1986

Geology and Vertebrate Paleontology of the Smith River Basin Montana

Anthony C. Runkel
The University of Montana

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Mary Elizabeth Kurz

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GEOLOGY AND VERTEBRATE PALEONTOLOGY OF THE SMITH RIVER BASIN, MONTANA

By
Anthony C. Runkel
B.A., University of Minnesota, 1982
presented in partial fulfillment of the requirements for the degree of
Master of Science
UNIVERSITY OF MONTANA
1986

Approved by:

[Signatures]
Chairman, Board of Examiners
Dean, Graduate School

[Signatures]
June 2, 1986
Date
Fifteen new vertebrate fossil localities were discovered during the course of this study. Fifteen genera were identified from among the eighty eight specimens collected from these and previously discovered localities. No new species are proposed. This fossil fauna was divided into five local faunas that range in age from Late Chadronian to early, Late Barstovian. This study revises previous work that suggested the Smith River basin fauna represented only the Arikareean through Early Barstovian land-mammal ages.

The Tertiary strata in the basin represent one lithologic unit and are not divisible into two formations as previous work suggested. The Early Oligocene sediments were deposited primarily by mass-flow processes, while the Late Oligocene and Miocene age sediments were deposited primarily by streams. A disconformity separates Late Oligocene from middle Miocene aged strata. Regional climatic and tectonic changes, and/or a volcanic hiatus, were probably responsible for the creation of this disconformity.

All of the normal faulting in the basin occurred after the Oligocene. These faults locally tilt and displace Tertiary strata. Unlike most other southwest Montana basins, normal faulting was subdued. Therefore, there are no major basin bounding faults. This low magnitude of normal faulting is a reflection of relatively minor compressive deformation that preceded extension in the Smith River basin region.
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Above all I am indebted to my parents, Bill and Janet Runkel, for their encouragement, patience, and understanding, and for their periodic financial support without which this thesis would not have been completed.
INTRODUCTION

Western Montana is characterized by north to northwest trending rugged mountain ranges separated by broad intermontane basins filled with Tertiary sediments. Many of these basins have been studied in detail in the past twenty years and the results of these investigations indicate that the basins share a similar geologic history, and that processes operating on a regional scale were responsible for their origin and basin filling sequences (Kuenzi and Fields, 1971), (Hoffman, 1971), (Petewich, 1972), (Monroe, 1976), (Dunlap, 1982).

Beginning in the Eocene (Rasmussen and Fields, 1983), normal faulting along zones of Laramide structural weakness outlined the basins (Petewich, 1972). The Tertiary rocks that accumulated in the basins were named the Bozeman Group (Robinson, 1963), which is composed of two distinct lithologic sequences: (1) the Late Eocene to Early Miocene Renova Formation, primarily composed of fine grained strata derived from volcanic ash; and (2) the middle to Late Miocene Six Mile Creek Formation, predominately a coarser grained sequence composed chiefly of sand and gravel (Kuenzi and Fields, 1971). The Six Mile Creek and Renova formations are separated by an unconformity that is angular in most basins but only erosional in some basins (Fields and others, 1985). The thickness of the Tertiary fill in some basins is more than 5000 meters but in most is less than 1500 meters (Thompson and others, 1981).

Normal faults, commonly along basin margins, have tilted and folded the Tertiary strata in most basins (Pardee, 1950), (Reynolds, 1979). The orientations and style of associated deformation suggest that the faults are inherited from earlier compressional regimes (Constenius, 1982), (Fields and others, 1985).
The Smith River basin

The Smith River basin in Meagher County, Montana is the northeasternmost of Montana basins (fig. 1). It is bordered by the Big Belt Mountains on the west, and by the Little Belt Mountains on the east. That portion of the basin north of Newland and Birch creeks, and south of Fort Logan (henceforth referred to as the northern Smith River basin) is the focus of this study because it contains the best exposures in the basin. The area includes portions of the 7 1/2 minute Fort Logan, Hanson, Whitetail Reservoir, and Gipsy Lake U.S.G.S. quadrangle sheets (plate 1).

The Tertiary sediments of the Smith River basin rest unconformably on Early Tertiary intrusive and volcanic rocks, and faulted and folded Proterozoic Belt and Paleozoic rocks. The Tertiary sediments are middle to Late Oligocene and Miocene in age and have a maximum thickness of about 185 meters in the northern Smith River basin. An unconformity separates the Oligocene age sediments from the Miocene age sediments. Quaternary sediments unconformably overlie the Tertiary strata in most areas.

Post compressional upwarping and normal faulting have tilted and displaced the Tertiary strata in the northern Smith River basin. This faulting is less intense than that of most other basins in western Montana and eastern Idaho and occurs in an area that experienced correspondingly less Laramide compressive deformation.

Structural and sedimentologic evidence indicates that the Smith River and Helena-Townsend basins (fig. 1) partially coalesced throughout much of the Tertiary. This continuity of the two basins is similar to most basins in western Montana and eastern Idaho which were much broader and continuous during their early development than at present (Fields and others, 1985).
Figure 1 - Tertiary intermontane basins of southwest Montana (dashed). Study area is enclosed within the block outlined north of White Sulpher Springs, MT.

Purpose

This study was undertaken in order to delineate the Tertiary geologic history of the Smith River basin, and to compare that history with the regional Tertiary geologic history of western Montana and eastern Idaho, especially that of the Helena-Townsend basin.

Method

1. Structure. Most of the structures identified in the northern Smith River basin have been previously mapped (see previous work section, page 5). However, I have gathered additional data necessary to elucidate the timing, magnitude, and at-depth geometry of the normal faults in the northern Smith River basin, an aspect that was largely ignored by earlier workers.

2. Sedimentology and stratigraphy. I prepared a detailed outcrop map, and recorded lithologic descriptions of each outcrop. I interpreted depositional processes based upon sedimentary structures and, by using fossil mammals for age determination of the sediments, elucidated a sedimentologic history for the basin.

3. Vertebrate paleontology. I collected vertebrate fossils and precisely recorded locality data. I prepared collected specimens and identified them by comparing them with specimens in the University of Montana museum and with specimens described in the literature.

4. Review of the Helena-Townsend basin. I have compiled previous work done in the Helena-Townsend basin in order to describe its relationships with the Smith River basin.
PREVIOUS WORK

G.B. Grinnell and E.S. Dana (1876) first described the Tertiary strata and general geology of the Smith River basin. Cope (1886), Dall and Harris (1892), Scott (1893), Douglass (1903), Matthew and Mook (1933), Wood (1935), Koerner (1939, 1940), Black (1961), Barnosky (1981, 1982), and Rensberger (1979, 1981) have all collected or described vertebrate fossils from the Smith River basin. Of these workers, only Koerner combined his paleontologic work with a detailed study of the Tertiary strata in the basin.

Several Masters theses have described the geology of the pre-Tertiary rocks in the Smith River basin area (Birkholz, 1967), (Hruska, 1967), (McClerman, 1969), (Phelps, 1969), (Dahl, 1971). These reports focus primarily on Laramide structure and Proterozoic Belt stratigraphy. Groff (1967) described the geology of the Smith River basin in a general sense prior to the preparation of these theses.

Gogas (1984) investigated gravity in the Smith River basin. He focused on the subsurface profile of the basin floor.

Several studies of a more regional scale have described portions of the Smith River basin area. Tanner (1949) described the geology of the Castle Mountains area, immediately southeast of the Smith River basin. Wolfe (1964) published a reconnaissance map of the Tertiary strata in the basin and described the character and extent of post-Miocene uplift for the Rocky Mountain region of west-central Montana. Reynolds (1979), as part of his report on the Cenozoic faulting of southwestern Montana, briefly described the normal faults in the Smith River basin.
Introduction

Fifteen new vertebrate fossil localities were discovered during the course of this study. Fifteen genera were identified from among the eighty-eight specimens collected from these and previously discovered localities. All identified specimens represent previously described species, so no new species are proposed. The systematic paleontology for the collected taxa is in Appendix I.

It is unfortunate that this highly fossiliferous and intensely collected basin should have remained in a state of biostratigraphic confusion for so long. In this study, a concerted effort has been made to incorporate previous paleontologic data. However, there are no recorded locality data for most of the previous work, and errors made in interpretations because of this oversight make most pre-1970 paleontologic work in the basin of little biostratigraphic value.

Fossils collected in the Smith River basin during this project, and previously collected or described by Koerner (1939, 1940), Black (1961), Asher (1973 UM collection), Rensberger (1979, 1981), and Barnosky (1981) represent the Smith River fossil fauna and are here divided into five local faunas; the Beaver Creek local fauna, the Whitetail Deer Creek local fauna, the Crabtree local fauna, the Rabbit Creek local fauna, and the Spring Creek east local fauna (Table I). Following Monroe (1976) a local fauna here consists of "one or several closely associated fossil localities within the same stratigraphic interval which have been grouped together for convenience and clarity in discussion". A fossil fauna does not represent all animal life in a given area at a particular time, but represents only those
Table 1. Identified specimens of the five local faunas in the Smith River basin. Abbreviations: MV, University of Montana fossil locality; UWA, University of Washington fossil locality.

| MV8444 | BEAVER CREEK LOCAL FAUNA | Archaeotherium cf. A. crassum |
| MV7362 | WHITETAIL DEER CREEK LOCAL FAUNA | Paleolagus burkei |
| MV7368 | | Rodentia |
| | | Paramercoydon (Gregorychoerus) meagherensis |
| MV7363 | | cf. Rhinocerotid |
| | Section 28 | Eumys eiliensis |
| | | Megalagus dawsoni |
| MV7367 | CRABTREE LOCAL FAUNA | Paleocastor sp. |
| MV7369 | | Merycoidodontidae |
| MV7370 | | Merycoidodontidae |
| MV7371 | | Merycoidodontidae |
| MV7372 | | cf. Miohippus sp. |
| MV7373 | | Merycoidodontidae |
| MV8431 | | cf. Promerychochoerus |
| | | Niglarodon koernerii |
| | | Eutypomys cf. E. montanensis |
| | | Paleocastor sp. |
| | | cf. Leidymys |
| | | Merycoidodontidae |
MV8438 Rhinocerotid

MV8441 Megoreodon grandis

MV8442 cf. Meniscomys
Paleocastor sp.
Paleolagus sp.

MV8443 Megoreodon cf. M. grandis

*UWA8867 Niglarodon koernerii

Section 4, T10N, R5E
Niglarodon koernerii

Section 8, T10N, R5E
Paciculus montanus

Section 5, T10N, R5E
Paleolagus hypsodus

*probably same locality as MV8438

RABBIT CREEK FAUNA

MV8433 cf. Megoreodon

MV8434 Cyclopidius simus
cf. Megoreodon
Diceratherium sp.
Testudo cf. T. osborniana

MV8440 Gregoromys douglassi
cf. Testudo

MV8445 cf. Megoreodon

UWA5867-1A* Niglarodon progressus
Niglarodon blacki
Proscalops intermedius

UWA5867-1B Niglarodon loneyi
Gregoromys sp.
Proscalops sp.
Promylagaulus montanensis

Section 1, Monosaulax cf. M. hesperus
T9N, R4E+

*probably same locality as MV8445
+probably same locality as MV8434

EAST SPRING CREEK FAUNA

MV7361 Mylagaulus sp.

MV7364 Merychippus severus
Mylagaulus
cf. Chalicotheridae
Rhinocerotid

MV7365 Mylagaulus sp.
cf. Merychys
cf. Chalicotheridae

MV7366 Mylagaulus sp.
Merychippus severus
Dromomeryx sp.
Carnivora
Tortoise

MV7374 Merychippus sp.

MV8436 Merychippus cf. M. severus

MV8432 Camelid
cf. Merychys

UWA 5867-2* Mesoscalops montanensis

*It is likely that MV7365, MV8432, and UWA5867-2 are the same locality.

==================================================================
species which have been collected and identified from that given area and particular time (Monroe, 1976). For this study, the given area is the Smith River basin and the particular time is a North American Land Mammal Age.

