Final Report on the geologic and paleontologic investigation of the Cimarron National Grassland

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Contents

View of area south of the Cimarron River in the Cimarron National Grassland. View shows the typical landscape of the area.

Introduction

Fort Hays State University (FHSU) and the United States Department of Agriculture's Forest Service entered into a mutually beneficial agreement (#CC2-2-12-94-07-028) in 1994 to explore the paleontologic resources on parts of the Cimarron National Grassland in Morton County, Kansas. This agreement called for the inventory of paleontologic resources by:

- producing a map of the surface geology
- producing hard-copy maps on mylar
- producing digital maps of the paleontology and geology
- and curating and cataloging the fossils recovered.

The Sternberg Museum of Natural History (a department of FHSU) supervised all aspects of this project. In addition, the museum is developing educational material, including a portable exhibit, for the Forest Service.

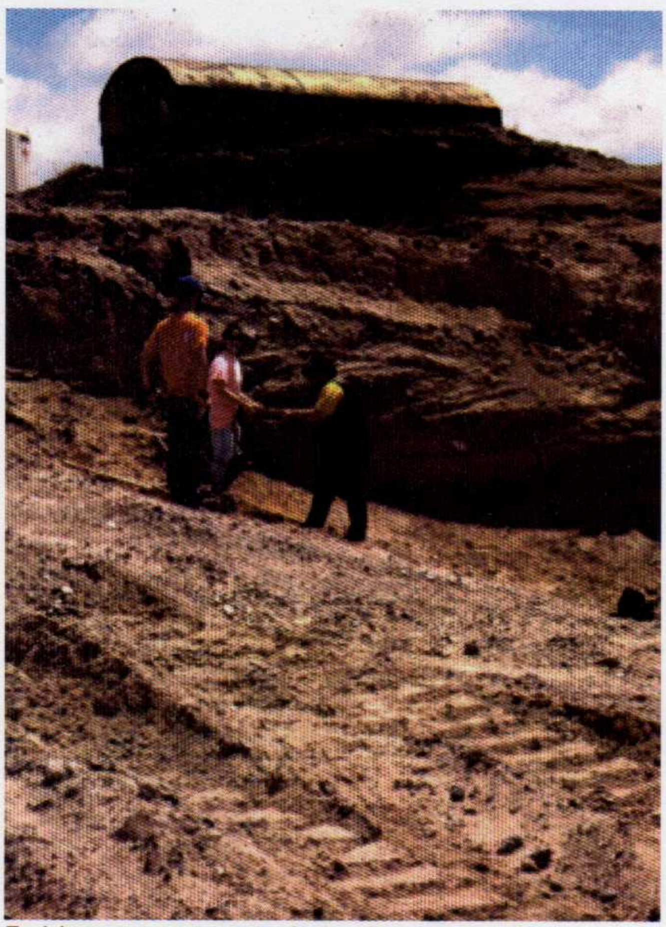
Such agreements are beneficial for all parties involved. Through this project, the museum trained three graduate and two undergraduate students in paleontologic field and lab work. One student used part of this study for his masters thesis. Additional students gained experience in the techniques of museum curation, exhibition, and education.

The Forest Service benefits by having quantified information on which to base management decisions. Presentations, exhibitions, and activities that grow out of this project will provide positive public relations for the agency.

The mylar maps and digital data produced for this project have been forwarded to the Forest Service under separate cover. This final report presents the results of field and laboratory analysis as required by the agreement.

Herein, the type and extent of fossil resources within the study area of the Cimarron National Grassland are documented, and recommendations on how to manage those resources, and descriptions of the rock units are included. Technical jargon within this report has been limited wherever possible. However, like any science, geology uses certain words as technical tools, and sometimes the most accurate way to describe something is with the word created for the purpose. A short glossary is included with this report. Words included in the glossary are boldfaced within the text.

Another user-friendly feature within the report is that important information is often reproduced in condensed form. For example, the Paleontologic Classification and Management Recommendations sections for each geologic unit are condensed in a table (Table 1) for easy reference. This condensing is intended to make the final report more useful to the land managers and decision makers.



Field crew screening the sediments at the Fullerton Gravel Pit for microfossils. From the left, Kevin McNinch, Susan Fishman-Armstrong, and H. Robins Richards.

Acknowledgments

Many people contributed to the success of this project. Mr. Joseph Hartman, Elkhart Office of the Cimarron National Grassland, was instrumental in getting this project started, and he provided us creature comforts during the field work. Al Kane, "Rusty" Dersch, Cathleen May, and Deb Dandridge, as well as others at the USDA Forest Service have all played a role in the project, and all their encouragement and support is much appreciated. Several departments at Fort Hays State University provided support, including the Department of Geosciences, Computing Center, Center for Teaching Excellence and Learning Technology (CTELT), and Business Office. University students hired for various phases of this project were Susan E. Fishman-Armstrong, Kevin McNinch, H. Robins Richards III, Steven C. Wallace, and Patricia Duffey; all of their work is greatly valued. Dale and Norma Lee Smith helped with fieldwork preparation. We thank the Morton County Data Processing Department for the loan of a GPS unit. No research gets done without access to library materials, and the staff at the Forsyth Library, especially those with inter-library loan, deserve a special thanks.

Steven C. Wallace painted an original work to illustrate the Cimarron National Grassland area during the late Miocene, and his painting is used through out this report.

Cameron Liggett deserves a special thanks. Without her unflagging support this work would not have been completed.

Almost none of the fossils would have been available for this study without the observant eyes, motivated collecting, and careful storage of them by the Morton County Road Department. These individuals deserve a special thanks. Hopefully, they will continue to be alert for fossils, and continue to forward them to the museum. In this way, the fossil resources of Morton County can be used to educate everyone about the past life of the area. In a small way, this will add to the general quality of life for the people of Morton County.

Methods

The study area consists of all lands of the Cimarron National Grassland within the Midway Southeast and Elkhart North 7.5 minute quadrangles. We began the study by investigating what was known about the **geology** and **paleontology** of the area. A general bibliography of works relating to the geology of southwestern Kansas, northwestern Oklahoma, and southeastern Colorado was compiled for the project (Liggett & Zakrzewski, 1995).

The fieldwork phase involved the principle investigator and a field crew of two graduate and one undergraduate students. The crew traveled extensively in and around the study area looking at outcrops, describing the geology, and recovering fossils. **Contacts** between geologic units were drawn directly onto a 7.5 minute quadrangle map in the field.

The contacts between units had to be inferred often because of the extensive soil cover over most of the study area. These inferred contacts are represented by dashed lines on the geologic map.

McLaughlin produced a geologic map of Morton County in 1942. His study concentrated on ground water resources, and did not mention any **fossils** from Morton County. We re-mapped the geology of the study area and our interpretation differs very little from that of McLaughlin's. We used his map and our field data to make the best possible inferences regarding contact placement.

Finally, we found it necessary to examine the greater geologic context by studying the geology of Texas County, Oklahoma, and Union County, New Mexico. This examination was particularly important for trying to understand the red beds at the base of Point of Rocks, which will be discussed later.

Fossils recovered during this project were collected with standard field techniques and placed in the Sternberg Museum of Natural History for cleaning, curation, and storage. All fossil localities were located using a GPS unit provided by the Morton County Data Processing Department.

After the fieldwork was completed, the field maps were transferred to a digital format. This phase of the project was completed as part of a M.S. Thesis by Kevin McNinch. Details on the Geographic Information Systems aspect of the project can be found in McNinch's thesis (1996).

What Time is it?: Geologic Time

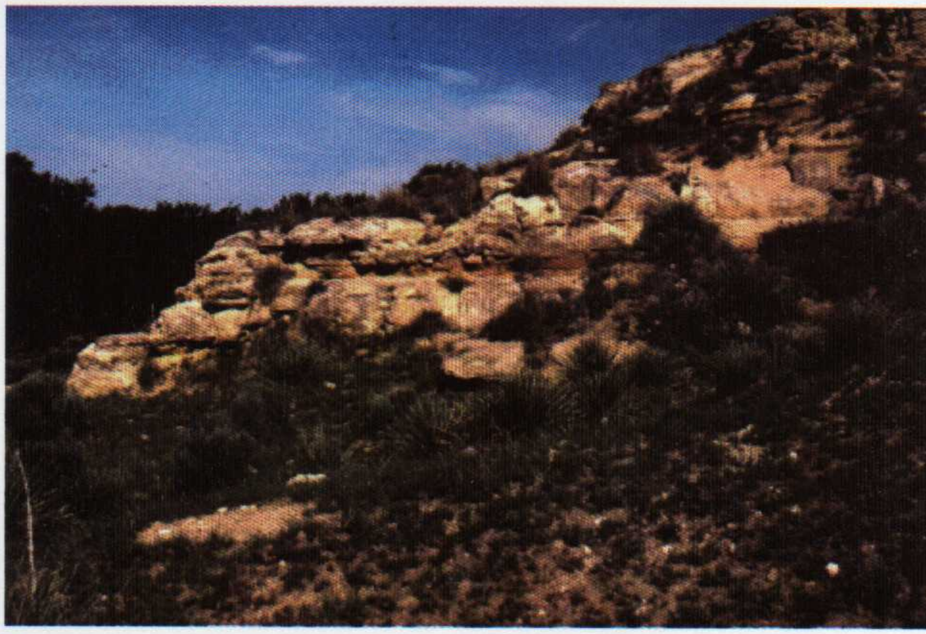
No one can fully grasp the immensity of geologic time. There is a parallel problem in sciences like astronomy that deal in immense distances. Geologists casually make statements like "The Cretaceous Period ended 60 million years ago," but these great lengths of time are not comprehended fully even by the professionals.

Several different schemes have been used to put geologic time in terms that the human mind can better comprehend. Some of these schemes include comparing geologic time to distances (every inch equals so many years on a sidewalk), or some length of time like a human life span, a day, or a year. The comparison with a calendar year works well for most people, as this time span can be understood as a discrete unit.

