CRETACEOUS VERTEBRATE FAUNAS FROM THE KAIPAROWITS PLATEAU, SOUTH-CENTRAL UTAH

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ABSTRACT

Abundant vertebrate fossils have been recovered throughout the several-kilometer-thick sequence of Upper Cretaceous strata present on the Kaiparowits Plateau. The late Cenomanian fauna from the Dakota Formation retains some Late Jurassic elements (*Glyptops* sp., *Ceratodus* sp., *Lepidotes* sp.) and the first diverse metatherian fauna. The late(?) Turonian Smoky Hollow Member of the Straight Cliffs Formation has a diverse vertebrate fauna entirely of Late Cretaceous aspect. Brackish elements are rare in this fauna due to a regression eastward of the epicontinental sea. The John Henry Member of the Straight Cliffs Formation marks a return of the epicontinental seaway into the region in the Coniacian and Santonian and contains a rich brackish fauna but only a limited record of the more fully terrestrial animals such as mammals and dinosaurs. The seaway again withdrew from the region in the late Santonian or early Campanian and the fauna is preserved in the nonmarine Wahweap Formation that correlates closely to the Milk River fauna of Canada and records the oldest certain record of eutherians in the region if not in North America. The overlying Kaiparowits Formation (Campanian, Judithian) contains the richest and most diverse record in the Late Cretaceous sequence of the Kaiparowits Plateau. The epicontinental seaway was well to the east and the formation contains a dominantly nonmarine fauna. Included in this diverse vertebrate fauna is the first occurrence of the insectivore *Gypsonictops* sp. and kinosternoid turtles.

INTRODUCTION

The Kaiparowits Plateau (figure 1) contains a thick (2 km) sequence of Upper Cretaceous, largely nonmarine rocks spanning the Cenomanian through Campanian stages (figure 2) (Gregory and Moore, 1931; Peterson, 1969a, 1969b; Eaton, 1991). The sequence formed in the foreland basin of the Sevier orogenic belt with detritus shed principally from the west and southwest (Eaton and Nations, 1991). The Cretaceous Western Interior Seaway advanced into the area from the east during the late Cenomanian. Although deeper waters withdrew from the

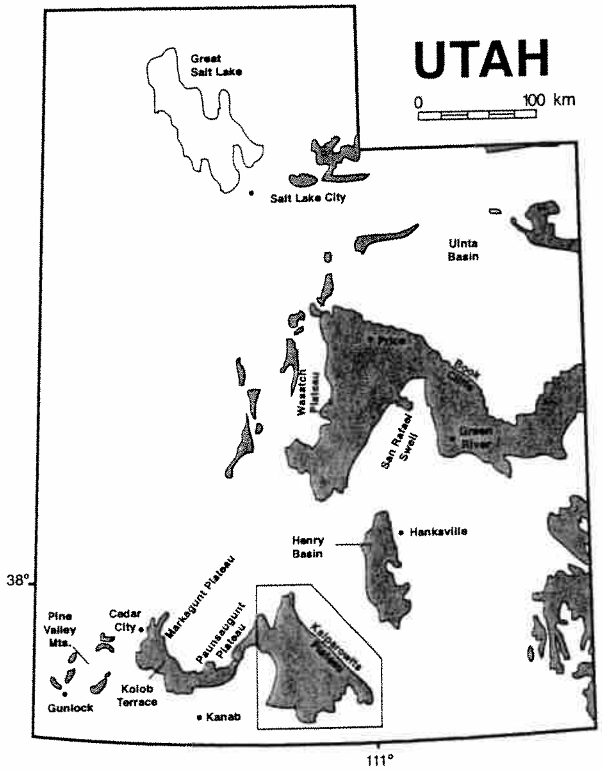

Figure 1. Cretaceous outcrop map of Utah (based on Hintze, 1974) showing the geographic location of the Kaiparowits Plateau.

STAGE	FORMATION	MEMBER	THICKNESS, m
Campanian	Kaiparowits		855
Campanian	Wahweap	capping ss	357-458
		upper	
		middle	
?		lower	
Santonian	Straight Cliffs	Drip Tank	295-493
Santonian / Coniacian		John Henry	
Coniacian / Turonian		Smoky Hollow	
Turonian		Tibbet Canyon	
Turonian	Tropic Shale		186-215
Cenomanian	Dakota	upper	4-51
		middle	
		lower	
Cenomanian			

Figure 2. Generalized stratigraphy and ages of Cretaceous units of the Kaiparowits Plateau (modified from Eaton, 1991).

area in the Middle Turonian, there was strong marine influence on depositional sequences along the eastern margin of the plateau through the Santonian. By the Campanian, the epicontinental sea had withdrawn to a position well east of the Henry Mountains (figure 1), and there are no brackish water or marine environments recorded in the Campanian rocks of the plateau (Eaton, 1991).