Oreodonts were not used as evidence for most of the age assignments of the local faunas in this report. Despite the work of Schultz and Falkenbach (1968) and Lander (1977), many taxa that have been collected from the Smith River basin have not yet been chronologically arranged in a logical manner. For example, two different species collected from the same locality as reported by Koerner (1940) are assigned two different ages (Late Whitneyan and middle Arikareean) by Lander (1977). In fact, in most instances, ages assigned to the Smith River oreodonts by Lander do not correlate with the suggested age of their associated local fauna. It appears that Schultz and Falkenbach, and Lander, assigned chronologic ranges to many genera and species without a clear understanding of the stratigraphic framework in the Smith River basin.

The following descriptions and correlations of the local faunas defined in this study are presented in ascending chronologic order.

**Beaver Creek Local Fauna**

The Beaver Creek local fauna is represented by a single specimen (UM8939 *Archeotherium* cf. *crassum*) collected from locality MV8444 near Beaver Creek (Plate I). The following age assignment of this local fauna may be subject to change following future collecting at this locality.

**Age and Correlation**

At the species level the assignment of UM8939 to *Archeotherium crassum* is tenuous. However, the specimen is complete enough to definitely rule out any previously described Whitneyan or Orelian species of *Archeotherium*. Peterson (1909) and Savage and Russell (1983) classify *A.
crassum as a Chadronian form. Until more specimens can be added to this local fauna, it is tentatively assigned to the Late Chadronian.

Additional evidence that supports a Chadronian age for some taxa is found in Scott’s (1893) report of Caenopus and Poebrotherium from the Smith River basin. These two genera, and Archeotherium are reported from the well established Late Chadronian Pipestones Springs localities in the Jefferson River basin. They are also reported from the Late Chadronian age strata in the Helena-Townsend basin (White, 1954), (Freeman, Ruppel, and Klepper, 1958).

Whitetail Deer Creek Local Fauna

The Whitetail Deer Creek local fauna includes three localities which have produced seven specimens, four of which are identifiable to the specific level and useful for age identification. These localities are clustered in a region two miles south of Whitetail Deer Creek (Plate I).

Age and Correlation

Paleolagus burkei is a species known from the Orellan and Whitneyan. Based upon the postexternal to anterointernal elongation of the trigonid in this specimen, a Whitneyan rather than Orellan age is suggested by Dawson (personal communication, 1984).

Eumys brachydus (= Eumys eliensis) and Megalagus dawsoni suggest a Late Whitneyan-Earliest Arikareean age for localities in section 28, T11N, R5E. Rensberger (personal communication, 1985) has collected many specimens of Eumys from several localities near Whitetail Deer Creek. Eumys is known only from the Orellan and Whitneyan in North America (Savage and Russell, 1983). This confirms a Whitneyan or Late Orellan aged local fauna from the strata in this region.
Crabtree Local Fauna

The Crabtree local fauna is composed of sixteen localities which have produced twenty five specimens identifiable to the family level. These localities are located primarily along the course of the Smith River (Plate I). Previous work in the Smith River basin indicates that nearly all exposures in the southern Smith River basin are age correlative with either the Crabtree or slightly younger Rabbit Creek local faunas.

The sediments that produce both the Crabtree and the Rabbit Creek local faunas are highly fossiliferous and often produce well preserved and relatively complete specimens. The majority of specimens collected from pre-Barstovian age strata in the Smith River basin over the last one hundred years appear to have been from these sediments.

The Crabtree local fauna is distinguished from the Rabbit Creek local fauna by the presence of *Paleolagus, Paleocastor*, and *Niglarodon koernerii*, and the absence of *Gregoromys* and the more progressive aplodontids *Niglarodon progressus, N. blacki*, and *N. loneyi*.

Age and Correlation

The following chart shows that the genera in the Crabtree local fauna show closest affinities with the local faunas of the Cabbage Patch lower and middle strata (Rasmussen, 1973) and the faunas of the Sharps Formation of South Dakota (J.R. MacDonald, 1970) than with the local fauna of the Cabbage Patch upper strata and the faunas of the Gering Formation of Nebraska (Martin, 1973) and the Monroe Creek (J.R. MacDonald, 1970) (L.J. MacDonald, 1972) and Harrison (J.R. MacDonald, 1970) formations of South Dakota (Table 2). This correlation leads to an assignment of early Early to late Early Arikareean Land Mammal Age for this local fauna.
Table 2. List of mammalian genera from the Crabtree and Rabbit Creek local faunas compared to their reported occurrence in the Cabbage Patch lower (CPL), middle (CPM), and upper (CPU) strata, and the Gering Formation of Nebraska (NG), and the Sharps (SDS), Monroe Creek (SDM), and Harrison (SDH) formations of South Dakota. Modified from Rasmussen (1973).

<table>
<thead>
<tr>
<th>Crabtree local fauna</th>
<th>CPL</th>
<th>CPM</th>
<th>CPU</th>
<th>NG</th>
<th>SDS</th>
<th>SDM</th>
<th>SDH</th>
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<tbody>
<tr>
<td><em>Paleocastor</em></td>
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<td>X</td>
<td>X</td>
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<td><em>Nothocyon</em></td>
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<td>X</td>
<td>X</td>
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<tr>
<td><em>Paleolagus</em></td>
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<tr>
<td><em>Niglarodon</em></td>
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<tr>
<td><em>Eutypomys</em></td>
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<td>X</td>
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<td>X</td>
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<td><em>Leidymys</em></td>
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<td><em>Megoreodon</em></td>
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<td><em>Paciculus</em></td>
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<th>Rabbit Creek local fauna</th>
<th>CPL</th>
<th>CPM</th>
<th>CPU</th>
<th>NG</th>
<th>SDS</th>
<th>SDM</th>
<th>SDH</th>
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<tr>
<td><em>Cyclopidius</em></td>
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<td><em>Diceratherium</em></td>
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<td><em>Gregoromys</em></td>
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<tr>
<td><em>Niglarodon</em></td>
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<td>X</td>
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<tr>
<td><em>Proscalops</em></td>
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<td>X</td>
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<tr>
<td><em>Promylagaulus</em></td>
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<tr>
<td><em>Monosaulax</em></td>
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13
The Rabbit Creek Local Fauna

The Rabbit Creek local fauna is composed of sixteen specimens collected from seven localities near Spring Creek, Rabbit Creek, and Thompson Gulch (Plate I).

Age and Correlation

Comparison at the generic level shows that the Rabbit Creek local fauna has more genera in common with the local faunas of the middle and upper Cabbage Patch strata and the faunas of the Sharps and Monroe Creek formations of South Dakota than with the local fauna of the Cabbage Patch lower strata, or the faunas of the Gering Formation of Nebraska and Harrison Formation of South Dakota (Table 2). The presence of *Gregoromys* at two Rabbit Creek local fauna localities and Rensberger's (1981) suggestion that *Niglarodon loneyi*, *N. blacki*, and *N. progressus* are age correlative to the upper *Meniscoymys* and lower *Gregoromys-Entopycus* concurrent range zones of Oregon (Rensberger, 1981) indicate that this local fauna correlates more closely with the local faunas of the upper and middle Cabbage Patch strata and fauna from the Monroe Creek Formation rather than the fauna of the Sharps Formation. This correlation leads to an assignment of early Late Arikareean Land Mammal Age for this local fauna.

Spring Creek East Local Fauna

The Spring Creek east local fauna is composed of eight localities from which sixteen specimens identifiable to the family level were collected. Seven of these localities are clustered just north of Newland Creek (Plate I). It is in this geographically small portion of the northern Smith River basin that I believe nearly all of the previously collected Barstovian taxa were collected. Post Arikareean age sediments are not nearly as extensive as reported by Koerner, (1939) but may be present as thin, isolated sections
such as the one that produced *Merychippus severus* (MV8436-UM8922) in the extreme western portion of this study area (Plate I).

The sediments that produced this local fauna are extremely fossiliferous. Less than sixty meters of section of post-Arikareean sediments are exposed in the northern Smith River basin, and yet a study of faunal lists of previous workers shows as many specimens collected from these strata as from the much thicker section of Arikareean and older sediments.

**Age and Correlation**

Based only upon specimens collected for this study, the Spring Creek east local fauna is assigned a Late Hemingfordian to Late Barstovian Land Mammal Age. *Mylagaulus* and *Merychippus* first appear in the Late Hemingfordian. *Dromomeryx* last occurs in the Late Barstovian (Tedford and others, 1985). Since I collected no specimens that differentiate Late Hemingfordian from Barstovian age, a more precise assignment cannot be made.

A compilation of the lists of specimens collected by previous workers suggests that the Spring Creek east local fauna is, at oldest, early Late Barstovian. Scott (1893) and Matthew (1909) both collected proboscideans in the basin. Proboscideans first appear in North America in Late Barstovian time (Tedford and others, 1985). Unless Scott and Matthew collected their specimens from a still unreported Barstovian locale, it is very likely that the Spring Creek east local fauna (given the very thin section that produces it) is Late Barstovian in age.
CONCLUSIONS—PALEONTOLOGY

A compilation and interpretation of previous paleontologic work in the Smith River basin (commonly referred to in the older literature as the Deep River beds) gives the erroneous impression that the unconformity within the Tertiary strata separates underlying strata that range in age from Early Arikareean to late Early Arikareean, from strata that range in age from Late Hemingfordian to Early Barstovian. I contend that the strata underlying the unconformity actually range from Late(?) Chadronian through early Late Arikareean and the strata above the unconformity are earliest Late Barstovian in age. Previous work seems to have been biased by the dominance of exposure of rocks of Arikareean age. They are highly fossiliferous and exposures are readily accessible. On the other hand, outcrops of Chadronian through Whitneyan aged strata are poorly exposed, isolated, and relatively unfossiliferous.

Barstovian strata in the Smith River basin are not nearly so extensive as reported by Koerner (1939) or as indicated by the large number of Barstovian taxa collected by previous workers. Ignoring biostratigraphic evidence, Koerner incorrectly mapped Barstovian strata throughout the basin, when, in fact they are present only at the very localized areas of Spring Creek and near the Camas Creek fault (Plate I).

The chronologic range of strata suggested by previous workers (e.g. Koerner, 1939, Schultz and Falkenbach, 1949) was anomalous when compared to the range of strata in other basin fill sequences in western Montana. The revised range interpreted for this study shows that the age-range of strata, and chronologic position of the unconformity in the Smith River basin closely correlates with that of other basins in western Montana, especially that of the Helena-Townsend basin (fig. 2).
### Figure 2 Stratigraphic framework and correlation chart of selected Tertiary basins.
(Modified from Fields and others (1985)).
Introduction

The Tertiary strata in the northern Smith River basin range from flat-lying to dips up to five degrees to the southeast as part of a large, northeast striking homocline. Cumulative thickness estimates range from 900 to 1200 meters (3000-4000 feet) but are not precise because of possible variations of the dip where strata are not exposed.

It is impossible to lithologically correlate individual units or bedding sequences except at a local level within the basin because of the dominance of massive bedding, uniformity of lithologies, absence of marker beds, and isolation of exposures. No single criterion or combination of criteria can be used to separate the Tertiary strata in the Smith River basin into members or facies. Exposures of strata of Barstovian age appear to have identical lithologies, sedimentary structures and interpreted depositional environments to the exposures of strata of Arikareean age. Deposition of the strata upon an irregular topography further complicates physical correlation and compilation of composite sections between scattered exposures.

For ease in description and interpretation, the thick section of strata is described in chronostratigraphic sequence. Vertebrate fossil collections, all with good or excellent locality data (see paleontology section), enable an accurate delineation of the chronologic sequence of strata in the northern Smith River basin. The strata are divided into five ages: (1) Late Chadronian; (2) Oreilian through Whitneyan; (3) Early Arikareean; (4) Late Arikareean; and (5) Barstovian (figure 3). Strata of each of these ages are individually described and interpreted.

The chronostratigraphic divisions are lithologically indistinguishable, and
Fig. 3  Chronologic division of the Tertiary sediments in the northern half of the Smith River basin.
although there are local differences in depositional processes and there are minor differences in lithology between each age, the strata are very similar throughout the basin and any lithic differences are subtle and gradational. Therefore, these five divisions do not represent mappable units.

