# PALEONTOLOGICAL RESOURCES

## Overview Of Reported Paleontological Resources

All sedimentary rock formations in eastern Montana have at least some potential to contain fossils. However, several formations are noteworthy in their consistent production of paleontological remains. Table 10 provides a summary of the characteristic fossils of geologic units that occur in the project area, and is based on information presented in the *Geology, Paleontological Review of Formations, and Lithic Resources* section of this report (see above). It should be emphasized that this section, Table 10, and the *Geology, Paleontological Review of Formations, and Lithic Resources* section present the types of fossils expected to occur in the project area. This summary information is based on existing publications available for areas within and adjacent to the project area. As such, it differs somewhat from the actual (i.e., documented) distribution of fossil types summarized below and shown on Table 11.

The most publicized paleontological resources of eastern Montana are derived from the Upper Cretaceous Hell Creek Formation. The terrestrial deposits of the Hell Creek have produced fossilized remains of dinosaurs (e.g., *Triceratops* sp. and *Tyrannosaurus rex*), mammals, crocodilians (crocodiles and alligators), turtles, lizards, snakes, champsosaurs, amphibians, fish, plants, invertebrates, and a bird. Another important and highly studied unit is the Tullock Member of the Lower Tertiary Fort Union Formation, which is also sometimes referred to as the Tullock Formation of the Fort Union Group. The Tullock contains fish, amphibian, turtle, champsosaur, lizard, crocodilian, mammal, bird, and plant remains. Fossils from the Hell Creek and Tullock formations, especially in Garfield and McCone counties, have been instrumental in studies examining the mass extinction event at the Cretaceous-Tertiary (K-T) boundary (Clemens 2002). Based on decades of careful collection and evaluation of mammalian remains from the Cretaceous Hell Creek and Tertiary Tullock formations, Clemens (2002) has demonstrated that post-extinction event faunal communities arose not only from evolutionary radiations of local survivors, but also from immigration of survivors from other, distant geographic areas. A brief overview of the K-T boundary and the various mass extinction theories is presented later in this section. Characteristic fossils of the entire Fort Union Formation (or Group) include: trace fossils, plants, invertebrates, fish, amphibians, turtles, champsosaur, lizards, crocodilians, mammals, and bird.

Another noteworthy sedimentary unit is the Judith River Formation, which contains trace, plant, invertebrate, fish, amphibian, reptile, dinosaur, bird, and mammal fossils (Table 10). The marine Bearpaw Shale overlies the Judith River Formation, and contains invertebrates, shark teeth, marine reptiles, turtles, and occasional dinosaurs. The Bearpaw thickens to the east where it is labeled as the Pierre Shale, which includes invertebrates, fish, and marine reptiles. The Bearpaw and Pierre formations are overlain by the Fox Hills Formation, which although not particularly fossiliferous does contain some exceptional leaf impressions. Trace fossils, invertebrates, and fish remains have also been reported from the Fox Hills Formation.

**Table 10. Characteristic fossils of geologic units that occur in the project area.**
(indicated ○)
See report text for references and discussion of occurrence, as some remains occur in regions adjacent to Montana and/or in laterally equivalent units. Fish category includes cartilagenous (e.g., sharks, rays) and bony fish. Reptile category includes lizards, turtles, snakes, crocodilians, champsosaurs, marine reptiles, and flying reptiles. Vertebrate column is for unspecified or unidentified remains. Abbreviations: Fm – Formation; Grp – Group; Sh – Shale; Ss – Sandstone.

| ▼STRATIGRAPHIC UNITS | FOSSIL CATEGORIES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Trace** | **Plant** | **Invertebrate** | **Fish** | **Amphibian** | **Reptile** | **Dinosaur** | **Bird** | **Mammal** | **Vertebrate** |
| Quaternary deposits | | | | | | | | | ○ | |
| Crane Creek gravel | | | | | | | | | | |
| Cartwright gravel | | | | | | | | | ○ | |
| Flaxville Fm | | | | ○ | | | | | ○ | |
| Rimroad gravel | | | | | | | | | | |
| Arikaree Fm | | | | | | | | | ○ | ○ |
| Chadron-Brule Fm | | ○ | ○ | | | | | | ○ | ○ |
| Wasatch Fm | | ○ | ○ | | | | | | ○ | ○ |
| Fort Union Fm | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | ○ | |
| Hell Creek Fm | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | |
| Fox Hills Fm | ○ | ○ | ○ | ○ | | | | | | |
| Bearpaw Sh | | | ○ | ○ | | ○ | ○ | | | |
| Judith River Fm | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | |
| Claggett Sh | | ○ | ○ | | | ○ | ○ | | | |
| Eagle Ss | ○ | ○ | ○ | ○ | | | ○ | | | |
| Telegraph Creek Fm | | | ○ | | | | | | | |
| Pierre Sh | | | ○ | ○ | | ○ | | | | |
| Niobrara Fm | | | ○ | | | ○ | | | | |
| Carlile Sh | ○ | ○ | ○ | ○ | | ○ | | | | |
| Greenhorn Fm | | | ○ | ○ | | | | | | |
| Belle Fourche Sh | | | ○ | ○ | | ○ | | | | |
| Mowry Sh | | | ○ | ○ | | ○ | | | | |
| Newcastle Ss | | ○ | ○ | | | | ○ | | | |

**Table 11. Detailed summary of documented fossil types that occur (●) in each formation.**
Based on paleontological locality data in ACRCS data base (n = 1929). Abbreviations: Amphib – amphibian; Champ – champsosaur; Croc – crocodile; Dino – dinosaur; Trace – trace fossil (e.g., coprolite, eggshell); Invert – invertebrate; Vert – unspecified/unidentified vertebrate; and Unspec - unspecified fossil material.

| ▼FORMATION | FOSSIL TYPES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Amphib | Bird | Champ | Croc | Dino | Fish | Invert | Lizard | Mammal | Marine Reptile | Plant | Other Reptile | Snake | Trace | Turtle | Vert | Unspec |
| **Quaternary*** | | | | | | | | | ● | | | | | | | ● | |
| **Pleistocene*** | | | | | | | | | ● | | ● | | | | | | |
| **Flaxville** | | | | | | ● | | | ● | | | | | | | | |
| **Rimroad*** | | | | | | | | | | | | | | | | | |
| **Arikaree** | | ● | | | | ● | | | ● | | | | | | | | |
| **Brule** | | | | | | | | | | | | | | | | ● | |
| **Chadron-Brule** | | | | | | | | | ● | | | | | | ● | | |
| **Wasatch** | | | | | | | ● | | ● | | ● | | | | | | |
| **Fort Union** | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | | | ● | ● | |
| **Hell Creek** | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● |
| **Montana*** | | | | | | | ● | | | | | | | | | | |
| **Fox Hills** | | | | | | | | | | | ● | | | | | | |
| **Bearpaw** | | | | | | | ● | | | ● | | | | | | ● | |
| **Judith River** | | | | | | | | | | | | | | | | | |
| **Claggett** | | | | | | | | | | | | | | | | | |
| **Eagle** | | | | | | | | | | | | | | | | | |
| **Telegraph Ck.** | | | | | | | | | | | | | | | | | |
| **Pierre** | | | | | | ● | ● | | | ● | | | | | | ● | |
| **Colorado*** | | | | | | | | | | | ● | | | | | ● | |
| **Niobrara** | | | | | | | | | | | | | | | | | |
| **Carlile** | | | | | | | ● | | | | | | | | | | |
| **Greenhorn** | | | | | | ● | ● | | | | | | | | | ● | |
| **Belle Fourche** | | | | | | | ● | | | | | | | | | | |
| **Mowry** | | | | | | | | | | | | | | | | | |
| **Newcastle** | | | | | | | | | | | | | | | | | |

*not formation rank (i.e., Montana Group, Colorado Group, Rimroad gravel, Pleistocene deposits, Quaternary deposits).

Below the Judith River Formation is a series of near-shore and marine deposits. The Newcastle Sandstone is the oldest bedrock unit in the project area, and reportedly contains plants, invertebrates, and a dinosaur bone fragment. It is overlain by the Mowry Shale, where invertebrates, fish, marine reptiles, and a rare crocodile have been found. The Belle Fourche Shale contains invertebrates, marine reptiles, and fish, and the overlying Greenhorn Formation contains invertebrates and fish. The Carlile Shale overlies the Greenhorn, and contains trace fossils, petrified wood, invertebrates, shark teeth, a ray, bony fishes, marine reptiles, and a marine turtle. The Niobrara Formation has produced invertebrates and mosasaur vertebrae, whereas the Telegraph Creek Formation has only produced invertebrates to date. Above the Telegraph Creek is the Eagle Sandstone, where trace fossils, plants, invertebrates, fish, and a dinosaur bone have been found. The Clagget Shale, which overlies the Eagle Sandstone and occurs below the Judith River Formation, contains plant, invertebrate, champsosaur, and dinosaur remains.

The remaining Tertiary and Quaternary deposits above the Fort Union Formation are often separated from one another by unconformities, which represent a depositional hiatus or period of erosion. From oldest to youngest, these units include Wasatch Formation, White River Group (i.e., Chadron and Brule formations, undivided), Arikaree Formation, Rimroad gravel, Flaxville Formation, Cartwright gravel, Crane Creek gravel, and Quaternary deposits. The Wasatch Formation is reported to contain fossilized plants, invertebrates, mammals, and lower vertebrates. Plants, invertebrates, mammals, and unspecified vertebrates are reported to occur in the White River Group, whereas mammals and unspecified vertebrates are present in the overlying Arikaree Formation. No fossils have been reported for the Rimroad gravel yet. The Flaxville Formation (i.e., Flaxville Gravel) contains isolated fish and mammal fossils. Although no fossil material has been reported for the Cartwright and Crane Creek gravels, an equivalent of the former (Wiota gravel) is reported to contain Pleistocene mammal fossils. Finally, remains of fossilized mammals are reported to occur in Quaternary deposits.