The stratigraphic sequence (figure 2) on the east side of the plateau is only interrupted by marine deposits during the late Cenomanian to middle Turonian. The rest of the sequence is nonmarine and represents one of the thicker nonmarine Cenomanian-Campanian sequences in the world.

Several early reports (for example, Gregory and Moore, 1931) mention the existence of fossil vertebrates in the Cretaceous sequence of the Kaiparowits region (also see Cifelli 1990a, 1990b, for references) but, until recently, the sequence was generally regarded as barren by paleontologists. Serious work on the vertebrates in the Kaiparowits region began in the 1982-1983 field seasons when parties led by Richard Cifelli (then at the Museum of Northern Arizona) and Jeffrey Eaton (then a graduate student at the University of Colorado, Boulder) began prospecting and large-scale screenwashing for microvertebrates. The last summary paper on the fauna of the plateau was Eaton and Cifelli (1988) and this paper represents a significant update of that preliminary report. Data were extracted from unpublished catalogues, manuscripts in preparation, comments and notes placed with specimens by a plethora of workers, and the published literature including Cifelli (1990a, 1990b, 1990c, 1990d, 1990e), Cifelli and Johanson (1994), Cifelli and Madsen (1986), Cifelli and Eaton (1987), Eaton (1987, 1993, 1995), Eaton and others (1997), Hutchison (1993), and Parrish and Eaton (1991).

Eaton was responsible for all of the multituberculate identifications and the therians from the Dakota Formation. Cifelli was responsible for all therians other than those reported from the Dakota Formation and for providing general taxonomic information on the collections housed at the Oklahoma Museum of Natural History. Hutchison has reviewed all of the turtle occurrences on the plateau, some of the marine chondrichthians from the John Henry Member of the Straight Cliffs Formation, and the bird and a few of the dinosaurs from the Kaiparowits Formation. Kirkland identified most of the nonmarine and marine chondrichthians and some of the osteichthians. Parrish reviewed most of the dinosaur material, but not all.

We also gratefully acknowledge identifications of taxa by workers who are not authors on this paper. The amphibians and squamates from the Dakota Formation and the Smoky Hollow Member of the Straight Cliffs Formation were identified by Robert Denton and Robert O'Neill (New Jersey State Museum); those recovered from the Kaiparowits Formation were identified by Robert McCord (Arizona State University); specimens from other units are only preliminarily identified and are less reliable. The crocodilians are still unstudied and probably represent the most problematic group in terms of consistency of identification.

There is considerable variation in this report as to the diversity within formations and the level of taxonomic resolution, particularly for the lower vertebrates. This is a result both of inherent variability of the fossil content of units within the sequence and the degree to which each group has been studied.

The collections upon which this report is based are housed at the Oklahoma Museum of Natural History and the Museum of Northern Arizona. Data regarding these collections may be obtained from collection managers at those institutions.

VERTEBRATE FAUNAS

Dakota Formation

The basal unit of the Cretaceous sequence rests on an unconformity of significant duration cut into the middle Jurassic Entrada Formation on the western side of the plateau and into the Upper Jurassic Morrison Formation on the eastern side. All existing evidence suggests the entire Dakota Formation is of late Cenomanian age (Eaton, 1991; 1995).

The Dakota Formation contains fluvial, paludal, lacustrine, brackish water, and marine environments. Most of the material described here was recovered from floodplain deposits, and although localities have been found in other paleoenvironments, particularly lacustrine, little work has been done on those faunas.

The fauna of the Dakota Formation (table 1) marks a transition between older faunas and those characteristic of the Late Cretaceous. Certain archaic relics of the Jurassic such as the turtle *Glyptops* sp., and the fishes *Lepidotes* sp. and *Ceratodus* sp. are present in the fauna along with the first relatively diverse assemblage of metatherian mammals (Eaton, 1991). The dinosaurs are of relatively low diversity and dinosaur remains (even teeth recovered by screenwashing) are relatively rare in sampled localities.

Straight Cliffs Formation

The Straight Cliffs Formation spans the middle Turonian through the Santonian and is divided into four distinct members (Peterson, 1969a). The stratigraphy is summarized in Eaton (1991).

