
tmp2015.0 44.0100	SADP2015 -PK-09	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	4.73	surface	enamel(oid)covered
tmp2015.0 44.0101	SADP2015 -PK-10	Elasmobran chii	<i>Pseudomyl edaphus</i>	tooth	6.01	surface	enamel(oid)covered
tmp2015.0 44.0102	SADP2015 -PK-11	Elasmobran chii	<i>Pseudomyl edaphus</i>	vertebra	4.98	surface	non- enamel(oid)covered
tmp2015.0 44.0103	SADP2015 -PK-12	Holocephal i	<i>Elasmodus sp.</i>	jaw fragment	8.15	surface	non- enamel(oid)covered
tmp2015.0 44.0104	SADP2015 -PK-13	Holocephal i	<i>Elasmodus sp.</i>	jaw fragment	16.24	surface	non- enamel(oid)covered
tmp2015.0 44.0105	SADP2015 -PK-14	Holostei	Holostean B	scale	8.11	surface	enamel(oid)covered
tmp2015.0 44.0106	SADP2015 -PK-15	Holostei	Holostean B	scale	8.72	surface	enamel(oid)covered
tmp2015.0 44.0107	SADP2015 -PK-16	Holostei	<i>Lepisosteus</i>	scale	12.53	surface	enamel(oid)covered
tmp2015.0 44.0108	SADP2015 -PK-17	Holostei	<i>Lepisosteus</i>	scale	11.84	surface	enamel(oid)covered
tmp2015.0 44.0109	SADP2015 -PK-18	Holostei	<i>Lepisosteus</i>	scale	12.81	surface	enamel(oid)covered
tmp2015.0 44.0110	SADP2015 -PK-19	Holostei	<i>Lepisosteus</i>	scale	8.25	surface	enamel(oid)covered
tmp2015.0 44.0111	SADP2015 -PK-20	Holostei	<i>Lepisosteus</i>	scale	10.27	surface	enamel(oid)covered
tmp2015.0 44.0112	SADP2015 -PK-21	Holostei	<i>Lepisosteus</i>	scale	10.98	surface	enamel(oid)covered
tmp2015.0 44.0113	SADP2015 -PK-22	Holostei	<i>Lepisosteus</i>	scale	6.81	surface	enamel(oid)covered
tmp2015.0 44.0114	SADP2015 -PK-23	Holostei	<i>Lepisosteus</i>	scale	6.18	surface	enamel(oid)covered