**ACEC Paleontological Localities**

Several locations in the project area are recognized for their paleontological and geological attributes. An Area of Critical Environmental Concern (ACEC) is a designation used by the BLM to indicate that special management attention is required to protect and prevent irreparable damage to: important historic, cultural, or scenic values; fish and wildlife resources; or other natural systems and processes. There are four paleontological ACECs in the project area: Ash Creek Divide ACEC in Garfield County, Bug Creek ACEC in McCone County, Hell Creek ACEC in Garfield County, and Sand Arroyo ACEC in McCone County. In addition, several National Natural Landmarks have been designated by the National Park Service. These include Bug Creek Fossil Area in McCone County, Hell Creek Fossil Area in Garfield County, and Capital Rock National Natural Landmark in Carter County. The National Natural Landmark Program identifies, recognizes, and encourages conservation of the best examples of biological and geological features on public and private lands. The Big Dry RMP provides additional protection (no surface disturbance) for significant paleontological sites/localities at Garbani and Flat Creek in Garfield County and Harbricht Hill in McCone County.

## Field Of Vertebrate Paleontology

Although the goals of vertebrate paleontology early on were limited to acquisition of museum-quality specimens and description of new species, they now include numerous sub-fields such as taphonomy, biomechanics, and molecular paleontology. The field of paleontology is built on and maintains a symbiotic relationship with geology and biology. Finding, recording, and collecting fossil specimens requires a basic understanding of sedimentary processes and stratigraphy, whereas identifying fossils requires knowledge of comparative anatomy. Conversely, fossils play an important role in geological studies, where they are often used to determine stratigraphic position and make lateral correlations. The fossil record is also studied by biologists to elucidate the processes of evolution and extinction. Furthermore, with the discovery of exceptional specimens such as those with soft tissue preservation, the need for collaboration with other scientists is becoming more commonplace. As aptly summarized by Clemens: "The boundaries of the field of vertebrate paleontology are not well defined; each project has a different emphasis and may be the meeting place for specialists from a variety of fields" (1980a:6B).

## Issue - "Site/Locality" Versus "Isolated Find" For Paleontological Remains

Currently, there is no universally accepted or widely used definition of what constitutes a "site/locality" in paleontology. In the cultural resource management realm, the terms "site/locality" and "isolated find" are commonly employed. In Montana, for example, five or more pieces of non-diagnostic prehistoric material within 50 m of each other constitute a site/locality, whereas an isolated find is defined as less than five pieces of non-diagnostic material, unless two or more of those artifacts are diagnostic (Montana State Historic Preservation Office 2000). Of course there are exceptions and other qualifications that can be applied to these definitions. For example, designation of a site/locality may be warranted for isolated occurrence of certain features, or when several pieces of material are in association with a feature. Application of these cultural resource concepts and definitions to paleontological localities is not appropriate without some modification. For example, using the cultural resource definitions, a complete Triceratops skull might be defined as an isolated find rather than a site/locality. Of course, the skull may have been slightly fragmented by weathering prior to discovery, but if none of those fragments are diagnostic, and the total number (including the skull) is less than five, then it would still just be an isolated find. The addition of qualitative statements to the existing cultural resource definitions could solve this problem and make them applicable to paleontological resources. Even so, some agencies (e.g., USDA Forest Service) do not use the term isolated find in regard to paleontological remains, and consider a single fossil element (partial or complete, identifiable or unidentifiable) to be a site/locality. Resolution of this issue should involve a wide spectrum of participants, including agency employees, consultants, and academics.

## Methodology

Paleontological Data Collection Methods

This overview is a synthesis of information regarding distribution of the paleontological resources in the project area. The summary information presented herein is based solely on literature review, file searches, and personal communications, and did not involve fieldwork. Although the main focus of the data collection centered on vertebrate localities, some plant and invertebrate locality information is also included.

Existing publications relevant to the project area were located using GeoRef bibliographic data base and its search engine. Some of these publications provided locality information included in the data base (Bishop 1986; Brown 1939; Carpenter 2004; Cobban and Larson 1997; Collier and Thom 1918; Davis and Wilson 1985; Denson and Gill 1965; Estes 1976; Gaffney and Hiatt 1971; Giffin 1989; Gilmore 1946; Hager and Hooker 1985; Harksen 1981; Hay 1924; Hill 2001; Hill and Davis 1998; Horner 1984; Howard 1960; Hunter et al. 1997; Hutchinson and Chiappe 1998; Krause 1987; Madden 1981; Mader and Alexander 1995; Melton and Davis 1999; Meylan and Gaffney 1989; Molnar 1978, 1979; Neas 1990; Robinson et al. 1959; Rohrer and Konizeski 1960; Sloan and Van Valen 1965; Storer 1969; Van Valen and Sloan 1965; Whetstone 1978; Wilimovsky 1956; Wilson and Hill 2000; Wolberg 1979; Wood 1945). File searches were undertaken with Montana State Historic Preservation Office (SHPO), U. S. Bureau of Land Management (BLM), U. S. Bureau of Reclamation (BOR), Montana Department of Natural Resources and Conservation (DNRC), and Montana Department of Transportation (MDT). In regard to the BLM files, locality data received after May 15, 2005, are not included in the present overview. Other federal and state agencies that were contacted during data collection include: U. S. Bureau of Indian Affairs (BIA), USDA Forest Service (USDA FS), U. S. Fish and Wildlife Service (USFWS), and Montana Fish, Wildlife, and Parks (FWP). These agencies either did not have the ability to provide electronic records of paleontological localities, or chose to be excluded from the study. During the course of literature review and file searches, additional data or clarifications were sometimes needed. In this case, the institution responsible for curating the fossil material was contacted. A list of institutions that house fossil material collected from the project area is presented in Table 12, and is based on the BLM permit files and information in the literature. For the purposes of data collection and summary, a data base was constructed using the application Microsoft Access, and is referred to hereafter as the ACRCS data base. Recorded attributes are described below in the Data Overview section.

Formation descriptions in the *Geology, Paleontological Review of Formations, and Lithic Resources* section (see above) of this report are based on geologic maps available for the study area (Bergantino 1999, 2001; Bergantino and Wilde 1998a, 1998b, 1998c, 1998d; Ross et al. 1955; Vuke and Colton 1998, 2003; Vuke and Wilde 2004; Vuke, Wilde, and Bergantino 2000, 2003a, 2003b; Vuke, Wilde, and Smith 2003; Vuke, Heffren, Bergantino, and Colton 2001a, 2001b, 2001c, 2001d; Vuke, Luft, Colton, and Heffren 2001; Vuke, Wilde, Bergantino, and Colton 2001; Vuke, Wilde, Colton, and Bergantino 2001; Vuke, Wilde, Colton, and Stickney 2001, 2003; Vuke, Wilde, Lopez, and Bergantino 2000; Vuke, Bergantino, Colton, Wilde, and Heffren 2001; Wilde and Bergantino 2004a, 2004b; Wilde and Smith 2003a, 2003b; Wilde and Vuke 2004a, 2004b). These maps were also utilized during data entry to identify or clarify geologic unit names if they were ambiguous or absent on the site/locality forms.

**Table 12. List of institutions that curate fossils collected from the project area. Current and previous BLM Paleontological Resources Use Permit holders are indicated by an asterisk (*).**

| |
|---|
| American Museum of Natural History, New York, NY |
| Burpee Museum of Natural History, Rockford, IL* |
| California Academy of Sciences, San Francisco, CA* |
| Carnegie Museum of Natural History, Pittsburg, PA* |
| Carter County Museum, Ekalaka, MT* |
| Cleveland Museum of Natural History, Cleveland, OH |
| Dawson Community College, Glendive, MT |
| Duke Univ., Durham, NC* |
| Emporia State University, Johnston Geology Museum, Emporia, KS |
| Field Museum of Natural History, Chicago, IL |
| Fort Peck Power Plant Museum, Fort Peck, MT |
| Fort Peck Dinosaur Field Station, Fort Peck, MT |
| Fort Peck Dam Interpretive Center, Fort Peck, MT |
| Garfield County Museum, Jordan, MT* |
| Makoshika State Park Visitors Center, Glendive, MT* |
| McCone County Museum, Circle, MT |
| Milwaukee Public Museum, Milwaukee, WI* |
| Museum of the Rockies, Montana State Univ., Bozeman, MT* |
| National Museum of Natural History, Smithsonian Institution, Washington, DC |
| Natural History Museum of Los Angeles County, Los Angeles, CA* |
| New Mexico Museum of Natural History and Science, Albuquerque, NM |
| Pratt Museum of Natural History, Amherst, MA |
| Princeton Univ., Princeton, NJ (collections transferred to Yale Univ.) |
| Royal Ontario Museum, Toronto, Ontario, Canada |
| Royal Tyrrell Museum, Drumheller, Alberta, Canada |
| Saint Louis Science Center, St. Louis, MO* |
| San Diego State Univ., San Diego, CA* |
| Science Museum of Minnesota, St. Paul, MN |
| Shenandoah Univ., Winchester, VA* |
| Shenandoah Valley Discovery Museum, Winchester, VA* |
| Sheridan College, Geology Museum, Sheridan, WY* |
| Sierra College Natural History Museum, Rocklin, CA* |
| South Dakota School of Mines and Technology, Rapid City, SD |
| Spokane Falls Community College, Spokane, WA |
| State University of New York, New York, NY* |
| Stony Brook University, Stony Brook, NY |
| Univ. of California Museum of Paleontology, Berkeley, CA* |
| Univ. of Michigan, Museum of Paleontology, Ann Arbor, MI |
| Univ. of Kansas, Lawrence, KS |
| Univ. of Minnesota, Minneapolis, MN |
| Univ. of Montana, Department of Geology, Missoula, MT |
| Univ. of North Dakota, North Dakota Energy & Environmental Research Center, Grand Forks, ND |
| Univ. of Notre Dame, Notre Dame, IN* |
| Univ. of Oklahoma, Oklahoma Museum of Natural History, Norman, OK* |
| Univ. of Washington, Burke Museum of Natural History and Culture, Seattle, WA* |
| Univ. of Wisconsin, Geology Museum, Madison, WI* |
| Univ. of Wisconsin, Milwaukee, WI* |
| Yale Univ., Peabody Museum of Natural History, New Haven, CT |
| Woolaroc Museum, Bartlesville, OK |

Paleontological Data Limitations

Paleontological data drawn from during this project occur in varying formats and are by no means standardized. The majority of the data included in the ACRCS data base is from BLM files at the Billings State Office and Miles City Field Office. The SHPO file search of the Cultural Resource Information System (CRIS) data base returned very few paleontological localities (54), indicating that the majority of sites/localities in the project area have not been assigned Smithsonian numbers. Other locality information is derived from the DNRC, available publications, and personal communications. A huge body of data is on file with the BLM, particularly the Miles City Field Office where such information is difficult to retrieve because of varied format and storage. An extensive effort was put forth in order to include all of this information in the ACRCS data base and a more "user friendly format" for filing and archiving this information is advised. However, since the majority of data recorded is from BLM files, it is expected that sites/localities on BLM land will have a much higher representation than those owned by non-BLM entities.