If the Earth's origin is equated to January 1st, the earliest known fossils (pre-Cambrian bacteria) were found on March 22nd. This means that the Earth was devoid of life for almost three months, or one quarter of its existence. Through most of the year, the only life were bacteria and algae. In fact, there is not much else until mid-November when many animals evolved hard shells. Fish, the first vertebrate animals, emerged several days later in November. Amphibians and reptiles likewise followed in short order, and mammals first show up on December 10th.

Dinosaurs were the dominent land dwellers from December 10th until their extinction on Christmas. Mammals have dominated for the rest of the year. The earliest hominids, or human ancestor, appeared on the scene about 2 p.m. on December 31st, and modern humans showed up around 10:30 p.m., barely in time to celebrate the new year.

Throughout this report, the geologic periods mentioned here are also put into this "geologic year." This should give the reader a sense of perspective for the age of the rocks in the Cimarron National Grassland.



Sandstone outcrop at the foot of Point-of-Rocks. The sandstone here is of uncertain age, and has been questionably mapped as Triassic Dockum Group.

Geologic Overview

Six geologic units were mapped within the study area (see Appendix 1). They represent three geologic time periods (Triassic?, Tertiary, and Quaternary). Each geologic unit is reviewed in the following sections. First, we outline the geologic specifics for each unit. This section is follwed by one entitled Paleontologic Classification and Management Recommendations where each unit is rated using the Fossil Yield Potential Classification (FYPC) developed by the Paleontology Center of Excellence and the Forest Service Rocky Mountain Region Paleontological Resources Initiative. The FYPC can be found in Appendix 2. We conclude the discussion of each geologic unit by describing its context in a continental or global view. This last section should give the reader a basic understanding of the geologic and biologic events that shaped each period of time recorded in the rocks of the Cimarron National Grassland.

Triassic? Dockum Group?

The oldest rock unit also presents the greatest enigma. This unit consists of approximately 12 m of **unfossiliferous** buff, yellow, brown, and white sandstone; red to maroon siltstone; and red shale. This section has been described by McLaughlin (1942), Merriam (1963), and McNinch (1996). These rocks are described as "red beds." The informal term "red bed" is often applied to sandstones and shales with a red or maroon color. On a regional scale, such rocks are generally thought to have been deposited in extensive, shallow basins that functioned as evaporation pools for mineral-rich waters. The water was periodically replenished during brief rises in sea level. These sea level changes caused the development of swampy estuaries and the deposition of sands and muds in the basins. The red color is due to oxidation of iron-rich minerals.

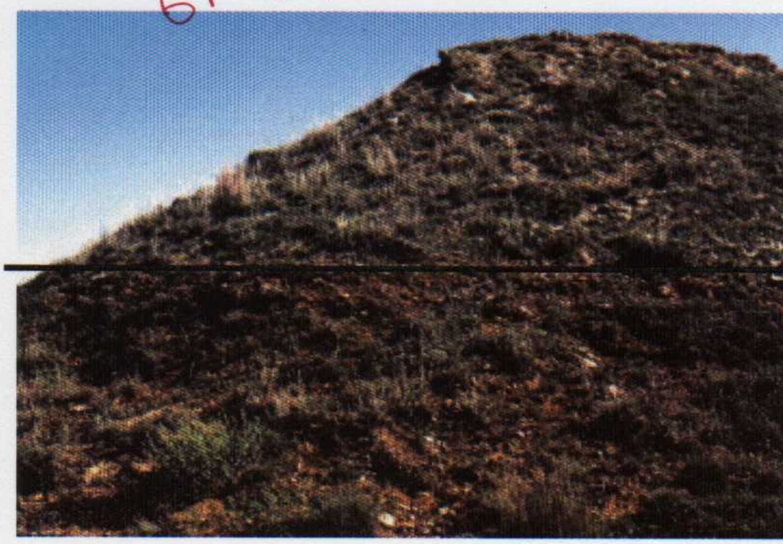
A review of the age determination and correlation of this unit is in order. According to Merriam (1963) the first time the Kansas Geological Survey stated that Triassic rocks crop out in Morton County was in 1937 when they were mapped on the geologic map of the state. McLaughlin (1942, p. 71) noted that "The red beds at Point Rock are lithologically very similar to those in the Red Point district in Texas county (sic), Oklahoma, which Schoff (1939, pp. 49-51) and others have called Triassic(?)." As further proof of the age of the Oklahoma red beds, McLaughlin stated (p. 71):

> "In 1900 Gould (1900, p. 139) wrote: 'it has been demonstrated that the upper part of the problematic Kansas Oklahoma redbeds is Triassic. Vertebrates taken from the lower part of these

beds, in eastern Oklahoma, have been identified by Dr. S. W. Williston as Permian forms similar to those from the Texas Permian. On the other hand, invertebrates obtained from near the top of the redbeds in western Oklahoma are classed as Triassic forms, on the authority of Dr. J. W. Beede and Mr. Charles Schuchert.'

The beds at Point Rock and Red Point generally are correlated with the Dockum group of Texas, New Mexico, and Colorado, rocks which are Triassic and probably Upper Triassic."

However, the above quote attributed to Gould by McLaughlin cannot be found. In fact, what Gould suggested (1900, p. 135) was that "Point of Rocks, in Morton county (sic), a line of bluffs on Bear creek (sic), in Stanton county (sic), and several exposures between these, on the North Fork of the Cimarron, are referred to [the Dakota]." The Dakota Group is Cretaceous in age, and therefore, what Gould actually wrote is far different than what McLaughlin quoted.



Outcrop near the foot of Point-of-Rocks showing the redbed shale below the line and the sandstone above.

Whether or not the quote attributed to Gould by McLaughlin is correct, there is generally assumed to be evidence for Triassic rocks in eastern Oklahoma. Assuming that such evidence is valid, it becomes necessary to see if the rocks of eastern Oklahoma can be traced to the western panhandle and the Red Point area, and if these rocks are indeed the same as those at Point of Rocks, Kansas.

In 1926, Gould and Lonsdale examined the rocks of Texas County, Oklahoma. According to them, the red beds along Beaver Creek, in the southeastern part of the county are the Permian Cloud Chief Formation, while they mapped red rocks in the Red Point area and along Tepee Creek as "questionable Triassic." However, they stressed that a Triassic assignment is tentative, and quoted from other papers:

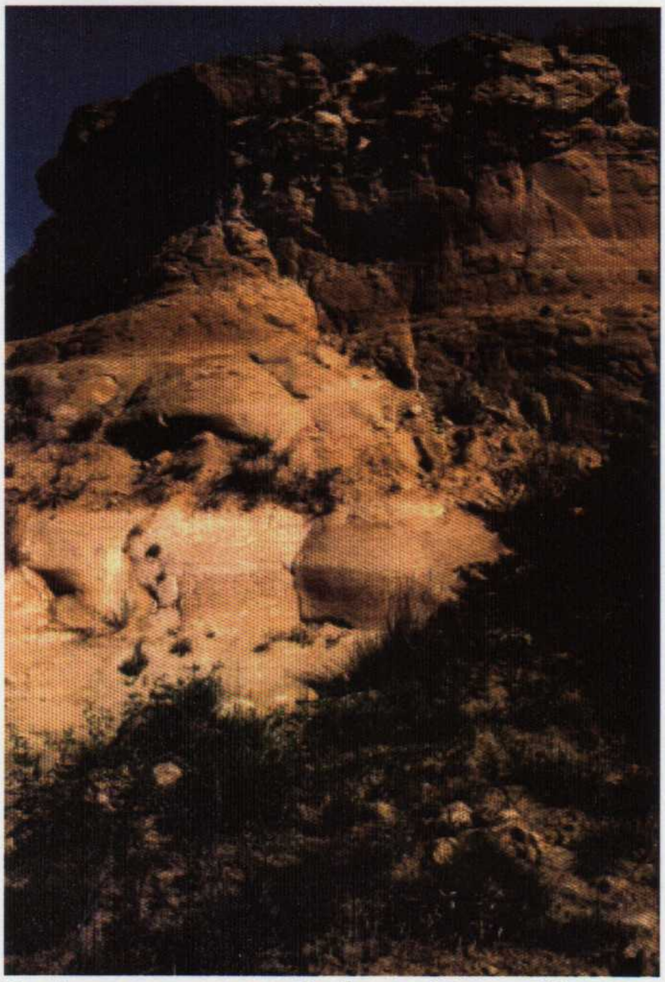
"It is the present opinion of the writer [Gould] that the rocks in question [rocks in the Red Point, Oklahoma area] are upper Permian (probably Cloud Chief formation), rather than Triassic. However, in deference to the opinions of other geologists, perhaps better qualified to judge, the beds are here tentatively referred to as Triassic." (Cited from Gould & Lonsdale, 1926, p. 26, citing a paper by Gould, 1925, Oklahoma Geological Survey Bulletin, volume 35).

Gould and Lonsdale (1926 p. 26) also cited a letter from Dr. T. W. Stanton, of the United States Geological Survey:

"I have not a particle of direct evidence concerning the age of the red beds in Texas and Cimarron counties, Oklahoma...The only reason for suspecting that the upper part of the underlying red beds may be of Triassic age is that the Triassic (Dockum formation) is known to be present in the Staked Plains region of Texas, and also in New Mexico on the Conchas River, southeast of Las Vegas." Gould and Lonsdale (p. 26) conclude the issue by saying that "the Texas and Cimarron County red beds do not resemble the Texas Triassic rocks and do have the **facies** of the Oklahoma and Kansas Permian red beds."

So it seems that the evidence, as interpreted by these earlier geologists, for the age of the Red Point area rocks does not conclusively demonstrate a Triassic age. The rocks could also be Permian or Cretaceous, but in "deference" the rocks got mapped as Triassic.

In 1939, Schoff studied the geology of Texas County, Oklahoma. He agreed with Gould and Lonsdale that the rocks in the southeastern part of the county are Permian Cloud Chief. In addition,



Sandstone outcrop at the base of Point-of-Rocks.

