Tertiary Geology of the Beaver Rim Area Fremont and Natrona Counties, Wyoming

GEOLOGICAL SURVEY BULLETIN 1164

Prepared in cooperation with the Geological Survey of Wyoming and the Department of Geology of the University of Wyoming as part of a program of the Department of the Interior for development of the Missouri River basin

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By FRANKLYN B. VAN HOUTEN

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By Franklyn B. Van Houten

ABSTRACT

The Beaver Rim area comprises about 600 square miles west and north of the Granite Mountains in eastern Fremont and southwestern Natrona Counties, Wyo. Sedimentary rocks as much as 2,000 feet thick of Eocene, Oligocene, and Miocene ages are well exposed along the Beaver Rim escarpment, which crosses the central part of the area and forms the southern margin of the Wind River Basin and the northern margin of the Sweetwater Plateau.

The Wind River Formation of early Eocene age is as much as 600 feet thick in the mapped area; it thickens northward toward the structural axis of the Wind River Basin. The basal contact is an angular unconformity. The formation consists chiefly of lenticular deposits of poorly sorted yellowish-gray feldspar-rich sandstone, poorly sorted pebble conglomerate, and variegated mudstone. Locally, thin layers of carbonaceous shale are present. Very large boulders of Precambrian and lower Paleozoic rocks also occur in the upper part of the formation. In the subsurface in the southwestern part of the area, the lower part of the formation apparently is a coarse boulder deposit. Dacitic pumice tuff is present in the upper part of the formation in the northwestern part of the area. Commercial concentrations of uranium minerals occur in poorly sorted arkose in the upper part of the formation in the Gas Hills area.

The Wind River Formation accumulated on low savannalike piedmonts and valley flats in a warm humid climate. The sediment was derived mainly from Precambrian rocks of the Sweetwater uplift. Near the end of early Eocene time, volcanic outbursts in the Yellowstone-Absaroka region in northwestern Wyoming spread showers of dacitic ash across the area.

The Wagon Bed Formation (new name) of middle and late Eocene age is conformable on the Wind River Formation and has a maximum thickness of 700 feet. Local thickness variations are the result of erosion prior to deposition of the overlying White River Formation of Oligocene age. The Wagon Bed Formation is characterized by persistent beds of greenish-gray to yellowish-gray sandstone, siltstone, and mudstone commonly containing considerable volcanic debris. The volcanic material in the formation in the western part of the area was derived from the Yellowstone-Absaroka calc-alkalic volcanic field; that in the eastern part was derived from the Rattlesnake Hills alkalic volcanic field.

The Wagon Bed Formation accumulated slowly during a warm humid period on poorly drained lowlands, on broad flood plains, and in lakes. Volcanic debris that reached the western part of the area was altered mostly to montmorillonite and silica, but acidic ash that accumulated in a lake during deposition of the middle part of the formation was altered to potassium feldspar, quartz, and zeolite. Alkalic volcanic debris deposited in the eastern part of the area accumulated more rapidly and generally was less altered.

The White River Formation of Oligocene age lies unconformably on the Wagon Bed Formation and has a maximum thickness of 650 feet. The White River Formation consists chiefly of massive yellowish-gray to grayish-orange tuffaceous bentonitic mudstone containing local lenses of arkosic sandstone and conglomerate. Unaltered volcanic debris occurs abundantly mixed with fine-grained detrital deposits and in beds of uncontaminated vitric tuff. In the western part of the area, the lower part of the formation includes the arkosic Big Sand Draw Sandstone Lentil (new name) overlain by the extensive very coarse and poorly sorted volcanic Beaver Divide Conglomerate Member.

During the Oligocene Epoch the climate was subhumid and warm-temperate, and there was a marked dry season. The area of deposition of the White River Formation was rather poorly drained, and fluvial sediments accumulated slowly on broad flood plains while many prolonged showers of ash from vents in the Yellowstone-Absaroka field spread over the region.

A minor erosional unconformity marks the contact of the Split Rock Formation of Miocene age and the underlying White River Formation. The Split Rock Formation is as much as 150 feet thick at the surface along the Beaver Rim, and as much as 300 feet thick in the subsurface. The formation is predominantly massive yellowish-gray and grayish-orange well-sorted volcanic sandstone with well-rounded grains. Light-gray flaggy limestone is present in the western part of the area. Rather persistent beds of coarse conglomerate are common, especially in the lower 50 to 100 feet of the formation. Basic volcanic detritus and a few beds of vitric tuff are also present.

During the Miocene Epoch the climate was cooler and drier than in Oligocene time. Arkosic detritus mixed with abundant sand-sized basic volcanic debris that apparently was blown into the area from northwestern Wyoming accumulated on extensive flood plains.

The principal structural features of the Beaver Rim area are:

1. The buried southeast-trending Emigrant Trail thrust fault along which the Sweetwater uplift was thrust southwestward.
2. Late Tertiary fractures and normal faults that are alined with the trend of the buried Emigrant Trail thrust fault.
3. A major system of east-trending normal faults and fractures of late Tertiary age along the north flank of the Sweetwater uplift.
4. Gentle folds in beds of the Wind River and Wagon Bed Formations where they overlie basin-margin folds.

Four distinct episodes of regional deformation affected the area during Tertiary time:

1. Major Laramide compressional forces during Paleocene and earliest Eocene time elevated and thrust the Sweetwater uplift southwestward while the Wind River Basin was being downwarped. Basin-margin folds were formed and eroded.
2. Marked downwarping of the Wind River Basin continued during Eocene time.
3. Epeirogenic uplift beginning after Eocene time ended in late Cenozoic time.
4. Late Cenozoic normal faulting and reversal of movement tilted the Sweetwater uplift southward when it failed to rise as the surrounding area was elevated.

INTRODUCTION

The Tertiary sedimentary rocks that crop out on Beaver Rim along the southern margin of the Wind River Basin and on the northern margin of the Sweetwater Plateau in central Wyoming constitute one of the most complete sequences of nonmarine rocks of Tertiary age in the Rocky Mountain region (pl. 2). As much as 2,000 feet of nearly horizontal Eocene, Oligocene, and Miocene rocks are well exposed along much of the extent of the Beaver Rim escarpment, which is also known as the Beaver Divide escarpment and the Sweetwater escarpment. "Beaver Rim" is used on U.S. Geological Survey topographic sheets of the area, but "Beaver Divide" has been widely used in previous geological reports.

These Tertiary rocks are an unusually complete sequence of nonmarine arkosic intermontane basin deposits which commonly accumulate after major orogenic episodes. The geologic work reported here was done to gain information about the tectonic and stratigraphic history of this part of the western interior of the United States during a major part of Cenozoic time. These geologic studies were made by the Geological Survey as part of the program of the Department of the Interior for the development of the Missouri River basin and were done with the cooperation of the Geological Survey of Wyoming and the Department of Geology, University of Wyoming.

LOCATION AND EXTENT OF THE AREA

The Beaver Rim area of this report includes about 600 square miles along the southern margin of the Wind River Basin and the northern margin of the Sweetwater uplift in eastern Fremont and southwestern Natrona Counties, central Wyoming (pl. 1; fig. 1). The eastern border of the area is about 60 miles west of Casper, the western border about 30 miles east of Lander, and the northwest corner about 16 miles south of Riverton.

The area lies approximately between lat 42°32′ and 42°50′ N. and long 107°25′ and 108°18′ W. and is included on part or all of the following Geological Survey 7½-minute quadrangle sheets: Yellowstone Ranch, Red Canyon, Sand Draw, Dishpan Butte, Sweetwater Station, Blue Gulch, Elkhorn Springs, Myers Ranch, Rongis Reservoir, Tin Cup Mountain, Graham Ranch, Rongis Reservoir SE, Muskrat Basin, Stampede Meadow, Puddle Springs, Coyote Springs, Black Rock Gap, Gas Hills, Agate Butte, Lankin Dome, Ervay Basin SW, and Blackjack Ranch.

PREVIOUS GEOLOGIC INVESTIGATIONS

Because the valley of the Sweetwater River affords one of the easiest routes of travel from the Great Plains into the Middle Rocky Mountain province, it was traversed by many explorers and early settlers of the West. In fact, few routes into the Rocky Mountain region have been used more continuously.

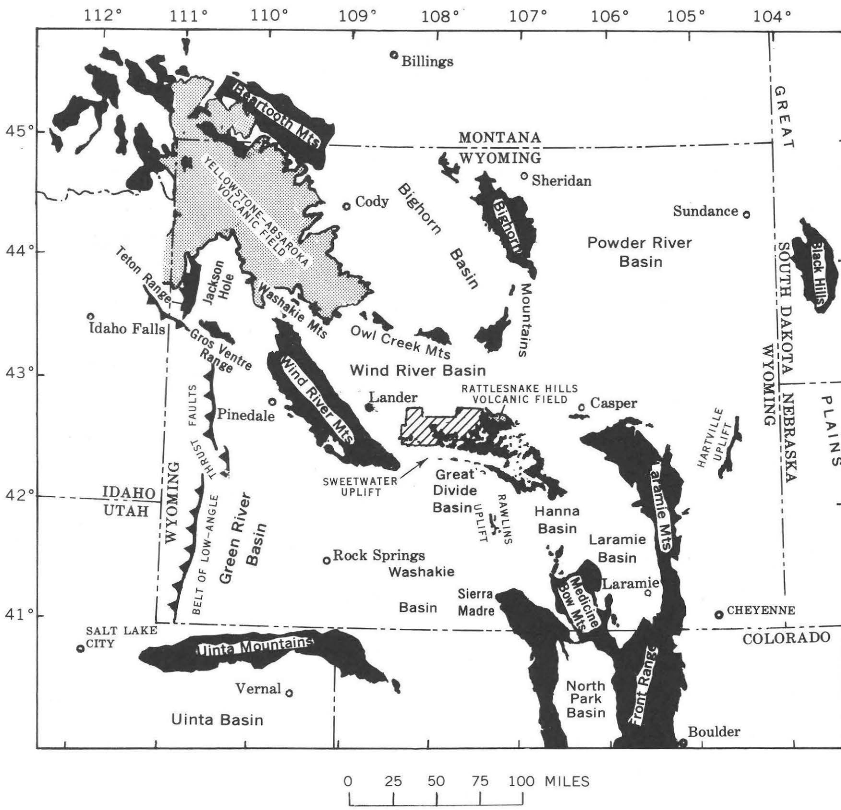

FIGURE 1.—Map of Wyoming and adjacent areas showing Beaver Rim area (diagonal pattern), outcrops of Precambrian rocks (solid pattern), and Yellowstone–Absaroka and Rattlesnake Hills volcanic fields (stippled pattern).

The following is a brief chronological summary of previous geological investigations of the area.

1860: Dr. F. V. Hayden (1862), attached to Captain W. F. Raynolds' expedition as surgeon and naturalist, traversed part of the Sweetwater Valley and produced a geologic map of central Wyoming (Hayden, 1869). On it are shown the Granite Mountains, Rattlesnake Hills, and the general position of the Beaver Divide.

1870: After further exploration of the Sweetwater Plateau by one of the Territorial Surveys, Hayden (1871) emphasized the setting of the Granite Mountains which were partly buried in a widespread mantle of upper Tertiary rocks. The assignment of a late Tertiary age to the mantle of the Sweetwater Plateau was based on oreodonts found by Hayden's party near Split Rock and described by Leidy (1870; 1873).

1877: F. M. Endlich (1833, 1879), geologist of the Sweetwater Division of the Geological Survey of Wyoming and Idaho, made a geologic map of central Wyoming and described the Tertiary formations along the Beaver Divide and on the Sweetwater Plateau. He recognized that these strata were remnants of deposits that once extended northward across the Wind River Basin.

1900: W. C. Knight (1900) discussed the anomalously low position of the Granite Mountains and, in a summary of the general geology of Wyoming, proposed that the Granite Mountains were outcrops of a downfaulted block of Precambrian rocks.

1909–10: On the basis of detailed field study of the Tertiary deposits along the western part of the "Beaver Divide," and the first collection of mammals from these strata, Walter Granger (1910) showed that these rocks constituted one of the most complete Tertiary sections in the Rocky Mountain region. Sinclair and Granger (1911) also discovered that the Tertiary deposits contained much volcanic debris, and they published one of the earliest reasonable interpretations of the mode of accumulation of Tertiary basin-fill sediments.

1911: L. G. Westgate and E. B. Branson (1913) made a regional study of the late Tertiary erosional history of the Wind River Range and the western part of the Sweetwater Plateau. They concluded that the surface of the plateau, called the Beaver Divide plain, was cut below a summit peneplain which they believed had formed during middle Tertiary time.

1913–14: C. J. Hares and his associates (1917, 1946a, 1946b) demonstrated that the Granite Mountains were the Precambrian core of the deeply eroded Sweetwater uplift flanked by basin-margin folds. Hares recognized the unique eastward trend of the core and discovered that it had been thrust southward on a fault along its southern flank.

1918: Collier (1919) made a detailed map of one of the basin-margin folds, Big Sand Draw anticline, and showed that the lower Eocene Wind River Formation was gently arched over it.

1930–31: C. M. Bauer (1934) mapped the Tertiary formations described by Sinclair and Granger (1911) eastward along Beaver Divide, and some folds in the Wind River Formation north of Beaver Divide. He (1934, p. 685), also described "* * * a great east-trending normal fault along the north side of the Green and Ferris Mountains". In a summary of the Tertiary history of the region, Bauer suggested that the southward-thrust Sweetwater uplift had been downfaulted at least 2,500 feet along its southern margin in late Cenozoic time, and that a boulder deposit on the Green Mountains was part of the Tertiary basin fill.

1944–60: Detailed geologic maps of more than 20 different areas in the western part of the Sweetwater Plateau and adjacent parts of the Wind River Basin have been published, principally by the U.S. Geological Survey and the Wyoming Geological Association.

PRESENT INVESTIGATION

PRELIMINARY REPORTS

Some of the results of the present investigation have been given in previous reports published by the U.S. Geological Survey. Mapping of the western part of the area (1948–50) was published in the U.S. Geological Survey Oil and Gas Investigations series as Maps OM–113 and OM–140 (Van Houten, 1950; 1954). Mapping of the eastern part of the area (summer of 1951) was published as Map

OM–180 (Van Houten and Weitz, 1956). A description of volcanic-rich middle and upper Eocene sedimentary rocks in the vicinity of Canyon Creek has been presented by Van Houten (1955). A brief summary and interpretation of the Tertiary sedimentary rocks in the southern Wind River Basin area has also been published (Van Houten, 1957).

FIELDWORK

Fieldwork began in 1948 and continued through 1951. In 1954, several weeks were spent on final field checking.

The geologic map (pl. 2) accompanying this report was compiled from geologic field observations plotted on aerial photographs. Field data were transferred later from the photographs to a base map constructed from U.S. Geological Survey topographic maps which were not available at the time the geologic mapping was done. Most of the geology of the area north and west of the Beaver Rim has been taken from Thompson and White (1952a, 1954), Van Houten and Weitz (1956), and Zeller (1957, pl. 1), as shown on plate 2.

Approximately 65 stratigraphic sections were measured along the Beaver Rim escarpment. These data are summarized in the graphic sections shown on plates 3, 4, and 5, and in diagrammatic profiles of the escarpment, plate 6. The stratigraphic sections were measured by tape and hand level. Elevations of sections and other critical points were established by use of an aneroid barometer to determine the relation to the numerous U.S. Geological Survey and U.S. Coast and Geodetic Survey triangulation stations and bench marks in the area. The elevations and thicknesses of the sections then were adjusted to elevations on U.S. Geological Survey topographic sheets. Dips are recorded on the geologic map only where they amount to several degrees or where a reading of 1° to 2° could be made with reasonable accuracy.

LABORATORY WORK

Laboratory work consisted of analyses and description of samples from measured stratigraphic sections and from cores and drill cuttings from wells and core holes. Many of the correlations based on the electric logs and lithologic samples from the wells are tentative because of the difficulty of interpreting electric logs of nonmarine Tertiary deposits and because of the contamination of many samples of drill cuttings caused by extensive caving of the relatively unconsolidated formations. Cores that were studied are listed below.

Minerals in the very fine sand grade (0.06 to 0.12 mm) of more than 400 crushed and sieved samples were separated by means of

TABLE 1.—*Core holes studied during this investigation*

Core hole No. (pl. 2)	Company No.	Company
CH 1	14A	Sinclair Oil & Gas.
2	15	Do.
3	8	Do.
4	9	Do.
5	13	Do.
6	6	Do.
7	2	Do.
8	2	Atlantic Refining.
9	1	Tidewater Associated Oil.
10	3	Atlantic Refining.
11	4	Do.
12	12	Sinclair Oil & Gas.

a magnetic separator; the magnetic minerals present are recorded on plate 7. Thin sections of pebbles of volcanic rocks and magnetic separates of minerals in crushed chips of the pebbles also were studied. Mineral colors reported are those seen under the petrographic microscope.

The very fine sand fraction of the sedimentary rocks consistently contains virtually the same accessory mineral suites as do the coarser fractions. Glass shards and volcanic biotite, however, are more abundant in the coarser sand fractions of some samples.

Feldspars in the nonmagnetic fraction of crushed chips of volcanic pebbles were identified by the immersion method and were checked in thin sections of some of the pebbles. Clay minerals, glauconite, zeolites, opal, and quartz and feldspar in devitrified glass were identified by their X-ray diffraction patterns.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the help and encouragement of J. D. Love throughout the progress of this investigation. Love's long interest in the Beaver Rim country and his experience with problems of Tertiary stratigraphy in the Rocky Mountain region have made his suggestions and advice invaluable.

I also wish to express my thanks to other geologists who have worked in the area. In particular, Robert L. Sielaff, formerly of the Sinclair Oil and Gas Co., Denver, Colo., generously made available samples and electric logs of Tertiary parts of core holes drilled in the area. Samples of the Tertiary rocks in the Carter Oil Immigrant Trail 1 test well were examined in the company office through the courtesy of James C. McCulloch. Study of the Tertiary samples and electric log of the British-American Oil Producing Co. Government-Heaney 1 and publication of the results were made possible by the cooperation of Donald E. Edstrom of the British-American Oil Producing Co., Casper, Wyo. The Tertiary parts of some core holes were made available by Bruce M. Choate of the Atlantic Refining Co. and by Robert E. Lindsay of the Tide Water Associated Oil Co., Casper, Wyo.

Raymond M. Thompson, Harry A. Tourtelot, and Joseph L. Weitz helped with some of the field problems and supplied information about several of the formations. B. D. Carey, Jr., furnished information about the volcanic rocks of the Rattlesnake Hills. Harry H. Hess and Richard L. Hay aided with identification of some of the minerals in the rock samples and offered helpful suggestions concerning volcanic debris in sediments. T. C. Yen identified fossil gastropods collected by the U.S. Geological Survey field parties. Restudy of these collections and comparison of the fossils with mollusks from sedimentary sequences in adjacent areas were made by D. W. Taylor.

I have benefited by discussing Tertiary mammals and problems of correlation with John Clark, C. Lewis Gazin, Paul McGrew, Horace E. Wood, 2d, and Jean Hough, and I am indebted to them for their help with the identification of some of the fossil mammals.

The following men assisted with the fieldwork: Robert Cossum in 1949, John B. Howe in 1950, and Colin C. McAneny in 1951.

The Princeton University Department of Geology provided facilities for the laboratory studies and defrayed the cost of thin sections and magnetic mineral mounts. Mrs. C. Sadlon prepared the thin sections of the sedimentary rocks, many of which are bentonitic and very difficult to cut.

GEOGRAPHY

CLIMATE

Like most basin areas in Wyoming, the Beaver Rim area has a semiarid middle-latitude steppe climate and an annual rainfall of almost 10 to 20 inches. During the summer months most of the days are hot, dry, and clear, except for the occurrence of scattered heavy rain which is commonly accompanied by hail. Because of the dry climate, all the streams, except Long Creek and the Sweetwater River, are intermittent and there are several small dry lakes on the plateau.

TOPOGRAPHY AND DRAINAGE

GENERAL SETTING

Parts of three distinctive physiographic sections of the Wyoming Basin province of Fenneman (1931, p. 133–149)—the Wind River Basin, the Sweetwater Plateau, and the Granite Mountains—are within the Beaver Rim area of this report (pl. 1). The maximum relief in the area is about 2,600 feet. The lowest point, 5,440 feet above sea level, is along Big Sand Draw in the northwest corner of the map area. The highest point, 8,041 feet above sea level, is on Black Mountain in the northeastern part of the area.

WIND RIVER BASIN

The Wind River Basin is one of the typical structural and topographic basins of the Rocky Mountain province in Wyoming. Its northern and southwestern borders are mountain ranges. Its eastern border is a broad, low northwest-trending structural divide separating the Wind River and Powder River basins. Its northwestern and southern topographic borders are conspicuous escarpments of Tertiary rocks. The northwestern escarpment is the southern margin of the Absaroka Plateau, the southern is the Beaver Rim.

Along the southern border of the basin, distinct cuestas and hogbacks of Paleozoic and Mesozoic strata outline the larger northwest-trending anticlines. The Conant Creek anticline, the largest anticline in the map area, is flanked by rocks of Paleozoic age that rise above the level of the Sweetwater Plateau and locally interrupt the Beaver Rim escarpment. Other conspicuous topographic and structural features along the southern edge of the Wind River Basin in the Beaver Rim area include the Big Sand Draw and Rogers Mountain anticlines in the northwestern part of the map area, Muskrat Basin in the north-central part, and the Gas Hills and the Dutton Basin in the northeastern part.

Badland topography is common along the southern margin of the Wind River Basin. Locally, however, northward-sloping (1° to 2°) remnants of a former smoother basin floor are preserved. Between Conant Creek anticline and Muskrat Basin are long benches between northward-flowing creeks. The broad extent and general accordance of some of these benches suggest that they are remnants of erosion surfaces cut during stages of less active dissection in late Tertiary or Quaternary time.

BEAVER RIM

The Beaver Rim is a conspicuous topographic rim at the northern margin of the Sweetwater Plateau (fig. 2). It extends from the Sheep Mountain anticline about 10 miles west of the map area eastward for 55 miles to the Rattlesnake Hills anticline about 5 miles east of the area, and it separates streams with relatively steep gradients that flow northward into the Wind River from streams with relatively gentle gradients that flow southward into the Sweetwater River. The escarpment rises from about 6,800 feet to about 7,600 feet above sea level and stands as much as 1,200 feet above the basin. Broad areas of hummocky landslide topography are rather common along the lower part of the northern face of the escarpment. Landmarks along the

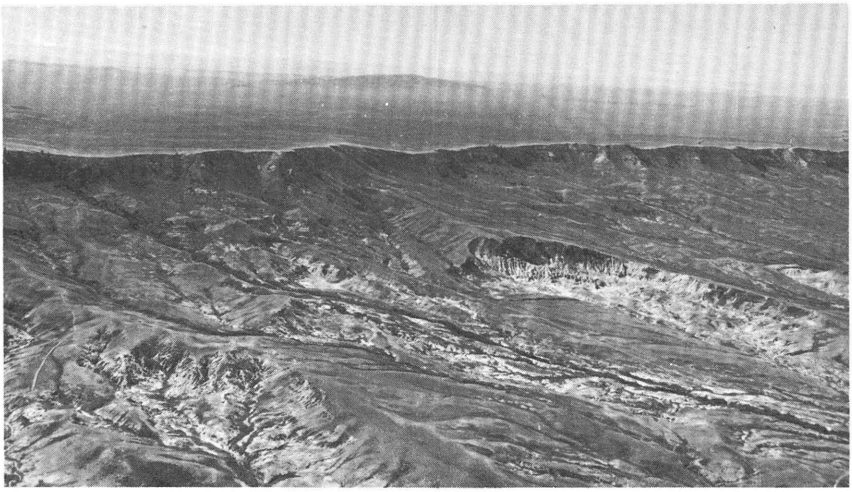

FIGURE 2.—Aerial photograph of Beaver Rim escarpment east of Conant Creek anticline, in secs. 17, 18, and 19, T. 32 N., R. 92 W., and sec. 13, T. 32 N., R. 93 W., looking southwestward. Photograph by R. M. Thompson.

rim include Green Cove, Devils Gap, Government Slide, and Wagon Bed Spring in the western part of the area; Findlay (Chalk) Springs and the Muskrat Creek reentrant in the central part; and Cameron Spring and the Canyon Creek reentrant in the eastern part.

In the vicinity of Cameron Spring (sec. 11, T. 32 N., R. 90 W.), several short ridges that end in northward-sloping triangular-shaped faces stand out from the present steeper rim. The faces of these ridges are remnants of a former smoother, less steep face of the Beaver Rim escarpment.

SWEETWATER PLATEAU

The relatively undissected and gently southward-sloping Sweetwater Plateau, underlain by southward-dipping upper Tertiary strata, is broadly modified in two areas. In the eastern part of the map area, the surface is extensively dissected between Muskrat Basin and Black Mountain (pls. 1 and 2). In the western part, a broad level area about 250 to 300 feet lower than the principal plateau surface has been cut by the Long Creek drainage on the east and west sides of Conant Creek anticline and along the west side of the Granite Mountains. The same type of level area is found farther west in Tps. 30 and 31 N., R. 95 W., along a drainage system flowing southeastward into the Sweetwater River (pl. 2). The altitude and extent of these lower levels, which are on the Oligocene White River Formation, apparently are largely controlled by the ease of erosion of the mudstone of the White River.

GRANITE MOUNTAINS

Rising from the middle of the Sweetwater Plateau are scattered knobs and masses of Precambrian rocks of the Granite Mountains that extend from the middle part of the plateau eastward for about 50 miles to the vicinity of the Pathfinder Reservoir. The northernmost mass is Black Mountain in the northeastern corner of the map area. Seen from a distance, the Granite Mountains "* * * present a very rugged appearance. No timber exists on the hills to modify their outlines, and the impression obtained is that of a high range. Rising abruptly from a very gentle, regular slope, they closely resemble rocky islands projecting above the level of the sea" (Endlich, 1879, p. 45). On all sides of the Precambrian masses, small alluvial fans and pediments, cut mainly on the Tertiary rocks, slope gently outward from the mountains.

In order to clarify terminology related to the Granite Mountains, the following definitions are introduced here: The Sweetwater uplift is a great east-trending crustal block whose Precambrian core has been carved into the Granite, Ferris, Seminoe, and Shirley topographic mountains. The Sweetwater anticline of Bell (1956, p. 83) is a complexly faulted fold in the southwesternmost corner of the mapped area (pl. 2).

SWEETWATER RIVER

The Sweetwater River rises in the southeastern end of the Wind River Mountains and flows generally eastward across the Sweetwater Plateau to join the North Platte River at the Pathfinder Reservoir (pl. 1). From the eastern foothills of the Wind River Mountains to the area west of Long Creek ("Heron Creek" of early reports; "Longs Creek" of some recent ones), the Sweetwater River flows over open country, underlain chiefly by unconsolidated upper Tertiary formations, but locally the river is superposed on structural blocks of Precambrian and Paleozoic rocks. From the area of Long Creek east to the Pathfinder Reservoir, the Sweetwater River flows across several masses of Precambrian rocks that project through the upper Tertiary deposits of the Sweetwater Plateau. Similarly, the larger southward-flowing tributaries of the Sweetwater River flow across Precambrian and Tertiary rocks in the Granite Mountains.

On the Sweetwater Plateau the Sweetwater River is adjusted at a base level about 1,200 feet higher than the base level of the Wind River drainage system north of the plateau. The rival Wind River drainage, which is actively eroding the northern margin of the plateau, will eventually capture the Sweetwater River west of the Granite Mountains if the present drainage pattern persists.

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West of the Granite Mountains are several large remnants of gravel-capped terraces at two levels, one 160 to 180 feet above the Sweetwater River and the other about 240 feet above the river. Although the origin of these terraces is not known, their location west of the Granite Mountains suggests that hard rock of the range may have retarded downcutting by the river and may have served as a local base-level control during some stage in a process of superposition. Other lower, less conspicuous terrace remnants, at 100, 55, 35, 12, and 5 feet above the river, presumably were produced by erosion and deposition by melt water from successive Pleistocene glaciers in the southwestern Wind River Mountains (Holmes and Moss, 1955, table 3, fig. 2).

