

APPENDIX E

TECHNICAL REVIEW OF PALEONTOLOGY/GEOLOGY

E-1. Literature Survey

Geologic mapping listed in the References Cited documents at least six different geologic deposits in the Cave Gulch-Bullfrog-Waltman Area. These include, from youngest to oldest: (1) unnamed deposits of late Holocene age, including unconsolidated eolian sands, gravels, alluvium, and colluvium; (2) Wind River Formation of early Eocene age; (3) Fort Union Formation of Paleocene age; (4) Lance/Meeteetse Formation of Latest Cretaceous age; (5) Mesaverde Formation of Late Cretaceous age; and (6) Cody Shale of Cretaceous age.

The Holocene deposits are probably for the most part too young to contain fossils, with the exception that anthills developed on thin Quaternary loess in the area may contain fossils reworked from older formations. The Wind River, Fort Union, Lance/Meeteetse, and Mesaverde Formations have a high paleontologic potential based on the occurrence of scientifically significant fossils found in these deposits elsewhere in Wyoming. Fossils from these units provide important scientific information about plants and animals during the latest Cretaceous and early Tertiary periods.

Fossils known from the Wind River and Fort Union Formations include a wide variety of mammals, reptiles, amphibians and plants that document the origin and diversification of modern mammal groups, and the diversification of mammals following the extinction of the dinosaurs, respectively. The formations also produce a wide variety of invertebrate and plant fossils. The Lance/Meeteetse Formation is the most prolific producer of late Cretaceous fossil vertebrates in Wyoming and records the abundance and diversity of land animals, including sharks, rays, bony fish, amphibians, champsosaurs, turtles, lizards, snakes, crocodiles, saurischian and ornithischian dinosaurs, pterosaurs, birds, and marsupial and placental mammals, and plants. Fossils known from the Mesaverde Formation include the remains of a wide variety of early mammals, marine fish (including sharks, rays and bony fish), amphibians, reptiles (including champsosaurs, turtles, lizards, snakes, crocodiles, pterosaurs), ornithischian and saurischian dinosaurs, and birds. The Cody Shale is known to yield the fossils of marine fish, including sharks and bony fish, and unidentifiable marine reptiles at localities throughout Wyoming.

Information on the geologic deposits exposed in the project area and their paleontologic potential is summarized in Table 3-2. Additional information on geologic units having a high paleontologic potential based on reference review is summarized below by formation.

Wind River Formation

The Wind River Formation is the most extensive sedimentary deposit exposed in the Wind River Basin. Sediments of the formation were deposited during the early Eocene (circa 52 ma to 50 ma) as the mountains surrounding the Wind River Basin were uplifted during the Laramide Orogeny. Sediments shed from the mountains accumulated in the central parts of the Wind River Basin throughout early Eocene time and exceed 6,000 feet thick in the subsurface. Deposits of the formation accumulated in a variety of environments related to their distance from the mountain fronts. Near the mountains, landslides, mudslides and alluvial fans accumulated coarse-grained sediments. Progressively basinward from the mountains, streams, rivers, and ponds or lakes accumulated fine-grained sediments in a broad ancient flood plain and lake basin.

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Traditionally the Wind River Formation has been divided into two members in the eastern part of the Wind River Basin-- an upper Lost Cabin Member and lower Lysite Member (Keefer 1965, Korth 1982, Lillegraven 1993). Stucky et al. (1989) however, recognized three additional lithologic units, the Red Creek Facies, Arminto Unit, and Pavillion Butte Unit. Only the Lost Cabin and Arminto unit appear to occur in the Cave Gulch-Bullfrog-Waltman area.