Paleontologic Classification and Management Recommendations

The Triassic? units within the study area are rated as Class 2. The basis for this classification is 1) vertebrate fossils are known to occur very rarely or not at all. Management recommendations for this unit within the study area are minimal. No specific care need be taken with regard to vertebrate fossils as none are known or anticipated. However, as the only Triassic? unit exposed within the state, care should be given to the outcrop. As the main outcrop is part of an already well known landmark (Point of Rocks), this recommendation should not pose a problem to the Forest Service. It would be very significant if any fossils were ever found within this unit, as this would shed much light on the question of its age.

Schoff suggested that he "obtained evidence suggesting that Jurassic rocks may be represented in addition to Triassic and Cretaceous. (p. 49)" This evidence was the discovery of some Cretaceous **pelecypod**s found in beds higher than the red beds of uncertain age in Texas County. Having Cretaceous fossils above the red beds confines their age to being older, and this suggested to Schoff that the rocks were from the immediately preceding geologic period, the Jurassic. However, he mapped all the rocks in question as Triassic(?) "because of incomplete field data, and the tentative character of the conclusions...(p. 49)."

Basically, Schoff seemed to be concerned with the following question: if there are Permian red beds present at the bottom of the section, and Cretaceous beds present at the top, should not there also be Triassic and Jurassic beds between? Of course, there is no inherent reason that Jurassic or Triassic beds should be present as they may have been eroded away prior to the deposition of the Cretaceous strata, or were never deposited in the first place.

The rest of the history of assigning names to these rocks, and by extension the name and age of the rocks in Morton County, seems to be a parroting of these earlier authors. As we have seen, McLaughlin (1942) correlated the Morton County section to the Red Point area rocks. Both Moore et al., 1944 and Moore et al., 1951 repeated these conclusions without adding any new information.

As can be seen, the rocks in Oklahoma, and by extension the rocks in Kansas, are of an uncertain age, and have been called Triassic almost for lack of anything better to call them. Unfortunately, this present study can shed little additional light on the subject. Like previous investigators, no **vertebrate** or **invertebrate** body fossils were found in the beds of Morton County. However, it may be possible to find **microfossils** within the section. **Pollen** has been found in the Dockum sequence of Texas (Dunay & Traverse, 1971), and if found in Kansas, this would be positive evidence of the age of the **strata**. As time allows it is hoped that samples of this rock can be examined for pollen. Unfortunately, red clays and sands are not the best rock type for preserving pollen.

Historical Geologic Context

The Triassic Period lasted from 245 - 208 million years ago, or December 10th - 13th of the "geologic year." At the beginning of the Triassic, the land masses of the Earth were still one huge supercontinent called **Pangaea** ("all lands"). Surrounding this supercontinent the one large ocean was called **Panthalassa** ("all oceans"). The global climate was significantly affected by the large land mass, and generally very dry and hot conditions existed during this time. Minor sea level fluctuations formed extensive shallow embayments where salts were deposited as the water evaporated in the hot, dry air; arid areas were marked by extensive deposits of dune sands. A few areas harbored extensive forest growth. As a result of the climate, extensive red beds, **evaporites**, desert dunes, and coals characterize the Triassic Period.

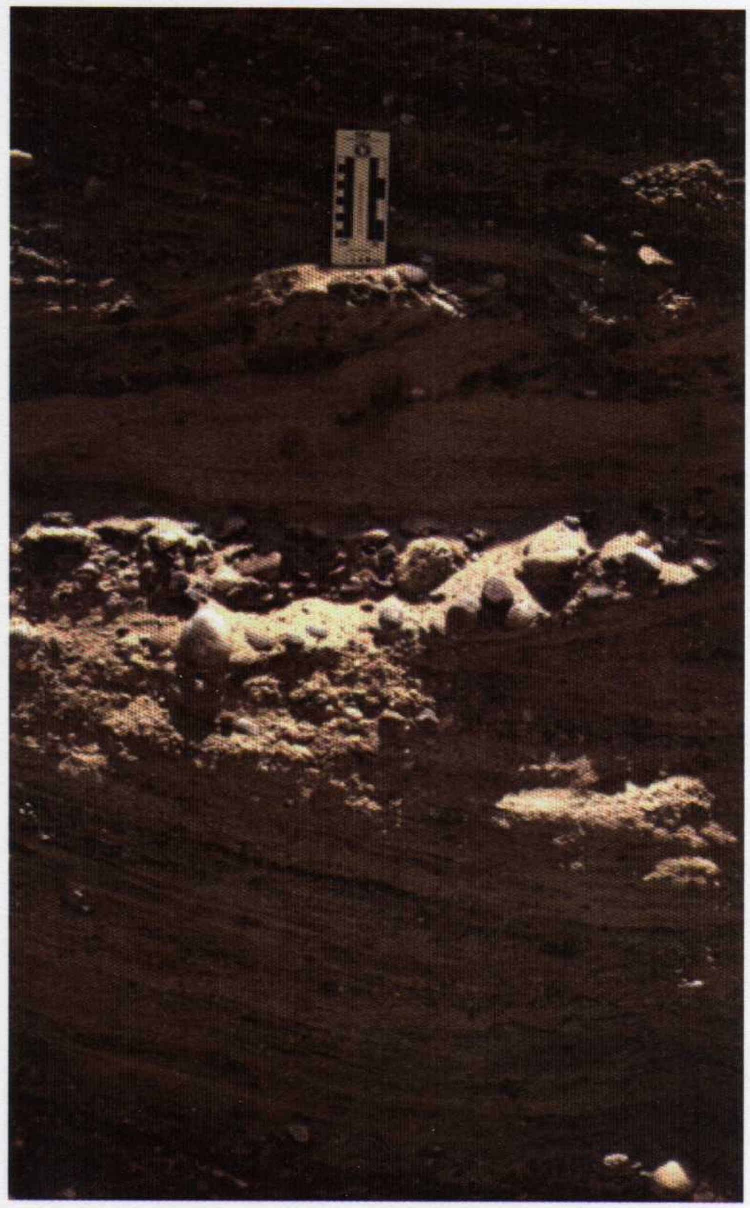
By the end of the Triassic Period, Pangaea had begun breaking up, with the continents splitting apart to eventually form the continental shapes that we are familiar with today. The Triassic is also the earliest of the three Periods in the "Age of Dinosaurs." The dinosaurs would remain the dominant land life form for the next 180 million years even though mammals also first appear in the Triassic.

Miocene Ogallala

The Ogallala crops out at several areas within the study area. These areas include the cap of Point of Rocks, the Fullerton Gravel Pit, and an area west of Point of Rocks around Section 17 in Township 34 South, Range 43 West. Most of the rest of the Ogallala is covered by a veneer of redeposited Ogallala indistinguishable from younger sediments, or younger sediments alone. Thus, on our map we have separated the Ogallala into two units: 1) Ogallala sand and gravel and 2) Undifferentiated Ogallala Group and Quaternary sediments. The separation of unconsolidated Ogallala from younger Quaternary sediments has long been a problem for **stratigraphers** (an example is the discussion in Smith, 1938). The

View to the southwest off of Point-of-Rocks. This outcrop of Miocene Ogallala is a well-known landmark along the Cimarron Trail. The cap rock is a resistant ridge of calcrete.

Above, the calcrete beds of the Ogallala form prominant ridges along the north side of the Cimarron River. Unconsolidated sand and gravel is the other characteristic lithology of the Ogallala. Below can be seen crossbedding, evidence of deposition in a swift stream.



problem is that both the Miocene Ogallala and much of the younger sediments are sands and gravels, with the younger sediment simply being reworked Ogallala laid down as new deposits. By convention rocks are mapped based on the **lithology**, so it is not always easy to separate these units. When found, fossils indicate the age of the sediment, but the units are so coarse grained that fossils are not often preserved.

The lithology of the Ogallala in this area is mixed. One characteristic form of these sediments can be seen at the Fullerton Gravel Pit. Here the **clasts** are uncemented coarse sands to cobbles and often **cross-bedded**. Some of the larger clasts are **basaltic**.

Another characteristic form of the Ogallala is represented by the resistant cap rock at Point of Rocks. These **calcrete** beds form resistant ridges on the north side of the river, and are typical of the Ogallala cap rock elsewhere in Kansas.

The cross-bedding of the sands and gravels indicate a **fluvial** origin. It is from these beds that the majority of the vertebrate fossils were recovered. The Fullerton Gravel Pit has yielded a nice veretebrate fauna from an area that was not previously known to be fossiliferous. Refer to the section entitled Annotated Systematic List of Vertebrate Fossils and Table 2 to get a complete listing of the different species identified from the grassland. In other areas, the Ogallala yields plant and small vertebrate fossils.

Paleontologic Classification and Management Recommendations

The Ogallala outcrops within the grasslands are rated as Class 5. The bases for this classification are: 1) Scientifically significant vertebrate fossils are known and occur. It is significant that such a diverse fauna of vertebrates occurs in Morton County where none was previously known. 2) These areas are in danger of human-caused adverse impacts. Specifically, the mining of gravel is uprooting and destroying fossils. Ironically, this is also the primary way that fossils have been recovered from the area. Recognizing the economic importance of the gravel resource to the county, it is not likely that mining will stop. Indeed, within this report we note another fossiliferous area that might be a good prospect for gravel mining. Therefore, the best win-win situation is for the everyone involved to be educated as to the importance of recovering fossils and getting those fossils into a scientific collection. Only in such a collection will they remain as a permanent record of past life in Morton County, and only in this way will the people of Morton County benefit from understanding the past life in their area. In addition, the recovery of fossils from the Ogallala could contribute to a display at the Morton County museum and act as an incentive for visitors to stop in Elkhart. Quality fossil displays have proven to be a great tourist attraction.

Although we did utilize screening and flotation techniques for recovering these fossils, we were unsuccessful. The lack of success is probably due to the fact that generally fine-grained sediments are required for microfossil preservation, and sediments within the Grassland are generally coarse. However, somewhere within the Grassland boundaries there could be a suitable outcrop.

