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An Ilium of a Juvenile *Stokesosaurus* (Dinosauria, Theropoda) from the Morrison Formation (Upper Jurassic: Kimmeridgian), Meade County, South Dakota

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ABSTRACT

A small ilium from the Morrison Formation of South Dakota is referred to the rare theropod *Stokesosaurus* on the basis of the presence of a marked vertical ridge on the lateral surface of the ilium. This specimen significantly extends the geographic range of the taxon north and east, indicating that *Stokesosaurus*, though relatively rare, was not geographically restricted within the Morrison ecosystem. Additional features are noted which support the generic separation of *Stokesosaurus* and *Iliosuchus*.

INTRODUCTION

Although the Cleveland-Lloyd Dinosaur Quarry in the Morrison Formation of Emery County, Utah, is best known for its abundant fossils of *Allosaurus fragilis*, it has also produced the remains of other theropods. One of these, *Stokesosaurus clevelandi* (Madsen 1974), is among the rarest and most poorly known theropods from the Late Jurassic of North America.

The type specimen of *S. clevelandi*, a left ilium (UUVP 2938 / UMNH 7434), is characterized by a distinct median vertical ridge ascending from the supra-acetabular hood to the dorsal margin of the blade (Madsen 1974). Galton (1976) referred *S. clevelandi* to the Middle Jurassic genus *Iliosuchus*, as *I. clevelandi*, but later recognized the genera as distinct (Galton and Jensen 1979). This distinction is supported by the new specimen. Referred specimens of *Stokesosaurus* material from CLDQ include a right ilium, a right premaxilla, and a braincase (Madsen 1974, Chure and Madsen, 1998). The only other referred material is three distal caudal vertebrae from the Dry Mesa Quarry in western Colorado (Britt, 1991), although this referral is not justified (Curtice and Wilhite, 1996).

Stokesosaurus remains one of the rarest theropods in the Morrison Formation. We report here on a new occurrence which is directly comparable with the type of *Stokesosaurus clevelandi* and which considerably extends its geographic range.

ABBREVIATIONS

BM	=	British Museum (Natural History), London
CLDQ	=	Cleveland-Lloyd Dinosaur Quarry, Emery County, UT
OUM	=	Oxford University Museum, Oxford
SDSM	=	South Dakota School of Mines & Technology Museum of Geology, Rapid City, SD
UUVP/UMNH	=	University of Utah Vertebrate Paleontology Collections and Utah Museum of Natural History, Salt Lake City, UT
YPM PU	=	Yale Peabody Museum (Princeton University Collection), New Haven, CT

LOCALITY

The Morrison Formation is exposed around the Black Hills Uplift in western South Dakota and northeastern Wyoming. The formation is much thinner in this region than on the Colorado Plateau. The lithologies are similar to areas south and west of the Black Hills, but the smectitic clays characteristic of the upper parts of the formation in areas like Como Bluff are absent. In the northwestern Black Hills, the Morrison consists mostly of clays with

thin, lenticular sandstones and thin lacustrine limestones. In the eastern Black Hills there is a higher percentage of siltstones and limestones in some areas, and in the southern Hills similar lithologies exist but much of the thickness of the formation consists of the eolian Unkpapa Sandstone Member (Szigeti and Fox, 1981).

The Wonderland Quarry (South Dakota School of Mines Locality V9141), where the specimen was collected, was discovered by G. Szigeti (1979). The quarry is located 18 km north of Rapid City, in Meade County, South Dakota (Fig. 1) and situated approximately five meters above the top of the eolian Unkpapa Sandstone Member (Foster, 1996). The quarry lithology consists of a light gray, silty claystone with several thin, interbedded limestone units. Ostracods and charophytes from just below the quarry level indicate a Kimmeridgian age (Schudack et al., 1998). Detailed locality information is available from the South Dakota School of Mines and Technology.

