PALEOCENE AND EARLY EOCENE OF THE BIGHORN AND CLARK'S FORK BASINS, WYOMING

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INTRODUCTION

The Bighorn Basin and Clark's Fork Basin together form a large southeast-northwest trending intermontane basin and structural trough in northwestern Wyoming and southern Montana. In Wyoming, the Bighorn and Clark's Fork intermontane basin measures some 200 km (120 mi) in length and 100 km (60 mi) in width (Fig. 1). The basin floor is broad and relatively flat, lying at an elevation of 1,200 - 1,500 m (4,000 - 5,000 ft), while surrounding mountains rise to an elevation of 3,000 - 4,000 m (10,000 - 13,000 ft). The Bighorn River drains most of this basin. It originates in the Wind River Basin (where it is called the Wind River), enters the Bighorn Basin though the Wind River Canyon, and from south-to-north along the eastern margin of the basin. The Clark's Fork River drains the northwestern part of the Bighorn - Clark's Fork intermontane basin, flowing northward to empty into the Yellowstone River at Laurel, Montana. The Bighorn River joins the Yellowstone River farther downstream near Custer, Montana. The Yellowstone is a tributary of the Missouri River, which joins the Mississippi River and drains into the Gulf of Mexico.

The Bighorn - Clark's Fork Basin formed by subsidence during the Laramide Orogeny simultaneous with uplift of the surrounding mountains. In the broadest interpretation, Laramide mountain building started in the late Cretaceous and ended in the Eocene. As we shall see however, deformation of the

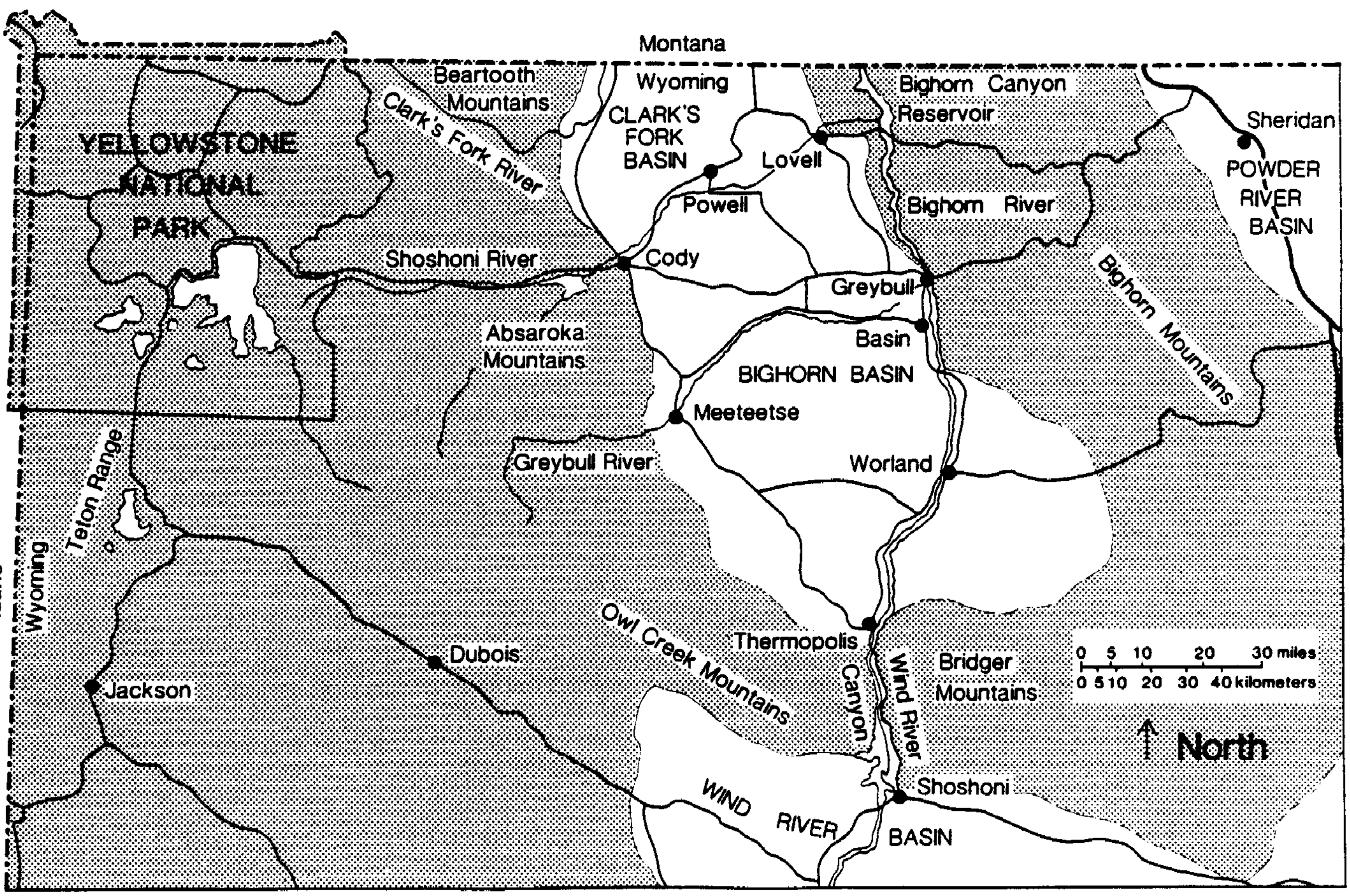

FIGURE 1. Location map showing the Bighorn and Clark's Fork basins in relation to surrounding mountains.