The age of the Ogallala across the High Plains is late Miocene. The Miocene epoch lasted from 23-5 million years ago (December 29th - 2:30 p.m. December 31st). However, the age of the Fullerton Gravel Pit can be determined more closely by using **biostratigraphy**.

By comparing the mammals from different sites and different time periods all across North America a system of estimating the age of any site 66 million years old or younger has emerged. The basis of the system is that an animal species has a life span, and by looking at the **assemblage** as a whole you can determine the approximate age. To illustrate this technique, think of an old photograph with several generations of people. Let us say that you know that one person in the picture lived from 1870-1920, another lived from 1890-1960, and a third lived from 1900-1970. With this information, you would know that any picture with all three individuals must have been taken between 1900-1920.

The North American Land Mammal Ages work the same way. By knowing when different species of animals were **extant** you can determine the approximate age of an assemblage by seeing which species co-occur. The age of the Fullerton Gravel Pit can be determined by the presence of the horse *Protohipus*, the dog *Osteoborus*, and the camels *Megatylopus?* and *Hemiachenia*. These animals co-occur during the early Hemphillian Land Mammal Age, a time from 8.5 - 6.5 million years ago (Voorhies, 1990). This means that the Fullerton Gravel Pit is roughly contemporaneous with the Bemis local fauna in Ellis County (Tallan, 1978), the Minium Quarry in Graham County (Thomasson et al., 1990), the Long Island Quarry in Phillips County (Bennett, 1984), and the Beckerdite Biota in Clark County (Liggett, 1997).

Additional Gravel

Part of the charge given to the field crew for this project by the Grassland manager was to locate new areas for the production of sand and gravel. Gravel is a valued resource in Morton County. Presently, the county leases the Fullerton Gravel Pit for mining of this resource, but the pit will not last many more years.

During the course of our investigation we did locate an area that may be worth further exploration by an economic geologist to assess the potential for development. This area is in Section 17 of Township 34 South, Range 43 West. From a surface survey it looks to be quite an extensive deposit of the same kind of sand and gravel presently being mined at the Fullerton. This area also yielded fossils similar to the Fullerton. We wish to stress that we did not spend much time assessing the economic potential of this area for mining of gravels, but indications are favorable.

Another area of Ogallala gravel. This site will be mined after the Fullerton Pit is full excavated. An additional sourse for gravel is suggested further to the west, near Point-of-Rock.

Historical Geologic Context

A hiatus of 220 million years exists between the older Triassic? and the younger Miocene rocks. Some rocks of the intervening years are preserved elsewhere in Kansas, and from these rocks we know that during the Cretaceous Period (144-66 million years ago, or 19 December to Christmas) Kansas and the rest of central North America was covered by a seaway. The sea inundated the land and partially retreated many times during the period. Within the sediments of these seas are preserved the fossils that Kansas is so well known for; the fish, and marine and flying reptiles from the last period of the age of dinosaurs.

After the seas retreated for the last time, central North America was left as a broad plain. During the next fifty million years, a relatively treeless savanna spread across these plains. North America continued the westward movement started with the breakup of Pangaea, and which continues today (giving us earthquakes in L.A.). The westward movement of the continent caused a series of mountain chains to form along its western edge.

The last of these mountain-building events (**orogeny**) to affect what is now the central part of the continent was the Laramide Orogeny. Today we know this mountain range as the Rocky Mountains. During the Miocene, sediments from this mountain chain were carried by rivers to the east, filling in the valleys of the Great Plains. This covering of the plain led to a general increase in surface elevation, and is the cause and boundary for the High Plains **physiographic province**.

Animals on the grass-covered plains of the late Miocene might seem more at home in Africa today: rhinoceroses, camels, lion-like cats, bone-crushing dogs, horses, and elephants. Fossils of these animals have been found all across western Kansas in rocks of the Ogallala Group. These fossils suggest a grassland plain, with a hotter climate, and wetter conditions than today. It never, or very rarely, got below freezing, reminiscent of the grassland savannas of eastern Africa today.

Quaternary Deposits

Dune sands dominate the area south of the Cimarron River. This sand is wind deposited, and many of the dune forms are still evident. Today, most of the dunes are covered with vegetation, reducing erosion.

Quaternary deposits dominate within the study area (1.6 million years to the present, or 10:18 p.m. December 31st to midnight). On our map we have classified these deposits as **loess**, **dune** sand, and **alluvium**. Loess occurs in the northwestern corner of the area. Loess is a fine-grained, wind-blown deposit of dust, and is wide spread in Kansas. In the study area it is not very thick, but in some areas can reach thicknesses of tens of feet. Loess is characterized by having a high angle of repose. This is the angle or slope from the horizontal that unconsolidated sediments remain stable. In areas with thick deposits there are often sheer walls of loess many feet high, however this does not occur in the study area.

Loess is known to contain **invertebrate** fossils. During the course of this study mollusks were noted in some loess deposits in Stevens County, outside of the study area. Frye and Leonard (1951) presented a listing of many sites across the western two thirds of Kansas that contained mollusks in loess. The site closest to the study area is in southwestern Stanton County.

No vertebrate fossil sites were located in loess within the study area. However, one site was located just outside the study area (SW SW sec. 7 T33S R42W). At this locality a partial bison skeleton was excavated. Whether or not the bison should be considered a fossil is uncertain, as there are many historic bison remains known. However, the specimen has been curated into the museum and as funds allow will be radiocarbon dated.

Dune sands are extensively deposited on the south side of the Cimarron River Valley. Most of the dunes have a vegetative cover, but their characteristic dune shape is very evident. The age

Paleontologic Classification and Management Recommendations

The Quaternary system within the study area can be rated as Class 2 for the following reasons: 1) vertebrate fossils occur rarely or not at all and 2) the alluvial age is younger than 10,000 BP. There does exist the possibility of significant invertebrate fossils in the form of mollusks within the loess deposits, as they do occur elsewhere. However, given that the thickness of the loess is minimal within the study area, a rating of Class 3 for potential invertebrate fossils seems unwarranted. In addition, the possibility of localities with archeological significance within this unit should be remembered. Such sites are known within the Grassland boundaries, so archeological potential should be evaluated prior to major disturbances.

Loess deposits are typical of the Quaternary Period in Kansas. A close-up of the loess, top, in which a partial *Bison* was found. Right, loess can be seen filling in the valley while Ogallala calcrete forms resistant ridges on both left and right sides of the picture.

of the dunes is unquestionably varied throughout the southwestern quarter of the state (Smith, H. T. U., 1940). According to Smith, the dunes in the area could be contemporaneous with the loess deposits, but in at least a few cases are younger, as the sand occasionally overlies the loess. For a more extensive study of the loess and dune sands within Morton County see works by Donna Porter (Kansas State University). Her dissertation concerns the effect of climate change on the soils and dunes in the area.

The Quaternary alluvium is recent valley fill from the Cimarron River. It covers the wide valley floor of the **meandering** river. In the study area it is generally covered with vegetatation.

Historical Geologic Context

The Quaternary Period is divided into two **epochs**, the Pleistocene and the Holocene. The Holocene, also known as the Recent epoch, is the geologic period that we are in today. The Holocene started about 10,000 years ago, with the end of the Pleistocene. The Pleistocene is sometimes called the Ice Age, as this is when glaciers spread over North America.

The Pleistocene was host to a wide and exciting bestiary. These animals often fascinate us, perhaps because of their temporal proximity to our own time. The saber-toothed cats, woolly mammoths, giant ground sloths, bison, and camels are evidence of a not too distant past when the world was very different, and yet very similar. These animals are vaguely familiar in their grotesque appearance. Dress a saber-tooth up in a lion's clothes, and shave the woolly mammoth, and they would look very much at home in our zoos. Also, because of the relative closeness to our time, these animals have left many striking reminders of their passing. Rancho la Brea in California, Mammoth Hot Springs in South Dakota, and Big Bone Lick in Kentucky are just of few of the localities where you can see great numbers of these animals exquisitely preserved.

Contrary to popular ideas, there was not one "ice age." Several times in the history of the Earth ice has moved over large areas of the continents. The most recent ice age occurred within the last 2.5 million years, with ice sheets advancing and retreating several times during that period. Traditionally, four of the major advances of ice and three of the interglacial periods were named. However, the situation is now known to be more complex (Boellstorff, 1978). The evidence for glacial advance is found throughout North America, Europe, and northern Asia; clearly showing that the ice age was global in its influence. In fact, many geologists hold that the present time period is nothing more than a fourth interglacial period, and we are still in the Ice Age.

The glaciers themselves were dramatic. Moving southward from the arctic, and being several miles thick in places, they had a profound influence on the topography and fauna of the northern hemisphere. As the glaciers moved over the landscape, they scraped the surface and ground the rock into a fine dust, called glacial powder. At their farthest extent, the central U.S. slightly beyond the present course of the Missouri River and the northeastern tip of Kansas was covered by ice.

The larger sediment was carried away from the toe of the glaciers by the tremendous amout of melt water rushing off the ice. These sediments formed sand and gravel deposits in ancient river channels, occasionally preserving fossils like mammoth teeth. However, these sediments are not the best for preserving fossils, and vertebrate remains are distributed sporadically.