Crews from the South Dakota School of Mines excavated the site in 1980. Vertebrate material recovered includes teeth of *Camarasaurus*, a metatarsal, caudal vertebra, and teeth of *Allosaurus*, numerous shell fragments of *Glyptops*, and crocodilian teeth. The main skeleton at the quarry was a partial *Barosaurus lentus* skeleton (SDSM 25210), which consisted mainly of caudal vertebrae but also included two dorsal vertebrae, an ilium, a pubis, an ischium, and a partial scapula.

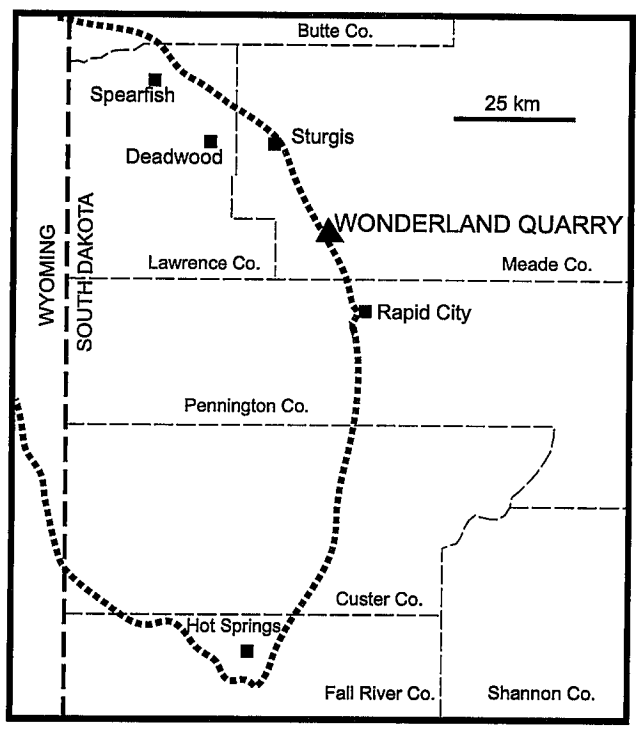

Figure 1. Location of the Wonderland Quarry (SDSM V9141) in Meade County, South Dakota, eastern Black Hills. Distribution of outcrops of the Upper Jurassic Morrison Formation shown by short-dash line.

DESCRIPTION

The specimen described herein was discovered by one of us (JRF) in 1991 during preparation of a block containing a dorsal vertebra and partial ilium of *Barosaurus* collected in 1980. The specimen is briefly mentioned by Foster (1996) in a description of South Dakota Morrison Formation localities. Unfortunately, the specimen was lost before cataloging. Although the specimen is missing, both authors had the opportunity to examine it first hand and photographs exist. Because of the extreme rarity of *Stokesosaurus*, and the fact that the specimen has already been mentioned in the literature, the specimen is significant enough to warrant documentation.

The ilium was approximately 8 cm long, as preserved, with the preacetabular blade broken off just cranial to the median vertical ridge (Fig. 2). Based on the proportions of the holotype of *Stokesosaurus clevelandi* (UUVP 2938 / UMNH 7434), the complete South Dakota ilium would have been about 12 cm long.

We refer the South Dakota specimen to *Stokesosaurus* because that is the only Morrison theropod with a vertical ridge on the lateral surface of the ilium (Figs. 2A, 3). However, the South Dakota ilium differs from the CLDQ ilia in that the ridge is less massive, is more vertically oriented, and flares more at its dorsal and ventral edges.

The postacetabular blade of the South Dakota specimen (Fig. 2) also resembles *Stokesosaurus* in having a rounded caudal border, as opposed to the squared off margin in *Allosaurus* and *Marshosaurus* (Fig. 3). The postacetabular part of the blade is not deflected ventrally nor is the dorsal margin of the ilium as strongly convex as in *Ceratosaurus* and *Torvosaurus*. The South Dakota specimen also differs from *Ceratosaurus*, *Torvosaurus*, and *Marshosaurus* in not having the medial wall of the brevis fossa visible in lateral view.

In ventral view (Fig. 2C) the brevis fossa in the South Dakota specimen has a squared off caudal margin, as in *Stokesosaurus* (Madsen 1974), and in contrast to the rounded margin in other Morrison theropods. The ischiadic peduncle (Figs. 2A, B) in the South Dakota specimen is short and wedge-shaped in lateral view, in contrast to *Marshosaurus* where the ischiadic peduncle is long and rectangular in lateral view.