On the Sweetwater Plateau both north and west of the Granite Mountains, the east sides of valleys cut by the southward-flowing tributaries of the Sweetwater River are steeper than the west sides. This feature is especially conspicuous east of the Conant Creek anticline and may be related in part to late Tertiary or Quaternary southeastward tilting of the area.

ACCESSIBILITY AND ROUTES OF TRAVEL

Paved U.S. Highway 287 crosses the southwestern part of the map area; a graded road across the western part of the Sweetwater Plateau leads from U.S. Highway 287 near the Sweetwater River northward to the Sand Draw postoffice and is oiled from there to Wyoming Highway 320 near Riverton. A graded Northern Utilities pipeline road north of Beaver Rim leads eastward from the town of Sand Draw to Ervay and Casper. The eastern part of the area is crossed by a graded road that goes southward from the Gas Hills area to Jeffrey City on U.S. Highway 287 several miles south of the map area. The easternmost part of the area can be reached on a graded road that leads northwestward from Wyoming Highway 220 in the vicinity of the Pathfinder Reservoir to Deer Creek Valley and the pipeline road. Numerous unimproved roads and trails cross the undissected plateau and make much of the area easily accessible.

REGIONAL STRATIGRAPHIC RELATIONS

Precambrian rocks that crop out in the Granite Mountains and in the southwestern corner of the map area are gneiss, schist, granite, and black dike rock.

Sedimentary rocks exposed along the southern margin of the Wind River Basin range in age from Cambrian to Quaternary and have an aggregate maximum thickness of about 14,000 feet. Mesozoic and Paleozoic rocks and the Fort Union Formation of earliest Tertiary (Paleocene) age were not studied in detail. The lithic features and thickness of these rocks at the Conant Creek anticline and in Dutton Basin are given by Love and others (1947), Thompson and others (1950), and Thompson and White (1952a). These sources were used in compiling table 2, which shows the succession of rocks exposed in the area and summarizes information on units that are not described in detail in this report.

Paleozoic rocks are exposed on the southwest flank of the Sweetwater uplift (p. 84) in T. 30 N., Rs. 93 and 94 W., and in small areas in sec. 1, T. 31 N., R. 94 W., and on the north flank in secs. 11 and 17, T. 31 N., R. 92 W. Paleozoic strata are extensively exposed on the northwestward-trending Conant Creek anticline in T. 32 N., R. 94 W., and crop out in an inlier in secs. 22, 23, and 26, T. 33 N., R. 89 W., that may be part of the core of the Dutton Basin anticline. North-

TABLE 2.—*Composite stratigraphic section of sedimentary rocks exposed in the Beaver Rim and nearby areas*

Age		Formation	Thickness (feet)	Character
Tertiary	Miocene	Split Rock Formation	150+	Yellowish-gray to pale-orange conglomerate and well sorted sandstone; a few beds of vitric tuff; contains volcanic pebbles east of Muskrat Basin.
		—Unconformity—		
	Oligocene	White River Formation	100–650	Bentonitic and tuffaceous yellowish-gray to grayish-orange mudstone; lenses of arkose and conglomerate; beds of vitric tuff; Big Sand Draw Sandstone Lentil and overlying Beaver Divide Conglomerate Member at base in western part of area.
		—Unconformity—		
	Eocene	Wagon Bed Formation	130–700	Bentonitic greenish-yellow to yellowish-gray, locally tuffaceous zeolitic mudstone and sandstone in persistent beds; volcanic sandstone and conglomerate.
		Wind River Formation	300–600	Yellowish-gray to variegated mudstone, sandstone, and conglomerate in lenticular beds; sandstone commonly arkosic; locally tuffaceous in upper part.
		—Unconformity—		
	Paleocene	Fort Union Formation	0–200+	Conglomeratic sandstone, gray clay shale, and brown carbonaceous shale; contains ironstone concretions; absent in the eastern part of the Beaver Rim area.
		—Unconformity—		

TABLE 2.—*Composite stratigraphic section of sedimentary rocks exposed in the Beaver Rim and nearby areas*—Continued

Age		Formation	Thickness (feet)	Character
Cretaceous	Late	Mesaverde Formation	0–1300	Light-gray to tan sandstone; lesser amounts of gray shale and siltstone; a few thin coal beds; absent in the eastern part of the Beaver Rim area.
		Cody Shale	4000–5000	Upper half is gray to tan sandy shale and sandstone; forms low ridges; prominent concretionary zone about 500 ft below top contains fossils of probable Eagle age; lower half is gray shale and sandy shale, calcareous in part; contains fossils of early Niobrara age (*Inoceramus deformis* Meek) in lower 100 ft; fossils identified by W. A. Cobban.
		Frontier Formation	581–909	Sandstone and shale; sandstone is gray, fine- to medium-grained; weathers gray to rusty; nonmarine; forms prominent ridges in upper 115 ft; 10-ft-thick sandstone bed 90 ft above base locally forms prominent ridge; shale is dark gray to black, sandy to silty, bentonitic in part; at the base is a 2-ft-thick, very light gray, waxy hard bentonitic bed; large calcareous concretions about 200 ft below top contain the ammonite *Acanthoceras* of Graneros age; fossils identified by J. B. Reeside, Jr.
	Early	Mowry Shale	395–536	Black to dark-gray siliceous shale; weathers light gray; forms prominent rounded hogbacks; contains numerous fish scales; includes siltstone and bentonitic shale in upper part and bentonite beds in lower part; contact with underlying formation arbitrarily placed at base of lowest siliceous shale.

TABLE 2.—*Composite stratigraphic section of sedimentary rocks exposed in the Beaver Rim and nearby areas*—Continued

Age		Formation	Thickness (feet)	Character
Cretaceous	Early	Thermopolis Shale	207–255	Black soft flaky shale, in many places poorly exposed; forms valleys; some fine-grained rusty sandstone, gray siltstone, and light-gray bentonitic shale; muddy sandstone member in upper half is light gray, fine grained, shaly in part; weathers rusty; forms very low ridge in some areas.
Cretaceous —?— Jurassic	Early —?— Late	Cloverly and Morrison Formations, undifferentiated	293–379	Top 40 ft is called the rusty beds and is light-gray fine- to coarse-grained sparkly sandstone that weathers rusty and contains some dark shale; rusty beds underlain by about 40 ft of conglomerate that is gray, weathers brown, contains black chert pebbles, grades laterally to gray sparkly sandstone, and forms prominent ridge; lower part of formation is mostly variegated claystone; at the base medium-grained, coarsely bedded sandstone that forms a low ridge.
Jurassic	Late	Sundance Formation	240±	"Upper Sundance" is sandstone, shale, and limestone; sandstone is green, very glauconitic, shaly in part; contains numerous Belemnites in lower part; limestone is brown, glauconitic, shaly in part; contains numerous large pelecypod fossils; 95 to 121 ft thick. "Lower Sundance" is sandstone and shale; sandstone is buff to light gray, near top includes two thin red shaly zones; shale is pale green, sandy in part, calcareous in part; 127 to 135 ft thick.
		Unconformity		
Jurassic	Early	Nugget Sandstone	171–325	Gray and greenish-gray sandstone, shaly in part, calcareous in part; middle part forms prominent ridge.
		Unconformity		

TABLE 2.—*Composite stratigraphic section of sedimentary rocks exposed in the Beaver Rim and nearby areas*—Continued

Age			Formation	Thickness (feet)	Character
Triassic		—?—	Chugwater Formation	1100± 1270	Reddish-brown sandstone and siltstone, shaly in part, calcareous in part; purplish-green zones containing limestone pellets near the top; Alcova Limestone Member in the upper part is gray hard limestone that forms a low ridge and prominent dip slope.
Triassic		Early	Dinwood Formation	62	Gray to tan shale and sandstone; locally calcareous in upper half; silty and dolomitic in lower half.
Permian			Phosphoria Formation	348	Gray to brown dolomitic siltstone and dolomite; contains some bedded chert and thin phosphatic zones; forms low ridge.
			Unconformity		
Permian / Carboniferous	Pennsylvanian		Tensleep Sandstone	230–299	Gray to rusty fine- to medium-grained sandstone, crossbedded in part, calcareous in part; includes some white dolomite and cherty dolomite; forms prominent ridges.
Carboniferous	Pennsylvanian		Amsden Formation	187–188	Red to gray sandstone and shale, silty near top and in middle part; cherty gray limestone and dolomite in upper middle part; sandstone at base is fine grained, thick bedded, slightly calcareous, and is probably equivalent to the Darwin Sandstone Member in Wind River Mountains.
			Unconformity		
Carboniferous	Mississippian		Madison Limestone	319–420	Light-gray to gray-brown limestone and dolomite more dolomite in lower part, cherty in part; forms ridges, cliffs, and rocky slopes.

TABLE 2.—*Composite stratigraphic section of sedimentary rocks exposed in the Beaver Rim and nearby areas*—Continued

Age		Formation	Thickness (feet)	Character
		Unconformity		
Cambrian	Late	Gallatin Limestone	0–209	Gray to red sandy glauconitic limestone and flat-pebble limestone conglomerate; thins eastward and is missing in Dutton Basin area; fossils 70 ft below top of formation in Conant Creek area include: *Eoorthis, Taenicephalus, Bemaspis, Orygmaspis, Billingsella, Huenella;* fossils a few feet lower include *Eoorthis, Billingsella, Bernia, Glyptotrophia, Parabolinoides, Dellea, Berkia, Linnarssonella.* Fossils identified by A. R. Palmer.
Cambrian	Middle	Gros Ventre Formation	327–430±	Gray to reddish-brown glauconitic siltstone and sandstone, calcareous in part, quartzitic in part; includes gray glauconitic flat-pebble limestone conglomerate in middle part.
Cambrian	Middle	Flathead Sandstone	245	Reddish-brown sandstone, quartzitic in part, locally glauconitic, crossbedded, arkosic to conglomeratic in part; in Dutton Basin area top 30 feet forms prominent quartzite ledges.
		Unconformity		
Precambrian				Granite, gneiss, and schist.

ward-dipping Paleozoic rocks in secs. 14 and 15, T. 30 N., R. 96 W., are part of the belt of complexly faulted anticlines southwest of the Sweetwater uplift.

Mesozoic rocks crop out extensively on anticlines along the southern border of the Wind River Basin and are especially well exposed in the map area in the structurally high area from Rogers Mountain anticline to the Conant Creek anticline and on the Dutton Basin anticline.

The Wind River Formation (lower Eocene), the oldest Tertiary formation exposed along the Beaver Rim, crops out extensively in the Wind River Basin and at the base of the Beaver Rim escarpment. The Wagon Bed (middle and upper Eocene) and White River (Oligocene) Formations crop out mainly on the Beaver Rim escarpment. The Split Rock Formation (Miocene) is extensively exposed on the Sweetwater Plateau, and south of the map area it is overlain by the Moonstone Formation (Pliocene) (Love, 1961).

Gravel occurs on several terrace remnants along the Sweetwater River. Alluvium composed of sand and silt underlies the flood plain of the Sweetwater River and is present also in the narrow valleys of the larger streams, especially in those of the Wind River tributaries. Along the base of Beaver Rim colluvium is widespread, notably debris (earth) flows which result in characteristic hummocky topography.

TERTIARY SEDIMENTARY ROCKS

Tertiary sedimentary rocks exposed along the Beaver Rim are chiefly flood-plain and stream-channel deposits but contain subordinate lacustrine and pyroclastic deposits. The Eocene formations generally consist of lenticular, poorly sorted deposits that overlap truncated basin-margin folds and wedge out against the Sweetwater uplift. The successively younger Tertiary formations, in contrast, are commonly better sorted, less lenticular, and overlap the older formations and extend farther southward onto and across the uplift. Most of the volcanic debris in the Tertiary rocks was derived from the Yellowstone-Absaroka volcanic field in northwestern Wyoming; the rest came from the Rattlesnake Hills volcanic field east of the map area (fig. 1).

The most complete and best exposed stratigraphic sections of the Tertiary formations are found at Green Cove in sec. 35, T. 31 N., R. 96 W. (fig. 3), at Wagon Bed Spring in sec. 34, T. 32 N., R. 95 W., between Cameron Spring and Rim triangulation station in secs. 10 and 11, T. 32 N., R. 90 W (fig. 4), and in the Canyon Creek reentrant in secs. 27, 33, 34, T. 33 N., R. 89 W. The most accessible section is exposed along U.S. Highway 287 where it descends the Beaver Rim escarpment in secs. 2, 3, 10, and 11, T. 30 N., R. 96 W. Rocks in the same stratigraphic position as those at Green Cove are exposed at this locality.

In the vicinity of the Conant Creek anticline and on the north flank of both the Sweetwater anticline (in the southwest corner of

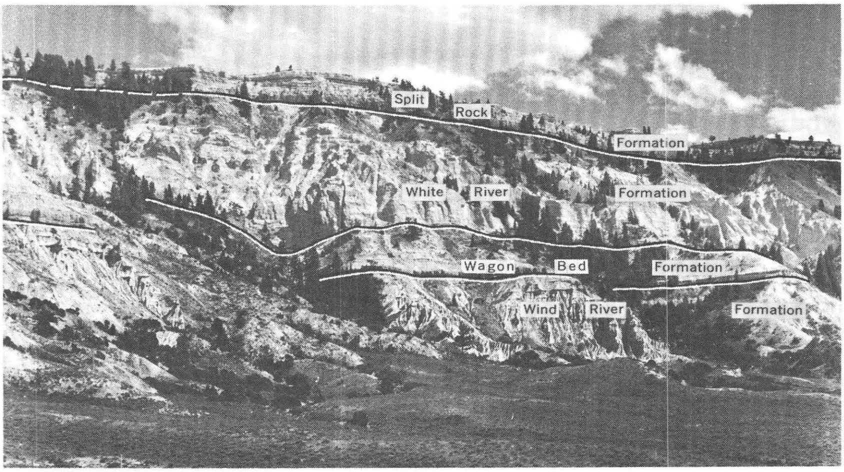

FIGURE 3.—Tertiary formations exposed on the Beaver Rim escarpment at Green Cove, sec. 35, T. 31 N., R. 96 W., looking southeastward. Transition zone of Wind River Formation crops out in steep lower quarter of slope below persistent ledge formed by unit 1 of Wagon Bed Formation. Unconformity at base of White River Formation cuts out several hundred feet of the Wagon Bed Formation. White River Formation crops out in rugged light-colored middle third of slope. Split Rock Formation forms vertical cliff at top of escarpment.

the map area) and the Sweetwater uplift, the Tertiary deposits contain coarse conglomerate and are not easily differentiated. Consequently, some of these conglomeratic deposits cannot be correlated positively.

Tentative regional correlation and age assignment of the Tertiary rocks are shown in table 3 (in separate volume). The age determinations are based principally on fossil mammals in the collections of the American Museum of Natural History (AMNH), New York City; the Carnegie Museum (CM), Pittsburgh; Princeton University Natural History Museum (PUNM), Princeton, N.J.; the U.S. National Museum (USGS and USNM), Washington, D.C.; and the University of Wyoming museum (Univ. Wyo.), Laramie, Wyo. Numbered fossil localities are shown on the geologic map (pl. 2); the stratigraphic horizons in which fossils were found are shown on the stratigraphic sections (pls. 3, 4, and 5).

The Tertiary provincial age terms Wasatchian, Bridgerian, Uintan, etc., based on mammalian faunas, are widely used in discussions of Rocky Mountain Tertiary stratigraphy. For this reason they have been used here in discussions of age assignments and correlation even though they have not been formally accepted by the U.S. Geological Survey.

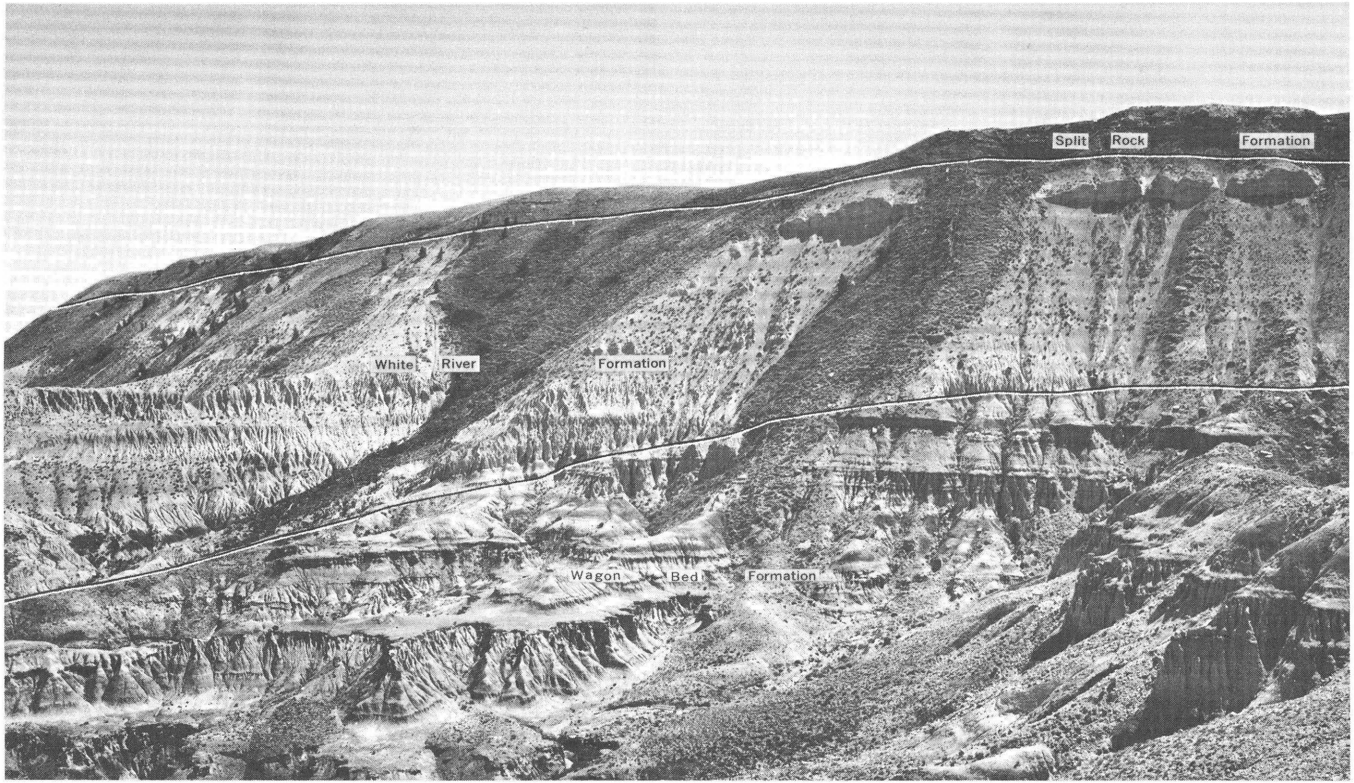

FIGURE 4.—Teritary formations exposed on the Beaver Rim escarpment southwest of Cameron Spring, secs. 10 and 11, T. 32 N., R. 90 W., looking southeastward.

TERMINOLOGY

In this report colors of the rocks have been determined from the "Rock-Color Chart" (Goddard and others, 1948).

Variegated is applied to rocks that are irregularly varicolored in large outcrops. Generally the layers and lenses are shades of reddish brown to grayish red and yellowish gray to greenish gray.

Intraformational refers to processes active or features produced during the deposition of a formation.

Detrital designates particles that originated away from the place of deposition.

Roundness refers to the angularity or sharpness of the edges and corners of a grain, and not to its **sphericity** or shape.

Matrix is a relative term applied to the subordinate smaller sized material that surrounds the larger **grains** of the predominating size that form the bulk of the rock (Williams, Turner, and Gilbert, 1954, p. 278; Pettijohn, 1957, p. 284).

Sorting indicates the distribution of size grades of grains in a sedimentary rock (Pettijohn, 1957, p. 36–37). The amount of matrix present is a general index of the effectiveness of the sorting process.

Cement is a chemical substance precipitated around grains and in the matrix.

Detrital rocks are named on the basis of principal grain size, composition, and degree of sorting observed in hand specimen and in thin section, generally following the descriptive classification of sedimentary rocks proposed by Gilbert (in Williams, Turner, and Gilbert, 1954, p. 289–297). The basic textural terms **well-sorted** (less than about 15 percent matrix) and **poorly sorted** (more than about 15 percent matrix) refer specifically to the relative amount of matrix in contrast to grains, not to the size grading of the principal detrital fraction (that is gravel, sand, or silt).

In the Beaver Rim area, the most distinctive kind of Tertiary sandstone is an **arkose** which contains at least 25 percent feldspar, predominantly of potassic and sodic types. Feldspathic sandstone containing 10 to 25 percent feldspar is also a common rock type. Both types may be well sorted or poorly sorted, but generally they contain less than 20 percent matrix.

Mudstone is the name applied to nonfissile rocks consisting predominantly of silt and clay (grains 0.062 to 0.005 mm in diameter) and containing lesser amounts of scattered sand; it is the common fine-grained detrital rock in the Beaver Rim area. **Shale** is a fissile rock containing more than 50 percent silt- and clay-sized grains.

Chert is a siliceous rock composed largely of cryptocrystalline, microcrystalline, and microfibrous quartz, and rarely of opal. Applied precisely, the mineral name chalcedony includes only microfibrous quartz (Folk and Weaver, 1952; Williams, Turner, and Gilbert, 1954, p. 357–359).

Opalite is a rock composed of both opal and chalcedony.

Granitoid is applied to coarse-grained granitelike Precambrian rocks of the Granite Mountains. The term does not imply plutonic origin.

Crystalline refers to coarse-grained Precambrian plutonic and metamorphic rocks, in contrast to fine-grained Precambrian dike rock and Tertiary volcanic rocks. Deposits containing abundant large fragments of these coarse-grained rocks are called crystalline conglomerates.

Tuff is a rock composed predominantly of sand-sized fragments of pyroclastic, or primary eruptive, origin. The debris may be (a) crystals, (b) vitric ash consisting of clear flat or keeled plates, or glass containing elongate bubbles and inclusions commonly giving the shard a fibrous appearance, or (c) lithic fragments of very fine grained igneous rock containing microlites.

Lapilli tuff is a rock rich in pyroclastic debris measuring 4 to 32 mm in diameter.

Tuffaceous is applied to sedimentary rocks containing a subordinate amount of pyroclastic material.

Inasmuch as the terms "tuff" and "tuffaceous" refer to debris transported by the explosive energy of volcanic eruption, they are used only when a pyroclastic origin can be inferred with reasonable certainty. Rocks containing volcanic debris eroded from a volcanic source area and transported by currents of water are referred to as **volcanic conglomerate, volcanic sandstone,** or **volcanic mudstone** (Williams, Turner, and Gilbert, 1954, p. 149–150). The term "volcanic" is also applied to those sedimentary rocks containing volcanic debris whose mode of transportation cannot be determined.

Since Hague (1899) first applied the terms "acid" and "basic" to volcanic rocks in the Yellowstone National Park region, these terms have been used in discussions of Tertiary volcanic rocks in western Wyoming, and they are widely used in general petrographic descriptions. The scheme of "acidic" and "basic" types, based on the amount of silica in an igneous rock, is not a satisfactory basis for classification (Williams, Turner, and Gilbert, 1954, p. 27). Nevertheless, it is a useful descriptive device, inasmuch as consistent mineral associations commonly occur in igneous rocks of acidic and basic composition. Rhyolite, dacite, and acidic andesite containing an excess of light-colored minerals and having a light-colored groundmass are characteristic acidic rocks. Acidic volcanic debris generally contains abundant biotite, green-brown hornblende, and potassium and sodium feldspars. Basic rock types found are darker andesites and basalt containing abundant pyroxene. Basic volcanic debris is characterized by olivine, augite, hypersthene, oxyhornblende, and calcic plagioclase.

In this report the terms "acidic" and "basic" have been used to describe mudstone, sandstone, and conglomerate containing tuffaceous and volcanic constituents. Sedimentary rocks containing acidic volcanic debris generally are light colored and contain shards, acidic lithic fragments, hexagonal biotite, and green-brown hornblende. Sedimentary rocks containing basic volcanic debris commonly are drab colored and contain more basic lithic fragments, augite, hypersthene, and oxyhornblende.

Volcanic detritus of diverse types commonly is mixed in the process of sedimentation. Consequently the minerals in volcanic sedimentary rocks do not necessarily indicate accurately the kind of volcanic rocks produced in the source area. Detrital volcanic minerals and minerals in volcanic pebbles are reliable guides to a particular volcanic source when they agree with minerals in the generally less common associated pyroclastic deposits.

For hand-specimen identification, sanidine-anorthoclase- and albite-oligoclase-bearing rocks derived from the Rattlesnake Hills volcanic field have been named **sodic trachyte** on the basis of abundant sodic plagioclase and a rarity of quartz seen in thin section. This name should not be confused with **soda trachyte,** a name commonly used for trachyte containing soda-rich mafic minerals. Oligoclase-andesine-bearing rocks are called **andesite.** Staining of thin sections with sodium cobaltinitrite (Chayes, 1952) reveals the presence of considerable potassium in the groundmass of both sodic trachyte and andesite. Calculations based on chemical analyses undoubtedly would result in different theoretical proportions of the diagnostic minerals in these rocks, requiring their assignment to different, though closely related, types. On the basis of their normative mineral composition the rocks called sodic trachyte actually may be quartz latite or rhyodacite and the andesite may be an alkalic trachyte or andesite, as suggested by B. D. Carey, Jr. (written communication, 1953; 1954a, p. 33).

EOCENE SERIES

WIND RIVER FORMATION

DEFINITION

The oldest Tertiary rocks exposed along the Beaver Rim are variegated deposits of the lower Eocene Wind River Formation. Hayden (1862, p. 310–311) used the name Wind River Group for deposits exposed throughout the Wind River Basin and later (1883) mapped these rocks along the southern margin of the basin. He pointed out

(1878) that these rocks are generally equivalent to the lower Eocene Wasatch Group; some geologists have applied the name Wasatch to the Wind River Basin deposits. The early Eocene age of the Wind River Formation was clearly established by Cope (1880).

Inasmuch as no type section of the Wind River Formation was designated by Hayden, the area of fossiliferous rocks exposed along the northeastern border of the basin in the vicinity of Lysite and Lost Cabin (about 40 miles northeast of Riverton), described in some detail by Granger (1910), has become the standard for comparison. Sinclair and Granger (1911) described the Wind River Formation in the western part of the Beaver Rim area and showed that it is of late Wasatchian (late early Eocene) age.

DISTRIBUTION AND THICKNESS

The Wind River Formation crops out extensively in the Wind River drainage basin west and north of the Beaver Rim, and it forms the lower 100 to 200 feet of the escarpment southwest of Government Slide (fig. 3).

The Wind River Formation wedges out south and southwest of the Beaver Rim area against the Sweetwater uplift and the Sweetwater and Sheep Mountain anticlines, and to the east against the Rattlesnake Hills anticline. The formation is also absent in the structurally high area between the Rogers Mountain and Conant Creek anticlines. The formation thickens northward into the basin. Tabulated below are thicknesses of the Wind River Formation at six locations in the southern Wind River Basin:

Location	*Thickness (feet)*
1. Sec. 10, T. 30 N., R. 96 W., U.S. Highway 287, southwest corner of map area (fig. 1)	300
2. Sec. 35, T. 31, N., R. 96 W., Green Cove; 2 miles northeast of loc. 1	430
3. SW¼ T. 33 N., R. 95 W., Northwest corner of map area; 14 miles north-northeast of loc. 2	500–600
4. Tps. 32–33 N., R. 90 W., Gas Hills area	900
5. NE¼ T. 33 N., R. 96 W., Beaver Creek anticline; 9 miles northwest of loc. 3	>1, 000
6. SE¼ T. 15 N., R. 4 E., Riverton anticline; 11 miles north-northwest of loc. 5	>2, 400

Along the structural axis of the Wind River Basin, about 50 miles north of U.S. Highway 287, a thickness of about 6,000 feet for lower Eocene rocks is suggested by geophysical data (Love, 1960, p. 207).

LITHOLOGY

The Wind River Formation is composed chiefly of lenticular beds of poorly sorted feldspathic to arkosic sandstone, pebble conglomerate, and variegated mudstone. The rocks commonly are poorly cemented with calcium carbonate and limonite.