Tibbet Canyon Member

The Straight Cliffs Formation records the epicontinental sea regression in the middle Turonian Tibbet Canyon Member. The member is dominated by sandstones which represent lower shore face overlain by upper shore face deposits. The most common vertebrates recovered from this unit are sharks, but screenwashing of two deltaic localities in the upper part of the member resulted in the recovery of other vertebrates including mammals.

There has been little study of the recovered specimens from this member which includes sharks, rays, lepisosteid fishes, crocodiles, and fragmentary teeth of marsupials. Identified chondrichthians include *Chiloscyllium greeni*, *Squalicorax falcatus*, *Scapanorhynchus raphiodon*, and *Ceratodus semiplicatus*.

Smoky Hollow Member

The seaway temporarily withdrew to somewhere east of the Kaiparowits Plateau during deposition of the overlying Smoky Hollow Member. This member contains coal and some brackish paludal deposits in its basal part following the retreating shoreline eastward. The lower brackish parts have only been sampled for vertebrates in the Markagunt Plateau region (see Eaton, Diem, and others, this volume), but would undoubtedly produce brackish water fish faunas in the Kaiparowits region. The upper part of the member contains both lacustrine and floodplain paleoenvironments and has produced abundant microvertebrates.

The fauna of the Smoky Hollow Member (table 2) does not contain any of the archaic elements present in the Dakota fauna (e.g., *Lepidotes* sp., *Ceratodus* sp., *Glyptops* sp.) and is completely Late Cretaceous in composition.

Table 1. Vertebrate fauna from the Dakota Formation.

- **Class Chondrichthyes**
  - Order Hybodontiformes
    - Family Hybodontidae
      - *Hybodus* n. sp.
    - Family Polyacrodontidae
      - *Lissodus* n. sp.
  - Order Rajiformes
    - Family Rhynobatidae
      - cf. *Myledaphus* n. sp.
- **Class Osteichthyes**
  - Order Periridiformes
    - Family Colobodontidae
      - cf. *Colobodus* sp.
  - Order Semionotiformes
    - Family Semionotidae
      - *Lepidotes* n. sp.
      - cf. *Semionotus* n. sp.
      - cf. *Dapedius*? sp.
  - Order Pycnodontiformes
    - Family Pycnodontidae indet.
  - Order Amiiformes
    - Family Amiidae indet.
  - Order Dipnoi
    - Family Ceratodontidae
      - *Ceratodus gustasoni* Kirkland, 1987
- **Class Amphibia**
  - Order Urodela
    - Family Prosirenoidea
      - cf. *Albanerpeton* sp.
    - Family Batrachosauroididae
      - cf. *Batrachosauroides* sp.
- **Class Reptilia**
  - Order Chelonia
    - Family Pleurosternidae
      - *Glyptops* sp.
    - Family ?Pleurosternidae indet.
    - Family Baenidae
      - cf. *Dinochelys* sp.
      - Baenidae gen. & sp. indet.
    - Family incertae sedis
      - cf. *Naomichelys* sp.
  - Order Squamata
    - Family Scincidae indet.
    - Family Cordylidae indet.
    - Family Teiidae indet.
    - Family Paramacellodidae
      - cf. *Saurilodon* sp.
    - Family incertae sedis
      - gen. & sp. indet.
    - Family Anguidae indet.
  - Order Crocodylia
    - Family Pholidosauridae
      - *Teleorhinus* sp.
    - Family Goniopholidae
      - *Goniopholis* sp.
    - Family ?Bernissartiidae indet.
  - Subclass Dinosauria
  - Order Saurischia
    - Family Dromaeosauridae
      - Velociraptorinae indet.
      - Dromaeosaurinae indet.
    - Family Troodontidae
      - cf. *Troodon* sp.
    - Family incertae sedis
      - cf. *Richardoestesia* sp.
      - cf. *Paranychodon* sp.
    - Family Tyrannosauridae indet.
  - Order Ornithischia
    - Family Nodosauridae indet.
    - Family ?Ankylosauridae (or Pachycephalosauria) indet.
    - Family Hadrosauridae indet.
    - Family Hypsolophodontidae indet.
- **Class Mammalia**
  - Order Multituberculata
    - Family Cimolodontidae
      - *Cimolodon* sp., cf. *C. similis* Fox, 1971
    - Family ?Taeniolabidoidea indet.
    - Family incertae sedis
      - *Paracimexomys* sp., cf. *P. robisoni* Eaton & Nelson, 1991
      - *Dakotamys malcolmi* Eaton, 1995
  - Order Symmetrodonta
    - Family Spalacotheriidae indet.
  - Order Marsupialia
    - Family incertae sedis
      - *Dakotadens morrowi* Eaton, 1993
    - Family Alphadontidae
      - *Alphadon clemensi* Eaton, 1993
      - *Alphadon lillegraveni* Eaton, 1993
      - *Protalphadon* sp.
    - Family ?Stagodontidae
      - *Pariadens kirklandi* Cifelli & Eaton, 1987