Lost Cabin Member

The Lost Cabin Member is recognized over large parts of the central parts of the Wind River Basin and extends into the eastern part of the project area. The member differs from the underlying Lysite Member in the greater frequency of variegated sediments, including more purple and red beds. Fossil mammals from the Lost Cabin Member range from late early Eocene (Lost Cabinian) to earliest middle Eocene (Gardnerbuttean) in age. Two fauna zones have been recognized in the Lost Cabin Member- the *Lambdotherium* Range Zone and the *Eotitanops* (=Paleosyops) *borealis* zone. The *Lambdotherium* zone characterizes the Lostcabinian Land Mammal Age which is latest Wasatchian (latest Early Eocene) in age. The fauna from the *Eotitanops borealis* zone is most similar to the Gardnerbuttean fauna from Huerfano Basin, Colorado.

Fossil vertebrates, plants and invertebrates are known from widely dispersed localities throughout the Lost Cabin Member in the Wind River Basin. Two fossil localities known from the Lost Cabin Member are of major importance in the eastern part of the basin, the Buck Spring Quarries and Davis Ranch. The Buck Spring Quarries, discovered in 1984, have produced 105 fossil vertebrate taxa including 65 species of mammals, and 22 species of frogs, salamanders, lizards, snakes, and birds. Many of these taxa are represented by skull and associated skeletal remains. Quarries have produced abundant small lizards and mammals and surface collection has produced abundant large mammals. The Davis (or Sullivan) Ranch locality is one of the most diverse Eocene fossil localities known in North America (Stucky et al. 1989). More than 2,000 specimens, representing 75 mammalian species, have been collected from this locality.

Arminto Unit

The Arminto unit is exposed along the Casper Arch, where it unconformably overlies the Fort Union and older formations, and is in turn overlain by the Lost Cabin Member. Some of these same sediments were included by Keefer (1965) in the Lysite Member, but differentiated by Stucky et al. (1989) because of their predominance of coarse sandy mudstones, and abundance of Cretaceous pebbles in conglomerates preserved at the bases of the sandstones. Many of these clasts were probably derived from the Casper Arch which was exposed and undergoing erosion at the time. Fossil vertebrates occur primarily in the conglomerates and sandstones and range in age from earliest Eocene (Graybullian) to early, but not earliest Eocene (Lysitean) in age. The Arminto Unit is well exposed at Hell's Half Acre, where a diverse, but undescribed fauna of about 40 mammalian species are known. In general the mammal species from the unit are more primitive than those of the same species in the Lysite Member, suggesting that the unit is somewhat older.

Fort Union Formation

The Fort Union Formation in the Wind River Basin includes rocks of Paleocene age and has been subdivided into two lithologic sequences; a lower part of interbedded sandstone, conglomerate, shale and carbonaceous shale that accumulated in a fluvial environment and an upper unit of very

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fine grained sediments deposited in and adjacent to a large lake (Keefer 1961, Keefer 1965, Phillips 1983). That lake may or may not have had a marine connection eastward, with the Cannonball Sea. The lower part of the Fort Union Formation is unnamed and referred to as the lower member. The upper part has two distinct lithologies, those sediments that accumulated adjacent to the lake (Waltman Lake), which are included in the Shotgun Butte Member, and those that accumulated in the lake, included in the Waltman Shale Member. Where the Waltman Shale Member is absent the Fort Union is not subdivided. The Shotgun Butte Member and Waltman Shale Member are known to be fossil-bearing. The lower member should prove fossiliferous, but has yet to be studied in enough detail. Only the lower member and Waltman Shale Member appear to occur in the Cave Gulch area (Phillips 1983).

Near Waltman the lower member consists chiefly of white fine to coarse-grained sandstone and interbedded very fine grained sandstone and siltstone. The Waltman Shale Member is characterized by chocolate-brown and gray silt and shaley claystone interbedded with thin beds of ledge-forming sandstone. South of Waltman, sandstones become thicker and more prominent in the member. The sandstones have conglomerate at their base and these conglomerates have yielded fossil mammal bones and teeth (Stucky et al. 1989). Both members have only limited exposure in the project area.

