Geology, Paleontology, and Correlation of Eocene Volcaniclastic Rocks, Southeast Absaroka Range, Hot Springs County, Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1201–A

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By T. M. BOWN

GEOLOGY OF THE ABSAROKA RANGE, NORTHWEST WYOMING

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Relations of Eocene volcaniclastic rocks and Eocene fossils date the sedimentary and structural evolution of the southeast Absaroka Range, clarify correlations with adjacent areas, and aid in timing large-scale events of gravity faulting

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By T. M. BOWN

ABSTRACT

The report area includes about 430 km² in the southeast Absaroka Range and southwest Bighorn Basin, Hot Springs County, Wyo. It is bounded on the south by the Wind River Indian Reservation (along the South Fork of Owl Creek), and on the north by Grass Creek. The eastern part of the area is dominated by rugged badland topography; whereas, the western part is characterized by mountainous terrain; local relief in the area is about 1,200 m.

Exposed sedimentary rocks are more than 3,500 m thick and include rocks of Devonian through Holocene age. Paleozoic rocks are restricted to the northern margin of the Owl Creek Mountains where they are overlapped by Tertiary volcaniclastics. Mesozoic rocks dip gently northward off the Owl Creek Mountains and are also exposed at the eastern margin of the Absaroka volcanic field, where they are unconformably overlain by essentially flat lying lower Eocene strata. Tertiary rocks are present throughout most of the report area. Four formations are recognized: the Willwood Formation of early Eocene age, and the Aycross, Tepee Trail, and Wiggins Formations of middle Eocene age. Each of these units is separated from older rocks by erosional or angular unconformities in the mapped area, and all, except the Willwood, are dominantly volcaniclastic. Quaternary deposits include alluvium, colluvium, landslide detritus, and large and small detached masses of Eocene rocks.

Mapping indicates that the names Aycross Formation and Tepee Trail Formation are more appropriate for middle Eocene rocks in the southeast Absaroka Range than are the names Pitchfork Formation and "late basic breccia," respectively, used by earlier workers. Aycross and Tepee Trail rocks were recognized in the report area on the basis of equivalent lithologies, age, stratigraphic position, and sedimentary and tectonic framework with the type rocks at A-cross Ranch and Tepee Trail. These formations are mappable units in the report area.

The Willwood Formation is characterized by brightly variegated mudstones, medium to fine sandstones, and pebble and roundstone conglomerates. Volcanic material is rare or absent in Willwood rocks, which are correlated with rocks of the upper part of the formation in the central Bighorn Basin; they are not considered basin margin equivalents of the Tatman Formation, as suggested by other workers.

The Aycross Formation overlies the Willwood by erosional unconformity and is marked by the first appearance of abundant volcanic detritus in the sediments. Volcanic roundstone conglomerates, andesitic tuff, and volcanic sandstone, mudstone, and shale are dominant. Kerogenic and ostracodal shales, carbonaceous mudstone, and green clay shales occur frequently near the base of the formation, where they generally contain little volcanic material. This lacustrine facies is correlated with similar rocks described in quadrangles to the north by other workers and with lacustrine rocks on Lysite Mountain; all are considered younger than Tatman rocks of the type locality. The Aycross Formation is middle Eocene in age; it is a correlative of the lower part of the Wapiti Formation on and north of Carter Mountain and is a correlative of the early basic breccia in the Yellowstone National Park region.

The Tepee Trail Formation is typified by volcanic sandstone and conglomerates, lava flows, tuffs, and lahars that unconformably overlie the Aycross Formation. These rocks occur at least as far north as the south flank of Carter Mountain, where they were included in the Pitchfork Formation by earlier workers. Tepee Trail rocks in the report area are probably all middle Eocene in age and are in part equivalent to the upper part of the early basic breccia unit of the Yellowstone–northern Absaroka region.

Wiggins strata comprise castellate exposures of volcanic conglomerate, light-colored tuff, and volcanic sandstone and mudstone that lie both topographically and stratigraphically well above rocks referred to the Wiggins Formation north of the report area by earlier workers. The Wiggins is an equivalent of the late basic breccia unit in the northern Absaroka Range and Yellowstone National Park and is nearly all middle Eocene in age.

The mapped area is at the boundary of three major late Laramide features: the western Owl Creek Mountains, the southwest Bighorn Basin, and the southeast Absaroka Range. Six principal episodes contributed to structural deformation during the Tertiary and Quaternary(?): (1) post-Fort Union (Paleocene) and pre-Willwood (lower Eocene) folding and erosion; (2) post-Willwood and pre-Aycross (middle Eocene) uplift and erosion; (3) post-Aycross and pre-Tepee Trail (middle Eocene) folding and erosion; (4) Post-Tepee Trail uplift that caused disharmonic folding in the Aycross Formation and local unconformities between Tepee Trail and Wiggins strata; (5) later Tertiary (Miocene?) regional uplift that initiated degradation in the Bighorn-Absaroka region and local intrusions that folded Wiggins rocks; and (6) late Tertiary or Quaternary volcanic activity in the Yellowstone area that triggered large-scale detachment faulting of Eocene rocks along the southeast front of the Absaroka Range. Detached rocks were largely derived from the Tepee Trail and Wiggins Formations; intense deformation associated with this faulting suggests that the masses must have been very thick to establish confining pressure.

Fossil mammals recovered from the Aycross Formation are of early middle Eocene age and are correlatives of faunas from the Bridger Formation of southwest Wyoming—and probably also of those from part of the Aycross Formation in its type area and the Wapiti Formation in the valley of the Shoshone River. Fossil turtles, invertebrates, and palynomorphs suggest a similar age and correlate with parts of the Bridger, Green River, Aycross, Tepee Trail, and Wagon Bed Formations.

Fifty-six mammalian species are described, constituting 40 genera. Three new taxa are named: *Alveojunctus minutus,* gen. et sp. nov. (Primates, Uintasoricinae), *Proviverroides piercei,* gen. et sp. nov. (Creodonta, Hyaenodontinae), and *Taxymys cuspidatus,* sp. nov. (Rodentia, Sciuravidae). Though the mammalian fauna is clearly a middle Eocene one, it is distinctive in the overlap of some typically late early Eocene and Bridger "A" and "B" forms, in the presence of several taxa apparently peculiar to it, and in the diversity of the omomyid primates. These considerations suggest that these mammals record paleoenvironments not developed, not preserved, or not yet discovered in adjacent parts of the Rocky Mountain region.

INTRODUCTION

LOCATION AND EXTENT OF AREA

This report describes an area of approximately 430 km² in western Hot Springs County, Wyo. (fig. 1), near the juncture of the western Owl Creek Mountains and the Absaroka Range. The mapped area is delimited by Grass Creek on the north and the Middle Fork of Owl Creek on the south (boundary with the Wind River Indian Reservation). Mapping and paleontological investigations were confined to the area of the geologic map (pl. 1), but reconnaissance surveys were made along the east front of the Absaroka Range as far north as the North Fork of the Shoshone River, west of Cody, Wyo.

PURPOSE AND SCOPE OF THIS REPORT

Geologic investigations were undertaken by the U.S. Geological Survey as part of its Wyoming State Geologic Map and Southern Absaroka Wilderness Area studies. These studies aid the correlation of Eocene rocks with equivalents in the northern and southwestern parts of the Absaroka volcanic field and are useful in the interpretation of the geologic history of the southeast Absaroka Range and southwest margin of the Bighorn Basin.

One of the most significant results of this study is the mapping of large and small remnants of detached masses of Tertiary volcanic rocks, identification of their lithology and of probable source areas, and determination of their late Cenozoic time of emplacement. An understanding of the nature, magnitude, and cause of these phenomena is essential to reconstruction of the Quaternary history of the region. Although detachment masses have been recognized in the southwest Bighorn Basin for many years, their extent, size, stratigraphy, structural relations, and time of emplacement have not heretofore been established in any detail.

FIELDWORK

Fieldwork was accomplished during the summers of 1977 through 1979. Mapping was done on U.S. Geological Survey quadrangle maps at a scale of 1:24,000, and on aerial photographs at a scale of about 1:18,000. Geologic mapping was detailed only in the Twentyone Creek Quadrangle; the rest is reconnaissance mapping. Attitudes were determined with the Brunton compass or were estimated. Mapping of stratigraphic contacts was assisted locally by the use of an altimeter, and estimates of rock thicknesses were obtained by trigonometric methods and were checked by tape and compass.

GEOLOGIC SETTING AND PREVIOUS INVESTIGATIONS

The Absaroka Range is composed of an immense, partly dissected accumulation of volcanic igneous and volcaniclastic rocks occupying approximately 11,300 km² in northwest Wyoming. These rocks are largely middle Eocene in age (Berggren and others, 1978), though late Eocene and earliest Oligocene equivalents may occur locally, and later Tertiary extrusives (Miocene or younger Caldwell Canyon Formation) and intrusives are also known (Love, 1939; Ketner and others, 1966; Love and others, 1976). Dorf (1939) presented floral evidence that the earliest more or less continuous volcanic activity in the Absaroka region (represented by the early acid breccia and equivalents) began in Wasatchian (early Eocene) time. In the northwest part of the volcanic field, the oldest volcanic rocks have been dated at about 53.5 m.y. (million years) (Chadwick, 1970; L. L. Love and others, 1976).

Absaroka volcanic rocks or their clastic equivalents at one time extended much farther to the east into Bighorn Basin (for example, McKenna and Love, 1972; Love, 1978; McKenna, 1980) and are about 300 m thick at Lysite Mountain, on the southeast margin of the basin (Love, 1964, p. E46–E54). Their present disjunct distribution has resulted from extensive later Tertiary and Quaternary erosion that began in response to regional uplift commencing in the Miocene or Pliocene. The lowest rocks of the volcanic sequence lie unconformably on older rocks, generally on surfaces of considerable erosional relief. The Washakie Range (Love, 1936) and the western Owl Creek Mountains have been partially exhumed from their volcanic cover, and volcanic rocks overlap the southern margin of the Beartooth Mountains (Foose and others, 1961).

Hague and others (1896, 1899) recognized six largely volcanic rock units in the central and northern Absaroka

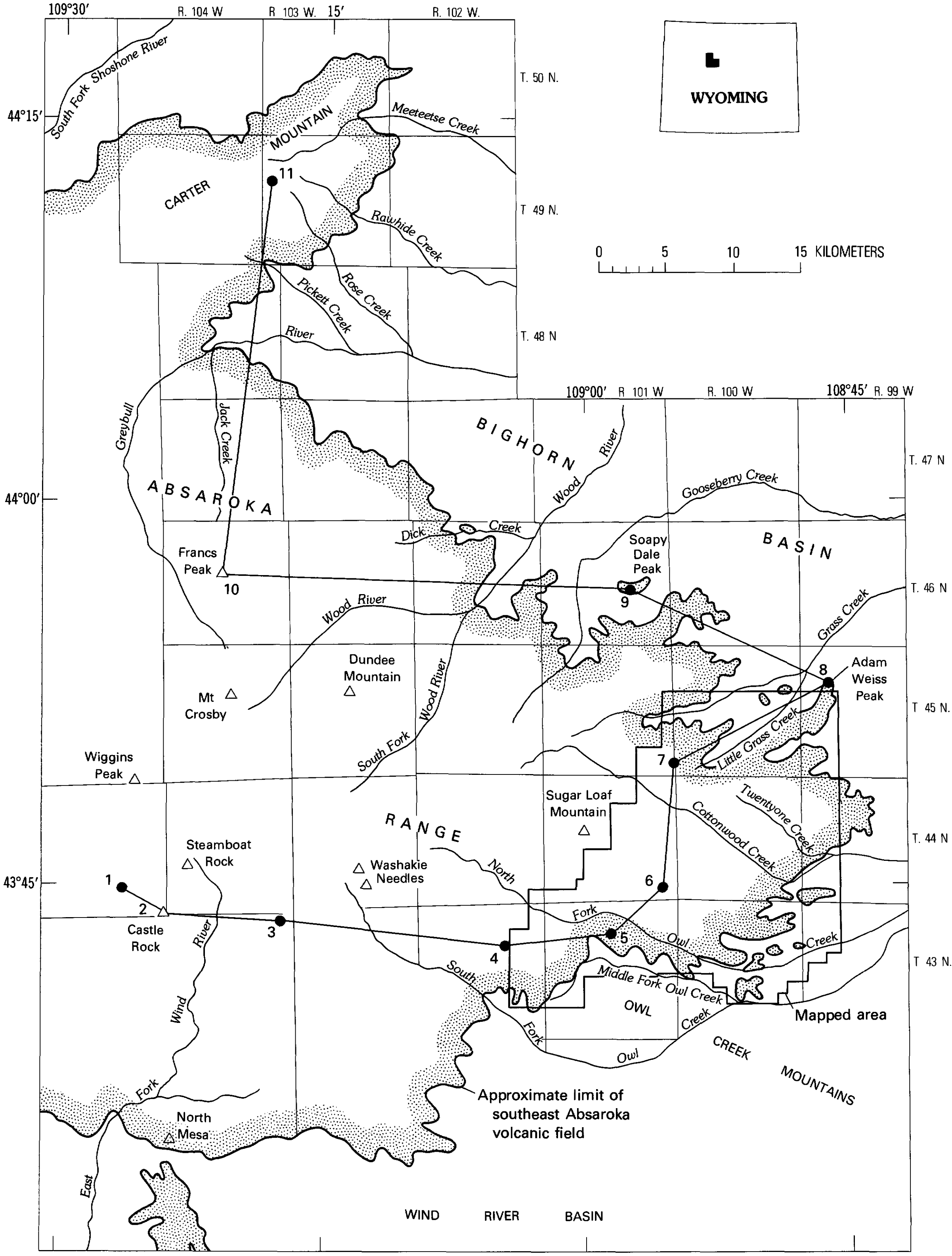

FIGURE 1.—Index map of southeast Absaroka Range showing location of mapped area with respect to principal streams, topographic landmarks, and other areas discussed in text. Solid circles provide index to lines of cross section; numbers refer to bends in section, figure 9.

volcanic plateau. Stratigraphically arranged, these units are

late basalt flows
late basic breccia
late acid breccia
early basalt flows
early basic breccia
early acid breccia.

Clastic and volcaniclastic equivalents of these rocks at and marginal to the eruptive centers are marked by rapid lateral facies changes. One dominantly volcaniclastic sequence occurs in the northwest Wind River Basin and in the south Absaroka Range where Love (1939) recognized three principal stratigraphic units: the Aycross, Tepee Trail, and Wiggins Formations. These units also occur in the southeast Absaroka range and southwest Bighorn Basin, and the lowest part of the sequence in that area, the Aycross Formation, forms the principal subject of this report. Pertinent geologic investigations in the southeast Absaroka Range are briefly summarized in table 1.

ABBREVIATIONS

Abbreviations used in the text are: AMNH, American Museum of Natural History (New York); CM, Carnegie Museum (Pittsburgh); FMNH, Field Museum of Natural History (Chicago); PU, Princeton University Museum (Princeton); TMM, Texas Memorial Museum (Austin); TTU-P, Texas Tech University (Lubbock); UCMP, University of California Museum of Paleontology (Berkeley); UMMP, University of Michigan Museum of Paleontology (Ann Harbor); USGSD, U.S. Geological Survey (Denver); USGSM, U.S. Geological Survey (Menlo Park); USNM, U.S. National Museum of Natural History (Washington, D.C.); UW, The Geological Museum, The University of Wyoming (Laramie); YPM, Peabody Museum of Natural History (New Haven); a, anterior; p, posterior; L, greatest anteroposterior measurement (length); W, greatest transverse measurement (width); Tr, trigonid; Tal, talonid.