Table 2. Vertebrate fauna of the Smoky Hollow Member of the Straight Cliffs Formation.

- **Class Chondrichthyes**
  - Order Hybodontiformes
    - Family Hybodontidae
      - *Hybodus* n. sp.
    - Family Polyacrodontidae
      - *Lissodus* sp.
  - Order Rajiformes
    - Family Sclerorhynchidae
      - *Ischyrhiza* sp., cf. *I. avonicola* Estes, 1964
    - Family Rhynobatidae
      - cf. *Myledaphus* n. sp.
  - Order Orectolobiformes
    - Family ?Ginglymostomatidae
      - *Squatirhina* sp.
- **Class Osteichthyes**
  - Order Palaeonisciformes
    - Family Platysomidae
      - *Platysomus*? sp.
  - Order Pycnodontiformes
    - Family Pycnodontidae indet.
  - Order Amiiformes
    - Family Amiidae indet.
      - *Melvius* sp.
      - Amiidae indet.
  - Order Lepisosteiformes
    - Family Lepisosteidae
      - *Lepisosteus* sp.
  - Order Elopiformes
    - Family Elopidae indet.
- **Class Amphibia**
  - Order Urodela
    - Family Prosirenoidea
      - cf. *Albanerpeton* sp.
    - Family Batrachosauridae
      - cf. *Batrachosauroides* sp.
  - Order Anura
    - Family Discoglossidae
      - *Scotiphryne postulosa* Estes, 1969
    - Family Pelobatidae
      - *Eopelobates* sp.
- **Class Reptilia**
  - Order Chelonia
    - Family Pelomedusidae
      - *Bothremys* sp.
      - cf. *Bothremys* sp.
    - Family Baenidae indet.
    - Family Pleurosternidae?
      - *Compsemys* sp.
    - Family ?Adocidae indet.
    - Family Trionychidae indet.
    - Family Chelydridae
      - n. gen. & sp.
    - Family incertae sedis
      - cf. *Naomichelys* sp.
  - Order Squamata
    - Family Teiidae
      - *Chamops* sp.
      - *Polyglyphanodon* sp.
    - Family Scincidae
      - *Contogenys sloani* Estes, 1969
      - *Contogenys* sp.
      - Scincidae indet.
    - Family Teiidae indet.
    - Family incertae sedis
      - gen. & sp. indet.
    - Family Dorsetisauridae
      - cf. *Dorsetisaurus* sp.
    - Family Anguidae
      - *Odaxosaurus piger* (Gilmore, 1928)
      - cf. *Odaxosaurus* sp.
    - Family Necrosauridae indet.
    - Family incertae sedis
      - gen. & sp. indet.

Order Crocodylia
Family Pholidosauridae
?*Teleorhinus* sp.
Family Goniopholidae indet.
Family ?Bernissartiidae
cf. *Bernissartia* sp.
?Bernissartiidae indet.
Family Crocodylia
Leidyosuchus sp.
Brachychampsa sp.
Order Pterosauria
Family indet.
Subclass Dinosauria
Order Saurischia
Family Dromaeosauridae
Velociraptorinae indet.
Dromaeosaurinae indet.
Family Troodontidae indet.
Family incertae sedis
cf. *Richardoestesia* sp.
cf. *Aublysodon* sp.
Order Ornithischia
Family ?Ankylosauridae indet.
Family Nodosauridae indet.
Family Hypsilophodontidae indet.
Family Hadrosauridae indet.
Class Mammalia
Order Multituberculata
Family Cimolodontidae indet.
Family ?Taeniolabididae indet.
Family incertae sedis
Paracimexomys sp., cf. *P. robisoni* Eaton & Nelson, 1991
Bryceomys fumosus Eaton, 1995
B. hadrosus Eaton, 1995
Order Symmetrodonta
Family Spalacotheriidae
Spalacotheridium mckennai Cifelli, 1990
Symmetrodontoides oligodontos Cifelli, 1990
Order incertae sedis
Family Picopsidae
Picopsis sp.
Order Marsupialia
Family incertae sedis
Dakotadens sp.
Family Didelphidae
Alphadon sp.
Protalphadon sp.
Anchistodelphys delicatus Cifelli, 1990
Family ?Stagodontidae indet.
Order Eutheria? indet.