Bighorn and Clark's Fork Basins was concentrated in the late Paleocene and early Eocene. This was followed at the beginning of the middle Eocene by activation of the Heart Mountain detachment and simultaneously by initiation of extensive deposition of Absaroka volcanics. Regional uplift in the late Cenozoic superimposed the present river system and excavated softer sedimentary rocks from the basin itself to yield present topography.

The Laramide tectonic regime in this region was one of strong compression in a northeasterly-southwesterly direction. Structurally, the Bighorn - Clark's Fork intermontane basin can be visualized as a broad southwesterly-dipping monocline bordered on the southwest by high-angle thrust faults involving basement rocks (Blackstone, 1985, 1986). The central part of the Bighorn - Clark's Fork monocline was tilted toward the southwest, but generally maintained its integrity during deformation. The southwestern margin of the monocline is bounded by several major thrust faults, and both the northeastern and southwestern margins are folded. The Bighorn structural basin in the south is tilted but retains some northeast-southwest symmetry, while the Clark's Fork structural basin in the north is markedly asymmetrical. Its central monocline dips westward to meet a sharply upthrust and overthrust Beartooth Mountain front. The transition between the two structural basins occurs along a weakly expressed lineament extending eastward from the mouth of the Clark's Fork Canyon and passing under Heart Mountain and the McCullough Peaks.

Present day drainage patterns reflect the differing symmetries of the Clark's Fork and Bighorn structural basins. The Clark's Fork River runs along the southern margin of the Beartooth Mountains and then turns abruptly northward to run along the eastern edge of this uplift. Tributaries draining the Clark's Fork Basin run down dip or along strike to the west or north. The Bighorn River occupies the eastern margin of the basin with most of its major tributaries (Shoshone River, Graybull River, Fifteenmile Creek, Gooseberry Creek, Cottonwood Creek, Owl Creek) running opposite to the direction of dip of basin sediments. The floor of the Bighorn Basin is irrigated and farmed wherever possible, but vast areas of badlands and open range lie between water courses.

Fossil mammals were first described from lower Eocene sediments of the Bighorn Basin by Cope (1880), four years after the U.S. Army was defeated at "Custer's last stand" on the Little Bighorn River. Custer's defeat is important historically as it marked a turning point in U.S. government policy toward native Americans. Prior to 1876, the Bighorn - Clark's Fork basin area was reserved Indian land. After 1876 all was opened to miners and ranchers (and paleontologists). The early history of paleontological research here is reviewed in Gingerich (1980b).

While best known for their Paleocene and Eocene mammalian faunas, the Bighorn and Clark's Fork basins have also yielded Ordovician Agnatha and Devonian Placodermi and Osteichthyes from the surrounding Bighorn and Beartooth mountains (Darton, 1906; Bryant, 1932, 1933, 1934, 1935), Cretaceous dinosaurs (e.g., Ostrom, 1970), new and important early and late Cretaceous mammals (Jenkins and Schaff, 1988; Lillegraven and McKenna, 1986), and an important Pleistocene fauna from Natural Trap Cave in the northern Bighorn Mountains (e.g., Martin *et al.*, 1977). Here we shall concentrate on Paleocene and Eocene faunas.

STRATIGRAPHY AND TECTONIC OUTLINE

Nine formations are of primary interest to stratigraphers concerned with the Paleocene and Eocene history of the Bighorn and Clark's Fork basins. These are, in order:

9. **Wapiti Formation**: middle Eocene; volcanic breccias, conglomerates, finer clastics, and lava flows; ca. 1000 m (3,300 ft) thick; poorly fossiliferous.
8. **Aycross Formation/Cathedral Cliffs Formation**: early middle Eocene; brown volcanic mudstones, green sandstones, some quartzite conglomerate; 200 m (650 ft) thick; yields diverse fauna of middle Eocene mammals and other vertebrate remains.
7. **Tatman Formation**: brown carbonaceous shales; 200 m (650 ft) thick; poorly fossiliferous, including a few early middle Eocene mammalian teeth; this is a localized basin facies correlative with basin margin Willwood Formation sediments to the west.
6. **Willwood Formation**: late Paleocene to early middle Eocene; interbedded sandstones, brightly colored gray, yellow, red, and purple mudstones (paleosols), rare carbonaceous shales, some freshwater limestones, locally conglomeratic along western margin of basin; 770 m (2500 ft) thick in Bighorn Basin and approximately 1600 m (5,200 ft) thick in Clark's Fork Basin; yields fossil plants and locally abundant molluscan, fish, amphibian, reptilian, bird, and mammalian remains.
5. **Fort Union Formation** (= Polecat Bench