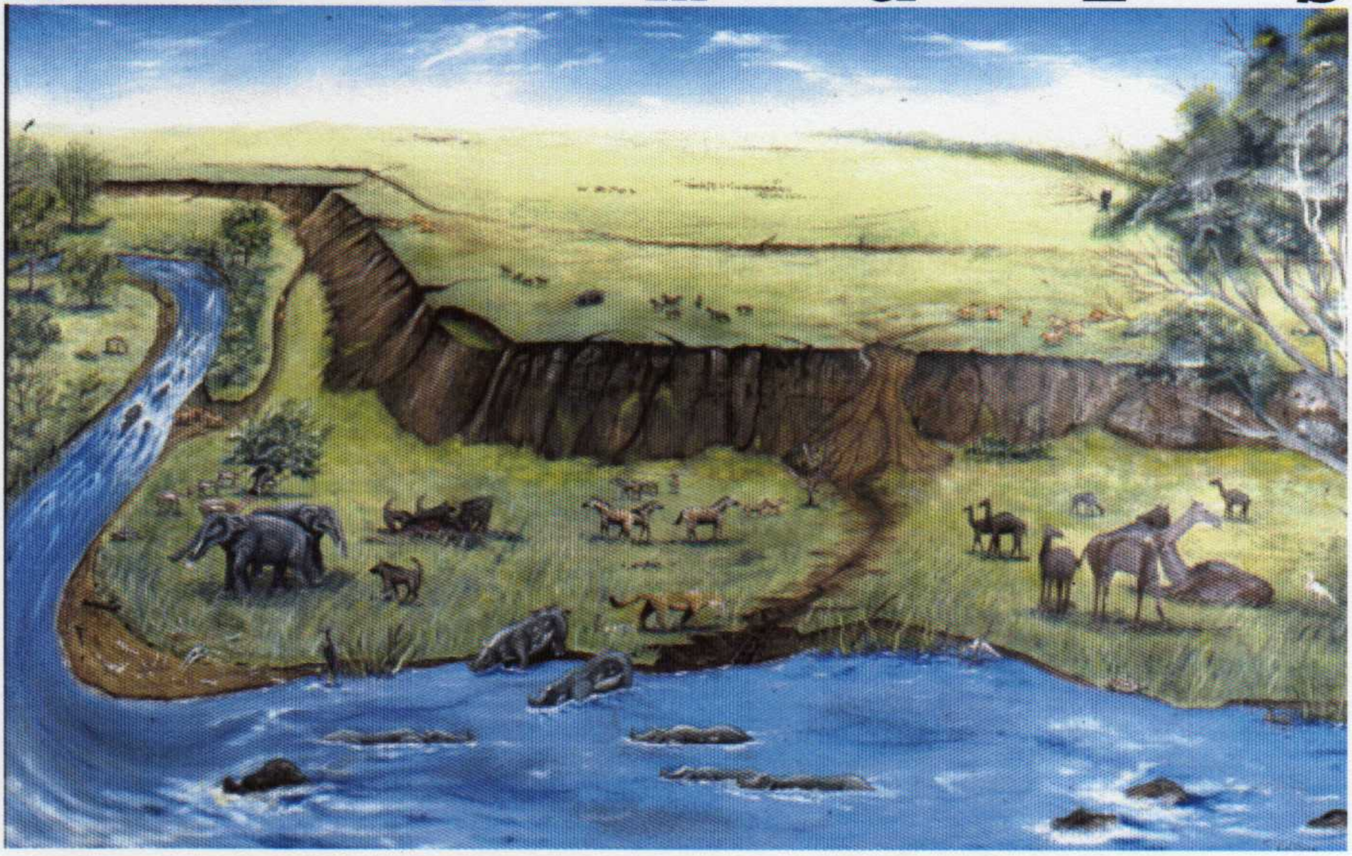
The high mountains of the west also had glaciers. The mountain ice caps expanded down the valleys, carving out a characteristic u-shape in the valley floor. Melt water from these glaciers also ran across the Great Plains, carrying sediment.

In southwest Kansas, the fine dust or glacial powder, was washed in by the flowing rivers and streams of melt water. As these waterways dried up, they left behind the fine dust to be picked up by the wind and blown across the landscape.

With the conclusion of this overview of the geology of the Cimarron National Grassland, we can let our imaginations fill in the details of these past times and places. It is while performing such exercises of the mind, recreating the animals and environments of long ago, that we are reminded that few things are as exhilarating as the study of the Earth's history.

The bones of giant beasts rest on the shore of an ancient stream, ready to be buried and fossilized. Millions of years later they are found by a curious human, and the excitement and wonder begins.

Annotated Systematic List of Vertebrate Animals



A recreation of the environment of deposition and the fauna of the Cimarron National Grassland area during the late Miocene (6-9 million years ago). Specific animals from the fauna are discussed in the text.

This list describes the animals represented as fossils from the study area, and where appropriate discusses their significance to the fauna or other interesting bits of information. All specimens were collected from the Ogallala. Each fossil was identified to the most specific **taxonomic** level possible. For example, if we could tell that the fossil was from a horse, but not what kind of horse, it is listed under the family Equidae. For a list of the fossils from each site see Table 2.

Class Reptilia
Order Chelonia (Turtles)

Referred Specimens: VP-13315, VP-13343, VP-13350, VP-13392, VP-13393, and VP-13397

Comments: Turtles are very common in the fossil record of Kansas. They mostly occur as broken shell fragments. Very little taxonomic work can be done with the material recovered.

Class Mammalia
Order, Family, Genus, and sp. indet.

Referred Specimens: VP-13307, VP-13308, VP-13309, VP-13310, VP-13311, VP-13312, VP-13314, VP-13407, VP-13408, VP-13409, VP-13410, VP-13411, VP-13412, and VP-13413

Comments: These are miscellaneous mammal bones. They are not identifiable any further.

Order Carnivora
Family Canidae (Dogs)
Genus and sp. indet.

Referred Specimen: VP-13316

Comments: This specimen is a vertebra from a small

dog.

Genus *Osteoborus*

Referred Specimen: VP-13344

Comments: *Osteoborus* is often referred to as a "bone-crushing" dog, and is compared to the modern hyenas because its life style is thought to be very similar, perhaps living in packs, hunting and scavenging, and specializing in the eating of bone marrow by crushing large bones with powerful jaws. However, unlike modern hyenas, *Osteoborus* is a true dog, being classed in the dog family. Although found in many Miocene faunas in Kansas, it like all **carnivores**, it is not common. By their nature, carnivores are going to be less common in the fossil record then herbivores for the simple fact that there are less individuals to become fossilized. In modern **ecosystems**, carnivores account for a small percentage of the **biomass**. It was the same in fossil ecosystems, so the occasion of recovering any carnivore material is cause for some excitement.

Evidence for *Osteoborus* in the Grassland is this jaw fragment (left, scale in inches).

Order Perissodactyla ("Odd-toed Ungulates")
Family Equidae (Horses)
Genus and sp. indet.

Referred Specimens: VP-13294, VP-13295, VP-13296, VP-13297, VP-13416, and VP-13417

Comments: These are miscellaneous horse specimens, not identifiable beyond family.

Genus *Protohippus* cf. *P. gidleyi*

Referred Specimens: VP-13292, VP-13293, and VP-13345

Comments: VP-13292 was the first vertebrate recovered from the Fullerton Gravel Pit that was brought to the attention of science. This horse maxillary was found by Donna Porter during a reconnaissance of the pit. It was identified by comparison with other specimens and conferring with other scientists. Horses are common in the Ogallala of Kansas. In fact, there were many different horses during the Miocene. At the end of the Pleistocene horses became extinct in North America, and were not part of the fauna until they

In the Grassland, only one identifiable horse was found, but it is not unusual to find 3-5 different types of horses at one locality of this age. Inset shows the first fossil recovered at the site, a *Protohippus* maxillary.

were reintroduced to North America by early Spanish explorers in the 16th century.

Order Artiodactyla ("Even-toed Ungulates") Family, Genus, and sp. indet.

Referred Specimen: VP-13304 and VP-13321

Comments: Specimen VP-13304 is a small right **calcaneus** from an artiodactyl. Similar specimens are found at other sites around the state, like the Beckerdite site (Liggett, 1997).

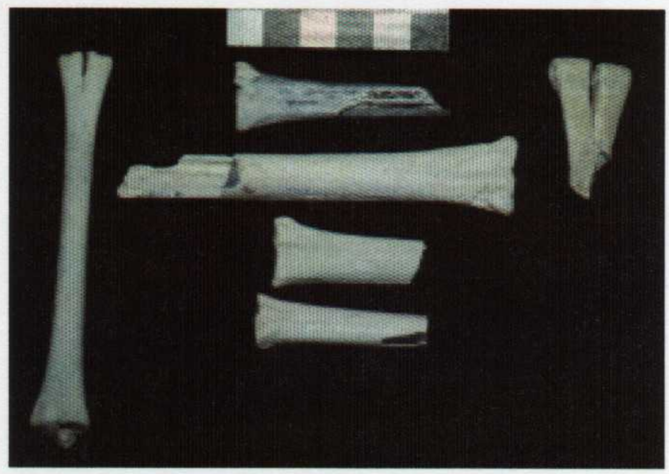
Family Camelidae (Camels) Genus and sp. indet.

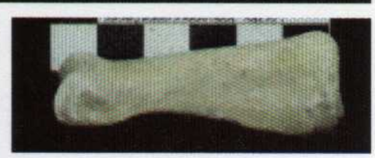
Referred Specimens: VP-13298, VP-13299, VP-13302, VP-13305, VP-13317, VP-13318, VP-13319, VP-13320, VP-13346, VP-13347, VP-13348, VP-13349, VP-13406, VP-13414, and VP-13415

Comments: These are miscellaneous camel specimens. It is interesting that there are so many camel remains in the Fullerton. However, the significance of the number of camel specimens is uncertain. It could mean that camels were abundant in the area, or perhaps that there was some sort of **taphonomic** filter working to preserve camels over other kinds of animals.

Examples of this sort of filter include the collection of carnivores from the tar pit deposits of Rancho la Brea in California. Here, carnivores are preserved in far greater numbers than is seen in other fossil assemblages. It is thought that the tar trapped animals, and the trapped animals then acted as bait to the carnivores in the area. Thus, the carnivores were attracted to the trapped animals, and had a greater likelihood of being trapped themselves. Other mechanisms are known to act as carnivore traps, such as caves and sink holes.

Of course, camels are not carnivores, so some other mechanism must be at work. It could be that the camels were herd animals, and the herd was caught in some catastrophic situation like a flood. This type of event is known in modern animals, as in mass death of caribou while migrating across flooded rivers, and has been interpreted to have occurred in the geologic past.