Determination of whether a reported fossil occurrence should be classified as an isolated find or site/locality was not undertaken during this project, since these definitions are still being developed and information needed to make this distinction is often not present in the source data.

Another limitation is that some productive fossil localities have been worked by multiple institutions. If it was obvious that two institutions were referring to the same locality, then duplication of the site/locality in the ACRCS data base did not occur. However, many of the legal or verbal descriptions for localities are simply not detailed enough to make a determination of discreteness. Thus, it is possible that some sites/localities are recorded more than once. The reluctance of professional paleontologists to share locality information is due, in part, to the rising commercial market for fossils and potential for illegal looting by commercial or non-commercial entities. Despite the potential for duplications and emphasis on BLM lands, the data set is still very useful for demonstrating overall distribution of sites/localities and fossil types according to geologic unit. This background information is used to assign a paleontological resource sensitivity rating to each geologic unit in the project area.

Paleontological Data Overview

The number of sites/localities included in this overview is 1929, with only 54 of those having been assigned Smithsonian numbers. Attributes recorded for each locality include: original site/locality name and number, repository, Smithsonian number, legal description, Universal Transverse Mercator (UTM) coordinates, county, landowner, geologic time division, stratigraphic unit, lithology of fossil-bearing unit, depositional environment, fossil type(s), publications, and use type. Original site/locality name and number are those assigned by the institution, museum, or agency who found or reported the locality. Repository refers to the institution or museum responsible for curating the specimens, and sometimes differs from the entity that collected the material. Smithsonian numbers are trinomials (e.g., 24SH4957) assigned by the Smithsonian Institution, which consist of a number for the state (24SH4957, i.e., Montana), an abbreviation that represents the county (24SH4957, i.e., Sheridan County), and a number assigned sequentially by county (24SH4957, i.e., 4957th site/locality recorded in Sheridan County, Montana). A standardized site/locality form (available in the appendix of Montana State Historic Preservation Office 2000) is filled out and submitted to Archaeological Resources at the University of Montana, which requests assignment of the site/locality number from the Smithsonian after checking their data base for duplication. Although Smithsonian numbers have predominantly been assigned to archaeological and historical sites in the past, efforts have begun to assign these numbers to paleontological sites/localities. Presently, DNRC and SHPO are the only agencies requiring such an assignment for Montana fossil localities (Montana State Historic Preservation Office 2000; Rennie 2002).

Legal descriptions were most often available by Township, Range, and Section. Although UTM coordinates were rarely encountered during data collection, some of the more recent site/locality forms only provide UTM coordinates for site/locality positioning. In this case, a topographic map program (All Topo Maps) was used to determine Township, Range, and Section. Site/locality forms also sometimes lacked county and landowner, and these attributes were determined using All Topo Maps and Montana Natural Resource Information System website, respectively.

Geologic time division refers to eras, periods, epochs, and ages shown on Figure 7. Stratigraphic units are rock units labeled as group, formation, member, and bed (Figure 7). When present, the time-rock unit (i.e., chronostratigraphic unit) was also recorded. Information regarding lithology of the fossil-bearing unit was recorded when available using the general categories of sandstone, mudstone, siltstone, claystone, limestone, chert, conglomerate, shale, bentonite/volcanic ash, and coal. Depositional environment refers to the conditions present during deposition of the sediments (i.e., before their lithification into bedrock), and includes marine, terrestrial, and transitional.

Up to eight types of fossils were recorded for each site/locality, using the following general categories: amphibian, bacteria, bird, champsosaur, coprolite, crocodile (i.e., alligators and crocodiles), dinosaur, eggshell, fish (e.g., bony fish, sharks, rays), flying reptile, fungi, invertebrate, lizard, mammal, marine reptile, other organic (i.e., unspecified plant), other reptile (i.e., unspecified Reptilia), plant, protoctist (i.e., all eukaryotes that are not animals, plants, or fungi), snake, trace fossil, turtle, unspecified (i.e., fossil type not specified in original documentation), and vertebrate (i.e., unspecified Vertebrata). When available, more specific taxonomic names were recorded in a taxa sub-form on each site/locality form, but availability of this information was variable. If the nesting classifications for an identified genus and species were not provided in the source material, then available references (e.g., Boardman et al.1987; Romer 1966; Russell 1988) were consulted to determine Order, Family, etc. Although some of the classifications in these references are likely outdated, it is beyond the scope of this effort to summarize changes in taxonomic classification, many of which are on-going.

Use type refers to categories established by the BLM, and include scientific, educational, and recreational. Recommended use categories were recorded whenever indicated on the site/locality forms, but otherwise have not been determined as a part of this study. Generally speaking, vertebrate fossil sites/localities should always be classified as scientific or scientific and educational, whereas non-vertebrate fossil sites/localities could be classified as scientific, educational, and/or recreational depending on the conditions of the site/locality (e.g., flora and fauna present; type of preservation; common or rare occurrence). Determination of the use category for a non-vertebrate fossil site/locality might require an on-site evaluation in addition to consultation with researchers familiar with the locality and fossils in question.

Paleontological Data Synthesis

Summary information generated using the ACRCS data base is used to look at distribution of paleontological resources in the study area. Distribution of sites/localities according to formation, county, and landowner are presented and discussed later in this report. Vertebrate versus non-vertebrate fossil sites/localities are tallied for each formation. The types of fossils documented to occur in each formation are summarized and compared to characteristic fossils that are reported to occur. Finally, each geologic unit is given a paleontological resource sensitivity rating that can be used to guide management decisions and during project planning.

Fossils in the project area occur in Mesozoic- and Cenozoic-age deposits. Each sedimentary geologic formation is outlined (see earlier *Geology, Paleontological Review of Formations, and Lithic Resources* section in this report), along with the type of paleontological remains it has the potential to produce.

**History Of Paleontological Exploration In Eastern Montana**

In 1855, Ferdinand Vandiveer Hayden with the United State Geological Survey discovered the first dinosaur remains in the Western Hemisphere in what is now central Montana (Horner 2001). Hayden's collections were made west of the project area in exposures of the Cretaceous Judith River Formation along the Missouri and Judith rivers (Horner 2001). It is reported that Native Americans referred to him as "he who picks up stones while running" (Horner 2001; Jaffe 2000). The first expedition to Montana with the sole purpose of fossil collection occurred in 1876, with Edward Drinker Cope and his party (Horner 2001). Upon Cope's arrival, he was informed of the events at the Little Bighorn River. Cope estimated that the Sioux would not pass through the Missouri River breaks until October, and decided that this would give them enough time to collect some fossils (Jaffe 2000). Across the Missouri River from their camp at Dog Creek (downstream from the Judith River), there was a large encampment of approximately one thousand Crow Indians, several of whom he was able to befriend and later amaze by removing his false teeth. Cope proceeded to collect remains of dinosaurs, crocodiles, turtles, fish, and mammals from the Judith River Formation. After much adventure getting themselves and their cargo to Cow Island, Cope loaded 1200 pounds of specimens onto the last steamboat heading downstream for the year. Shortly thereafter, the Sioux crossed the Missouri River at Cow Island, where a brief battle left 5 soldiers dead (Jaffe 2000).

In 1901, the director of the New York Zoological Park, W. T. Hornaday, who had hunted buffalo north of Jordan in Garfield County beginning in 1886, discovered Triceratops fossils in the valley of Hell Creek while deer hunting (Clemens 1980b). In

1902, Hornaday was informed of fossils north of Ingomar along Porcupine Creek, which were discovered by J. Scott Harrison, a special examiner with the U. S. Surveys based in Miles City. Hornaday sent this information to Barnum Brown at the American Museum of Natural History, who subsequently explored the finds north of Forsyth before heading to Hell Creek (Clemens 1980a, 1980b). On July 2, 1902, Brown arrived at Hell Creek (in what is now Garfield County), and discovered what was to become the type specimen of *Tyrannosaurus rex* that afternoon (Clemens 1980b). Between 1903 and 1910, Brown collected numerous fossils from the Hell Creek Formation in Garfield and McCone counties, including a second *T. rex* skeleton, ceratopsians, hadrosaurs, other dinosaurs, crocodilians, champsosaurs, turtles, mammals, miscellaneous microvertebrates, and invertebrates (Horner 2001; Clemens 1980b, 2002).

Beginning in 1904 and continuing until 1960, many different institutions sent field parties to eastern Montana in order to make collections for their respective museums (Clemens 1980a). In 1905, Carnegie Museum paleontologist Earl Douglass did a geological reconnaissance through North Dakota, Montana, and Idaho, traveling mainly by rail. One objective of his journey was to investigate exposures near Glendive for mammalian remains in order to better ascertain their age, which had previously been reported as late Cretaceous or early Tertiary based on plant fossils (Douglass 1909). He either does not stop to explore, or does not find any vertebrate material near Glendive. He continues westward and makes several important discoveries north of Big Timber and south of Harlowton (Douglass 1909). As shown by the list of institutions provided in Table 12, eastern Montana has been and continues to be a popular place for paleontological exploration and collection.

**Types Of Vertebrate Fossil Sites/Localities**

Fossils can occur as isolated elements, microsites, bonebeds, or individual skeletons. Isolated bones, teeth, or fragments are by far the most common mode of occurrence. Significance of these isolated specimens must be evaluated on a case-by-case basis, and is usually dependent on the age of the bedrock, nature of previous discoveries in that formation, and preservation of the specimen. For example, discovery of an identifiable isolated element or tooth in a formation that has produced little fossil material would likely be significant.

Vertebrate microfossil localities (i.e., microsites) are concentrations of small pieces of disarticulated material that are usually more resistant to weathering and transport (e.g., teeth, scales, scutes, and compact bone) (Rogers and Kidwell 2000). Although microsites can contain material solely from microvertebrates, they often produce small pieces of large animals, especially teeth. Collection of fossils from microsites usually involves dry and/or wet screening (Schiebout 1997). Ant mounds have also proven to be good places to recover fossils specimens, as harvester ants utilize small fossils to armor their mounds (Matthias and Carpenter 2004). One area famous for this type of fossil concentration is the Bug Creek Anthills in McCone County, which was designated as a National Natural Landmark in 1966. As Matthias and Carpenter (2004) have demonstrated in their ant experiment however, ant mounds are likely to contain a mixture of material from different horizons since the ants not only collect surface material but also bring up subsurface material for mound armoring.