The Fort Union Formation has produced a wide variety of fossils from widely dispersed localities throughout the Wind River Basin (Brown 1962, McGrew and Patterson 1962, Paterson and McGrew 1962, Keefer 1965, Gazin 1971) and throughout Wyoming. Fossil plants, including leaves, spores and pollen occur throughout the basin. Fossil vertebrates are primarily known from the Shotgun Butte Member in the Shotgun Butte area (Keefer 1965) in the northwestern part of the basin and the Badwater Creek Area (Stucky et al. 1989). Fossil mammals from the formation include a wide variety of primitive marsupials and placentals including insectivores, archaic ungulates, and primates.

Lance/Meeteetse Formation

The Lance and Meeteetse Formations consist of nonmarine deposits that accumulated in parts of Wyoming during the latest Cretaceous and late Cretaceous, respectively. Where the formations can be mapped separately they are separated by marine shales and sandstones of the Lewis Shale, which represents the last major inundation of the Cretaceous seas across Wyoming. The Meeteetse Formation is generally restricted in usage to deposits in the western part of the Wind River Basin and the Big Horn Basin. The Lance Formation is applied state-wide to deposits of latest Cretaceous age. In areas where the Lewis Shale is absent, the two formations are not well differentiated and often lumped (Keefer 1965, Flemings and Nelson 1991).

Lance Formation

The Lance Formation crops out along the western edge of the Casper Arch in a northwest-southeast trend. At Waltman the Lance is about 5,000 feet thick and consists of shale and sandstone in its lower part and thick shale in its upper part. Three distinct units that accumulated in marginal marine, deltaic, and nonmarine-flood plain-swamp environments are recognized in the formation adjacent to the Lewis Sea during late Cretaceous time (Gillespie and Fox 1991).

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The Lance Formation has produced abundant fossils, including those of vertebrates, non-marine invertebrates, and plants at widely separated localities throughout Wyoming. Vertebrate fossils are known from localities in the Lance Formation in at least 11 counties of Wyoming including Natrona, but the most abundant and diverse fossils are known from Niobrara, Park, and Sweetwater Counties. State-wide, the formation has produced the fossil remains of a wide variety of organisms. Fossil taxa known from the formation include at least 57 species of plants, 4 sharks, 2 rays, 9 bony fish, 14 amphibians, 12 turtles, 14 lizards, 5 crocodiles, 7 ornithischian dinosaurs, 18 saurischian dinosaurs, 8 birds, at least 18 genera of mammals, and a single species each of champsosaur, snake, and pterosaur (Dorf 1942, Estes 1964, Clemens 1966, Clemens et al. 1979, Breithaupt 1985, Weishampel 1992, Archibald 1993). The formation has also produced the remains of several species of bivalve and gastropod invertebrates and annelid worm tests.

Dinosaurs from the Lance include the more popularly known genera *Tyrannosaurus*, *Pachycephalosaurus*, *Ankylosaurus*, and *Triceratops*. Mammals from the formation include species of multituberculates, and primitive marsupials and placental mammals.

Meeteetse Formation

The Meeteetse Formation consists of tan to brown sandstone, and interbedded gray to black siltstone and shale, carbonaceous shale and coal that accumulated in widespread swamps, broad flood plains and lagoons along the western edge of the late Cretaceous seaway. The remains of plants, including leaves, pollen, and spores, and vertebrates, including dinosaurs and several species of mammals (multituberculates, and primitive marsupial and placental mammals) are known from localities in the Meeteetse Formation in the Wind River and Bighorn Basins (Hewett 1926, Keefer 1965).

Mesaverde Formation

The Mesaverde Formation consists of alternating sandstone, shale, carbonaceous shale, and coal of varying thickness that accumulated in marine, marginal marine, and terrestrial environments. It includes in descending order, the Teapot Sandstone, unnamed middle, and Fales (=Phayles) Members (Keefer 1972, Shapurji 1978, Hogle and Jones 1991). The Teapot Sandstone and Fales Member accumulated in marine environments, whereas the unnamed middle member accumulated in terrestrial, fluvial-lagoonal, and coastal swamp environments. The Mesaverde is separated in places from the overlying Meeteetse Formation by a tongue of the Lewis Shale. Where this tongue is absent the placement of the boundary between the Mesaverde and Meeteetse is problematic.