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STRATIGRAPHY

The sedimentary rocks exposed in the report area have an aggregate thickness of more than 3,500 m and range in age from Devonian (Darby Formation) through Holocene. Eocene volcaniclastic and clastic rocks overlap the Devonian through Cretaceous parts of the sequence along the south and east margins of the area. The Mesaverde Formation is the youngest exposed Cretaceous rock; the Paleocene Fort Union Formation, as well as Oligocene, Miocene, and Pliocene rocks, are not represented. Quaternary alluvium and colluvium obscure the bedrock in and marginal to the principal drainages, and Quaternary landslide deposits and

TABLE 1.—*Historical summary of geological investigations in the southern Absaroka Range*

Date	Remarks
1874, 1894	Comstock (1874) and Eldridge (1894) were the first to report on the geology of the region.
1896, 1899	Hague and others first defined mappable rock units in the northern part of the Absaroka volcanic field.
1906	Darton was first to prepare a geologic map of the Owl Creek Mountains and adjacent areas. Fisher included this area in his geologic map of the Bighorn Basin.
1926	Hewett mapped and described volcanic rocks in the eastern part of the report area.
1936	Wood, Seton, and Hares described mammals from rocks that later (Love, 1939) were made the type area of the Aycross Formation.
1939	Love defined the Aycross, Tepee Trail, and Wiggins Formations in the northwest Wind River Basin. Jepsen described the first mammals from the "early basic tuff" of Rouse (1935). Dorf published a preliminary floral correlation of the early acid and early basic breccias.
1935, 1937, 1940	Rouse described volcanic rocks in the Shoshone, Wood, and Greybull Rivers area and in the central part of the Absaroka volcanic field, referring most of the lower part of the sequence to the early basic breccia.
1941	Pierce and Andrews mapped an area south of Cody, Wyo., referring volcanic rocks along the southwestern border of the Bighorn Basin to the early basic breccia.
1944	Van Houten described Willwood rocks in the report area and reviewed the correlation of the volcanic sequence with Love's (1939) units in the Wind River Basin. Jepsen (in Van Houten) commented on additional mammals from the early acid and early basic breccias in the drainage of the South Fork of the Shoshone River.
1952	Masursky published a geologic map of the western Owl Creek Mountains, extending the Aycross, Tepee Trail, and Wiggins Formations of Love (1939) into the southeastern Absaroka Range.
1953	Dorf published a preliminary correlation of floras from the early basic breccia.
1954, 1956	Hay described the relationships of tuff breccias in the South Fork of Shoshone River and Greybull River areas. Hay defined the Pitchfork Formation in the Greybull River valley and extended the formation southward to the Owl Creek Mountains, thus supplanting Masursky's (1952) usage of the term Aycross and Tepee Trail in this area. Hay discussed the correlation of the Pitchfork Formation with other Eocene units in the Absaroka volcanic field and Bighorn Basin.
1957	Keefer described and mapped Tepee Trail and Wiggins strata in the du Noir area. Long mapped volcanic rocks in the Enos Creek area and recognized the erosional unconformity between the Willwood and Pitchfork Formations in the region.
1963, 1964	W. H. Wilson described the structural and stratigraphic relationships of volcanic rocks in the Wood River and Greybull River areas, and defined the Blue Point Member of the Wiggins Formation. Simons (in Wilson, 1963) noted the occurrence of Eocene mammals in rocks on and adjacent to Carter Mountain.
1966	Rohrer described the geology of Adam Weiss Peak Quadrangle and was the first to recognize detachment faults involving Eocene volcanic rocks in the southwest Bighorn Basin. Ketner and others mapped Tepee Trail, Wiggins, and intrusive rocks in the Stratified Primitive Area, south of the Kirwin mineralized district.
1968	Nelson and Pierce named the Wapiti Formation as a principally volcanic equivalent of the Pitchfork Formation, supplanting the term early basic breccia for rocks in the Shoshone River–Carter Mountain area. The Trout Peak Trachyandesite was considered to be a local equivalent of the early basalt flows of Hague and others (1899).
1969	Rohrer and Smith discussed the correlation of the Pitchfork and Tatman Formations.
1970	W. H. Wilson's geologic map of Soapy Dale Peak Quadrangle recorded additional evidence of detachment faulting of Eocene volcanic rocks. Pierce published a geologic map of Devil's Tooth Quadrangle, mapping Wapiti Formation, Trout Peak Trachyandesite, and Wiggins Formation on and adjacent to Carter Mountain.
1972	Smedes and Prostka published a correlation of the Eocene rocks of Yellowstone National Park with the units of Hague and others (1899) in the northern Absaroka volcanic field. McKenna described Eocene vertebrate fossils and localities in the Togwotee Pass area of the northwest Wind River Basin.
1974	MacGinitie and others published data on middle Eocene floras from the northwest Wind River Basin.
1975	Wilson described detachment faulting involving volcanic rocks in the Deer Creek and Wood River areas.
1978	Pierce published the geology of the Cody 1°× 2° Quadrangle. Berggren and others offered a reappraisal of the middle-late Eocene boundary that implies most of the Absaroka volcanic supergroup is middle Eocene in age (49.0–40.0 m. y.).
1979	Bown described four new anaptomorphine primates from the Aycross Formation of the southeast Absaroka Range.

detachment masses emplaced in late Tertiary or early Quaternary times occupy several large areas.

Berry and Littleton (1961) have adequately summarized the stratigraphy of Paleozoic and Mesozoic rocks exposed in and adjacent to the eastern part of the report area.

STRATIGRAPHIC TERMINOLOGY FOR VOLCANICLASTIC ROCKS

Several formation-rank names have been applied to the lower part of the volcanic series in the east Absaroka Range. Hague, Iddings, Weed, Walcott, Girty, Stanton, and Knowlton (1899) originally named this sequence, from base upwards, the early acid breccia, the early basic breccia, and the early basalt sheets. Rouse (1937) broadened the use of the early basic breccia by extending the unit southward along the front of the Absaroka Range to the Owl Creek Mountains, and Pierce (1963a) renamed the early acid breccia the Cathedral Cliffs Formation in the Clark's Fork area of the northern Absaroka volcanic field.

The Aycross and Tepee Trail Formations were named by Love (1939) for the lower part of the volcanic-derived clastic sequence of Eocene rocks in the northwest Wind River Basin. Love believed the Tepee Trail Formation to be an equivalent of Hague's early basic breccia. In 1952, Masursky published a geologic map of the western Owl Creek Mountains depicting volcanic-derived sediments in the valley of Owl Creek. He believed that these rocks, referred to the early basic breccia by Rouse (1937), were mappable as the Aycross and Tepee Trail Formations of Love (1939).

Hay (1956) defined the Pitchfork Formation to include the detrital facies of the early basic breccia, exposed from Carter Mountain south to the northern flank of the Owl Creek Mountains. In contrast with the early basic breccia, rocks that Hay referred to the Pitchfork Formation are more clastic than pyroclastic, and several beds in the Pitchfork are more dacitic than andesitic in composition. Hay acknowledged the lithologic similarities shared by his Pitchfork Formation and the Aycross Formation of Love, and he considered the two units to be correlatives; but he chose to maintain a dual terminology for these units, observing (p. 1880) that:

> * * * the use of Aycross for these beds is misleading, as the beds * * in the Bighorn Basin may never have been continuous with beds of the Aycross Formation south of the Owl Creek Range, in the Wind River basin.

Hay named no type section for the Pitchfork Formation, but noted (p. 1869) that:"* * * exposures on the prominent cliff on the east side of Francs Fork, on the south side of Greybull Valley, most nearly approach a type section * * *." The term Pitchfork Formation has been widely used in the southeast Absaroka Range since its inception. (See, for example, Pierce, 1963a; Wilson, 1963, 1964a, 1970, 1975; Nelson and Pierce, 1968; Rohrer, 1966a; Rohrer and Smith, 1969; and others.)

In 1968, Nelson and Pierce named the Wapiti Formation and the Trout Peak Trachyandesite to supplant Hague's (Hague and others, 1899) now informal terms "early basic breccia" and "early basalt sheet," respectively. They restricted usage of Wapiti Formation to exposures where breccia is the dominant rock type, and they restricted usage of Pitchfork Formation to breccia-poor rocks dominated by volcanic siltstone and sandstone. They noted that the area of lateral transition between the Pitchfork and Wapiti Formations is poorly exposed—but probably occurs near the principal northeast salient of Carter Mountain, in the E½ T. 50 N., R. 103 W.

RECOMMENDED NOMENCLATURE

Mapping investigations in the upper Owl Creek, Cottonwood Creek, and Grass Creek regions of the southeast Absaroka Range demonstrate that three formations of different lithologic aspect and separated by unconformities are mappable in rocks attributed by Rouse (1937) to the early and late basic breccias, and by Hay (1956) to the Pitchfork Formation and late basic breccia. These rocks are here referred to the Aycross, Tepee Trail, and Wiggins Formations, from whose type sections or areas they are virtually indistinguishable on a lithologic basis.

Tepee Trail strata have been traced north into West Gooseberry Creek (NE¼ T. 45 N., R. 102 W., in fig. 1), into the South Fork of Wood River (SW¼ T. 46 N., R. 102 W.), and to the south flank of Carter Mountain. The exposures in the cliff face on the east side of Francs Fork—cited by Hay (1956) as a quasi type section for his Pitchfork Formation—are in the lower part of the Eocene volcaniclastic sequence, and the exposures in the cliff face closely resemble rocks of Aycross and Tepee Trail aspect (as here used) exposed in the drainage of Cottonwood Creek. Strata of Aycross aspect overlie the nonvolcanic lower Eocene Willwood Formation and older rocks at several places in the valley of the Greybull River (notably including badland exposures in secs. 23 and 26, T. 48 N., R. 104 W., and west of Foster Reservoir in secs. 24–26, T. 50 N., R. 103 W.). In the valley of the South Fork of Shoshone River (fig. 1), rocks of Aycross lithology intertongue with a thick sequence of flow breccia, volcanic sandstone, and lahar in the lower part of the Wapiti Formation.

Aycross, Tepee Trail, and Wiggins nomenclature was originally applied in the southeast Absaroka Range by Masursky (1952), setting priority for this usage there. Use of the term Wiggins Formation for presumed equivalents of the late basic breccia in this area is well established (for example, Wilson, 1963, 1964a, 1970; Dunrud, 1962; McGrew, 1965; Ketner and others, 1966; Nelson and Pierce, 1968; Pierce and Nelson, 1969; Pierce, 1970). In the interest of parsimony of nomenclature, the threefold terminology for volcaniclastic rocks developed by Love (1939) for the northwest Wind River Basin is here applied to lithologically equivalent rocks on the Bighorn Basin side. This correlation is defended by the following observations:

1. Both the type Aycross Formation and the lower part of the volcaniclastic sequence in the southeast Absaroka Range (Hay's Pitchfork Formation) are dominantly fluviatile rocks that represent the earliest influx of sediments from Tertiary igneous source areas to the north and west, respectively. Both sequences lie unconformably on and fill topography developed on earlier rocks, both are about the same age (with early middle Eocene equivalents), and both are approximately equivalent to the lower part of the Wapiti Formation and the early basic breccia. (See Rouse, 1937; Hay, 1956, p. 1896; Nelson and Pierce, 1968.)

2. Lithologies virtually indistinguishable from those of the Aycross and Tepee Trail Formations in its type area or section, respectively (Love, 1939), are separated by an erosional unconformity (in places angular) and are mappable throughout the Owl Creek—Greybull River area in the southeast Absaroka Range. Though most recent workers have assigned all of the lower volcaniclastic sequence there to the Pitchfork Formation of Hay (1956), all, including Hay, have stressed the similarities of the sequence to the Aycross and Tepee Trail Formations. The Aycross Formation, like the Pitchfork of Hay, is both dacitic (Coulee Mesa) and andesitic (type area on North Mesa) in mineralogy; and Hay (1956, p. 1895) has recorded other pertinent mineralogic and stratigraphic similarities.

Above the upper bounding unconformity, at least 400 m of rocks comprise strata of Tepee Trail aspect. Hay (1956, p. 1896) called these rocks the late basic breccia and observed that they "were mapped as far south as the divide between Little Grass and Cottonwood creeks," where Hay placed the lower contact at the top of an absarokite agglomerate and tuff sequence that underlies a coarse conglomerate sequence. Because Masursky (1952) mapped these rocks farther south as Tepee Trail, Hay believed that at least the lower part of his late basic breccia was an equivalent of the Tepee Trail Formation. Hay did not record the unconformity between the two sequences on the Little Grass–Cottonwood Creek divide (although one exists there), but Dunrud (1962) and Wilson (1963, p. 15) observed that an unconformity occurs in rocks they called Pitchfork Formation "between the lower dacitic facies and the upper andesitic facies" in the Jack Creek, Dick Creek, and Twentyone Creek areas (fig. 1). Wilson (1963, p.15) further observed that:

> * * * much of the upper part of the Pitchfork Formation on the Wood River, Jack Creek, and other Greybull River tributaries * * * is similar to the Tepee Trail Formation * * * (lithology, color, and general appearance) * * * the variable thickness of Aycross equivalents (within the Pitchfork) could be accounted for by the unconformity within the Pitchfork with the overlying beds indicating initial Tepee Trail deposition.

The sequence on the Little Grass–Cottonwood Creek divide was mapped in detail, and units on both sides of the unconformity were examined by reconnaissance in the upper drainages of Grass and Gooseberry Creeks, and in tributary drainages to the Greybull River. In all of these areas, the unconformity provides a mappable contact between a lower sequence of Aycross lithology, and an upper unit of Tepee Trail lithology. Locally, rocks mapped as Pitchfork Formation by earlier workers include definite Tepee Trail strata. (See, for example, Wilson, 1964a, pl. 1 for the NE¼ T. 45 N., R. 102 W.)

3. Hay (1956, p. 1869) named no type section for his Pitchfork Formation. Exposures cited by him east of Francs Fork on the south side of the Greybull River Valley are unsuitable because neither the top nor the bottom of the sequence is exposed there, much of the outcrop is inaccessible, and the rocks are partly displaced and gouged by detachment faulting. Much better exposures that represent a similar sequence occur in the drainage of Cottonwood Creek.

   In compiling the Cody 1° × 2° geologic quadrangle map, Pierce (1978) included the "type" section of the Pitchfork Formation and rocks east of Francs Fork in the Wapiti Formation, as mapped in the adjoining area to the northwest. However, as these rocks contain little or no breccia, they are included in this writer's concept of the Aycross and lower part of Tepee Trail Formations.

4. Hay's principal reason for introducing the "Pitchfork Formation" as a new name is a lack of physical contiguity of these rocks with the Aycross Formation in its type area. Studies of Love (1939), Masursky (1952), Ketner and others (1966), Wilson (1963, 1964a), and Pierce (1970) demonstrate the physical continuity of Wiggins strata between the southern and southeastern parts of the Absaroka Range. Mapping by Love (1939) and Masursky (1952) and aerial photography study by this writer indicate continuity of the upper part of the Tepee Trail Formation between the two areas, across Black Ridge and the Crow Creek basin in T. 43 N., R. 103 W.

Because the rocks overlie a topography of considerable relief developed on Precambrian through Cretaceous strata in the Washakie Range and Owl Creek Mountains, it is only an oddity of pre-Eocene erosion that the Aycross section is not continuous across these structural highs.

In summary, maintenance of a dual nomenclature for the lowest rocks of the volcanic series on the margins of the Bighorn and Wind River Basins clearly obscures equivalence with Aycross, Tepee Trail, and Wiggins strata that is demonstrated by their lithology, age, source areas, and structural and sedimentologic settings. The name Pitchfork is abandoned in favor of Aycross and lower part of Tepee Trail. The Aycross is now included as the basal formation of the Thorofare Creek Group of the Absaroka Volcanic Supergroup.

WILLWOOD FORMATION

The name Willwood Formation was applied by Van Houten (1944, p. 178) to approximately 750 m of interbedded sandstone, variegated mudstone, and shale exposed in the central Bighorn Basin. The type area is south of the town of Willwood, Park County, Wyo. The term "border Wasatch" was applied by Hewett (1926) to rocks now referred to the Willwood Formation that underlie the volcanic series in the east Absaroka Range.

DISTRIBUTION

In the upper Cottonwood Creek–Grass Creek area of this report, about 20–100 m of the border Willwood Formation are preserved between unconformities at the top of the Cody and Mesaverde Formations and the base of the Aycross Formation. Masursky (1952) mapped Willwood deposits in the Owl Creek area as "Wind River." The best exposures are (1) on the north side of Cottonwood Creek, east of the Rhodes Ranch, in secs. 20–22, T. 44 N., R. 99 W., (2) in drainages tributary to Wagonhound Creek in secs. 3, 4, 10, 15, and 16, T. 44 N., R. 99 W. (Hewett, 1926, pl. III), and (3) in the drainages of Wagonhound, Prospect, Little Grass, and Grass Creeks (this report, pl. 1). Everywhere, the Willwood lies unconformably on beveled rocks of the upper Cretaceous Mesaverde Formation or Meeteetse Formation that dip off structural highs in the Wagonhound Creek, Grass Creek, and Prospect Creek oil and gas fields. North of Putney Flat, near the township corner for Ts. 43–44 N., Rs. 99–100 W., the Willwood unconformably overlies the Cody Shale, which dips gently to the north off the Owl Creek Mountains (fig. 2).