Generally speaking, microsites represent time averaged deposits (Rogers and Kidwell 2000). Abrasion experiments have shown that the presence of unabraded enamel-coated teeth in a deposit should not be used as an indicator of minimal transport and reworking, since transport does not cause rapid or extensive changes (Argast et al. 1987). Although microsites are great for providing a sample of the different species living during a segment of time, they usually cannot be used to reconstruct ancient community structure (Bryant 1989).

Bone beds are bone-bearing horizons that record either the sequential accumulation of skeletal elements through time or their reworking and concentration by hydrodynamic processes. They can contain a wide variety of species or predominantly one species, and remains can be disarticulated, partially articulated, or fully articulated.

Complete individual skeletons are relatively uncommon in the fossil record. In order for the skeleton of an animal to be preserved, the carcass must be buried by sediment before scavengers and weathering have a chance to remove limbs or otherwise damage elements. Complete articulated skeletons are usually found by themselves, and skin impressions can often be found in the matrix surrounding the bones (Horner 2001). Many processes can affect an animal after it dies, and reconstructing these processes by looking for clues on the bones and in the deposits is the focus of taphonomy. Taphonomy also plays an important role in interpreting other site/locality types, such as microsites and bone beds. As a result of all the different processes that can potentially occur, skeletons of individuals are rarely completely preserved. The bones of a single individual are often slightly disarticulated before burial. When the bones are found in very close proximity to one another, and are of the right size and number for a single individual, it is termed an associated skeleton. Individual skeletons are often described in conjunction with a completeness percentage (e.g., 50 percent complete indicates half of the skeletal elements are present).

**Other Fossil Material**

Non-vertebrate fossils can occur alone or in association with vertebrate remains, and include invertebrates, plants, and trace fossils. Invertebrates allow inference of depositional environment and often serve as index fossils (Gill and Cobban 1973). Plant fossils occur as leaf compressions and impressions, petrified wood, seeds, cones, spores, pollen, and amber (Tidwell 1998). Plants can indicate climatic conditions and provide a glimpse of vegetative material available for consumption by herbivores. Trace fossils include plant casts and molds (e.g., root casts, seed molds), invertebrate and vertebrate traces, fossilized feces (coprolite), and eggshell (Donovan 1994). These traces can be used to infer presence of plants, invertebrates, or vertebrates whose physical remnants are absent or poorly preserved (Kvale et al. 2001). Trace fossils also provide a glimpse of animal behavior, "...where the interaction between a living animal and its environment leaves a permanent record" (Varricchio et al. 1999:92). Root and invertebrate traces can play a role in determining depositional environment (Flight 2004). Footprints can reveal the existence of particular vertebrates in the absence of their body fossils, and trackways have been used to infer travel routes and speeds, among other things (Kvale et al. 2001). Coprolites vary in composition depending on their producer, and can be important for elucidating interspecific relationships (Chin and Gill 1996; Chin et al., 2003). For example, identification of herbivorous dinosaur coprolites in western Montana allowed linkage of members of the Cretaceous food web: herbivorous dinosaurs, conifers, and dung beetles (Chin and Gill 1996). As well, two tyrannosaurid coprolites have been identified in Upper Cretaceous rocks of southern Canada, and one of these contains undigested muscle tissue in addition to bone fragments (Chin et al. 1998; Chin et al., 2003). Fossil eggshell can occur as fragments or in the form of complete eggs. Intact eggs can contain vertebrate remains (embryonic skeletons) (Varricchio et al. 2002), and clutches of eggs may be associated with nesting traces (Varricchio et al. 1999). Although microstructure can indicate general taxonomic affinities, definitive assignment of an egg to a particular genus and species can only occur when associated embryos or hatchlings are present (Hirsch 1989).

**Cretaceous-Tertiary (K-T) Boundary: End Of The Age Of Dinosaurs**

The Cretaceous-Tertiary (K-T) boundary in the terrestrial rock record is well exposed in only a few geographic areas globally (Archibald 1997; Clemens 2002). The best of these stratigraphic sections is, by far, in Garfield and McCone counties south of Fort Peck Reservoir on the Missouri River. The K-T boundary dates to ~65 million years ago at the end of the Cretaceous Period. Several Late Cretaceous events are known to have occurred, and these include: mass extinction, Western Interior Cretaceous Seaway regression, meteorite impact, and volcanism. Examination of the fossil record across the K-T boundary is important for characterizing changes in fauna and flora. Over 80 different hypotheses have been put forth to explain the Late Cretaceous mass extinction event, but the majority of these are not testable or falsifiable (Archibald 1997). Whatever caused the mass extinction, one thing is for certain: the extinction event was selective and non-random (Archibald 1997; Clemens 2002). Dinosaurs, pterosaurs, most marsupials, some lizards, some sharks, and many invertebrates are absent from the fossil record in Tertiary System rocks (Archibald 2002). However, some animals survived including amphibians, bony fish, turtles, crocodiles, champsosaurs, some mammals, and some birds (Archibald 2002; Bryant 1989).

The nature of the K-T boundary has been and continues to be the focus of numerous articles in the scientific literature (e.g., Archibald 1997, 2002; Clemens 2002; Clemens et al. 1992; Fastovsky and Sheehan 2005; Hurlbert and Archibald 1995; Retallack et al. 1986; Sheehan and Fastovsky 1992; Sheehan et al. 1991; Sheehan et al. 1996; Sloan et al. 1986; Williams 1994; Wolfe and Upchurch 1986). It is beyond the scope of this report to analyze data and conclusions in this huge body of literature, however the three most accepted and best-supported theories are briefly outlined below. Debate continues regarding the rate of the mass extinction (i.e., gradual versus sudden). These theories are referred to as seaway regression, meteorite impact, and volcanism (Archibald 2002). Given that there is good evidence for all three of these events, it seems the most parsimonious explanation as to what caused the mass extinction and global changes at the end of the Cretaceous Period would be a combination of them all.

Seaway Regression Theory

During the Cretaceous Period, the Western Interior Cretaceous Seaway bisected North America from north to south. At the end of the Cretaceous, this seaway began to shrink as global sea level fell (Archibald 2002). Dinosaurs and other animals living along the coast of the seaway (in what is now eastern Montana) would have had less coastal habitat to occupy. In addition, exposure of land bridges between continents provided opportunities for immigration of new animals into North America. Disappearance of the interior seaway would have caused the tropical to subtropical climate present in the Cretaceous Period to become more seasonal in the Tertiary Period (Archibald 2002). In addition, Tertiary depositional environments reflect "...a rise in the water table and a dramatic increase in the amount of standing water" (Clemens 2002:222). These changes in habitat distribution and overall climate, in addition to the newly immigrated fauna, could have all contributed to the mass extinction (Archibald 2002; Clemens 2002).

Meteorite Impact Theory

A rare element called iridium is often present in the rock layers at the K-T boundary (Archibald 2002). Iridium is generated by meteorite impact events, but can also be produced by volcanoes. Furthermore, a large meteorite impact scar called the Chicxulub Crater has been identified off the coast of Central America. The impact of a meteor with the earth would have blasted large amounts of dust and debris into the atmosphere, darkening the sky, affecting plants, and potentially initiating a change in climate. Researchers have inferred that a significant loss in the plant community would have adversely affected herbivores, and consequently carnivores (Archibald 2002).

Volcanism Theory

Volcanic activity is well documented in western North America during the Cretaceous Period. However, the volcanic field central to this theory is located in India and referred to as the Deccan Traps (Archibald 2002). Near the end of the Cretaceous Period, this volcanic field started producing large amounts of basaltic lava. Although eruptions of this composition are more fluid than explosive, they still would have produced dust particles, increasing the amount of particulate matter in the earth's atmosphere. It is postulated that these eruptions caused a shift in the climate, and perhaps the dinosaurs (and some of the other Cretaceous animals) could not tolerate such a change (Archibald 2002).

## Distribution Of Paleontological Sites/Localities And Fossils In Eastern Montana

Paleontological Site/Locality Distribution

A total of 1929 paleontological sites/localities are included in the ACRCS data base. Table 13 shows the distribution of these sites/localities by geologic formation and county, whereas Table 14 shows site/locality distribution by landowner and county. The distribution of paleontological sites/localities by county is as follows: Garfield = 811 (42%); Carter = 433 (22.5%); Dawson = 242 (12.5%); McCone = 231 (12%); Powder River = 71 (3.7%); Treasure = 37 (1.9%); Rosebud = 26 (1.3%); Daniels = 25 (1.3%); Fallon = 15 (<1%); Custer = 14 (<1%); Prairie = 12 (<1%); Big Horn = 5 (<1%); Richland = 2 (<1%); Valley = 2 (<1%); Wibaux 2 (<1%); and Sheridan = 1 (<1%). No sites/localities were documented in

Roosevelt County. The distribution of sites/localities by geologic unit is: Hell Creek Formation = 1543 (80%); Fort Union Formation/Group = 271 (14%); Pierre Shale = 29 (1.5%); Flaxville Formation = 28 (1.4%); Pleistocene deposits = 17 (<1%); Chadron-Brule formations (White River Group) = 7 (<1%); Quaternary deposits = 6 (<1%); Greenhorn Formation = 5 (<1%); Arikaree Formation = 4 (<1%); Bearpaw Shale = 4 (<1%); Fox Hills Formation = 4 (<1%); Montana Group (undivided) = 3 (<1%); Wasatch Formation = 3 (<1%); Belle Fourche Shale = 2 (<1%); Carlile Shale = 2 (<1%); and Colorado Group (undivided) = 1 (<1%). No sites/localities were documented in the Newcastle Sandstone, Mowry Shale, Niobrara Formation, Telegraph Creek Formation, Eagle Sandstone, Claggett Shale, Judith River Formation, Rimroad gravel, Cartwright gravel, or Crane Creek gravel. The paleontological site/locality distribution by landowner type is: BLM = 1440 (75%); Private = 278 (14.4%); State owned = 128 (6.6%); Other state owned = 25 (1.3%); USDA Forest Service = 7 (<1%); Army Corps of Engineers = 1 (<1%); Other federal owned = 1 (<1%); and Combination (State owned and BLM) = 1 (<1%). Landowner information for 48 of the sites/localities (2.5%) is unavailable due to ambiguity of legal descriptions.