The sandstone and conglomerate generally erode to form minor cliffs on slopes of badland topography. The common coarser detrital materials are subangular quartz, quartzite, chert, white feldspar, white graphic granite, gneiss, schist, muscovite, and biotite. Fragments of limestone and black Precambrian dike rock are scarce. Amphibole, epidote, opaque oxide, glauconite, colorless to pale-pink garnet, tourmaline, and zircon are present in the sand-size fraction. Although most of the detritus in the Wind River Formation was derived from Precambrian metamorphic and instrusive rocks of the Sweetwater uplift, pebbles and sand grains of quartzite, chert, and limestone, and scarce rounded grains of tourmaline and glauconite had their source in the upturned Paleozoic and Mesozoic sedimentary rocks on the north flank of the uplift. Except in the upper 100 feet in Muskrat Basin, fragments of dike rock are scarce in the conglomerate, especially in the western part of the area. Apparently dike rock in the source area was subjected to chemical weathering in early Eocene time. In contrast, dike-rock fragments presumably derived from the same source are common in Oligocene and Miocene conglomerate.

In the subsurface in the western part of the area, beds assigned to the Wind River Formation are darker shades of green than are seen in outcrop, and they contain abundant dark-green biotite flakes.

Throughout the region, beds and lenses of conglomerate are common in the upper part of the Wind River. Along the north flank of the Sweetwater uplift, these beds and lenses are thicker and coarser because they are nearer the source area. The coarsest fragments in the conglomerate generally are less than a foot in diameter, but locally boulders in the Wind River Formation are more than a foot in diameter.

Conglomerate that includes unusually coarse detrital material is present at several localities along the north flank of the Sweetwater uplift. The conglomeratic deposits, which usually have a limited horizontal and vertical extent (pl. 2), consist of very large boulders scattered through a poorly sorted conglomeratic sandstone and mudstone matrix. The conglomeratic facies between the Muskrat Creek reentrant and the Canyon Creek reentrant has been mapped in detail by H. D. Zeller and P. E. Soister (written communication, 1955).

North of Findlay (Chalk) Springs, in the northern half of T. 32 N., R. 93 W., subrounded cobbles and small boulders of black chert, quartzose sandstone (Flathead(?) Sandstone), and gray Precambrian granitoid rocks occur throughout about 100 to 125 feet of the stratigraphically highest variegated beds of the Wind River Formation, which in this area are about 150 feet below the top of the formation. Locally, rather well-rounded boulders as much as 8 feet in diameter are concentrated in the lower part of the conglomerate. Most of these big boulders are granitoid rock, but some are quartzose sandstone.

Boulders of Precambrian rock as much as 9 feet in diameter are present at various stratigraphic levels in the upper 50 to 100 feet of the Wind River Formation in Muskrat Basin (south part of T. 32 N., R. 91 W.). The best exposures are in secs. 19, 20, 29, and 30, where a reddish-brown conglomerate contains cobbles and small boulders as much as 18 inches in diameter. Some of the cobbles are composed of black dike rock and schist. Similar cobble and small-boulder conglomerate is also present locally in the lowest 10 to 25 feet of the overlying Wagon Bed Formation in the Muskrat Basin area.

In core hole 5 (sec. 4, T. 30 N., R. 94 W.; pl. 4) and core hole 7 (sec. 16, T. 30 N., R. 94 W.), conglomeratic rocks tentatively assigned to the Wind River Formation are as much as 470 feet thick and contain a dark yellowish-orange sandy mudstone matrix and interbedded pale greenish-yellow to yellowish-gray bentonitic mudstone. Many of the larger pebbles and small cobbles in the conglomerate are dark-green much altered schist and diabasic rock; many of the smaller pebbles are granitoid rock. Some of the sandstone and conglomerate is hematite stained. Grayish-green biotite-bearing sandy mudstone is common, and pyrite nodules are present. Biotite in various stages of alteration is common in the dark yellowish-orange sandy mudstone matrix. Patches of the matrix are a light-olive and yellowish-orange waxy mineral that probably belongs to the serpentine-chlorite group.

Variegated bentonitic mudstone and hematite-stained conglomerate as much as 250 feet thick are found below the White River Formation in core holes 6 (sec. 36, T. 30 N., R. 94 W.) and 4 (sec. 3, T. 30 N., R. 94 W.). These rocks are assigned to the Wind River Formation; however, they may be a coarse basal part of the younger White River Formation.

The Immigrant Trail 1 deep test well penetrated variegated beds, about 255 feet thick, tentatively assigned to the Wind River Formation. These beds overlie 2,475 feet of Precambrian granitoid rock (pl. 4, 605 to 3,088 feet). Samples from this 2,475-foot interval are almost entirely unweathered chips, except for some in the upper 640 feet which are limonite- and hematite-stained fragments. Samples from a correlative interval in core hole 12 (pl. 4) consist of abundant chips of granitoid rock and scarce rounded limonite-stained pebbles and chips of sandy mudstone matrix. These features suggest that the upper 640 feet of rubble may be either weathered and shattered Precambrian granitoid rock (in the Immigrant Trail dry hole) or may be limonite- and hematite-stained, very coarse conglomeratic lower Eocene(?) rocks. The 1,835 feet of rock below the conglomerate is part of the Precambrian basement along the southwestern margin of the Sweetwater uplift.

Two distinctive types of sandstone are present in the Wind River Formation. The first type is yellowish-orange to yellowish-gray arkose which was derived primarily from Precambrian gneissic and granitoid rocks. It contains little clay matrix, an appreciable amount of calcium carbonate and limonite cement, and generally is associated with conglomeratic deposits. In the eastern part of the area, sandstone of this type is impregnated locally with uranium minerals. The second distinctive type of sandstone is pale yellowish gray to very pale olive. This type, which was apparently derived largely from areas of schists of Precambrian age, contains much micaceous clay matrix and little calcium carbonate cement and is interbedded with mudstone containing chlorite in the clay fraction. Generally, feldspar is less abundant in this type of sandstone. Large amounts of partially altered biotite (grayish green in thin section) are present in the sand and silt fraction.

Most of the layers and lenses of poorly sorted mudstone in the formation are shades of reddish brown to grayish red and yellowish gray to greenish gray, although locally some are light brown to yellowish orange. In the northwestern part of the map area, the upper part of the Wind River Formation contains much acidic volcanic debris and bentonitic mudstone. Conspicuous, local layers of well-sorted claystone in this area are pastel shades of red, lavender, and gray.

Carbonaceous shale and thin layers of lignite are present in the upper part of the formation in the eastern segment the area. Some of these organic-rich beds have an abnormally high uranium and selenium content in the Muskrat Creek, Gas Hills, and Canyon Creek areas. Carbonaceous shale also occurs in the lower 600 feet of the formation in the subsurface northwest of the map area in the vicinities of the Beaver Creek, Riverton, and Alkali Butte anticlines (Yenne and Pipiringos, 1954).

Small limonite-stained selenite fragments scattered on mudstone outcrops probably were derived largely from masses of selenite deposited at or near the surface by ground water during the present arid cycle. Selenite crystals are especially common in the lower fine-grained part of the formation in the Gas Hill area (Zeller, Soister, and Hyden, 1956).

The upper part of the Wind River Formation is transitional in lithic features and bedding between the lower variegated part and the overlying Wagon Bed Formation (fig. 5). The transition zone

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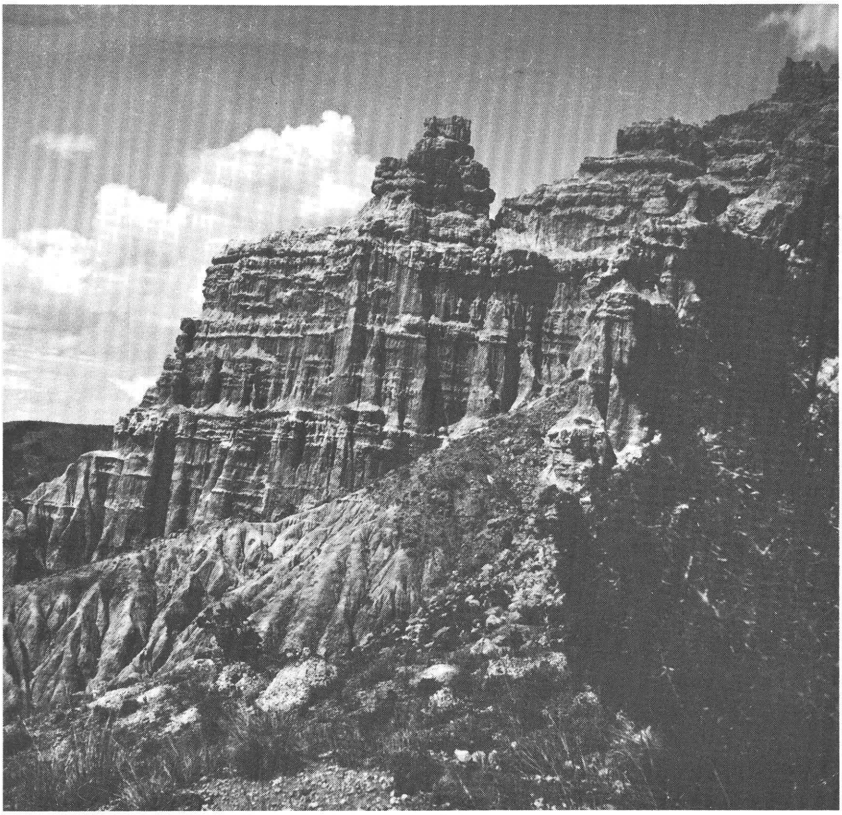

FIGURE 5.—Transition zone in upper part of the Wind River Formation at Green Cove, sec. 35, T. 31 N., R. 96 W., looking northward. Mostly very sandy mudstone interbedded with resistant beds of arkose; ledges at top are sandy mudstone.

has no red mudstone and sandstone beds. It is about 15 feet thick near Devils Gap, sec. 25, T. 31 N., R. 96 W.; about 185 feet thick in the Green Cove area, sec. 35, T. 31 N., R. 96 W.; and about 100 feet thick between Muskrat Basin and the Gas Hills (Zeller, 1957, p. 157).

East of Conant Creek anticline, particularly in the Muskrat Creek and Canyon Creek areas, persistent coarse arkose and conglomerate beds in the transition zone locally form ledges that support scanty evergreen vegetation. Coarse arkose and mudstone beds in the lower part of the transition zone support a similar discontinuous belt of evergreens in the vicinity of the Kirby Draw syncline. The uppermost 30 to 40 feet of the transition zone commonly contains rather persistent beds of hard light greenish- to bluish-gray, very poorly sorted sandstone and mudstone that form cliffs with pitted surfaces. Some of the mudstone layers resemble the ledge-forming basal beds of the Wagon Bed Formation. Darker hard mudstone in the ledge-forming sequence consists mainly of kaolinite and quartz; thinner, lighter colored layers consist of montmorillonite, opal, quartz, and some potassium feldspar presumably derived from altered ash. A soft bentonitic mudstone interbedded with the cliff-forming beds in the upper 20 to 30 feet of the formation south of the Gas Hills contains considerable volcanic debris.

Acidic volcanic debris occurs in the upper part of the Wind River Formation throughout much of its extent in the Wind River Basin (Sinclair and Granger, 1911, p. 93–94; Hay, 1956, p. 1888–1891). All dated occurrences are of late Wasatchian age. Volcanic constituents of the formation are shown in table 4.

A westward increase in the amount of volcanic debris in the Wind River Formation in the Beaver Rim area and the distribution, thickness, and texture of tuff in the formation in the central and northwestern parts of the basin (Hay, 1956, p. 1888–1892) indicate that the pyroclastic debris had its source in the Yellowstone-Absaroka volcanic field.

In the vicinity of the Big Sand Draw anticline (pl. 2) and in the area north and northwest as far as Hudson and Riverton (pl. 1), three persistent zones of light-gray tuff and tuffaceous sandstone interbedded with yellowish- to greenish-gray bentonitic mudstone are exposed. Thompson and White (1954) called the lowest of these the Hudson tuff zone of the Wind River Formation. The Hudson tuff zone of these authors is 2,000 feet above the base and about 450 feet below the top of the formation in the subsurface 13 miles northwest of the map area on the Riverton anticline. The second tuff zone is about 200 feet above the Hudson tuff zone and the third zone is 200 feet higher than the second in exposures on the Riverton anticline. These tuffaceous zones contain beds of relatively pure tuff that generally are less than 5 feet thick but locally are as much as 20 feet thick. The conspicuous layers are white to pale yellowish-gray lapilli tuff containing dacite pumice and lithic fragments as much as 2 inches long. Some beds of volcanic sandstone also contain pebbles and small cobbles of crystal tuff. The mineral composition of the tuffaceous zones indicates a predominantly dacitic volcanic source.

In the Kirby Draw syncline, T. 33 N., Rs. 94 and 95 W., some unaltered pyroclastic debris is interbedded with an uncommon abundance of variegated bentonitic mudstone. East of the Conant Creek anticline only a few volcanic-rich layers have been identified in the upper 500 feet of the formation. Some of these contain basic minerals and lithic fragments. (See table 4, samples b–e.)

TABLE 4.—*Volcanic constituents in the upper part of the Wind River Formation, Beaver Rim area*

[A, abundant; C, common; R, rare; VR, very rare; --, none; An, anorthite; subfigure indicates percentage]

Sample	Rock type, stratigraphic position	Location			Augite	Hypersthene	Oxyhornblende	Green-brown hornblende	Amber biotite	Green-brown biotite	Pleochroic apatite	Euhedral quartz	Lithic fragments	Platy shards	Feldspar
		Section	Township N.	Range W.											
a1	Pumice pebble in tuff about 500 ft below top of formation, Beaver Creek anticline.	3	33	96	--------	--------	--------	C	--------	C	--------	--------	--------	--------	An_{36}.
a2	Tuffaceous sandstone, Beaver Creek anticline.	NW¼	33	96	R	--------	R	A	C	A	C	C	--------	A	An_{32-36}; potassium feldspar.
b	Tuffaceous arkose in transition zone, 125 ft below top of formation, 4 mi. east of Conant Creek anticline.	SE¼ 11	32	93	R	R	--------	R	--------	C	R	--------	C	--------	Not determined.
c	Bentonitic mudstone in transition zone, 50 ft above sample b, 75 ft below top of formation, 4 mi. east of Conant Creek anticline.	SE¼ 11	32	93	R	C	C	--------	--------	A	--------	--------	A	R	Do.
d	Bentonitic claystone, approximately 500 ft below top of formation, at base of Sarcophagus Butte.	21	33	90	--------	--------	--------	--------	R	A	--------	--------	--------	R	Do.
e	Bentonitic mudstone, 15 ft below top of formation, south of Sarcophagus Butte.	NE¼ 10	32	90	--------	--------	R	R	--------	C	--------	--------	C	--------	Do.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

Along the southern margin of the Wind River Basin, the Wind River Formation overlies the Paleocene Fort Union Formation with a discordance of 5° to 10°. On the flanks of the larger anticlines, the Wind River Formation overlies Cretaceous and older rocks with an angular discordance of as much as 40° (Thompson and White, 1954).

In the area between the Muskrat Creek reentrant and the Canyon Creek reentrant, the land surface on which the Wind River Formation was deposited had a local relief of more than 1,300 feet (Zeller, 1957, p. 157). The Wind River Formation is thin over topographic highs and in these areas younger beds of the formation overlap older beds. (See pl. 4, area between core holes 1 and 3.)

The Wind River Formation commonly has a gentle northward dip west and northwest of the Granite Mountains, except on the flanks of the larger anticline where the formation is tilted as much as 8° to the east or west. Along the north flank of the Sweetwater uplift the Wind River Formation in the map area generally dips southward. Farther north, however, the beds dip northward into the Wind River Basin.

Zeller (1957, p. 157) reports that in the Gas Hills area, movement occurred along generally northeastward trending faults during early Eocene time, contemporaneous with the deposition of the Wind River Formation.

AGE AND CORRELATION

In the northeastern part of the Wind River Basin, the Wind River Formation comprises two lithologically distinct members, the Lysite and the conformably overlying Lost Cabin, which yield the diagnostic Lysite and Lost Cabin mammalian faunas. Representatives of these two faunas, of middle and late Wasatchian ages, respectively, have been found in other areas, but the Lysite and Lost Cabin Members cannot be traced to other parts of the basin (Tourtelot, 1953; Tourtelot and Thompson, 1958).

In the Beaver Rim area, a few mammals of Lost Cabin age have been found in the upper 500 feet of variegated strata in the Wind River Formation (Sinclair and Granger, 1911, p. 91). These beds also yield the following fossil plants in the vicinity of the Big Sand Draw anticline: *Lygodium kaulfussi*, *Zelkova nervosa*, and *Quercus castaneopsis* (Collier, 1919, p. 78; R. W. Brown, written communication, 1953).

Crumbly carbonaceous shale about 60 feet below the top of the Wind River Formation east of Canyon Creek yields poorly preserved leaves of the following species identified by R. W. Brown (Rachou, 1951; J. L. Weitz, written communication, 1954):

Fossil locality 20

NE¼ sec. 27, T. 33 N., R. 89 W., vicinity measured section 51, 60 feet below top of Wind River Formation, early (?) Eocene age:

Quercus castaneopsis Lesquereux
Zizyphus cinnamomoides Lesquereux
Zelkova nervosa (Newberry) Brown
Sparganium antiquum (Newberry) Berry
Leguminosites sp.
Aralia sp.
Ulmus sp.

The four identified species, two of which are also present in the Big Sand Draw collection (p. 31), are characteristic of leaves in the Green River Formation. The same species are found in northwestern Wyoming in or below beds yielding early Eocene mammalian fossils. On this basis, all the Wind River Formation in the map area is tentatively assigned an early Eocene age.

The Wind River Formation in the northeastern part of the basin, as dated by mammalian fossils, correlates with the upper 500 feet of the Willwood Formation and probably with at least the lower part of the overlying Tatman Formation in the Bighorn Basin (Tourtelot and Nace, 1946; Hay, 1956, p. 1888). It also correlates with the middle part of the Wasatch Formation and the interbedded lacustrine tongues of the Green River Formation and equivalent parts of the Battle Spring Formation in the Great Divide Basin (Pipiringos, 1955, p. 103; 1956, p. 47–49), and with the Knight Formation in southwestern Wyoming (Gazin, 1952, p. 7–17). (See table 3.)

The composition, stratigraphic position, and age of the upper part of the Wind River Formation, which is rich in volcanic debris, suggest correlation of these rocks with at least the lowest part of the early acid breccia in Yellowstone National Park (Dorf, 1939; Hay, 1956, p. 1885–1886).

On the basis of stratigraphic and structural relations the coarse conglomerate (lower Eocene(?) rocks in core hole 5, pl. 4) present in the subsurface in the southwestern part of the area is tentatively correlated with the very coarse conglomerate of the Wasatch(?) on Green Mountain and Crooks Mountain 8 miles to the south (J. G. Stephens, written communication, 1955).

CONDITIONS OF DEPOSITION

Lower Eocene rocks were deposited in the structural Wind River Basin after the Sweetwater uplift and other folds and fault blocks elevated during the Laramide revolution had been deeply eroded.

Deposits of the Wind River Formation accumulated in valley-flat and piedmont environments in a humid, warm-temperate to subtropical climate (Dorf, 1955, p. 587–588).

Very coarse rubble of Precambrian rocks may have accumulated along a high scarp at the south edge of the Sweetwater uplift in the southwestern part of the Beaver Rim area, in the vicinity of Green Mountain and Crooks Mountain, and in adjacent parts of the Great Divide Basin. A similar rubble of early Eocene age in the northern part of the Hanna Basin southeast of the map area was derived from the area of the present Shirley Mountains at the eastern end of the Sweetwater uplift (S. H. Knight, 1951).

On the piedmont along the north flank of the Sweetwater uplift, coarse gravel accumulated locally as fanglomerates (Zeller, 1957, p. 157) and perhaps in part as landslide debris. The coarsest boulder deposits apparently were formed as a result of torrential transportation, perhaps in response to renewed uplifts of the mountains.

In valley flats, arkosic sand and gravel accumulated in stream channels, variegated sandy mud was deposited on flood plains, and carbonaceous layers formed in local wooded swamps. Much of the mud transported to the basin presumably was derived from red lateritic soil formed on deeply weathered uplands and, at least locally, from older red beds such as the Chugwater Formation (Triassic). Red mud that accumulated in more open, well-drained savannas retained its color, whereas any ferric oxides in muds that accumulated in swampy and forested areas were reduced by organic compounds derived from plant debris, and gray or green colors resulted. As aggrading streams meandered across the basin floor, the environments of deposition continually shifted; variegated deposits were thus produced.

More uniform conditions of deposition prevailed on broad flood plains in late early Eocene time. These conditions permitted the accumulation of persistent beds of arkose and mud and of at least three extensive sheets of acidic volcanic ash from outbursts in the Yellowstone-Absaroka volcanic field.

Pyroclastic debris was reworked locally and incorporated in the Wind River Formation, and some of it was altered to bentonitic mud. Weathering of volcanic deposits during an interval of reduced aggradation toward the end of early Eocene time may have produced the conspicuous red, lavender, and gray bentonitic mudstone in the northwestern part of the area as well as similar variegated bentonitic and tuffaceous deposits in the upper part of the Wind River Formation in the northwestern part of the Wind River Basin (Keefer, 1956, p. 113–114; 1957, p. 192).

Absence of appreciable volcanic debris in correlative deposits of the Willwood and Tatman Formations in the Bighorn Basin has been interpreted by Hay (1956, p. 1891) to suggest southeasterly prevailing winds in early Eocene time.

WAGON BED FORMATION

DEFINITION

A sequence of pale greenish-yellow to yellow-gray sedimentary rocks overlying the variegated Wind River Formation was included in the Sweetwater Group in early reports on the area (Hayden, 1871, p. 29; Endlich, 1879, p. 110–112). Granger (1910) found late Eocene mammals in the upper part of the sequence and correlated these beds with the Uinta Formation. He tentatively correlated the lower part with the middle Eocene Bridger Formation. The rocks that Granger called Bridger(?) and underlying beds transitional with the Wind River Formation were later provisionally named Green Cove Beds and still later the Green Cove Formation by Wood (1934, p. 245–249; 1948, p. 38).

Carey (1954a, p. 34) suggested that the volcanic and tuffaceous sedimentary rocks of middle and late Eocene age that overlie the Wind River Formation in the eastern part of the area, and, presumably, the middle and upper Eocene rocks throughout the Beaver Rim region, be assigned to the upper(?) Eocene Continental Peak Formation which crops out on the northwest flank of the Great Divide Basin (pl. 1). This is not a valid extension of that name, however, for middle and upper Eocene deposits in the Beaver Rim area and in the Great Divide Basin accumulated separately in different structural basins and accordingly should be assigned to different formations. Moreover, Carey based his suggestion on the erroneous belief that volcanic material in the Continental Peak Formation of the Great Divide Basin was derived from the Rattlesnake Hills field which supplied the volcanic debris in the eastern part of the Beaver Rim area.

The lower and upper parts of the succession of rocks involved here differ locally in color, lithic features and mineral content, but the differences are neither persistent or conspicuous enough to warrant assigning the parts to different formations. In lithic characters and stratigraphic relations the sequence resembles middle(?) and upper Eocene volcanic-rich rocks in the northeastern part of the Wind River Basin that have been assigned to the Tepee Trail Formation (Tourtelot, 1957, p. 5–19). Originally, Tepee Trail was applied to upper Eocene deposits overlying the middle Eocene Aycross Formation along the northwestern margin of the basin (Love, 1939, p. 73–79). Extension of the name Tepee Trail to the sequence in the Beaver Rim area can only create confusion, because the lower part includes established middle Eocene deposits that can locally be separated from the upper Eocene.

In the interest of avoiding stratigraphic uncertainties, the name, Wagon Bed, is here given to the middle and upper Eocene succession in the Beaver Rim area that lies conformably on the lower Eocene Wind River Formation and is overlain unconformably by the Oligocene White River Formation. The name is taken from Wagon Bed Spring; the type section (measured section 24, pl. 2) is in SE¼ sec. 33, SW¼ sec. 34, T. 32 N., R. 95 W.

Rocks assigned to the Wagon Bed Formation in the northwestern and northeastern parts of the Wind River Basin and in the Beaver Rim area undoubtedly are remnants of an extensive sedimentary unit.

DISTRIBUTION AND THICKNESS

The Wagon Bed Formation is exposed along most of the Beaver Rim in the lower half of the escarpment. It forms the crest of the divide in the vicinity of Government Slide (NW¼ T. 31 N., R. 95 W.), between the Big Sand Draw and Conant Creek anticlines in the N½ T. 32 N., R. 94 W., and east of the Canyon Creek reentrant in T. 33 N., R. 89 W. An outlier of the formation 3.5 miles long and 2 miles wide is preserved in the Kirby Draw syncline, and a small outlier of the basal part of the formation is preserved in a graben east of Dutton Basin in the W½ T. 33 N., R. 89 W. (Zeller, 1957, pl. 1, p. 157).

The Wagon Bed Formation wedges out against the Sweetwater uplift, the Conant Creek anticline, and the Sweetwater anticline. An eastern volcanic facies of the Wagon Bed overlaps the southern end of the Rattlesnake Hills anticline east of the map area and is widespread in the Rattlesnake Hills volcanic field at the south end of the anticline and in the adjacent Granite Mountains (Carey, 1954b).

In the western part of the mapped area the formation thickens basinward from about 130 feet in the southwest (sec. 10, T. 30 N., R. 96 W.) to its maximum preserved thickness of 700 feet 15 miles to the northeast in the vicinity of Asbell triangulation station (sec. 7, T. 32 N., R. 94 W.). East of Conant Creek anticline the formation generally is about 250 to 275 feet thick. At the northeast corner of Muskrat Basin it is 340 to 380 feet thick. At the eastern end of the Beaver Rim it thickens to at least 550 feet.

Most local variations in thickness are due to erosion of the Wagon Bed Formation prior to the deposition of the overlying White River Formation, as, for example, between Wagon Bed Spring and Asbell triangulation station. Some of the variation probably is due to local unconformities within the formation, as in the area from Green Cove to U.S. Highway 287 (pl. 3, sections 1–9).

LITHOLOGY

The Wagon Bed Formation is characterized by persistent beds of rather well-sorted sandstone, siltstone, and mudstone, which commonly contain volcanic debris and bentonitic clay.

Volcanic debris is especially abundant at the eastern and western ends of the Beaver Rim. The volcanic debris in the west was derived from the Yellowstone-Absaroka volcanic field; a spectacular volcanic facies in the east was derived from the Rattlesnake Hills volcanic field (fig. 1). In the middle of the map area, between Conant Creek anticline and Muskrat Creek reentrant, volcanic debris is scarce and most of that has been altered.

Many layers rich in volcanic debris are shades of yellowish green, pale olive, and dark greenish gray. In three samples of green mudstone and one of arkose that were analyzed, the clay fraction is predominantly montmorillonite. Authigenic zeolite is a common constituent of beds of altered tuff in the middle part of the formation.

Beds of greenish- to yellowish-gray, poorly sorted arkose and pebble conglomerate occur in the lower and uppermost parts of the formation. The lower coarse deposits resemble arkose in the transition zone at the top of the underlying Wind River Formation, except that in the Wagon Bed Formation, pebbles and sand grains of Paleozoic rock are less common and the beds are somewhat more persistent. Local boulder deposits are found in the lower part of the formation, mostly in the eastern half of the map area where boulders are present locally in the upper part of the Wind River Formation.

Nodules and beds of chert and beds of silicified mudstone and sandstone are common, especially in the upper part of the formation, and there are also several layers of silicified limestone. Some of the siliceous beds are 3 to 5 feet thick and occur in persistent zones that can be traced for several miles.

The Wagon Bed Formation contains little limestone or calcareous cement throughout most of the area. A notable exception is beds of limestone and calcite-cemented sandstone and conglomerate composed largely of pebbles of Paleozoic rock that occur in the northern part of the area between Asbell triangulation station in sec. 7, T. 32 N., R. 94 W., and the Conant Creek anticline.

For convenience of detailed description, the Wagon Bed Formation has been subdivided rather arbitrarily into five units west of the Conant Creek anticline, two units between the Conant Creek anticline and Muskrat Basin, and six units east of Muskrat Basin, as shown on figure 6 and on plates 3, 4, and 5. Only the basal unit is recognizable along the entire length of the Beaver Rim escarpment. Units numbered 2 to 5 in the west are not exactly equivalent to similarly numbered units in the east.