John Henry Member

There was a significant transgression of the seaway that began in the mid-Coniacian and by the Santonian the strand line was established in the middle of the Kaiparowits Plateau (Eaton, 1991). Minor fluctuations in relative sea level occur throughout John Henry deposition, but in general the John Henry Member is primarily marine along the eastern margin of the plateau and brackish water to nonmarine along the western margin. Because of Cifelli's and Eaton's interest in mammals, most of the localities that have been worked are from the west side of the plateau (except for some of the sharks which were collected by Hutchison from the eastern part of the plateau). There is a large brackish component to the fauna (table 3) due to the nearby influences of the seaway, and mammals and other fully terrestrial components of the fauna are relatively rare in this member.

Drip Tank Member

The uppermost member of the Straight Cliffs Formation is the Drip Tank Member. It is composed predomi-

Table 3. Vertebrate fauna from the John Henry Member of the Straight Cliffs Formation.

Class Chondrichthyes
Order Lamniformes
Family Lamnidae
Squalicorax sp., cf. *S. falcatus* (Agassiz, 1843)
Family Mitsukurinidae
Scapanorhynchus sp.
Order Hybodontiformes
Family Polyacrodontidae
Lissodus sp.
Family Hybodontidae
Hybodus sp.
Family Ptychodontidae
Ptychodus mortoni Agassiz, 1843
Order Orectolobiformes
Family Brachaeluridae
Chiloscyllium? sp.
Family ?Ginglymostomatidae
Squatirhina sp.
Order Rajiformes
Family Rhynobatidae
cf. *Myledaphus* n. sp.
Family Sclerorhynchidae
Ischyrhiza sp.
Family incertae sedis
Ptychotrygon sp., cf. *P. triangularis* Reuss, 1845
Pseudohypolophus sp.
Class Osteichthys
Order Lepisosteiformes
Family Lepisosteidae
Lepisosteus sp.
Atractosteus sp.
Order Amiiformes
Family Amiidae
Amia sp.
Melvius sp.
Order Elopiformes
Family ?Phyllodontidae
Paralbula sp.
Order Perciformes
Family Palaeolabriadae
Palaeolabrus sp.
Class Amphibia
Order Urodela
Family Prosirenoidea
Albanerpeton sp.
Order Anura indet.
Class Reptilia
Order Chelonia
Family Pelomedusidae
Bothremys? sp.
Family Baenidae
"*Baena*" *nodosa*? Gilmore, 1916
Baenidae indet.
Family Adocidae
Adocus sp.
Family Trionychidae
cf. *Aspideretes* sp.
Family Nanhsiungchelyidae
Basilemys sp.
Family incertae sedis
Naomichelys sp.
Order Squamata
Family Teiidae indet.
Family Anguidae
Odaxosaurus piger (Gilmore, 1928)
Family Varanidae indet.
Order Crocodylia
Family Goniopholidae indet.
Family Atoposauridae indet.
Family Bernissartidae
Bernissartia sp.
Subclass Dinosauria
Order Saurischia
Family Dromaeosauridae
Velociraptorinae indet.
Dromaeosaurinae indet.
Order Ornithischia
Family Fabrosauridae(?) indet.
Family Ankylosauridae indet.
Family Hadrosauridae indet.
Class Mammalia
Order Multituberculata
Family Cimolodontidae

Cimolodon sp., cf. C. similis Fox, 1971
Family incertae sedis
Paracimexomys n. sp.
Order Symmetrodonta
Family Spalacotheriidae
Symmetrodontoides sp.
Order Marsupialia
Family Peradectidae indet.
Family Stagodontidae indet.

nantly of sandstones deposited by braided and meandering streams (Eaton, 1991). Rare thin layers of mudstones are also present. Only water-worn fragments of turtle and crocodile have been recovered from this member. There is no basis for dating this member other than stratigraphic position.