Formation of Jepsen): Paleocene; interbedded sandstones, drab mudstones, carbonaceous shales, lignites, some conglomerates and some freshwater limestones; 1150 m (3800 ft) thick; continental; yields fossil plants and molluscan, fish, amphibian, reptilian, bird, and mammalian remains.

4. **Lance Formation**: late Maastrichtian; poorly indurated shales interbedded with harder ridge-forming sandstones, very few carbonaceous shales; 400 m (1300 ft) thick; continental; yields dinosaurs and mammalian remains.
3. **Meeteetse Formation**: early Maastrichtian; poorly indurated white, gray, brown, and black shales, carbonaceous shales, and sandstones; 275 m (900 ft) thick; possibly marine; poorly fossiliferous; thin or absent on east side of basin.
2. **Mesaverde Formation**: late Campanian/early Maastrichtian; predominantly ridge-forming sandstone, some lignite; 360 m (1200 ft) thick; continental in part; yields sharks and some mammalian remains in southeast, reptilian bone in west.
1. **Cody Shale**: Coniacian, Santonian, and early Campanian; soft gray, green, and black shale; 600+ m (2,000+ ft) thick; marine; yields abundant marine fossils.

AGE (Ma)				ZONE	PRINCIPAL TAXON MAKING FIRST APPEARANCE AT BEGINNING OF ZONE	AUXILIARY TAXON MAKING FIRST APPEARANCE AT BEGINNING OF ZONE	ALTERNATIVE NAME FOR ZONE
EOCENE	49.5	Wasatchian	Late	Wa_7	* *Lambdotherium primaevum*		Lostcabinian
				Wa_6 (C)	* *Heptodon calciculus*		Lysitean
			Middle	Wa_5 (B)	* *Homogalax protapirinus*	* *Bunophorus etsagicus*	Late Graybullian
				Wa_4		* *Hyracotherium pernix*	Middle Graybullian
				Wa_3 (A)		* *Hyracotherium aemulor*	Early Graybullian
			Early	Wa_2	* *Hyracotherium grangeri*	* *Cantius mckennai*	Late Sandcouleean
				Wa_1		* *Cantius ralstoni*	Middle Sandcouleean
				Wa_0		* *Cantius torresi*	Early Sandcouleean
PALEOCENE	53.5	Clarkfork.	L	Cf_3	* *Phenacodus-Ectocion* Zone	* *Plesiadapis dubius*	
			M	Cf_2	* *Plesiadapis cookei*		
			E	Cf_1	* *Plesiadapis gingerichi*		
		Tiffanian	Late	Ti_5	* *Plesiadapis simonsi*	* *Plesiadapis fodinatus*	
				Ti_4	* *Plesiadapis churchilli*		
			M	Ti_3	* *Plesiadapis rex*		
			Early	Ti_2	* *Plesiadapis anceps*		
				Ti_1	* *Plesiadapis praecursor*		
	60.0	Torrejonian	Late	To_4	* *Pantolambda cavirictum*	* *Pronothodectes jepi*	
				To_3	*Pantolambda intermedium*	*Pronothodectes mathewi*	
			Early	To_2	*Deltatherium fundaminis*		
				To_1	*Conoryctella dragonensis*		Dragonian
		Puercan	L	Pu_3	*Taeniolabis taoensis*		
			M	Pu_2	*Ectoconus ditrigonus*		
			E	Pu_1	* *Mimatuta minuial*		Mantuan
	65.0						

FIGURE 2. Paleocene and early Eocene biostratigraphic zonation based on mammalian faunal succession. Zones involving taxa preceded by asterisks are found in the Clark's Fork/Bighorn Basins. Modified from Gingerich (1983).