tmp2015.0 44.0115	SADP2015 -PK-24	Holostei	<i>Lepisosteus</i>	tooth	4.94	surface	enamel(oid))-covered
tmp2015.0 44.0116	SADP2015 -PK-25	Holostei	<i>Lepisosteus</i>	vertebra	8.09	surface	non- enamel(oid))-covered
tmp2015.0 44.0117	SADP2015 -PK-26	Lissamphib ia	<i>Scapherpet on</i>	dorsal vertebra	7.11	surface	non- enamel(oid))-covered
tmp2015.0 44.0118	SADP2015 -PK-27	Squamata	Squamata indet.	vertebral fragment	11.99	surface	non- enamel(oid))-covered
tmp2015.0 44.0119	SADP2015 -PK-28	Squamata	Mosasaurid ae indet.	phalanx	24.31	surface	non- enamel(oid))-covered
tmp2015.0 44.0120	SADP2015 -PK-29	Testudines	<i>Adocus</i>	carapace fragment	24.20	surface	non- enamel(oid))-covered
tmp2015.0 44.0121	SADP2015 -PK-30	Testudines	<i>Adocus</i>	carapace fragment	17.38	surface	non- enamel(oid))-covered
tmp2015.0 44.0122	SADP2015 -PK-31	Testudines	<i>Adocus</i>	carapace fragment	14.95	surface	non- enamel(oid))-covered
tmp2015.0 44.0123	SADP2015 -PK-32	Testudines	<i>Adocus</i>	carapace fragment	18.16	surface	non- enamel(oid))-covered
tmp2015.0 44.0124	SADP2015 -PK-33	Testudines	<i>Adocus</i>	carapace fragment	12.82	surface	non- enamel(oid))-covered
tmp2015.0 44.0125	SADP2015 -PK-34	Testudines	<i>Adocus</i>	carapace fragment	7.79	surface	non- enamel(oid))-covered
tmp2015.0 44.0126	SADP2015 -PK-35	Testudines	<i>Adocus</i>	carapace fragment	9.89	surface	non- enamel(oid))-covered
tmp2015.0 44.0127	SADP2015 -PK-36	Testudines	<i>Adocus</i>	carapace fragment	8.92	surface	non- enamel(oid))-covered
tmp2015.0 44.0128	SADP2015 -PK-37	Testudines	Baenidae indet.	costal fragment	30.42	surface	non- enamel(oid))-covered
tmp2015.0 44.0129	SADP2015 -PK-38	Testudines	Baenidae indet.	carapace fragment	20.13	surface	non- enamel(oid))-covered
tmp2015.0 44.0130	SADP2015 -PK-39	Testudines	Baenidae indet.	carapace fragment	14.91	surface	non- enamel(oid))-covered
tmp2015.0 44.0131	SADP2015 -PK-40	Testudines	Baenidae indet.	carapace fragment	20.45	surface	non- enamel(oid))-covered
tmp2015.0 44.0132	SADP2015 -PK-41	Testudines	Baenidae indet.	carapace fragment	17.26	surface	non- enamel(oid))-covered
tmp2015.0 44.0133	SADP2015 -PK-42	Testudines	Baenidae indet.	carapace fragment	15.45	surface	non- enamel(oid))-covered

tmp2015.0 44.0134	SADP2015 -PK-43	Testudines	<i>Basilemys</i>	carapace fragment	36.59	surface	non- enamel(oid)covered
tmp2015.0 44.0135	SADP2015 -PK-44	Testudines	<i>Basilemys</i>	carapace fragment	24.74	surface	non- enamel(oid)covered
tmp2015.0 44.0136	SADP2015 -PK-45	Testudines	Chelydrida e	peripher al fragment	22.97	surface	non- enamel(oid)covered
tmp2015.0 44.0137	SADP2015 -PK-46	Testudines	Solemydid ae	scute	11.97	surface	non- enamel(oid)covered
tmp2015.0 44.0138	SADP2015 -PK-47	Testudines	Solemydid ae	scute	13.12	surface	non- enamel(oid)covered
tmp2015.0 44.0139	SADP2015 -PK-48	Testudines	Solemydid ae	carapace fragment	29.26	surface	non- enamel(oid)covered
tmp2015.0 44.0140	SADP2015 -PK-49	Testudines	Solemydid ae	carapace fragment	34.99	surface	non- enamel(oid)covered
tmp2015.0 44.0141	SADP2015 -PK-50	Testudines	Solemydid ae	carapace fragment	27.09	surface	non- enamel(oid)covered
tmp2015.0 44.0142	SADP2015 -PK-51	Testudines	Solemydid ae	carapace fragment	5.87	surface	non- enamel(oid)covered
tmp2015.0 44.0143	SADP2015 -PK-52	Testudines	Solemydid ae	carapace fragment	14.40	surface	non- enamel(oid)covered
tmp2015.0 44.0144	SADP2015 -PK-53	Testudines	Solemydid ae	carapace fragment	19.23	surface	non- enamel(oid)covered
tmp2015.0 44.0145	SADP2015 -PK-54	Testudines	Solemydid ae	carapace fragment	21.14	surface	non- enamel(oid)covered
tmp2015.0 44.0146	SADP2015 -PK-55	Testudines	Solemydid ae	carapace fragment	12.76	surface	non- enamel(oid)covered
tmp2015.0 44.0147	SADP2015 -PK-56	Testudines	Solemydid ae	carapace fragment	10.39	surface	non- enamel(oid)covered
tmp2015.0 44.0148	SADP2015 -PK-57	Testudines	Solemydid ae	carapace fragment	17.28	surface	non- enamel(oid)covered
tmp2015.0 44.0149	SADP2015 -PK-58	Testudines	Solemydid ae	carapace fragment	13.75	surface	non- enamel(oid)covered
tmp2015.0 44.0150	SADP2015 -PK-59	Testudines	Solemydid ae	carapace fragment	11.73	surface	non- enamel(oid)covered
tmp2015.0 44.0151	SADP2015 -PK-60	Testudines	Solemydid ae	carapace fragment	12.40	surface	non- enamel(oid)covered
tmp2015.0 44.0152	SADP2015 -PK-61	Testudines	Solemydid ae	carapace fragment	14.98	surface	non- enamel(oid