Various camel bones from the Grassland. Scales are in inches.

None of the above scenarios are proposed for the camel remains from the Grassland, as there is not enough evidence for a definitive interpretation.

Genus *Megatylopus* ("Giant" Camel)

Referred Specimen: VP-13300

Comments: *Megatylopus* is a very large member of the camel family, being larger than any of the modern camels. It has been found at several sites around Kansas, including the Beckerdite local biota in Clark County (Liggett, 1997).

Genus *Hemiauchenia* (Llama)

Referred Specimens: VP-13301, VP-13303, VP-13398, VP-13399, VP-13400, VP-13401, VP-13402, VP-13403, VP-13404, and VP-13405

Comments: This animal is known as the long-legged llama, and has been found coast to coast in North America. It is larger than the **extant** llama, and was a fast running grazer (Anderson, 1984).

Family Cervidae (Deer)
Genus and sp. indet.

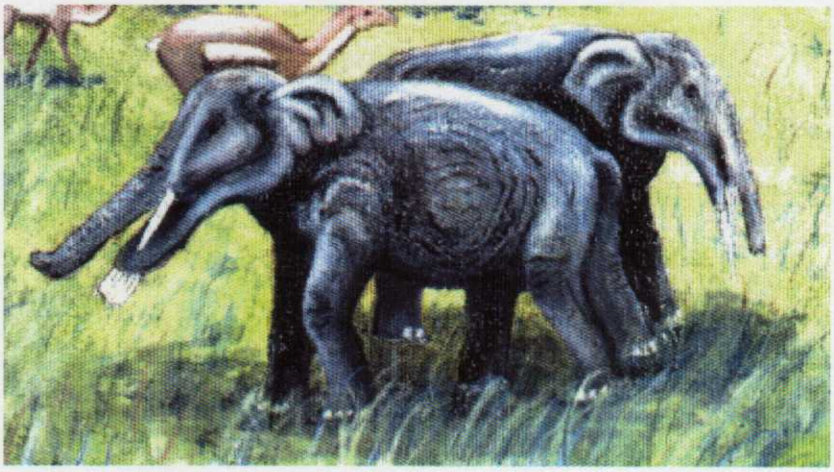
Referred Specimen: VP-13306

Comments: This fossil represents a member of the deer family.

Order Proboscidea (Elephants)
Family, Genus and sp. indet.

Referred Specimen: VP-13313

Comments: This specimen is from one of the



elephants that roamed the plains during this time period. There were several **genera**, from two families of elephants that could be represented in the fauna.

Elephant bones, of course, are large and robust. There is a high likelihood that these bones would be well preserved in the gravels of the Fullerton, and it is possible that more specimens will turn up at the pit.

Elephant tusk fragment (VP-13313) from the Grassland. Scale in inches.

Animals found outside the study area

A few specimens were collected from outside the study area. They are listed below.

Class Mammalia
Order, Family, Genus, and sp. indet.

Referred Specimens: VP-13338, VP-13339, VP-13340, VP-13341, VP-13395, and VP-13396

Comments: These specimens were collected during the Friends of the Pleistocene field trip in March 1995. They are probably of recent origin, and being outside the study area, are not significant for this study.

Order Artiodactyla
Family Bovidae
Genus *Bos* or *Bison*

Referred Specimen: VP-13342

Comments: This specimen is probably of recent origin and is not considered significant.

Genus *Bison*

Referred Specimen: VP-13336, VP-13337, and VP-13342

Comments: The age of these specimens is uncertain. It may be recent or fossil.

Order Proboscidea (Elephants)
Family, Genus and sp. indet.

Referred Specimen: VP-13394

Comments: Part of an elephant tusk. This specimen is a fossil, but it is outside of the study area, and is not overly significant by itself.

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Glossary

This is a glossary of terms used in this final report. In most cases the definitions come from the Dictionary of Geological Terms, Third Edition, edited by Robert L. Bates and Julia A. Jackson, Anchor Press, Garden City, New York. However, some definitions are modified or embellished by the authors.

aeolian same as *eolian*

alluvium A general term for *detrital* deposits made by streams on river beds, flood plains, and alluvial fans.

basalt A dark-colored volcanic rock, formed from a cooled lava flow, often with visible vesicles from escaping gases.

basaltic Having the characters of basalt.

benthic Said of marine lifeforms that are bottom-dwelling.

biomass the total mass of living organisms in a given area, in terms of weight or volume per unit area.

biostratigraphy Stratigraphy based on the paleontologic aspects of rocks; the differentiation of rock units through study of the fossils they contain.

calcaneus The heel bone.

calcrete A *conglomerate* of surficial sand and gravel cemented into a hard mass by calcium carbonate precipitated from solution by infiltrating waters. Locally, this term refers to the cap-rock of the Ogallala Group

carnivore An organism that nourishes itself mainly by feeding on other animals, living or dead.

clasts An individual constituent, grain, or fragment of a *detrital* sediment or sedimentary rock, produced by the physical disintegration of a larger rock mass.

conglomerate A coarse-grained clastic sedimentary rock, composed of larger fragments, mixed with a fine-grained matrix, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay; the consolidated equivalent of gravel.

contact The surface between two types or ages of rock.

cross-bed Also called current bed, any layer of rock or sediment produced by current action; specifically cross-stratification resulting from water or air currents of variable direction.

detrital Pertaining to or formed from *detritus*, especially said of minerals occurring in sedimentary rocks, which were derived from pre-existing rocks either within or outside the basin of deposition.

detritus 1. Loose rock and mineral material produced by mechanical means, i.e. disintegration or abrasion, and removed from its place of origin; 2. Any fine particulate debris of organic origin, e.g. plant detritus in coal.

dune A mound, ridge, or hill of wind-blown sand, either bare or covered with vegetation.

Ecosystem An ecologic system, composed of organisms and their environment. It is the result of interaction between biological, geochemical, and geophysical systems.

eolian Pertaining to the wind; esp. said of such deposits as loess and dune sand, of sedimentary structures such as wind-formed ripple marks, or of erosion and deposition accomplished by the wind.

epoch An interval of geologic time longer than an age and shorter than a period, i.e. the Pleistocene Epoch is contained in the Quaternary Period, and is made up of several ages.

evaporite One of the sediments which are deposited from aqueous solution as a result of extensive or total evaporation. Examples include anhydrite, rock salt, and various nitrates and borates.

extant Now living, opposite of *extinct*.

extinct No longer living, opposite of *extant*.

facies The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin

fluvial Of or pertaining to rivers; growing or living in a stream or river; produced by the action of a stream or river.

formation 1. A lithologically distinct, mappable body of rock. 2. A body of rock strata that consists dominantly of a certain lithologic type or combination of types. Formations may be combined into groups, or subdivided into *members*.

fossil Any remains, trace, or imprint of a plant or animal that has been preserved in the Earth's crust since some past geologic or prehistoric time; loosely, any evidence of past life.

fossiliferous Containing fossils

genera Plural of genus. The first in the genus and species scientific binomial name. e.g. *Canis familiaris*, or the familiar dog, with *Canis* being the genus name, and *familiaris* being the specific.

geology The study of the planet earth—the materials of which it is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin.

Gondwana The late Paleozoic supercontinent of the Southern Hemisphere, named for the Gondwana System of India. The present-day southern continents are believed to be fragments that have separated from each other.

igneous said of a rock or mineral that solidified from molten or partly molten material, i.e., from a magma; also applied to processes related to the formation of such rocks. Etymol: Latin *ignis*, "fire"

invertebrate An animal belonging to the Invertebrata, i.e. without a backbone, such as the mollusks, arthropods, and coelenterates; of or pertaining to an animal that lacks a backbone.

Laurasia The protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present northern continents have been derived by a break-up and displacement of this land-mass.

lithologic of *lithology*

lithology 1. The description of rocks, especially in hand specimen and in outcrop, on the basis of such characteristics as color, mineralogic composition, and grain size; 2. The physical character of a rock.

loess It is considered to be windblown dust of Pleistocene age, characterized as a blanket deposit of buff-colored calcareous silt, homogeneous, nonstratified, weakly coherent, porous, and friable. A rude vertical parting allows it to stand in steep or vertical faces. Loess covers wide areas in northern Europe, eastern China, and the central United States.

meander One of a series of sinuous curves or loops in the course of a mature stream, produced as the stream swings from side to side in flowing across its floodplain or shifts its course laterally toward the convex side of an original curve.

member A unit of rock strata that is specially developed as part of a *formation*. It may be formally defined and named, informally named, or unnamed.

metamorphic Pertaining to the process of ***metamorphism*** or its results

metamorphism The mineralogical, chemical, and structural adjustment of solid rocks to physical and chemical conditions imposed at depth below the surface zones of weathering and cementation, which differ from the conditions under which the rocks originated. Changes imposed upon solid rock.

microfossil A fossil too small to be studied without the aid of a microscope. e.g., invertebrate such as an *ostracode*. It may be the remains of a microscopic organism or a part of a larger organism.

orogeny The process of formation of mountains, commonly including thrusting, folding, and faulting in the outer and higher layers of rocks, and plastic folding, metamorphism, and plutonism in the inner and deeper layers of rock.

ostracode Any aquatic crustacean belonging to the subclass Ostracoda, characterized by a bivalve, generally calcified carapace with a hinge along the dorsal margin. Most ostracodes are of microscopic size (0.4-1.5 mm) although freshwater forms up to 5 mm long are known. They are known to occur within the Ogallala Group in Kansas.

Pangaea A supercontinent that existed from about 300 to 200 million years ago and included most of the continental crust of the earth. The present continents were derived from it by fragmentation, via an intermediate stage of *Laurasia* on the north and *Gondwana* on the south.