The South Dakota specimen is about the same size as the type of *Iliosuchus incognitus* (BM R83), an equally poorly known Middle Jurassic theropod from England (Fig. 4). Both have a marked ridge on the lateral surface

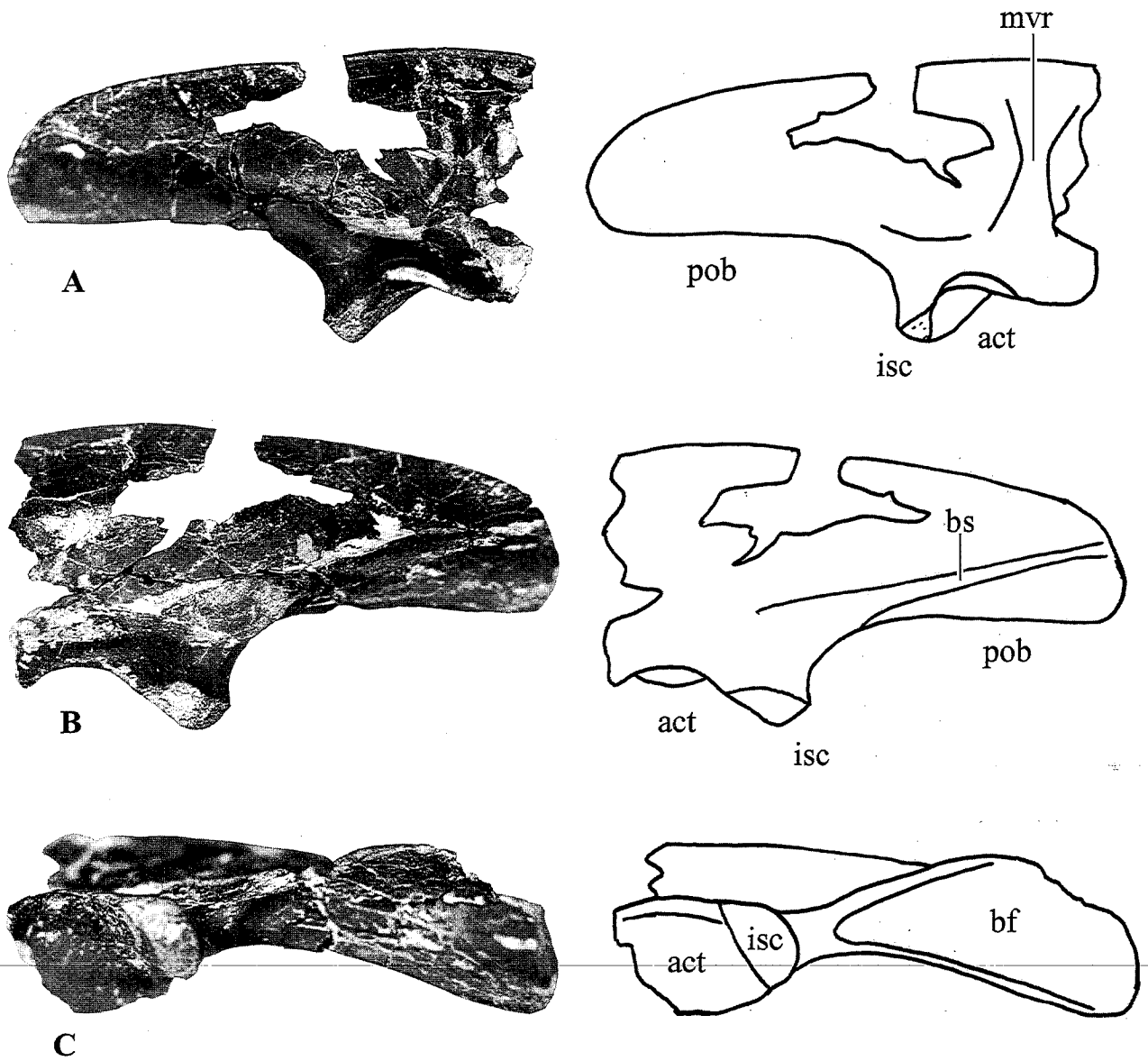

Figure 2. Right ilium of Stokesosaurus *from the Wonderland Quarry in A) lateral, B) medial, and C) ventral views. act = acetabulum; bf = brevis fossa; bs = brevis shelf; isc = ischiadic peduncle; mvr = median vertical ridge; pob = postacetabular blade. No specimen number is assigned to this now lost specimen. Length as preserved approximately 8 cm.*