It should be noted that the Late Chadronian and most of the Orellan and Whitneyan age strata were observed and mapped on only a reconnaissance scale. More paleontologic and stratigraphic work on these strata is needed for a complete description of the entire section.

DESCRIPTIONS AND INTERPRETATIONS

Late Chadronian

Strata of Late Chadronian age are exposed near Beaver Creek (figure 3). The bedding attitudes (3-5 degrees southeast) and geophysically determined depth of the strata (Gogas, 1984) indicate that the strata of Late Chadronian age do not extend to any other regions of the basin. Because of this limited lateral extent and the characteristically poor exposure of Tertiary sediments in this portion of the basin, interpretations of depositional processes are tenuous, as are sequential relationships with the younger strata to the east and south.

Description

Strata of Chadronian age are dominated by tan to white, very fine silt to coarse silt packages. Composition of these silts is eighty percent devitrified glass shards with whole, unaltered glass shards and volcanic rock fragments comprising the remaining twenty percent. Matrix supported, angular, fragmentary clasts of pre-basin rock and red, blue, and yellow pumice clasts up to two centimeters in diameter are fairly common.

Bedding in the Beaver Creek area is distinct, and is possibly better defined than anywhere else in the basin. Thin to medium, tabular beds of
clast free silt and claystone comprise more than eighty percent of the exposed section. Interbedded with the clay and silt beds are medium to thick tabular to elongate lensoidal beds of coarse silt and sand exhibiting thick (20 centimeters to .5 meter) sets of high angle planar and tangential cross-beds, and thin planar laminations.

**Interpretation**

The rocks of Chadronian age exposed near Beaver Creek appear to have been deposited by fluvial processes. The thin to medium bedded, fine-grained units probably represent overbank deposition, and the coarser grained, heavily crossbedded units represent the result of in-channel deposition. Over eighty percent of the exposed section is comprised of overbank deposits and this suggests that these rocks represent the deposits of a high sinuosity, predominately fine-grained, meandering stream system (Allen, 1964, 1977) (Walker and Cant, 1980).

**Orellan Through Whitneyan**

The strata of Orellan and Whitneyan age crop out in limited exposures north and south of Whitetail Deer Creek (figure 3).

**Description**

Tan and white to pink, very fine silt to clay sized shards of devitrified volcanic glass mixed with lesser proportions of silt sized grains of unaltered glass and volcanic rock fragments make up over ninety percent of the bulk of the exposures of this age. Matrix supported clasts of pre-basin rocks (dominantly Spokane Shale) are randomly scattered in these units. The percentage of clasts to matrix increases dramatically near the pre-Tertiary-Tertiary rock contacts. Bedding in these fine-grained sediments is mostly massive but some faint thick, irregular tabular beds can be discerned.
Breccia is rare, but where present is dominated by poorly sorted, pebble to boulder size clasts of Spokane Shale from nearby exposures to the north and east. Pumice, Newland Limestone, Greyson Shale, and intraformational clasts compose a minor percentage of the breccia. The breccia is present as isolated, channel shaped lenses that have basal scoured surfaces, and range in width from a few centimeters to two meters, and in depth from a few centimeters to one meter. Horizontally stratified or massive clast supported debris in the channels grades upward, above the channel, into massive matrix supported breccia and finally into the massive, nearly clast free siltstone that dominates the exposed section.

Thin, white, crystal ash-rich beds occur as isolated lenses that cannot be traced from one exposure to the next. A thin, irregular bed of moderately sorted pumice granules mixed with lesser amounts of pure glass shards is exposed near Sheep Creek.

Interpretation

The thinly bedded ash and pumice suggests that a few beds of this age represent primary airfall into the basin. However, outcrops of massive to crudely bedded, fine grained rocks with matrix supported, randomly oriented angular clasts of pre-basin rocks are more common. This suggests that the dominant basin fill process was mass-flow deposition; similar to mudflow deposits described by Blissenbach (1954), and Axelrod (1984). The dominance of locally derived clasts of Spokane shale in these mass-flow deposits suggest that most of the sediments of this age, in this portion of the basin, originated from highlands to the east where the Spokane Shale crops out extensively. Primary airfall ash accumulated in these highlands where it was periodically washed down into the basin as ashy mudflows. The overall low percentage of clasts to matrix in these ashy mudflows indicates limited
bedrock exposure of these highlands at the time of deposition, probably in a subdued topography, buried by huge amounts of ash.

The breccia filled channels within the massive, fine-grained units are not the deposits of a major drainage system. The small size of these channels and the angularity, poor sorting, and local derivation of the clasts within them, indicates that the breccias are the result of deposition in small, localized channels which were perhaps formed by periodic runoff from nearby hills or the result of reworking by dewatering of underlying ashy mudflows.

Early Arikareean

The strata of Early Arikareean age crop out just south of Hatch Creek and along the course of the Smith River (figure 3) where they are fairly well exposed. However, fossils from the earliest Arikareean stage are rare, probably because that part of the section is in general poorly exposed.

Description

The composition of the Early Arikareean strata is similar to that of the Orellan and Whitneyan strata, with the bulk of exposures comprised of devitrified volcanic glass. However, these younger units have a slightly greater percentage of coarse-grained (coarse sand and above) lenses and unaltered glass shards. These strata are commonly cemented by silica or calcium.

About eighty percent of the exposed section is characterized by strikingly uniform, tan, massive or thick ill-defined beds of moderately sorted siltstone. Most of these exposures contain very rare, randomly oriented, matrix supported clasts of angular pre-basin rocks and pumice from .5 to 5 centimeters in diameter. However, a few are clast free, and composed entirely of devitrified and whole glass shards.
Clast and matrix supported pebble and cobble conglomerate with angular to subrounded, poorly sorted clasts comprise the remaining twenty percent of the exposed section. The bulk of the clasts in these conglomerates reflect the most nearby pre-basin rock lithologies including early Tertiary intrusives, a variety of Precambrian and Paleozoic rocks, and intraformational clasts. The clasts commonly are horizontally stratified and are rarely imbricated. Basal contacts of the conglomerates with the massive siltstones beneath are sharp and most show scouring. Bedding is irregular to lensoidal (commonly channel shaped) with most lenses less than three meters wide and one meter thick.

Coarser packages near the top of the section, at Crabtree Bluff (Plate I), show better sorting and roundness, and exhibit a more heterogenous admixing of pre-basin rocks than the underlying crude conglomerates. Here, channels (up to .5 meters thick) are scoured into the massive silty units common elsewhere in the basin. Clast supported lag deposits in these channels is poorly sorted, massive, and ranges from sand to cobble. Above these lag deposits grain size and bedding thickness gradually decrease to medium to well sorted sand and pebble packages that exhibit well defined and laterally extensive (up to 20 meters) thin to medium, tabular to slightly irregular beds of planar laminations and low angle tangential cross-beds.

Finer grained rocks grade laterally into, and overlie the coarse package at Crabtree bluff. This siltstone is slightly darker and coarser-grained than the siltstone in the basal portion of the section. Rootlet casts and diatoms, rare in the basal portion of the section, are common in the upper part of the section. Some of the siltstone is massive, but characteristically it consists of thin to very thin, tabular beds of alternating coarse silt/fine silt.

Where Early Arikareean strata are exposed in contact with basement
rocks, they are cemented with silica. The cemented matrix at these contacts has a high percentage of unaltered glass shards compared to uncemented, similar age sediments, and commonly contains randomly scattered clasts of pumice (up to 3 centimeters in diameter) and obsidian (up to 5 millimeters in diameter). All of the other clasts reflect the most proximal pre-basin rock lithology. These clasts rapidly decrease in density away from the Tertiary-pre-Tertiary contact. Ten meters away from the contact there are usually few, or no clasts. At a greater distance from the contact these cemented exposures grade into the devitrified, relatively unindurated, massive beds that are prevalent throughout the basin.

**Interpretation**

The units of massive, uniform siltstone that dominate exposures of the lower section represent ashy mudflows. These apparently unbedded sediments are, at first, difficult to interpret. However, near basin margins, depositional processes can be elucidated where silica cement has preserved the original bedding, lithologies, and textures of the strata. The crude to massive bedding, and matrix supported, randomly oriented clasts in these exposures suggest mass flow deposition, and the lateral, gradational relationship of these exposures to the tan, uniform beds further out in the basin suggests that those beds also represent ashy mudflows even though their original bedding and textures are obscured by weathering.

The rare, crudely stratified, conglomerate lenses interbedded with the fine-grained packages in the lower section suggest minor reworking of mudflows by fluvial processes. The small size and limited occurrence of these channels and the dominance of nearby sources of the clasts within them, indicates that the channels are not part of a major drainage system but are more likely the product of dewatering of the ashy mudflows.
The well bedded sediments at Crabtree Bluff represent the in-channel and overbank deposits of a meandering stream depositional system. The fine-grained, tabular beds of alternating fine/coarse silt with climbing ripples and rootlet casts are similar to overbank deposits described by Allen, (1964,1977) and Collinson (1978). The upward fining and decrease in bedding thickness within the coarse package, and the predominance of overbank deposits laterally to and overlying this package, suggests that these rocks represent the result of deposition by lateral accretion of a point bar in a meandering stream system, similar to point bars described by Allen, (1964) and Collinson (1978).

The strata at Crabtree Bluff mark a change from dominant mass flow deposition in the basal part of the section, to fluvial deposition in the upper section. This lithofacies change is well exposed in the northwest sector of section 9, T10N, R5E (plate I) and was interpreted by Koerner (1939) as an unconformity separating the underlying Arikareean Fort Logan Formation from the Barstovian Deep River Formation. Fossils collected by Rensberger (1981) and those collected for this study indicate that this unconformity passes through deposits that are entirely Arikareean in age. I interpret this change in lithologies to represent a change from mass-flow to fluvial processes and not an unconformity.

**Late Arikareean**

The strata of Late Arikareean age occur in widely scattered outcrop in and around Rabbit and Spring creeks and Thompson Gulch (figure 3). Lateral exposure is good, enabling depositional processes to be interpreted for a geographically large area of the basin.

**Description**

The composition of the fine grained units of this stage is similar to the
upper siltstone beds of Early Arikareean age, but rootlet casts are more common. As a whole, these slightly younger strata exhibit a wider variety of sedimentary structures and are coarser grained, with fine sand to pebbles comprising about thirty percent of the exposed section.

Fine-grained packages at Rabbit Creek (figure 4) display thin, tabular beds of subtly alternating fine silt/medium silt. At Spring Creek (figure 4) the siltstone is mostly massive, and lithologically uniform. Rootlet casts are common at both areas and climbing ripples are common in the thinly bedded units at Rabbit Creek.

Near Rabbit Creek the siltstone laterally bounds and is interbedded with coarser grained sediments. Overall, both grain size and the scale of sedimentary structures decrease upward in this coarse package. Poorly sorted gravel to pebble breccia and conglomerate at the base of the exposed section are overlain by medium to thick tabular beds of low angle tangential cross-beds and planar laminated medium and coarse sands that grade upward to thin to medium tabular to elongate lenses of well sorted, planar laminated sand. Within this package, smaller scale (.5-1 meter) fining up sequences are common. Small, gravel and pebble conglomerate filled troughs are scoured into tabular beds of sand and are overlain by planar laminated sands and capped by a thin (1-5 centimeters) mud drape. Pebble and gravel lithologies reflect a mixture of pre-basin rocks in which the nearest formation contributes only a slightly larger percentage of clasts.

In contrast, sediments of the same age, near Thompson Gulch (figure ) are massive or crudely bedded siltstones interrupted by many small to large (up to 5 meters long and 1.5 meters deep) breccia filled channels. The breccia is poorly sorted, and consists of angular cobble and boulder clasts that are either crudely stratified or more commonly massive. A siltstone member of
the Newland Formation outcrops to the west, and has contributed more than ninety-five percent of the clasts in these breccias.