The Mesaverde Formation has produced fossils from widely dispersed localities in Wyoming. These fossils, including some found in Natrona County, consist of the remains of plants, a wide variety of marine invertebrates, and marine and terrestrial vertebrates. Non-mammalian vertebrates from the formation include 9 species of shark, 2 rays, 9 bony fish, 6 amphibians, 3 turtles, 14 lizards, 3 crocodiles, 4 ornithischian dinosaurs, 3 saurischian dinosaurs, and a single species each of champsosaur, snake, pterosaur, unidentified marine reptile, and bird (Breithaupt 1985). The Mesaverde has also produced the fossils of 12 species of mammals (Clemens and Lillegraven 1986, Lillegraven and McKenna 1986). The marine part of the formation has produced the abundant remains of marine invertebrates including ammonite, baculites, bivalves, and

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planktonic foraminifera (Keefer 1972, Kauffman 1977, Shapurji 1978). A varied fauna of fossil sharks is known from the formation in the southern part of the Bighorn Basin (Case 1987).

Dinosaurs from the Mesaverde include the more popularly known genera *Edmontosaurus* and *Albertosaurus*. Mammals from the formation include species of multituberculates, primitive marsupials and placental mammals, and primitive mammals which can neither be classified as being either placental or marsupial, based on dental anatomy. Three of the taxa represent species known only from the Wind River Basin. Specimens from the Wind River Basin were all collected from the unnamed middle member of the formation along the northeast flank of the Rattlesnake Mountains, southwest of the project area (Lillegraven and McKenna 1986).

Cody Shale

The Cody Shale consists of marine shale and sandstone. Shale predominates in the lower part and interbedded sandstone and shale in the upper part. The Cody Shale is described as being very fossiliferous in that it contains abundant marine invertebrate fossils (Fox 1954, Keefer 1972). Limestone concretions in shale beds and friable irregular sandstone masses in the sandstone beds commonly contain well-preserved fossils in great number and variety including bivalves, ammonites, baculites, and scaphites (Keefer 1972, Kauffman 1977, Lang et al. 1991). The Cody Shale has also produced a number of vertebrate fossils from widely dispersed localities in Wyoming, including some in Natrona County (Breithaupt 1985). These specimens represent 3 species of shark, two bony fish, and an unidentified species of marine reptile. Fossils of scientific interest and significance are documented in the Cody Shale, but they appear to be rarer and less abundant than in the other formations discussed above.

Field Survey

The Cave Gulch Unit area was surveyed on March 26-31, 1995 for paleontologic resources. The survey was conducted by Gustav F. Winterfeld, Ph.D., Principal Paleontologist (PI), Erathem-Vanir Geological (Pocatello, ID, formerly Santa Barbara, CA). The PI conducts paleontologic resources evaluation and mitigation work on BLM lands in Wyoming in response to specific construction project demands as authorized by a paleontologic collecting permit No. 137-WY-PA92 issued by that agency and is a Professional Geologist (PG 2224), registered with the State of Wyoming. The PI was assisted by Dr. Andres Aslan (University of Colorado, Boulder), who holds a Ph.D. in sedimentary geology and has considerable experience prospecting for and collecting vertebrate fossils in Tertiary rocks of Wyoming. An additional field geologic check of the project area was conducted on July 21 and 22, 1996 by the PI and field associate Ms. Denny V. Diveley (Idaho State University, Pocatello, ID).

Methods

The Cave Gulch area was prospected using standard paleontologic prospecting methods, including visual examination of outcrops during pedestrian survey and inspection of anthills for fossil material. The survey involved an intensive search of rock exposures that cropped out within the project area. Representative sections of each geologic formation were carefully examined, such that all representative lithologies of each deposit were examined for fossil materials in order to identify concentrations of fossils. In places where fossils were discovered on the surface, the immediate vicinity of the remains was intensively visually examined. In places underlain by

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vegetated stretches, anthills and animal burrows were examined for clues to the nature of underlying strata and to the presence of potential fossils. If fossil material of any kind was observed, exposures in the vicinity were intensively scrutinized. Fossil material was collected and identified at the University of Wyoming and specimen and locality numbers were assigned and entered into the Department Vertebrate Paleontology Collections database.