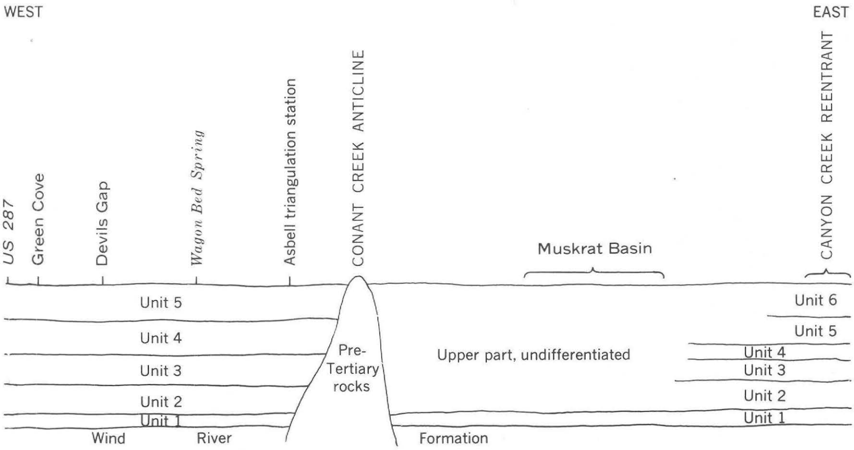

FIGURE 6.—Diagram showing lithologic subdivisions of the Wagon Bed Formation along the Beaver Rim escarpment.

Wagon Bed Formation west of the Conant Creek anticline.—West of the Conant Creek anticline the basal 10 to 20 feet of the Wagon Bed Formation makes up unit 1 and is composed of tough bluish- to greenish-gray and very pale olive gnarly-weathering mudstone. These beds commonly weather to a single ledge; however, there are in the unit as many as eight subdivisions of slightly different color, hardness, and weathering habit locally separated by minor unconformities. The unit includes layers of hard brittle mudstone, waxy mudstone, crumbly mudstone characterized by limonite-stained patches, mudstone containing numerous irregular tubular structures ½ to 2 mm in diameter filled with light-gray clay, and intraformational mudstone conglomerate containing mud pellets as much as an inch long. Silicified clay composed principally of kaolinite forms many hard aphanitic layers in the unit; softer beds consist mostly of montmorillonite. The tubular structures probably are fossil worm borings.

From U.S. Highway 287 (NW¼ sec. 10, T. 30 N., R. 96 W.) to Government Slide (sec. 17, T. 31 N., R. 95 W.), unit 1 forms a conspicuous cliff and bench (fig. 3). Northeast of Government Slide, where it is poorly exposed, the unit consists largely of crumbly yellowish-gray to pale yellowish-brown mudstone. In the vicinity of Wagon Bed Spring and southeast of the Big Sand Draw anticline, the contact between the Wind River and Wagon Bed Formations is obscure, and unit 1 includes greenish-yellow to grayish yellow-green poorly sorted biotite-rich glauconitic arkose and mudstone composed mainly of chlorite and montmorillonite.

Most of the mudstone in unit 1 contains many irregular cavities as much as half an inch long (fig. 7). Generally the cavities are lined

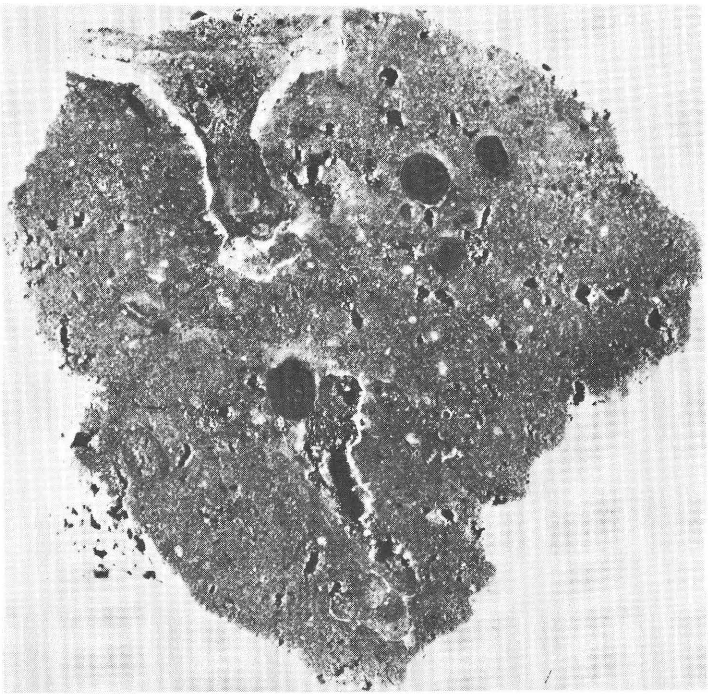

FIGURE 7.—Porous mudstone from unit 1 of Wagon Bed Formation showing abundant irregular pores. × 1½.

with soft waxy montmorillonite and pearly lustered kaolinite. Some cavities are lined with silica, and, locally, north of Asbell triangulation station (sec. 32, T. 33 N., R. 94 W.), many of the cavities are lined or filled with asphalt.

Most of the sand and silt scattered through the mudstone is detritus derived from older rocks of the Sweetwater uplift, but rare, partially altered volcanic lithic fragments and shards are present also in some beds. A light-gray mudstone layer at Green Cove (pl. 3, section 7, sample 1) contains partially altered pumiceous and fibrous shards, lithic fragments, and hexagonal pale-brown biotite.

Unit 2 of the Wagon Bed Formation west of the Conant Creek anticline consists of 1- to 3-foot-thick beds of light bluish- to greenish-gray and yellowish-gray, poorly sorted arkose interbedded with beds of mudstone that are as much as 60 feet thick south of Wagon Bed Spring. In the southwestern part of the area is some pebble- and cobble-sized detritus consisting mostly of fragments of Precambrian granitoid and gneissic rock and Flathead (Cambrian)

Sandstone. Along U.S. Highway 287 (pl. 3, section 1), boulders of the same material as much as 3 feet in diameter occur in a 5-foot-thick lens about 5 feet above the base of the unit.

Some of the mudstone in unit 2 contains glauconite and sparse acidic volcanic material. Locally, mudstone in the upper part of unit 2 is characterized by patches stained reddish brown by iron oxide.

Massive yellowish-gray to pale yellowish-brown and very pale olive sandstone and bentonitic mudstone 75 to 125 feet in thickness, containing abundant basic volcanic debris (pl. 7*B*, samples 3 and 4), constitute the upper part of unit 2 from the vicinity of Wagon Bed Spring northeastward to Rogers Mountain anticline. Yellowish-brown to light olive-gray chert (locally opaline) masses as much as 3 feet in diameter commonly occur in the mudstone; some irregular chert masses as much as 15 feet long occur in the Kirby Draw syncline.

A conglomeratic sandstone that is 15 feet thick and contains round pebbles of Tertiary volcanic rock as large as 2 inches in diameter crops out in unit 2 at Wagon Bed Spring. North of Asbell triangulation station (pl. 4, section 37) the coarse sandstone reaches a maximum thickness of 40 feet and contains small cobbles of volcanic rock. Most of the volcanic pebbles and cobbles are light to very dark gray vesicular porphyritic andesite. Some are dark-red porphyritic felsite. Minerals in representative pebbles are recorded in table 5. These volcanic pebbles and the associated volcanic and tuffaceous sedimentary rocks are the most basic in composition in the entire sequence of Tertiary rocks along the Beaver Rim.

Unit 2 contains no distinctive volcanic deposits in the southwestern part of the area, and it contains only sparse volcanic minerals and lithic fragments south of Wagon Bed Spring.

Unit 3 west of the Conant Creek anticline consists of yellowish-orange to yellowish-gray and light-gray limonite-stained well sorted fine-grained altered biotitic vitric tuff containing quartz and feldspar grains and tuffaceous locally ripple marked siltstone and sandstone of acidic composition. In the northern part of the area, the unit reaches its maximum thickness of about 250 feet, and the rocks generally are thick bedded and locally contain carbonaceous layers as much as 1 foot thick. Throughout much of its extent, unit 3 is poorly exposed and disrupted by landslides.

In the southwestern part of the map area, unit 3 ranges in thickness from 20 to 110 feet as a result of local erosion preceding deposition of unit 5 (pl. 3, sections 1–8). The lower beds assigned to the unit are interbedded mudstone, claystone, and arkose. The mudstone is pale

TABLE 5.—*Relative abundance of minerals in pebbles and cobbles of Tertiary volcanic rocks in Wagon Bed and White River Formations, Beaver Rim area*

[VA, very abundant; A, abundant; C, common; R, rare; VR very rare; ------, none; nd, not determined. An, anorthite (subfigure indicates percentage). Based on 0.70-ampere magnetic refraction]

Rock unit	Magnetite	Altered olivine	Dark-green augite	Light-green augite	Medium-green clinopyroxene	Hypersthene	Oxyhornblende	Very dark brown hornblende	Green-brown hornblende	Very dark green hornblende	Amber biotite	Brown biotite	Green-brown biotite	Apatite	Sphene	Garnet	Quartz	Dominant feldspar	Sanidine-anorthoclase
	Western part of Beaver Rim area																		
White River Formation, Beaver Divide Conglomerate Member.	R	------	------	VR	------	A	A	------	VR	------	R	------	------	------	------	C	------	An_{38-45}	------
	C	------	------	VR	------	A	VR	------	VA	------	------	------	C	------	------	------	R	An_{38}	------
	C	------	R	C	------	VA	C	------	VR	------	------	------	------	------	------	------	R	An_{58}	------
	R	------	------	R	------	A	------	------	A	------	------	------	------	------	------	VR	------	An_{38}	------
	C	------	------	R	------	C	------	------	C	------	------	------	------	------	------	------	------	An_{45}	------
Wagon Bed Formation: Unit 5	VR	------	------	------	------	VA	VA	------	------	------	R	------	------	------	------	------	------	An_{40}	------
	R	------	------	------	------	VR	VR	------	VA	------	VR	R	------	------	------	------	R	An_{35}	------
	C	------	------	------	------	C	R	------	VA	------	------	C	------	------	------	VR	R	An_{43}	------
	R	------	------	------	------	------	A	------	------	------	C	------	------	VR	------	------	R	An_{38}	------
Unit 2	VA	R	------	VA	------	------	VR	------	VR	------	------	------	------	------	------	------	R	An_{52}	------
	A	R	------	A	------	C	------	------	------	------	------	R	------	------	------	------	------	An_{59}	------
	A	------	------	R	------	VA	------	------	VA	------	------	R	------	------	------	------	R	An_{40}	------
	A	------	------	C	------	C	A	------	------	------	------	------	------	------	------	------	nd	nd	------
	Canyon Creek area																		
Unit 6	VA	------	------	C	A	------	R	A	------	------	R	VR	------	VR	VR	------	------	Oligoclase-andesine	------
	A	------	------	------	------	------	VR	VA	C	------	------	------	R	VR	VR	------	------	do	------
	R	------	------	A	VR	------	R	C	------	------	------	------	------	VR	------	------	------	Andesine	------
	VA	------	------	C	A	------	------	C	A	------	------	------	------	VR	VR	------	------	do	------
	C	------	------	VR	------	------	------	A	A	------	------	C	------	VR	VR	------	------	Oligoclase-andesine	------
	VA	------	------	R	VR	VA	------	VR	------	------	------	------	------	VR	VR	------	------	Oligoclase-labradorite	------
Unit 5	VR	------	------	VA	------	------	R	------	------	------	------	------	------	VR	------	------	------	Andesine	VR
	VA	------	------	C	A	------	------	C	A	------	------	------	------	VR	VR	------	------	do	------
	A	------	------	C	A	------	------	C	A	------	------	R	VR	VR	VR	------	------	do	VR
Unit 4	R	------	------	R	C	------	------	R	R	A	------	VR	R	VR	R	------	------	Albite-oligoclase	R
Unit 3	C	------	------	R	------	------	------	C	C	------	------	------	------	VR	VR	------	------	do	R
	VR	------	------	VR	R	------	------	VR	VA	R.	------	------	------	VR	VR	------	------	do	R
Unit 2	R	------	------	------	------	------	------	R	VA	------	------	------	------	VR	VR	------	------	do	R
	VR	------	------	------	------	------	VR	R	VA	------	------	------	------	VR	VR	------	------	do	R

greenish gray to pale olive, is bentonitic, and consists principally of montmorillonite and some authigenic potassium feldspar and quartz. The arkose is greenish yellow, contains scattered pellets of glauconite, and has a matrix composed chiefly of montmorillonite and a minor amount of illite. At Green Cove these beds yield middle Eocene (Bridgerian) mammals (pls. 2, 3, fossil locality 1). The upper part of the unit is more distinctly bedded yellowish- to light-gray altered tuff which locally is thin bedded. In the uppermost 15 to 20 feet are numerous siliceous nodules a few inches in diameter, 6- to 12-inch-thick beds of chert, and rock composed of quartz, opal, and dolomite. Nodules and beds of chert commonly grade outward into thin peripheral layers of soft pink biotitic claystone.

Some beds of altered tuff containing about 7 percent K_2O and 1.9 percent Na_2O (by flame photometer analysis) have devitrified to cryptocrystalline quartz and potassium feldspar. More commonly the tuff is altered to the zeolite clinoptilolite and rarely to erionite.

Rocks assigned to unit 4 in the Government Slide-Conant Creek area consist of a maximum of 180 feet of well-bedded nonresistant yellowish- to greenish-gray and very pale olive volcanic claystone, siltstone, and sandstone locally yielding garpike scales, turtle bones and nonmarine gastropods and pelecypods. The unit is absent in the Green Cove area southwest of Government Slide, perhaps as a result of nondeposition or of local erosion before deposition of unit 5. The mineral content of rocks in unit 4 is rather varied (pl. 7*B*, samples 9–13), but the presence of abundant dark green-brown hornblende and plagioclase more sodic than An_{35} suggests derivation of much of the material from an acidic volcanic source.

The lower 130 feet of unit 4 is conspicuous green claystone and mudstone commonly containing pale greenish-gray claystone pellets less than 2 mm in diameter. These rocks are markedly thin bedded in the vicinity of Wagon Bed Spring. The upper 50 feet of unit 4 typically contains thin layers of chert, brittle silicified mudstone and tuff, and siliceous nodules a few inches long. This part of unit 4 also contains a 15-foot-thick bed of distinctively laminated, very light yellowish-gray shale (fig. 8) southeast of Big Sand Draw anticline. Comprising the shale are layers of dull yellowish-gray claystone generally ranging from 0.5 to 2 mm thick and rarely several centimeters thick, composed principally of montmorillonite and dolomite; white laminae composed of clinoptilolite from 0.4 to 1.5 mm thick; and laminae of soft reddish-brown organic material 0.1 to 0.3 mm thick that alternate with the thicker laminae of claystone and zeolite. The rock resembles the varved lacustrine deposits in the lower and middle Eocene Green River Formation in southwestern Wyoming and northern Utah (Bradley, 1929b, p. 95–96).

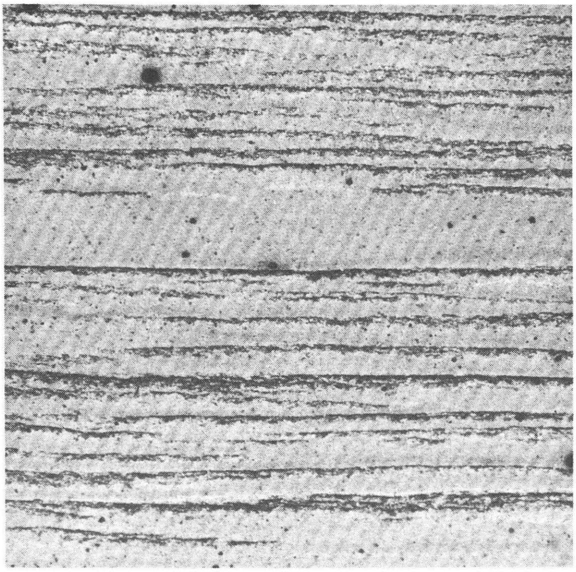

FIGURE 8.—Photomicrograph of varved zeolitic shale in upper part of unit 4 of Wagon Bed Formation southeast of Big Sand Draw anticline, sec. 26, T. 32 N., R. 95 W. Thicker light-colored layers are clinoptilolite; thinner dark laminae are organic material. Plain light. × 7.

The uppermost part of unit 4 is a 5- to 10-foot-thick cliff-forming bed composed of siliceous and calcareous sandstone, silicified limestone, and chert (fig. 9). This bed is exposed almost continuously from

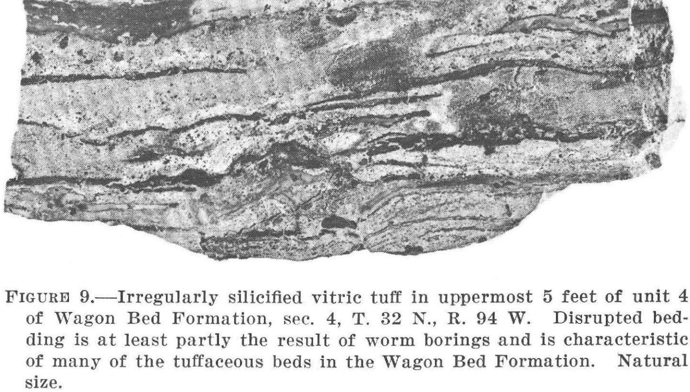

FIGURE 9.—Irregularly silicified vitric tuff in uppermost 5 feet of unit 4 of Wagon Bed Formation, sec. 4, T. 32 N., R. 94 W. Disrupted bedding is at least partly the result of worm borings and is characteristic of many of the tuffaceous beds in the Wagon Bed Formation. Natural size.

Wagon Bed Spring to Conant Creek anticline. East of Asbell triangulation station (pl. 4, sections 43–47), asphalt lines cavities in chert lenses near the top of the sandstone.

The uppermost 45 feet of unit 4 in a landslide block in the Kirby Draw syncline (pl. 5, section 49) is composed of light-gray to yellowish- and bluish-gray silicified irregularly laminated limestone. Chalcedony replaces the limestone in thin layers (fig. 10*A*). The original rock apparently was similar to porous irregularly laminated limestone in the middle of the White River Formation (fig. 10*B*) north of Findlay (Chalk) Springs (sec. 19, T. 32 N., R. 93 W.).

Unit 5, the uppermost unit of the Wagon Bed Formation west of Conant Creek anticline, has a maximum thickness of 120 feet and is composed of massive greenish-yellow to yellowish-gray volcanic mudstone, arkosic sandstone, and conglomerate. These rocks contain abundant fragments of green-stained quartz, feldspar, chert as much as half an inch long, and pebbles and cobbles of red-brown and gray Tertiary volcanic rocks. Along most of the Beaver Rim, beds and lenses of silica-cemented sandstone and conglomerate in the uppermost part of the unit form a conspicuous cliff at the top of the formation. At Green Cove, the upper part of unit 5 rests unconformably on unit 3 (pl. 3, sections 1–8), and the underlying parts of unit 5 and unit 4 are absent.

Volcanic debris is present throughout unit 5. It is most abundant and least weathered in the lower half of the unit. From Wagon Bed Spring to Conant Creek anticline the lower beds are pale yellowish-brown, very poorly sorted tuffaceous sandstone of basic composition containing pebbles and cobbles of Tertiary volcanic rock as much as 6 inches in diameter. Most of the volcanic pebbles and cobbles are light- to dark-gray and dark reddish-brown vesicular porphyritic andesite; a few are light-gray pumiceous porphyritic rock. Minerals contained in several representative pebbles are reported in table 5.

Generally, volcanic pebbles in unit 5 are a little more angular than those in unit 2, the volcanic rock is somewhat fresher, and its composition is a little less basic. Moreover, volcanic sedimentary rock in unit 5 contains more oxyhornblende and green-brown hornblende than does the upper part of unit 2. (See pl. 7.)

East of Asbell triangulation station (pl. 4, sections 37–43), beds of silicified limestone and calcareous sandstone that contain several chert layers 1 to 3 feet thick are present in the lower part of unit 5. East of sec. 5, T. 32 N., R. 94 W., asphalt locally impregnates beds of arkose and silicified limestone and some cobbles of Tertiary volcanic rock in the locally silicified very tuffaceous lower part of the unit. In sec. 3, T. 32 N., R. 94 W., uranium minerals are concentrated in coarse-

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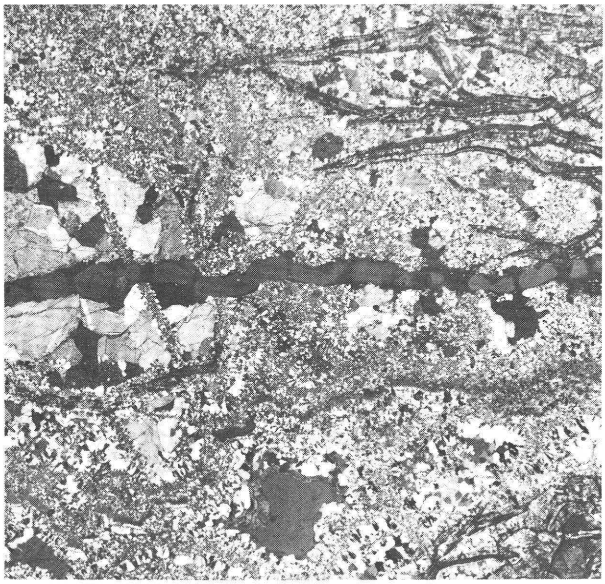

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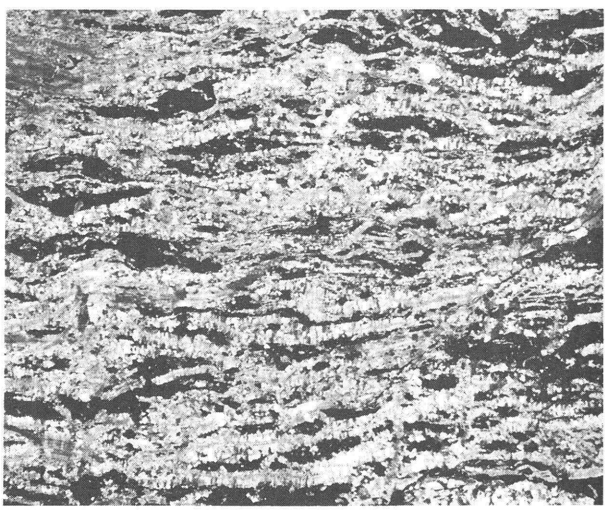


B

FIGURE 10.—Photomicrographs of silicified porous, irregularly laminated limestone in the Wagon Bed and White River Formations. Crossed nicols. × 7. *A,* In upper part of unit 4 of Wagon Bed Formation in Kirby Draw syncline, SE¼ sec. 24, T. 33 N., R. 95 W. Chalcedony replaces thin layers within calcareous laminae. Colloform chalcedony fills areas between laminae and surrounds patches of clear, coarsely crystalline calcite. *B,* In middle part of White River Formation north of Findlay Springs, sec. 19, T. 32 N., R. 93 W. Irregular laminae composed of elongate calcite crystals oriented perpendicular to length of laminae. Chalcedony locally fills voids between laminae. This limestone apparently is the kind that was more extensively silicified to produce the rock illustrated in *A*.

grained asphaltic sandstone (H. D. Zeller and P. E. Soister, written communication, 1955), and in sec. 6, T. 32 N., R. 94 W., uranium minerals occur in a 1-foot-thick tuffaceous siltstone (H. D. Zeller and P. E. Soister, written communication, 1956).

The coarsest of all the volcanic debris in the Wagon Bed Formation in the western part of the map area occurs in the cliff-forming upper part of unit 5 one-half mile north of Devils Gap (pl. 3, section 14). At this locality abundant, slightly weathered cobbles 3 to 4 inches in diameter and rare boulders as much as 3 feet in diameter are scattered through a 5-foot-thick lens of very poorly sorted volcanic sandstone.

Wagon Bed Formation between the Conant Creek anticline and Muskrat Basin.—Poorly exposed yellowish- to greenish-gray rocks of the Wagon Bed Formation generally are about 250 to 275 feet thick in the area between Conant Creek anticline and Muskrat Basin. In the vicinity of Findlay (Chalk) Springs on the east flank of the Conant Creek anticline, however, they are only about 135 feet thick. Unaltered volcanic debris is extremely rare in the formation in this area.

Unit 1 of the sequence west of the Conant Creek anticline maintains about the same thickness and lithic features in the Conant Creek anticline-Muskrat Basin area. Overlying this unit is about 75 feet of beds composed chiefly of bentonitic mudstone and sandstone, some layers of which contain partially altered shards. At Muskrat Basin, boulders of Precambrian granitoid rock as much as 3 feet in diameter occur locally in the lower 50 to 75 feet of the formation.

The upper part of the formation consists predominantly of sandy mudstone and coarse-grained limonite-stained arkose and feldspathic sandstone. Cliff-forming lenses and layers of silica-cemented conglomeratic arkose at the top of the formation resemble beds of silica-cemented arkose in the upper part of unit 5 near Asbell triangulation station.

Wagon Bed Formation east of Muskrat Basin.—Along the eastern part of the Beaver Rim, the Wagon Bed Formation contains considerable alkalic volcanic debris derived from the Rattlesnake Hills volcanic field. Detritus from Precambrian source rocks decreases in abundance, and volcanic debris increases from the base to the top of the formation. In the lower half of the formation, pyroclastic debris is rather common, and pebbles and cobbles of volcanic rock are sodic trachyte; in the upper half, coarse detrital volcanic material predominates and most of the pebbles, cobbles, and boulders are alkalic andesite.

Throughout the area east of Muskrat Basin, most of the fragments of volcanic rock in the Wagon Bed Formation are relatively fresh except in secs. 10 and 11, T. 32 N., R. 90 W., where volcanic pebbles and cobbles are altered and many of the finer grained layers are bentonitic. The restricted areal distribution of the altered rocks suggests that the alteration was produced by localized postdepositional processes. Significantly, the area of alteration coincides with a buried topographic trough at the base of the overlying White River Formation (fig. 4). This relation suggests that unstable volcanic debris in the Wagon Bed Formation may have been altered by ground water moving along the buried valley.

In the vicinity of the Canyon Creek reentrant (pls. 1 and 2), the Wagon Bed Formation consists of an exceptionally volcanic-rich sedimentary sequence divisible into six rather distinct, conformable units, most of which become thinner, finer grained, and more bentonitic to the west. Except for unit 1, these units do not correspond to those in the western part of the area. Although these units are readily recognizable only as far as 3 to 4 miles west of the Canyon Creek reentrant, unaltered volcanic debris is present in the Wagon Bed Formation as far as 9 miles west of the reentrant. The westernmost occurrence of recognizable volcanic debris from the Rattlesnake Hills is in a 10-foot-thick bed of grayish orange-pink bentonite 125 feet above the base of the Wagon Bed Formation in the SE¼ sec. 27, T. 32 N., R. 91 W., about 13 miles west of the Canyon Creek reentrant.

A detailed description of these units has already been published (Van Houten, 1955), and only a summary is presented here.

Unit 1 is the persistent ledge-forming mudstone sequence already described at the base of the formation and recognizable along the entire length of the Beaver Rim. Locally it crops out in a conspicuous ledge 30 feet high. At the east end of the Beaver Rim and in a small graben in the S½ sec. 17, N½ sec. 20, T. 33 N., R. 89 W., a few thin layers of unaltered soft acidic tuff are present in the unit. Mudstone in unit 1 commonly has a vague shard texture; montmorillonite is the only clay mineral present in the mudstone matrix.

In the area east of Muskrat Basin, several 2- to 3-foot-thick beds similar to those of unit 1 occur in the uppermost 15 to 20 feet of the underlying Wind River Formation, and the boundary between the two formations is arbitrarily placed at the base of the uppermost ledge-forming mudstone sequence.

Unit 2 has a maximum thickness of 100 feet and consists of soft pale-olive to greenish- and yellowish-gray mudstone and arkosic sandstone containing very little volcanic debris. Cobbles and small boulders of Precambrian granitoid and metamorphic rocks are locally present in the upper 20 feet of the unit. The uppermost 3 to 5 feet of unit 2 is a calcite-cemented arkose and pebble and small cobble conglomerate which forms a discontinuous ledge. In the Canyon Creek area, this capping arkose contains volcanic minerals and pebbles of sodic trachyte lava.