The outcrop of the Willwood Formation depicted on plate 1 is less extensive than that mapped by Masursky (1952), who included some volcanic sandstones of the lower part of the Aycross Formation in his "Wind River" Formation.

FIGURE 2.—Cretaceous Cody Shale (Kco) truncated by lower Eocene Willwood (Twl) and middle Eocene Aycross (Ta) Formations on south side of Putney Flat, sec. 1, T. 43 N., R. 100 W., sec. 36, T. 44 N., R. 100 W., and sec. 31, T. 44 N., R. 99 W. View to north.

LITHOLOGY

The composition of the border Willwood in the southeast Absaroka Range is heterogeneous and varies considerably from north to south; but, as observed by Hewett (1926) and Van Houten (1944), these rocks resemble the upper part of the Willwood Formation of the central Bighorn Basin more closely than they do the lower and middle parts.

In the Owl Creek–Grass Creek area, the basal unit is commonly a sheet of interbedded yellow and gray, medium- to coarse-grained sandstone that locally contains chert pebbles, and, particularly, pebbles and roundstones of quartzite and vein quartz. It varies from 1 to about 10 m in thickness and is typified by either medium-scale trough cross-stratification or apparent plane bedding. The large clasts commonly form discrete bands at the bottoms of bedform set boundaries. Hewett (1926) observed that conglomerates are also commonly found near the base of his "Wasatch" Formation in the adjacent Grass Creek Basin Quadrangle.

Above the basal sandstone, the formation is dominated by sandy gray, red, purple, and yellow mudstone and by a few thin lenses of chert pebble conglomerate, sandstone, and carbonaceous paper shales. Carbonaceous shales are particularly distinctive interbeds near the base and top of the Willwood Formation, north and west of the Rhodes Ranch in secs. 19 and 20, T. 44 N., R. 99 W.

The preserved top of the Willwood Formation varies in lithology owing to the superjacent unconformity. In the Owl Creek–Cottonwood Creek area, the boundary usually can be drawn at the top of a medium- to fine-grained quartz arenite that contains a few scattered chert and vein quartz granules and pebbles, but no volcanic material. In the Prospect Creek, Wagonhound Creek, and Grass Creek drainages, this sandstone is absent, and volcanic rocks or shales generally overlie variegated mudstones. Chert granule and pebble conglomerates and quartz arenites occur at the top of the sequence in secs. 14, 15, and 22, T. 45 N., R. 100 W., on the Little Grass Creek–Grass Creek divide.

Pre-Aycross erosion was variable, but on a regional scale the Willwood Formation appears to be uniformly beveled. In areas of low dip, the Aycross appears to lie nearly conformably on the Willwood, as in the NE¼ sec. 20, T. 44 N., R. 99 W.; however, in the drainages of Prospect and Wagonhound Creeks, the contact is clearly an angular unconformity. West of the Rhodes Ranch, in the NE¼ sec. 19, T. 44 N., R. 99 W., Aycross rocks fill shallow swales developed in the top of the Willwood Formation. Here, the maximum erosional relief is about 6–8 m, in marked contrast with the nearly 100 m observed by Pierce and Andrews (1941) on the Fourbear and South Sunshine anticlines, some 25 km to the northwest.

CORRELATION

The Willwood Formation underlies volcanic rocks from the Owl Creek region in this report area northward to the North Fork of Shoshone River. For much of this outcrop, the formation is thin and poorly exposed. The border Willwood has been mapped by several authors (for example, Hewett, 1926; Pierce and Andrews, 1941; Masursky, 1952; Wilson, 1963, 1964a, 1970; Rohrer, 1966a; Pierce, 1941, 1957, 1970, 1978; Pierce and Nelson, 1968, 1969), but the ages of most of these rocks and their stratigraphic positions relative to Willwood rocks in the central Bighorn Basin have not been satisfactorily determined. Jepsen (1939) obtained Willwood mammals from several localities in the Shoshone River area that suggest that most of the Wasatchian (all of early Eocene) is represented there.

A maximum of 100 m of Willwood strata was measured in the drainage of Cottonwood Creek, and Van Houten (1944) and Rohrer (1966a) noted that about 35–75 m and 100 m of Willwood rocks occur, respectively, in the Grass Creek and Adam Weiss Peak areas. Farther north, in the valley of the Greybull River, Pierce and Andrews (1941) computed a thickness of more than 500 m in the NE. part of T. 48 N., R. 104 W., Park County.

These border Willwood exposures generally resemble rocks of the upper part of the Willwood Formation on the Tatman Mountain table and Squaw Buttes divide in the central Bighorn Basin. In the Cottonwood Creek and Wagonhound Creek areas, the variegated mudstones are often sandy, form pillars, and contain small admixtures of tuffaceous material. Pierce and Andrews (1941) recorded about 2.5 m of tuff in the Willwood Formation in the SW¼ sec. 34, T. 47 N., R. 101 W. Willwood mudstones in the Soapy Dale Peak area are dominantly brick red and rust yellow, rather than purple, maroon, green, or gray.

Sandy, probably tuffaceous mudstones also occur rarely in the upper part of the Willwood section in the central Bighorn Basin where facies resembling those of the border Willwood occur at Buck Buttes (sec. 36, T. 48 N., R. 99 W.) and in the upper drainage of the South Fork of Fifteenmile Creek (as in secs. 24, 25, and 26, T. 47 N., R. 97 W.).

Rohrer (1964a, 1964b) mapped a bentonite unit approximately 60 m below the top of the Willwood Formation in the Tatman Mountain and Sheep Mountain areas. Volcanic detritus also occurs in the upper part of the correlative Wind River Formation. (See Sinclair and Granger, 1911.)

Pierce and Andrews (1941) recorded quartzite roundstone conglomerates in the lower part of the Willwood Formation south of Carter Mountain in the Greybull River valley. Long (1957) observed that a quartzite conglomerate forms the base of the Willwood in the Enos Creek area, west of Grass Creek Basin. Similar conglomerates are developed (1) on the divide separating the headwaters of Fifteenmile Creek and the Greybull River, east of Meeteetse (Hewett, 1926; Young, 1971), where they overlap the Lance and Fort Union Formations and intertongue with *Lambdotherium*-bearing Willwood rocks (late early Eocene) and (2) on eastern Blue Mesa, where they conformably overlie Fort Union rocks and underlie *Haplomylus*-bearing mammal faunas (early early Eocene).

Because upper Willwood rocks overlap older rocks to the west in the Meeteetse area and lie on truncated folds along the eastern front of the Absaroka Range, it is probable that the border Willwood of the southwest Bighorn Basin is late early Eocene in age and is in part equivalent with the upper quartzite pebble and cobble-bearing sequence on the headwaters divide east of Meeteetse. This correlation is also suggested by the presence of a small amount of tuffaceous material in fine clastics in upper Willwood rocks of both the border area and the more central Bighorn Basin. The 15-m-thick quartzite conglomerate that forms the base of the 500-m Willwood section in the Greybull River valley (Pierce and Andrews, 1941, p. 136) may be of similar age as the lower quartzite conglomerates on eastern Blue Mesa, though this is uncertain. The lower part of the folded Willwood sequence in this area (secs. 9–15, T. 48 N., R. 104 W.) also resembles middle and upper Willwood rocks developed in the Jim Creek area, west of Cody, Wyo.

Quartzite conglomerates appear to have been a locally common lithologic feature of the basin margin Willwood

Formation (Hewett, 1926; Van Houten, 1944; Young, 1971). Love and Reed (1968) and Lindsey (1972) have demonstrated that the source of the quartzite was probably near or west of Jackson Hole. But vein quartz pebbles and roundstones have not been recorded for any other Willwood conglomerates, though Lindsey (1972, p. 59) did find them in Fort Union exposures near Heart Mountain. Because vein quartz clasts do not occur in the upper Cretaceous Harebell Formation or upper Cretaceous and Paleocene Pinyon Conglomerate of the Jackson Hole–Gros Ventre area, it is probable that these roundstones in the Owl Creek–Grass Creek area were derived from buried crystalline sources in the Washakie Range.

DEPOSITIONAL ENVIRONMENT

The Willwood Formation in the area of this report was deposited on a gently undulating surface of little relief. This surface is encountered at increasing elevations northward, though the formation thickens to the north between Owl Creek and the Greybull River, implying post-Willwood warping of the basin margin. Equivalents of the lower and (or) middle Willwood Formation (as well as the upper parts) are believed to occur in the western parts of the drainages of the Shoshone and Greybull Rivers, but south of Grass Creek only equivalents of the upper part of the formation are present. This overlap and development of sheetlike sandstones and conglomerates lying on beveled pre-Eocene rocks in the Cottonwood Creek and Grass Creek areas and the headwater divide area east of Meeteetse indicates that downwarping of the basin margin east of the report area could no longer keep pace with deposition.

Sandstone stratification types indicate that the Willwood environment was wholly fluviatile in the report area. The development of sheet sandstones is suggestive of the lateral migration and coalescing of point bars, even though a predominance of horizontal stratification indicates upper flow regime velocities possibly related to occasional sheet flooding. Apron-channel and shoestring sandstone geometries (Bown, 1979a) are absent.

Willwood mudstones are flood-plain deposits whose color has been related to incipient soil-forming processes (Neasham and Vondra, 1972; Bown, 1979a). Red coloration and carbonate glaebules in the Willwood mudstones probably resulted from the oxidation of ferrous iron minerals and the stabilization of calcium carbonate in response to intermittent rainfall. Concentration of organic matter in small flood-basin swales or ponds formed carbonaceous shales. Plant and vertebrate remains from the central basin Willwood Formation suggest that these deposits accumulated in a warm temperate to subtropical regime.

POSSIBLE EQUIVALENTS OF THE TATMAN FORMATION

The Tatman Formation was named by Sinclair and Granger (1912, p. 62–63) for approximately 220–280 m of yellow, gray, and green shales and sandstones that lie conformably on the late early Eocene part of the Willwood Formation on Tatman Mountain and Squaw Buttes divide of the south-central Bighorn Basin. More recent and detailed descriptions of Tatman rocks in the type locality were presented by Van Houten (1944) and Rohrer and Smith (1969). Because the middle Eocene Aycross Formation rests upon Willwood rocks in the southeast Absaroka Range, the stratigraphic relations of the Tatman and Aycross Formations are of interest.

Tourtelot (1946) referred about 70 m of shale and sandstone on Lysite Mountain (in the eastern Owl Creek Mountains) to the Tatman Formation, and he observed (1957, p. 18) that these rocks are overlain with apparent conformity by what he believed to be the Tepee Trail Formation. The reference of these rocks to the Tepee Trail has been questioned by Krishtalka and Black (1975) and Berggren, McKenna, Hardenbol, and Obradovich (1978). Van Houten (1944, p. 200) believed that Tatman strata 15–45 m thick were preserved beneath the early basic breccia (Aycross Formation as used here) between Cottonwood and Grass Creeks. Hay (1956, p. 1880), Wilson (1964a, p. 61; 1970), Rohrer (1966a, p. 20–21), and Rohrer and Smith (1969, p. 49) have also mapped or described similar rocks beneath the lowest volcanic rocks in the Little Grass Creek, Wood River, Enos Creek, and Adam Weiss Peak areas, mostly north of this report area.

DISTRIBUTION

Rocks of lacustrine aspect occur as local interbeds in the Aycross Formation of the Owl Creek–Grass Creek area. Because of discontinuous outcrop, these rocks cannot be correlated with Tatman rocks in their type locality, but their stratigraphic position and lithology are suggestive of the Tatman. For the most part, these units are thin, discontinuous, and not mappable at a scale of 1:24,000, and they are, therefore, included in the Aycross Formation.

East of the Rhodes Ranch, on Cottonwood Creek in the SE¼ sec. 17 and NE¼ sec. 20, T. 44 N., R. 99 W., 1 m of kerogenic shale is associated with about 20 m of persistent thin-bedded sandstone, green clay shale, and carbonaceous paper shale. Similar units are less well developed west of the ranch, in the N½ of sec. 19. In both areas, the lacustrine facies appears to contain little volcanic material even though it is enclosed in tuffaceous sandstones and mudstones.

Thicker lacustrine squences (about 60 m) containing abundant tuffaceous detritus occur about 50–70 m above the base of the Aycross Formation in the upper drainages of Wagonhound, Twentyone, and Prospect Creeks. These rocks are best exposed (1) in the SE¼ sec. 35 and SW¼ sec. 36, T. 45 N., R. 100 W., (2) in the SE¼NW¼ sec. 1, T. 44 N., R. 100 W., where they intertongue with the upper badland sequence of the Aycross Formation, and (3) in the S¼ sec. 31, T. 45 N., R. 99 W. These thicker, tuffaceous sequences appear to thin to the west, north, and south, though alluvial cover and faulting have obscured what appears to be a complex intertonguing relationship. Several thin, persistent interbeds of lacustrine aspect found in the lower Aycross Formation in secs. 13, 14, 22–24, T. 44 N., R. 100 W. possibly reflect this intertonguing to the south.

This facies does not occur between the Willwood and Aycross Formations near the head of Little Prospect Creek (SW¼ sec. 17 and NW¼ sec. 20, T. 45 N., R. 99 W.), even though Rohrer (1966a) recorded it at that stratigraphic position near Adam Weiss Peak only 2.5 km to the north. The facies is also not well developed beneath the Aycross in secs. 15 and 16, T. 45 N., R. 100 W., on the Little Grass Creek–Grass Creek divide. However, on the north side of Little Grass Creek in the S½ of sec. 22, about 40–50 m of carbonaceous and kerogenic shales lie on Willwood rocks. This is the only locality in the report area where lacustrine rocks were found directly on top of the Willwood rocks and is only about 1.5 km south of the divide, but the top of Willwood is exposed approximately 120 m topographically lower (pl. 1). Such regional topographic irregularities at the top of the Willwood Formation throughout the report area, involving both fluviatile and lacustrine facies of the Aycross, indicate that the upper Willwood contact is an unconformity.

LITHOLOGY

The composition of the lacustrine facies varies spatially. Nontuffaceous rocks are invariably found near or at the base of the Aycross Formation and tuffaceous rocks are usually developed somewhat higher in the section, although no sections are completely free of volcanic material. The Little Grass Creek locality described above has the best exposures of the lacustrine facies within the report area. About 50 m of green calcareous shale, black carbonaceous ostracodal shale, brown kerogenic paper shale, and thin but persistent yellow and gray sandstones are interbedded with thin volcanic mudstones and sandstone. A limestone coquina of freshwater mollusks about 0.5 m thick occurs in about the middle of this section. The shales contain little or no visible volcanic matter and resemble thinner shale units described previously east of the Rhodes Ranch.

The stratigraphically higher 60 m lacustrine sequence mentioned previously contains conspicuous amounts of volcanic material and is somewhat coarser in mean grain size, and shales are less common than at the Little Grass Creek locality. The 60-m sequence was measured in the E½ sec. 35, T. 45 N., R. 100 W., where it contrasts markedly with mudstone, sandstone, and conglomerate badlands developed in intertonguing rocks of the Aycross Formation (fig. 6) and consists principally of persistent thin-bedded gray, green, aquamarine, and brown volcanic siltstones. Although similar tuffaceous siltstones are interbedded throughout the lower Aycross sequence elsewhere in the area, only on the divide separating Twentyone, Wagonhound, and Prospect Creeks do they make up virtually the whole local section.

CORRELATION

Rohrer (1966a, p. 21) and Rohrer and Smith (1969, p. 51) believed that lacustrine rocks in the Lysite Mountain region probably represent the upper part of the Tatman Formation that is not represented on either Tatman Mountain or the Squaw Buttes divide. This impression was reinforced by a large amount of volcanic material in the Lysite Mountain section that is absent in central basin deposits. Rohrer (1966a) did not record whether or not tuffaceous material was found in the thin sequence of lacustrine rocks in the Adam Weiss Peak area. Rohrer correlated these rocks with the upper part of the Tatman Formation preserved on the Squaw Buttes divide (Rohrer and Smith, 1969, fig. 5, cols. 2 and 4[1]), but it is uncertain how much of the Tatman section originally present in the Squaw Buttes area is preserved. Rohrer and Smith (1969, p. 49) believe that: "The stratigraphic section at Squaw Teats is nearly complete for that part of the formation; however, it is possible that as much as 50 feet of upper strata of the Tatman were removed by the Enos Creek detachment fault." Unless a late early or early middle Eocene age can be demonstrated for this episode of detachment faulting (the diminished probability of this is discussed later), it is equally likely that a few to a few hundred meters of Tatman rocks have been removed by erosion from the top of the column at the Squaw Buttes divide. A substantial erosional episode is also indicated by the presence of tuffaceous lacustrine strata on Lysite Mountain, because the highest Tatman rocks exposed on the Squaw Buttes divide contain little or no volcanic material.