							)-covered
tmp2015.0 44.0153	SADP2015 -PK-62	Testudines	Trionychid ae indet.	neural fragment	19.31	surface	non- enamel(oid)covered
tmp2015.0 44.0154	SADP2015 -PK-63	Testudines	Trionychid ae indet.	carapace fragment	26.17	surface	non- enamel(oid)covered
tmp2015.0 44.0155	SADP2015 -PK-64	Testudines	Trionychid ae indet.	carapace fragment	35.60	surface	non- enamel(oid)covered
tmp2015.0 44.0156	SADP2015 -PK-65	Testudines	Trionychid ae indet.	carapace fragment	11.13	surface	non- enamel(oid)covered
tmp2015.0 44.0157	SADP2015 -PK-66	Testudines	Trionychid ae indet.	carapace fragment	19.83	surface	non- enamel(oid)covered
tmp2015.0 44.0158	SADP2015 -PK-67	Testudines	Trionychid ae indet.	carapace fragment	18.04	surface	non- enamel(oid)covered
tmp2015.0 44.0159	SADP2015 -PK-68	Testudines	Trionychid ae indet.	carapace fragment	19.87	surface	non- enamel(oid)covered
tmp2015.0 44.0160	SADP2015 -PK-69	Testudines	Trionychid ae indet.	carapace fragment	18.22	surface	non- enamel(oid)covered
tmp2015.0 44.0161	SADP2015 -PK-70	Testudines	Trionychid ae indet.	carapace fragment	31.06	surface	non- enamel(oid)covered
tmp2015.0 44.0162	SADP2015 -PK-71	Choristoder a	<i>Champsosa urus</i>	vertebra	18.72	surface	non- enamel(oid)covered
tmp2015.0 44.0163	SADP2015 -PK-72	Choristoder a	<i>Champsosa urus</i>	vertebra	18.13	surface	non- enamel(oid)covered
tmp2015.0 44.0164	SADP2015 -PK-73	Choristoder a	<i>Champsosa urus</i>	vertebra	15.49	surface	non- enamel(oid)covered
tmp2015.0 44.0165	SADP2015 -PK-74	Choristoder a	<i>Champsosa urus</i>	vertebra	19.43	surface	non- enamel(oid)covered
tmp2015.0 44.0166	SADP2015 -PK-75	Choristoder a	<i>Champsosa urus</i>	vertebra	19.11	surface	non- enamel(oid)covered
tmp2015.0 44.0167	SADP2015 -PK-76	Choristoder a	<i>Champsosa urus</i>	vertebra	18.39	surface	non- enamel(oid)covered
tmp2015.0 44.0168	SADP2015 -PK-77	Choristoder a	<i>Champsosa urus</i>	vertebra	17.73	surface	non- enamel(oid)covered
tmp2015.0 44.0169	SADP2015 -PK-78	Choristoder a	<i>Champsosa urus</i>	vertebra	16.81	surface	non- enamel(oid)covered
tmp2015.0 44.0170	SADP2015 -PK-79	Choristoder a	<i>Champsosa urus</i>	vertebra	6.95	surface	non- enamel(oid)covered