Unit 3 of the Wagon Bed Formation is about 90 feet thick and consists of soft greenish- to yellowish-gray tuffaceous sandstone, sandy mudstone, and poorly sorted conglomerate containing pebbles and cobbles of sodic trachyte pumice, tuff, and lava, and Precambrian metamorphic rocks. There are also a few layers of lapilli tuff. In sec. 26, T. 33 N., R. 89 W., boulders of Precambrian gneissic and granitoid rock as much as 12 feet long are present in the lower 25 feet of the unit. These giant boulders are associated with the lowest stratigraphic occurrence of abundant volcanic debris in the formation. Boulders of Precambrian rock less than 3 feet in diameter in poorly sorted arkosic sandstone are found locally in the basal part of the unit.

Unit 4 is as much as 45 feet thick and consists of light-gray to pale yellowish-gray calcareous coarse-grained lapilli tuff and fine-grained biotitic vitric tuff (fig. 11). Throughout the deposit are abundant rounded pebbles and cobbles of pumice and pumiceous tuff of sodic trachyte composition which record a major episode of explosive activity in the Rattlesnake Hills volcanic field. Locally, a channel deposit in the uppermost 8 feet of the unit contains many angular cobbles and boulders of Tertiary volcanic rock and Precambrian metamorphic rock. Nine miles west of the Canyon Creek reentrant, unit 4 consists of vitric tuff and tuffaceous mudstone containing scattered pebbles and cobbles of pumice and pumiceous tuff.

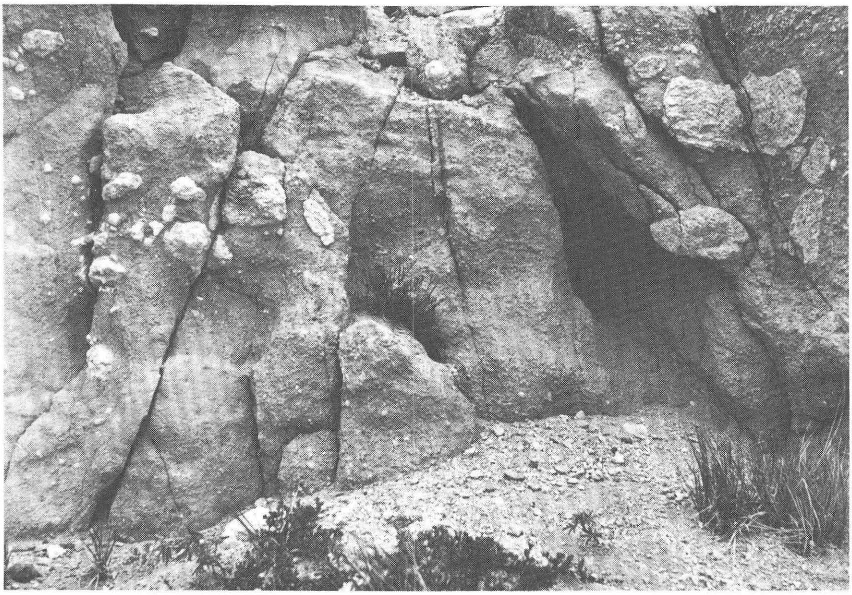
Unit 5 is 130 feet thick and consists of poorly sorted dark yellowish-gray tuffaceous sandstone and volcanic conglomerate containing pebbles and cobbles of Precambrian metamorphic rock and alkalic andesite porphyry of Tertiary age.

Unit 6 is at least 140 feet thick and is mostly a pale-olive to olive-gray volcanic conglomerate composed largely of alkalic andesitic volcanic debris like that in unit 5. Nine miles west of the Canyon Creek reentrant, equivalent deposits consist of lenses of conglomerate scattered through poorly sorted mudstone and sandstone.

Near the eastern edge of the map area, units 5 and 6 overlap on Precambrian rocks and contain angular boulders of Precambrian rock as much as 6 feet in diameter and boulders of Tertiary volcanic rock as much as 4 feet in diameter.

MINERALOGY

Glauconite is common as an accessory mineral west of the Conant Creek anticline in unit 1 and in some beds in unit 2 (pl. 3, sec. 7,



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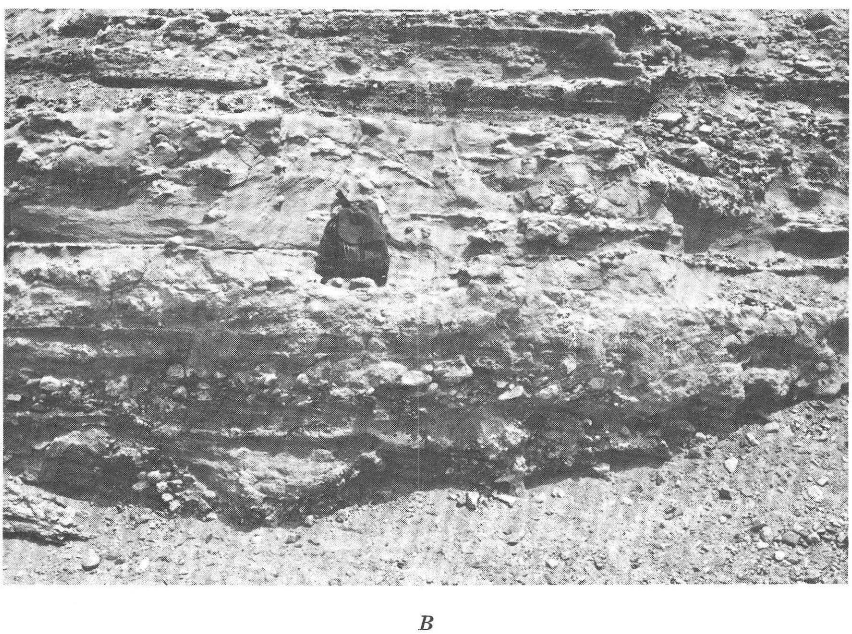

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FIGURE 11.—Tuff in unit 4 of the Wagon Bed Formation, east side of Canyon Creek reentrant, SW¼ sec. 26 and NE¼ sec. 34, T. 33 N., R. 89 W. *A*, Lapilli tuff containing pumice blocks as much as 8 inches long. *B*, Fine-grained biotitic vitric tuff interbedded with lapilli tuff.

sample 2; sec. 26, sample 6) and unit 3. It is especially common in poorly sorted biotite- and chlorite-rich green arkose in the northwestern part of the area. Most of the glauconite is in medium- to dark-green sand-sized grains of a shape described by Burst (1958, fig. 3) as free form. Its X-ray diffraction pattern is that of disordered glauconite (Burst, 1958, p. 313). Detrital glauconite is scattered through some of the Eocene rocks and locally is common in beds with pebbles of glauconitic Paleozoic rocks in the White River Formation of Oligocene age on the flank of the Conant Creek anticline. However, glauconite of unit 1 is lighter green than most of the detrital glauconite observed in the older Tertiary rocks; it apparently is not associated with fragments of glauconitic Paleozoic rock, and its X-ray pattern indicates a more disordered type than the detrital glauconite in the White River Formation. The abundance and freshness of the glauconite in units 1 and 2 and the fact that much of the nonvolcanic detritus in the Wagon Bed Formation was derived from nonglauconitic Precambrian rocks suggest that the glauconite in the nonmarine Wagon Bed Formation may be authigenic.

A high-silica member of the heulandite group of zeolites, clinoptilolite ($N_x = 1.476\pm$, $N_z = 1.480\pm$) is a common constituent of unit 3 and of parts of unit 4. The mineral occurs in several different associations: as irregular cottonlike masses of colorless crystals less than 1/8 inch long in soft pale-olive bentonitic mudstone, as an abundant mineral with montmorillonite in pale greenish-gray mudstone and in pink biotite-rich claystone surrounding chert, as thin laminae interbedded with layers of montmorillonite and dolomite in varved shale, and as cryptocrystalline aggregates composing entire layers of pale yellowish-gray altered tuff. Some beds of cryptocrystalline aggregates consist of a mixture of clinoptilolite and erionite.

Early diagenetic zeolitization of volcanic glass apparently took place in alkaline lakes (Bradley, 1929a, p. 4–6); the zeolites formed as a reaction product of silica and alumina dissolved from the glass with salts of the lake water. In the Beaver Rim area, calcium-rich clinoptilolite and erionite were formed by this process, whereas in the correlative Green River Formation in northern Utah and Colorado and the Tepee Trail Formation and the underlying middle Eocene deposits along the southern border of the Bighorn Basin, to the north of the map area, the soda-rich zeolite, analcime, was formed instead.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The Wagon Bed Formation and the underlying Wind River Formation are comformable in outcrops along most of the Beaver Rim.

Angular unconformities reported by Bauer (1934, p. 676) and Wood (1934, p. 246–247, pl. 24) were not seen; although, in the vicinity of the Rogers Mountain anticline a difference of several degrees between the dip of the Wind River Formation and nearly horizontal strata of the nearest exposed Wagon Bed Formation suggests a local angular unconformity. In the structurally high areas along the Beaver Rim, the Wagon Bed Formation overlaps the Wind River Formation and extends onto older strata. In the subsurface on the west flank of the Sweetwater uplift (pl. 4, between well 4 and core hole 2), progessively younger beds of the Wagon Bed Formation overlap older ones southeastward. The overlapping beds lie unconformably on the Wind River Formation.

An intraformational unconformity between units 3 and 5 in the southwestern part of the area is probably the result of recurrent uplift of the Sweetwater anticline during middle and late Eocene time.

The Wagon Bed Formation generally dips gently southward except on the flanks of the larger basin-margin folds, as in the area between Rogers Mountain anticline and Conant Creek anticline, and in the Canyon Creek reentrant where the strata dip as much at 5° SW.

In sec. 31, T. 31 N., R. 94 W., the upper part of the Wagon Bed Formation crops out in a complexly fractured and tightly folded(?) eastward-trending syncline whose limbs dip as much as 75° toward the axis (fig. 12). The fold was formed before Oligocene time as indicated by the fact that it is unconformably overlain by nearly horizontal beds of the lower part of the White River Formation of Oligocene age. Presumably the fold is a tectonic feature, although the field relations are not sufficiently clear to rule out the possibility that the folded strata are part of a large pre-Oligocene landslide.

AGE AND CORRELATION

The Wagon Bed Formation yields fossils of middle and late Eocene age, as shown by the following collections which have been made in the map area:

Fossil locality 1 (pl. 2)

SE¼ sec. 35, T. 31 N., R. 96 W., measured section 7; 95 feet above base of formation (20 feet above base of unit 3); USGS vertebrate locality D553; middle Eocene (Bridgerian) age.

Helohyus sp. indet. (USGS D553A)
Tritemnodon cf. *T. agilis* (Marsh) (USGS 553B)
Sciuravid rodent (USGS specimen [1])

Fossil locality 2 (pl. 2)

NW¼ sec. 36, T. 31 N., R. 96 W., measured section 9; talus block of upper 60 feet of unit 5; USGS vertebrate locality D554; late Eocene (Uintan) age:

Amynodon cf. *A. advenus* (Marsh) (USGS D554)

[1] Number not yet assigned.

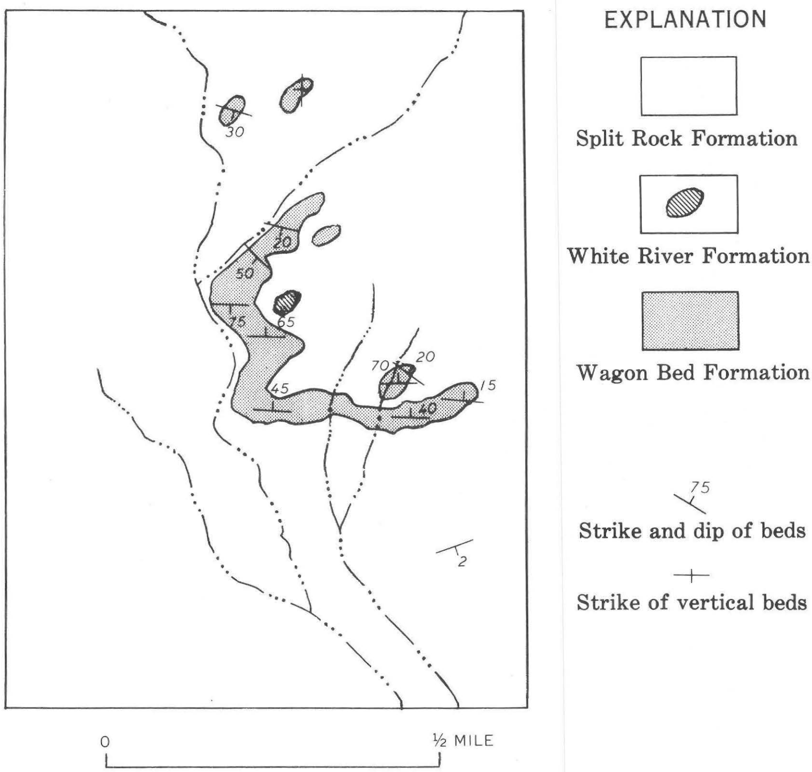


FIGURE 12.—Geologic map of part of sec. 31, T. 31 N., R. 94 W., showing locally deformed Wagon Bed Formation uncomformably overlain by gently southward dipping Split Rock Formation.

Fossil locality 7 (pl. 2)

SW¼ sec. 3, T. 31 N., R. 95 W., measured section 23; 60 feet below top of formation (lower part of unit 5); late Eocene (Uintan) age:

Protoreodon cf. *P. parvus* Scott and Osborn (AMNH 14602, 14603)
Amynodon advenus (Marsh) (AMNH 14601)
Camelodon arapahovius Granger [2] (AMNH 14604)
cf. *Protitanotherium* or *Diplacodon* (AMNH 14606)

Fossil locality 13 (pl. 4)

SE¼ sec. 5, T. 32 N., R. 94 W., measured section 42; upper half of unit 5; USGS Cenozoic locality 20089; late Eocene (Uintan) age (D. W. Taylor, written communication, April 1962):

Lymnaea aff. *L. similis* Meek
Planorbina pseudoammonus (Schlotheim)
Aplexa?
Gastrocopta?

[2] Following a suggestion of Peterson and Kay (1931, p. 296), Scott (1945, p. 211–212, 214, 227) erroneously assigned *Camelodon arapahovius* to the Duchesnean fauna.

Approximately S½ sec. 5 and N½ sec. 8, T. 32 N., R. 94 W.; presumably in the vicinity of measured sections 40–42; upper 50 feet of unit 5; USGS Cenozoic locality 8256; Collier (1919, p. 79); late Eocene (Uintan) age (D. W. Taylor, written communication, April 1962):

Lymnaea aff. *L. similis* Meek.
Planorbina pseudoammonus (Schlotheim)
Aplexa?
Oreoconus

Above Cogswell Spring, presumably S½ secs. 4 and 5, T. 32 N., R. 94 W., unit 5; late Eocene (Uintan) age:

Amynodon sp. (AMNH 14605)

Fossil locality 21 (pl. 5)

SE¼ sec. 27, T. 33 N., R. 89 W., measured section 51; 275 feet above base of formation, 10 feet above base of unit 5; middle Eocene (Bridgerian) to late Eocene (Uintan) age (Rachou, 1951):

Eometarhinus sp. (Univ. Wyo. 928)

The only identifiable plant remains recovered from the Wagon Bed Formation was the seed *Carpolithus* sp. indet. which occurs in carbonaceous shale in the middle of the formation (unit 3) in SE¼ sec. 28, T. 32 N., R. 95 W. According to R. W. Brown (written communication, 1951), this seed is a common fossil in the Green River Formation (middle Eocene).

Granger (1910, p. 240–241) identified a titanothere from locality 7 as ?*Diplacodon* and called the fossiliferous beds the ?*Diplacodon* zone. However, his specimen consists of a jaw fragment having only M_3 remaining; this fragment could pertain to *Protitanotherium* or *Telmatotherium* equally as well.

Formations in nearby parts of Wyoming that correlate with the Wagon Bed Formation are shown in table 3. The following regional correlations of parts of the Wagon Bed Formation are suggested by lithic features and stratigraphic position. The basic volcanic rocks of unit 2 west of Conant Creek anticline probably correlate with the andesitic facies of the Aycross and Pitchfork Formations (Hay, 1956, p. 1895–1896). The limonite-stained, zeolite-bearing altered tuff of unit 3 west of the Conant Creek anticline may correlate with: (a) the dacitic facies of the Aycross and Pitchfork Formations, (b) variegated tuffaceous mudstone and light-gray acidic tuff in the middle part of the undivided middle and upper Eocene rocks on Togwotee Pass east of the Jackson Hole (Love, 1956b, p. 86; Houston, 1956, p. 133), (c) the 220 feet of lake beds composed of analcimized tuff, "paper shale," and mudstone containing algal deposits, and thin coal beds that conformably underlie the Tepee Trail Formation on Lysite Mountain between the Owl Creek and Bighorn Mountains (Tourtelot, 1957, p. 18; Tourtelot and Nace, 1946), and

(d) possibly the upper 125 feet of the Tatman Formation in the Bighorn Basin which contains rare hexagonal biotite and pleochroic apatite of volcanic origin (Hay, 1956, p. 1887). Unit 5 west of the Conant Creek anticline apparently is equivalent to at least part of the typical Tepee Trail Formation and Continental Peak Formation of Nace (1939) and possibly to the late basic breccia of Hay (1956, p. 1896). The color and even bedding of units 4 and 5 west of the Conant Creek anticline are duplicated in the finer facies of the Tepee Trail Formation in its southernmost and easternmost exposures in the southern Absaroka Range (Love, 1939, p. 74). Gastropod-bearing beds of unit 5 probably correlate with similar limy deposits in the upper part of the "green and brown member" and in the lower part of the Hendry Ranch Member of the Tepee Trail Formation in the northeastern part of the basin (Tourtelot, 1957, fig. 5). The uppermost shard-rich fine-grained yellowish-gray sandstone and siltstone of unit 5 (pl. 4, sec. 47) on the west flank of the Conant Creek anticline may correlate with the upper, tan volcanic siltstone of the Hendry Ranch Member.

CONDITIONS OF DEPOSITION

Accumulation of sediments in the map area continued without significant interruption in middle and late Eocene time. Parts of the Sweetwater uplift (p. 84) and the Sweetwater anticline (pl. 1) were uplifted, and basin-margin folds were further compressed either during or at the end of the epoch.

The climate of the region continued to be humid warm-temperate to subtropical, but there was marked seasonal dryness (MacGinitie, 1941, p. 87–94).

In middle and late Eocene time the region was a poorly drained lowland on which well-sorted sediments slowly accumulated. Deposition of the Wagon Bed Formation began with the accumulation of acidic ash and ash-rich mud that were altered by weathering to montmorillonite-rich mud and siliceous kaolinitic mud. The muds were penetrated by burrowers and were made porous by shrinking and cracking during lithification. The deposits were less lenticular than lower Eocene deposits and included significant amounts of authigenic quartz and potassium feldspar, zeolites, silica, montmorillonite, and possibly glauconite.

Deformation of the Sweetwater uplift and Sweetwater anticline apparently produced arkose and local boulder deposits. Faulting of Precambrian rocks in the Rattlesnake Hills area was accompanied by volcanic activity that supplied abundant volcanic debris.

Basic volcanic debris from the Yellowstone-Absaroka volcanic field was transported at least 80 miles southeastward to the western part of the area (fig. 1). Transportation of detritus eastward along the southern margin of the basin apparently was prevented by a topographic barrier formed by the Conant Creek anticline.

In the Rattlesnake Hills area, early stages of volcanic activity produced quartz latite or rhyodacite, much of which was spread as pyroclastic deposits. Later, coarse dacitic to andesitic debris accumulated in volcanic mudflows that carried very coarse angular unsorted detritus to the eastern part of the area.

Approximately contemporaneous explosive activity in the two volcanic source areas produced ash that accumulated in thick uncontaminated beds in the middle of the formation. Some of the ash in the eastern part of the area has no bedding or gravity sorting and is mingled with pumice fragments of widely different sizes; this lack of grading indicates transportation in relatively cool ash avalanches containing little gas (Williams and Meyer-Abich, 1955, p. 33; Cotton, 1944, p. 211–215). In the western part of the area, considerable ash fell in carbonate-rich lakes and much of it was altered to zeolites.

Late in Eocene time, lime mud derived from limestones of Paleozoic age on the Conant Creek anticline accumulated in a local lake and was diagenetically replaced by silica derived from altered volcanic debris.

OLIGOCENE SERIES

WHITE RIVER FORMATION

DEFINITION

Generally massive fine-grained tuffaceous sedimentary rocks overlying the Wagon Bed Formation were originally assigned to the Sweetwater Group by Hayden (1871, p. 29) and Endlich (1879, p. 110–112). Darton (1908, p. 463) pointed out that these deposits can be traced into the White River Formation to the east. The following year Granger (1910, p. 232–241) found Oligocene mammalian fossils in these deposits, showed that they rest unconformably on older rocks, and assigned them to the White River Group. The Chadron Formation and Brule Clay of the White River Group in eastern Wyoming are not recognizable in central Wyoming, and the name White River Formation is used (Love, Weitz, and Hose, 1955).

DISTRIBUTION AND THICKNESS

The White River Formation is exposed mostly in the upper part of the Beaver Rim escarpment, except where locally removed by erosion. It forms the basin floor and the lower part of the divide at the head of Muskrat Basin and in the vicinity of Cameron Spring. It also crops out on the Sweetwater Plateau in a broad area along the Long Creek valley, in the vicinity of Dishpan Butte west of the

Granite Mountains, and in smaller areas on the north side of a major fault zone east of Muskrat Basin. In the mapped area, the formation is excellently exposed in steep slopes and conspicuous badlands along U.S. Highway 287, at Green Cove, at Devils Gap, at Wagon Bed Spring, on the east side of Muskrat Basin, and in the vicinity of Cameron Spring.

The thickness of the White River Formation (fig. 13) varies locally. The formation reaches its maximum exposed thickness of approximately 650 feet along the Beaver Rim in the vicinity of Cameron Spring and may have been as much as 800 feet thick 2.5 miles north of

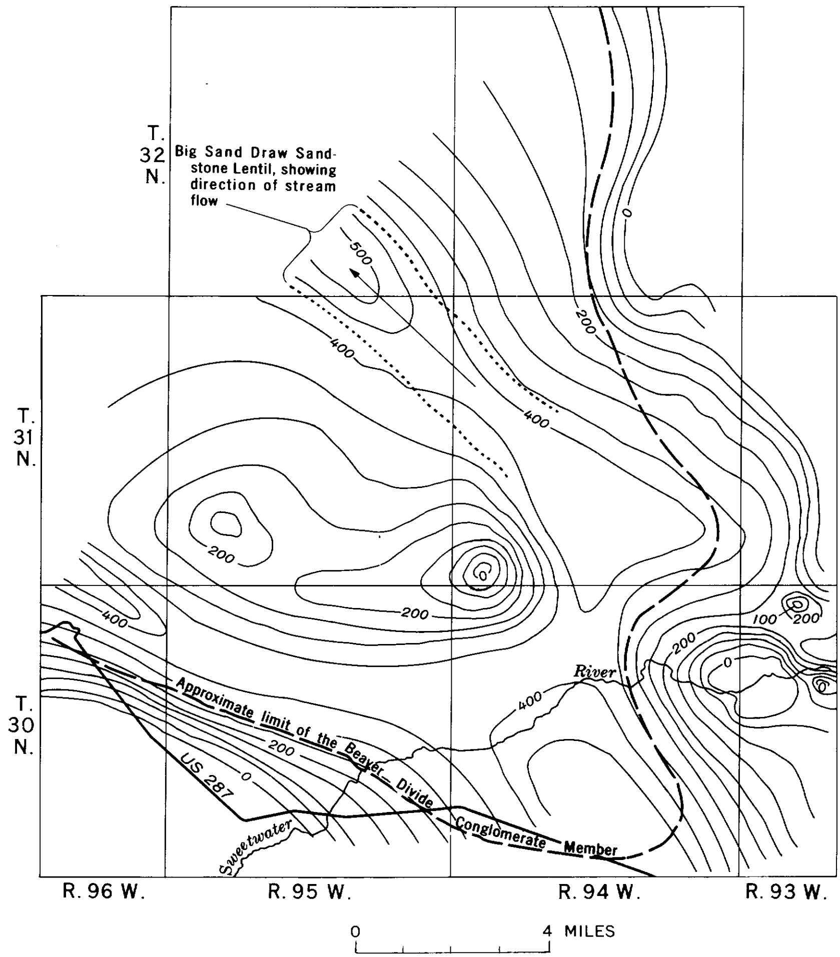


Figure 13.—Isopach map of the White River Formation, western part of the Beaver Rim area, showing approximate distribution of principal stratigraphic units. Contour interval 50 feet; isopach lines approximately located.

the divide. It wedges out southward against the Sweetwater uplift and the Sweetwater anticline.

GENERAL FEATURES

Throughout most of the Beaver Rim area, the White River Formation is predominantly a massive light yellowish-gray to grayish-orange calcareous tuffaceous mudstone and a fine-grained muddy sandstone containing some pink-stained quartz grains.

West of Conant Creek anticline the White River Formation comprises three locally distinct units. The lowest one is a broad lenticular unit here named the Big Sand Draw Sandstone Lentil. The unit was originally called the Sand Draw Sandstone Lentil (Van Houten, 1954), but the name is here modified to Big Sand Draw in order to avoid confusion with the Sand Draw fauna of Pleistocene age (McGrew, 1944, p. 33–42). It is overlain conformably by the very coarse poorly sorted Beaver Divide Conglomerate Member (Nace, 1939, p. 31–34) which in turn is conformably overlain by an unnamed mudstone and fine-grained sandstone unit typical of the formation in most of central Wyoming. The stratigraphic relations and distribution of the Big Sand Draw and Beaver Divide Conglomerate Members are shown on figure 13 and plate 6, but these members are not shown separately on plate 2.

The White River Formation is characterized by abundant unaltered vitric ash commonly containing biotite and fibrous shards, both mixed with nonvolcanic detritus and occurring in beds of light-gray vitric tuff or pumicite. The index of refraction of the shards in the White River Formation ranges from 1.497 to 1.504. Montmorillonite derived from altered ash is the predominant clay mineral throughout the formation. The composition and widespread distribution of most of the pyroclastic debris suggest a source in the Yellowstone-Absaroka volcanic field.

BIG SAND DRAW SANDSTONE LENTIL

South of the Big Sand Draw anticline the basal part of the White River Formation is a distinctive sandstone having a maximum thickness of 75 to 80 feet in the SE¼ T. 32 N., R. 95 W. The sandstone, which fills a former broad shallow valley, is here named the Big Sand Draw Sandstone Lentil; its type section is north of Wagon Bed Spring and is shown by section 25 on plate 3. The unit previously was referred to as the Sand Draw Sandstone Lentil.

The Big Sand Draw Lentil is about 2 miles wide in its outcrop along the Beaver Rim. The lentil grades upward into the Beaver Divide Conglomerate Member; it apparently is about 60 feet thick in core hole 1, sec. 17, T. 31 N., R. 94 W., 5 miles southeast of the type section, and 40 to 50 feet thick in core hole 7, sec. 16, T. 30 N., R. 94 W., 6 miles south of core hole 1.

At Wagon Bed Spring the lowest 15 feet of the lentil is well-bedded yellowish-gray biotite-rich volcanic mudstone and sandstone that is silicified in the basal 1 to 3 feet. The upper part of the lentil consists of soft calcareous pale greenish-yellow to yellowish-gray volcanic arkose containing lenses and layers of pebble conglomerate generally less than 1 foot thick. Most of the pebbles are feldspar, well-rounded quartz stained light brown, and light-gray Precambrian igneous and metamorphic rock; some pebbles are dark-gray and reddish-brown Tertiary volcanic rock.

BEAVER DIVIDE CONGLOMERATE MEMBER

A very coarse conglomerate at the base of the White River Formation in most of the western part of the map area was named the Sweetwater Member by Bauer (1934, p. 678–680). Inasmuch as this name was preempted, Nace (1939, p. 32–34) proposed a new name, Beaver Divide Conglomerate Member, for the conglomerate 40 miles to the south at Oregon Buttes, 7 miles west of Continental Peak on the northwest flank of the Great Divide Basin (pl. 1).