Results

Fossil vertebrate remains were discovered and collected from numerous locations that can be grouped into six recognizable localities in the Wind River Formation (Tables E-1 and E-2). This material was derived from bone-bearing fluvial conglomerates and sandstones developed in the base of the formation (=Arminto Member?) along the north side of the Cave Creek Escarpment and from anthills developed proximal to these conglomerates. Geologic observations suggest that this basal sequence may be considerably older than deposits of the Arminto Member at Hells Half Acre.

One of the bone-bearing conglomerates is widespread over the central and southeastern parts of the area, where it rests with marked angular unconformity above Paleocene and Cretaceous deposits, which are steeply dipping to overturned. In places proximal to underlying Cretaceous deposits the sandstones contained reworked dinosaur bones. Other bone-bearing conglomerates occur as sandstone channel lag deposits developed at several levels throughout the Arminto Member and overlying the Lost Cabin Member along the north side of the Cave Creek escarpment.

Anthills containing fossil teeth and bones of small vertebrates occur in sediments of the Arminto Member and the deposits of fine-grained sand and loess of Pleistocene or Holocene age that immediately overlies the member. Additional fossil vertebrate material was discovered in a sandstone "blow-out" or wind deflated area of channel sandstone in the overlying Lost Cabin Member that caps the rim of the Cave Creek escarpment and flats that extend southward to Waltman.

Unidentifiable fossil vertebrate fragments and plant remains (including imprints and wood) were identified at several locations in the Lance/Meeteetse Formation and although none of this material was deemed significant enough to collect or warrant formal locality designation, these localities are included here for completeness. One of these localities was brought to the attention of the PI by an Archaeologist with the BLM Platte River Resource Area. As mentioned above, large pieces of reworked dinosaur bones were also observed to occur sporadically in coarse-grained sandstones that form the base of the Wind River Formation where it onlaps the Lance Formation. No fossil remains were identified in the Fort Union, Mesaverde Sandstone or Cody Shale.

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Table E-1. University of Wyoming Fossil Vertebrate Localities Wind River Formation.

Locality	Location			Geologic Unit	Age
	Section	Township	Range		
V-96054	7	36 N	86 W	Arminto? Member	early Wasatchian
V-96055	25	37 N	87 W	Arminto Member	early Wasatchian
V-96056	6	36 N	87 W	Arminto Member	early Wasatchian
V-96057	7-8	36 N	86 W	Arminto Member	early Wasatchian
V-96058	7	36 N	86 W	Arminto Member	early Wasatchian
V-96059	7	36 N	86 W	Lost Cabin Member	late Wasatchian

Table E-2. Unnumbered University of Wyoming Fossil Vertebrate Localities in the Cave Gulch-Bullfrog-Waltman Area.

Locality	Location			Geologic Unit/Age	Type of Material
	Section	Township	Range		
Lance 1	6	36 N	86 W	Lance/Late Cretaceous	dinosaur bone scrap
Lance 2 (anthill)	6	36 N	86 W	Lance/Late Cretaceous	fish teeth and small bone scrap
Lance 3	30	37 N	86 W	Lance/Late Cretaceous	dinosaur bone scrap
Lance 4	30	37 N	86 W	Lance/Late Cretaceous	dinosaur bone scrap

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Significance

Fossil vertebrates collected from the Wind River Formation in the Cave Gulch-Bullfrog-Waltman area document the occurrence of fish, crocodile, turtle and mammals in the lower part of the formation (Table E-3) in an area that has been largely overlooked by paleontologists because of a supposed paucity of fossils there. At least eight mammalian orders and 14 species have been identified in the small collection made as a result of the field survey for this project. Fossils from the Arminto Unit (pre-Lysitean) including those undescribed from Hells Half Acre are particularly of scientific interest because they are older than those typical of the formation in the eastern part of the Wind River Basin. The specimens recovered from the Cave Gulch area may be in part significantly older than those from Hells Half Acre and for that reason have added significance.