tmp2015.0 44.0171	SADP2015 -PK-80	Choristoder a	<i>Champsosa urus</i>	vertebra	15.13	surface	non- enamel(oid)covered
tmp2015.0 44.0172	SADP2015 -PK-81	Choristoder a	<i>Champsosa urus</i>	vertebra	7.84	surface	non- enamel(oid)covered
tmp2015.0 44.0173	SADP2015 -PK-82	Choristoder a	<i>Champsosa urus</i>	vertebra	10.23	surface	non- enamel(oid)covered
tmp2015.0 44.0174	SADP2015 -PK-83	Choristoder a	<i>Champsosa urus</i>	vertebra	8.87	surface	non- enamel(oid)covered
tmp2015.0 44.0175	SADP2015 -PK-84	Choristoder a	<i>Champsosa urus</i>	vertebra	11.44	surface	non- enamel(oid)covered
tmp2015.0 44.0176	SADP2015 -PK-85	Choristoder a	<i>Champsosa urus</i>	rib fragment	13.62	surface	non- enamel(oid)covered
tmp2015.0 44.0177	SADP2015 -PK-86	Choristoder a	<i>Champsosa urus</i>	rib fragment	22.13	surface	non- enamel(oid)covered
tmp2015.0 44.0178	SADP2015 -PK-87	Choristoder a	<i>Champsosa urus</i>	tooth	8.25	surface	enamel(oid)covered
tmp2015.0 44.0179	SADP2015 -PK-88	Choristoder a	<i>Champsosa urus</i>	ilium frag.	21.84	surface	non- enamel(oid)covered
tmp2015.0 44.0180	SADP2015 -PK-89	Choristoder a	<i>Champsosa urus</i>	ilium frag.	20.79	surface	non- enamel(oid)covered
tmp2015.0 44.0181	SADP2015 -PK-90	Choristoder a	<i>Champsosa urus</i>	ilium frag.	18.68	surface	non- enamel(oid)covered
tmp2015.0 44.0182	SADP2015 -PK-91	Choristoder a	<i>Champsosa urus</i>	ilium frag.	18.54	surface	non- enamel(oid)covered
tmp2015.0 44.0183	SADP2015 -PK-92	Crocodylo morpha	Eusuchia indet.	scute	12.72	surface	non- enamel(oid)covered
tmp2015.0 44.0184	SADP2015 -PK-93	Crocodylo morpha	Eusuchia indet.	scute	10.96	surface	non- enamel(oid)covered
tmp2015.0 44.0185	SADP2015 -PK-94	Crocodylo morpha	Eusuchia indet.	scute	18.20	surface	non- enamel(oid)covered
tmp2015.0 44.0186	SADP2015 -PK-95	Crocodylo morpha	Eusuchia indet.	scute	14.45	surface	non- enamel(oid)covered
tmp2015.0 44.0187	SADP2015 -PK-96	Crocodylo morpha	Eusuchia indet.	scute	15.65	surface	non- enamel(oid)covered
tmp2015.0 44.0188	SADP2015 -PK-97	Crocodylo morpha	Eusuchia indet.	scute	22.09	surface	non- enamel(oid)covered
tmp2015.0 44.0189	SADP2015 -PK-98	Crocodylo morpha	Eusuchia indet.	scute	19.52	surface	non- enamel(oid)covered