Wahweap Formation

The sediments of the Wahweap Formation were deposited predominantly by meandering streams during the early part of the Campanian. The formation is overall not very fossiliferous, with the most productive known horizons occurring in basal lag deposits of streams. There is no evidence of either brackish water or marine deposits in the formation, as the seaway had retreated well to the east by the Campanian (Eaton, 1987; 1991). The early Campanian age is based in part on the similarity of the fauna to that reported by Fox (1971) from the Milk River Formation of Canada. The Wahweap is also correlative to the Masuk Formation to the east (Peterson and Kirk, 1975) from which palynomorphs indicate a post-Santonian age and mollusks in the underlying Blue Gate Member of the Mancos Shale indicate an age for the upper part of the member close the Santonian-Campanian boundary (Eaton, 1990).

We are following the standard application of ammonite-based zonal terminology developed by Cobban (e.g., 1993); however, a recent challenge to the orthodox correlation of North American ammonites to European stages was presented by Leahy and Lerbekmo (1995). If their evaluation is correct, then both the Milk River and Wahweap faunas may be late Santonian in age or span the Santonian-Campanian boundary.

The Wahweap fauna (table 4) is notable for the first definite occurrence of eutherian mammals in the region and, assuming contemporaneity with the upper Milk River Formation of Alberta, this occurrence represents the oldest unambiguous record of eutherians from North America, although specimens in the Smoky Hollow Member of the Straight Cliffs Formation (table 2, Order Eutheria? indet.) hint at a much earlier occurrence.

Table 4. Vertebrate Fauna of the Wahweap Formation.

Class Chondrichthyes
Order Hybodontiformes
Family Polyacrodontidae
Lissodus sp.
Family Hybodontidae
Hybodus sp.
Order Rajiformes
Family Sclerorhynchidae
Ischyrhiza avonicola Estes, 1964
Ischyrhiza sp.
Family Rhynobatidae
cf. *Myledaphus* n. sp.
Order Orectolobiformes
Family Brachaeluridae
cf. *Cantioscyllium* n. sp.
Family ?Ginglymostomatidae
Squatirhina sp.
Class Osteichthys
Order Lepisosteiformes
Family Lepisosteidae
Lepisosteus sp.
Astractosteus sp.
Order Amiiformes
Family Amiidae
Amia sp.
Melvius sp.
Order Elopiformes
Family ?Phyllodontidae
Paralbula sp., cf. *P. casei* Estes, 1969
Paralbula sp.
Order Perdiformes
Family Palaeolabridae
Palaeolabrus sp.
Class Amphibia
Order Urodela
Family Batrachosauroididae
Opisthotriton? sp.
Order Anura indet.
Class Reptilia
Order Chelonia
Family Baenidae
Baena nodosa Gilmore, 1916
Family Pleurosternidae?
Compsemys sp.
Family Adocidae
Adocus sp.
Family Trionychidae
cf. *Aspideretes* sp.
Family Nanhsiungchelyidae
Basilemys sp.
Family incertae sedis
Naomichelys sp.
Order Squamata
Family Anguidae indet.
Family Varanidae indet.
Order Crocodylia
Family Atoposauridae? indet.
Family Bernissartiidae
Bernissartia sp.
Family Crocodylidae
Brachychampsa sp.
Subclass Dinosauria
Order Saurischia
Family Dromaeosauridae
Dromaeosaurinae indet.
Velociraptorinae indet.
Family Troodontidae
Troodon sp.
Family Tyrannosauridae indet.
Order Ornithischia
Family Hadrosauridae indet.
Suborder Ankylosauria indet.
Family Nodosauridae? indet.
Suborder Ceratopsia? indet.
Class Mammalia
Order Multituberculata
Family Neoplagiaulacidae
Mesodma sp., cf. *M. formosa* (Marsh, 1889)
?*Mesodma* sp.
Family Cimolodontidae
Cimolodon similis Fox, 1971
Cimolodon electus Fox, 1971
Cimolodon sp.
?*Cimolodon* sp.

Kaiparowits Formation

This formation represents more than 800 m of Cam-

Family Cimolomyidae
Cimolomys sp., cf. *C. clarki* Sahni, 1972
Cimolomys n. sp.
?*Meniscoessus* sp.
Family ?Cimolomyidae indet.
Family incertae sedis
Cimexomys sp., cf. *C. antiquus* Fox, 1971
Paracimexomys n. sp.
Paracimexomys sp.
Order uncertain
Family incertae sedis
Zygiocuspis goldingi Cifelli, 1994
Order Symmetrodonta
Family Spalacotheriidae
Symmetrodontoides foxi Cifelli & Madsen, 1986
Order Marsupialia
Family Peradectidae
Protalphadon crebreforme Cifelli, 1990
Alphadon sp.
Family incertae sedis
Iugomortiferum thoringtoni Cifelli, 1990
cf. *Iugomortiferum* n. sp.
gen. & sp. indet.
Anchistodelphys archibaldi Cifelli, 1990
Anchistodelphys sp.
Order Insectivora
Family ?Nyctitheriidae
Paranyctoides spp.

panian strata deposited by large rivers with broad alluvial floodplains (Eaton, 1991). Localities occur in the sandstones associated with rivers, and mudstones associated with floodplain and lacustrine environments. The Kaiparowits Formation is the most fossiliferous of Cretaceous units on the plateau.