**Interpretation**

Most of the exposed strata of Late Arikareean age reflect a depositional system dominated by low gradient fluvial processes, as opposed to the thick ashy mudflows and high gradient fluvial processes characteristic of the older rocks in the basin. The thin alternating coarse/fine silt beds, rootlet casts and climbing ripples in the fine-grained package that overlies and is lateral to the coarse package at Rabbit Creek suggest that this siltstone represents overbank deposits (Allen, 1964) (Collinson, 1978). The sand, pebble and gravel beds at Rabbit Creek represent the result of in-channel deposition in a fluvial system. The dominance of the overbank deposits lateral to this coarse package, the overall fining up of this package and the decrease in scale of sedimentary structures all suggest that this package represents the in-channel deposits of a point bar in a meandering stream system, similar to point bars described by Allen, (1964, 1977) and Collinson (1978). The small channel scours and lag deposits that display small scale fining up sequences and mud drapes are similar to chute deposits in the upper part of a point bar described by Collinson (1978).

At Spring Creek, bedding is obscured, so depositional processes are difficult to determine. These beds may represent mass-flow deposition. However, approximately age equivalent beds at Rabbit Creek suggest that fluvial depositional processes were dominant in this portion of the basin. From this you may infer that the beds at Spring Creek represent floodplain deposits, probably lateral to channel deposits elsewhere in the basin.

The isolated exposures near Thompson Gulch are indicative of deposition in a higher gradient system. Most of the outcrops are dominated by ashy
mudflows, cut by channels and filled with breccia. The coarseness, angularity, poor sorting, crude bedding and scoured bases of these breccia lenses, and the almost complete dominance of Newland Formation siltstone clasts strongly suggest that they represent filled channels in the distal to mid portion of an alluvial fan. Blissenbach (1954) describes a similar fan deposit in which massively bedded mudflows and cut and fill channels comprise the entire fan section. Channel geometry and clast lithology suggest that the apex of this fan was to the west, and limits the source area to the Big Belt Mountains.

Unconformity

An unconformity separates the strata of Late Arikareean age from the overlying strata of Barstovian age. Exposure of this early-Miocene unconformity is limited to a single outcrop in the southeast sector of section 14, T10N, R5E, near Spring Creek. Here, thin, tabular to massive beds of light pink, poorly sorted, coarse to fine silt of Barstovian age lie in a broad trough upon mostly massive beds of brown, moderately sorted, fine to medium silt of Late Arikareean age. Local relief of the contact is about three meters. Although faint bedding can be discerned in a few areas, most of the bedding in the Late Arikareean strata directly below the unconformity is obliterated, and the ash is more decomposed compared to similar aged deposits elsewhere in the basin. Also, there is a marked increase in the number of rootlet casts in these strata compared to floodplain sediments elsewhere in the basin.

Fossils collected above and below the unconformity, from localities separated by less than 5 meters of section suggest a hiatus of 3-7 million years.
Interpretation

An unconformity with a temporal equivalent hiatus to the unconformity in the Smith River basin is identified in many other basins in western Montana and eastern Idaho (Fields and others, 1985). A marked increase in faulting with a regional change to a moister climate (Thompson, Fields, Alt, 1981), and a hiatus in volcanic activity (Rasmussen, 1973) resulted in the removal of an unknown quantity of sediments in the basins during the Early Hemingfordian. Sedimentation resumed in the mid Barstovian when a more arid climate returned and tectonic activity was more subdued.

There is no evidence for tectonic tilting within the Smith River basin so I believe the major causes of the unconformity are climatic changes and regional tectonic and volcanic activity. Both the Arikareean and Barstovian sediments were deposited during arid conditions so they are very similar. However, the regional climatic change to a moist period and the hiatus in volcanic activity in the Hemingfordian undoubtably included the Smith River basin as well, and this change at least partially contributed to the removal of sediments. In addition, uplift of the Smith River basin relative to the Townsend basin, beginning in Late Arikareean time, (see structure section) lowered the base level of the Helena-Townsend Valley and caused streams to be incised into the Smith River basin.

Barstovian

Strata of Barstovian age crop out in a small, isolated exposure near Camas Creek, and extensively near Spring Creek (figure 3).

Description

The strata of Barstovian age, near Spring Creek, are dominated by fine-grained packages at the base of the section, but coarsens abruptly upward in the section. The fine-grained packages are extremely similar in
lithology to the fine-grained packages of Arikareean age. However, the Barstovian siltstone is pink to white, and contains a greater percentage of larger, whole glass shards, and more commonly exhibits well defined bedding. More than ninety percent of the fine grained units are very thin to thin, tabular to slightly irregular beds of fine silt alternating with medium to coarse silt. Massive siltstones and interbeds of sand or coarser packages are rare.

Coarser units are more common toward the top of the section. Here, medium to thick, irregular, tabular beds and lenses of subrounded sands that display planar laminations, and low angle tangential and trough cross-beds, dominate the exposed section. Internally massive matrix and clast supported pebble to boulder breccia occurs in channel shaped lenses that are randomly scoured into the finer grained beds throughout the upper part of the section. These channels range in size from a few centimeters to three meters wide. Breccia lithology reflects a wide variety of pre-basin source rocks, with the nearest pre-basin rock lithology only slightly dominating.

Rare interbeds of coarse silt and finer grained packages at the top of the section display similar lithology and texture to those in the basal portion of the section.

Interpretation

The fine-grained, thinly bedded sediments in the lower part of the section are similar to overbank-floodplain sediments described by Allen (1964, 1977) and Collinson (1978). These floodplain strata are probably lateral to in-channel deposits not exposed elsewhere in the basin. Rare, massive, fine grained beds could represent mass flow deposition similar to the clast-free ashy mudflows common in Arikareean age rocks, or more likely could represent floodplain deposition in which the original bedding and
sedimentary structures were destroyed by weathering.

The coarser grained, cross-bedded and scoured units in the upper part of the section represent the fluvial deposits of a mixed braided and meandering stream system. Although there is little lateral exposure in the upper part of the section it appears that overbank deposits are rare, as are fining up sequences. Clast and matrix supported conglomerate and breccia are common. This suggests that deposition occurred in a higher gradient and lower sinuosity stream system than the older fluvial deposits in the basin (Walker and Cant, 1984) (Bridge, 1983). The evenly mixed lithologies of the contained source rock clasts suggest it was a broad drainage system.

The outcrop of Barstovian strata near Camas Creek is too poorly exposed to interpret. These strata appear to have been deposited under similar processes to those in the basal portion of the Barstovian section near Spring Creek.
REGIONAL LITHOLOGIC COMPARISONS

A two-fold subdivision of the Tertiary strata in the Smith River basin, based upon faunal assemblages, has been recognized since 1876 (Grinnel and Dana, 1876). These strata have been named the *Ticholeptus* beds (Cope 1879), Deep Creek Beds (Dall and Harris 1892), upper and lower Deep River beds (Scott 1893), Smith Lake Beds (Weed, 1899), Deep River (for the upper section) and Fort Logan (for the lower section) beds (Douglass, 1903), and Deep River and Fort Logan Formations (Koerner, 1939). Koerners' classification is based upon lithologic as well as faunal distinctions, and while it is the last formally proposed, his subdivision of the strata seems to be incorrect and is not useful in the field (see paleontology and stratigraphy sections). Most workers still informally refer to the entire section as the Deep River beds.

The stratigraphic terminology developed by Robinson (1963) and Kuenzi and Fields (1971) for other western Montana and eastern Idaho basins cannot be used for subdividing the Tertiary strata in the Smith River basin. While there is an apparent lithologic difference in other basins, it is not obvious enough in the Smith River basin to be mappable, and mappability is a criteria to distinguish formations (Hedberg, 1976). The exposed rocks are similar enough throughout the section to be designated as a single formation. No formal names are proposed in this unpublished report and the informal designation "Deep River beds" must be retained for the time being.
STRUCTURE

Introduction

The north-south trending Smith River basin is bounded by the foothills of the Little Belt Mountains on the east, by the Big Belt Mountains on the west, and by the Dry Range on the north (Figure 4). It continues southward into the Shields River Valley. The Little Belt and Big Belt mountains are broad anticlinoria that owe their structure (although not their present elevation) to the Laramide orogeny (Birkholz, 1967). The Dry Range is a plateau uplifted in post-Miocene time (Wolfe, 1964).

The Smith River basin lies within the northern "shore" of the central Montana trough and the eastern boundary of the disturbed belt (Figure 5). The central Montana trough began to subside in the Proterozoic and subsidence persisted with varying degrees of intensity throughout the remainder of geologic history (Peterson, 1981). Proterozoic Belt strata were deposited in this subsiding trough. These strata mark the easternmost extent of the Belt Supergroup.

The disturbed belt consists of a generally north-south trending zone of Laramide (Late Cretaceous-Early Tertiary) thrusts and folds (Woodward, 1981). The thrusts generally follow bedding planes and place Proterozoic Belt strata eastward over Paleozoic rocks (Woodward, 1981). The disturbed belt appears to be underlain by a westward dipping decollement fault within or near the base of the Belt Supergroup. Most of the thrusts merge with the decollement in the subsurface (Robinson, 1959). This decollement dies out eastward beneath the folds marking the eastern and southern margins of the disturbed belt (Woodward, 1981). North of the Big Belt Mountains, the thrusts of the disturbed belt conform closely to the zero isopach of Belt rocks. The
Concealed Hill Tertiary Sediments

PreTertiary Sedimentary rocks

Tectonic map of the Smith River basin and northern half of the Helena-Townsend Valley showing the location of normal and thrust faults.

Fig. 4 Tectonic map of the Smith River basin and northern half of the Helena-Townsend Valley showing the location of normal and thrust faults.
Fig. 5  The disturbed belt and central Montana trough of Western Montana. Modified from Gogas (1984) and Reynolds (1979).
craton along this isopach acted as a buttress, and the zone of thrusts and folds of the disturbed belt occurs where belt rocks pinch out eastward (Woodward, 1981).

In the northern Big Belt Mountains, near the northwest sector of the central Montana trough, the disturbed belt branches into two distinct zones of thrust faults; the Meagher County branch and the south branch (Birkholz, 1967) (Figure 5). The south branch follows the trend of the disturbed belt from the north and cuts perpendicular to the trough, across the Helena-Townsend basin. Deformation of the south branch is intense, with suggested horizontal displacement of up to 80 kilometers (50 miles) and associated isoclinal, overturned folds are common (Woodward, 1981). The Meagher County branch cuts eastward across the northern foothills of the Big Belt Mountains, follows the northeast flank of the Smith River basin, and then turns south, terminating in the Castle Mountains (Birkholz, 1967). The northern edge of the central Montana trough also trends eastward across the northern Big Belt Mountains and the eastward swing of the thrusts of the Meagher County branch coincides with the edge of the trough because crystalline rocks to the north acted as a buttress during Laramide compression (Birkholz, 1967). Intensity of deformation of this branch decreases eastward, and displacement and folds are of a much smaller magnitude than those of the south branch or of the disturbed belt northward (Birkholz, 1967) (Woodward, 1981).

Intra arc extension followed the Laramide orogeny and resulted in listric normal faults whose patterns are inherited from the compressional structures of the disturbed belt and "sole" onto an earlier thrust zone (Fields and others, 1985). Basins of southwest Montana formed by this normal faulting coincide with weaknesses created from the compressional regimes.
of the Laramide orogeny in most or all of the western Montana and eastern Idaho basins (Fields and others, 1985).

In this study I describe a similar structural tie between the thrusts and the normal faults in the Smith River basin. The configuration and position of the northern edge of the central Montana trough has caused the deformation and overthrusting of the disturbed belt to swing eastward into the Smith River basin. The compressive forces responsible for this easternmost extent of the disturbed belt have created zones of weakness along thrust planes that later Tertiary extensional faults sole onto at depth. Thus, the easternmost occurrence of later Basin and Range type faults in Montana, those within the Smith River basin, coincide with the easternmost occurrence of thrust faults in southwest Montana.