tmp2015.0 44.0190	SADP2015 -PK-99	Crocodylo morpha	Eusuchia indet.	scute	21.29	surface	non- enamel(oid)covered
tmp2015.0 44.0191	SADP2015 -PK-100	Crocodylo morpha	Eusuchia indet.	scute	20.88	surface	non- enamel(oid)covered
tmp2015.0 44.0192	SADP2015 -PK-101	Crocodylo morpha	Eusuchia indet.	scute	12.51	surface	non- enamel(oid)covered
tmp2015.0 44.0193	SADP2015 -PK-102	Crocodylo morpha	Eusuchia indet.	scute	11.66	surface	non- enamel(oid)covered
tmp2015.0 44.0194	SADP2015 -PK-103	Crocodylo morpha	Eusuchia indet.	scute	17.50	surface	non- enamel(oid)covered
tmp2015.0 44.0195	SADP2015 -PK-104	Crocodylo morpha	Eusuchia indet.	skull frag.	29.80	surface	non- enamel(oid)covered
tmp2015.0 44.0196	SADP2015 -PK-105	Crocodylo morpha	Eusuchia indet.	skull frag.	29.12	surface	non- enamel(oid)covered
tmp2015.0 44.0197	SADP2015 -PK-106	Crocodylo morpha	Eusuchia indet.	skull frag.	15.87	surface	non- enamel(oid)covered
tmp2015.0 44.0198	SADP2015 -PK-107	Crocodylo morpha	Eusuchia indet.	vert frag.	17.87	surface	non- enamel(oid)covered
tmp2015.0 44.0199	SADP2015 -PK-108	Crocodylo morpha	Eusuchia indet.	rib frag.	16.55	surface	non- enamel(oid)covered
tmp2015.0 44.0200	SADP2015 -PK-109	Crocodylo morpha	Eusuchia indet.	tooth	21.37	surface	enamel(oid)covered
tmp2015.0 44.0201	SADP2015 -PK-110	Crocodylo morpha	Eusuchia indet.	tooth	11.49	surface	enamel(oid)covered
tmp2015.0 44.0202	SADP2015 -PK-111	Crocodylo morpha	Eusuchia indet.	tooth	3.19	surface	enamel(oid)covered
tmp2015.0 44.0203	SADP2015 -PK-112	Crocodylo morpha	Eusuchia indet.	tooth	9.33	surface	enamel(oid)covered
tmp2015.0 44.0204	SADP2015 -PK-113	Crocodylo morpha	Eusuchia indet.	tooth	12.41	surface	enamel(oid)covered
tmp2015.0 44.0205	SADP2015 -PK-114	Crocodylo morpha	Eusuchia indet.	tooth	12.97	surface	enamel(oid)covered
tmp2015.0 44.0206	SADP2015 -PK-115	Crocodylo morpha	Eusuchia indet.	tooth	8.67	surface	enamel(oid)covered
tmp2015.0 44.0207	SADP2015 -PK-116	Crocodylo morpha	Eusuchia indet.	tooth	5.79	surface	enamel(oid)covered
tmp2015.0 44.0208	SADP2015 -PK-117	Dinosauria	Hadrosauri dae indet.	tooth	11.24	surface	enamel(oid)covered
tmp2015.0 44.0209	SADP2015 -PK-118	Dinosauria	Hadrosauri dae indet.	tooth	7.91	surface	enamel(oid)covered
tmp2015.0 44.0210	SADP2015 -PK-119	Dinosauria	Hadrosauri dae indet.	tooth	6.93	surface	enamel(oid)covered
tmp2015.0 44.0211	SADP2015 -PK-120	Dinosauria	Ankylosaur ia indet.	scute frag.	36.32	surface	non- enamel(oid)covered

tmp2015.0 44.0212	SADP2015 -PK-121	Dinosauria	Ankylosaur idae indet.	tooth	8.08	surface	enamel(oid)-covered
tmp2015.0 44.0213	SADP2015 -PK-122	Dinosauria	Ankylosaur idae indet.	tooth	7.32	surface	enamel(oid)-covered
tmp2015.0 44.0214	SADP2015 -PK-123	Dinosauria	Nodosaurid ae indet.	tooth	9.77	surface	enamel(oid)-covered
tmp2015.0 44.0215	SADP2015 -PK-124	Dinosauria	Pachyceph alosauridae indet.	dome frag.	41.10	surface	non- enamel(oid)-covered
tmp2015.0 44.0216	SADP2015 -PK-125	Dinosauria	Tyrannosau ridae indet.	tooth	11.56	surface	enamel(oid)-covered
tmp2015.0 44.0217	SADP2015 -PK-126	Holocephal i	<i>Elasmodus</i> <i>sp.</i>	jaw fragment	9.11	surface	non- enamel(oid)-covered

Appendix 3: Size data for unidentified vertebrate material at PK microsite.