The northeasternmost known outcrops of the conglomerate member are in sec. 16, T. 32 N., R. 94 W. The member reaches a maximum thickness of about 80 feet in outcrops along the Beaver Rim and apparently is as much as 115 to 125 feet thick in core hole 7, sec. 16, T. 30 N., R. 94 W. It is less than 10 feet thick southwest of Green Cove and apparently wedges out against the Sweetwater anticline to the southeast. Where the Big Sand Draw Sandstone Lentil is present, the Beaver Divide Conglomerate Member lies conformably on it; where the lentil is not present, the member lies unconformably on the Wagon Bed Formation.

The lower part of the conglomerate member overlying the Big Sand Draw Sandstone Lentil and the upper part of the member east of the lentil has been designated the crystalline facies of the Beaver Divide Conglomerate Member (Van Houten, 1954). The more extensive remainder of the member is called the volcanic facies. In contrast to the volcanic facies, the crystalline facies of the Beaver Divide Conglomerate Member is distinctly bedded with both parallel and cross stratification, and, rather than thick continuous beds of conglomerate, it contains many distinct local lenses of conglomerate in a sandy matrix.

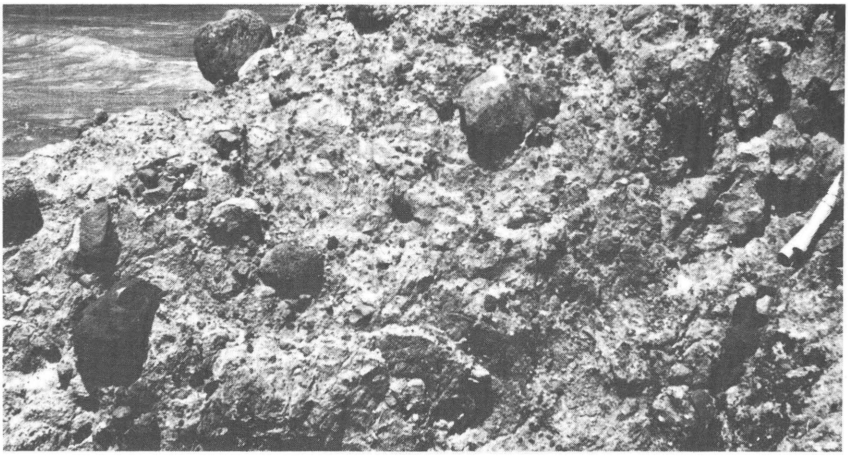
In the vicinity of the Big Sand Draw Sandstone Lentil, the crystalline facies consists of poorly sorted grayish-orange volcanic-rich sandstone containing lenses of angular pebbles, cobbles, and rare boulders of white, gray, and black Precambrian rock and rare pebbles and small cobbles of Tertiary volcanic rocks. There are also some beds of yellowish-gray mud-pellet conglomerate. Most of the coarse detritus less than an inch in diameter is brown-stained quartz, feldspar, and crystalline rock. Pink-stained granitoid rock is present but scarce. Pink-stained quartz is common in the sand fraction. East of the Big Sand Draw Lentil, the crystalline facies consists of as much as 70 feet of light-gray and very pale yellowish- to greenish-gray mudstone and sandstone containing scattered angular fragments of Precambrian rock as much as 2½ feet in diameter.

The volcanic facies consists principally of light-gray to yellowish-gray crudely bedded calcite-cemented volcanic sandstone and tuff interbedded with conglomerate containing very poorly sorted angular to subround Tertiary volcanic fragments (fig. 14). The volcanic debris ranges from sand size to boulders 8 feet long and was derived mainly from the Yellowstone-Absaroka volcanic field. There are also some fragments of Precambrian rock and pieces of greenish-yellow chert derived from the upper part of the Wagon Bed Formation. Locally, as in the vicinity of Devils Gap (pl. 3, sec. 15), there are beds of pumice lapilli tuff. At a few places (pl. 3, secs. 15, 17, and 21) lenses of white sandy limestone as much as 5 feet thick are partly replaced by irregularly fibrous chalcedonic chert and massive gray opaline silica containing irregular tubes and pores similar to those in unit 1 of the Wagon Bed Formation. Many of the tubes are filled with calcareous mountmorillonitic clay.

The fine-grained sand fraction of the volcanic facies contains abundant shards, green-brown hornblende, oxyhornblende, hypersthene, and augite. The hypersthene crystals generally are light colored and are deeply etched and acicular as a result of solution along the c axis.

The volcanic fragments consist of light- to dark-gray and reddish-brown porphyritic felsite and andesite and light-gray porphyritic pumiceous rock. Compared with volcanic pebbles and cobbles in the underlying unit 5 of the Wagon Bed Formation, those in the Beaver Divide Conglomerate Member are much more abundant, larger, more angular, less weathered, and generally less vesicular. The composition of five volcanic pebbles from the Beaver Divide Conglomerate Member is given in table 5.

Boulders in poorly sorted mudflow deposits of the volcanic facies are largest and most angular in the area between the NE¼ sec. 9 and the SW¼ sec. 19, T. 31 N., R. 95 W., where they reach a maximum of 8 feet in diameter (fig. 14*A*). Very angular 5- to 6-foot boulders are present from this area southward to Dishpan Butte. Boulders 4 to 5 feet in diameter are scarce but occur as far south as the N½ sec. 36, T. 31 N., R. 96 W.



A

B

FIGURE 14.—Conglomerate in volcanic facies of the Beaver Divide Conglomerate Member of the White River Formation. *A,* Mudflow, SE¼ sec. 9, T. 31 N., R. 95 W.; largest fragments 3 to 4 feet long. *B,* Fluviatile deposit, NE¼ sec. 25, T. 31 N., R. 96 W.; largest fragments about 18 to 24 inches long. Pick, lower right center, rests on base of unit.

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In the vicinity of Devils Gap (NE¼ sec. 25, T. 31 N., R. 96 W., pl. 3, section 14), the lower third of the volcanic facies is locally a fluviatile deposit of rather well-sorted round boulders commonly 1 to 2 feet in diameter (fig. 14*B*). Nearby to the north, a very poorly sorted boulder conglomerate at the same horizon has contorted bedding that suggests deposition by landslides.

Farther south, at Green Cove, the volcanic facies consists predominantly of lenticular deposits of sandstone and pebble conglomerate; it contains a few fragments 3 to 6 inches in diameter. Along U.S. Highway 287 the volcanic facies is apparently about 5 to 10 feet thick. This occurrence is the southernmost of the volcanic facies along the Beaver Rim. On the north flank of the Sweetwater anticline three-fourths mile to the south (sec. 10, T. 30 N., R. 96 W.), basal beds of the White River Formation are pale greenish-gray bentonitic mudstone containing lenses of conglomerate composed chiefly of Precambrian crystalline detritus as much as 6 inches in diameter. In the subsurface the volcanic facies is present as far southeast as core hole 7 in sec. 16, T. 30 N., R. 94 W.

At the margins of the Big Sand Draw Sandstone Lentil (pl. 3, section 25; pl. 4, section 28), the volcanic facies contains only a few volcanic cobbles as much as 8 inches in diameter; these are scattered through very pale grayish-orange tuffaceous sandstone. Locally, the facies comprises thin-bedded siliceous mudstone and tuffaceous sandstone and numerous yellowish-gray mudstone pellets 1 to 3 inches long.

East of the Big Sand Draw Sandstone Lentil (pl. 4, sections 29–31), the volcanic facies is 15 to 45 feet thick and contains well-rounded volcanic boulders, cobbles, and abundant pebbles.

The magnetic mineral composition of the shard-rich matrix of the crystalline facies is much like that of the volcanic facies, except that there is less hypersthene and more blue-green hornblende. In composition it resembles the volcanic matrix of the Beaver Divide Conglomerate Member in the Oregon Buttes area (Nace, 1939, p. 32–34).

UPPER PART OF WHITE RIVER FORMATION SOUTHWEST OF THE CONANT CREEK ANTICLINE

The upper part of the White River Formation is exposed in steep slopes above the Beaver Divide Conglomerate Member and attains a thickness of as much as 400 feet. In these deposits, unaltered glass shards, green-brown hornblende, and biotite indicate an acidic source for much of the pyroclastic material. A subordinate amount of augite and hypersthene is also present as shown by the samples from these beds listed on plate 7.

These deposits are remarkably uniform throughout the region; however, a few local variations in lithic features reflect minor differences in conditions of deposition. Three rather distinct stratigraphic units occur in the area from U.S. Highway 287 south to the vicinity of Devils Gap (pl. 3, sections 1–16). The lowest one is 50 to 100 feet thick and is composed of massive light-gray tuffaceous biotite-rich siltstone and fine-grained sandstone grading in color, texture, and composition into the underlying volcanic facies of the Beaver Divide Conglomerate Member. Between Green Cove and U.S. Highway 287, lenses of volcanic conglomerate are scattered through the lower 30 feet of the unit. Locally the lower unit is stratified in 12- to 15-inch layers, and some beds are silicified.

The middle unit has a maximum thickness of 250 feet and consists of massive, very pale grayish-orange sandstone and siltstone; it differs from the unit below mainly in being more clayey.

The upper unit is massive grayish-orange arkose and arkosic conglomerate, 60 to 80 feet thick, which rests on an erosional unconformity. Pink-stained pebbles and cobbles of Precambrian rock containing pink feldspar predominate. Rare large cobbles as much as 10 inches in diameter are chiefly fragments of black igneous and metamorphic rocks. The conglomerate is coarsest between Green Cove and U.S. Highway 287 (pl. 3, sections 1–6), and in this area crude cross-stratification that generally dips northward suggests that the detritus was derived from the core of the Sweetwater anticline to the south and southeast. The uppermost unit wedges out at Devils Gap.

Conglomerate and poorly sorted grayish-orange arkose similar to the uppermost unit constitute the upper 80 feet of the White River Formation in outcrops in the Sweetwater valley in sec. 15, T. 30 N., R. 94 W., and arkose predominates in the upper part of the formation in the scarp west of Long Creek in sec. 9, T. 30 N., R. 93 W. A 95-foot-thick hematite- and limonite-stained arkosic conglomerate with grayish-orange to reddish-orange matrix makes up the top of the formation in the subsurface in core hole 6 in SW¼ sec. 36, T. 30 N., R. 94 W. This occurrence indicates that the pink color of the conglomerate was not produced by recent weathering.

From Devils Gap to the northernmost outcrop of the White River Formation along the Beaver Rim (pl. 3, sections 13–26; pl. 4, sections 27–31), the upper part of the formation generally is crudely bedded grayish-orange volcanic sandstone and mudstone and has a maximum thickness of 350 feet. Some layers are very calcareous and weather to a gnarly surface. Above the Big Sand Draw Sandstone Lentil, a few beds in the lower part of the sequence are light yellowish gray to greenish gray. East of the sandstone lentil all the lower beds are this color, are more massive and more uniformly fine grained than west of the lentil, and are similar to the matrix in the underlying crystalline facies of the Beaver Divide Conglomerate Member. At Beaverton triangulation station (pl. 4, section 31; secs. 19 and 30, T. 32 N., R. 94 W.) the upper part of the formation changes rapidly from grayish orange at the west end to greenish gray at the east end of the ½-mile-long butte. Southeast of the butte as far south as the N½ secs. 13 and 14, T. 31 N., R. 94 W., the entire formation is a distinctive light yellowish- to greenish-gray calcareous mudstone.

In a prominent 160-foot-high south-facing escarpment south of the Conant Creek anticline, in secs. 3 and 4, T. 31 N., R. 94 W., the lower 50 feet of beds contains numerous irregular tubular structures, and locally layers of brittle limonite-stained light bluish- to greenish-gray opaline chert containing round pellets less than 3 mm in diameter. The upper 100 feet of beds exposed in the scarp contain numerous lenses of conglomerate that have schistose and granitoid pebbles and cobbles as much as 8 inches in diameter derived from rocks of Precambrian age. In Long Creek valley to the south, the White River Formation overlaps Precambrian rocks, and the upper part of the formation is coarser grained and locally contains abundant boulders as much as 4 feet in diameter.

From the West Fork of Long Creek in the S½ sec. 13 and sec. 14, T. 31 N., R. 94 W., to the southern end of Long Creek valley in secs. 9 and 16, T. 30 N., R. 93 W., the upper part of the formation consists in its lower part of pale grayish-orange to reddish-orange bentonitic sandstone and mudstone 50 to 75 feet thick that contains numerous lenses of conglomerate composed of limonite-stained pebbles, cobbles, and a few boulders as much as 8 feet in diameter of Precambrian rock. The great size, angularity, and local distribution of the boulders, together with the fact that in several places they rest in Precambrian bedrock locally exposed in the valley, suggest that some are residual blocks that have been moved only a very short distance.

East of Long Creek, the White River Formation is preserved in two reentrants in the western margin of the Granite Mountains. It consists chiefly of grayish-orange calcareous mudstone, sandstone, and sandy limestone overlain by yellowish-gray calcareous schist-pebble conglomerate and rather well sorted sandstone that can be assigned tentatively to the White River Formation also. Locally, there is a basal boulder facies, but it is not as thick or as persistent as the boulder facies west of Long Creek.

WHITE RIVER FORMATION EAST OF THE CONANT CREEK ANTICLINE

The White River Formation east of Conant Creek anticline generally is massive rather uniform grayish-orange to pale yellowish- and greenish-gray mudstone and sandstone containing local lenses and layers of coarse-grained grayish-orange arkose and conglomerate. Boulders of Precambrian rock are present locally in the lower third of the formation along the southwest side of Muskrat Basin in the NW¼ T. 31 N., R. 92 W. Conglomerate lenses in the formation east of Muskrat Basin contain volcanic pebbles and cobbles derived either directly or secondarily by erosion of the Wagon Bed Formation from the Rattlesnake Hills volcanic field.

From Conant Creek anticline eastward as far as sec. 21, T. 32 N., R. 93 W., the formation has a maximum thickness of 175 feet, is calcareous, and is pale greenish gray to yellowish gray. On the east flank of the anticline in sec. 13, T. 32 N., R. 94 W., the formation contains abundant cobbles and boulders of Paleozoic rock and detrital glauconite. The middle 50 to 60 feet of the formation is partly silicified gastropod-bearing limestone exposed in a steep scarp north of Findlay (Chalk) Springs in sec. 19, T. 32 N., R. 93 W. Some of the limestone is a porous, irregularly laminated tufalike variety (fig. 10*B*) like that in the upper part of unit 4 of the Wagon Bed Formation, but is less completely silicified.

East of sec. 21, T. 32 N., R. 93 W., the lower 50 to 100 feet of the formation is greenish- to yellowish-gray mudstone, somewhat similar to the underlying Wagon Bed Formation in color and texture; however, the lower part of the White River Formation generally is greener, better sorted, less bentonitic, and more tuffaceous.

In the lower greenish-gray tuffaceous mudstone in sec. 14, T. 32 N., R. 93 W., are several 2- to 4-inch-thick layers of slightly calcareous opaline chert containing intraformational ellipsoidal to subspherical pellets 1 to 2 mm in diameter (fig. 15). Most of the pellets are structureless; a few have irregular concentric layers. Both pellets and matrix contain abundant ooliths and round structureless thick-rimmed particles. Less common round particles having faint partitions probably are shells and suggest that many of the indeterminate fragments may be organic remains. The rock also contains sparse quartz grains, altered biotite, and an undetermined pale yellowish-gray to reddish-brown flaky mineral that probably is an alteration product of biotite. The opalite resembles the pellet phosphorite in the siliceous Monterey Shale (Miocene) of California, described by Rogers (1944) and may

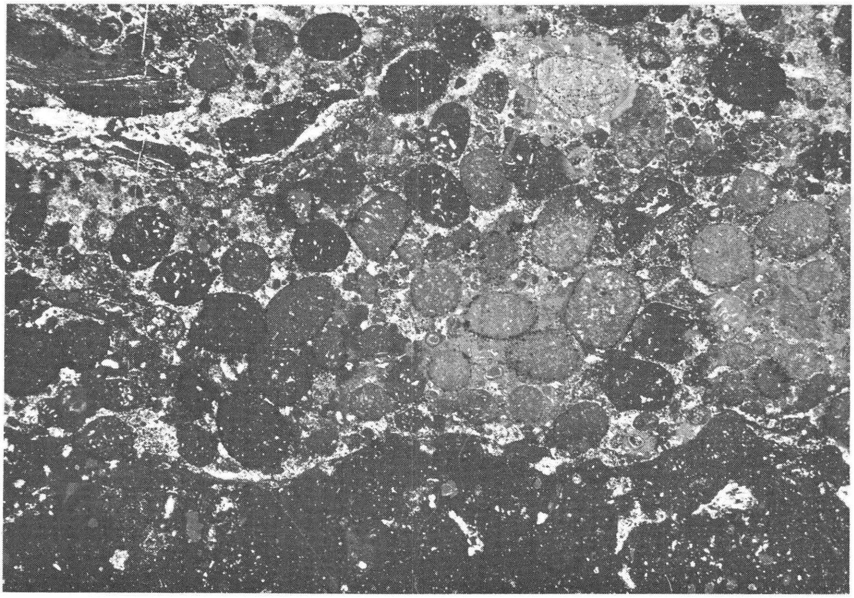

FIGURE 15.—Photomicrograph of opaline chert containing intraformational pellets in lower part of White River Formation, sec. 14, T. 32 N., R. 93 W. Crossed nicols. × 4.5.

have been originally an impure tuffaceous limestone rich in shell fragments.

Along the east side of Muskrat Basin, in secs. 24 and 25, T. 32 N., R. 91 W., and sec. 30, T. 32 N., R. 90 W., greenish- to yellowish-gray mudstone at the base of the formation is overlain by exceptionally bentonitic orange-pink to pale-red mudstone containing rare lenses of conglomerate comprised of round weathered volcanic pebbles, cobbles, and small boulders. The distinctive red ferric-oxide pigment may be from a regolith that formed locally on the slowly accumulating tuffaceous sediments.

Between Muskrat Basin and the Canyon Creek reentrant, the uppermost 25 to 50 feet of the formation commonly includes orange-pink to moderate reddish-brown and greenish-gray bentonitic mudstone and thin layers of pebble conglomerate.

In the vicinity of Cameron Spring, from the NW¼ sec. 31, T. 33 N., R. 89 W., to the SE¼ sec. 10, T. 32 N., R. 90 W., the White River Formation was deposited in a channel which in its deepest part cuts through the Wagon Bed Formation and extends about 150 feet into the Wind River Formation. In this area the lower 250 to 300 feet of the White River Formation apparently accumulated in a broad valley before widespread deposition of the formation began in the surrounding area. At the bottom of the ancient valley in the NW¼ sec. 31 and the adjacent NE¼ sec. 36, the basal bed of the formation is a conglomeratic arkose 3 to 5 feet thick, much like the arkose in the underlying Wind River Formation but containing scattered pebbles of sodic trachyte porphyry derived from the Rattlesnake Hills volcanic field. A similar channel is present in secs. 24 and 25, T. 32 N., R. 91 W., at the head of Coyote Creek. The White River Formation may also truncate the Wagon Bed Formation where the White River rests on older strata around the south end of the Conant Creek anticline in the SE¼ T. 32 N., R. 94 W.

The lower 80 feet of the valley-fill sequence near Cameron Spring is mainly pale orange-gray to pale-red bentonitic mudstone containing scattered lenses of volcanic-pebble arkose, similar to the variegated bentonitic beds of the White River Formation on the east side of Muskrat Basin. Red layers in these beds differ from superficially similar reddish-brown mudstone in the underlying Wind River Formation in that they contain bentonitic clay and volcanic detritus.

The upper two-thirds of the valley fill consists of alternating light greenish-gray, pale-olive, and yellowish-gray well-sorted bentonitic mudstone and fine-grained sandstone containing varying amounts of unaltered ash and in some layers traces of clinoptilolite. There are two thin layers of light-gray vitric tuff and several layers and lenses of conglomeratic arkose. Some beds of mudstone and sandstone contain considerable calcareous cement, and these commonly erode into nodular cliffs and pinnacles. Similar sequences of nodular calcareous mudstone in the White River Group in eastern Wyoming and western Nebraska have been interpreted to be paleosol complexes formed during periods of reduced aggradation (Schultz, Tanner, and Harvey, 1955).

Volcanic pebbles in the White River Formation east of Muskrat Basin were derived from the Rattlesnake Hills volcanic field, either directly or as volcanic detritus reworked from the underlying Wagon Bed Formation. Most of the beds of uncontaminated tuff, on the other hand, probably were derived from the Yellowstone-Absaroka volcanic field. Samples of tuff from different levels and localities throughout the Beaver Rim area are predominantly biotitic vitric tuff but contain some green-brown hornblende; they contain no minerals diagnostic of volcanic rocks of the Rattlesnake Hills field. In addition, the beds of tuff show no systematic textural variation related to distance from the Rattlesnake Hills.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The White River Formation is unconformable on the Wagon Bed Formation and overlaps older rocks along the margin of the basin.

The basal contact is an erosional unconformity characterized by considerable topographic relief (fig. 16; pl. 6).

The maximum relief in different parts of the area, measured by the change in thickness of the formation, is 275 feet in a mile in the vicinity of Green Cove (NW¼ sec. 36, T. 31 N., R. 96 W., to NE¼ sec. 2, T. 30 N., R. 96 W.); 280 feet in 1½ miles in the southwest corner of Muskrat Basin (SW¼ sec. 24, T. 32 N., R. 91 W., to SW¼ sec. 19, T. 32 N., R. 90 W.); 370 feet in 2¾ miles in the vicinity of Cameron Spring (NW¼ sec. 31, T. 33 N., R. 89 W., to SE¼ Sec. 10, T. 32 N., R. 90W.); and 250 feet in ½ mile in the Canyon Creek reentrant (sec. 34, T. 33 N., R. 89 W.).

The White River Formation generally dips gently southward. In the vicinities of Green Cove and southwest of Cameron Spring, however, the bedding of the basal strata parallels the slope of the erosional unconformity. At these localities the upper part of the formation has a locally steepened dip of 3° to 4° as a result of differential compaction.

From Devils Gap eastward for 4 miles through Dishpan Butte (pl. 2) (N½ secs. 29 and 30, T. 31 N., R. 95 W., to sec. 27, T. 31 N., R. 95 W.), the White River Formation is much thinner than it is to the north and south (fig. 13), and the upper part of the formation lies on an intraformational unconformity truncating a minor eastward-trending syncline.

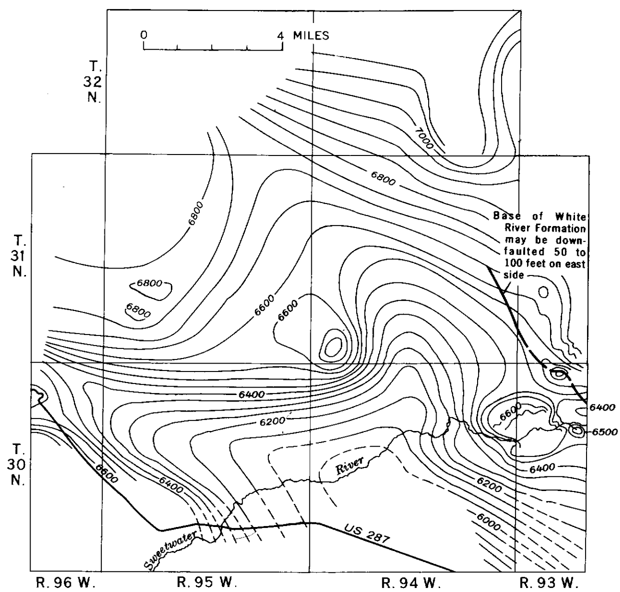

FIGURE 16.—Map showing approximate elevation of base of the White River Formation, western part of the Beaver Rim area. Contour interval 50 feet. Datum is mean sea level.

AGE AND CORRELATION

Within the map area the White River Formation yields mammalian fossils of early (Chadronian) and possibly of middle (Orellan) Oligocene ages.

The following mammalian fossils have been found in the Big Sand Draw Sandstone Lentil in the vicinity of Wagon Bed Spring:

Fossil locality 9 (pl. 2)

SW¼ sec. 34, T. 32 N., R. 95 W., measured section 25; Big Sand Draw Sandstone Lentil; early Oligocene (early Chadronian) age:

Menodus heloceras (Cope) (AMNH 14576)
cf. *Teleodus* (USGS specimen)

Fossil locality 11 (pl. 2)

E½ NW¼ sec. 34, T. 32 N., R. 95 W., measured section 26; Big Sand Draw Sandstone Lentil; early Oligocene (early Chadronian) age:

Brachyhyops wyomingensis Colbert (CM 12048)
Caenopus yoderensis Schlaikjer (CM specimen; USGS specimen)
Metamynodon cf. *M. planifrons* Scott and Osborn (USGS specimen)
Hyracodon cf. *H. priscus* Lambe (PUNM 17329)
cf. *Epihippus intermedius* Peterson or small species of *Mesohippus* (USGS specimen)
cf. *Leptomeryx* (CM specimen)
cf. *Teleodus* (CM specimen)

Metamynodon is known only from Chadronian and younger Oligocene faunas, and the Beaver Rim specimen is an advanced type (H. E. Wood, 2d, written communication, 1954). The specimen of cf. *Epihippus intermedius* is about the size of the smallest *Mesohippus* specimens from basal beds of the Chadron Formation in western South Dakota (John Clark, written communication, 1955) and closely resembles ?*Epihippus* from the Yoder Formation of Schlaikjer (1935) in southwestern Wyoming which is of early Chadronian age. *Caenopus yoderensis* also occurs in the Yoder fauna. *Teleodus*, on the other hand, is known from both early Chadronian and Duchesnean faunas.

The following fossils have been recovered from the Beaver Divide Conglomerate Member (locations of fossil localities shown on pl. 2).

Fossil locality 5

SE¼ sec. 24, T. 31 N., R. 96 W., measured section 14; 15 feet below top of Beaver Divide Conglomerate Member (volcanic facies):

Hyopsodus sp. (USGS specimen)
Hypertragulid or leptomerycid (USGS specimen)

Fossil locality 6

NE¼ sec. 9, T. 31 N., R. 95 W., between measured sections 21 and 22; upper 15 feet of Beaver Divide Conglomerate Member (volcanic facies):

Protoreodon sp. or *Agriochoerus* sp. (USGS specimen)

Fossil locality 7

Presumably SW¼ sec. 3, T. 31 N., R. 95 W., vicinity measured section 23; Beaver Divide Conglomerate Member (volcanic facies):

Protoreodon cf. *P. primus* (Peterson) (AMNH 22558)

Fossil locality 8

S½ sec. 34, T. 32 N., R. 95 W., vicinity measured section 25; upper 25 feet of Beaver Divide Conglomerate Member (crystalline facies):

Protoreodon pumilus (Marsh) (CM 12049)

Fossil locality 10

SW¼NW¼ sec. 34, T. 32 N., R. 95 W., between measured sections 26 and 27; 7 feet above base of Beaver Divide Conglomerate Member (crystalline facies):

Selenodont artiodactyl (CM specimen)

Fossil locality 12

SE¼ sec. 24, T. 32 N., R. 95 W., measured section 31; 10 feet above base of Beaver Divide Conglomerate Member (volcanic facies); USGS Cenozoic locality 20031:

Lymnaea aff. *L. similis* Meek
Planorbina pseudoammonius (Schlotheim)
Aplexa?
Oreoconus

The undescribed genus of selenodont artiodactyl appears to represent a stage of evolution reached in the Oligocene (John Clark, oral communication, 1953). The other mammals from the Beaver Divide Conglomerate Member anomalously suggest a late Eocene (Uintan) age (Gazin, 1955, p. 7–8, 49–50, 57–58). The fossil snails from locality 12 are forms that also occur in the upper part of the Wagon Bed (upper Eocene) Formation (D. W. Taylor, written communication, April 1962).

The following mammals presumably were found in the upper part of the White River Formation west of Conant Creek anticline from 50 to 200 feet above the base of the formation (Granger, 1910, p. 241; Wood, 1948; locations of fossil localities shown on pl. 2).