Fossils are most common in the lower half of the formation. Eaton and Cifelli (1988) suggested that this might be an artifact of extensive badlands being well developed in the lower part of the formation, while the upper part has limited access due to steep topography controlled by the overlying Canaan Peak and Claron Formations. Although this may in part be true, work in subsequent years (by Eaton and Hutchison) suggests the upper part is actually not as fossiliferous as the lower.

When the preliminary report was published, there was an attempt made to separate the fauna of this thick formation into lower and upper faunas, but it is evident from Eaton and Cifelli (1988) that there is no significant faunal distinction; however, there is some indication of up-section change in the fauna including the first occurrences of *Paranyctoides* sp., *Gypsonictops* spp. and some marsupials such as *Alphadon attaragos* in the upper part of the section. Nonetheless, it appears this thick formation was deposited relatively quickly in a rapidly subsiding basin (Eaton, 1991).

The age of the fauna is determined mostly by palynomorphs (see Eaton, 1991; Nichols, 1997) and the lack of diagnostic Maastrichtian mammals. The stratigraphically highest locality from which significant amounts of matrix have been processed is about 200 m below the top of the formation so it is unknown if the Kaiparowits Formation could cross the Campanian-Maastrichtian boundary, but palynomorph samples (see Eaton, 1991, figure 16) appear to be Campanian in age and lack diagnostic Maastrichtian taxa (Farabee, 1991).

Perhaps most distinctive of the Kaiparowits fauna (table 5) is the first appearance of the insectivore *Gypsonictops* sp. which may be a good index fossil for the beginning of the Judithian North American Land-Mammal "Age" (see Cifelli, 1994). Among the turtles, kinosternoids and baenid *Boremys* sp. first appear, and the pleurosternid *Compsemys* is common. Sharks become much rarer, with *Ischyrhiza* sp. and *Hybodus* sp. known only from a single locality near the base of the formation (locality FB1 in Eaton and Cifelli, 1988, figure 3). The multituberculates are still very tentatively identified and do not differ greatly from the list presented in Eaton (1987). Subsequent, almost annual, collection from the Kaiparowits Formation over the past decade has made the ongoing revision of the multituberculates increasingly complex. Multituberculates from the Wahweap compare closely to forms described from the Milk River Formation, but the Kaiparowits taxa do not compare well to any fauna and include many new forms.

Table 5. Vertebrate fauna of the Kaiparowits Formation.

Class Chondrichthyes
Order Hybodontiformes
Family Hybodontidae
Hybodus sp.
Family Polyacrodontidae
Lissodus sp.
Order Rajiformes
Family Sclerorhynchidae
Ischyrhiza sp.
Family Rhynobatidae
Myledaphus bipartis Cope, 1876
Order Orectolobiformes
Family Brachaeluridae
Brachaelurus? sp.
Family ?Ginglymostomatidae
Squatirhina sp.
Class Osteichthys
Order Semionotiformes
Family Lepisosteidae
Lepisosteus sp.
Order Amiiformes
Family Amiidae
Amia sp.
Melvius sp.
Order Elopiformes
Family ?Phyllodontidae
Paralbula sp.
Order Perciformes
Family Palaeolabridae
Palaeolabrus sp.
Order Acipenseriformes
Family Acipenseridae
Acipenser sp.
Order Elopiformes
Family Elopidae indet.
Class Amphibia
Order Urodela
Family Prosirenoidea
Albanerpeton sp., cf. *A. nexuosus* Estes, 1981
Albanerpeton sp.
Family Scapherpetontidae n. gen. & sp.
Family Sirenidae
Habrosaurus dilatus Gilmore, 1928
Order Anura
Family Discoglossidae
Scotiphryne pustulosa Estes, 1969
Family Pelobatidae
Eopelobates sp.