Because lacustrine strata in the report area lie unconformably on Willwood rocks or occur interbedded with Aycross rocks (where they are tuffaceous), it is possible that the lacustrine strata in the southeast Absaroka

[1]Note that labeling for columns 3 and 4 has been reversed for Tatman Mountain and Squaw Teats.

Range, like the rocks on Lysite Mountain, correlate with higher levels of the Tatman Formation that are not preserved on the Squaw Buttes divide. Because of the Willwood–Aycross unconformity, it is not likely that the border Willwood Formation is a basin-margin facies of the Tatman Formation, as suggested by Hay (1956, p. 1887) and by Rohrer and Smith (1969, p. 49). The latter concept requires that border basin Tatman correlative rocks consisted of all the following elements: (1) now-eroded Willwood strata, (2) an unconformity, (3) non-volcanic lacustrine strata, and (4) volcanic lacustrine rocks that intertongue with the fluviatile part of the Aycross Formation.

That the lacustrine rocks on Lysite Mountain are still younger than those in the report area is indicated by the fact that at least 120 m of Aycross strata containing early middle Eocene (Bridgerian) mammals conformably overlie the highest lacustrine rocks in the southeast Absaroka Range. In contrast, so-called Tepee Trail rocks containing Uintan mammals (Black, 1969) conformably overlie the presumed Tatman strata on Lysite Mountain (Tourtelot, 1946, 1957). Figure 3 illustrates a possible restored correlation of early and middle Eocene rocks in the Absaroka–Bighorn Basin–Lysite Mountain areas that deviates somewhat from that offered by Rohrer and Smith (1969, fig. 4).

The few fossil mammals known from the Tatman Formation (p. 63) are not very diagnostic but suggest that the lower 75–140 m of the formation on Tatman Mountain are older than the stratigraphically lowest vertebrate assemblages from the Aycross Formation. On the basis of fossil plants identified by Dorf, Van Houten (1944, p. 195) concluded that the Tatman was a correlative of the early basic breccia near Valley, Wyo. (Wapiti Formation of this report), and of the Aycross near A-cross Ranch, and of the Green River along the Green River in southwest Wyoming. These determinations are not refined enough to assist with precise correlation.

Fossil pollen was obtained from both the lacustrine and fluviatile facies of the Aycross Formation, and one sample was collected from the upper part of the Tatman Formation on the Squaw Buttes divide. D. J. Nichols of the U.S. Geological Survey studied these samples and offered the following comments (written commun., 1978) on their identification and correlation:

USGS Locality D5946: Carbonaceous shale from the upper part of the Tatman Formation, about 650 feet above the top of the Willwood Formation and 250–300 feet below the top of Tatman Formation: NW¼SW¼SW¼NW¼ sec. 22, T. 48 N., R. 98 W., Park County, Wyo.
USGS Locality D5945: Dark-brown, kerogenic shale from lacustrine facies of Aycross Formation; sec. 2, T. 44 N., R. 100 W., Hot Springs County, Wyo.
USGS Locality D5944: Black, kerogenic shale from lacustrine facies of Aycross Formation; NW¼SE¼ sec. 22, T. 45 N., R. 100 W., Hot Springs County, Wyo.
USGS Locality D5854: Weathered, medium-dark, gray-brown shale from upper part of Aycross Formation; SW¼NW¼SW¼NE¼NW¼ sec. 5, T. 43 N., R. 101 W., Hot Springs County, Wyo.
USGS Locality D5855: Weathered, medium-brown shale with plant fragments from the basal Aycross Formation, about 10 m above lower contact with Willwood Formation; SE¼NE¼SW¼SW¼ sec. 19, T. 44 N., R. 99 W., Hot Springs County, Wyo.
USGS Locality D5856: Medium-dark-gray mudstone from the basal Aycross Formation, 12 m above lower contact with Willwood Formation: SE¼NW¼NE¼NW¼ sec. 32, T. 45 N., R. 99 W., Hot Springs County, Wyo.
Two problems * * * make it difficult to give precise age and correlation information for these samples. One is that very little is known * * * about Eocene spore and pollen taxonomy and biostratigraphy in this part of the world. * * * The second * * * is a small number of samples. * * * The conclusions must be regarded as preliminary at best, pending further work on Eocene palynomorphs. Only two species of known biostratigraphic importance turned up in the assemblages from these samples: *Platycarya platycaryoides* and *Pistillipollenites mcgregorii*. Both species are known from the lower and middle Eocene in the Rockies. In these samples *Platycarya platycaryoides* occurred only in sample [D5946] and *Pistillipollenites mcgregorii* occurred only in samples [D5856 and D5854] (it is the dominant palynomorph in the latter sample) * * * both species occur in the Wind River flora (late early Eocene), only *P. mcgregorii* occurs in the Aycross (Kisinger Lakes) flora (early middle Eocene), and neither is known from the Green River flora (late middle Eocene). These relative ages agree with the general stratigraphic relations of the samples. On this basis maximum and minimum ages for some of the samples would seem to be as follows:

No.	Formation	Maximum age	Minimum age
D5946	Tatman	early Eocene	late early Eocene
D5856	basal Aycross	early Eocene	early middle Eocene
D5854	upper Aycross	early Eocene	early middle Eocene

The locality data and general stratigraphic relations indicated for these samples suggest that sample [D5855] is about the same age as sample [D5856] but it lacks the species mentioned above, which emphasizes the hazards of regarding these age determinations as firm. * * * I compared the assemblages with each other and with those of the Wind River, Kisinger Lakes, and Green River floras * * *. Three observations can be made from these data. First, while the assemblages from these samples show similarities, up to 50 percent of each assemblage is unlike that of any of the other samples. Second, all samples show closer affinity with the early middle Eocene Kisinger Lakes flora than any other known at present. Third, all samples show closer affinity with the late early Eocene Wind River flora than they do with the late middle Eocene Green River flora.

An occurrence list of specific pollen taxa is presented in table 2.

Fossil ostracodes and freshwater mollusks were also obtained from a locality (D-1291NM) near pollen locality D5944. The ostracodes indicate a Green River (latest early to middle Eocene) age and are similar to *Candona whitei* reported from the Green River Formation of the Uinta and Piceance Creek basins (R. M. Forester, written commun., 1978). Though the mollusks

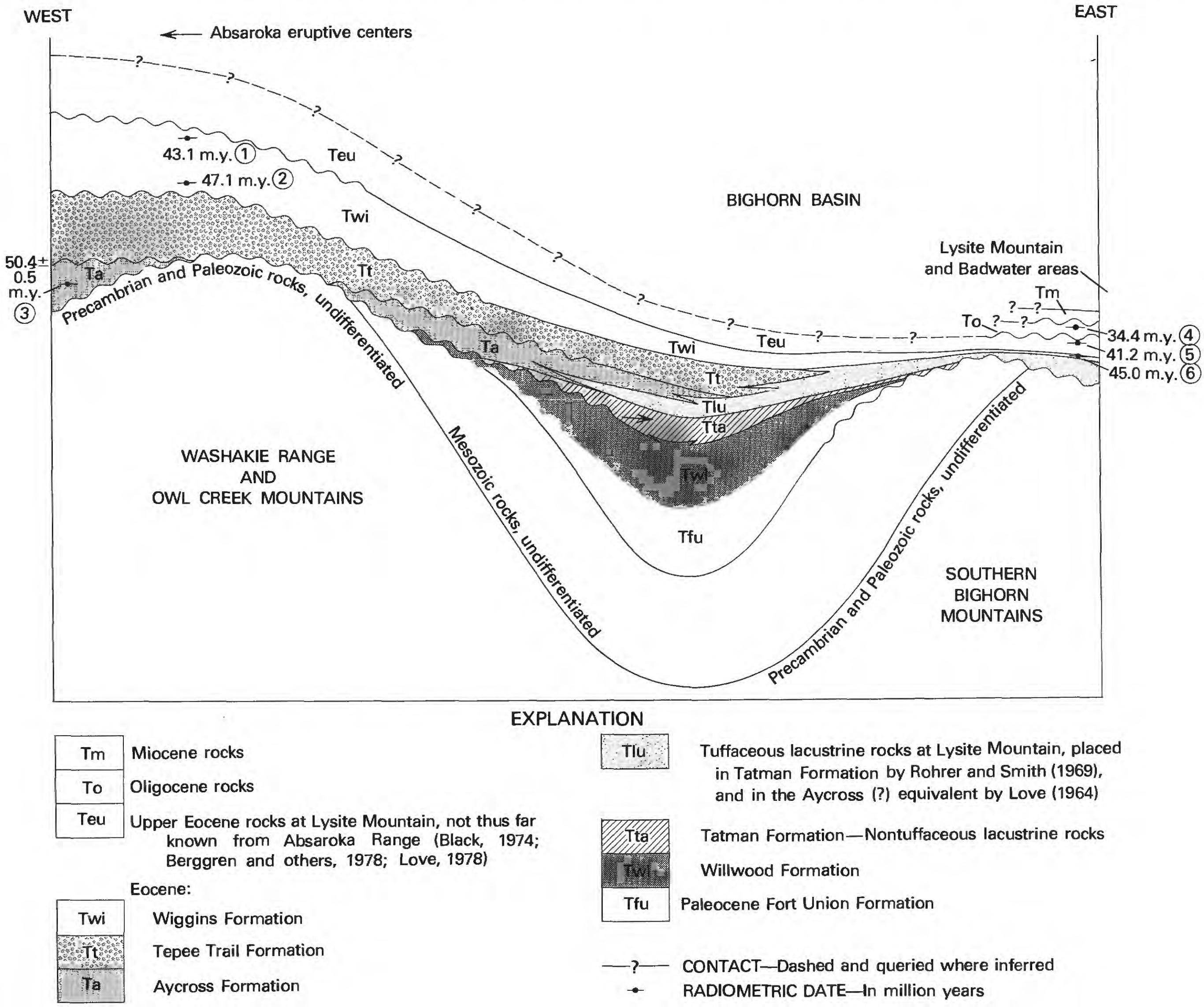


FIGURE 3.—Diagrammatic cross section of southern Bighorn Basin showing hypothetical restored stratigraphic relations of Eocene rocks shortly after the end of Wiggins deposition in the late middle or late Eocene. Younger units on Lysite Mountain and in the Badwater area are also depicted for reference. Arrow within Tatman Formation denotes position of top of preserved Tatman rocks on the Squaw Buttes divide. Length of cross section approximately 170 km. Circle numbers refer to sources of radiometric dates: (1) Love and Keefer (1975, p. 37); (2) J. D. Obradovich, in Smedes and Prostka (1972, p. 32); (3) Love, McKenna, and Dawson (1976, p. 17), age of 49.2 m.y. revised by J. D. Obradovich (oral commun., 1979); (4) Black (1969, p. 45); (5) Black (1974, p. 151); (6) Evernden, Savage, Curtis, and James (1964, p. 184)—at Beaver Divide.

are poorly preserved, J. H. Hanley (written commun., 1978) has tentatively identified the following taxa:

Bivalves:	Unionidae: Gen. and sp. indet.
Gastropods:	*Viviparus* cf. *V. meeki* Wenz
	Viviparus sp. indet.
	Goniobasis sp. indet.

The specimens are too poorly preserved to permit identification to the species level. * * * I cannot suggest a maximum or minimum age for the fauna. The fauna (unionid bivalves, *Viviparus*, and *Goniobasis*) is identical to that of the *Goniobasis-Viviparus* mollusk association of Hanley (1976). This association dominates the nearshore lacustrine environment in the Green River Formation (early-middle Eocene) in southwestern Wyoming.

DEPOSITIONAL ENVIRONMENT

Lacustrine rocks were deposited on a surface of little relief in the southern part of the report area, and of moderate relief in the northern part. The erosional surface suggests that Willwood rocks were being eroded in

TABLE 2.—*Occurrence list for pollen taxa from the Tatman Formation (D5946) and Aycross Formation (other samples)*

[Identified by D. J. Nichols, U.S. Geological Survey, Denver, Colo.]

Taxon	Sample No.					
	D5946	D5945	D5944	D5855	D5856	D5854
Ulmipollenites sp.	X	--	X	X	X	--
Pandaniidites sp.	X	--	X	--	--	--
cf. *Momipites* spp.	X	X	X	X	--	--
Caryapollenites veripites	X	--	--	X	X	--
C. inelegans	X	--	--	X	--	--
Tricolpites sp.	X	--	X	--	X	--
Cyathidites minor	X	X	X	X	--	--
Bisaccate pollen	X	--	X	X	X	--
Momipites sp.	X	--	--	--	--	--
Liliacidites? sp.	X	--	--	--	--	--
Alnipollenites sp.	X	--	--	--	--	--
Pediastrum paleogeneites	X	--	--	--	--	--
Platycarya platycaryoides	X	--	--	--	--	--
Polypodiidites sp.	--	X	--	--	--	--
cf. *Araucariacites* sp.	--	X	--	--	--	--
Rhoipites sp. B	--	--	X	--	--	--
cf. *Alnipollenites* sp.	--	--	X	--	--	--
Laevigatosporites sp.	--	--	--	X	X	--
Arecipites sp. A	--	--	--	X	X	--
Triporopollenites spp.	--	--	--	X	X	X
Taxodiaceaepollenites hiatus	--	--	--	X	--	--
Striopollenites sp.	--	--	--	X	--	--
Momipites coryloides	--	--	--	--	X	--
M. cf. *M. triradiatus*	--	--	--	--	X	--
Nyssapollenites spp.	--	--	--	--	X	--
Rhoipites sp. A	--	--	--	--	X	--
Caryapollenites sp.	--	--	--	--	X	--
Pistillipollenites mcgregorii	--	--	--	--	X	X
Osmundacidites sp.	--	--	--	--	--	X
Psilastephanocolpites sp.	--	--	--	--	--	X
Arecipites sp. B	--	--	--	--	--	X
Tetracolporopollenites sp.	--	--	--	--	--	X
Brevcolporites sp.	--	--	--	--	--	X

the report area during the time of deposition of the Tatman Formation in the central Bighorn Basin, because lowered stream base levels in the report area accompanied the depression of the lake basin formed to the east. At a later time, intermittent depression of the border area or more rapid sedimentation in the central basin may have allowed lacustrine rocks to overlap the eroded Willwood Formation and intertongue with their fluviatile equivalents, the Aycross Formation.

Van Houten (1944, p. 198–199) believed that most of the central basin Tatman Formation originated in the "widespread environment of a forest swamp and in the open waters of a shallow lake." The thick exposures of shale and tuffaceous siltstone that comprise the border belt lacustrine facies resemble persistent sandstones and siltstones in the shore facies of the Green River Formation that were described by Bradley (1926). The freshwater mollusks and ostracodes from locality D-1291NM indicate a more lacustrine than fluviatile regime for rocks at this locality. R. M. Forester (written commun., 1978) observed that the ostracode:

> *Candona whitei* is a species that probably indicates freshwater to somewhat saline paleoenvironments. Its possible salinity tolerances are not known, but could extend to hypersaline conditions if its occurrences, abundance and diversity relationships can be compared to modern analogs. It, along with most ostracodes, should indicate high pH conditions of 7 to 10 or higher. This pH is often correlative with a moderate amount of dissolved carbonates. *Candona whitei* probably lived on the margins of large lacustrine systems and or in nearby fluvial systems. No other paleoenvironmental information is available for this species. However, the occurrence of numerous instars does suggest the presence of very low depositional energy environment.

J. H. Hanley (written commun., 1978) concluded that the mollusks also lived in a littoral (nearshore) environment. He based this interpretation on three factors:

> 1. Similarity of the composition of the assemblage to that of the *Goniobasis-Viviparus* association of Hanley (1976) * * * . In the Green River Formation, this faunal association is an excellent and consistent indicator of nearshore lacustrine habitat * * * . 2. The biofabric of the matrix * * * abundant mollusk shell fragments that probably originated by physical abrasion of shells in the original environment. The biofabric is typical of shoreline accumulations of mollusks in the Green River Formation * * * wave action was the dominant factor in concentration of the mollusk shell fragments. 3. The lithostratigraphic setting. Your sample comes from a laterally persistent, ledge-forming unit that overlies shale * * * rich in organic matter. * * * This * * * setting is similar to that observed by me in the Green River Formation. I have interpreted this rock package as reflecting shallowing (regression?) of a lake with shoreline littoral deposits overlying offshore (sublittoral) lacustrine shales * * *.