of the ilium. The ridge in BM R83 is more posteriorly inclined than in the South Dakota specimen. However, in the only other specimen of *Iliosuchus incognitus* (OUMJ29871), a larger and equally incomplete ilium, the ridge is oriented vertically. If this reorientation of the ridge is ontogenetic in origin, the pattern in *Iliosuchus* is the opposite of that in *Stokesosaurus*. OUM J29871 also differs from *Stokesosaurus* is having additional ridges cranial and caudal to the main ridge.

The OUM specimen also differs from the South Dakota specimen in having a foramen on the ridge and another cranial to the ridge (Fig. 4). Bonaparte (1986) interpreted similar foramina in the ilium of *Piatnitzkysaurus floresi* as being pneumatic in origin. Britt (1993: 188–189) noted the small size of these foramina in contrast with the large size of pneumatic foramina and suggested that they are nutrient foramina. We concur with that interpretation. Furthermore, the presence of these foramina appears to be the result of individual variation, as they are occasionally present in "*Megalosaurus bucklandi*" (BM R1100, DJC pers. obs.).

The brevis shelf in the South Dakota specimen differs from that in *Iliosuchus incognitus* in being proportionately

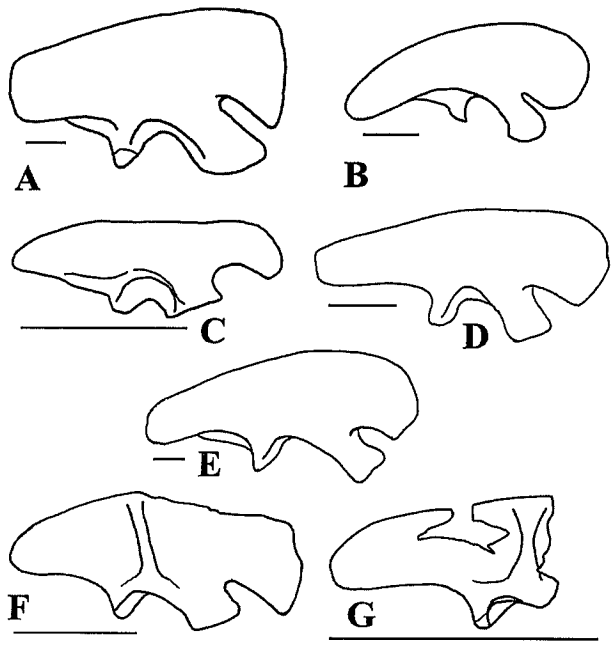

Figure 3. Ilia of theropods from the Morrison Formation in lateral view. A) Allosaurus fragilis *(after Madsen 1976, reversed). B)* Ceratosaurus nasicornis *(after Gilmore 1920, reversed). C)* Ornitholestes hermanni *(after Osborn 1917, reversed). D)* Torvosaurus tanneri *(after Britt 1991, reversed). E)* Marshosaurus bicentesimus *(YPM PU14554). F)* Stokesosaurus clevelandi *(after Madsen 1974, reversed). G) South Dakota specimen of* Stokesosaurus. *Scale bars = 10 cm.*

wider and having a squared off caudal border. The medial wall of the brevis shelf appears to be broadly exposed in lateral view in BM R83. However, in this specimen the ventral and caudal margins of the postacetabular blade are incomplete, thus giving an unnatural exposure of the medial wall. In OUM J29871 this part of the ilium is complete and the medial wall of the fossa is not visible in lateral view (compare Figs. 4A and C).