As previously mentioned, the USFWS requested that their paleontological localities be excluded from this overview, and thus the 294 sites/localities within the boundaries of the Charles M. Russell National Wildlife Refuge near Fort Peck Lake in Garfield and McCone counties were removed from the ACRCS data base. The USFWS sites/localities are distributed by county as follows: Garfield = 237 (81%) and McCone = 57 (19%). Bedrock for 271 (92%) of the localities is the Hell Creek Formation, and the remaining 24 localities (8%) occur in the Tullock Formation (Fort Union Group). No paleontological sites/localities on USFWS land outside the Charles M. Russell National Wildlife Refuge were encountered during data collection, and no paleontological localities were recorded on tribal lands.

Approximately 95% of the 1929 paleontological sites/localities in the Miles City Field Office unit occur in Garfield, Carter, Dawson, McCone, Powder River, and Treasure counties. The Hell Creek Formation is the most fossiliferous unit in the project area, and it forms the bedrock at 80% (1543) of the documented sites/localities (Table 13). The Fort Union Formation/Group contains 14% (271) of the documented sites/localities, with at least 74% of these occurring in the Tullock Member/Formation. The occurrence of paleontological sites/localities in Garfield, Carter, Dawson, McCone, Powder River, and Treasure counties parallels the overall geologic formation distribution, and most of the sites/localities in these six counties occur in the Hell Creek and Fort Union formations.

Vertebrate Versus Non-Vertebrate Sites/Localities

Vertebrate fossils are the main focus of this overview and data collection efforts concentrated on assimilating information for localities that have produced vertebrate remains. Even so, some non-vertebrate fossil sites/localities, where invertebrate, plant, and/or trace fossils occur, are included. Note that these distributions do not accurately portray the number and type of non-vertebrate localities in each formation, since vertebrate localities were the primary targets during data collection.

**Table 13. Distribution of paleontological sites/localities by formation and county in the project area.**
County abbreviations: BH - Big Horn, CT - Carter, CR - Custer, DN - Daniels, DW - Dawson, FA - Fallon, GF - Garfield, MC - McCone, PR - Powder River, PE - Prairie, RL - Richland, RV - Roosevelt, RB - Rosebud, SH - Sheridan, TE - Treasure, VL - Valley, and WX - Wibaux. Note that only portions of Big Horn and Valley counties are included in the study area.

| ▼FORMATION | COUNTY | | | | | | | | | | | | | | | | | ▼TOTAL (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BH | CT | CR | DN | DW | FA | GF | MC | PR | PE | RL | RV | RB | SH | TE | VL | WX | |
| **Newcastle** | | | | | | | | | | | | | | | | | | **—** |
| **Mowry** | | | | | | | | | | | | | | | | | | **—** |
| **Belle Fourche** | | 2 | | | | | | | | | | | | | | | | **2 (<1)** |
| **Greenhorn** | | 4 | | | | | 1 | | | | | | | | | | | **5 (<1)** |
| **Carlile** | | 1 | | | | | 1 | | | | | | | | | | | **2 (<1)** |
| **Niobrara** | | | | | | | | | | | | | | | | | | **—** |
| **Colorado*** | | 1 | | | | | | | | | | | | | | | | **1 (<1)** |
| **Pierre** | | 24 | | | | 2 | | | | | | | | | | | | **29 (1.5)** |
| **Telegraph Ck.** | | | | | | | | | | | | | | | | | | **—** |
| **Eagle** | | | | 3 | | | | | | | | | | | | | | **—** |
| **Claggett** | | | | | | | | | | | | | | | | | | **—** |
| **Judith River** | | | | | | | | | | | | | | | | | | **—** |
| **Bearpaw** | | | | | | | 1 | | | | | | 1 | | 2 | | | **4 (<1)** |
| **Fox Hills** | | | | | | | | | | | | | 1 | | | | | **4 (<1)** |
| **Montana*** | | | | | | | | | | | | | | | | | | **3 (<1)** |
| **Hell Creek** | | 380 | 3 | 3 | 221 | 8 | 656 | 198 | 46 | | | | | | 30 | | 1 | **1543 (80)** |
| **Fort Union** | 1 | 10 | 7 | 3 | 10 | 5 | 152 | 29 | 21 | 10 | | | 21 | | 5 | | | **271 (14)** |
| **Wasatch** | 3 | | | | | | | | | | | | | | | | | **3 (<1)** |
| **Chadron-Brule** | | 5 | | | | | | | | | | | | | | | | **5 (<1)** |
| **Brule** | | 2 | | | | | | | | | | | | | | | | **2 (<1)** |
| **Arikaree** | | 4 | | | | | | | | | | | | | | | | **4 (<1)** |
| **Rimroad*** | | | | | | | | | | | | | | | | | | **—** |
| **Flaxville** | | | | 25 | | | | | | 1 | | | | | | 2 | | **28 (1.4)** |
| **Pleistocene*** | 1 | | 4 | | 2 | | | 2 | 1 | | | | 3 | 1 | | | 1 | **17 (<1)** |
| **Holocene*** | | | | | | | | | | | | | | | | | | **—** |
| **Quaternary*** | | | | | | | | 2 | 3 | 1 2 | | | | | | | | **6 (<1)** |
| **►TOTAL (%)** | **5 (<1)** | **433 (22.5)** | **14 (<1)** | **25 (1.3)** | **242 (12.5)** | **15 (<1)** | **811 (42)** | **231 (12)** | **71 (3.7)** | **12 (<1)** | **2 (<1)** | **—** | **26 (1.3)** | **1 (<1)** | **37 (1.9)** | **2 (<1)** | **2 (<1)** | **1929** |

*not formation rank (i.e., Colorado Group, Montana Group, Rimroad gravel, Pleistocene deposits, Holocene deposits, Quaternary deposits).

**Table 14. Distribution of paleontological sites/localities by landowner and county in the project area.**
Landowner abbreviations: BLM - Bureau of Land Management; Corps of Eng - Army Corps of Engineers; and Forest Serv - USDA Forest Service. County abbreviations: BH - Big Horn, CT - Carter, CR - Custer, DN - Daniels, DW - Dawson, FA - Fallon, GF - Garfield, MC - McCone, PR - Powder River, PE - Prairie, RL - Richland, RV - Roosevelt, RB - Rosebud, SH - Sheridan, TE - Treasure, VL - Valley, and WX - Wibaux. Note that only portions of Big Horn and Valley counties are included in the study area.

| ▼LANDOWNER | COUNTY | | | | | | | | | | | | | | | | | ▼TOTAL (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BH | CT | CR | DN | DW | FA | GF | MC | PR | PE | RL | RV | RB | SH | TE | VL | WX | |
| **BLM** | | 389 | 4 | | 201 | 9 | 544 | 208 | 46 | 12 | | | 19 | | | | 1 | **1440 (75)** |
| **Corps of Eng** | | | | | | | | 1 | | | | | | | | | | **1 (<1)** |
| **Forest Serv** | | 5 | | | | | | | | | | | 2 | 7 | | | | **7 (<1)** |
| **Other federal** | | | 1 | | | | | | | | | | | | | | | **1 (<1)** |
| **Private** | 3 | 26 | 6 | 10 | 14 | 5 | 146 | 13 | 22 | | 1 | | 3 | | 28 | 1 | | **278 (14.4)** |
| **State owned** | | | 2 | 4 | 2 | | 110 | 4 | 1 | | | | | | 2 | | | **128 (6.6)** |
| **Other state** | | | | | 21 | | 3 | 1 | | | | | | | | | | **25 (1.3)** |
| **Combination** | 3 | 1 | | | | | | | | | | | | | | | | **1 (<1)** |
| **No data** | 2 | 9 | 1 | 11 | 4 | 1 | 8 | 4 | 2 | | 1 | | 2 | 1 | | 1 | 1 | **48 (2.5)** |
| **►TOTAL (%)** | **5 (<1)** | **433 (22.5)** | **14 (<1)** | **25 (1.3)** | **242 (12.5)** | **15 (<1)** | **811 (42)** | **231 (12)** | **71 (3.7)** | **12 (<1)** | **2 (<1)** | — | **26 (1.3)** | **1 (<1)** | **37 (1.9)** | **2 (<1)** | **2 (<1)** | **1929** |

*State owned and BLM

Of the 1929 documented sites/localities, 1805 are vertebrate fossil localities and 124 are non-vertebrate sites/localities. The non-vertebrate sites/localities include 68 plant, 51 invertebrate, 1 plant and invertebrate, and 4 trace fossil. Table 15 shows the distribution of vertebrate versus non-vertebrate sites/localities recorded for each formation, which is as follows: Hell Creek Formation = 1496/47 (vertebrate/non-vertebrate); Fort Union Formation = 230/41; Pierre Shale = 11/18; Flaxville Formation = 28/0; Pleistocene deposits = 17/0; Chadron-Brule formations = 7/0; Quaternary deposits = 6/0; Greenhorn Formation = 2/3; Arikaree Formation = 4/0; Bearpaw Shale = 2/2; Fox Hills Formation = 0/4; Montana Group (undivided) = 0/3; Wasatch Formation = 1/2; Belle Fourche Shale = 0/2; Carlile Shale = 0/2; and Colorado Group (undivided) = 1/0. No sites/localities were documented in the Newcastle Sandstone, Mowry Shale, Niobrara Formation, Telegraph Creek Formation, Eagle Sandstone, Claggett Shale, Judith River Formation, Rimroad gravel, Cartwright gravel, or Crane Creek gravel. The Montana Group localities occur in either the Pierre Shale or Fox Hills Formation, and the Colorado Group locality occurs in either the Belle Fourche Shale or Mowry Shale. Further analysis of the 230 vertebrate sites/localities in the Fort Union shows that 179 of these occur in the Tullock Member/Formation (Table 15).

Types Of Fossils By Formation

Each formation contains its own suite of fossil types, and these are summarized in several different ways. Table 10 shows the characteristic fossil types for each formation, and is based on reported occurrences within or adjacent to the project area. Table 11 also summarizes fossil types for each formation, but is based on the 1929 sites/localities documented in the ACRCS data base. Table 16 combines these two data sets and shows fossil types reported to occur in a formation (i.e., expected occurrence) along with fossil types documented during this study within the Miles City Field Office unit (i.e., documented occurrence). Expected occurrences are discussed in more detail elsewhere in this report, but will be mentioned here when necessary.