AYCROSS FORMATION

The Aycross Formation was named by Love (1939, p. 66) for approximately 1,000 ft (≈300 m) of volcanic roundstone conglomerates, andesite tuffs, volcanic clays, shales, and sandstones exposed in the North Mesa (type area) and Coulee Mesa areas of the northwest Wind River Basin. Aycross equivalents in the Wind River Basin probably include part of the "Eocene rocks, undifferentiated" of Keefer (1957), and part of the "upper volcaniclastic unit" of Rohrer (in MacGinitie and others, 1974), in the Sheridan Pass–Fish Lake–Kisinger Lakes area. Virtually all the lower volcaniclastic sequence in the southeast Absaroka Range, between the Willwood and Tepee Trail Formations, is here referred to the Aycross Formation, following the usage of Masursky (1952), and the term Aycross includes most (but not all) rocks assigned by earlier workers to Hay's (1956) Pitchfork Formation.

DISTRIBUTION

The Aycross Formation unconformably overlies the lower Eocene Willwood Formation from Cottonwood Creek to the Carter Mountain area, north of the valley of the Greybull River (fig. 1). In the Owl Creek area, the Aycross fills deep strike valleys incised in Paleozoic and lower Mesozoic rocks (pl. 1). On the north side of Carter Mountain and in the valley of South Fork Shoshone River, Aycross lithologies intertongue with the lower part of the Wapiti Formation of Nelson and Pierce (1968). In the Shoshone River drainage these rocks are breccia and lava rich (Wapiti Formation; see Nelson and Pierce, 1968); whereas, those on the south flank of Carter Mountain (north side of the Greybull River) are breccia and lava poor (Aycross Formation: see descriptions of "Pitchfork" units in this area by Dunrud, 1962; Wilson, 1963, 1964a). Sections on the north side of Carter Mountain indicate that the lowest volcanic rocks in that area belong to the Wapiti Formation (Nelson and Pierce, 1968), but Aycross lithologies occur in the Foster Reservoir area (W½ sec. 24, T. 50 N., R. 103 W.) and are recorded by J. D. Love (unpub. data, 1979) in the Rawhide Creek–Rose Creek area, north of the Greybull River and on the south side of Carter Mountain. The lateral boundary of the Aycross and Wapiti Formations is, therefore, tentatively placed north of Foster Reservoir on the north side of Carter Mountain. Mapping by this writer indicates that rocks mapped in the Greybull River–Wood River area as the "Pitchfork" Formation by both Dunrud (1962) and Wilson (1963, 1964a) include both Aycross and Tepee Trail strata that are separated by an unconformity.

The best exposures of the Aycross Formation in the Bighorn Basin occur in the report area, where complete sections are developed in the drainages of Cottonwood and Twentyone Creeks (pl. 1). An incomplete but well-exposed Aycross section (base is not exposed) is preserved along the North Fork of Owl Creek, and good exposures also exist in the drainages of Prospect and Wagonhound Creeks, and in Dugout Draw.

Approximately 290 m of the Aycross Formation was measured along Cottonwood Creek; apparently the formation thins somewhat to the north.

LITHOLOGY

As observed by Love (1939, p. 66–67) for the type area of the Aycross: "The physical appearance of the Aycross Formation changes so rapidly in a short distance that even a general description at the type area on North Mesa does not apply 4 miles to the south on Coulee Mesa, or 4 miles farther north, on Alkali Creek."

Rapid facies changes are also typical of Aycross strata in the southeast Absaroka Range. In decreasing order of importance, volcanic mudstones, volcanic sandstones, volcanic pebble and roundstone conglomerates, shale, arkose, tuff, and breccia are present. Flows and intrusive bodies are unknown in Aycross rocks of the report area (in contrast to Masursky, 1952). The terminology follow that of Williams, Turner, and Gilbert (1954) for volcaniclastic rocks.

Aycross rocks are roughly divisible into five successive units in the Cottonwood Creek and Twentyone Creek sections, though considerable intergradation exists and these unmappable units are not everywhere recognizable. A lower sequence, composed principally of about 30 m of volcanic mudstone, fine-grained volcanic sandstone (tuffaceous sandstone of Hay, 1952), tuff, shale, and chert-pebble and vein-quartz roundstone conglomerate, is exposed at the south margin of Putney Flat, and east and west of the Rhodes Ranch, on Cottonwood Creek. The chert-pebble and vein-quartz roundstone conglomerates are best developed in the W½ sec. 1, T. 43 N., R. 100 W., and the volcanic mudstones and fine-grained volcanic sandstones form badlands in the center of sec. 35, T. 44 N., R. 100 W. Carbonaceous and kerogenic shales occur interbedded with the volcanic mudstones and sandstones in secs. 17–20, T. 44 N., R. 99 W., and a resistant arkose is exposed on the margins of a small anticline in secs. 34 and 35, T. 44 N., R. 100 W.

In the drainages of Cottonwood and Twentyone Creeks and of Dugout Draw, approximately 60 m of fine-grained volcanic sandstone, siltstone, and tuff overlie the lower sequence. These rocks commonly form strike valleys between more resistant beds and are consequently not very well exposed, but they are best seen in secs. 13, 14, 23, and 24, T. 44 N., R. 100 W., and sec. 18, T. 44 N., R. 99 W. The siltstones are commonly brown or gray; the sandstones are yellow, green, or gray. Strongly indurated, bright-green- and turquoise-colored siltstones locally form good markers.

The middle part of the formation is a conspicuous badland sequence about 80 m thick capped by coarse volcanic sandstones that form resistant hogbacks in secs. 13, 14, 15, 22, and 23, T. 44 N., R. 100 W. This sequence is dominantly bentonitic mudstone, volcanic sandstone, and conglomerate. The mudstones are generally light gray or buff, but rare olive-green, aquamarine, and red beds do occur. Similar beds are exposed in the middle of the local Aycross sections along the North Fork of Owl Creek (N½ sec. 7, NW¼ sec. 8, and SW¼ sec. 5, T. 43 N., R. 100 W., and S½ sec. 1 and N½ sec. 12, T. 43 N., R. 101 W.).

FIGURE 4.—Light-colored volcanic mudstones and darker, more resistant volcanic sandstones and conglomerates in the upper badland sequence of the Aycross Formation, SW¼ NW¼ sec.1, T. 44 N., R. 100 W. View to northwest.

Overlying the middle badland unit is a tongue of volcanic lacustrine rocks (see prevous discussion), composed of about 60 m of variegated siltstone, shale, and fine-grained volcanic sandstone. The top of the Aycross Formation, everywhere that this level is exposed in the drainages of Cottonwood and Twentyone Creeks and Dugout Draw, is a third badland sequence: about 70 m of bentonitic mudstone, volcanic conglomerate, and volcanic sandstone (figs. 4–6). This is easily recognized in four areas: (1) on the Dugout Draw–Wagonhound Creek divide in the center of the W½ sec. 6, T. 44 N., R. 99 W., (2) on the tripartite divide between Twentyone, Prospect, and Wagonhound Creeks in the N½ sec. 1, T. 44 N., R. 100 W. (fig. 4), (3) on the Cottonwood Creek–Twentyone Creek divide, in the S½ sec. 9 and N½ sec. 16, T. 44 N., R. 100 W., and (4) on Ota Creek and north of Dvarishkis Hunting Camp in secs. 5–8, T. 44 N., R. 100 W.

The upper unit may be equivalent to the badland sequence in the upper part of the Aycross Formation on the North Fork of Owl Creek (in, for example, secs. 34 and 35, T. 44 N., R. 101 W., and secs. 5 and 6, T. 43 N., R. 101 W.), but this is uncertain. In that area, the upper badland sequence is overlain by about 80 m of coarse volcanic sandstones, volcanic pebble and granule conglomerates, bentonitic mudstones, and tuff, which may be a younger unit not represnted in more basinward areas.

The Aycross sandstones and mudstones vary considerably in the amounts of contained tuffaceous material, but most of these units are at least partly volcaniclastic. Hay (1956) observed that most of the volcaniclastic debris in the Cottonwood Creek area was derived from dacitic rocks; whereas, this study suggests that andesitic debris is also present and that pumicite and lapilli tuff clasts are locally important. A white lapilli tuff containing euhedral biotite fills shallow swales in an interbedded sequence of shale, arkosic sandstone, and volcanic siltstone in the center of the NE¼ sec. 34, T. 44 N., R. 100 W. White pumicite tuff is also a common matrix constituent in some of the sandstones (for example, in the upper badland sequence in the center of the S½NW¼ sec. 6, T. 44 N., R. 99 W.).

Without detailed petrographic analysis, Aycross sandstones appear to consist principally of lithic and feldspathic quartz arenites, volcanic wackes, and lithic subarkoses; the lithic component is clastic material derived from extrusive igneous rocks. Several sandstones, for example, an exposure at Vass quarry (SE¼ sec. 33, T. 44 N., R. 100 W.), appear to be composed almost exclusively of fine-grained tuff with a few grains of detrital quartz. Nonvolcanic material is primarily detrital quartz (in sandstones and siltstones), feldspar (as arkose), and quartzite, chert, and vein quartz (both sandstones and conglomerates). Most sandstones are cemented by a fine clastic fraction or calcium carbonate. Brown, yellow, and gold oxyhydrates of iron are important cementing materials in certain sandstones that are associated with thick sequences of carbonaceous mudstone and shale.

Bed geometries in the Aycross vary from thin, tabular units (shales, many siltstones, and fine-grained volcanic sandstones) to conspicuous lenses (many of the conglomerates and coarser sandstones). Tabular varieties are similar to the multistory sheet sandstones of the Willwood Formation (Bown, 1979a; Kraus, 1980) but are generally thinner. Shoestring and apron-channel sandstones (Bown, 1979a) were not seen.

No massive conglomerates occur in the Aycross Formation of the report area; however, several lenticular beds of andesite roundstone conglomerate (as thick as 10 m) are present in the middle and upper badland sequences (fig. 5). Other conglomerates contain pebbles and cobbles of limestone, volcanic sandstone, and quartzite—though andesite, flow breccia, vesicular and amygdaloidal basalt, pyroxene basalt, and dacite cobbles dominate. The conglomerates have a lithic matrix of volcanic-derived sand and silt particles, and cementation is calcite or yellow, green, or blue iron minerals.

Hay (1956, p. 1869) observed that: "* * * pebbles are generally no larger than peas in the Cottonwood Creek area." Pebble and cobble conglomerates are locally common in the Aycross Formation, and I have found no field evidence that corroborates Hay's impression that the Pitchfork Formation becomes finer grained southward through the Cottonwood Creek and Grass Creek areas. It is possible that this observation was made because he included some Tepee Trail rocks in his original concept of the Pitchfork Formation. Moreover, exposures are better

FIGURE 6.—Upper lacustrine (Tacl) and upper badland (Tacb) units of the Aycross Formation as exposed on east side of West Fork of Twentyone Creek, SE¼ sec. 35, T. 45 N., R. 100 W. and NE¼ sec. 2, T. 44 N., R 100 W. View to northwest.

FIGURE 5.—Andesite pebble and roundstone conglomerate beds in upper badland sequence of Aycross Formation exposed on Cottonwood Creek, center of SW¼NW¼NE¼ sec. 7, T. 44 N., R. 100 W. Hammer gives scale. View to north. Except in a few areas where massive conglomerate channels are developed, pebbles and cobbles generally occur as bands in thick sandstone units, as shown here. Primary soft sediment convolute bedding in sandstone at top of foreground exposure is typical of Aycross sandstones.

in the report area than they are farther north where the section is steep and where slumping of the badland units and overgrowths of vegetation have left few but the more resistant (and coarser) units exposed.

Aycross mudstones are lenticular and consist principally of blocky, structureless silt, but they locally contain significant admixtures of clay and sand. The degree of absorption of water and expansion of the mudstones when wet indicates that they contain some quantity of mixed-layer clay minerals. In the report area, the mudstones are typically somber shades of gray, brown, and green, but aquamarine, turquoise, pink, and red beds do occur in the badland sequences. The origin of these colored bands is uncertain, but it is probable that they are related to the oxidation states of contained iron minerals, as is the case in the underlying Willwood Formation. (See Van Houten, 1948; Bown, 1979a.) Ketner, Keefer, Fisher, Smith, and Raabe (1966) attributed some of the blue-green color in the Pitchfork and Tepee Trail rocks to unoxidized iron compounds, but Rohrer (1966a, p. 23) believed it was due to celadonite, and Keefer (1957, p. 194) suggested the coloring agent was chlorite. Keller (1953) has observed that the green color in certain mudstones of the Morrison Formation is due to the presence of montmorillonites—common clay constituents of both the Aycross Formation and Tatman Formation.

In both its type area and in the study area, the Aycross Formation is dominated by mudstones, although these beds form proportionally less of the Cottonwood Creek–Twentyone Creek sections. Mudstones in the type area of the Aycross are also more brilliantly variegated and contain a larger number and greater thickness of red and purple beds. Keefer (1957, p. 193) used this criterion to include all post-Wind River and pre-Wiggins strata in the Tepee Trail Formation, though he observed that the lower part of his Tepee Trail contains biotite- and hornblende-rich rocks similar to those in the type Aycross.

Within the report area, Aycross mudstones are typically somber shades of gray, brown, and green; but aquamarine, turquoise, pink, and red beds do occur. Red, purple, and green mudstones like those in the type area occur only in the center of a small anticline on the south fork of the North Fork of Owl Creek, along the join between T. 43 N. and 44 N., R. 101 W.

The vetch *Astragalus bisulcatus* growing on bedrock soils and alluvium indicates the presence of selenium in the lower part of the Aycross Formation (Beath and others, 1946). The vetch is essentially limited to those rocks and can be useful as a mapping aid. It is particularly abundant in the drainages of Wagonhound Creek and Dugout Draw.

CORRELATION

Aycross rocks in the report area more closely resemble Aycross exposures on Coulee Mesa and at Tipperary (Love, 1939) than they do those in the type area on North Mesa. The resemblances include the less strikingly variegated mudstones, nonvolcanic roundstone conglomerates and carbonaceous shales near the base of the section, and the presence of thin but persistent tuffaceous sandstones. Virtually every lithology encountered in the type area of the Aycross Formation and in the Bitterroot Ranch area has an equivalent in Aycross rocks of the Owl Creek–Grass Creek area.

Characters other than lithology also strongly indicate equivalence of the Aycross depositional regime in the two areas. Both sequences contain conglomerates with some pebble and roundstone clasts that are not locally derived, and both contain a high proportion of both andesitic and dacitic debris. The Aycross in both areas lies unconformably on all older rocks, generally on a surface of considerable relief. Everywhere the contact with lower Eocene rocks (the next oldest preserved rocks) is unconformable. In most sections, significant amounts of carbonaceous shale exist near the base. In both areas, the top of the Aycross section is marked either by a disconformity or by an angular unconformity and is overlain by the Tepee Trail Formation. Both Aycross sequences are of middle Eocene age (see p. 59–61), although fossil evidence suggests that parts of the Aycross type area are younger than any fossil-dated Aycross rocks in the report area. It is fairly certain that Aycross and Wapiti rocks intertongue on the north side of Carter Mountain.

Large collections of vertebrate fossils from the Aycross Formation in the report area demonstrate conclusively that these rocks are middle Eocene in age, and the bulk of the fauna indicates it is correlative with the early part of the middle Eocene (Bridgerian, "A" and "B"). (See p. 60.) These mammals are similar to but not positively correlated with fossils from low in the Wapiti Formation in the Aldrich Creek and Ishawooa Hills areas of the South Fork of Shoshone River (Jepsen, 1939; Jepsen, in Van Houten, 1944).

J. Howard Hutchison (UCMP) has identified fragmentary remains of fossil turtles from the Aycross of the report area (written commun., 1977). His identifications are given in table 2. Regarding their age, he commented: "* * * I would estimate that the age is Bridgerian * * * because of * * * the presence of a large *wyomingensis*-like *Baptemys* and *septaria*-like *Echmatemys* * * *."