Panthalassa The ocean that surrounded *Pangaea* before its fragmentation.

paleontology The study of life in past geologic time, based on fossils plants and animals and including phylogeny, their relationships to existing plants, animals, and environments, and the chronology of the Earth's history.

pelecypod Any *benthic* aquatic mollusk belonging to the class Pelecypoda, characterized by a bilaterally symmetrical bivalve shell, a hatchet-shaped foot, and sheetlike gills.

phylogeny The line, or lines, of direct descent in a given group of organisms (their evolutionary relationships), as opposed to the development of an individual organism.

physiographic province A region of which all parts are similar in geologic structure and climate and which has had a unified geomorphic history; its relief features differ significantly from those of adjacent regions.

pollen The several-celled reproductive unit of seed plants, enclosed in the microspore wall. Fossil pollen consists entirely of the microspore wall, or exine.

sedimentary Pertaining to or containing sediment, or formed by sediment deposition

stratigrapher One who studies or specializes in stratigraphy.

stratigraphy 1. The science of rock strata. It is concerned with all characters and attributes of rocks as strata; and their interpretation in terms of mode of origin and geologic history. All classes of rocks, consolidated or unconsolidated, fall within the general scope of stratigraphy; 2. The arrangement of strata, especially as to geographic position and chronologic order of sequence; 3. The sum of the characteristics studied in stratigraphy; the part of the geology of an area or district pertaining to the character of its stratified rocks.

stratum (a) A layer of sedimentary rock, visually separable from other layers above and below; a bed. The term is frequently used in its plural form, strata.

taphonomy The study of the transition of skeletal elements from parts of living animals to fossilized fragments; also, the processes or events affecting bone destruction or preservation during this transition.

taxonomy Refers to the theory and practice of classifying plants and animals. Plants and animals are classified into increasingly more restrictive levels or rank, until each species is uniquely placed within the hierarchy. Example: Phylum Chordata, Class Mammalia, Order Carnivora, Family Canidae, Genus *Canis*, Species *familiaris* is the classification of the domestic dog.

unfossiliferous Having no fossils; opposite of *fossiliferous*

vertebrate A member of the subphylum of the Chordata called the Vertebrata, characterized by an internal skeleton of cartilage or bone, and by specialized organization of the anterior end of the animal; the front of the body is a head that bears organs of sight, smell, taste, and hearing, and the front of the central nervous system is a brain; animals with a central spinal cord, often surrounded by a string of bones called vertebrae.

Table 1. Summary of Paleontologic Classification and Management Recommendations

Triassic? Dockum Group?

The Triassic? units within the study area are rated as Class 2. The basis for this classification is vertebrate fossils known to occur very rarely or not at all. Management recommendations for this unit are minimal. No specific care need be taken with regard to vertebrate fossils as none are known or anticipated. However, as the only Triassic? unit exposed within the state, care should be given to the outcrop. As the main outcrop is part of an already well-known landmark (Point of Rocks), this recommendation should not pose a problem to the Forest Service.

Miocene Ogallala

It is warranted to rate the Ogallala outcrops within the grasslands as Class 5. The basis for this classification are that scientifically significant vertebrate fossils are known to occur and the areas are in danger of human-caused adverse impacts.

It is significant that such a large fauna of vertebrates occurs in Morton County where none was previously known, but these fossils are in danger of human-caused adverse impacts. Specifically, the mining of gravel is up-rooting and destroying fossils. Ironically, this is also the only way these fossils have been recovered by county workers at the gravel pit. Recognizing the economic importance of the gravel resource to the county, it is not likely that mining will stop. Indeed, within this report we note another fossiliferous area that might be a good prospect for gravel mining. Therefore, the best win-win situation is for the county workers and everyone else involved to be educated as to the importance of recovering fossils and getting those fossils into a scientific collection. Only in such a collection will they remain as a permanent record of past life in Morton County.

Quaternary system

The Quaternary system as a whole within the study area can be rated as Class 2. The basis for this classification are that vertebrate fossils occur rarely or not at all and the alluvial age is younger than 10,000 BP. There does exist the possibility of significant invertebrate fossils in the form of mollusks within the loess deposits, as they do occur elsewhere. The possibility of localities with archeological significance within this unit should be remembered. Such sites are known within the Grassland boundaries, so archeological potential should be evaluated prior to major disturbances.

Table 2. List of Vertebrate Fossils from the Cimarron National Grassland

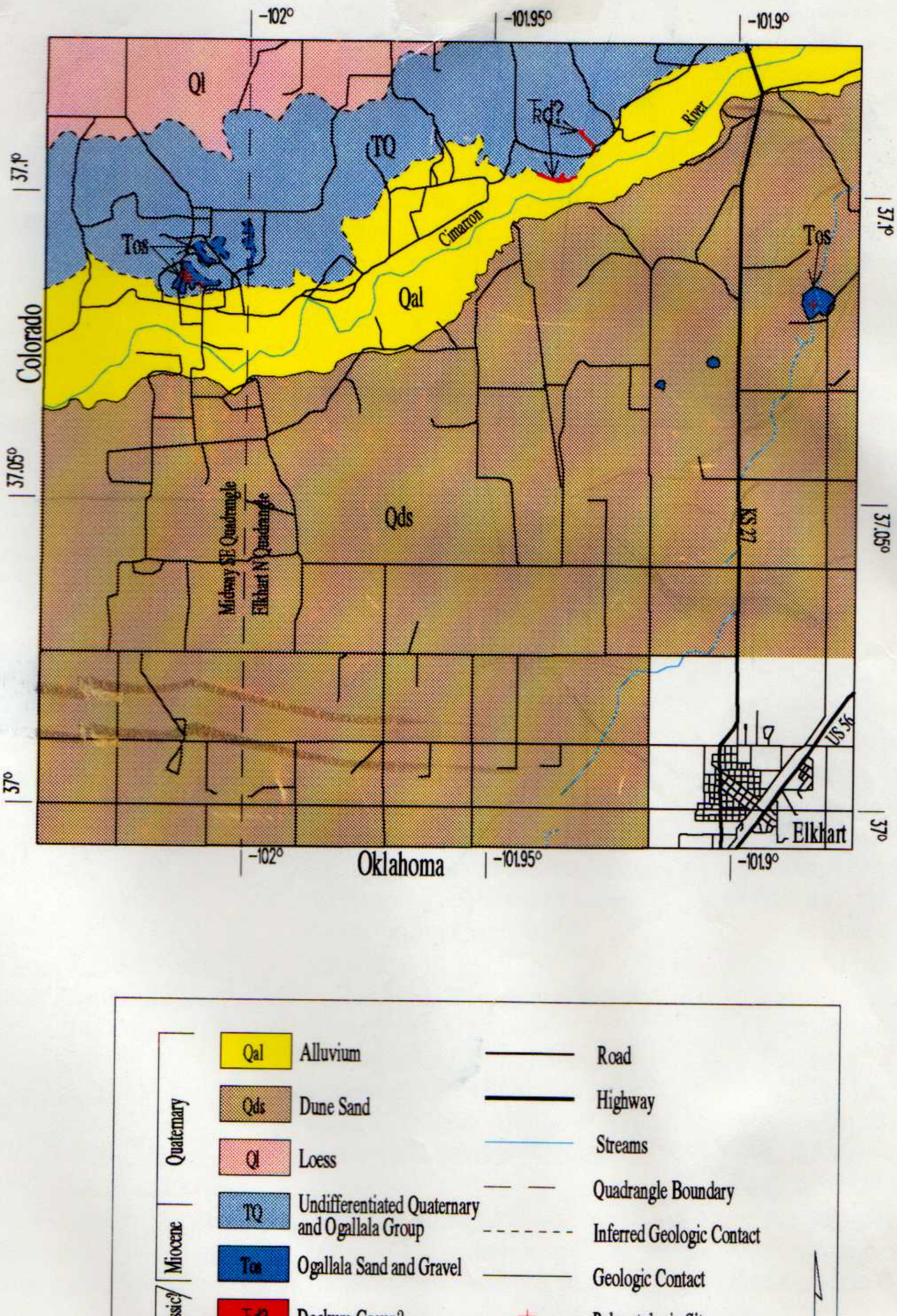
Specimens from the Cimarron National Grassland at the Sternberg Museum of Natural History as of October 1997. Specimens are listed by site number (as reported in McNinch, 1996). The legal description for each locality, the most specific taxonomic rank that a specimen was identified to, and the specimen number in the museum catalogue are also given.

Site Number	Site Description	Systematics	Specimen Number
2	SE SE1/4 Sec, T34S, R43W	Turtle	VP-13343
2	SE SE1/4 Sec, T34S, R43W	Turtle	VP-13392
3	C Sec 17, T34S, R43W	Turtle	VP-13393
4	NE1/4 Sec 21, T34S, R42W	*Protohippus*	VP-13292
4	NE1/4 Sec 21, T34S, R42W	*Protohippus*	VP-13293
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13294
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13295
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13296
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13297
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13298
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13299
4	NE1/4 Sec 21, T34S, R42W	*Megatylopus*	VP-13300
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13301
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13302
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13303
4	NE1/4 Sec 21, T34S, R42W	Artiodactyl	VP-13304
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13305
4	NE1/4 Sec 21, T34S, R42W	Cervid	VP-13306
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13307
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13308
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13309
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13310
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13311
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13312
4	NE1/4 Sec 21, T34S, R42W	Proboscidean	VP-13313
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13314
4	NE1/4 Sec 21, T34S, R42W	Turtle	VP-13315
4	NE1/4 Sec 21, T34S, R42W	Canid	VP-13316
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13317
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13318
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13319
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13320
4	NE1/4 Sec 21, T34S, R42W	Artiodactyl	VP-13321
4	NE1/4 Sec 21, T34S, R42W	*Osteoborus*	VP-13344
4	NE1/4 Sec 21, T34S, R42W	*Protohippus*	VP-13345

Site Number	Site Description	Systematics	Specimen Number
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13346
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13347
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13348
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13349
4	NE1/4 Sec 21, T34S, R42W	Turtle	VP-13350
4	NE1/4 Sec 21, T34S, R42W	Turtle	VP-13397
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13398
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13399
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13400
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13401
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13402
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13403
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13404
4	NE1/4 Sec 21, T34S, R42W	*Hemiauchenia*	VP-13405
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13406
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13407
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13408
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13409
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13410
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13411
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13412
4	NE1/4 Sec 21, T34S, R42W	Mammal	VP-13413
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13414
4	NE1/4 Sec 21, T34S, R42W	Camel	VP-13415
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13416
4	NE1/4 Sec 21, T34S, R42W	Horse	VP-13417
5	SW1/4 Sect 7, T33S, R42W	*Bison*	VP-13336
7	NW1/4 Sec 11, T33S, R40W	*Bison*	VP-13337
7	NW1/4 Sec 11, T33S, R40W	Mammal	VP-13338
7	NW1/4 Sec 11, T33S, R40W	Mammal	VP-13339
7	NW1/4 Sec 11, T33S, R40W	Mammal	VP-13340
7	NW1/4 Sec 11, T33S, R40W	Mammal	VP-13341
7	NW1/4 Sec 11, T33S, R40W	*Bison*	VP-13342
	NW1/4 Sec 24, T30S, R35W	Proboscidean	VP-13394
	SE1/4, Sec 3, T33S, R40W	Mammal	VP-13395
	SE1/4, Sec 3, T33S, R40W	Mammal	VP-13396

Appendix 1. Geologic Map of the Study Area

Map of the surface geology for the Kansas portion of the Midway SE and Elkhart North quadrangles.