Although no sites/localities were documented in the Lower Cretaceous Newcastle Sandstone during the present study, occasional plant fossils, invertebrates, fragmentary wood, and a dinosaur bone fragment are reported. The potential for discovery of fossils in this unit is low, and the probability that those fossils would be considered significant is also low. These ratings reflect the relatively high energy depositional conditions that were present during its accumulation, as it formed along the shoreline of the Cretaceous seaway.

Localities are not documented for the Lower-Upper Cretaceous Mowry Shale within the study unit, but characteristic fossils include fish, marine reptiles, a rare crocodile, and scarce ammonites. Invertebrate fossils are documented for the overlying Upper Cretaceous Belle Fourche Shale, whereas marine reptile and fish remains are reported for this unit in northeastern Wyoming.

**Table 15. Number of vertebrate and non-vertebrate sites/localities documented for each geologic unit in the Miles City Field Office unit.**

Non-vertebrate fossil sites/localities are localities that have only produced invertebrate, plant, and/or trace fossils. Note that many of the vertebrate sites/localities also contain non-vertebrate material. An asterisk (*) indicates that the locality type is reported to occur within or adjacent to the project area, despite its absence in the data base. Abbreviations: Fm – Formation; Grp – Group; Invert – Invertebrate; Mbr – Member; Non-vert – Non-vertebrate; Sh – Shale; Ss – Sandstone; Vert – Vertebrate.

| STRATIGRAPHIC UNIT | VERT LOCALITIES | NON-VERT LOCALITIES | TYPE OF NON-VERT (# of localities ) | TOTAL # LOCALI-TIES |
|---|---|---|---|---|
| Hell Creek Fm (Upper Cretaceous) | 1496 | 47 | Plant(30)<br>Invert(13)<br>Trace(4) | 1543 |
| Tullock Mbr/Fm of the Fort Union Fm/Grp (Tertiary, Paleocene) | 179 | 22 | Plant(20)<br>Invert(1)<br>Plant & Invert(1) | 201 |
| Fort Union Fm/Grp excluding Tullock Mbr/Fm (Tertiary, Paleocene) | 51 | 19 | Plant(13)<br>Invert(6) | 70 |
| Pierre Sh (Upper Cretaceous) | 11 | 18 | Invert(18) | 29 |
| Flaxville Fm (Tertiary, Miocene-Pliocene) | 28 | | | 28 |
| Pleistocene deposits | 17 | | | 17 |
| Chadron Fm-Brule Fm of the White River Grp (Tertiary, Oligocene) | 7 | * | | 7 |
| Quaternary deposits | 6 | | | 6 |
| Greenhorn Fm (Upper Cretaceous) | 2 | 3 | Invert(3) | 5 |
| Arikaree Fm (Tertiary, Miocene) | 4 | | | 4 |
| Bearpaw Sh (Upper Cretaceous) | 2 | 2 | Invert(2) | 4 |
| Fox Hills Fm (Upper Cretaceous) | * | 4 | Plant(4) | 4 |
| Montana Grp (Upper Cretaceous) | | 3 | Invert(3) | 3 |
| Wasatch Fm (Tertiary, Eocene) | 1 | 2 | Plant(1)<br>Invert(1) | 3 |
| Belle Fourche Sh (Upper Cretaceous) | * | 2 | Invert(2) | 2 |
| Carlile Sh (Upper Cretaceous) | * | 2 | Invert(2) | 2 |
| Colorado Grp (Lower-Upper Cretaceous) | 1 | | | 1 |
| Newcastle Ss (Lower Cretaceous) | * | * | | 0 |
| Mowry Sh (Lower-Upper Cretaceous) | * | * | | 0 |
| Niobrara Fm (Upper Cretaceous) | * | * | | 0 |
| Telegraph Ck Fm (Upper Cretaceous) | | * | | 0 |
| Eagle Ss (Upper Cretaceous) | * | * | | 0 |
| Claggett Sh (Upper Cretaceous) | * | * | | 0 |
| Judith River Fm (Upper Cretaceous) | * | * | | 0 |
| Rimroad gravel (Tertiary, Oligocene-Miocene) | | | | 0 |
| Cartwright gravel (Quaternary, Pleistocene) | * | | | 0 |
| Crane Creek gravel (Quaternary, Pleistocene) | | | | 0 |
| **TOTALS** | **1805** | **124** | **Plant(68)<br>Invert(51)<br>Plant&Invert(1)<br>Trace(4)** | **1929** |

**Table 16. Documented (●) and expected occurrence (○) of fossil types in each of stratigraphic unit.**
Documented occurrence is based on sites/localities recorded in the ACRCS data base, whereas expected occurrence is based on material reported to occur within or adjacent to the project area. Fish category includes cartilagenous (e.g., sharks, rays) and bony fish. Reptile category includes lizards, turtles, snakes, crocodilians, champsosaurs, marine reptiles, and flying reptiles. Vertebrate column is for unspecified or unidentified remains. Abbreviations: Fm – Formation; Grp – Group; Sh – Shale; and Ss – Sandstone.

| ▼STRATIGRAPHIC UNITS | FOSSIL TYPES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Trace | Plant | Invertebrate | Fish | Amphibian | Reptile | Dinosaur | Bird | Mammal | Vertebrate |
| Quaternary deposits | | | | | | | | | ●○ | ● |
| Pleistocene deposits | | ● | | | | | | | ● | |
| Crane Creek gravel | | | | | | | | | | |
| Cartwright gravel | | | | | | | | | | |
| Flaxville Fm | | | | ●○ | | | | | ●○ | |
| Rimroad gravel | | | | | | | | | | |
| Arikaree Fm | | | | ● | | | | ● | ●○ | ○ |
| Chadron-Brule Fm | | ○ | ○ | | | ● | | | ●○ | ●○ |
| Wasatch Fm | | ●○ | ●○ | | | | | | ●○ | ○ |
| Fort Union Fm | ○ | ●○ | ●○ | ●○ | ●○ | ●○ | ● | ●○ | ●○ | ● |
| Hell Creek Fm | ●○ | ●○ | ●○ | ●○ | ●○ | ●○ | ●○ | ●○ | ●○ | ● |
| Montana Grp | | | ● | | | | | | | |
| Fox Hills Fm | ○ | ●○ | ○ | ○ | | | | | | |
| Bearpaw Sh | | | ●○ | ○ | | ●○ | ○ | | | ● |
| Judith River Fm | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | |
| Claggett Sh | | ○ | ○ | | | ○ | ○ | | | |
| Eagle Ss | ○ | ○ | ○ | ○ | | | ○ | | | |
| Telegraph Creek Fm | | | ○ | | | | | | | |
| Pierre Sh | | | ●○ | ●○ | | ●○ | | | | ● |
| Colorado Grp | | ● | | | | | | | | ● |
| Niobrara Fm | | | ○ | | | ○ | | | | |
| Carlile Sh | ○ | ○ | ●○ | ○ | | ○ | | | | |
| Greenhorn Fm | | | ●○ | ●○ | | | | | | ● |
| Belle Fourche Sh | | | ●○ | ○ | | ○ | | | | |
| Mowry Sh | | | ○ | ○ | | ○ | | | | |
| Newcastle Ss | | ○ | ○ | | | | ○ | | | |

At a locality in southernmost Carter County where bedrock is either Belle Fourche Shale or Mowry Shale (Vuke, Wilde, Colton, and Bergantino 2001), vertebrate material and possible plant fossils are documented and coded in the ACRCS data base as Colorado Group (undivided). Isolated vertebrate fossils have been observed here, along with what appear to be numerous petrified tree stumps (Steve Platt, personal communication with Rebecca Hanna, June 3, 2005).

There are no documented occurrences of petrified wood in either the Mowry or Belle Fourche shales, and although transported pieces of wood can be preserved in marine settings, the presence of in situ petrified stumps would be an extremely important paleoenvironmental indicator. Another possibility is that these features are actually concretions, which are more resistant to weathering than surrounding bedrock and might replicate the appearance of fossilized stumps. Additionally, many of the concretions in the Belle Fourche Shale weather to colors similar to those commonly observed in petrified wood, such as brown, red, grayish red, and dark purplish red (Robinson et al. 1964). In any case, the presence of vertebrate remains is significant as no vertebrate fossils have been specifically documented for either of these formations within the study area. Although fossil potential for the Mowry Shale is low, there is a high probability that the material would be considered significant. The Belle Fourche Shale has moderate fossil potential and significance probability.

Documented fossil types in the Upper Cretaceous Greenhorn Formation include invertebrates, unspecified vertebrate remains, and shark teeth. Abundant but fragmentary invertebrates (bivalves and ammonites) occur in some parts of the formation, and fish remains are also reported. The Greenhorn Formation is rated as having moderate fossil potential and significance probability.

Although invertebrates are the only fossil type documented for the Upper Cretaceous Carlile Shale in the project area, remains of cartilaginous fish (i.e., shark teeth, a ray), bony fish, turtles, marine reptiles, carbonized wood, and petrified wood have been found in adjacent states. This unit has a moderate potential to produce fossil remains, which have a high probability of being significant.

No fossil localities are documented for the Upper Cretaceous Niobrara Formation in the study area, even though invertebrates and mosasaur remains are reported to occur. This formation has a low potential for producing fossil material, but there is a high probability that its fossils would be considered significant.

As discussed in the *Geology, Paleontological Review of Formations, and Lithic Resources* section of this report, the Upper Cretaceous Pierre Shale is a thick marine deposit exposed in eastern-most Montana, which is laterally equivalent to a sequence further west that includes almost the entire Montana Group (i.e., Telegraph Creek Formation, Eagle Sandstone, Claggett Shale, Judith River Formation, and Bearpaw Shale). Documented fossils for the Pierre Shale in the study area include invertebrates, shark teeth and scales, bony fish, marine reptiles, and unspecified vertebrate remains. Fossil potential for the Pierre Shale is moderate, and significance probability is rated as high.

No fossils are documented in the project area for the Upper Cretaceous Telegraph Creek Formation, Eagle Sandstone, Claggett Shale, or Judith River Formation. Expected fossil occurrences for these formations include: invertebrate fossils for the Telegraph Creek Formation; trace, plant, invertebrate, shark, and dinosaur fossils for the Eagle Sandstone; plant, invertebrate, champsosaur, and dinosaur fossils for the Claggett Shale; and trace, plant, invertebrate, fish, amphibian, reptile, dinosaur, bird, and mammal fossils for the Judith River Formation.