Size Fractions - Unidentified Vertebrate Remains - Long Axis Measurements

2009 (screened) (mm)	2011 (screened) (mm)	2013 (screened) (mm)
57.87	2.93	1.27
14.81	7.34	8.26
19.20	16.51	19.21
13.13	13.83	27.28
19.87	12.95	25.62
6.69	18.60	16.91
9.90	3.88	13.25
	1.30	12.54
	1.33	17.68
	0.72	16.31
	16.38	17.43
	9.46	7.32
	4.68	12.16
	11.30	9.43
	7.79	6.92
	1.64	3.73
	5.46	4.60
	1.16	14.53
	2.53	13.62
	1.24	3.20
	2.01	7.14
	2.04	4.94
	2.52	11.85
	1.13	14.43
	0.63	3.21
	1.12	12.84
	0.58	11.03
	1.14	9.63
	1.69	16.90
	2.55	10.14
	2.09	13.70
	4.11	8.79
	2.74	8.97
	4.03	10.84
	5.06	6.25
	3.95	1.79

	2.99	1.39
	3.06	2.89
	3.92	1.78
	2.72	2.63
	4.28	13.16
	1.01	8.62
	9.60	7.04
	2.40	14.47
	2.87	13.20
	2.42	12.28
	0.37	10.89
	1.37	8.06
	2.07	14.48
	1.76	5.26
	1.35	2.69
	2.91	2.54
	3.42	17.30
	13.56	6.57
	11.40	6.72
	4.28	4.53
	4.39	2.01
	1.78	2.16
	3.76	10.97
	3.12	4.00
	3.85	7.90
	3.08	4.97
	3.32	1.18
	5.10	5.01
	3.10	4.06
	1.70	4.10
	0.31	3.25
	0.97	6.36
	2.43	2.56
	1.62	3.05
	0.42	2.55
	0.44	2.93
	6.38	7.92
	16.51	6.14
	5.89	1.27
	3.16	6.65
	5.49	2.36
	5.77	7.85
	6.53	6.11

	4.76	5.44
	1.48	2.35
	1.91	4.90
	3.75	1.58
	1.32	0.75
	1.22	2.38
	4.56	1.43
	2.60	3.66
	2.10	0.95
	2.06	1.71
	1.53	1.98
	1.98	5.24
	3.50	6.87
	3.56	3.15
	2.17	5.58
	1.35	7.51
	3.04	3.67
	4.07	7.37
	9.94	1.30
	7.97	10.75
	12.13	10.22
	10.41	9.19
	12.63	11.81
	6.07	9.96
	13.39	10.93
	16.26	4.96
	9.82	6.77
	15.83	6.00
	11.77	9.52
	5.29	7.45
	12.27	5.68
	3.38	5.63
	3.21	7.09
	3.36	6.99
	7.46	8.20
	4.31	3.75
	3.35	3.18
	6.67	5.75
	6.90	7.69
	4.62	6.56
	10.99	3.32
	5.59	3.27
	1.22	1.53