Smith River Basin

Laramide Structure

The Meagher County branch of the disturbed belt is represented in the Smith River basin by the Scout Camp-Willow Creek, Craig, and Volcano Valley thrusts (figure 6). Smaller splays off of these main thrusts are common. The thrusts generally follow bedding planes and place Proterozoic Belt strata northeast over Paleozoic rocks (Birkholz, 1967). Surface traces of the thrusts trend N70W west of the basin, east-west as they cross the northern fourth of the basin, and N70W again after emerging from beneath the Tertiary basin fill sediments.

Birkholz (1967) suggests that the vertical displacement near the basin ranges from 152 meters (500 feet) for the smaller splay faults to 2750 meters (9000 feet) for the Scout Camp-Willow Creek thrust. Horizontal displacement is uncertain but probably in miles (Birkholz, 1967). Displacement increases northwest of the basin where Woodward, (1981),
Fig. 6  Tectonic map of the northern half of the Smith River basin showing the location of faults.
suggests a true horizontal displacement of at least 16 kilometers (10 miles) for the Scout Camp-Willow Creek thrust. Birkholz (1967) identified a component of left-lateral strike-slip movement for the thrusts of the Meagher County branch and suggests that this movement accommodated east-west compressive forces along east-trending Belt strata near the zero isopach of the central Montana trough.

All of the thrusts dip at high angles (45 degrees) near the surface, but Birkholz (1967) suggests that they flatten at depth, and merge as a set of imbricate thrusts, forming a single sole that merges with decollement and underlies most of the Smith River basin, and passes beneath the Big Belt Mountains. The Big Belt anticlinorium and surrounding country moved eastward along this decollement and when movement was no longer possible, Laramide compression was released by a second set of thrusts forming the south branch of the disturbed belt (Birkholz, 1967). Later thrust movements of the Laramide orogeny did not affect the area east of the Big Belt Mountains (Birkholz, 1967).

**Tertiary Structure**

Tertiary basin fill strata in the northern Smith River basin are present as one large, northeast striking, southeast dipping, homoclinal package. Dips average two degrees but range from zero to eight degrees. The strata are not folded. Maximum basin fill thickness, based upon geophysical data, is 180 meters (600 feet) near Rabbit Creek and increases to 457 meters (1500 feet) south of this study area, near White Sulphur Springs (Fields, personal communication, 1983; Reynolds, personal communication, 1984). Gogas (1984) suggests that the Tertiary-pre-Tertiary rock interface in almost all areas of the northern Smith River basin is a shallow, smooth sided, depression with evenly spaced contours.
Nearly all surface traces of the contact between Tertiary rocks and pre-basin rocks in the northern Smith River basin are irregular, depositional contacts, rather than linear, fault contacts. There are no fault scarps along margins, and Tertiary strata extend as far as five miles away from the basin up into many of the present drainages from the surrounding highlands. These drainages are exhumed pre-Oligocene drainages that were clogged with ash as the basin filled during the Oligocene and Miocene.

Three different trends of normal faults have disrupted the homoclinal package of the basin, and displaced and faulted Tertiary strata in several areas (figure 6). These faults are: the north-south trending Camas Creek fault along the western portion of the basin (Birkholz, 1967); the northeast-southwest trending faults in the center of the basin (Birkholz, 1967); and the northwest-southeast trending faults in the eastern portion of the basin.

Displacement along any one fault is minor and ranges from a few meters for the northwest-southeast trending faults near Newland Creek, to a maximum vertical throw of 152 meters (500 feet) for the Camas Creek fault. There is a maximum of three degrees of rotation along any one fault, and only the Camas Creek fault is long enough and has had enough displacement to delineate a significant portion of a basin margin.

Although the at-depth geometry of most normal faults in the northern Smith River basin is obscure because of limited exposure of strata near the faults and limited displacements along them, it appears that the northwest-southeast trending faults are listric, and merge with thrusts at depth. These faults either parallel or overprint the thrusts along the eastern margin of the basin (figure 6), and hanging wall strata near the fault traces are rotated toward the footwall block. This evidence suggests that these
faults are listric and may sole onto thrust fault planes.

Reynolds (1979; and personal communication) and Gierke (1984) believe that the normal faults in the southern Smith River basin, near White Sulphur Springs, are listric and Gierke suggests that these normal faults represent the interaction between regional east-west extension and previously established Laramide zones of weakness. Gierke (1984) believes that both the Horse Butte and Moors Mountain (Willow Creek) thrusts show clear evidence of recurrent normal movement along their fault surfaces and that all of the normal faults in this portion of the basin either merge with these thrusts or represent reactivated portions of these thrusts (figure 4). A similar structural correlation between thrusts and normal faults was described by Zim and Lageson (1985) in the Three Forks basin and Constenius (1982) in the Kishenehn basin. Thus, the Smith River basin might have a structural style similar to that of the Kishenin basin to the north and the Three Forks basin to the south.

Although these listric normal faults have locally tilted Tertiary in some areas Birkholz (1967) suggests that upwarping to the north (the Dry Range uplift) and west of the Smith River basin explains the gentle, southeast regional dip of the Tertiary strata. Birkholz's interpretation is supported here in the absence of major basin bounding faults large enough to produce this regional tilt along the eastern or southern margins of the basin.

Most normal fault movement in the northern Smith River basin occurred after the Arikareean (Early Miocene) but before Quaternary time. Evidence for normal faulting that occurred before Tertiary sedimentation began is obscure because only displacement that post-dates the oldest exposed Tertiary strata can be chronologically interpreted. There is no differential deformation of Chadronian (Early Oligocene) through Late Arikareean age
strata which suggests fault activity during that span of time was negligible. A hiatus that spans latest Arikareean and Hemingfordian (late Early Miocene) time probably marks an active period of normal faulting. However, there is no angular discordance between strata above and below the unconformity so faulting on a local level was minor, and, more important to the creation of the unconformity, were regional climatic influences, and displacement along the eastern basin bounding fault in the Helena-Townsend basin that uplifted the Smith River basin (figure 4) (see page 29 for a full discussion of the unconformity). Strata lying above the unconformity are displaced or tilted by all trends of faults which suggests that most, if not all fault activity post-dates the deposition of these Barstovian (middle Miocene) sediments. Quaternary faulting has not been significant as there are no fault scarps along margins and Quaternary sediments are not displaced.

Helena-Townsend Basin

The Helena Townsend basin lies immediately to the west of the Big Belt Mountains (figure 4). Sedimentologic and structural evidence, discussed later in this section, suggest that for a portion of their histories the Smith River and Helena-Townsend basins were partially coalesced, in some places sharing the the same depositional surface. In the following discussion only structures pertinent to the geologic history of the Smith River basin are discussed. Structures elsewhere in the Helena-Townsend basin are not germane to the scope of this study.

Laramide structure

In contrast to the complex set of imbricate thrusts that represent the Meagher County branch of the disturbed belt in the Smith River basin, the south branch is represented by the single Eldorado thrust in the Helena-Townsend basin (figure 4). The Eldorado thrust is a north-south
trending, concave west thrust, placing Proterozoic Belt rocks eastward over Paleozoic, Mesozoic and less commonly upon other Belt strata.

Bregman (1971) suggests a minimum horizontal displacement of 10.5 miles (16.5 kilometers) for the Eldorado thrust, while Lochman and Duncan (1944) suggest a probable true horizontal displacement of fifty miles (80 kilometers). The Eldorado thrust is nearly flat at depth in the Helena-Townsend basin, and like all other thrusts of the disturbed belt, it merges with decollemont (Woodward, 1981). The great depth of Belt strata below the Helena-Townsend basin suggests that this decollemont is also at great depth.

Tertiary Structure

Tertiary basin-fill strata in the Helena-Townsend basin are commonly folded and generally dip from five to twenty degrees east-southeast. Locally, dips increase to as much as forty eight degrees (Nelson 1963), (Mertie, Fisher and Hobbs, 1951), (Reynolds, 1979), (Freeman, Ruppel, and Klepper, 1958). Pardee (1925) described an angular unconformity within the Tertiary section that separates pre-Hemingfordian strata from Barstovian through Hemphillian (Late Miocene) age strata. The angular discordance between strata above and below the unconformity ranges from four to eight degrees.

A curvilinear, roughly north-south trending normal fault delineates the contact between Tertiary basin fill sediments and pre-basin fill sediments along the eastern margin of the Helena-Townsend basin (Ruppel, Freeman and Klepper, 1958). Vertical displacement along this fault is significant. East of the fault, in the northern Big Belt Mountains, near the summit of Magpie Gulch pass (figure 4) elevation 2012 meters (6600 feet) Tertiary sediments of probable Early Oligocene age crop out, and display a twelve degree dip to the southeast. Strata of similar lithology and age are exposed near the north
end of Canyon Ferry Lake (Figure 4) west of the fault at an elevation of about 1219 meters (4000 feet). This infers a down to the west, post-Early Oligocene vertical throw of at least 792 meters (2600 feet) along the fault in this area (figure 7 cross section B-B’). Thirty five miles to the south, at Deep Creek pass (figure 4), elevation 1828 meters (6000 feet) Tertiary sediments that are most likely Early Arikareean (Late Oligocene) crop out at the crest of the pass. Strata of similar lithology and age lie upon pre-basin rocks directly west of the pass at an elevation of 1463 meters (4800 feet) in the Helena-Townsend basin, inferring a post-Arikareean vertical throw along this portion of the eastern basin bounding fault of at least 366 meters (1200 feet) (figure 7 cross section D-D’). Early Arikareean age sediments lying directly upon pre-basin rocks are found in the Helena-Townsend basin at an elevation of approximately 1175 meters (3800 feet), and in the Smith River basin at an elevation of 1493 meters (4900 feet). This infers a relative uplift to the east of at least 335 meters (1100 feet) for the Smith River basin relative to the Helena-Townsend basin.

The eastern basin bounding fault is listric normal and merges at depth with the Eldorado thrust (Reynolds, 1979; and personal communication 1986). Reynolds (1979) postulates that a listric normal fault geometry and crustal extension with resultant rotation of the downthrown block explains localized dips as high as fifty degrees into the fault. Reynolds believes that all of the listric normal faults along the eastern basin margin sole into, or represent direct reactivation of the earlier formed thrust surfaces. Freeman, Ruppel, and Klepper (1958) describe a monoclinal fold of the Tertiary strata lying directly above the buried Eldorado thrust west of Deep Creek pass and suggest that post-Miocene reverse reactivation of the thrust caused this drape fold.
Fig. 7  Generalize geologic cross-sections across northern (B-B'), middle (C-C'), and southern (D-D') Big Belt Mountains, Smith River, and Helena-Townsend basins. (emphasizing major Tertiary structure)
Fault activity has been pulsatory along the fault. The first major episode of Tertiary extensional movement along the fault is marked by the angular unconformity, and folded and tilted pre-Hemingfordian age strata. After a short subsidence, renewed faulting in the Late Miocene is marked by a sharp increase in coarser grained sedimentation due to increased gradients and overloaded drainage systems. Barstovian through Hemphillian age fanglomerate along the western flank of the Big Belt Mountains record this episode. The present tilt of these fanglomerate deposits, and recent seismic activity (Pardee, 1925) along the fault suggest that displacement has continued to the present.

The timing of post-Hemingfordian displacement along the eastern basin bounding fault has varied from area to area. Pardee (1950) reports that while evidence for normal faulting along the western margin of the Big Belt mountains south of Deep Creek Pass and north of Confederate Gulch is good, the Big Belt Mountains between these drainages appear old, with smooth slopes and an irregular faultline scarp receded east from its previous position near the present day fault contact (figure 7, cross section C-C'). Early Miocene Tertiary strata along this margin dip only five to twenty degrees into the fault as opposed to twenty to forty degree dips of similar aged strata north and south of this margin. It appears that displacement after the Early Miocene along the fault here was minor relative to displacement north and south along the fault. This suggests that much of the present elevation of the Big Belt Mountains directly east of this portion of the fault, relative to the elevation of the Helena-Townsend basin, was attained before Miocene time.
Summary and Discussion

In light of the previously described structural characteristics, I contend that the northern Smith River basin fill strata do not lie in a primarily normal fault bounded, extensionally formed structural depression, but rather a degraded, primarily Laramide generated topography between the Big Belt and Little Belt anticlinoria. The shallow, smooth sided, evenly spaced contours of the subsurface profile of the basin fill-pre-basin fill rock interface, the irregular surface trace of this interface, and the back-filled channels along basin margins all suggest that most Tertiary-pre-Tertiary rock contacts at the surface and at depth represent original depositional contacts upon this topography (figure 8). Normal faults are a minor contributing factor towards basin subsidence and delineation as no single fault in the northern Smith River basin has a suggested post-middle Miocene throw of more than 152 meters (500 feet) and only the Camas Creek fault delineates a significant portion of the basin margin.