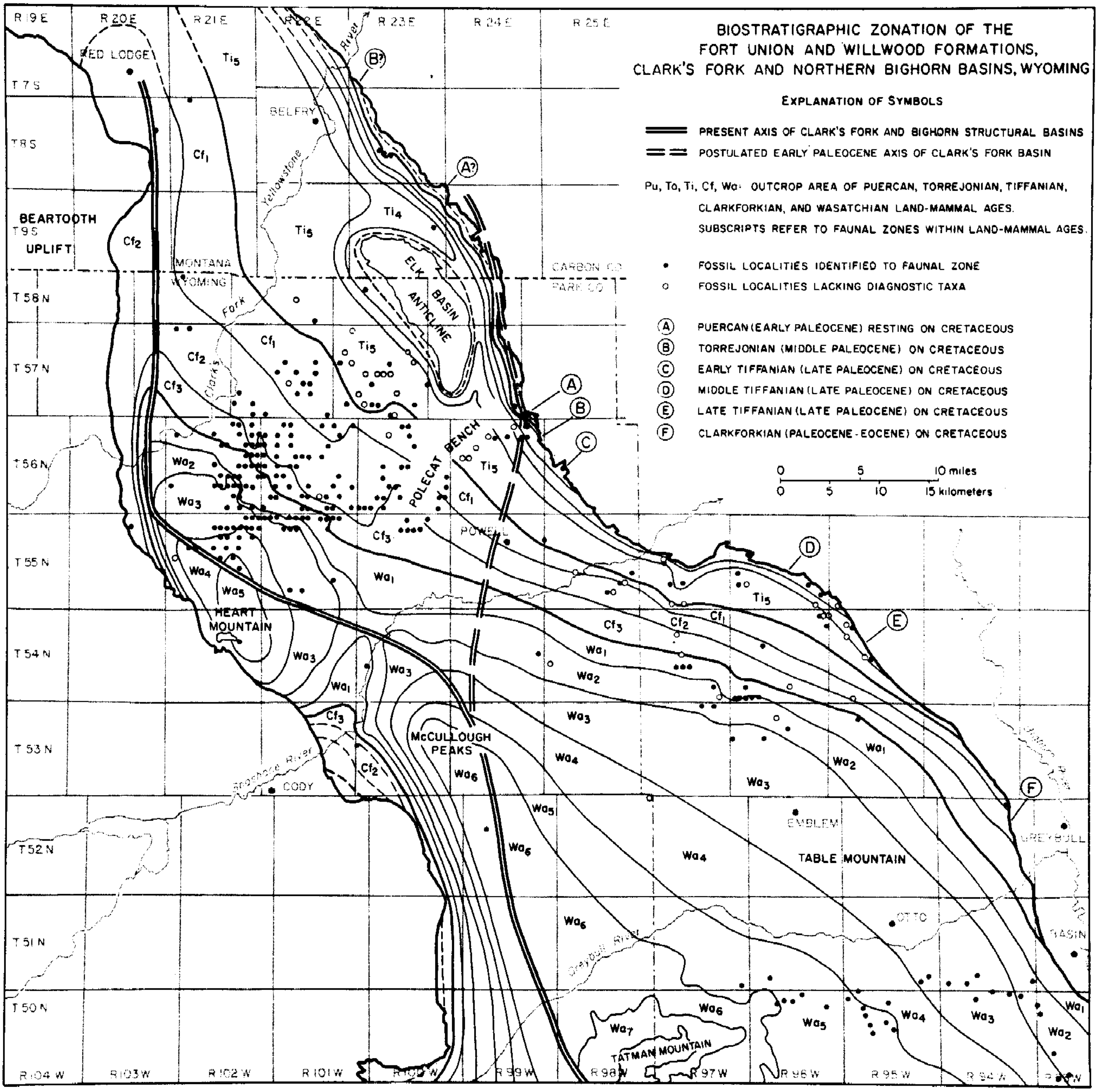

FIGURE 3. Preliminary biostratigraphic zonation of the Fort Union and Willwood Formations in the Clark's Fork and northern Bighorn basins. Contours are based on successive computer plots of localities containing taxa characteristic of zones listed in Figure 2. From Gingerich (1983).

Principal references discussing one or more of these formations are Sinclair and Granger (1911, 1912), Granger (1914), Hewett (1914, 1926), Jepsen (1930, 1940), Van Houten (1944), Pierce (1957, 1963, 1980), Neasham and Vondra (1972), Gingerich (1976b, 1983), Bown (1979, 1982), Bown and Kraus (1981, 1987), Eaton (1982), Torres (1985), and Lillegraven and McKenna (1986).

The nine formations listed above record (1) alternating depositional conditions in the broad transition from a marine to a continental environment in the Late Cretaceous: Cody Shale, Mesaverde Formation, Meeteetse Formation, Lance Formation; (2) moderate deformation of the Bighorn - Clark's

Fork basins with initiation of tectonic compression in the latest Cretaceous: Lance Formation and lower part of the Fort Union Formation; (3) strong deformation, rapid basin subsidence, and overthrusting in the late Paleocene and early Eocene with some tectonic ponding of water in both the Clark's Fork and Bighorn Basins: middle and upper Fort Union Formation, Willwood Formation, Tatman Formation; (4) relaxation of compression, Heart Mountain detachment, and initiation of Absaroka volcanism in the early middle Eocene: Aycross Formation/Cathedral Cliffs Formation, Wapiti Formation.