DISCUSSION

A vertical ridge on the lateral surface of the ilium occurs sporadically in theropods. It is present in the basal tetanuran *Piatnitzkysaurus floresi* (Bonaparte 1986), the therezinosauroid *Segnosaurus galbinensis* (Barsbold and Maryanska 1990), the tyrannosaurs *Albertosaurus libratus* (Lambe 1917), *Siamotyrannus isanensis* (Buffetaut, Suteethorn, and Tong 1996), and *Tyrannosaurus rex* (Osborn 1917), and some specimens of *"Megalosaurus bucklandi"* (Galton and Jensen 1979). Although the presence of this ridge is probably of little general phylogenetic significance, it is of value in differentiating *Stokesosaurus* ilia from the ilia of other theropods of the Morrison Formation. Furthermore, the median vertical ridge in *Iliosuchus* and *Stokesosaurus* are similar in being broad and robust. This contrasts with the relatively narrow ridge in other theropods with such a ridge.

The apparent different ontogenetic patterns in orientation of the medial vertical ridge, the broader bevis fossa, and the presence of accessory edges on the lateral surface of the ilium (at least in OUM 29781) provide further support for the generic separation of *Iliosuchus* and *Stokesosaurus* (Galton and Jensen 1979, *contra* Galton 1976).

Although the theropod fauna of the Morrison Formation, with nine genera, is moderately diverse, it is dominated both stratigraphically and geographically by *Allosaurus* (Foster and Chure 1998). Nearly three-quarters of the Morrison Formation theropod individuals (72.8%) are *Allosaurus,* exclusive of the CLDQ sample (Fig. 5). Among the taxa comprising the approximately one-quarter of non-*Allosaurus* specimens, *Ceratosaurus, Torvosaurus* (including *Edmarka*), and *Coelurus* are the most common. *Ceratosaurus* accounts for 5.4% of the total Morrison Formation theropod specimens, *Torvosaurus* 6.0%, and *Coelurus* 6.5%. The remaining taxa account for between 3.3% and 0.5% of the theropod sample, with *Stokesosaurus* at 1.6%.

The relative rarity of some of these theropods may be partially accounted for by their smaller size and presumably lower preservation potential. However, larger forms, such as *Saurophaganax, Torvosaurus* and *Ceratosaurus* were as large as or larger than *Allosaurus* and would have the same probability of preservation. Thus, we interpret the data as reflecting the lower abundance of these large theropods in the Morrison ecosystem.

Previously, *Stokesosaurus* was known only from the CLDQ in Utah. The discovery of the South Dakota specimen significantly extends the geographic range of the taxon north and east and indicates that *Stokesosaurus,* though relatively rare, was not geographically restricted within the Morrison ecosystem.