In the southern Smith River basin, marginal faults are more common, longer, and have had greater displacements along them compared to the faults in the northern Smith River basin. North-south trending faults west of the southern Smith River basin and northwest-southeast trending faults within and along the eastern margin of the basin have down-dropped this portion of the basin to a greater extent than in the north (Reynolds, personal communication, 1986; Gierke, 1984). Here, the depth of basin fill is correspondingly deeper (450 meters) than the depth in the north (185 meters). However, post-Oligocene throw on any one fault is probably less than 300 meters (Reynolds, personal communication, 1986) and the magnitude of these displacements, and the depth of Tertiary fill in this portion of the basin are still anomalously low compared to the
Figure 8  Geologic cross section of the Smith River Basin.
(For section location see figure 6 or plate I).
Helena-Townsend basin and most other basins of similar size in western Montana and eastern Idaho (see Monroe [1976], Dunlap [1982], Kuenzi and Fields [1971], Axelrod [1984], and Petewich [1972] for comparison).

The Helena-Townsend basin on the other hand, has a structural fabric and at depth configuration that are similar to most other Montana and Idaho basins. The basin is deep (about 1500 meters) (Reynolds, personal communication, 1986), and has a major basin bounding fault. The throw along this fault is estimated at well over a thousand meters and this displacement has tilted and folded Tertiary strata and defined a sharp Tertiary-pre-Tertiary rock contact along the eastern basin margin.

Generally, the Basin and Range type listric normal faults that characterize the basins in Montana and Idaho lie within the thrust belt in a regional sense. It appears that the normal faults in the Helena-Townsend and Smith River basins are also listric and merge with thrusts at depth (Reynolds, personal communication 1986, Gierke, 1984, this paper). In figure 4 the major thrust with significant displacement is the Eldorado thrust in the Helena-Townsend basin. It is overprinted by a major normal fault. The Craig and Willow Creek thrusts in the Smith River basin are smaller with much smaller tectonic displacements. Correlatively, the normal faults in the Smith River basin also have minor displacements, but still occur within the region of Paleocene thrusting. Constenius (1982) describes a similar correlation in the Kishenin basin. He states "regions of maximum extension coincide with areas formerly marked by the greatest degree of compressive stress and resultant shortening".

Reynolds (personal communication, 1986) believes that the shallow depth of Proterozoic Belt and Paleozoic strata in the Smith River basin has had an influence on the magnitude of extensional faulting in the region. He suggests
that because the crystalline core is relatively close to the surface in the Smith River basin, this region has behaved as a more coherent and rigid block than the Helena-Townsend basin where the core is deeper. Therefore, when extension began, the major breakup occurred west of the Smith River basin, where a deeper section of thrust and folded Belt strata provided a thicker, more ductile block that more readily accommodated large normal fault displacement.

**Early Basin Configurations**

Tertiary strata, exposed near the crest of a portion of the Big Belt Mountains, suggests that for a portion of the Tertiary the Helena-Townsend and Smith River basins were partially coalesced, in some regions sharing the same depositional surfaces. Remnant patches of Early Arikareean (Late Oligocene) strata at Deep Creek Pass, located medially between strata of similar age in the Helena Townsend and Smith River basins infers these strata were deposited across a continuous depositional surface connecting the southern portions of the basins during this period (figure 4).

Although Reynolds (personal communication, 1984) has extrapolated these local connections to propose that the Smith River and Helena Townsend basins Tertiary sediments were deposited upon a single, broad depositional surface, sedimentologic and structural evidence suggests that the two basins were at least partially separated by highlands now represented by Boulder Baldy, Mount Baldy, and Mount Edith of the Big Belt Mountains. Pardee (1950) showed that the Big Belt Mountains between Deep Creek Pass and Confederate Gulch had, by Arikareean time, already been significantly uplifted (page 47, this report). This implies that this portion of the Big Belt Mountains was exposed as a portion of the present range between the Smith River and Helena-Townsend basins. Sedimentologic evidence gathered in the
Smith River basin supports this interpretation. Directly below the eastern slope of the same portion of the Big Belt Mountains Arikareean alluvial fan deposits are preserved. Interpretation of this fan (page 29) limits the source area to the Big Belt Mountains. Therefore this portion of the Big Belt Mountains must have attained a significant elevation relative to the Smith River basin by Arikareean time and partially separated the two basins.

Thus, the Smith River basin Tertiary strata can be considered a large remnant of the easternmost portion of what was once a much larger depositional system that incompletely spanned both basins and was later disintegrated by a renewal in normal faulting along the western flank of the Big Belt Mountains in the Helena-Townsend basin. Evidence along the fault suggests that this disintegration began in Hemingfordian time (marked by the angular unconformity in the Helena-Townsend basin), continued through the Hemphillian (recorded by fanglomerate deposits), and was renewed in post-Hemphillian time (marked by the tilting of these fanglomerates). Recent seismic activity along the eastern basin margin in the Helena-Townsend basin suggests that this disintegration is still active.

In this study I have described the Cenozoic structures of both basins in order to present a clearer picture of the geologic history of the Smith River basin. However, more detailed work is still sorely needed in the Helena-Townsend basin for a clear understanding of its apparently close structural and sedimentologic relationship with the Smith River basin.
SUMMARY—GEOLOGIC HISTORY

LATE CRETACEOUS TO PALEOCENE: During Late Cretaceous to Early Paleocene time Laramide compressional forces resulted in the formation of the Big and Little Belt anticlinoria and the disturbed belt in western Montana. This belt, influenced by the configuration of the central Montana trough, branched into two distinct thrust zones, one along the eastern margin of the Helena-Townsend basin, and the other along the eastern margin of the Smith River basin.

EOCENE: The evidence in both basins is obscure, but if they share a similar early tectonic history with that of most other basins in western Montana and eastern Idaho, faulting and/or erosion that initially developed the ancestral Smith River and Helena-Townsend basins began in Eocene time (Fields and others, 1985). Topographically the Smith River and Helena-Townsend basins, like other basins in western Montana and eastern Idaho, were interconnected in at least one region, and separated by a low relief range in others.

EARLY TO MIDDLE CHADRONIAN: Lacustrine basin fill deposition is recorded in the northern portion of the Helena-Townsend basin (White, 1954).

LATE CHADRONIAN: A large, fine grained meandering stream system deposited sediments in the northeasternmost portion of the Smith River basin during the Late Chadronian.

WHITNEYAN THROUGH EARLY ARIKAREEAN: Enormous quantities of ash accumulated directly as airfall into the basins, and as ashy mudflows that originated from accumulations of ash in nearby highlands. Deposition in the Smith River basin was upon a subdued topography, and extended from the region near Beaver Creek to regions eastward and southward. The Helena-Townsend and Smith River basins shared a continuous depositional surface across Deep Creek Pass but most of the two basins were already
separated by the Big Belt Mountains.

LATE ARIKAREEAN: Debris shed from the Big Belt Mountains accumulated as alluvial fans in the western portion of the Smith River basin while a meandering stream system migrated over ashy mudflow deposits in the region near Rabbit and Spring creeks.

HEMINGFORDIAN: A renewal of normal faulting along earlier zones of weakness, and a changing climate resulted in the removal of an unknown quantity of Tertiary sediments in both the Helena-Townsend and Smith River basins. The Big Belt Mountains, uplifted between faults along both flanks, began to separate the Helena-Townsend and Smith River basins and broke any remaining continuous depositional surfaces between the two basins. Arikareean and older strata in the Helena-Townsend basin were tilted into this fault. Normal faulting and subsidence within the Smith River basin, influenced by the weak Laramide deformation in the basin and/or the shallow depth of pre-Tertiary rocks in the region, was comparatively minor, and the entire basin as a whole began to be uplifted with respect to the Helena-Townsend basin.

BARSTOVIAN: Coarse grained fanglomerates were deposited in the Helena-Townsend basin in response to renewed faulting. These strata were deposited with angular discordance upon tilted and folded older Tertiary strata. In the Smith River basin, deposition continued under similar processes that dominated during the Late Arikareean.

POST-BARSTOVIAN THROUGH CLARENDONIAN: Continued uplift of the Smith River basin and through flowing drainage prevented deposition, or resulted in the removal of nearly all post-Arikareean sediments in the basin. Small magnitude displacements along normal faults beneath the Tertiary basin fill sediments, and along some basin margins, stratigraphically offset, and
locally tilted some strata into the faults. In the Helena-Townsend basin, post-Barstovian deposition continued as the basin subsided and coarse-grained debris shed off of the western flank of the Big Belt Mountains accumulated along the eastern margin of the basin.

POST-CLARENDONIAN TO PLEISTOCENE: Continued faulting in the Helena-Townsend basin tilted strata as young as Clarendonian into the fault bounding the eastern margin of the basin. Fault activity may have continued in the Smith River basin, but probably with decreasing magnitude.

PLEISTOCENE TO RECENT: Glacial related deposition and erosion occurred in both basins. Basin fill sediments continue to be removed, as does tectonic activity in the Helena-Townsend basin.
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McCleran, H.G., 1969, Geology of the Sheep creek area, Meagher County, Montana: Masters thesis, Montana College of Mineral Science and


Rasmussen, D.L., 1973, Extension of the middle Tertiary unconformity into


APPENDIX I: SYSTEMATIC PALEONTOLOGY

The following systematic paleontology does not include specimens collected by previous workers in the Smith River basin. A compilation of previously collected specimens is included in the faunal lists presented in the paleontology section of this report (page 7).

The taxonomic arrangement used by Simpson (1945) is utilized in describing the mammals, and that of Romer (1966) for the reptiles. The classification of the Merycoidodontidae follows Schultz and Falkenbach (1968). Lander (1977) revised the Merycoidodontidae, and his classifications and synonymy are mentioned where pertinent.

University of Montana fossil localities for the Smith River basin are on Plate I.

ABBREVIATIONS:
A-P- Anterior to posterior length
C.M.- Carnegie Museum collection
F.A.M.- Frick collection/American Museum
fo.-foramen
frag.- fragment
lgth.- length
max.- maxilla
metiph.- metaloph
muzzl.- muzzle
M.V.- University of Montana vertebrate locality
protiph.- protoloph
S.D.S.M.- South Dakota School of Mines
Tr.- transverse width
U.M.- University of Montana fossil specimen
wdt.- width
CLASS MAMMALIA Linnaeus, 1758
Order Rodentia Bowdich, 1821
Family Aplodontidae Trouessart, 1897
Genus Niglarodon Black, 1961
Niglarodon koerneri Black, 1961

LOCALITY AND REFERRED SPECIMENS: MV8431-UM8907, palate with right and
left P4-M2; UM8908, right M2; UM8909, left M1.


DESCRIPTION: (Table 3); UM8907 shows moderate wear; no fossettes on right
and left M1; posterolingual fossette worn off right and left M2. UM8908 and
UM8909 show little wear. All other characteristics are as described by

Table 3. Measurements of the upper teeth of UM8907, Niglarodon koerneri.