It is not possible to examine field evidence for each of these in a single day, and we will concentrate on phases 2 and 3 here, looking at the Cretaceous-Tertiary boundary where it is most complete and at the thick and richly fossiliferous Fort Union and Willwood Formations in several well known localities.

BIOSTRATIGRAPHIC ZONATION OF THE FORT UNION AND WILLWOOD FORMATIONS

A composite biostratigraphic zonation and biochronology of the North American Paleocene and early Eocene based on mammalian faunal succession is outlined in Figure 2. This zonation is based almost entirely on the sequence of fossils found in the Bighorn and Clark's Fork basins: 18 of the 23 zones are represented here (taxa marked with asterisks). Eleven zones, Pu_1, To_4, and nine in sequence, Ti_2 - Wa_1, are represented on Polecat Bench. Four more in sequence, Wa_2 - Wa_5, are represented in the Sand Coulee area of the Clark's Fork Basin. This is easily the most detailed and complete record of the Paleocene-Eocene transition known in continental sediments anywhere in the world. The Puercan and Torrejonian Land-Mammal Ages on Polecat Bench occur within a relatively thin stratigraphic unit, together comprising only about 100 m (330 ft) of section. In contrast, the Tiffanian Land-Mammal Age on Polecat Bench is about 850 m (2800 ft) thick, and the Clarkforkian Land-Mammal Age on Polecat Bench is about 570 m (1900 ft) thick. The first half of the Wasatchian Land-Mammal Age is about 500 m (1650 ft) thick in the Clark's Fork Basin. The rate of sediment accumulation in the Tiffanian, Clarkforkian, and Wasatchian was more than ten times that in the Puercan and Torrejonian.

One of the principal features of the paleontological record on Polecat Bench is an earliest post-dinosaurian mammalian fauna, from Mantua Quarry, representing the early Puercan Land-Mammal Age (Pu_1) and the very beginning of the Cenozoic age of mammals. This is found at the eastern edge of Polecat Bench. A second feature of the paleontological record on Polecat Bench is the earliest North American record of perissodactyls, artiodactyls, and primates of modern aspect. This is found at the southwestern tip of Polecat Bench.

It is possible to map the surface distribution of each of the Paleocene and early Eocene zones recognized in the Clark's Fork and Bighorn basins (Figure 3). The most interesting feature of this plot is the clear indication of progressive onlap of Paleocene and early Eocene faunal zones on the underlying Cretaceous as one traces the Cretaceous-Tertiary boundary southward along the eastern margin of the Bighorn Basin (letters A through F). At *A*, Mantua Quarry, the earliest Paleocene rests conformably on the Lance Formation and the stratigraphic section here appears to be relatively complete (although two independent attempts to find the iridium anomaly commonly associated with the Cretaceous-Tertiary boundary both failed). At *B (lateral extension of Rock Bench Quarry) and C* (University of Michigan locality SC-337), Torrejonian and early Tiffanian faunas are present on or just above the Lance Formation. At *D (Cedar Point Quarry)*, *E* (Divide Quarry), and *F (Princeton "Bathyopsoides"* locality), middle Tiffanian, late Tiffanian, and Clarkforkian faunas are present on or just above the Lance Formation. This means that an increasing amount of Paleocene time is unrepresented by sediment as one moves southward along the basin margin, and it probably means that an increasing amount of late Cretaceous Lancian time is also missing. The contact of the Fort Union and Lance formations remains conformable, if disconformable, indicating that very little deformation occurred on the eastern margin of the Bighorn Basin while the western margin was altered profoundly.

There is some evidence for similar onlap of Paleocene zones onto the Upper Cretaceous as one proceeds northward from Mantua Quarry. One explanation for this involves a major shift in the structural axis of the northern Bighorn Basin during the middle and late Tiffanian as the Clark's Fork Basin subsided against the rising Beartooth uplift. The Puercan, Torrejonian, and early Tiffanian were times when a relatively narrow ribbon of sediment was deposited down the middle of a shallowly and symmetrically downwarped basin. By the middle and late Tiffanian, however, the rate of sediment accumulation had increased more than ten-fold. There is some evidence of lake deposits in the middle part of the Fort Union Formation near the Beartooth Mountain front (Yuretich *et al.*, 1984; Yuretich and Hicks, 1986), suggesting tectonic ponding of water in a rapidly subsiding basin. Westward shift of the basin axis in the middle and late Tiffanian as the Clark's Fork Basin became well defined and separate from the northern Bighorn Basin would explain both the pattern of onlap of Paleocene sediments on the Cretaceous and the sharp westward deflection of the basin axis as one crosses from the Bighorn Basin into the Clark's Fork Basin.