Appendix 2. Fossil Yield Potential Classification (FYPC)

I. Introduction

This is a planning tool wherein geological units, usually at the **formation** or **member** level, are classified according to the probability of yielding paleontological resources that are of concern to land managers. Existing statutes and policies regulate the collection and disposition of vertebrate fossils, but not nonvertebrate fossils except in special circumstances. Therefore this classification is based largely on how likely a geologic unit is to produce vertebrate fossils of terrestrial (i.e. nonmarine) origin. The classes are described below, with some examples of corresponding management considerations or actions. Useful references are the Paleoresources Use and Management Action Spectrum (PUMA), Criteria for Scientific Significance -Specimen, Criteria for Sensitivity Ranking - Locality.

II. Paleo Classes

<u>A. Class 1</u>

<u>Description</u>: **Igneous** and **metamorphic** (ashes are excluded from this category) geologic units that are not likely to contain recognizable fossil remains.

<u>Basis</u>:

1. Fossils of any kind known not to occur except in the rarest of circumstances.

Igneous or metamorphic origin

<u>Example</u>: Vishnu Schist

<u>Management examples</u>:

1. Paleo acres not weighted the Geology Resource Base Acres budget allocation criterion.

2. No Class 1 paleo acres included in Geology Management Acres budget allocation criterion

3. Acres with this classification not included in paleontological reconnaissance work plans

<u>B. Class 2</u>

<u>Description</u>: **Sedimentary** geologic units that are not likely to contain vertebrate fossil nor scientifically significant nonvertebrate fossils.

<u>Basis</u>:

1. Vertebrate fossils known to occur very rarely or not at all.

2. Age greater than Devonian.

3. Age younger than 10,000 years before present.

4. Deep marine origin.

5. **Aeolian** (**eolian**) origin.

6. Diagenetic alteration

<u>Example</u>: Mancos Shale

<u>Management examples</u>:

1. Paleo acres not weighted in the Geology Resource Base Acres budget allocation criterion.

2. Paleo acres generally not included in Geology Management Acres, but rare exceptions are likely to be scientifically significant and require some management prescription.

3. Class 2 Paleo generally not included in paleontological reconnaissance work plans. There may be rare exceptions.

<u>C. Class 3</u>

<u>Description</u>: Fossiliferous sedimentary geologic units whose fossil content varies in significance, abundance, and predictable occurrence. Also, sedimentary units of unknown fossil potential.

<u>Basis</u>:

1. Primarily marine origin with sporadic known occurrences of vertebrate fossils (other than fish scales and shark teeth).

2. Vertebrate fossils and significant nonvertebrate fossils known to occur inconsistently-predictability known to be low.

3. Poorly studied and/or poorly document-potential yield cannot be assigned without ground reconnaissance.

<u>Example</u>: Chinle Formation

<u>Management examples</u>:

1. Some Class 3 paleo acres may be weighted in the Geology Resources Base Acres budget allocation criterion.

2. Some Class 3 paleo acres may be included in Geology Management Acres budget allocation criterion and reported in MAR:

a) opportunity areas

b) highly sensitive areas needing special protection (see Criteria for Sensitivity Ranking - Locality).

c) areas actively being researched

3. Acres with this classification may be included in paleontological reconnaissance work plans, if this designation is made on the basis of criterion 3 above.

4. Fee-based and/or user based recreational opportunities possible

D. Class 4

Description: Class 4 geologic units are Class 5 units (see below) that have lowered risks of human-caused adverse impacts and/or lowered risk of natural degradation.

Basis:

1. Significant vegetative cover; outcrop is not exposed.
2. Areas of exposed outcrop are smaller than 2 contiguous acres
3. Outcrop forms cliffs of sufficient height that most is out of reach by normal means.
4. Other characteristics that lower the sensitivity of both known and unidentified fossils sites (see Criteria for Sensitivity Ranking - Locality).

Example: Covered acres of Morrison Fm.

Management examples:

1. Class 4 paleo acres are weighted in the Geology Resources Base acres budget allocation criterion.
2. Some Class 4 paleo acres may be included in Geology Management Acres budget allocation criterion and reported in MAR:
   a) opportunity areas-see below
   b) highly sensitive areas needing special protection (see Criteria for Sensitivity Ranking - Locality)
   c) areas actively being researched
3. Paleo reports likely to be counted in Geology Reports MAR (permits, agreements, contracts, etc.)
4. Acres with this classification should be included in paleontological reconnaissance work.
5. Scientific and educational use likely. Paleo special use permits and Challenge Cost Share agreements likely.
6. Ongoing curation agreements with regional accredited museums recommended.
7. Fee-based and/or user based recreational opportunities most likely

E. Class 5

Description: Highly fossiliferous geologic units that regularly and predictably produce vertebrate fossils and/or scientifically significant nonvertebrate fossils, and that are at risk of natural degradation and/or human-caused adverse impacts.

Basis:

1. Vertebrate fossils and/or scientifically significant nonvertebrate fossils are known and documented to occur consistently, predictably, and/or abundantly.
2. Outcrop is exposed; little or no vegetative cover.
3. Extensive exposed outcrop; discontinuous areas are larger than 2 contiguous acres.
4. Outcrop erodes easily, may form badlands.
5. Easy access to extensive outcrop in remote areas (increased potential for illegal collection; vandalization).
6. Other characteristics that increase the sensitivity of both known and unidentified fossil sites (see Criteria for Sensitivity Ranking—Locality).

Example: White River Formation/Group

Management examples:

1. Class 5 paleo acres are weighted in the Geology Resource Base Acres budget allocation criterion.
2. Some Class 5 paleo acres may be included in Geology Management Acres budget allocation criterion and reported in MAR:
   a) opportunity areas–see below
   b) highly sensitive areas needing special protection (see criteria of Sensitivity Ranking—Locality).
   c) areas actively being researched.
3. Paleo reports likely to be counted in Geology Reports MAR (permits, agreements, contracts, etc.)
4. Paleontological reconnaissance work should focus only on poorly known areas of Class 5 acres because they are already considered a management priority.
5. Scientific and education use highly likely. Highest number of paleo special use permits expected for Class 5 acres. Challenge Cost Share agreements with a broad spectrum of professional and avocational paleontologists expected.
6. Fee–based and/or user based recreational opportunities possible.
7. On-going curation agreements with regional accredited museum recommended.
8. The land manager's highest concern for paleoresources should focus on Class 5 acres. These areas are likely to be poached. Mitigation of ground disturbing activities is required and may be intense. Frequent use by the full range of interested publics is to be expected. Areas of special interest and concern should be designated and intensely managed. Field–based, technical training in paleoresource management should be provided to Forest and District staff and to Law Enforcement Officers.

Appendix 3. List of Documents Relating to the Cimarron National Grassland

The following is a list of all documents, in chronologic order, relating to the Paleontologic Investigation of the Cimarron National Grassland as undertaken by Challenge Cost Share #CC2-2-12-94-07-028.

Liggett, G.A. 1997. The Beckerdite local biota (early Hemphillian) and the first Tertiary occurrence of a crocodilian from Kansas. Transactions of the Kansas Academy of Science, 100(3-4).

Liggett, G. A. and R. J. Zakrzewski. 1997. Final report on the geologic and paleontologic investigation of the Cimarron National Grasslands. Report to the United State Department of Agriculture Forest Service.

Liggett, G. A. and R. J. Zakrzewski. 1996. Paleontology of the Cimarron National Grasslands, Morton Co., Kansas. Abstracts of Papers Presented at the 128th Annual Meeting of the Kansas Academy of Sciences, 15.

McNinch, K. L. 1996. An integrated GIS database, geologic and paleontologic reconnaissance, and areal correlation of soils to geology within Cimarron National Grassland, Morton County, Kansas. Masters Thesis, Fort Hays State University, Hays, Kansas, 99p.

McNinch, K. L., G. A. Liggett, and R. J. Zakrzewski. 1996. An integrated GIS database relating to the Cimarron National Grasslands, Morton Co., Kansas. Abstracts of Papers Presented at the 128th Annual Meeting of the Kansas Academy of Sciences, 15.

Liggett, G. A. and R. J. Zakrzewski. 1995. Interim annual report on the geologic and paleontologic investigation of the Cimarron National Grasslands. Report to the U. S. Department of Agriculture Forest Service.

Liggett, G. A. and R. J. Zakrzewski. 1995. Selected bibliography for the geologic and paleontologic investigation of the Cimarron National Grasslands. Report to the U. S. Department of Agriculture Forest Service.