The potential for collecting additional fossils of scientific importance from the Wind River Formation, including the remains of new species of animals, in the Cave Gulch area remains excellent. These specimens, as well as the interesting geology of the area could be the focus of important scientific research concerning early Eocene paleontology and geologic history of Wyoming.

Recommendations

Significant fossils were discovered in the Cave Gulch-Bullfrog-Waltman Analysis Area in the Arminto and Lost Cabin Members of the Wind River Formation and in certain areas these fossils appear to have been concentrated from that formation into deposits of late Pleistocene or Holocene age directly overlying the fossil-bearing Wind River beds. These areas, outlined on Figure C-1 are designated as having a high paleontologic potential. In these areas, where surface disturbance is unavoidable, a representative sample of fossil remains from the surface and from anthills in or adjacent to the area of disturbance will be collected prior to construction. Anthill material should be bagged, screened, and sorted under a binocular microscope by a qualified paleontologist. Collected fossils will be curated into the collections of the University of Wyoming and costs associated with curation will be borne by the project proponent. Finally, a letter report describing the results of preconstruction collecting and documenting the curation of specimens into the collections will be prepared and copies of the report will be provided to the BLM and project proponents.

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Table E-3. University of Wyoming Department of Geology and Geophysics Vertebrate Paleontology Collections Specimen List.

UW Specimen Number	Taxon	Element(s)*	Locality
15871	<i>Coryphodon</i> sp.	left m1	V-96054
15872	<i>Phenacodus</i> sp.	right jaw fragment with m3	V-96054
15873	<i>Heptodon</i> sp.	right m3	V-96054
15874	<i>Hyopsodus</i> sp.	left M1-2	V-96054
15875	<i>Hyracotherium</i> sp.	right P4, right M3, left M3, right m1	V-96054
uncatalogued	miscellaneous	edentulous mammalian jaw ; fragments, proximal tibia ; fragments, distal humeral ; fragments, tarsal elements	V-96054
15876	<i>Cantius</i> sp.	left m1-2, left M2	V-96055
uncatalogued	miscellaneous	calcaneus medium sized, phalanx, astragalus, <i>Hyracotherium</i> left m3; talonid, trace fossil ; <i>Edaphichnium</i> , teeth; fragments	V-96055
15879	<i>Hyracotherium</i> sp.	left m1-3	V-96056
uncatalogued	miscellaneous	fish teeth, lizard scutes- glyptosaur, rodent incisor, crocodile teeth, high spired gastropod	V-96056
15880	<i>Hyracotherium</i> sp.	left p4-m3	V-96057
15881	<i>Hyracotherium</i> sp.	left jaw fragment with m3	V-96057
15882	<i>Phenacodus</i> sp.	left p4, left m1	V-96057
15883	<i>Hyopsodus</i> sp.	right P4, left M1, right M3, right m1	V-96057
15884	<i>Microsyops</i> sp.	right m1	V-96057
15885	<i>Paramys</i> sp.	right M3	V-96057
15886	<i>Vulpavus</i> sp.	left m3	V-96057
15888	<i>Hyracotherium</i> sp.	upper molar fragments (5)	V-96058
15889	<i>Hyopsodus powellianus</i>	left M1-3	V-96058
15890	<i>Esthonyx</i> sp.	left M2	V-96058
15891	<i>Paramys</i> sp.	right m1-2	V-96058
15892	<i>Oyxaena transiens</i>	left m1	V-96058
15893	<i>Homogalax</i> sp.	left P4 fragment	V-96058
15894	<i>Lambdotherium popoagicum</i>	right m3, left upper molar fragments	V-96058
uncatalogued	miscellaneous	gar scales, crocodile scrap	V-96058

* lower case letters refer to lower teeth, upper case letters refer to upper teeth

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