EVOLUTIONARY STUDIES

Simpson (1943) was the first to discuss fossils from the Bighorn - Clark's Fork basin in an explicitly evolutionary context, using species of *Ectocion* from successive land-mammal ages to illustrate his concept of evolutionary chronoclines. McKenna (1960, p. 103) countered that "locality data of practically all existing collections of Willwood mammals are inadequate for detailed stratigraphic (and hence evolutionary) analysis." Radinsky (1963, p. 16) noted that "the Bighorn Basin Willwood Formation, with its thick section of fossiliferous strata, contains the information for working out detailed evolutionary lineages...accurate biostratigraphic investigations should be carried out." This challenge was answered by E. Simons of Yale University, who initiated an intensive collecting program in the Willwood Formation of the central Bighorn Basin. In 1965, Grant Meyer and Leonard Radinsky measured the first stratigraphic section relating Yale Willwood localities. Subsequently, successively more detailed and comprehensive sections were measured by Neasham and Vondra, by Shankler and Wing, and by Bown. The first stratigraphic section relating Fort Union fossil localities was measured in 1969 on Polecat Bench by Gingerich, and this was subsequently extended upward through the Willwood Formation in the Clark's Fork Basin.

There are now approximately 1,000 Paleocene and early Eocene fossil localities tied to measured stratigraphic sections in the Bighorn and Clark's Fork basins. As anticipated by McKenna and Radinsky, these yield extraordinarily detailed evolutionary records for many species lineages (see Gingerich, 1974, 1976a, 1976b, 1980a, 1985; Gingerich and Simons, 1977; Gingerich and Gunnell, 1979; Bown, 1979; Rose, 1981; Rose and Bown, 1984; Bown and Rose, 1987). There is also a detailed record of Paleocene and early Eocene faunal evolution preserved in the Bighorn and Clark's Fork basins, although study at this level is still in its infancy (Schankler, 1980, 1981; Badgley and Gingerich, 1987).

PRINCIPAL STOPS ON FIELD TRIP

This one-day trip begins and ends in the town of Cody. Given the size of the Bighorn - Clark's Fork intermontane basin, and the long history of paleontological activity here, one day is insufficient to gain more than an overview.

Drive north and east from Cody to Powell on U.S. highway 14A. Heart Mountain rises as an isolated mountain some 16 km (10 mi) directly north of Cody. The base is Willwood Formation of late Wasatchian early Eocene age (ca. 50 Ma), while the top is a large detachment (see discussion in next section) block of Madison Limestone of early Carboniferous age (ca. 330 Ma).

Sage Creek lies five km (3 mi) east of Cody. The Sage Creek Road south of highway 14A follows the Cretaceous-Tertiary boundary. The Lance Formation on the west (forming the valley of Sage Creek) is overlain by a Fort Union chert-pebble conglomerate on the east. This conglomerate has not yielded diagnostic fossils, but softer sediments immediately above yield a late Tiffanian fauna and it is almost certain that Tiffanian strata lie disconformably on Cretaceous strata here.

Highway 14A crosses the Shoshone River eight km (5 mi) east of Cody. This crossing is near the boundary between the drab Fort Union and brightly colored Willwood Formations, which are exposed spectacularly in the McCullough Peaks to the east of the highway. Strata at the Shoshone River crossing dip steeply to the north because of a structural flexure related to the Oregon Basin thrust fault cutting Clarkforkian and early Wasatchian strata in the southwestern part of the McCullough Peaks. Oregon Basin itself is a major oil-producing anticlinal structure lying several kilometers southeast of Cody. The highest of the McCullough Peaks are covered with remnant blocks of Madison Limestone, indicating that these peaks too owe their present topographic prominence to the Heart Mountain detachment.

The town of Ralston is on highway 14A twenty-nine kilometers (18 mi) northeast of Cody. The large mesa or bluff rising north of Ralston is the southern tip of Polecat Bench. Polecat Bench begins to dominate the northern skyline as we continue eastward toward Powell. Like many "benches" in this part of Wyoming, the flat top of Polecat Bench is capped with gravel transported outward from the Absaroka Mountains by the Shoshone River during the Pleistocene, and Polecat Bench owes its origin as a physiographic feature to its erosion-resistant gravel surface. Willwood, the type area of the Willwood Formation, is a small agricultural settlement on the north side of the McCullough Peaks just south of Powell.

Reaching Powell, turn north on Wyoming highway 295. Twelve kilometers (8 mi) north of Powell the highway climbs up the south side of Polecat Bench. Here we are in the lower part of Tiffanian zone Ti-4. Most of Polecat Bench is of reversed paleomagnetic polarity, but this interval is normal. Butler *et al.* (1981) interpret it as representing paleomagnetic anomaly 26. Tiffanian zones Ti-2 and Ti-3 are present on the south side of Polecat Bench east of the highway, and Tiffanian, Clarkforkian, and Wasatchian zones Ti-4 through Wa-1 are present in stratigraphic sequence west of the highway. The normal paleomagnetic interval interpreted as anomaly 25 is located in the lower part of zone Cf-1 several kilometers west of here.