Fossil locality 3

NE¼ sec. 2, T. 30 N., R. 96 W., to SE¼ sec. 35, T. 31 N., R. 96 W., vicinity of Green Cove.

?*Titanotheriomys* sp. (AMNH 14581, 14582)
Poebrotherium sp. (AMNH 14593)

Fossil locality 4

NE¼ sec. 25, T. 31 N., R. 96 W., vicinity of Devils Gap:

Titanotheriomys wyomingensis Wood (AMNH 14579, 14580)
Merycoidodon cf. *M. culbertsoni* Leidy (AMNH 14588)
Cylindrodon cf. *C. fontis* Douglass (AMNH 14575, 14583)
Poebrotherium sp. (AMNH 14590, 14592)

Fossil locality 8

Presumably SE¼ sec. 34, T. 32 N., R. 95 W., vicinity of measured section 25:
Caenopus yoderensis Schlaikjer (AMNH 14578)
cf. *Merycoidodon* (AMNH 14589)

Fossil locality 14

NW¼ sec. 13, T. 31 N., R. 95 W. (Chaffee, 1954):
Campylocynodon personi Chaffee (Dartmouth College Museum 50–26–6919)

Fossil locality 15

Presumably secs. 29 and 30, T. 31 N., R. 95 W., vicinity of Dishpan Butte (Government Slide Butte, fossils collected by Walter Granger in 1909):
Subhyracodon cf. *S. occidentalis* (Leidy) (AMNH 14577)
Leptomeryx cf. *L. esulcatus* Cope (AMNH 14594)
Palaeolagus cf. *P. temnodon* Douglass (AMNH 14586)
Merycoidodon, cf. *M. culbertsoni* Leidy (AMNH 14587)
Titanotheriomys wyomingensis Wood (AMNH 14966)
Cylindrodon cf. *C. fontis* Douglass (AMNH 14584, 14585)
cf. *Ictops* (AMNH 14595)

The faunas from localities 3, 4, 8, and 15 indicate an early Chadronian or later Oligocene age. *Titanotheriomys*, *Cylindrodon*, and *Palaeolagus temnodon* are characteristic early Oligocene (Chadronian) fossils. *Merycoidodon culbertsoni*, *Poebrotherium*, and *Subhyracodon* are middle Oligocene (Orellan) forms (Wood, 1948, p. 40).

The following fossils have been found in the White River Formation east of Conant Creek anticline (locations of fossil localities shown on plate 2):

Fossil locality 17

Center sec. 19, T. 32 N., R. 93 W., ¼ mile north of Findlay (Chalk) Springs; 40 to 50 feet above base of White River Formation, USGS collection, now lost (D. W. Taylor, written communication, 1962):
Lymnaeidae
Planorbina pseudoammonius (Schlotheim)
Aplexa?

Fossil locality 18

NE¼ sec. 30, T. 32 N., R. 90 W., southeast corner of Muskrat Basin, variegated facies, upper part of White River Formation, USGS collection, early (Chadronian) or middle (Orellan) Oligocene age:
Megalagus turgidus Cope
Leptomeryx sp.
cf. *Hyracodon*
cf. *Hyaenodon*
Large titanothere

Megalagus turgidus is a characteristic middle Oligocene (Orellan) form according to H. E. Wood (written communication, 1951), but the large titanothere points to an early Oligocene age (G. E. Lewis, written communication, 1962). An upper molar of *Heptodon* sp., apparently reworked from the underlying Wind River Formation, was found with these Oligocene fossils.

Fossil locality 19

NW¼ sec. 1, T. 32 N., R. 90 W., vicinity of Cameron Spring; lower 250 feet of White River Formation (USNM collection); early Oligocene (early Chadronian) age (Hough, 1956, p. 531):

Peratherium sp.
Oligoryctes cameronensis Hough
Titanotheriomys cf. *T. veterior* (Matthew)
Cylindrodon fontis Douglass?
Cylindrodon sp.
Pseudocylindrodon? sp.
Cedromus? sp.
Palaeolagus temnodon Douglass
Magalagus brachyodon (Matthew)
Hyaenodon sp.
Pseudocynodictis cf. *P. paterculus* (Matthew)
Mesohippus cf. *M. montanensis* Osborn
Menodus heloceras (Cope)
Trigonias sp.
Caenopus sp.
Hyracodon sp.
Leptomeryx sp.
Leptomeryx esculcatus Cope
Bathygenus alpha Douglass
Merycoidodon culbertsoni Leidy
Merycoidodon gracilis (Leidy)

Fossil locality 22

S½ sec. 33, T. 33 N., R. 89 W., vicinity of measured section 48; lower half of White River Formation; early Oligocene (early Chadronian) age (Rachou, 1951):

Hyracodon cf. *H. leidyanus* Troxell (USGS specimen)
Agriochoerus sp. (Univ. Wyo. 932)
Archaeotherium cf. *A. mortoni* Leidy (Univ. Wyo. 927)
Cylindrodon cf. *C. fontis* Douglass (Univ. Wyo. 933)
Ischyromys cf. *I. typus* Leidy (Univ. Wyo. 934)
Titanothere
Acer glabroides Brown (USGS specimen)

Fossil locality 23

SW¼ sec. 2, NW¼ sec. 11, T. 32 N., R. 89 W., southwest of flank of Black Mountain; lower 50 feet of White River Formation; early Oligocene (early Chadronian) age (Rachou, 1951):

Archaeotherium sp. (Univ. Wyo. 929)
Mesohippus sp. (Univ. Wyo. 935)
Merycoidodon sp. (Univ. Wyo. 936)

Fossil locality 24

S½ secs. 22 and 23, T. 32 N., R. 89 W., 2½ miles south of Black Mountain; lower 50 feet of White River Formation; early Oligocene (early Chadronian) age (Rachou, 1951):

Agriochoerus sp. (Univ. Wyo. 931)
Agriochoerus cf. *A. minimus* Douglass (Univ. Wyo. 930)
Colodon sp. (USGS specimen)
Titanothere

As shown in table 3, the White River Formation in the Beaver Rim area correlates in a general way with the Wiggins Formation in the southern Absaroka Range, the White River Formation in central Wyoming, and the Chadron Formation and possibly the Brule Clay in eastern Wyoming. The early Chadronian faunas from the lower part of the formation in the map area indicate correlation with the lower part of the Chadron Formation in eastern Wyoming and western South Dakota. There is no clear evidence of deposits of late Oligocene age in the southern part of the Wind River Basin.

CONDITIONS OF DEPOSITION

Epeirogenic uplift of the region began after Eocene time. Oligocene climate was subhumid warm-temperate to subtropical, had a marked dry season (MacGinitie, 1953, p. 57–59), and probably was very much like that in the warmer parts of our present-day humid subtropical Louisiana and Mississippi.

Reduced relief resulted in slow accumulation of stream-laid deposits; however, numerous showers of ash from vents in the Yellowstone-Absaroka volcanic field contributed a substantial amount of sediment. Altered ash that mantled the uplands supplied most of the mud that was spread as an almost continuous sheet on flood plains over much of Wyoming and the adjacent Great Plains. Some of the ash that fell on flood plains and lakes was preserved in unaltered, uncontaminated layers, but most of it was altered to bentonitic mud and very locally some was altered to zeolite.

Deposition of the White River Formation began with the filling of the larger valleys in the Wagon Bed Formation and older rocks, probably in part because the streams that had been eroding the basin margin became overloaded with volcanic ash. Arkosic sand and gravel carried northwestward from the Sweetwater uplift filled a broad valley in the northwestern part of the area (fig. 13). The valley was blocked eventually by a southeastward advance of a mass of coarse volcanic debris that encroached on the valley fill and spread widely across irregular topography of the erosion surface. At this time considerable ash and lapilli reached the area, and calcium carbonate and silica were concentrated in local ponds. Most of the volcanic detritus was transported by streams from the northwestern part of the Wind River Basin; some of the coarser, more angular debris probably was transported by southeastward-moving volcanic mudflows.

After the main mass of volcanic debris had spread across the western part of the Beaver Rim area, more arkosic gravel was swept northwestward from the Sweetwater uplift. These deposits, represented by the crystalline facies of the Beaver Divide Conglomerate Member apparently accumulated in the same general drainage system that had deposited the Big Sand Draw Sandstone Lentil. Along the course of the old valley, the volcanic facies was eroded and part of it was incorporated in the crystalline facies.

After the deeper valleys were filled, tuffaceous grayish-orange mud locally containing lenses of tan- and pink-stained gravel was deposited widely on flood plains across the area. Toward the south these deposits overlapped Paleozoic and Precambrian rocks where they incorporated very large boulders, some of which were residual blocks. Erosion of Paleozoic rocks along the border of the basin produced greenish-gray calcareous mudstone in the adjacent area. Some of the limy mud accumulated in shallow ponds where a few thin beds of this mudstone formed as fossiliferous oolitic and mud-pellet deposits.

During deposition of the uppermost part of the formation, the Sweetwater anticline was uplifted abruptly, and strata along its north flank were folded, temporarily uplifted, and eroded. A flood of gravel then spread northward from the anticline.

MIOCENE SERIES

SPLIT ROCK FORMATION

DEFINITION

Coarse conglomerate, sandstone, tuff, and limestone overlying the White River Formation were called Pliocene deposits by Hayden (1871, p. 29) and Endlich (1879, p. 110–112). Granger (1910, p. 232–241) and Bauer (1934, p. 681–682) included the lower part of the sequence in the White River Formation. These rocks have been shown to be part of a formation that yields middle Miocene mammal fossils 10 miles south of the area (Van Houten, 1950, 1954; Rachou, 1951) and in the vicinity of Split Rock along the Sweetwater River (Schultz and Falkenbach, 1940). Within 25 miles south and east of the map area, early and middle Miocene mammal fossils have been found (Van Houten, 1950, 1954; Rachou, 1951; Rich, 1962). Love (1961) named the sandstone sequence in central Wyoming the Split

Rock Formation, and that name is applied in the Beaver Rim area.

DISTRIBUTION AND THICKNESS

The Split Rock Formation forms a persistent cliff at the top of the Beaver Rim escarpment (fig. 3) and underlies the surface of the Sweetwater Plateau except where removed by erosion.

The present thickness of the formation in the Beaver Rim area is largely dependent upon the amount of erosion of the plateau surface. From a maximum thickness of about 150 feet along the Beaver Rim, the formation thickens to about 275 to 300 feet in core hole 6, sec. 36, T. 30 N., R. 94 W. (pl. 4) in the southwestern part of the area. At and near the type section in T. 29 N., R. 90 W., the Split Rock Formation reaches a thickness of at least 1,000 feet.

GENERAL FEATURES

The Split Rock Formation is characterized by massive well sorted volcanic sandstone and rather persistent beds of coarse conglomerate composed largely of angular pebbles and cobbles of pink- and tan-stained Precambrian rocks. Commonly the formation is light gray to yellowish gray; locally it is grayish orange.

Pebble-and-cobble conglomerate predominates in the lower 50 to 100 feet of the Split Rock Formation. Uniform, locally crossbedded, medium- to fine-grained sandstone constitutes the bulk of the upper part of the formation and is present also in the conglomeratic lower part of the formation in the western part of the area. Unlike any other sandstone of Tertiary age in the area, sandstone in the Split Rock Formation contains conspicuous well-rounded and frosted grains. Although the sandstone generally contains some calcareous cement, it is poorly consolidated in many places. Interbedded with the sandstone are beds of light-gray vitric tuff, white to light-gray flaggy limestone, and thin lenses of conglomerate of Precambrian crystalline rock. Small irregular chert nodules and fibrous siliceous aggregates are scattered throughout the formation.

Sandstone in the Split Rock Formation is typically well-sorted arkose (arkosic arenite) containing abundant reworked shards and basic volcanic lithic fragments and minerals. Most of the quartz grains are colorless, but about 5 percent are conspicuous pink grains irregularly speckled with hematite. A few grains derived from older red sandstone have red rims. Most of the pink quartz grains, however, owe their color to patchy hematite in pits on the surface of round grains. Round grains of pink-stained felspar are found also.

Considerable magnetite, augite, hypersthene, and green-brown hornblende are present in the sandstone, in the matrix of conglomerate (table 7), and in some beds of tuff. The composition and widespread distribution of volcanic material suggest that it had its origin in northwestern Wyoming.

AREA WEST OF CONANT CREEK ANTICLINE

South of Devils Gap (pl. 3 sections 1–13) the basal 10 to 15 feet of the Split Rock Formation is a conglomerate containing pink-stained pebbles, cobbles, and angular fragments as much as 15 inches in diameter, and abundant fragments of black igneous and metamorphic rocks. Conglomerate in the Split Rock Formation is darker gray, less lenticular, has less matrix, and has a sand fraction richer in hypersthene than the conglomerate in the underlying White River Formation. It also is more calcareous and weathers with a gnarly surface.

Along a structural alinement trending eastward from Devils Gap (southern part of T. 31 N., R. 95 W.) and in outcrops on the butte in the N½ sec. 30, T. 32 N, R. 94 W. basal conglomeratic deposits in local channels as much as 50 feet deep show slump structures and contain pebbles or pellets and slabs of pale grayish-orange mudstone as much as 6 feet long; this material apparently was derived from the upper part of the White River Formation.

North of Devils Gap (pl. 3, sections 14–16; pl. 4, sections 26–31) the basal conglomerate of the Split Rock Formation is less than 10 feet thick and is finer grained than it is to the south; delimitation of the Split Rock and White River Formations is therefore arbitrary at some places.

Above the basal conglomerate in the area west of the Conant Creek anticline is 15 to 20 feet of massive well-sorted tuffaceous sandstone that is irregularly calcareous and that has scattered thin lenses of pebble conglomerate. The unit contains thin-bedded sandy limestone that has abundant small black or gray chert nodules. The sandstone weathers to hard sheets and lenses several inches thick and to horizontal pipelike concretionary bodies as much as 18 inches in diameter (fig. 17). Locally, the pipelike concretions have a parallel orientation, but the direction of elongation varies from place to place. These concretions resemble those in well-sorted volcanic sandstone of Miocene age in eastern Wyoming and adjacent Nebraska (Schultz, 1941).

In well-sorted calcareous sandstone southeast of Devils Gap (sec. 5, T. 30 N., R. 95 W.) are irregular domal structures several feet in diameter composed of sand adhering to an opaline skeletal structure (fig. 18). The general shape of these bodies suggests a tufalike structure that may have been produced by an algal mat of intertwined filaments binding together the grains of sand (Rezak, 1957, p. 145).

The uppermost deposits of the Split Rock Formation preserved along the Beaver Rim consist of interbedded, very light gray lime-

FIGURE 17.—Horizontal pipelike concretions as much as 18 inches in diameter in lower part of the Split Rock Formation, SE¼ sec. 19, T. 31 N., R. 95 W.

stone and calcareous tuffaceous sandstone generally in beds 2 to 6 inches thick. Thin beds of chert, irregular concretions of opaline silica, and fibrous siliceous aggregates commonly occur in the limestone.

AREA EAST OF CONANT CREEK ANTICLINE

The lower 50 to 100 feet of the Split Rock Formation along the Beaver Rim escarpment east of the Conant Creek anticline consists principally of coarse, poorly sorted conglomerate and arkose in a large amount of yellowish-gray to pale grayish-orange mudstone matrix that is similar to mudstone in the underlying White River Formation. The basal beds locally contain abundant grayish-orange mud pellets. West of Muskrat Basin, coarse detritus, the fragments of which are very rarely as much as 2 feet in diameter, consists of Precambrian gneissic, granitoid, and dike rocks, except in the westernmost part 3 miles east of Conant Creek anticline (sec. 19–21, T. 32 N., R. 93 W.) where black schist fragments predominate. East of Muskrat Basin volcanic pebbles and cobbles derived from the Rattlesnake Hills volcanic field also occur in the conglomerate.

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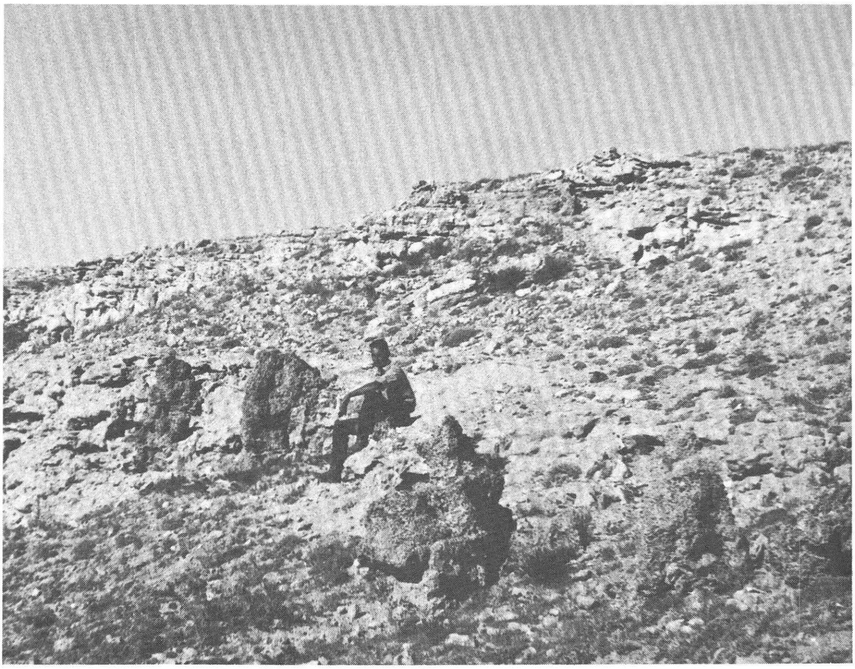

FIGURE 18.—Irregular silicified algal(?) structures in sandstone of Split Rock Formation, NW¼ sec. 5, T. 30 N., R. 95 W.

The lower conglomeratic part of the formation east of Conant Creek anticline is conformably overlain by a thick deposit of well-sorted well-rounded volcanic sandstone with local beds of gray vitric tuff and lenses of conglomerate; the sandstone is characteristic of the upper part of the Split Rock Formation throughout the Sweetwater Plateau. This distinctive upper sandstone crops out in a graben at Indian Grove on the west side of Muskrat Basin (SE¼ sec. 21, T. 32 N., R. 92 W.), on the south side of the fault zone at the southeast corner of Muskrat Basin (secs. 30 and 31, T. 32 N., R. 90 W.), locally along a structural alinement to the east, and in extensive exposures in the larger valleys south of the Beaver Rim.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The base of the Split Rock Formation surface dips about 2° to 5° S., except where locally modified by a broad dome in the Sweetwater valley in secs. 10, 11, 14, and 15, T. 30 N., R. 94 W., and along zones of late Tertiary faulting (pl. 8).

East of Conant Creek anticline a minor erosional unconformity has been detected at the base of the Split Rock Formation in the SE¼ sec. 19, T. 32 N., R. 93 W., and east of Cameron Spring in secs. 1 and 12, T. 32 N., R. 90 W.

No Tertiary rocks younger than the Split Rock Formation have been identified in the Beaver Rim area, but to the southeast, in T. 30 N., R. 89 W., the formation is overlain with erosional unconformity by the Pliocene Moonstone Formation (Love, 1961, p. I25).

The Split Rock Formation overlaps older Tertiary rocks and extends southward onto Precambrian and Paleozoic rocks of the Sweetwater uplift and the Sweetwater anticline. It extends eastward onto Eocene volcanic rocks of the Rattlesnake Hills volcanic field.

AGE AND CORRELATION

Fossil gastropods collected from a silicified sandstone and limestone were identified as follows:

Fossil locality 16 (pl. 2)

SW¼ sec. 18, T. 30 N., R. 95 W., upper part of Split Rock Formation, USGS Cenozoic locality 20090; probably post-Oligocene age (D. W. Taylor, written communication, April 1958):
Pseudosuccinea sp.

Fragments of bone have been found in the Split Rock Formation in the map area, but no identifiable mammalian fossils have been recovered. The following middle Miocene (Hemingfordian) mammals were found by Rachou (1951) in the upper part of the formation about 10 miles east-southeast of the map area: SW¼ NE¼ sec. 4, T. 31 N., R. 87 W., *Oxydactylus* cf. *O. longipes* Peterson; SE¼ NE¼ sec. 10, T. 31 N., R. 87 W., *Oreodontoides* cf. *O. curtus* Loomis, and *Cynodesnus* cf. *C. canavus* Simpson. In its type area, the formation yields a large middle Miocene mammalian fauna (Schultz and Falkenbach, 1940, p. 250–251; McGrew, 1951, p. 56; Love, 1961, p. I17).

Twenty-five miles east of the area, in the SW¼ sec. 12, T. 31 N., R. 85 W., the early Miocene mammal *Merycoides cursor* Douglass has been recovered from the formation by Rich (1962). The unconformity between the White River and Split Rock Formations indicates erosion during part of late Oligocene and early Miocene time, but the erosion did not greatly change the regional topography.

The Split Rock Formation correlates at least in part with the Browns Park(?) Formation in the northern part of the Great Divide Basin and in southern Wyoming and adjacent parts of Colorado, and with the Colter Formation in the Jackson Hole area of northwestern Wyoming. The Split Rock Formation is equivalent, also, to the Hemingford Group of Lugn (1938) in western Nebraska.

CONDITIONS OF DEPOSITION

Epeirogenic uplift continued during Miocene time, and the climate was drier and cooler than during the Oligocene Epoch (Dorf, 1955, p. 588).

After a late Oligocene and possibly early Miocene interval of nondeposition, locally accompanied by erosion, aggradation was renewed in a setting of low topographic relief. Sediments that accumulated differed markedly from those deposited in earlier Tertiary time. Despite the reduced relief, persistent sheets of gravel were spread across the area.

Abundant well-sorted well-rounded volcanic arkosic sand that was spread widely and uniformly across extensive flood plains accumulated slowly enough to be reworked by streams and wind and to be locally concentrated into dunes. Calcareous deposits accumulated in local lakes. Basic volcanic debris in the sand originated at least in part in the Yellowstone-Absaroka volcanic field and the adjacent Jackson Hole area. Some of it was carried eastward by streams across the aggraded Wind River Basin, and some sand-sized volcanic debris was blown into the area. With little increase in grain size these deposits encroached high on the core of the Sweetwater uplift and extended eastward as a virtually continuous sheet over much of Wyoming and the adjacent Great Plains.

SUMMARY OF DEPOSITIONAL ENVIRONMENTS AND SEDIMENTATION

The unusually complete sequence of nonmarine Miocene and older Tertiary sedimentary rocks preserved in the Beaver Rim area provides abundant information about sedimentation and depositional environments in this part of central Wyoming. The principal events and conditions of deposition are summarized on figure 19 and are summarized briefly below.

During Late Cretaceous time, central Wyoming was in the eastern part of the Rocky Mountain geosyncline, a broad mobile belt extending from the Arctic to Mexico. The eastern part of this belt had been a stable continental platform in earlier geologic time.

The Sweetwater uplift was thrust southward or southwestward during or just prior to early Eocene time while basin-margin folds, already formed and eroded, were further deformed. As the Sweetwater uplift rose, the axis of the Conant Creek anticline apparently was forced into a southwesterly recurved pattern.

As a result of the combined uplift of ranges and downwarping of the Wind River Basin in early Tertiary time, the base of the earliest Tertiary rocks was displaced at least 15,000 feet. If the Granite

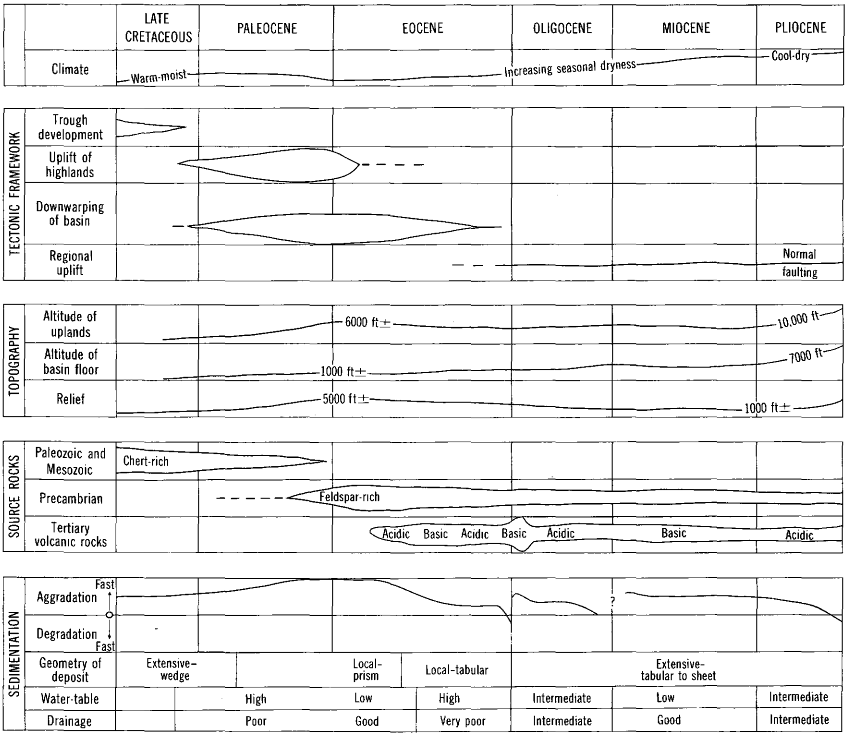

Figure 19.—Summary of depositional environments and sedimentation, Beaver Rim area.

Mountains were covered by Mesozoic or Paleozoic rocks, then the subsequent amount of displacement would increase accordingly.

Epeirogenic uplift that began in Oligocene time culminated in an episode of post-middle(?) Pliocene elevation that was accompanied by normal faulting and reversal of movement of some of the crustal blocks (Love, 1960, p. 212). During this late Cenozoic deformation, the southern part of the Sweetwater uplift failed to rise. As a consequence, southward-dipping upper Tertiary deposits on the uplift have been preserved from erosion.

The maximum topographic relief of the area during the Tertiary Period probably was achieved in early Tertiary time and was perhaps 5,000 to 6,000 feet along the southern side of the Wind River Basin. A humid warm-temperate to subtropical climate prevailed.

During Tertiary time the climate became cooler and drier, in late Miocene time it became slightly warmer (Dorf, 1955, p. 587–588), and the topographic relief was gradually reduced to about 1,000 feet by erosion of the uplands and aggradation on the lowlands.

The progressive change in climate in the Rocky Mountain region probably was due partly to epeirogenic elevation of the area; however, a similar change of climate also occurred in northwestern Europe (Dorf, 1955, p. 588–589), which indicates a global climate trend.

The Tertiary rocks of the Beaver Rim area constitute an arkosic suite (Pettijohn, 1957, p. 628–630) in which most of the differing textures and compositions, as shown on figure 20, resulted from varia-

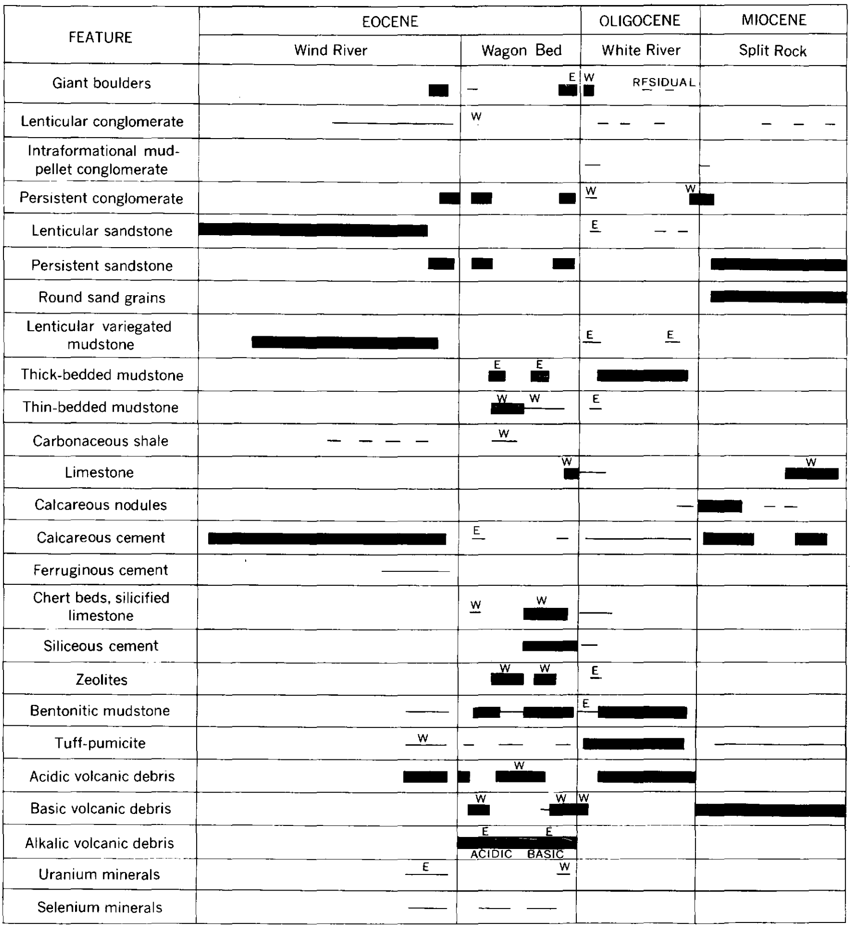

FIGURE 20.—Distinguishing features of Tertiary formations, Beaver Rim area. Broad line, common; narrow line, rare or local; W, present mainly in western part of area; E, present mainly in eastern part of area.

tions in the source of the sediments, from the climate, the rate of deposition and burial, and the height of the water table.