<table>
<thead>
<tr>
<th></th>
<th>LEFT A-P</th>
<th>Tr.</th>
<th>RIGHT A-P</th>
<th>Tr.</th>
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<tr>
<td>M3</td>
<td>1.75</td>
<td>1.96</td>
<td>M3</td>
<td>1.68</td>
</tr>
<tr>
<td>M2</td>
<td>1.82</td>
<td>2.63</td>
<td>M2</td>
<td>1.82</td>
</tr>
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<td>M1</td>
<td>1.80</td>
<td>2.98</td>
<td>M1</td>
<td>1.82</td>
</tr>
<tr>
<td>p4</td>
<td>3.36</td>
<td>3.15</td>
<td>P4</td>
<td>3.40</td>
</tr>
<tr>
<td>p3</td>
<td>1.44</td>
<td>1.35</td>
<td>P3</td>
<td>1.44</td>
</tr>
</tbody>
</table>

DISCUSSION: UM8907 is the most complete specimen of the upper dentition of
N. koerneri yet reported. The following characteristics exhibited by this
specimen are indicative of N. koerneri (Rensberger, 1981): The relatively
greater transverse width of p3 relative to the anteroposterior length; p4
66
anteroposteriorly shorter relative to the transverse width; $P^4$ relatively short; and the anteroposterior length of the lingual moiety of $P^4$ is between 1.8–2.3 mm. UM8908 and UM8909 are identified as *N. koeneri* based upon a close comparison with a cast of the type in the UM collection.

Genus *Meniscomy* Cope, 1878

**LOCALITY AND REFERRED SPECIMEN:** MV8442-UM8935, right $M^2$.

**LOCAL FAUNA AND SUGGESTED AGE:** Crabtree local fauna. Early Arikarean.

**DESCRIPTION:** Extremely hypsodont. Anterolabial and lingual, posteriolabial and lingual fossettes present; no central fossette present; anterolabial fossette smallest of remaining fossettes; posteriolabial fossette next smallest; lingual fossettes deep, round, and of equal size; anteroposterior length subequal to transverse width; posterolabial fossette compressed and elongate antero-posteriorly; mesostyle prominent.

**DISCUSSION:** The long A–P length and short transverse width relative to *Niglarodon*, and the small size of the posterolabial fossette relative to the same fossette of *Niglarodon* are indicative of the genus *Meniscomy* (Rensberger, 1983).

Family Geomyidae Gill, 1872

Genus *Gregoromys* Wood, 1936

*Gregoromys douglassi* Wood, 1936

**LOCALITY AND REFERRED SPECIMEN:** MV8440-UM8928, skull with articulated mandible.

**LOCAL FAUNA AND SUGGESTED AGE:** Rabbit Creek local fauna. Late Arikareean.

**DESCRIPTION:** Teeth show moderate wear. Detailed description as described by Rensberger (1971), and Wood (1936).

**DISCUSSION:** The thin nasals, and their extension posteriorly to nearly the posterior extension of the pre-maxillaries, the molariform nature of $P^4$, and
lower molars with prominent anterolabial cingulum in which the main cusp is distinct and separated from the protostyloid by a deep cleft are just a few of the characteristics of UM8928 indicative of the sub-family Entopychinae (Rensberger, 1971). The short rostrum, and prominent anterior cingulum on P₄ and lack of a posteromedial process on the metaconid of the lower molars suggest *Gregoromys* rather than *Enoptychus* (Rensberger, 1971). The proportionately smaller size of P₄ as compared to M¹-M³, the small size overall, and the anteroposterior compression of M¹-² eliminates all of the species of *Gregoromys* except *G. Douglassi* (Wood, 1936). Comparison with measured specimens from Wood (1936) are as follows (Table 4):

Table 4. Measurements of the upper teeth of UM8928, *Gregoromys Douglassi*.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>UM8928</th>
<th>Type.C.M.No.1187</th>
<th>Ref.Spec.(A.M.No.21342)</th>
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</thead>
<tbody>
<tr>
<td>P₄ A-P crown</td>
<td>1.93</td>
<td>1.82</td>
<td>2.05</td>
</tr>
<tr>
<td>P₄ wid. protlph.</td>
<td>1.75</td>
<td>1.92</td>
<td>1.92</td>
</tr>
<tr>
<td>P₄ wid. metlph.</td>
<td>1.96</td>
<td>1.95</td>
<td>2.31</td>
</tr>
<tr>
<td>M¹ A-P</td>
<td>1.75</td>
<td>1.53</td>
<td>1.80</td>
</tr>
<tr>
<td>M¹ wid. protlph.</td>
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</tr>
<tr>
<td>M¹ wid. metlph.</td>
<td>1.86</td>
<td>1.94</td>
<td>2.21</td>
</tr>
<tr>
<td>M² A-P</td>
<td>1.72</td>
<td>1.46</td>
<td>1.45</td>
</tr>
<tr>
<td>M² wid. protlph.</td>
<td>2.03</td>
<td>1.96</td>
<td>2.36</td>
</tr>
<tr>
<td>M² wid. metlph.</td>
<td>1.72</td>
<td>1.78</td>
<td>1.90</td>
</tr>
<tr>
<td>M³ A-P</td>
<td>1.54</td>
<td>1.30</td>
<td>----</td>
</tr>
<tr>
<td>M³ wid. protlph.</td>
<td>1.72</td>
<td>1.67</td>
<td>----</td>
</tr>
<tr>
<td>M³ wid. metlph.</td>
<td>1.51</td>
<td>1.27</td>
<td>----</td>
</tr>
</tbody>
</table>

68
Family Castoridae Gray, 1821
Genus Paleocastor Leidy, 1869

LOCALITIES AND REFERRED SPECIMENS: MV7367-UM8912, maxilla frag. with left P4-M3; MV8434-UM8911, M1 or M2; MV8442-UM8934, right P4.


DESCRIPTION: As described by Stirton (1935) with the following variations: P4 of UM8912 with complete development of mesofossette; UM8934 with undeveloped mesofossette; UM8912 with parafossette positioned posterior to hypofossette; UM8934 with parafossette anterior to hypofossette.

DISCUSSION: The lack of P3 on UM8912, the relatively low crowned teeth as compared to later genera of castorids, and the small overall size of teeth indicate that these specimens are referable to Paleocastor (Stirton, 1935).

Family Eutypomyidae Miller and Gidley, 1918
Genus Eutypomys Mathew, 1905

Eutypomys cf. E. montanensis Wood and Konizeski, 1965

LOCALITY AND REFERRED SPECIMEN: MV8434-UM8905, partial right maxilla with P4-M2.


DESCRIPTION: P4 not fully erupted, shows no wear. M1 and M2 with slight wear.

DISCUSSION: The complex occlusal crenulations make this specimen readily referable to Eutypomys. Wood and Konizeski (1965) reported that E. montanensis is distinguished from E. thompsoni and E. magnus by a more complex crenulation pattern, less well developed ectolophid, and narrower teeth. However, this distinction is for lower dentition only. The upper dentition of E. montanensis has not been described although MacDonald (1970) reported upper dentition from the Wounded Knee local fauna.
MacDonald hesitated to make a definite assignment to *E. montanensis* because of the lack of previous descriptions of the upper dentition. Below is a comparison of MacDonalds' specimens with UM8905 (Table 5).


<table>
<thead>
<tr>
<th>Measurement</th>
<th>UM8905</th>
<th>SDSM6227 right</th>
<th>SDSM6227 left</th>
</tr>
</thead>
<tbody>
<tr>
<td>P^4A-P</td>
<td>3.8</td>
<td>3.45</td>
<td>---</td>
</tr>
<tr>
<td>P^4Tr.</td>
<td>3.1</td>
<td>3.65</td>
<td>---</td>
</tr>
<tr>
<td>M^1A-P</td>
<td>3.8</td>
<td>3.55</td>
<td>---</td>
</tr>
<tr>
<td>M^1Tr.</td>
<td>3.5</td>
<td>3.6</td>
<td>---</td>
</tr>
<tr>
<td>M^2A-P</td>
<td>3.8</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>M^2Tr.</td>
<td>3.9</td>
<td>3.4</td>
<td>3.3</td>
</tr>
</tbody>
</table>

It is obvious from this comparison that these specimens are not similar. However, *E. montanensis* and UM8905 both have a well developed protoloph and metaloph with the separation of the two regions extending nearly into the center of the occlusal surface. This characteristic does not appear in any of the previously reported species. Although UM8905 appears to be unique, this is most likely a reflection of the paucity of specimens of *E. montanensis* described, and the dominance of those specimens being lower dentition. Therefore, I do not feel that this specimen represents a new species and tentatively assign it to cf. *E. montanensis*.

Family Cricetidae Rochebrune, 1883

Genus cf. *Leidymys* Wood, 1936

LOCALITY AND REFERRED SPECIMENS: MV8431-UM8903, maxilla frag. with M^1
attached.


DISCUSSION: UM8903 compares closely to *Eumys (Leidymys) blacki* (MacDonald, 1963). However, M₁ and M² of *Leidymys* are difficult to distinguish from *Eumys* (Wood, 1936). Therefore, this specimen is tentatively referred to *Leidymys*.

Order Perissodactyla Owen, 1848
Family Equidae Gray, 1821
Genus *Merychippus* Leidy, 1857
*Merychippus* cf. *M. seversus*

LOCALITIES AND REFERRED SPECIMENS: MV7367-UM8942, left P²-P⁴; UM8934, upper cheek teeth frags.; MV8436-UM8922, left M¹ or M² and associated bone frags.; MV7366-UM8945, maxilla frag. with left dP⁴-M², UM8947, left dP₃-M₂, right dP₃-M₂.

LOCAL FAUNA AND SUGGESTED AGE: Spring Creek east local fauna. Late Barstovian.

DESCRIPTION:
Upper Molariform: UM8942 teeth well worn; hypocone joined with metaconule; protocone nearly joined with protoconule; pli-caballin bifurcate; protocone and hypocone subequal in size, elongate, oval; protocone slightly rounder and larger than hypocone; protocone with slight spur extending towards protoconule. Metaloph complex with 5 or 6 pli-prefossettes and 4 or 5 pli-postfossettes. UM8922 poorly preserved but compares favorably with the above description.

Lower Molariform: M₁-₂ of UM8947 well worn with simple enamal pattern. Paralophid slightly curved with no spur-like projections; hypoconulid
connected to metalophid; entoconid irregular in shape with slight anterior spur; protoconid-hypoconid inflection deep, extends about 3/4 of transverse diameter. External and internal walls of protoconid and hypoconid curved and smooth; metastylid-metaconid columns of equal size and shape and barely connected.

DISCUSSION: A description of *M. isonesus* is given by Osborne (1918). Equid material from the Smith River basin compares favorably with this description, and with specimens of *M. isonesus* in the UM collection. However, Downs (1956) synonymy of *M. isonesus* with *M. seversus* is followed here.

**Family Rhinocerotidae Owen, 1845**

**Genus Diceratherium Marsh, 1875**

*Diceratherium* cf. *D. armatum* Marsh, 1875

LOCALITIES AND REFERRED SPECIMENS: MV8434-UM8881, left P4.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.

DESCRIPTION: Tooth moderately worn with crosslophs complete and parallel; protocone and hypocone connected by well developed mure. The internal cingulum uninterrupted, extends labially past protoloph anteriorly and nearly as far as metaloph posteriorly; accessory folds with no crista other than mure.

DISCUSSION: The P4 transverse width measurements of this specimen do not compare favorably with those reported by H.E. Wood (1933). However, the A-P length, the complete internal cingulum, the presence of a mure, and the absence of crochets or cistars are indicative of *D. armatum*.

*cf. Rhinocerotid gen. indet*

LOCALITY AND REFERRED SPECIMEN: MV8439-UM8927, distal end of right tibia, right calcaneum, right astragulus, navicular, cuboid, ectocuneiform,
metatarsals I, II, and III, associated frags.


DISCUSSION: The large size, shape, and stoutness of the tarsals are indicative of the Rhinocerotid family.

Order Artiodactyla Owen, 1848
Family Entelodontidae Lydekker, 1883
Genus Archeotherium Peterson, 1909

Archeotherium cf. A. crassum

LOCALITY AND REFERRED SPECIMEN: MV8444-UM8939, right M2-M3, left lower C, left P2-P4, right P3, fragment of left squamosal, associated bone fragments.

LOCAL FAUNA AND SUGGESTED AGE: Beaver Creek local fauna. Late Chadronian.