After driving up the south side of Polecat Bench, continue north on highway 295 for 0.8 km (0.5 mi). Powell airport is on our left. Turn right and drive east on a dirt road for approximately 3.4 km (2.1 mi). Then turn north on a dirt track for 0.3 km (0.2 mi). This is our first stop.

Stop 1: Mantua Quarry

We will proceed to Mantua Quarry on foot. Rattlesnakes are common here as elsewhere in the area—please watch where you are walking and be careful where you put your hands!

The fossil-bearing stratum at Mantua Quarry is the clay-gall conglomerate at the base of the massive Mantua Lentil sandstone, just above the lignite marking the base of the Fort Union Formation. The Fort Union overlies the Lance Formation, which is the principal unit exposed in Little Polecat Anticline here. The quarry, discovered by W.J. Sinclair and G.L. Jepsen in 1929 yields an early Puercan mammalian fauna (Pu-1) of eleven genera (the multituberculates *Mesodma*, *Stigmys*, *Catopsalis*, and *Cimexomys*, the marsupial *Peradectes*, the proteutherian *Procerberus*, and the condylarths *Ragnarok*, *Mimatuta*, *Earendil*, *Maiorana*, and *Oxyprimus*; Jepsen, 1930; Van Valen, 1978; Archibald *et al.*, 1987). Dinosaur bones have been found in the Lance Formation within a few meters of the basal lignite along strike from the quarry. This is one of the few places in the Bighorn Basin where there appears to be a continuous stratigraphic section from the latest Cretaceous to the earliest Tertiary. Two research groups have attempted to find an iridium anomaly in this Cretaceous-Tertiary transition, but none has yet been found.

An important Torrejonian locality, Rock Bench Quarry (To-4), is located 0.8 km (0.5 mi) northwest of Mantua Quarry. This was also discovered by Sinclair and Jepsen in 1929. A preliminary faunal list was given by Jepsen (1930). As presently known, this fauna includes some 37 genera (Rose, 1981). The fossil-bearing stratum at Rock Bench Quarry, like that at Mantua Quarry and several Tiffanian localities, is a clay-gall conglomerate at the base of a sandstone.

Follow road log to Stop 2.

Stop 2: Fossil Hollow

Fossil Hollow (University of Michigan locality SC-198) is late Tiffanian (Ti-5) in age. Princeton Quarry, another late Tiffanian locality described by Jepsen (1930), is at about the same stratigraphic level in badlands 5.3 km (3.3 mi) west of here. Both were found by Sinclair and Jepsen in 1929. Rose (1981) provides an up-to-date list of the Princeton Quarry fauna as it is now known. Fossil Hollow illustrates the Fort Union lithologies yielding most late Tiffanian and Clarkforkian fossils in the Clark's Fork basin. Most vertebrate remains from the Clark's Fork Basin are surface finds and most come from mudstones rather than sandstones or clay-gall conglomerates.

Continue south along the west edge of Polecat Bench for 12 km (7.5 mi). Here we are traversing the entire Clarkforkian section, which is well exposed in badlands to the west. Turn right and drive 0.8 km (0.5 mi) out onto the narrow point of land overlooking the Clark's Fork Basin.

Stop 3: Clark's Fork Basin Overlook

To the west we can see Heart Mountain, and in the background the Absaroka Mountains, the Clark's Fork Canyon, and the Beartooth Mountains. Extensive badlands in front of us are Tiffanian, Clarkforkian, and early Wasatchian sediments of the Clark's Fork Basin. The early Wasatchian part of the section here is especially fossiliferous and important for evolutionary studies, complementing the late Wasatchian section that is so well studied in the central Bighorn Basin. Fort Union and Willwood strata dip gently toward the southwest, and it is possible to collect mammalian fossils from each of the many successive step-like benches produced by erosion.

Here we are standing on the Clarkforkian-

Wasatchian boundary sandstone, a sandstone first recognized as being important in the mid-1970s because it separates Clarkforkian and Wasatchian faunas and because it is a marker horizon that can be traced across much of the Clark's Fork Basin. Study by Kraus (1980) showed that the boundary sandstone is a multistory sheet sandstone deposited by rivers that worked and reworked their way across a flood plain removing fine-grained sediment at a time when there was probably little basin subsidence. Pockets of fine-grained sediment that remain are usually highly oxidized and bright red or purple in color. These yield a new fauna (zone Wa-0) older than any Wasatchian fauna known before.

Stop 4: Earliest Wasatchian Locality SC-67

Drive south along the west edge of Polecat Bench 4.8 km (3.0 mi). Here we have a good bird's-eye view of the bright red beds of University of Michigan locality SC-67, the most productive of 20 or so known Wa-0 localities. It was first collected by Sinclair in 1911, when he found the holotype of the creodont *Dipsalidictis platypus*. We know this is where Sinclair collected *D. platypus* because in 1986 we found the crown of a molar here that fits onto the holotype. It is probably also the type locality of *Ectocion parvus* and *Meniscotherium priscum*, although these were described as coming from the "head of Big Sand Coulee." Fossil bone from the Wa-0 interval differs from most found in the Clarkforkian and early Wasatchian in being light in color, which is undoubtedly related to the unusually advanced grade of soil formation here (Kraus, 1987, has published a paleosol section from SC-67, which grades the soils here as stage 3 and 4 on the scale of Bown and Kraus, 1987).