Fossil freshwater mollusks were recovered from four localities in the Aycross Formation. The fossils from two of these were studied by John H. Hanley of the U.S. Geological Survey who identified the following taxa:

USGS Cenozoic locality D1245NM, SE¼NE¼ sec. 17, T. 43 N., R. 100 W., Hot Springs County, Wyo.

Bivalvia: Gen. et sp. indet.
Biomphalaria aequalis (White)
Goniobasis tenera (Hall)
Lymnaea (Stagnicola) similis Meek

USGS Cenozoic locality D1246NM, SE¼NE¼ sec. 17, T. 43 N., R. 100 W., Hot Springs County, Wyo.

Goniobasis tenera (Hall)
cf. *Goniobasis terera* (Hall)
Viviparus sp. indet.

Regarding their correlation, Hanley observed (written commun., 1978):

> The presence of *Lymnaea similis* indicates your sample is not older than middle Eocene (Bridgerian equivalent). I cannot specify a minimum age for the sample because the upper stratigraphic range of *Biomphalaria aequalis* and *Goniobasis tenera* is incompletely known * * * in Wyoming. I am not aware that either species has been reported from rocks of Oligocene age. I support inclusion of Taylor's (1975) specimens of *Lymnaea (Stagnicola)* aff. *L. similis* within our morphologic concept of *L. similis*. Therefore, the stratigraphic distribution of your species is as follows: 1. Laney Member of the Green River Formation; middle Eocene (Bridgerian equivalent) (Hanley, 1974), 2. Tepee Trail Formation; upper Eocene; Wind River Basin, 3. Wagon Bed Formation; upper Eocene; Beaver Divide area, central Wyoming, 4. Beaver Divide Conglomerate Member of the White River Formation; lower Oligocene; Beaver Divide area, central Wyoming. The critical aspect of this distributional data is that *L. similis* is not known from rocks older than middle Eocene * * *.

Norman Frederiksen of the U.S. Geological Survey has summarized incomplete studies of palynomorphs from six Aycross localities as follows (written commun., 1978):

> * * * most of the species were definitely, or probably, found by Leopold (in MacGinitie and others, 1974) in the Kisinger "A" flora of what she called the Aycross Formation in Fremont County * * * your samples could not be too much different in age from Leopold's.

Several tuff samples submitted for dating were unsatisfactory, but Love, McKenna, and Dawson (1976, p. 17) obtained a K-Ar date of 49.2±0.5 m.y. for Aycross rocks exposed at Duncan Ranch, near the type area. J. D. Obradovich (oral commun., 1979) has since recalibrated this age to 50.4±0.5 m.y.

DEPOSITIONAL ENVIRONMENT

Aycross rocks in the southeast Absaroka Range were deposited in a combination of fluviatile, palustrine, and border lacustrine environments. Earliest Aycross rocks were deposited on a surface of moderate to considerable relief, but in the upper part of the formation, in areas more removed from upturned Paleozoic strata, this surface became essentially featureless even though it almost certainly was inclined to the east, away from depositional centers. The presence of lenticular mudstones, conglomerates, and sandstones in sequences segregated from thinner, more persistent fine-grained sandstones, siltstones, and shales is suggestive of the alternating fluviatile and lake margin environments in the Green River Formation.

Sandstones represent channel and near-channel deposits, and conglomerates accumulated on bars or as channel lags. Mudstones developed as a result of overbank deposition of fine clastic material, and carbonaceous mudstones probably reflect the accumulation of organic matter with fine clastic sediment in floodbasin swales or ponds. Laterally persistent shales strongly suggest local and temporally sporadic incursions of a lake. On the basis of freshwater mollusks found in limestone nodules in a mudstone, carbonaceous mudstone, and shale sequence (USGS Cenozoic loc. D1245NM), J. H. Hanley has observed (written commun., 1978) that these animals

> * * * probably inhabited a seasonally permanent, shallow, freshwater lake or pond * * *. The few bivalves indicate the presence of some current in the habitat to provide nutrients in suspension for these filter feeders, *i.e.* the environment was not stagnant * * *. *Biomphalaria aequalis* is abundant in pond and quiet, shallow, nearshore (littoral) lacustrine habitats in the Wasatch and Green River formations in southwestern Wyoming.

Conglomeratic material was derived principally from igneous rocks, including lava flows and lahars, that were accumulating to the west and northwest, nearer eruptive centers. Vein quartz and quartzite roundstones have no nearby source areas and were probably derived from the Washakie Range and Teton area, respectively. Detrital quartz and feldspar probably also had sources in the buried Washakie Range, on account of the paucity of exposed crystalline rocks in the western Owl Creek Mountains in middle Eocene time (in contrast to Hay, 1956, p. 1882).

Middle Eocene floras from Aycross equivalents in the Wind River Basin indicate that the climate was warm temperate to subtropical (MacGinitie and others, 1974). Dorf (in Van Houten, 1952) believed that the early Eocene flora of the Willwood Formation was a lowland one, comparable to the Wilcox flora of the Gulf Coast area. No structural evidence exists to suggest that the southeastern Absaroka region was substantially uplifted following early Eocene deposition, and MacGinitie and others (1974) suggested that the Kisinger Lake area is 4,000–8,000 ft (1,220–2,440 m) higher in elevation now than in the middle Eocene.

TEPEE TRAIL FORMATION

The name Tepee Trail Formation was applied by Love (1939, p. 73) for about 500–600 m of conglomerate, sandstone, mudstone, shale, tuff, thin lava flows, and flow breccias that unconformably overlie the Aycross Formation and older rocks in the northwest Wind River Basin. Throughout the south Absaroka Range, the Tepee Trail Formation generally is unconformably overlain by the Wiggins Formation (Love, 1939); however, other authors have suggested that this contact is gradational (Ketner and Fisher, 1978), or intertonguing (Rohrer and Obradovich, 1969) in some areas.

Keefer (1957) and Rohrer (1966b; and in MacGinitie and others, 1974) have recognized Tepee Trail equivalents in the Du Noir, Sheridan Pass, Fish Lake, Kisinger Lakes, and Togwotee areas of the marginal northwest Wind River Basin, and Tourtelot (1946, 1957) questionably referred rocks along the southern Owl Creek Mountains and at Lysite Mountain to the Tepee Trail. Masursky (1952) traced Tepee Trail strata over the western Owl Creek Mountains and into the report area, supplanting Hague's (in Hague and others, 1899) terms early basic breccia (in part) and late basic breccia (in part) that had been applied to these rocks by Rouse (1937).

DISTRIBUTION

Throughout the report area, Tepee Trail rocks unconformably overlie the Aycross Formation, except in the western Owl Creek Mountains along the South Fork of Owl Creek where they overlie the Devonian Darby Formation and the Mississippian Madison Limestone. The unconformable contact is normally sharply angular, but where underlying Aycross strata are flat lying it is simply erosional. The angular unconformity is best developed in the drainage of the south fork of the North Fork of Owl Creek. Erosional contacts are well developed on the Cottonwood Creek–Grass Creek divide (for example, in secs. 31–34, T. 45 N., R. 100 W., and secs. 3–6, 8, and 9, T. 44 N., R. 100 W.) and on the highest part of the divide separating Twentyone and Wagonhound Creeks (W¼ sec. 6, T. 44 N., R. 99 W., and E½ sec. 1, T. 44 N., R. 100 W.).

Tepee Trail rocks were traced as far north as Noon Point in sec. 24, T. 46 N., R. 102 W. (fig. 7), and the south side of Carter Mountain, and as far west as the mouth of Warhouse Creek (center of sec. 30, T. 48 N., R. 104 W.; fig. 8). Some of the rocks in Soapy Dale Peak Quadrangle assigned by Wilson (1970) to the Wiggins Formation are here assigned to the Tepee Trail.

LITHOLOGY

A maximum of 425 m of Tepee Trail strata occurs in the report area, and the formation appears to thicken to the west. Tepee Trail rocks were not examined in detail except near the base. The Tepee Trail is extremely heterogeneous in lithology; sections vary considerably from place to place. Tuff and volcanic sandstone are the dominant constituents, but volcanic conglomerates, thin hornblende-biotite andesite flows, flow breccias, shales, and volcanic siltstones make up much of the section locally. Mudstones occur rarely in the lower part of the formation in some areas.

In the South Fork of Owl Creek drainage, the lower part of the Tepee Trail Formation consists largely of light-colored tuff, fine-grained volcanic sandstone, and volcanic siltstone in steep, rounded hills with few ledge-forming beds. The exposures resemble those northeast of Sugar Loaf Mountain, in the drainage of South Fork of Cottonwood Creek, but they contrast significantly with lower Tepee Trail strata elsewhere. In the upper part of the formation farther west on Rock Creek, conglomerates, breccias, thin andesite and basalt flows, coarse sandstones, and tuff are exposed.

In an intervening area on Meadow Creek (S½ sec. 21, T. 44 N., R. 101 W.), a distinctive badland area, called The Holy City, is developed in the lower part of the Tepee Trail. Here, the lithology is principally volcanic mudstone, conglomeratic mudstone, coarse volcanic sandstone, volcanic siltstone, and volcanic conglomerate. (See also Sundell, 1980.)

In other places in the report area, only the lower part of the Tepee Trail section is preserved, and it consists mostly of volcanic conglomerates, tuff, and volcanic sandstone. In contrast to the South Fork of Owl Creek section, other sections in the report area resemble the type Tepee Trail section in that they form somber cliffs of alternating green, gray, and brown coarse- and fine-grained rocks (fig. 7).

CORRELATION

Both Aycross and Tepee Trail strata have, in some areas, been included together in the Pitchfork Formation of Hay (1956), and rocks of Tepee Trail lithology have also been assigned to the Wiggins Formation. Wilson (1963, p. 15) observed that: "* * * the Tepee Trail formation as mapped by Masursky would be equivalent to the lower part of the Late Basic Breccia (Wiggins formation of this paper)." Wilson advanced this correlation because he believed that rocks immediately beneath the early basalt sheets (Trout Peak Trachyandesite) in the

FIGURE 7.—Tepee Trail rocks in upper drainage of Gooseberry Creek, SW¼ sec. 5 and secs. 6 and 7, T. 45 N., R. 101 W., sec. 31, T. 46 N., R. 101 W., and secs. 24, 25, and 36, T. 46 N., R. 102 W. Noon Point is the high butte to the far right (arrow). These rocks were included in the Pitchfork and Wiggins Formations by Wilson (1964a, 1975). View to northwest.

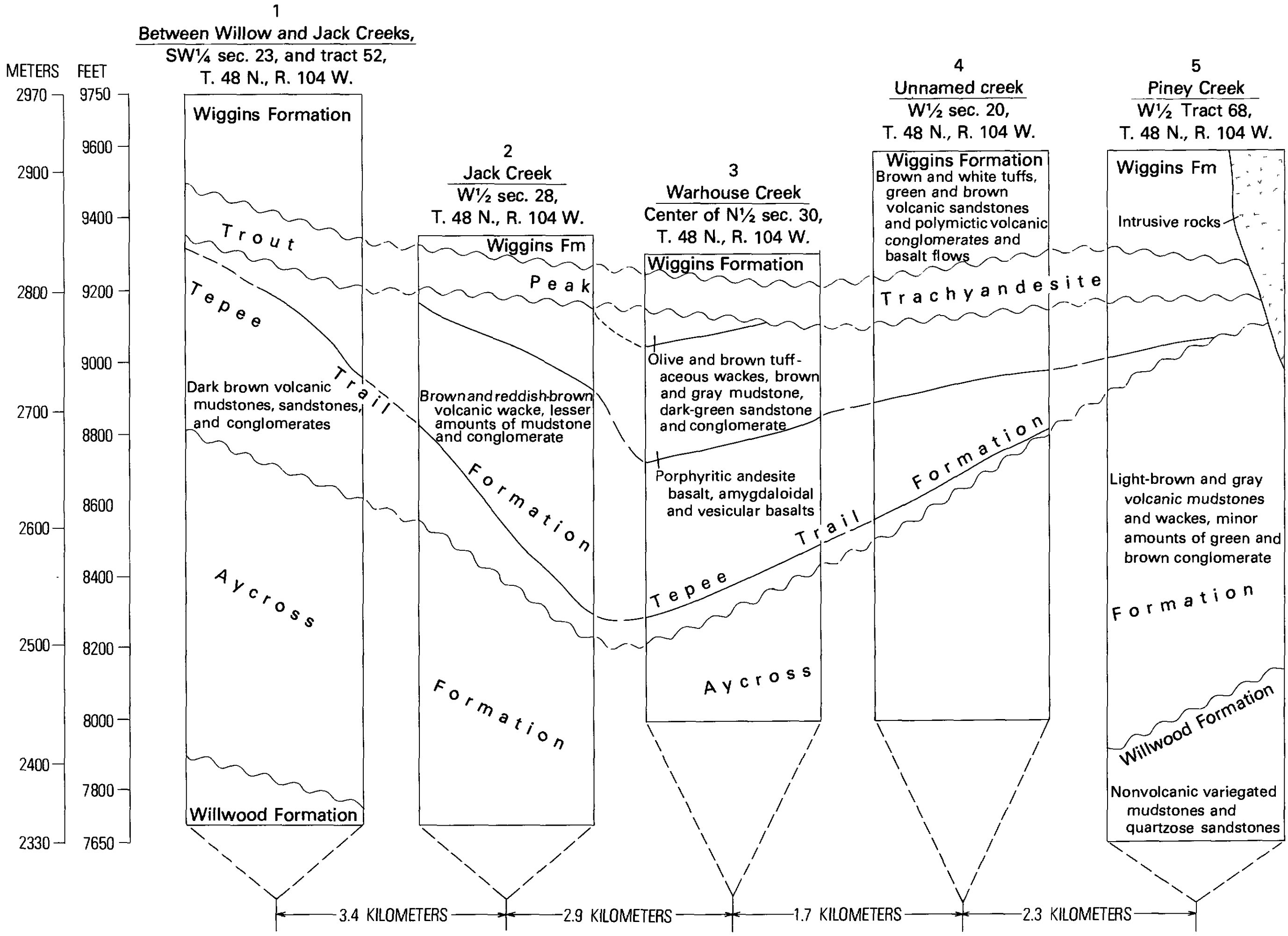
Greybull River area were equivalent to the upper part of the Aycross Formation, as mapped by Masursky. Masursky's (1952) map contains several discrepancies, among these being the inclusion of lower Aycross strata in his "Wind River" Formation and the local inclusion of lower Tepee Trail strata in the Aycross Formation. It is, therefore, likely that the upper Aycross of Masursky that was referred to by Wilson (who did not record a locality) is actually in the lower part of the Tepee Trail Formation.

Wilson's correlation of his Pitchfork-Wiggins contact with Masursky's mapped units is based on his recognition and tracing of two units—the early basalt flows (Trout Peak Trachyandesite) and the Blue Point Conglomerate Member of the Wiggins Formation—from the Greybull River area into or near the area of this report. The Blue Point Conglomerate Member was named by Wilson (1963, p. 17) for a distinctive volcanic conglomerate containing andesite roundstones. In its type area on Wood River, this conglomerate was considered by Wilson to be the lower member of the Wiggins Formation. Wilson believed that the Blue Point can be traced "* * * from the North Fork of Owl Creek in the south to Carter Mountain and possibly to the South Fork of the Shoshone River to the north and northwest." In a written communication (1978), Wilson noted that he had mapped the Blue Point in (1) the upper drainages of Grass and Cottonwood Creeks in secs. 17, 20, 21, 26–29, 33, and 34, T. 45 N., R. 101 W., (2) at the heads of Meadow and Sugar Loaf Creeks, in secs. 10 and 15, and possibly sec. 22, T. 44 N., R. 101 W., and (3) possibly on the Cottonwood Creek–Twentyone Creek divide, secs. 4, 8, and 9, T. 44 N., R. 100 W. Andesitic roundstone conglomerates indeed occur at one or several places in the local sections in these areas, and most of them are confined to the lower 150 m of the Tepee Trail Formation, as used in this report. These occurrences substantiate Wilson's (1963, table 1) conclusion that the Blue Point Conglomerate Member in the Cottonwood Creek–Wood River area is in part a correlative of units Masursky (1952) mapped as Tepee Trail, but they indicate that the conglomerate, as well as most of the sequence between it and the Crosby Breccia Member (which Wilson, 1964a, p. 63–64, also placed in the Wiggins), does not belong in the Wiggins Formation. True Wiggins strata that are much more comparable lithologically with the type rocks on Wiggins Fork do occur at much higher elevations (usually above 2,750 m) farther west, near and west of Squaw Teat Butte and Sugar Loaf Mountain. (See discussion of Wiggins rocks to follow.)