DESCRIPTION: Right M3 of UM8939 heavily worn; (A-P 27.3 mm. Tr. 32.9 mm.); occlusal outline triangular with lingual moiety having greater A-P diameter than buccal moiety; anterior cingulum wide (A-P 5.8 mm.) due to advanced stages of wear; no buccal, lingual, or posterior cingulum; protocone and paracone subequal in size, worn, exist as connected, shallow, concave, elongate oval fossette; metacone, metaconule, and hypocone show little wear; hypocone and metaconule subequal in size, metacone much smaller.

Right M2 of UM8939 extremely worn; (A-P 32.8 mm. Tr. 37.4 mm.). Nearly square in outline but with slightly wider transverse diameter in anterior moiety; anterior cingulum well developed; small median buccal cingulum present, extends 7.2 mm. along the tooth; Nearly all cones are worn flat making morphologic descriptions obscure; protocone largest of cones; paracone smaller; protoconule subequal to paracone; the posterior lingual portion of tooth broken off.
Left P₂ of UM8939 exhibits little wear. (A-P 26.9 mm. Tr. 15.6 mm.).
Simple cone; no cingulum or heels; double rooted; anterior face of tooth is steeper than posterior face.

Right and left P₃ of UM8939; left A-P 30.5 mm.; right A-P 29.9 mm.; left Tr. 20.0 mm.; right Tr. 19.7 mm.; morphology exactly as that of P₂ but with less wear and greater size.

Left P₄ of UM8939 greatly worn; (A-P 29.3 mm. Tr. 19.6 mm.); morphology as P₂ and P₃ but with a well developed heel on posterior moiety; heel extends 11.5 mm. posteriorly past primary cusp and nearly as wide transversely; occlusal surface of heel lunate.

Left lower C of UM8939 well worn; (A-P 25.1 mm. Tr. 25.0 mm.); stout, simple cone.

DISCUSSION: Based upon size alone, all of the Whitneyan, and most of the Orellan species of *Archeotherium* can by eliminated. Tentative assignment of the specimen to *A. crassum* is based upon a favorable comparison of the tooth measurements of UM8939 with those reported by Peterson (1909), Troxell (1920), and Marsh (1893) for *A. crassum*. In addition, the external smoothness of the upper molars, the reduction of P₁ and P₂ Peterson (1909), the large flat heel not as wide as the base of the cone anterior to it, and the thick bony or dentine sheath around the lower premolars (Troxell, 1920) are together indicative of *A. crassum*.

Family CAMELIDAE Gray, 1821
Gen. and sp. indet.

LOCALITY AND REFERRED SPECIMEN: MV8432-UM8918, right jaw fragment with badly fractured M₃.
LOCAL FAUNA AND SUGGESTED AGE: East Spring Creek local fauna. Late Barstovian.

Family MERYCOIDODONTIDAE Thorpe, 1923
Genus Cyclopidius Cope, 1878
Cyclopidius simus Cope, 1878

LOCALITY AND REFERRED SPECIMENS: MV8434-UM8899, skull; UM8894, left maxilla with P1-M2; UM8895, right maxilla frag. with P4-M3, right mandible frag. with M1-M3; UM8898, right mandible frag. with M3; UM8896, right mandible frag. with M2-M3; UM8897, left mandible frag. with P3-M1.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.
DESCRIPTION: UM8899 juvenile, right M3 barely erupted. Morphology of all specimens as described by Schultz and Falkenbach (1940) and Koerner (1940).
DISCUSSION: The small size (basal length 115 mm.) of UM889, prominent nasal-facial vacuity, shortened facial region and low braincase are indicative of the subfamily Leptaucheniinae (Schultz and Falkenbach, 1940). The brachyodont teeth and skull size distinguish it from the Sespiini tribe of Leptaucheniinae. The light mandible and dentition, crowded premolars, wide facial vacuity, and prominent sagital crest suggest UM8899 is referable to Cyclopidius rather than any other genera of the tribe Leptaucheniine. C. simus is similar to C. emydinus but the narrow space between M3 and the anterior portion of the auditory bulla on UM8899 and a favorable comparison with measurements of C. simus reported by Koerner (1940) suggest that UM8899 is referable to C. simus.

UM8894, UM8895, UM8896, UM8897, and UM8898 are identified as C. simus based upon a close comparison with the dentition of UM8899.

Lander (1977) believes C. simus is synonymous with Leptauchenia major.
Genus *Megoreodon*

*Megoreodon grandis* Douglass, 1907

LOCALITY AND REFERRED SPECIMENS: MV8441-UM8930, skull with complete dentition, articulated mandible, innominate bone with articulated sacral vertebrae, articulated lumbar vertebrae, 1 thoracic vertebrae, left humerus, left radius and ulna, right calcaneum and astragulus, right femur, left scapula, right tibia and fibula, right patella.


DESCRIPTION: Morphology exactly as described by Schultz and Falkenbach (1954).

DISCUSSION: An oreodont with a skull of this large size (see Table 6) is indicative of either *Megoreodon* or *Promerychochoerus*. UM8930 is distinguished from *Promerychochoerus* by its relatively long and narrow skull, elongated facial region, strong facial ridge, and more robust dentition (Schultz and Falkenbach, 1954). The assignment to *M. grandis* rather than *M. fricki* is based upon the comparisons in Table 6.

Lander (1977) believes that *M. grandis* is synonosous with *Promerychochoerus superbus*.

Genus *Megoreodon*

*Megoreodon cf. M. grandis*

LOCALITIES AND REFERRED SPECIMENS: MV8433-UM8878, mandible with right and left I₁-M₂; MV8445-UM8940, palate with right P²-M² and left C-M², mandible frag with left M₁ and M₂; MV8443-UM8937, partial right mandible with P₂-P₃; MV8443-UM8939, left M₂-M₃, left M²-M³.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.

DISCUSSION: All of these specimens compare closely in dental, cranial, or

<table>
<thead>
<tr>
<th>Skull meas.</th>
<th>UM8930</th>
<th>M. fricki F.A.M.33308</th>
<th>M. grandis C.M.990</th>
<th>M. grandis C.M.1194</th>
</tr>
</thead>
<tbody>
<tr>
<td>total length</td>
<td>394.1</td>
<td>285</td>
<td>391</td>
<td>---</td>
</tr>
<tr>
<td>basal length</td>
<td>343</td>
<td>246</td>
<td>327</td>
<td>327</td>
</tr>
<tr>
<td>max. width</td>
<td>227.4</td>
<td>212.5</td>
<td>189</td>
<td>243</td>
</tr>
<tr>
<td>width brain case</td>
<td>80.5</td>
<td>85</td>
<td>73</td>
<td>92</td>
</tr>
<tr>
<td>width interorbital</td>
<td>96.8</td>
<td>89.5</td>
<td>83</td>
<td>99</td>
</tr>
<tr>
<td>length, orbit to canine</td>
<td>160.0</td>
<td>130</td>
<td>171</td>
<td>157</td>
</tr>
<tr>
<td>length, orbit to supraocc. crest</td>
<td>214.9</td>
<td>155</td>
<td>207</td>
<td>---</td>
</tr>
<tr>
<td>length, nasals</td>
<td>150.0</td>
<td>126.5</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>muzzle width at infraorbital foramen</td>
<td>90.2</td>
<td>84</td>
<td>89</td>
<td>96</td>
</tr>
<tr>
<td>width canines</td>
<td>93.6</td>
<td>79.5</td>
<td>71</td>
<td>97</td>
</tr>
<tr>
<td>length C–M3</td>
<td>190.4</td>
<td>168</td>
<td>199</td>
<td>191.5</td>
</tr>
<tr>
<td>length P1–M3</td>
<td>160.5</td>
<td>151</td>
<td>176</td>
<td>162.5</td>
</tr>
<tr>
<td>length P1–P4</td>
<td>80.42</td>
<td>68.5</td>
<td>83</td>
<td>78</td>
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<tr>
<td>length M1–M3</td>
<td>87.2</td>
<td>88</td>
<td>96</td>
<td>88.5</td>
</tr>
<tr>
<td>width M3</td>
<td>31.2</td>
<td>33.5</td>
<td>34</td>
<td>31</td>
</tr>
</tbody>
</table>
mandibular morphology and size with UM8930.

Family Merycoidodontidae

Genus cf. Megoreodon sp. indet.

LOCALITIES AND REFERRED SPECIMENS: MV8434-UM8890, partial M2.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local Fauna. Late Arikareean.

DISCUSSION: This badly fragmented tooth is definitely of the family Merycoidodontidae and is tenuously assigned to *Megoreodon* because of its large size.

Genus cf. *Merychys* Leidy, 1858

sp. indet.

LOCALITY AND REFERRED SPECIMEN: MV8432-UM8917, partial left ramus with P3-M3.

LOCAL FAUNA AND SUGGESTED AGE: Spring Creek east local fauna. Late Barstovian.

DISCUSSION: This specimen compares closely with UM4546, *Merychys arenarum idahoensis*. However, the A-P length of M1-M3 and the depth of the ramus below M3 of UM4546 are the same as several species of *Merychys* described by Schultz and Falkenbach (1947). Lander believes that *Merychys* is synonymous with *Ticholeptus zygomaticus*.

Family Merycoidodontidae Thorpe, 1923

Sub-Family, Genus, and Species indet.

LOCALITY AND REFERRED SPECIMENS: MV8434-UM8880, left astragulus; MV8437-UM8923, fractured P1; MV8431-UM8910, partial left ramus with P3.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.

DISCUSSION: The slightly offset condyles of UM8880 are indicative of the Merycoidodontids.
Family Cervidae Gray, 1821
Genus *Dromomeryx* Douglass, 1909
sp. indet.

LOCALITY AND REFERRED SPECIMEN: MV7366-UM8949, right ramus with $P_3$-$M_3$, proximal end of scapula, right calcaneum, left calcaneum, left cannon bone, left ectocuneiform, left navicular cuboid, left proximal phalanges, left middle phalange; right proximal phalange, right ectocuneiform, right navicular cuboid, distal end of right cannon bone.

LOCAL FAUNA AND SUGGESTED AGE: Spring Creek east local fauna. Late Barstovian.

DISCUSSION: The only cervid genera of comparable size to UM8949 and with unreduced premolars, are *Rakomeryx* and *Dromomeryx* (Frick, 1937). UM8949 has a large $P_3$ that is subequal in size to $P_4$ which suggests it is referable to *Dromomeryx*. Based upon the large size of the mandible, UM8949 could only be assigned to *D. whittfordi* or *D. borealis*. These two species are distinguished from one another on the basis of horn morphologies (Downs, 1956) and this specimen lacks fossil horn.

**CLASS REPTILIA** Linnaeus, 1758
Order Chelonia Brongniart, 1800
Family Testudinidae Gray, 1825
Genus *Testudo*

*Testudo* cf. *T. osbornia*

LOCALITY AND REFERRED SPECIMEN: MV8434-UM8879, entire carapace and plastron, left coracoid, ulna frags.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.

DESCRIPTION: (Table 7); Morphology is exactly as described by Hay (1908).

<table>
<thead>
<tr>
<th>UM8879</th>
<th>Plastron</th>
<th>Carapace</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-P</td>
<td>395</td>
<td>450</td>
</tr>
<tr>
<td>Tr.</td>
<td>275</td>
<td>340</td>
</tr>
<tr>
<td>height</td>
<td>230</td>
<td>---</td>
</tr>
</tbody>
</table>

DISCUSSION: The extensively joined carapace and plastron, abruptly projecting epiplastral lip, and the plastron notch behind this lip are indicative of *Testudo* (Hay, 1908). The high vaulted carapace and its acute free borders suggest that UM 8879 is probably assignable to *T. osbornia*.

*cf. Testudo*

LOCALITY AND REFERRED SPECIMENS: MV8440-UM8929, right femur and tibia, associated carapace fragments.

LOCAL FAUNA AND SUGGESTED AGE: Rabbit Creek local fauna. Late Arikareean.

DISCUSSION: UM8929 compares favorably to *Testudo* femurs described by Hay (1908).