Here we also have a good view of the Willwood Formation exposed on the McCullough Peaks to the south. The section visible from Polecat Bench is Sandcouleean (Wa-2) at the base, Graybullian (Wa-3 to Wa-5) in the middle, and Lysitean (Wa-6) at the top. The vast area of Willwood Formation badlands in the central Bighorn Basin, beginning some 32 km (20 mi) south of the McCullough Peaks, is principally middle and late Wasatchian in age. Cope, Wortman, Granger, Sinclair, and more recently Simons, Bown, and Rose have concentrated their efforts there.

Drive back along the west edge of Polecat Bench 0.8 km (0.5 mi), then turn left and proceed west and south for 4.8 km (3 mi), descending on the old Billings-to-Meeteetse stage coach road. As we descend, you will see the bright red beds of Wa-0 locality SC-69 on your left. Below this level we are driving on Clarkforkian strata and we will remain in the Clarkforkian until we approach Stop 6. Turn right on County Lane 9 and proceed 1.6 km (1 mi) to a T-intersection with the Badger Basin highway. Turn right and proceed 3.2 km (2 mi) to the edge of Ralston Flats. Here the highway descends into the head of Big Sand Coulee, one of the most important Clarkforkian collecting areas of the American Museum of Natural History's 1911 and 1912 expeditions to Wyoming. Continue for another 3.5 km (2.2 mi) until the highway crosses Big Sand Coulee. Turn left onto the graded dirt road and proceed 1.5 km (0.9 mi).

Stop 5: Freshwater Limestones at SC-29

University of Michigan Willwood Formation locality SC-29 is on our right just southwest of the road at this point. We can walk to the front of the locality, where a number of small rust-colored lenses or pods of limestone are weathering out of a gray mudstone. Careful examination and acid preparation of 5 kg (11 lbs) of scattered fragments of one of these yielded eight species of gastropods and remains of a salamander, a frog, three species of lizards, a small heron-like bird, and twelve species of mammals (Gingerich, 1987). This fauna is late Clarkforkian in age. Sedimentological characteristics, faunal composition, and the pattern of bone breakage suggests that the assemblage may have been a predator accumulation preserved where it was dropped inside a hollow and rotting tree. The size and distribution of other limestone lenses at this site also suggest the spacing of trees in a woodland or forest. Vertebrate remains have not been found in the other lenses here, but they have been found in isolated limestone lenses at many other sites in the Clark's Fork Basin.

Return to the Badger Basin highway and turn left. Drive 3.0 km (1.9 mi) to the northwest and then turn left (west) onto the graded dirt Little Sand Coulee road. Exposures to the north and south of the road here are middle and late Clarkforkian in age. About 4.8 km (3 mi) down the graded dirt road you can see a saddle-shaped mountain to the north. The Clarkforkian-Wasatchian boundary sandstone runs through the middle of this mountain. We will cross the boundary sandstone in an additional 1.9 km (1.2 mi) where the dirt road makes a slight rise. Now we are travelling across early Wasatchian strata. Locality SC-2 lies 4 km (2.5 mi) ahead.

Stop 6: Locality SC-2

University of Michigan locality SC-2 has been collected for many years. Jepsen set up camp in the middle of this locality in 1928, making a sizable collection for Princeton University. This locality, or one at about the same stratigraphic level nearby, is the locality "five miles SE of the mouth of Pat O'Hara Creek" where Granger collected many of the American Museum's type specimens of early Graybullian mammals. There is a collection of more than 600 catalogued specimens from this locality at Michigan: *Hyopsodus loomisi* is the most common species (164 specimens), *Haplomylus speirianus* is next (98), and *Hyracotherium grangeri* is next (74).

Bown (1979) was the first to recognize that organic-rich gray beds overlying weathered red and orange paleosols are the important fossil-producing intervals in Willwood Formation localities like this, and Winkler (1983) made a careful quantitative analysis confirming this at a similar locality a few kilometers north of here. These gray beds often warrant screen-washing, and they sometimes contain quarriable concentrations of fossils. Many localities like this are located off the road in badland hills to the north and at the base of the escarpment to the south, where diligent investigation by a large collecting party yields tens and sometimes hundreds of identifiable specimens.

Continue southwest on Little Sand Coulee road for 7.2 km (4.5 mi). The top of the escarpment south of the road here is late Graybullian in age (Wa-5). To return to Cody, turn south on Wyoming highway 120 and follow road log.

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