As defined in this report, rocks of Tepee Trail lithology are continuous from their type section on the East Fork of Wind River, northeast over the Owl Creek Mountains and along the front of the Absaroka Range to the south flank of Carter Mountain. In the Gooseberry Creek area, Wilson (1964a, pl. 1; 1975) mapped Tepee Trail rocks as both the Pitchfork and Wiggins Formations. Strata mapped as Wiggins by Wilson (1970) in Soapy Dale Peak Quadrangle (secs. 3, 8–10, T. 45 N., R. 101 W., sec. 6, T. 45 N., R. 100 W., and sec. 34, T. 46 N., R. 101 W.) belong to both the upper part of the Aycross and the lower part of the Tepee Trail.

In the Greybull River–Carter Mountain area, Tepee Trail rocks lie atop Aycross rocks and both form a folded sequence that lies with angular unconformity beneath the Trout Peak Trachyandesite. These relations are particularly explicit in exposures mapped by me in the drainages of Wood River, Dick Creek, Timber Creek, Francs Fork, Willow Creek, Jack Creek, Warhouse Creek, and Piney Creek (fig. 8), and this sequence is clear but less well exposed on the south flank of Carter Mountain (fig. 1). Anticlines and synclines developed on the folded Aycross and Tepee Trail sequence were breached by post-Tepee Trail and pre-Trout Peak erosion such that the Aycross Formation unconformably lies beneath the Trout Peak in the anticlines and the Tepee Trail Formation unconformably lies beneath the Trout Peak in the synclines (fig. 8). The post-Tepee Trail and pre-Trout Peak erosion surface is remarkably planar south of the Greybull River and coincides with the erosional unconformity between the Tepee Trail and Wiggins Formations farther south. In the South Fork of Owl Creek area, the Tepee Trail–Wiggins unconformity occurs at an elevation of about 2,835 m. In the Sugar Loaf Mountain area secs. 16 and 17, T. 44 N., R. 101 W.), the unconformity is also at about 2,835 m, and in the upper Gooseberry Creek drainage (as, sec. 24, T. 45 N., R. 102 W.), it occurs between 2,800 and 2835 m. The angular unconformity between the folded Aycross–Tepee Trail sequence and the Trout Peak Trachyandesite is uniformly developed at about 2,770 and 2,835 m between Timber Creek and Piney Creek (fig. 8). South of Timber Creek, the Trout Peak Trachyandesite pinches out along this surface of unconformity. Paleomagnetic studies by Shive and Pruss (1977) and mapping investigations by Nelson, Prostka, and Williams (1980) in the east-central Absaroka Range also indicate an angular unconformity at the base of, and (or) within, rocks assigned to the Trout Peak Trachyandesite. These relations demonstrate that the Aycross and Tepee Trail Formations are both lateral equivalents of the breccia-rich Wapiti Formation and are both older than the Trout Peak. The top of the Trout Peak is deeply eroded locally, which suggests that it is unconformably overlain by the lower part of the Wiggins Formation. However, stratigraphic relations clearly demonstrate that the Trout Peak is related to renewed volcanic activity that marks the base of the Wiggins Formation throughout most of the central and southern Absaroka Range.

Wilson (1963, 1964a, 1975) and McGrew (1965) observed that the Blue Point Conglomerate Member of the Wiggins Formation is distributed from the Cottonwood Creek area in the south to the Carter Mountain area in the north. As shown previously, the Blue Point Conglomerate Member in the Cottonwood Creek area occurs in the lower part of the Tepee Trail Formation. In its type area on Wood River (NW¼NW¼ NE¼NW¼ sec. 29, T. 46 N., R. 102 W.), the conglomerate is also in the lower part of the Tepee Trail Formation, where it occurs at an elevation of about 2,255 m. Wilson (1963, p. 17) observed that the Blue Point Member lies "* * * within 100 feet above the top of the Early Basalt flows in the Carter Mountain–Greybull River area." This correlation would place the Blue Point well above the angular unconformity between the Tepee Trail and Trout Peak Formations, at an elevation greater than 2,800 m and more than 550 m above its position on Wood River. The mapping in the Wood River–Greybull River area I have done indicates that at least two and possibly as many as five polymicitic volcanic conglomerates that occur stratigraphically in lower Tepee Trail through lower Wiggins rocks were inadvertently believed by Wilson (1963) and McGrew (1965) to be a single marker unit. I recommend that the term Blue Point Conglomerate Member of the Wiggins Formation



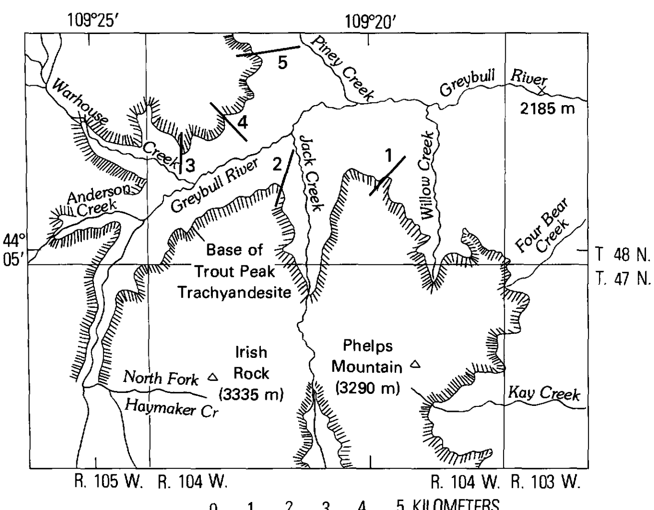


FIGURE 8.—Correlation and relations of the Aycross and Tepee Trail Formations, the Trout Peak Trachyandesite, and the Wiggins Formation in a part of the western Greybull River valley. (See inset map.) Contact dashed where uncertain or approximate.

(Wilson, 1963, p. 17; 1964a, p. 63; 1975, p. 167) be abandoned because (1) the type section of the Blue Point is not in the Wiggins Formation, and (2) as originally defined, the Blue Point Member includes rocks in two previously named formations (Tepee Trail and Wiggins) and these rocks are widely separated stratigraphically by other rocks not included by Wilson in the Blue Point Conglomerate Member (for example, the Trout Peak Trachyandesite).

J. D. Obradovich (oral commun., 1978) has obtained K-Ar dates of 47.9±0.5 and 48.5±0.6 m.y. from biotite- and hornblende-bearing tuffs interbedded with the so called "Blue Point Conglomerate Member" in the SW¼ NE¼ sec. 30, T. 49 N., R. 104 W. (in the lower part of the Wiggins Formation). These dates are consistent with an early middle Eocene age (in the sense of Berggren and others, 1978), and they are supported by the age of collections of fossil mammals from a bentonitic mudstone that lies directly atop the Trout Peak Formation on Carter Mountain in sec. 24, T. 50 N., R. 103 W., Park County (J. D. Love, T. M. Bown, J. G. Eaton, E. L. Simons, R. S. Houston, K. A. Sundell, unpub. data, 1979). Ages published for the Wiggins Formation elsewhere range in age from 47.1 to 43.1 m.y. (See, for example, Love and others, 1978.)

Few vertebrate fossils were collected from Tepee Trail strata within the report area, however, large collections from several localities farther west and northwest await description at the University of Wyoming (J. A. Lillegraven, oral commun., 1978) and at the American Museum of Natural History (M. C. McKenna, oral commun., 1980). A specimen of a large telmatheriine titanothere was recovered from upper Tepee Trail exposures on the South Fork of Owl Creek, about 200 m above the local base of the formation. M. C. McKenna (written commun., 1978) has forwarded the following comments on this specimen:

> USNM No. 251553 shows strong similarities to specimens in the AMNH collections presently assigned to *Palaeosyops grangeri* (Bridger C/1), *Manteoceras uintensis* (Uinta C) and a specimen (AMNH 2032) labeled *Diplacodon* (Uinta C), but the closest similarity by far is with the type and only specimen of *Desmatotitan tukhumensis* from the Irdin Manha of Mongolia * * * . The large titanothere (USNM No. 251553) seems most likely to be Uintan, rather than Bridgerian, in age, although *Palaeosyops grangeri* is a big Bridgerian species.

Tepee Trail localities elsewhere typically yield Uintan mammals (as, McKenna, 1972); however, McKenna (1972) has recorded Bridgerian mammals from referred Tepee Trail rocks at Togwotee Pass. New evidence of Berggren, McKenna, Hardenbol, and Obradovich (1978, p. 71-72) indicates that Uintan mammal faunas from the Absaroka Range are probably middle Eocene in age (not younger than 40.0 m.y.).

WIGGINS FORMATION

The Wiggins Formation was named by Love (1939, p. 79) and includes approximately 500-900 m of volcanic rocks that overlie the Tepee Trail Formation in the south Absaroka Range. Near Wiggins Fork River, the Wiggins Formation consists principally of volcanic conglomerate, andesitic lava flows, and light-colored tuff. Love believed the lower contact to be unconformable near Wiggins Fork. Ketner, Keefer, Fisher, Smith, and Raabe (1966), and Rohrer and Obradovich (1969) suggested that in places the formation intergrades or intertongues, respectively, with the top of the Tepee Trail Formation. J. D. Love, E. B. Leopold, and D. W. Love (1978, pl. 5, sec. 7) showed various interpretations of correlations in the southwestern Absaroka area and suggested that the Tepee Trail Formation is absent there and the Wiggins Formation lies on an Aycross equivalent.

Keefer (1957) and Rohrer (1966b) have mapped Wiggins rocks in the Du Noir and Kisinger Lakes areas, and Masursky (1952) applied the name to similar rocks on the Bighorn Basin side of the Owl Creek Mountains. The age of the Wiggins Formation, long thought to be late Eocene and Oligocene, now appears to be exclusively middle Eocene. (See progression of thought in Rohrer and Obradovich, 1969; McKenna, 1972; J. D. Love and others, 1976; Berggren and others, 1978.)

Wiggins rocks were not examined in detail because most of these occur west of the report area; however, about 180 m of white tuffs, volcanic conglomerates, and light-colored tuffaceous mudstones and sandstones exposed on Sugar Loaf Mountain and Squaw Teat Butte (secs. 16, 17, T. 44 N., R. 101 W.) closely resemble the Wiggins Formation at its type area near Wiggins Fork. These rocks occur at elevations of 2,800 to 3,000 m and overlie approximately 425 m of Tepee Trail rocks that are exposed in the headwater drainages of Lake and Sugar Loaf Creeks (pl. 1). Sugar Loaf Mountain and Squaw Teat Butte are outliers capped by about 30-100 m of contorted volcanic conglomerate and andesite breccia. Similar units occur at Castle Rock (sec. 25, T. 44 N., R. 102 W.) and farther north along the upper drainage of the North Fork of Owl Creek (Castle Rocks chaos; Sundell, 1980). It is uncertain whether or not any of these units are in place because structural deformation in the area is locally intense and suggests the possibility of Tertiary (Wiggins age) low-angle or gravity faulting, or lahar formation.

Southwest of Sugar Loaf Mountain, typical Wiggins rocks form the high divides between the South Fork of Owl Creek and Rock Creek (see Love, 1939, p. 81, and pl. 5, fig. 1)—and between Rock Creek and the south fork of the North Fork of Owl Creek. As observed previously, rocks that were referred to the Wiggins Formation by earlier workers at lower elevations in and north of the report area are here included in the lower part of the Tepee Trail Formation.

Washakie Needles, a dacite plug 16 km west of the map area (fig. 1), is intruded into the Wiggins Formation and has yielded a fission-track age of 38. 8±1.6 m.y. (L. L. Love and others, 1976, p. 1455–1462). Therefore, the dacites were intruded during the latest Eocene (probably Duchesnean of Berggren and others, 1978). The oldest age in the type area of the Wiggins is 47.1 m.y. (Obradovich, in Love and others, 1978, pl. 5, sec. 11), and the youngest age for Wiggins rocks is 43.1 m.y. (Love and Keefer, 1975, p. 37).

A provisional correlation of Eocene volcanic rocks in the southeast Absaroka Range is presented in figure 9.

STRUCTURAL GEOLOGY

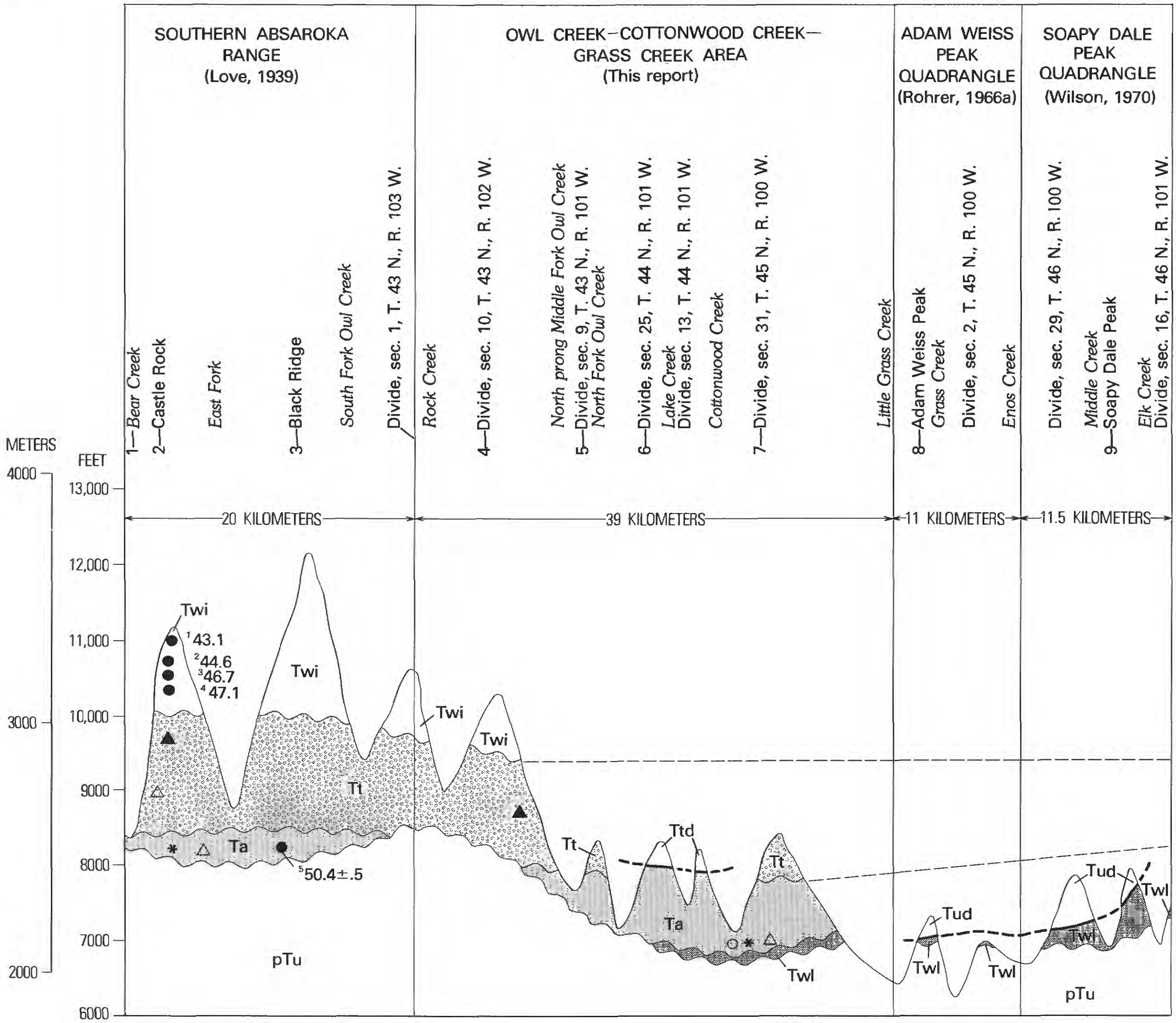
The Owl Creek–Grass Creek area of this report lies in the southwest Bighorn Basin, near the juncture of the western Owl Creek Mountains and the Absaroka Range (fig. 1). The Owl Creek Mountains are essentially east-west-trending fold mountains that have, in places, been overthrust toward their steeply asymmetrical southern limb (Tourtelot and Thompson, 1948; Love, 1960; Keefer and Love 1963; Keefer, 1965). The Absaroka Range, on the other hand, is a remnant of a thick accumulation of volcanic and volcanic-derived rocks that overlap the folded Owl Creek Mountains, Washakie Range, and Beartooth Mountains. Briefly, the Cenozoic structural history of the west margin of the Bighorn Basin consists of: (1) several episodes of compression in late Laramide time, resulting in the elevation of the border fold belt, the depression of the central basin area, and contemporaneous terrestrial sedimentation; (2) an episode of detachment (low-angle gravity) faulting involving Paleozoic sedimentary and Eocene volcanic rocks (Heart Mountain, South Fork, and Reef Creek detachment faults; for example, Pierce, 1941, 1957, 1963b, 1975); (3) extensive late Laramide extrusive igneous activity in the Absaroka region and associated deformation of volcanic rocks; (4) later Cenozoic regional uplift with concomitant excavation of thick sedimentary deposits (Mackin, 1937, 1947; McKenna and Love, 1972); and (5) a second episode of detachment faulting, this time displacing only rocks of the Eocene volcanic sequence.