Class Reptilia
Order Chelonia
Family Baenidae
Boremys pulchra Lambe, 1906
Baena nodosa Gilmore, 1916
Family Pleurosternidae?
Compsemys victa Leidy, 1856
Family Neurankylidae
Neurankylus sp.
Superfamily Kinosternoidea n. gen. & sp.
Family Adocidae
Adocus sp.
Family Trionychidae
cf. *Aspideretes* sp.
Family Nanhsiungchelyidae
Basilemys sp.
Family incertae sedis
Naomichelys sp.
Family Chelydridae indet.
Order Squamata
Family Teiidae
Chamops segnis Marsh, 1892
Leptochamops denticulatus (Gilmore, 1928)
Meniscognathus altimani Estes, 1969
Paraglyphanodon gazini Gilmore, 1943
cf. *Polyglyphanodon* n. sp.
Family Anguidae
Odaxosaurus piger (Gilmore, 1928)
cf. *Odaxosaurus* n. sp.
Anguidae n. gen.? & sp.
Family Xenosauridae
Exostinus sp.
Family Parasaniwidae
Parasaniwa wyomingensis Gilmore, 1928
Parasaniwa sp.
Family ?Helodermatidae indet.
Family incertae sedis
Litakis sp.
Suborder Serpentes indet.
Order Crocodylia
Family Bernissartidae
Bernissartia sp.
Family Crocodylidae
Brachychampsa sp.
Family Goniopholidae indet.
Subclass Dinosauria
Order Saurischia
Family Dromaeosauridae
Velociraptorinae indet.
Dromaeosaurinae indet.
Family Troodontidae
Troodon sp.
Family Ornithomimidae
Ornithomimus velox Marsh, 1890
Family Tyrannosauridae indet.
Order Ornithischia
Family Nodosauridae
Family Ankylosauridae
Euoplocephalus sp.
Family Hadrosauridae
Parasaurolophus sp., cf. *P. cyrtocristatus* Ostrom, 1961
Family Pachycephalosauridae
Stegoceras sp.
Family Ceratopsidae indet.
Class Aves
Order Enantiornithiformes
Family Avisauridae
Avisaurus n. sp.
Class Mammalia
Order Multituberculata
Family Neoplagiaulacidae
Mesodma n. sp., cf. *M. hensleighi* Lille graven, 1969
Mesodma sp., cf. *M. senecta* Fox, 1971 or *M. thompsoni* Clemens, 1964
Mesodma sp., cf. *M. formosa* (Marsh, 1889)
Mesodma n. sp. A
Mesodma n. sp. B
Family Cimolodontidae
Cimolodon sp., cf. *C. similis* Fox, 1971
Cimolodon sp., cf. *C. nitidus* Marsh, 1889
Cimolodon n. sp. A
Cimolodon n. sp. B
Family Cimolomyidae
cf. *Cimolomys* n. sp.
cf. *Bryceomys* n. sp.
Cimolomys n. sp. A
Cimolomys n. sp. B
Meniscoessus sp.
Family incertae sedis
Cimexomys sp., cf. *C. judithae* Sahni, 1972
Paracimexomys spp.
Order Symmetrodonta
Family Spalacotheriidae
Symmetrodontoides sp.
Order Marsupialia
Family Peradectidae
Aenigmadelphys archeri Cifelli and Johanson, 1994
Protalphadon wahweapensis Cifelli, 1990
Turgidodon lillegraveni Cifelli, 1990
Turgidodon sp., cf. *T. lillegraveni* Cifelli, 1990
Turgidodon madseni Cifelli, 1990
Turgidodon sp.
Alphadon halleyi Sahni, 1972
Alphadon sahnii Lillegraven & McKenna, 1986
Alphadon sp. cf. *A. sahnii* Lillegraven & McKenna, 1986
Alphadon attaragos Lillegraven & McKenna, 1986
Order Insectivora
Family Leptictidae
Gypsonictops spp.
Family Palaeoryctidae
Cimolestes sp.
Family ?Nyctitheriidae
Paranyctoides spp.
Order uncertain
Family incertae sedis
Avitotherium utahensis Cifelli, 1990

CONCLUSIONS

The Kaiparowits Plateau contains a remarkable record of vertebrate evolution from the late Cenomanian through the Campanian. The enormous number of specimens recovered from the plateau include many new taxa and new temporal and geographic occurrences. Mammals have been the most studied of the classes and an enormous amount of work remains to be done on the lower vertebrates. New recently discovered localities that appear to be very productive suggest that the collections reported on here mark only the beginning.

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