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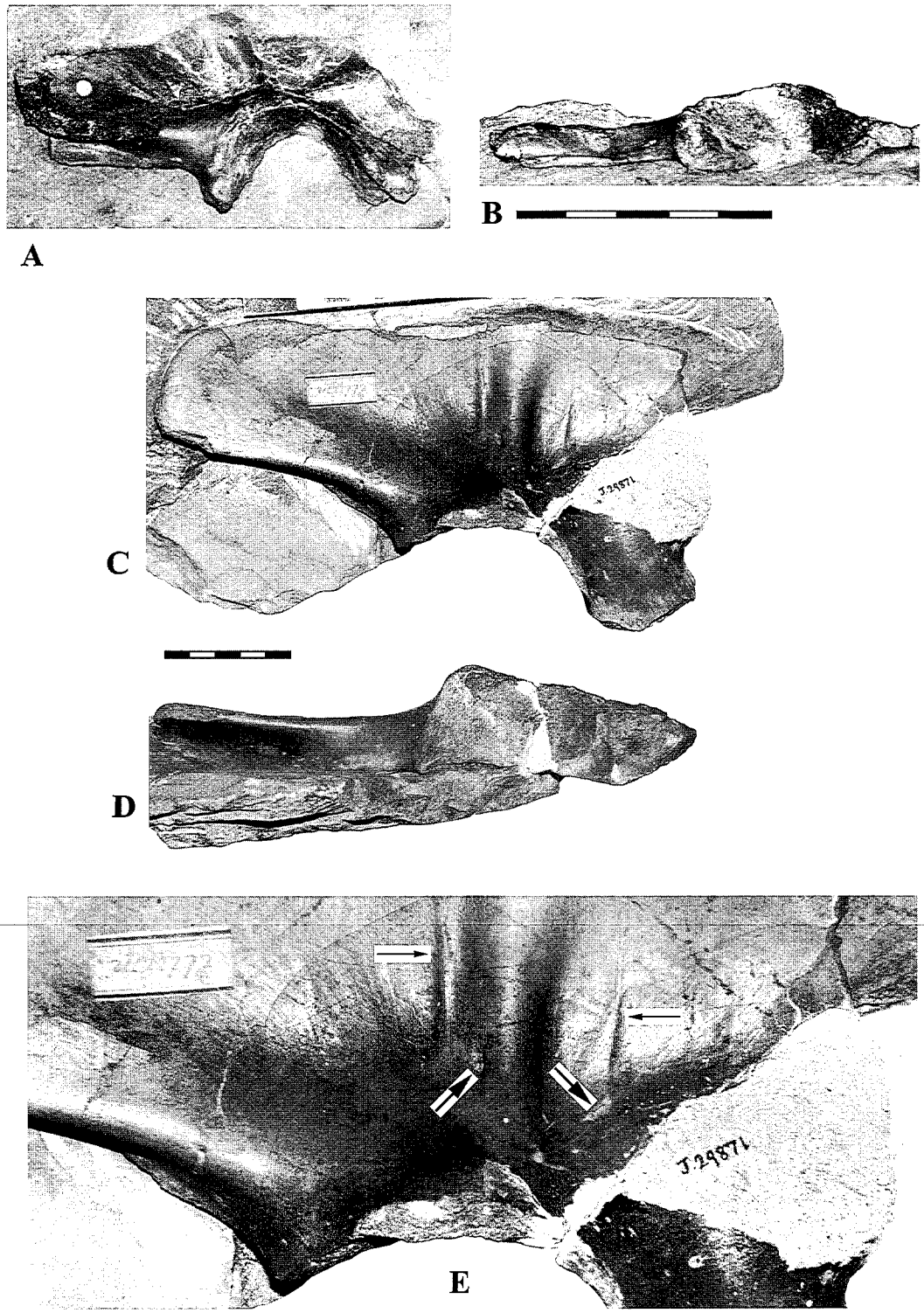

Figure 4. Iliosuchus incognitus. *Type specimen (BM R83, right ilium) in A) lateral and B) ventral views. Referred right ilium (OUM 29871) in C) lateral, and D) ventral views, and E) close up of median vertical ridge showing nutrient foramina (large arrows) and accessory ridges (small arrows). Scale bar in cm.*

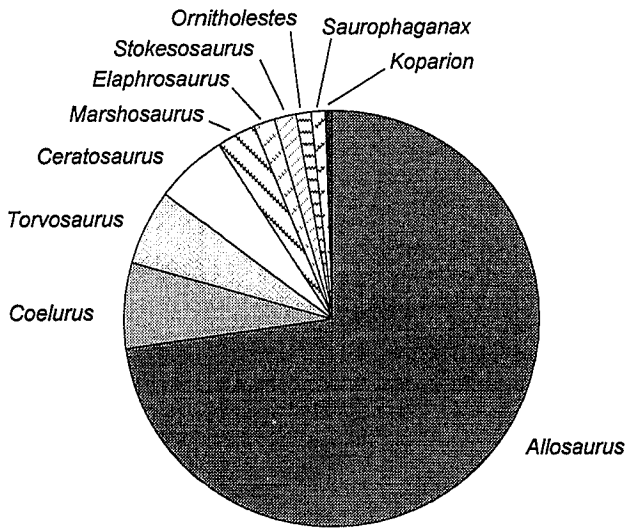

Figure 5. Composition of the Morrison Formation theropod dinosaur sample. N = 184 individuals.

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