Despite the lack of documented localities for the Miles City Field Office unit, the Judith River Formation is still considered to have a moderate potential for producing fossil material, with a high probability the fossils would be considered significant. For the Claggett Shale, fossil potential and significance probability are both rated as moderate. The Eagle Sandstone has low fossil potential and significance probability, which reflect the high energy, nearshore depositional regime present during its formation in the Late Cretaceous. The Telegraph Creek Formation also has a low fossil potential, but is rated as moderate for significance probability.

Documented fossils for the Upper Cretaceous Bearpaw Shale include invertebrate and marine reptile remains. Marine reptiles (mosasaurs, plesiosaurs), shark teeth, marine turtles, mollusks, and even dinosaurs are reported for the Bearpaw Shale outside the Miles City Field Office unit. Given these occurrences, the Bearpaw Shale is considered to have moderate fossil potential and high significance probability.

Plant fossils are documented in the Upper Cretaceous Fox Hills Formation, and other fossil types that may be present include invertebrates, fish, and trace fossils. Several invertebrate localities in the Cedar Creek Anticline of Dawson County are documented and occur in either the Pierre Shale or Fox Hills Formation. These are coded as Montana Group (undivided) in the ACRCS data base since a more specific geologic unit was not indicated in the source data. Fossil potential and significance probability for the Fox Hills Formation are rated as low, and as with the Newcastle and Eagle sandstones, these ratings reflect the relatively high energy depositional conditions present during its accumulation in a shoreline environment.

Documented and reported fossil types for the Upper Cretaceous Hell Creek Formation include trace, plant, invertebrate, amphibian, bird, champsosaur, crocodile, dinosaur, fish, lizard, mammal, other reptile, snake, and turtle. This formation has a high fossil potential, and there is a high probability that its fossils would be considered significant.

Given that the majority of the sites/localities documented for the Paleocene Fort Union Formation/Group occur in the Tullock Member/Formation, this unit is considered on its own. Documented fossil types in the Tullock include plant, invertebrate, amphibian, bird, champsosaur, crocodile, dinosaur, fish, lizard, mammal, other reptile, and turtle. The fossil potential for Tullock Member/Formation is rated as moderate, and its fossils are given a high significance probability. Documented fossil types in the remainder of the Fort Union Formation/Group (i.e., excluding the Tullock Member/Formation but including the Ludlow

Member, which is equivalent to the Tullock and Lebo members) include: plant, invertebrate, amphibian, champsosaur, crocodile, fish, mammal, other reptile, and turtle. Trace fossils are also reported to occur. In absence of the Tullock, the Fort Union has moderate fossil potential and significance probability.

Exposures of the Eocene Wasatch Formation in the study area are documented to contain plant, invertebrate, and mammal remains. Fossil potential and significance probability for the Wasatch are both considered to be moderate.

Turtle, mammal, and vertebrate fossils are documented for the Oligocene White River Group (Chadron-Brule formations, undivided), which is also reported to contain plants and invertebrates. The Brule Formation reportedly contains diverse and abundant vertebrates, and thus is given separate fossil potential and significance probability ratings of moderate and high, respectively. The underlying Chadron Formation has low fossil potential, but high significance probability.

In the Miles City Field Office unit, the Miocene Arikaree Formation has produced fish, bird, and mammal fossils. This formation has a low fossil potential, but there is a high probability that its fossils would be considered significant.

Four gravel-capped benches (Rimroad, Flaxville, Cartwright, and Crane Creek) are present in the northern part of the Miles City Field Office unit. The oldest of these is the Oligocene-Miocene (?) Rimroad, for which no fossils are documented or reported. Fish and mammal fossils have been collected from the Flaxville Formation, which is thought to be late Tertiary (Miocene-Pliocene) in age. Although no fossils are documented for the Pleistocene Cartwright gravel, fossilized mammal bones are reported to occur in a unit that is probably its equivalent, the Wiota gravel. No fossils are documented or reported for the Pleistocene Crane Creek gravel. Due to their coarse grained nature, the fossil potential and significance probability for the Rimroad, Cartwright, and Crane Creek gravels, as well as portions of the Flaxville Formation (i.e., south of the Missouri River), are rated as low. The vast majority of fossil localities in the Flaxville Formation occur north of the Missouri River, where finer grained deposits that formed in lower energy conditions are present. In this area, the Flaxville Formation is considered to have moderate fossil potential and significance probability.

Pleistocene deposits in the study area are documented to contain plant remains and mammal fossils. Although the fossil potential for these deposits is low, the likelihood that the fossils would be considered significant is high.

Quaternary deposits include undivided Pleistocene- and Holocene-age sediments, in which mammals are documented and unspecified vertebrate remains are reported to occur. This unit has low fossil potential and moderate significance probability.

**Types Of Surveys, Survey Coverage, And Source Data Limitations**

The majority of paleontological surveys that have occurred in the project area have been academic in nature, and only two reports were encountered that describe the results of surveys initiated by NEPA or FLPMA. These include paleontological inventories of a pipeline corridor through Powder River, Carter, and Fallon counties (Hager and Hooker 1985), and a land exchange in northeastern Garfield County (Harksen 1981).

The pipeline project inventory area described by Hager and Hooker (1985) in Powder River, Carter, and Fallon counties is 138 miles in length and 100 feet wide, crossing from Wyoming into Montana approximately 8-10 miles east of Biddle, and from Montana into North Dakota northeast of Ollie. It also includes several microwave stations. In addition to personal communications and literature review, the inventory includes "...pedestrian inspection of all rock outcrops, ant hills, and nearby outcrops not on the right-of-way" (Hager and Hooker 1985:7). Total acreage surveyed for paleontological resources is not provided. Four fossil localities in the Paleocene Fort Union Formation and three localities in the Cretaceous Pierre Shale are identified and recommended for monitoring during construction activities (Hager and Hooker 1985). A sensitivity analysis based on the probability of discovery of vertebrate remains and the paleontological importance of these resources is included, but details on application of the methodology and determination of management recommendations based on the resource sensitivity are lacking.

Harksen (1981) describes the results of a pedestrian survey of 12,787.62 acres in the Sleeping Giant/Haxby Addition land exchange in Garfield County. This inventory also includes library research and consultation with other paleontologists. One microvertebrate locality is identified in the Paleocene Fort Union Group and recommended for further data collection (Harksen 1981).

Paleontological data assimilated for this project are derived from field surveys that by their very nature are non-comparable as they are driven by the research goals of the particular institution overseeing field work. Field projects are usually limited by time and money, and thus often concentrate on areas or formations that are known to be fossiliferous. Given the distribution of sites/localities according to geologic formation described above, it seems apparent that the Hell Creek and Fort Union formations have been more frequently chosen for prospecting and exploration. This apparent predilection is probably a reflection of fossil abundance. For example, researchers more often choose to prospect the Hell Creek Formation rather than the Fox Hills Formation because the former consistently produces abundant vertebrate material.

Two other characteristics that make an area attractive for prospecting are accessibility and bedrock exposure. Thus, inaccessible areas or poorly exposed formations have not been as thoroughly explored, and such areas are likely underrepresented in this overview. Even so, these types of areas may have good to excellent potential for producing significant fossil material. Assignment of a formation-wide paleontological resource sensitivity rating helps circumvent these limitations to some extent.

As described in the methodology section, the manner in which data was recorded for this project favors sites/localities located on BLM land. Therefore, the distribution of sites/localities by landowner does not accurately portray their actual distribution.

Data collection focused on vertebrate sites/localities and directly reflects various agency policy statements that emphasize the importance of vertebrate over non-vertebrate fossils. This emphasis on vertebrates was also necessary because of time limitations, since inclusion of all reported non-vertebrate fossil sites/localities would double or possibly triple the number of paleontological localities in the study area. Thus, another limitation of this study is that relatively few invertebrate and plant sites/localities were included. The distribution of non-vertebrate fossil sites/localities documented in the project area does not accurately reflect their actual occurrence.

Despite these limitations, the data set and summary results are useful for identifying broad patterns on a formation-wide basis. However, the absence of reported paleontological sites/localities in a particular county or geologic unit should not be used to infer that these areas are barren of fossil material. Some of the aforementioned limitations can be overcome by comparing the types of fossils in each geologic unit that are documented in this overview with the characteristic fossil types reported (Table 16). Along with formation descriptions and site/locality distribution statistics, these data are used to make assessments of fossil potential and significance probability, which are listed for each formation in the preceding section. These two parameters can be combined to determine the paleontological resource sensitivity of each geologic formation or deposit, and this assessment is presented in the following section.

**Synthesis And Management Recommendations**

<u>Paleontological Resource Sensitivity Rating Assessment</u>

Paleontological resource sensitivity ratings have been assigned to each sedimentary formation or deposit exposed at the present-day ground surface in the Miles City Field Office unit, and these are shown on Table 1 along with fossil potential and significance probability. Lithologic descriptions, site/locality distributions (documented), and types of fossils (documented and characteristic) for each geologic unit are used to assess fossil potential and estimate significance probability. As previously described, the sensitivity rating is the intersection of the potential of the unit to contain fossils (i.e., fossil potential), and the probability that those fossils would be considered significant (i.e., significance probability) (Table 1).

Further analysis of the 230 vertebrate sites/localities in the Fort Union Formation/Group shows that the majority of these (i.e., 179) occur in the Tullock Member/Formation (Table 15). Additionally, with the exception of one locality in Prairie County, all of the sites/localities documented for the Flaxville Formation occur north of the Missouri River in Daniels and Valley counties. Given these distributions, the formations were subdivided during assessment of the paleontological resource sensitivity rating into the following categories: Tullock Member/Formation of the Fort Union Formation/Group; Fort Union Formation/Group, excluding the Tullock Member/Formation; Flaxville Formation, north of the Missouri River; and Flaxville Formation, south of the Missouri River. The Chadron and Brule formations of the White River Group (undivided) were also evaluated separately, since the Brule Formation reportedly contains more diverse and abundant vertebrate fossils in comparison to the Chadron.