	1.12	4.04
	2.27	1.25
	1.23	2.31
	4.11	2.75
	2.43	1.61
	1.51	2.00
	1.38	3.01
	6.47	7.39
	6.91	2.44
	2.27	4.19
	1.53	2.93
	5.70	2.40
	3.62	2.87
	4.69	1.19
	5.94	1.74
	4.62	9.10
	4.98	2.71
	9.19	5.21
	13.13	1.85
	5.92	2.60
	9.88	1.25
	7.25	5.89
	11.77	3.72
	3.26	3.84
	2.56	3.48
	13.45	5.44
	15.16	5.59
	8.87	6.49
	12.03	0.45
	6.69	1.52
	8.88	1.78
	5.72	1.17
	4.81	3.57
	0.61	3.03
	4.73	2.59
	1.25	4.05
	1.90	7.31
	6.37	2.12
	4.29	2.98
	6.70	1.86
	8.00	0.83
	8.46	2.16
	10.92	3.31

	7.19	3.42
	2.70	1.63
	7.43	4.87
	7.10	5.74
	9.30	2.74
	6.74	2.43
	3.82	1.35
	9.69	6.21
	3.56	1.22
	11.76	2.66
	7.30	1.95
	7.80	2.38
	1.21	0.33
	8.34	2.90
	5.83	2.11
	7.82	0.93
	6.89	1.28
	4.27	1.55
	7.84	1.97
	10.70	0.41
	1.30	0.99
	7.67	2.16
	8.25	1.12
	5.01	1.59
	6.93	1.01
	7.21	0.91
	5.51	4.19
	5.69	1.12
	9.80	3.26
	9.37	2.94
	9.93	2.31
	6.75	1.83
	11.26	3.37
	9.96	1.09
	9.49	1.08
	3.63	1.05
	2.09	0.62
	3.35	1.51
	2.04	1.40
	1.89	1.55
	2.62	2.00
	11.31	1.71
	3.83	1.78

0.98	5.52
15.91	1.46
2.64	0.90
3.44	1.47
2.85	1.58
1.39	1.14
3.18	0.74
0.62	2.47
4.65	1.30
3.31	2.31
3.14	3.93
2.80	0.53
5.80	0.26
10.12	0.64
4.35	1.15
3.47	1.19
2.36	0.09
1.63	1.00
1.68	1.74
3.70	0.85
4.72	2.60
4.04	
1.69	
6.24	
3.66	
2.50	
10.01	
0.54	
4.58	
4.04	
3.67	
1.86	
3.70	
3.16	
6.95	
6.37	
3.52	
1.33	
6.11	
1.91	
0.67	
2.26	
6.11	

	5.25
	5.16
	2.96
	3.50
	4.63
	1.65
	3.29
	4.10
	1.25
	0.85
	1.91
	2.44
	0.77
	2.14
	1.19
	0.85
	2.27
	1.22
	0.32
	0.29
	2.22

Appendix 4: Comparison of proportional abundances of lissamphibians and sharks in microsites analyzed in this study.

Amphibian Proportions											
	PHS(O1)	EZ(O1)	PHR93-2(O1)	WS(O1)	HoS(O1)	SPS(For)	PHR-1(For)	PHR-2(For)	PK(For)	Frampton(Fo	
total amph	102		125	293	392	297	433	74	134	2	31
total all site	967		720	813	1782	1761	1738	7375	6750	280	7924
proportion	10.5480869	17.36111111	36.0393604	21.9977553	16.8654174	24.9136939	1.00338983	1.98518519	0.71428571	0.39121656	
		avg terr	21.2875708								
		avg mar	1.02351932								
		avg terr (no SPS)	20.5623462								
		avg mar (no PK)	1.12659719								
Shark Proportions											
	PHS(O1)	EZ(O1)	PHR93-2(O1)	WS(O1)	HoS(O1)	SPS(For)	PHR-1(For)	PHR-2(For)	PK(For)	Frampton(Fo	
total sharks	0		0	1	1	0	5	42	145	8	876
total all site	967		720	813	1782	1761	1738	7375	6750	280	7924
proportion	0		0.12300123	0.05611672		0	0.287687	0.56949153	2.14814815	2.85714286	11.0550227
		avg terr	0.07780082								
		avg mar	4.15745131								