In early Eocene time, uplifted crustal blocks provided a prodigious supply of sediment which accumulated in the downwarped basin. Much of the detritus carried basinward was fine-grained arkosic gravel, sand, and reddish-brown mud that accumulated rapidly.

In middle and late Eocene time the rate of downwarp and accumulation was slower and sediment was spread more uniformly in the sinking basin. Streams were more sluggish and lakes were present during part of the interval. Facies relations in the correlative Green River Formation (Sears and Bradley, 1924, p. 99–100) in nearby areas suggest that a broad lake may have persisted in the center of the Wind River Basin.

By Oligocene time the region became better drained, and most of the detritus deposited was composed largely of fresh and altered volcanic ash. In late Tertiary time, burial of the major crustal blocks, except for their crests, produced a broad constructional plain that graded into pediments in the central part of the ranges. Only inselbergs protruded above this surface.

The following sequence of volcanic debris preserved in Tertiary rocks of the Beaver Rim and adjacent areas was derived from the Yellowstone-Absaroka volcanic field in northwestern Wyoming.

Lower Eocene rocks:

- Quartz latite and abundant green-brown hornblende and biotite, shards and pumice lapilli; less commonly acidic andesite and augite, hypersthene, and oxyhornblende; principally pyroclastic debris; in the upper part of the Wind River Formation.

Middle Eocene rocks:

- Basic andesite associated with augite, hypersthene, olivine, oxyhornblende, and green-brown hornblende in the lower part of the Wagon Bed Formation; the most basic suite in the sequence.
- Green-brown hornblende, biotite, sanidine and quartz, and shards, principally pyroclastic debris, suggestive of a rhyolitic to acidic andesite source during deposition of the middle of the Wagon Bed Formation.

Upper Eocene rocks:

- Basic andesite, augite, hypersthene, oxyhornblende, and green-brown hornblende in the upper part of the Wagon Bed Formation.

Oligocene rocks:

- Basic andesite associated with hypersthene, oxyhornblende, green-brown hornblende and augite as detrital sediments in the lowest part of the White River Formation and in the upper part of the White River in the northwestern part of the area.
- Rectangular fibrous shards, green-brown hornblende and biotite, principally pyroclastic debris, suggestive of an acidic andesite to quartz latite source, throughout most of the White River Formation.

Miocene rocks:

- Pyroxene andesite, keeled-shards, augite, hypersthene, oxyhornblende and green-brown hornblende in the Split Rock Formation.

Pliocene rocks:

- Red-brown and green-brown biotite, orthopyroxene, augite, and oxyhornblende; rectangular, needle-shaped, and sickle-shaped shards in the Moonstone Formation (Love, 1961, p. I30).

The volcanic-rich facies of the Wagon Bed Formation in the eastern part of the Beaver Rim area contains the following rock types derived from the Rattlesnake Hills volcanic field:

Middle(?) Eocene rocks:
- Quartz latite or rhyodacite and very dark green to brown hornblende, fibrous and platy shards and pumice lapilli, largely pyroclastic in ıe lower part of the Wagon Bed Formation.

Upper(?) Eocene rocks:
- Alkalic dacite and trachyte or andesite rich in augite, medium-green pyroxene, and very dark green to brown hornblende in the upper part of the Wagon Bed Formation.

These data agree with the petrographic calendar of Tertiary volcanism in Wyoming proposed by Love (1950) and amplified by Houston (1956); they corroborate these writers' observations of alternating acidic and basic volcanic activity during Tertiary time.

QUATERNARY SURFICIAL DEPOSITS

Remnants of high stream terraces along the Sweetwater River in the southwestern part of the area consist of a veneer of gravel several feet thick. The gravel is composed of fairly well rounded pebbles and rare small cobbles of black and tan chert, fine-grained black schist and dike rock, and, less conmmonly, brown-stained quartz, sandstone, quartzite, and granitoid rock. Most of the gravel presumably was derived from the Wind River Mountains and the Sweetwater anticline; some may have been reworked from Tertiary formations. Holmes and Moss (1955, table 3, p. 638) believed that these high gravel terraces are older than the Bull Lake Glaciation of Pleistocene age in the Wind River Mountains.

Many patches of very poorly sorted angular pebbles and cobbles were found on the Sweetwater Plateau north and south of the Granite Mountains. These scattered deposits have no apparent systematic distribution. Although some of the gravel may be lag deposits derived from the Tertiary formations, most of it appears to be coarse angular detritus eroded from the Granite Mountains during the present erosion cycle. If so, most of the deposits north of the Granite Mountains must have been transported northward before the present superposed southward drainage of the Sweetwater tributaries was established.

Many talus blocks as much as 50 feet long, broken from the Split Rock and the Wagon Bed Formations at the rim of the divide, have slid and tumbled to the base of the escarpment. The largest of these occur in the N½ sec. 33, T. 33 N., R. 89 W., and in the NW¼ sec. 35, T. 32 N., R. 92 W. Similar blocks of the White River Formation are present in the E½ sec. 10, T. 30 N., R. 96 W. Incipient blocks separated by open joints and crevices as much as a foot wide and several feet deep are found at several localities along the crest of the divide.

Four huge rotated blocks, from one-fourth mile to more than a mile long, have slid almost intact to the base of the Beaver Rim in the northwest part of the area (pl. 2). The slides undoubtedly resulted from erosion of the divide in an area where the Wagon Bed Formation is very bentonitic.

At the base of the Beaver Rim along much of its extent, debris or earth flows composed chiefly of material from the bentonitic Wagon Bed and White River Formations form characteristic hummocky topography. The larger debris flows are shown on the geologic map.

Quaternary deposits of alluvium and colluvium in the Beaver Rim area consist of feldspar-rich sand and silt derived chiefly from the Tertiary formations of the area. The deposits cover narrow flood plains along the Sweetwater River, Long Creek, and some of the larger intermittent streams north and west of the Beaver Rim. No information is available on the thickness of these deposits.

Conspicuous boulders as much as 8 feet long composed of Precambrian granite and gneiss and of sandstone from the Cambrian Flathead are scattered along the lower slope below the Beaver Rim in the vicinity of U.S. Highway 287 (secs. 3 and 10, T. 30 N., R. 96 W.). These boulders apparently are a lag concentration, for they are limited to areas in which the upper part of the Wind River Formation and the lower part of the Wagon Bed Formation crop out, and these formations are the only ones of Tertiary age in this part of the Beaver Rim area that contain large boulders.

A debris flow lying on the Wind River Formation is well exposed in a roadcut on U.S. Highway 287 in the southwest part of the area, NW¼ sec. 10, T. 30 N., R. 96 W. The displaced material is composed mostly of unconsolidated massive light-brown muddy arkosic sand and sandy mud that contains rounded boulders and angular blocks of quartzose sandstone (Flathead(?)), a few cobbles and boulders of gneiss of Precambrian age as much as 4 feet long, and angular slabs of brittle greenish- to yellowish-gray siliceous sandstone and chert as much as 6 inches long that were derived from the upper part of the Wagon Bed Formation. The uppermost few feet of the outcrop is crudely stratified and gently contorted.

Although small earth flows are forming under present conditions, the huge rotated blocks and extensive debris flows presumably moved into place during a late Cenozoic interval of greater rainfall.

STRUCTURE

GENERAL FEATURES

The Wind River Basin is an elongate east-trending structural basin flanked by major Laramide uplifts (fig. 1) and associated folds. These great uplifts are eastern ranges of the Cordillera according to King (1959, p. 92) and the eastern shelf ranges of Eardley (1951, p. 347).

Along most of its southern border, the basin is delimited by the generally east trending Sweetwater uplift, a large (90 miles long and 30 miles wide) upraised block that is thrust faulted on its southern and western margins and is inclined gently basinward along its northern flank.

The Sweetwater uplift has a Precambrian core that crops out discontinuously in two belts (Blackstone, 1951, p. 26; pl. 4). The northern, wider one comprises the Granite Mountains and their northern extension into the Rattlesnake Hills area where some 35 middle and late Eocene volcanoes constitute a volcanic field of less than 150 square miles (Carey, 1954a, 1954b). The narrower belt, the southern part of the core, which includes the Ferris, Seminoe, and Shirley Mountains, was named the Pathfinder uplift by Lovering (1932, p. 656–657). Because the two areas are part of one structural unit, the name "Sweetwater uplift" is used in this report.

The west side of the Sweetwater uplift is bounded by the Emigrant Trail thrust fault which at its southeast end joins the east-trending thrust faults that mark the southern edge of the uplift. The trace of the Emigrant Trail thrust is covered by Tertiary rocks in the Beaver Rim area; however, the Immigrant Trail 1 well (table 6, well 5) intersects the fault in sec. 32, T. 30 N., R. 93 W.

Major systems of east-trending late Tertiary normal faults are present on both the north and the south side of the Sweetwater uplift (pl. 1). The southern system, which parallels but is generally somewhat north of the trace of the southern thrust faults, probably was downthrown several thousand feet on the north (Bauer, 1934, p. 687; J. G. Stephens, written communication, 1955). Late Tertiary normal faults along the northern flank of the Sweetwater uplift are downthrown not more than a few hundred feet on the south side. As a result of the faulting, the Sweetwater uplift is a tilted graben, still largely buried by Tertiary sedimentary rocks.

Complexly faulted folds flank the Wind River Range and are overridden by thrust blocks at the western end of the Sweetwater uplift (Bell, 1956, p. 83). These complexly faulted blocks, including the Sweetwater anticline in the southwestern corner of the map area, are in a narrow southeastward-projecting arm of the Wind River Basin, which, together with the southeastern end of the Wind River Mountains, forms part of a structural divide between the Wind River Basin and the Great Divide Basin to the south. (See pl. 1; fig. 1.)

The attitudes of Tertiary rocks in the Beaver Rim area are shown on the structure sections (pl. 2).

Large northwestward-trending folds in Cretaceous and older rocks, including the Big Sand Draw, Rogers Mountain, Conant Creek, and Dutton Basin anticlines, are overlain with angular unconformity by gently dipping Eocene and younger rocks. The gentle regional dip of the Tertiary rocks is locally modified by shallow arching over some of the older anticlines and by a few tight folds such as the one in the White River Formation east of Devils Gap (p. 66).

In the northwestern part of the map area the Wind River Formation is gently arched over each of the major Laramide folds. Along the north face of Beaver Rim, the Wagon Bed Formation is draped over buried southward-trending structures that are prominently developed in Mesozoic rocks. In the valley of the Sweetwater River, the White River and Split Rock Formations are gently folded in a low dome. Fractures in the Split Rock Formation on the steeper east limb suggest that the flexure is a post-Miocene adjustment of the Paleozoic rocks along the buried Emigrant Trail thrust fault (pl. 8).

NORMAL FAULTS

A zone of fractures and faults in the Tertiary rocks extends from the Rogers Mountain anticline southward for about 16 miles to sec. 13, T. 30 N., R. 94 W., approximately parallel to and slightly east of the buried Emigrant Trail thrust fault. Displacement along most of the faults in this zone is down on the east or south sides; the maximum displacement is about 90 feet.

Another belt of fractures and faults east of the one just described occurs along the west side of Long Creek valley where the White River Formation overlaps Precambrian rocks. East of the north end of this fracture zone lies a basal boulder facies of the White River Formation and outcrops of Precambrian rock. East of the southern part of the belt (secs. 9 and 16, T. 30 N., R. 93 W.) the upper part of the White River Formation has been downfaulted about 50 to 100 feet against basal beds of the formation on the west side.

In sec. 2, T. 30 N., R. 96 W., a small normal fault upthrown 6 feet on the south side lies in a northeastward-trending zone of steepened regional dip of the Split Rock Formation along which the strata are conspicuously jointed. This zone of jointed strata coincides with the projection of the Spring Creek strike-slip fault on the northwest side of the Sweetwater anticline just outside the map area on the west (pl. 1) and suggests that the fault extends northeastward under the Tertiary mantle and that post-Miocene movement occurred. The Spring Creek fault and the overlying fracture zone both strike northeastward, which is the strike of conspicuous foliation and dikes in the western part of the Sweetwater uplift.

Zones of faulted, fractured, and folded Tertiary rocks occur where no buried faults are known. One northwestward-trending belt includes (a) conspicuous lineations in sec. 6, T. 30 N., R. 93 W., (b) a small area of intricately faulted and fractured Split Rock Formation in sec. 32, T. 31 N., R. 94 W., (c) intricately faulted, fractured, and tightly folded(?) rocks of the Wagon Bed Formation overlain unconformably by the White River and the Split Rock Formations in sec. 31, T. 31 N., R. 94 W., and (d) a syncline in the upper part of the White River Formation at Dishpan Butte and Devils Gap in secs. 29 and 30, T. 31 N., R. 95 W. The White River Formation is much thinner along most of this zone than it is to the north and south. In secs. 29 and 32, T. 31 N., R. 95 W., brown-stained arkose in the formation is silicified and strongly jointed. The belt of disturbed rocks may overlie faults in Mesozoic and older rocks on the north flank of the Sweetwater anticline along which movement may have occurred intermittently since late Eocene time.

In sec. 18, T. 30 N., R. 95 W., and sec. 13, T. 30 N., R. 96 W., less than 1 mile north of an outcrop of Precambrian rocks of the Sweetwater anticline, silicified limestone and sandstone of the Split Rock Formation are arched and intricately faulted in a northeastward-trending zone.

The north flank of the Sweetwater uplift is bounded by two roughly parallel belts or zones of normal faults and fractures in Miocene and older Tertiary rocks. The two belts are about a mile apart at their west ends in the SE¼ T. 32 N., R. 93 W., but diverge to about 4 to 5 miles at the east edge of the map area. Most of the faults in the two zones are upthrown on the north side. The maximum displacement on any of the faults is not known to exceed a few hundred feet. Displacements apparently diminish westward along the belts. The southern belt, which was called the Rattlesnake fault zone by Blackstone (1951, p. 27) and which is the North Granite Mountains fault zone of Carey (1954a, p. 33), extends at least 65 miles from the Conant Creek anticline eastward to the southeastern corner of the Wind River Basin (pl. 1).

Between the Conant Creek anticline and the west side of Muskrat Basin both belts are inconspicuous and have been located principally by reference to lineations noticeable on aerial photographs. At Indian

Grove (secs. 21 and 22, T. 32 N., R. 92 W.) a graben with at least 125 feet of displacement marks the northern belt (pls. 1 and 6). In Muskrat Basin the northern belt is represented mainly by fractures and faults which have displacement of only a few feet; these fractures and faults are identifiable on aerial photographs as lineations. Many of these also have been found by seismic methods (Zeller, 1957, p. 157, pl. 1). Eastward-trending faults in the vicinity of Coyote Springs (NE¼ T. 32 N., R. 91 W.) are downthrown on the north. The southern belt in Muskrat Basin is a conspicuous system of fractures and faults, most of which are downthrown on the south.

Between Muskrat Basin and the Rattlesnake Hills anticline both zones are well developed. The northern one lies along the Beaver Rim escarpment; most of the faults are downthrown on the north and have displacements of about 15 feet in secs. 2, 3, 10, and 11, T. 32 N., R. 90 W., and of about 75 feet in secs. 32 and 33, T. 33 N., R. 89 W. The southern belt is marked by a conspicuous change in topography, by a series of large springs, and by local outcrops of the Split Rock Formation faulted against the White River Formation; the faults exhibit estimated displacement of more than 150 feet. At the south end of the Rattlesnake Hills anticline (pl. 1), east of the map area, outcropping Precambrian rocks of the Sweetwater uplift are complexly fractured and faulted in a 4-mile-wide belt bounded by the two zones. The two fault zones described above apparently functioned as a hinge along which the Sweetwater unlift was tilted southward in late Cenozoic time; only minor displacement resulted. Much greater down faulting along the southern edge of the uplift resulted in the general southward dip of the late Tertiary rocks that partly cover the uplift.

Generally, east-trending faults and fault zones occur between the Beaver Rim and the south end of the Dutton Basin anticline. The maximum displacement along any of these faults is about 300 feet, as indicated by remnants of basal beds of the Wagon Bed Formation preserved in a graben in the W½ T. 33 N., R. 89 W. (Zeller, 1957, p. 157).

NATURAL RESOURCES

OIL AND GAS

Oil and gas are produced in the northwestern part of the Beaver Rim area from the Big Sand Draw and South Sand Draw fields and from a well drilled about 3 miles north of the Big Sand Draw field in sec. 21, T. 33 N., R. 95 W. (table 6, well 20). In this group of fields, the Frontier Formation, the Muddy Sandstone Member of the Thermopolis Shale, and the Cloverly, Morrison, and Phosphoria Formations contain gas and the Phosphoria and Tensleep Formations contain oil. The geology of the Big Sand Draw and South Sand Draw fields has been described by Jenkins (1957) and Taylor (1957), respectively.

Many wells have been drilled for oil and gas in the Beaver Rim area in addition to the ones in the Big Sand Draw and South Sand Draw fields (pl. 2). Information on 38 of the wells is given in table 6.

URANIUM

Uranium was discovered in the Gas Hills area in September 1953; since then the Mesozoic and Tertiary rocks along the Beaver Rim and in adjacent parts of the Wind River Basin have been actively prospected for uranium minerals. Many claims have been staked in the Gas Hills and northern Muskrat Basin area, as well as along the Beaver Rim in the vicinity of Findlay (Chalk) Springs, and between the Conant Creek and Big Sand Draw anticlines. Large-scale mining operations were in progress in the Gas Hills area in 1962.

Most of the mineralization in the Gas Hills area occurs in the upper part of the lower Eocene Wind River Formation and is concentrated in coarse-grained arkose interbedded with thin lenses of carbonaceous shale and mudstone (Zeller, Soister, and Hyden, 1956). The ore bodies typically follow bedding and other sedimentary structures. Moreover, the ore seems to be concentrated in places of greatest fracture density and in the most permeable lenses of coarse-grained arkose. The primary ore minerals, uraninite and coffinite, are disseminated as microscopic particles in coarse-grained arkose in the unoxidized zone. A uraniferous carbonate-fluorapatite found as cement and in fracture fillings may also be primary. The secondary uranium minerals include liebigite, meta-autunite, and a uranium phosphate.

Tuffaceous deposits of the Oligocene White River Formation are believed to have been the source of some of the uranium found in the Gas Hills area (Love, 1954, p. 8–10). The location of some of the mineralization in the Wind River Formation seems to be related to valleys, or buried channels, along the erosional unconformity at the base of the Oligocene rocks (pl. 6; figs. 3 and 4). The uranium probably was deposited after post-Miocene tilting of the area (Zeller, 1957, p. 156).

Uranium minerals are concentrated locally in the upper part of the Wagon Bed Formation west of Conant Creek anticline. In sec. 6, T. 32 N., R. 94 W., uranium occurs in a tuffaceous siltstone 1 foot thick. In sec. 3, T. 32 N., R. 94 W., the uranium is in coarse-grained asphaltic sandstone. Some of this ore has been mined.

TABLE 6.—*Selected wells drilled for oil and gas in the Beaver Rim area*

Well (pl. 2)	Location: Township N.	Location: Range W.	Location: Section	Operator, lease, well	Completion date	Ground elevation (feet)	Total depth (feet)	Formation at bottom of hole	Production, producing zone
1	32	94	NE¼SE¼ 8	Roy G. Steel Government 1	1955	7,071	1,403	Phosphoria	Dry hole.
2	30	95	NE¼NE¼ 24	Ashland Oil and Refining Co. Scarlett Ranch 1.	1958	6,530	2,883	Tensleep	Do.
3	32	95	NE¼NW¼ 26	Sand Draw Oil Co. 2 Unit	1946	6,571	(?)	do	Gas, Frontier; abandoned.
4	31	94	NW¼NE¼ 5	British-American O. P. Government Heaney 1 Unit.	1949 (Recompleted 1950)	7,116	6,306	Madison	Gas, Phosphoria.
5	30	93	SE¼NW¼ 32	Carter Oil Co. Immigrant Trail 1 Unit.	1950	6,435	6,591	Tensleep	Dry hole.
6	32	94	NW¼SE¼ 32	Sun Oil Co. Government-Downing 1 Unit.	1951	7,125	5,959	do	Do.
7	31	95	NE¼SW¼ 27	Sohio Petroleum Co. Government 1 Unit.	1952	6,848	7,343	do	Do.
8	32	91	SE¼SW¼ 25	Perry Fulk Ben Roberts 1	1952	6,757	1,235	do	Do.
9	31	94	NW¼NW¼ 6	Sohio Petroleum Co. Government-Hagood 1.	1955	7,103	9,122	do	Do.
10	32	95	SE¼SW¼ 36	Sohio Petroleum Co. State 2 Unit	1954	7,175	9,191	do	Oil, Phosphoria.
11	32	95	NW¼NE¼ 22	Sinclair Oil & Gas Co. 1 Unit	1931	6,195	3,634	Frontier	Dry hole.
12	32	94	SE¼NW¼SE¼ 5	Ryan Oil Co. & Davis Oil Co. Burley Dome 1 Unit.	1954	6,862	3,154	Phosphoria	Do.
13	30	95	SW¼SW¼ 14	California Oil Co. Government 1 Unit.	1954	6,710	2,525	Madison	Do.
14	30	94	SE¼NW¼ 29	Utah Southern Oil Co. & H. C. Arnold Ames 1 Unit.	1955	6,600	2,609	Tensleep	Do.
15	30	94	NW¼NE¼ 30	Utah Southern Oil Co & H. C. Arnold Besore 1 Unit.	1956	6,654	1,952	do	Do.
16	32	95	SE¼SE¼ 26	Sohio Petroleum Co. Government-Downing 1 Unit.	1956	7,227	9,018	do	Gas, Muddy.
17	31	94	?SW¼NE¼ 22	Stanolind Oil & Gas Co. 1 Unit	1956	6,868	8,000	Granite	Dry hole.
18	30	95	NE¼NE¼ 8	Atlantic Refining Co. Government-Sweetwater Crossing 1 Unit.	1957	6,725	2,835	Phosphoria at 2700(?)	Do.
19	33	94	SE¼NW¼ 17	Shannon Oil Co. 6 Unit	1958	5,990	5,424	Tensleep	Do.
20	33	95	SE¼SW¼ 21	Sinclair Oil & Gas Co. 1 Unit	1953	5,887	11,500	Madison	Oil, Tensleep.
21	33	95	NW¼SW¼ 27	Sinclair Oil & Gas Co. 1 Unit	1954	5,774	8,646	Tensleep	Gas, Frontier and Lakota.
22	32	95	SW¼SW¼ 20	West Sand Draw Syndicate 1	1955	5,804	8,221	Morrison	Dry hole.
23	32	95	SW¼NW¼ 3	Sinclair Oil & Gas Co. Federal-7-Fremont 1.	1958	5,891	8,138	Tensleep	Do.
24	32	95	NE¼NE¼ 9	Producers and Refiners Corp. Government 1.	1929	5,942	3,762	Frontier	Do.

TABLE 6.—*Selected wells drilled for oil and gas in the Beaver Rim area*—Continued

Well (pl. 2)	Location			Operator, lease, well	Completion date	Ground elevation (feet)	Total depth (feet)	Formation at bottom of hole	Production, producing zone
	Township N.	Range W.	Section						
25	32	95	SE¼NW¼ 10	Sinclair-Wyoming Oil Co. 7 Unit	1948	7,071	7,725	Tensleep	Oil, Tensleep.
26	32	95	SW¼NW¼ 14	Sinclair-Wyoming Oil Co. 9 Unit	1948	6,164	8,169	Madison	Do.
27	32	93	NW¼SE¼ 5	Far West Government-Sande 1	1952	6,131	3,627	Tensleep	Dry hole.
28	32	93	SW¼NW¼ 12	Oil Capitol Corp. Government 1	1956	6,450	2,378	Morrison	Do.
29	32	91	NW¼NW¼ 28	Fresno Exploration Co. Government 1.	1959	6,472	1,952	Tensleep	Do.
30	32	90	NW¼SE¼ 7	Richfield Oil Corp. Rogers 1	1956	6,718	2,867	do	Do.
31	32	91	NW¼NW¼ 1	Richfield Oil Corp. Monterey 1	1956	6,372	3,704	do	Do.
32	33	91	SW¼SW¼ 34	Davis Oil Co.-Government-Grieve Land and Cattle 1.	1958	6,116	2,461	Morrison	Do.
33	33	91	NE¼NE¼ 24	Western States Oil Co.-Government 1 Unit.	(?)	(?)	2,320	Frontier	Do.
34	33	90	SE¼NE¼ 22	Sinclair Oil & Gas Co. 1 Unit	1953	6,418	3,418	Tensleep	Do.
35	33	90	SE¼NE¼ 14	Stott Oil Co. Government 1	1954	6,534	1,156	do	Do.
36	32	89	NE¼SW¼ 7	Edward Neppel Government 1	1958	7,266	1,323	Precambrian	Do.
37	31	92	SW¼NE¼ 1	Stanolind Oil & Gas Co. Morle 1	1955	6,626	729	Tensleep on granite at T.D.	Do.
38	32	95	SW¼ 25	Stanolind Oil & Gas Co. 1 Unit	1954	(?)	8,081	Chugwater	Do.

GOLD

Gold occurs in quartz veins associated with pegmatites in areas of schist in the Granite Mountains (Osterwald and Osterwald, 1952, p. 69). In addition to numerous prospects, there are several inactive mines in the Tin Cup district, notably the Anderson mine in the SE¼ sec. 13, T. 31 N., R. 93 W., others in secs. 24, 25, 36, T. 31 N., R. 93 W., and one to the east in sec. 36, T. 31 N., R. 92 W.

GRAVEL, SAND PUMICITE, AND BENTONITE

The terrace gravels along the Sweetwater River are a thin veneer of poorly sorted, well-rounded gravel composed of locally derived quartzite, chert, granitoid rock, and finer grained black igneous and metamorphic rock mixed with finer grained alluvium. No information on the sorting and average size is available. The gravel in sec. 28, T. 30 N., R. 95 W., has been used locally as aggregate in road construction. Lenses of coarse angular, poorly sorted gravel composed of light- and dark-colored igneous and metamorphic rock are scattered through the Beaver Divide Conglomerate Member of the White River Formation in the vicinity of Wagon Bed Spring and in the lower part of the Split Rock Formation throughout much of the area.

Layers of poorly consolidated well-sorted sandstone several feet thick occur locally in the Split Rock Formation. In the valley of the Sweetwater River, alluvium derived in part from the Split Rock Formation is concentrated in dunes.

Throughout the Beaver Rim area in the White River and Split Rock Formations are beds of almost pure vitric tuff that is satisfactory for use as the abrasive pumicite; however, few beds are thick enough to be economically valuable. Pumicite claims have been staked on the White River Formation in the SE¼ sec. 3, T. 30 N., R. 96 W.

Bentonite and bentonitic mudstone occur in layers in a few feet thick in the upper part of the Wind River Formation in the northwestern part of the area and in the lower part of the Wagon Bed Formation in the vicinity of Green Cove and between Wagon Bed Spring and the Asbell triangulation station. They are present also in the lower part of the White River Formation on the east side of Muskrat Basin. Most of these deposits are silty or sandy, however, and none has been tested for purity.

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