Seven stratigraphic units in the study area have high paleontological resource sensitivity ratings (see Table 1), and these include: Bearpaw Shale (Upper Cretaceous); Brule Formation of the White River Group (Tertiary, Oligocene); Carlile Shale (Upper Cretaceous); Hell Creek Formation (Upper Cretaceous); Judith River Formation (Upper Cretaceous); Pierre Shale (Upper Cretaceous); and Tullock Member/Formation of the Fort Union Formation/Group (Tertiary, Paleocene). Moderate sensitivity ratings are given to the following units: Arikaree Formation (Tertiary, Miocene); Belle Fourche Shale (Upper Cretaceous); Chadron Formation of the White River Group (Tertiary, Oligocene); Claggett Shale (Upper Cretaceous); Flaxville Formation, north of the Missouri River (Tertiary, Miocene-Pliocene); Fort Union Formation/Group excluding the Tullock Member/Formation (Tertiary, Paleocene); Greenhorn Formation (Upper Cretaceous); Mowry Shale (Lower-Upper Cretaceous); Niobrara Formation (Upper Cretaceous); Pleistocene deposits; Quaternary deposits; Telegraph Creek Formation (Upper Cretaceous); and Wasatch Formation (Tertiary, Eocene). Geologic units with low sensitivity ratings include: Cartwright gravel (Quaternary, Pleistocene); Crane Creek gravel (Quaternary, Pleistocene); Eagle Sandstone (Upper Cretaceous); Flaxville Formation, south of the Missouri River (Tertiary, Miocene-Pliocene); Fox Hills Formation (Upper Cretaceous); Newcastle Sandstone (Lower Cretaceous); and Rimroad gravel (Tertiary, Oligocene-Miocene).

Despite the inherent subjectivity of this method, these paleontological resource sensitivity ratings will be useful for general management decisions and new project planning. For example, the sensitivity of particular geologic units in the Miles City Field Office unit can be used in the preliminary stage of a project to help predict the scope of a paleontological inventory and potential mitigation measures. Requirement of monitoring programs where ground disturbing activities are proposed for geologic strata with moderate or high sensitivity ratings would expedite stabilization and assessment of newly discovered fossils. Although construction delays are an inevitable result of unexpected fossil discoveries, having a specialist on-site would certainly decrease the overall delay time. In addition, if the fossil material is immediately recognized, the chances that it will be damaged beyond recognition are significantly decreased. Units with low sensitivity ratings could potentially be excluded from a monitoring program, but their exclusion should only follow an on-site evaluation and field inventory.

It is important to emphasize that the paleontological resource sensitivity rating is only an estimate, and although it is useful as a predictive planning tool, its application is not intended to preclude field inventories. In addition, significant paleontological resources can still be encountered in units that have been assigned a low sensitivity rating. Finally, publication of new data or discovery of new specimens could also necessitate the revision of a previously assigned rating.

**Recommendations**

Several different types of anthropogenic activities have the potential to adversely impact paleontological resources. These include ground disturbing activities and increased access into remote areas associated with development of new roads. Clemens (1980a: 9-10) identifies four activities that have the potential to "destroy or obliterate" paleontological resources: excavation and construction; agricultural expansion; reservoir filling; and recreational vehicle traffic. Natural erosion, the means by which most fossils are revealed for discovery, may also result in their degradation or complete destruction.

Assuming the material is properly handled and not too damaged, a beneficial result of the aforementioned activities is the discovery of unknown, rare, or significant fossils, which would otherwise go undiscovered (Clemens 1980a; John R. Horner, personal communication with Rebecca Hanna, 2005). Unexpected discovery of specimens may occur in cases where the material is shallowly or deeply buried, or in the absence of a paleontological field inventory prior to project onset. Such accidental discoveries can result in project delays, and would be more efficiently dealt with by on-site monitoring during ground disturbing activities.

Historically, there have been several instances where paleontological resources have been accidentally discovered in Montana. These unexpected discoveries occurred during various ground disturbing activities, including gravel pit excavation, dam emplacement, road building, and pipeline trenching. During normal quarry operations at JTL Gravel Quarry near Belgrade, the first in situ mammoth material (partial lower jaw and teeth) for Gallatin County was discovered (Hill 2001). South of Deer Lodge in Powell County, several important specimens were discovered at the Mastodon Sand and Gravel site including a complete mastodon, camel jaw fragments, and rhinoceros jaw pieces (Honkala 1958). The Doeden Gravel Pit near Miles City in Custer County has produced Pleistocene vertebrates such as musk ox (both tundra and woodland forms), ground sloths, mammoth, mastodon, giant short-faced bear, horse(s), camel, and other ungulates (Wilson and Hill 2000). Remains of extinct late Pleistocene fauna were also recovered during excavations and dredging activities associated with construction of Fort Peck dam in Valley and McCone counties (Davis 1975; Rasmussen 1974). During maintenance of a county road in Dawson County, the most complete mammoth ever found in Montana (i.e., "Lindsay Mammoth") was discovered when the road grader hit its tusk (Davis and Wilson 1985; Hill and Davis 1998). A duck-billed dinosaur skeleton was encountered and mostly destroyed during construction of Interstate 90 near Columbus in Stillwater County (John R. Horner, personal communication with Rebecca Hanna, 2000). During preparation for a proposed road project near Melstone in Musselshell County, the skull and skeleton of a marine reptile (mosasaur) were discovered but heavily impacted by curious visitors before collection could take place (Patrick Leiggi, personal communication with Rebecca Hanna, 2000). Finally, dinosaur remains were encountered near Wolf Creek in Lewis and Clark County during trench excavation for Montana Power Company's 16-inch pipeline, prompting the company to request that their trenching activity be monitored (John R. Horner, personal communication with Rebecca Hanna, 2000).

Road construction and excavation into bedrock or other sedimentary units are activities that have the highest potential to disturb paleontological resources. A field inventory of fossils exposed at the present-day ground surface should occur in project areas underlain by sedimentary rocks and deposits. Recommendations stemming from the inventory might include monitoring of construction of activities, avoidance, or possibly data recovery if adverse impacts to the resource are unavoidable. If geologic deposits known to yield scientifically significant fossils underlie an area slated for ground disturbance, then excavations should be monitored by someone trained to recognize fossil material characteristic of the area. If fossils are discovered during construction, activities should be redirected to avoid adversely affecting the resource until its significance can be assessed. Recommendations regarding further mitigation, if any is warranted, would be made at that time. If an agency chooses not to require a monitoring program, then a protocol should be developed for accidental discovery of fossil material.

Other potential impacts to paleontological resources should be considered during project planning and evaluation. For example, illegal collection or accidental disturbance of fossils may result from increased access into remote areas. Public education efforts or signage might help reduce the potential for theft.

The Cultural Resource Information System (CRIS) data base, which is maintained by Montana SHPO and Archaeological Records at the University of Montana, contains information on cultural, historic, and paleontological sites/localities in Montana. Approximately 800 paleontological sites/localities are currently documented in the CRIS data base statewide, and these localities have been assigned Smithsonian numbers (e.g., 24GF441). Thus, a mildly surprising outcome of the SHPO file search undertaken for this overview was the fact that only 54 of the 1929 documented sites/localities discussed herein possess Smithsonian numbers. The small number of paleontological localities that were located during this file search can be attributed to the following: (1) a concerted effort to add paleontological site/locality data to CRIS began only 5-10 years ago; and (2) very few agencies require the assignment of Smithsonian numbers to paleontological localities. Presently, only the DNRC and SHPO require that Smithsonian trinomials be obtained for paleontological sites/localities in Montana. This requirement and the existence of a standardized form for site/locality recordation (i.e., Paleontological Information System form) provide the basis for the systematic recordation of paleontological sites/localities. Furthermore, if paleontological resource inventories become more frequently required by agencies (and this seems to be the overall trend), paleontological sites/localities will gradually be assigned Smithsonian numbers and entered into the CRIS data base on a project-by-project basis.

This does not solve the problem of the huge body of site/locality data that is generated annually by academic institutions, which are, for the most part, unaware of the utility of having a Smithsonian site/locality number assigned. When approached with this concept, several paleontologists expressed discomfort with the idea of their paleontological locality data being recorded in the CRIS data base. This reluctance stems from the expanding commercial market and public value placed upon fossils. It is also rooted in the relationship that many paleontologists have developed with private landowners, who often prefer to keep things confidential. The commercial collectors, general public, and private landowners are not the only ones at fault however, as there is a high amount of competitiveness in the academic realm, and an institution often needs to keep its locality data confidential to protect a site/locality from being worked (legally or illegally) by another entity. Although this type of activity is less common today than it was during the "bone wars" that took place in the late 1800s between field parties of Edward Drinker Cope and Othniel Charles Marsh, it still does occur. Confidentially concerns can be partially addressed by stipulating that paleontological locality data be entered into the CRIS data base in the same manner as human burials and other sensitive cultural sites are coded. In addition, each page of the Paleontological Information System site form, which is on file at Archaeological Records, could be labeled as confidential. Another option would be for the institution to provide more specific locality information after they are done working a site/locality.

As more agencies begin to require paleontological resource inventories, survey methods will need to become more standardized. After testing and evaluation of several different paleontological survey methods that are statistical and relatively objective, Clemens concludes "...that the quest for an absolutely objective measure of paleontological resources is not a reasonable goal" (1980a:43). After discarding these approaches, Clemens goes on to recommend procedures for evaluating paleontological resources in a given project area, and these are included here with slight modification.

Project direction and final report writing should be overseen by a qualified vertebrate paleontologist (i.e., principal investigator), whereas field crews can include students of paleontology or amateurs skilled in fossil recognition. Prior to field work, geologic overviews, topographic maps, and aerial photos for the project area should be assembled and made available to the survey crew. Prospecting and collection in the project area should be similar to the manner employed by university and museum field parties (Clemens 1980a). This entails inspection of bedrock exposures, documentation of sites/localities, collections of a sample of identifiable fossil material from the surface, and possibly test excavations and/or screening. Major data recovery excavations should always involve taphonomic data collection, the attributes of which are well summarized by Rogers (1995). For example, a stratigraphic section should be measured through or very near the fossil locality before excavation. Additionally, other geologic and biologic data need to be recorded prior to specimen removal (Rogers 1995). After collected specimens are prepared and identified, the principal investigator should compile faunal and floral lists and ascertain the significance of each documented locality. Finally, a paleontological resource sensitivity rating can be assessed for each geologic unit in the project area, and will assist in the development of management recommendations or future project planning.