At least three major periods of deformation are recorded in the report area by prominent angular or erosional unconformities between lower and middle Eocene rocks and two disconformities in the middle Eocene sequence; one between the Aycross and Tepee Trail Formations, and another between the Tepee Trail and Wiggins Formations. The most competent and lowest of the Eocene rocks, the lower Eocene Willwood Formation, is the least deformed, even though most of the superjacent Aycross Formation is moderately to intensely folded throughout the report area. The finer grained, tuffaceous beds of the Aycross have throughout much of their structural history acted as nearly plastic units between the more competent Willwood and Tepee Trail Formations, causing the Aycross to be a structurally disharmonic sequence over most of its outcrop area. Most of the folds, normal and thrust faults, and detachment remnants are local and (or) subtle features and are often impossible to visualize or map accurately with remote sensing methods. Although nearly all of this study was accomplished by both reconnaissance and detailed mapping on the ground, the structural geology of volcanic rocks (particularly the Aycross Formation) warrants more detailed mapping.

FOLDS AND THRUST FAULTS

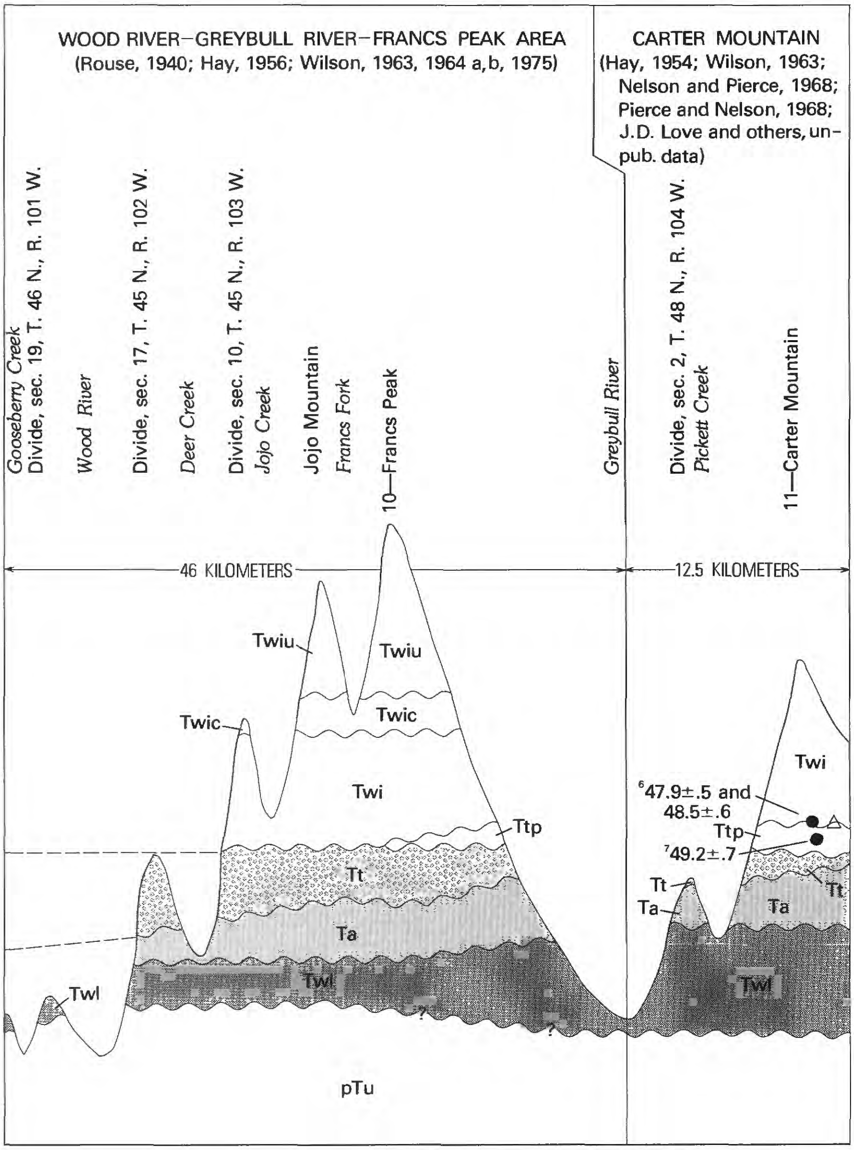
Folded pre-Tertiary rocks are exposed at the periphery of the Absaroka volcanic field where they consist principally of truncated structures that are overlain unconformably by the more or less flat-lying lower Eocene Willwood Formation. The structural grain of these rocks, as with folds in pre-Tertiary rocks elsewhere in the border belt of the Bighorn Basin, roughly parallels the mountains that form the margins of the basin. At the south border of the report area, Paleozoic and Mesozoic rocks dip north off the east-west trending Owl Creek Mountains; however, farther north the upper Cretaceous Cody, Mesaverde, and Meeteetse Formations are the only exposed pre-Tertiary rocks in the report area, and they are structurally controlled by Hamilton Dome and other essentially northwest trends in the Grass Creek basin area. (See pl. 1, this report; also Hewett, 1926, pl. III.) These folds and probably others, several of which are well known oil and gas structures (Hewett and Lupton, 1917), persist to the west for an unknown distance beneath the Eocene volcanic rocks. Within the report area, buried and partially buried oil and gas structures are presently being drilled in the Prospect Creek and Aspen Creek fields.

Where Willwood rocks are gently inclined, their attitudes either correspond with those of subjacent rocks or dip basinward; their strike coincides with the trends of pre-Tertiary folds that parallel the basin margin. But because this surface was one of planation, and because the Aycross Formation has largely been deformed disharmonically, structures above the Cretaceous-Tertiary unconformity may not necessarily reflect underlying trends.



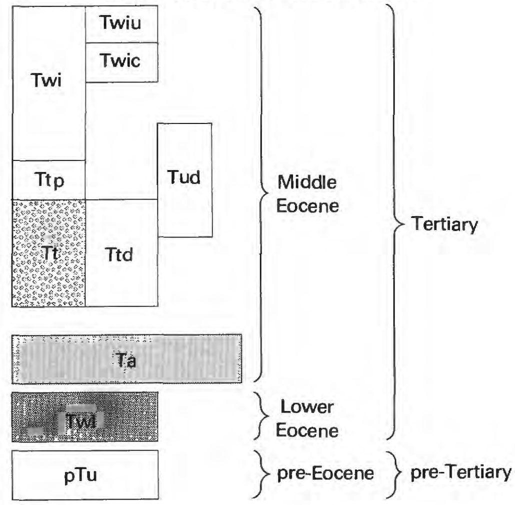
¹Love and Keefer (1975, p. 37).
²J. D. Obradovich (in Smedes and Prostka, 1972, p. 32).
³J. D. Obradovich (in Smedes and Prostka, 1972, p. 32).
⁴J. D. Obradovich (in Smedes and Prostka, 1972, p. 32).
⁵Love and others (1976, p. 17)
⁶J. D. Obradovich (oral commun., 1979).
⁷Near Sylvan Pass (not in area of this section) J. D. Obradovich (in Smedes and Prostka, 1972).
¹⁻⁵, ⁷Ages recalibrated by J. D. Obradovich (oral commun., 1979).

FIGURE 9 (above and facing page).—Schematic cross section showing geographic and stratigraphic relations of Eocene rock in the southeast Absaroka Range, and the horizons of radiometric, mammal, pollen, and invertebrate age determinations. Vertical exaggeration × 20; surface profile is diagrammatic and highly generalized.



- ● Radiometric date (m.y.)
- ✱ Middle Eocene pollen
- ○ Middle Eocene invertebrates
- ▲ Late Eocene mammals
- △ Middle Eocene mammals

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Twi WIGGINS FORMATION, UNDIFFERENTIATED (MIDDLE EOCENE)—Light-colored volcanic sandstone, volcanic conglomerate, agglomerate, white tuff, tuff breccia, and lava flows. Dominantly fluviatile, but extrusive and intrusive igneous rocks occur locally. Thickness 180–1,200 m

Twiu UPPER MEMBER OF WIGGINS FORMATION (MIDDLE EOCENE)—Hornblende-biotite andesite flows, pyroxene andesite flows, lahars, and light fluvial tuffs. Thickness about 500 m

Twic CROSBY BRECCIA MEMBER (WILSON, 1963) OF WIGGINS FORMATION (MIDDLE EOCENE)—Igneous breccias, lahars, and light-colored fluvial tuffs. Thickness about 160 m

Tud DETACHED ROCKS OF WIGGINS AND TEPEE TRAIL FORMATIONS (MIDDLE EOCENE)—Detached masses (variety 2 allochthons) of green and brown volcanic wackes; minor amounts of gray volcanic sandstone and conglomerate. Thickness up to 150 m

Tt TEPEE TRAIL FORMATION (MIDDLE EOCENE)—Green, gray, and brown volcanic sandstone and tuff, volcanic conglomerate, flow breccia, and thin andesite flows; minor amounts of volcanic mudstone and shale. Dominantly fluviatile, but extrusive igneous rocks occur locally. Thickness 425–600 m

Ttd DETACHED ROCKS OF TEPEE TRAIL FORMATION (MIDDLE EOCENE)—Detached masses (variety 1 allochthons) of Tepee Trail lithology. Thickness up to 325 m

Ttp TROUT PEAK TRACHYANDESITE (MIDDLE EOCENE)—Pyroxene and andesitic vesicular and nonvesicular basalts. Thickness 0–120 m

Ta AYCROSS FORMATION (MIDDLE EOCENE)—Gray, green, brown, and variegated volcanic mudstone, volcanic sandstone, volcanic pebble and roundstone conglomerate, shale, arkose, tuff, breccia, and limestone. Dominantly fluviatile; however, lacustrine shales, sandstones, and limestones occur locally in middle and lower parts. Thickness about 250–290 m

Twl WILLWOOD FORMATION (LOWER EOCENE)—Variegated nonvolcanic mudstone, light-colored quartzose and arkosic sandstone, and chert and quartzite granule and pebble conglomerate. Thickness 20–500 m

pTu PRE-EOCENE ROCKS (MESOZOIC, PALEOZOIC, AND PRECAMBRIAN)—Includes all pre-Tertiary rocks depicted on plate 1, as well as Precambrian rocks

Deformation of the volcanic series in the Owl Creek–Grass Creek area was much more intense than that noted for these rocks by Love (1939) or Keefer (1957, p. 200) in the northwest Wind River Basin and southern Absaroka Range. As observed by Love (1939, p. 97) for the latter area, none of the folding is directly related to local intrusions or eruptive centers, for these do not exist in or near the report area.

The Aycross Formation is folded over most of its outcrop area and, in a few places, small-scale disharmonic deformation was so intense that structures cannot be adequately mapped at a scale of 1:24,000. The basal Aycross is commonly horizontal or only gently tilted, probably because the lower Aycross is typically made up of several resistant sandstones and conglomerates. Consequently, relatively undeformed Aycross rocks occur only at the south margin of Putney Flat, near the Rhodes Ranch on Cottonwood Creek, south of the chimney-like rocks in secs. 1–3, 10 and 11, T. 43 N., R. 100 W., and south of the North Fork of Owl Creek, in secs. 17, 18, 20–22, T. 43 N., R. 100 W. (pl. 1). Elsewhere in the report area, Aycross rocks are gently to moderately folded in a succession of northeast-trending anticlines and synclines. Local dips vary but generally do not exceed 30°. These structures are the most obvious and persist for about 10 km on the interfluves separating Cottonwood and Twentyone Creeks, and Dugout Draw; however, the structural grain continues again about 9 km farther west in secs. 32 and 33, T. 44 N., R. 101 W., in the south fork of the North Fork of Owl Creek. On the north side of the North Fork of Owl Creek, beneath the large remnant of the Owl Creek detachment fault on the Owl Creek–Lake Creek divide, Aycross rocks vary in dip from a few degrees to overturned, and the general grain of northeast-trending anticlines and synclines has been obliterated. East-west trending folds depicted by Masursky (1952), that involve both Aycross and Tepee Trail rocks in the North Fork of Owl Creek–Putney Flat areas, were not seen during the field study.

Folds in Aycross rocks in the report area are disharmonic, die out downward, and do not reach the Aycross-Willwood contact. They, therefore, apparently follow no older lines of weakness. They are commonly, but not invariably, steeper to the south. This asymmetry may be variable (on either side of the axis) at different points on the same fold and, in these cases, is usually related to local small-scale thrust faulting (fig. 10). One such fold is developed in the interval between Vass quarry and the Rhodes klippe (SW. and NE. of sec. 23, T. 44 N., R. 100 W.). On either side of the axis of this anticlinal trend, Aycross rocks dip about 3°–40° and the fold has been thrust or tear faulted at its axis in several places (figs. 11, 12).

Where a thrusted axis is distinguished, the upthrown side is invariably to the north, the displacement is probably minimal, and rocks on the downthrown side usually show strong drag folds (fig. 11). At a few localities (for example, the center of the E½ sec. 23, T. 44 N.,

FIGURE 10.—Thrust fault in middle part of Aycross Formation on east side of Dugout Draw, SE¼ NE¼ sec. 7, T. 44 N., R. 99 W. Angular discordance of upper plate is about 15°; view, to the northeast, is foreshortened.

FIGURE 11.—Drag fold in Aycross volcanic sandstone (ss) beneath upper plate of small thrust fault, about 225 m northeast of Vass quarry in the SE¼SE¼SE¼NE¼ sec. 33, T. 44 N., R. 100 W. View to east. (See also fig. 12*A*.)

R. 100 W.), the axial fault is marked by a brecciated zone of vertical or near vertically inclined rocks on either side (fig. 12*B*). These occurrences suggest that both the fold and axial faulting might reflect a tightly folded or faulted anticline at depth. This impression is reinforced by the fact that the thrust fault departs from the anticlinal trend in about the center of sec. 27, T. 44 N., R. 100 W., northeast of Vass quarry. The age of this fold and the axial faulting is unknown, but elsewhere folded Aycross rocks are truncated by a pre-Tepee Trail erosion surface and doubtless predated that formation.

Elsewhere in the report area, thrust faulting is also highly localized and is commonly associated areally with remnant outliers of the Owl Creek detachment fault. The age of this thrust faulting is also uncertain, but the possibility cannot be dismissed that some of the thrusts represent the lower boundaries of blocks that were locally rotated or gouged out beneath a detachment sheet moving across an uneven surface.

Small-scale thrust faults are common in and near the drainage of Dugout Draw where, as one moves southeast, the local structure progresses from (1) shallow dips to the northwest to (2) steep dips to the northwest to (3) overthrust to south, and back to (1) shallow dips to the northwest, and so forth (fig. 10). In sec. 17, T. 44 N., R. 99 W., several local thrusts overlap adjacent to a large detached remnant, the Rhodes klippe (pl. 1). These thrusts are believed to be shallow features that flatten to bedding faults or that die out at depth because none were observed to displace Willwood or older rocks in the western part of the adjacent Wagonhound oil and gas field. Because they are both localized in areal extent and are probably shallow features, the possibility that some of the faults resulted from the displacement of blocks beneath a moving detached mass is reinforced.

With the exception of detached masses, Tepee Trail strata in the report area are characterized by shallow dips and few faults. Folded Tepee Trail rocks rarely follow trends in the underlying Aycross Formation and where they do this is perhaps coincidental. The Tepee Trail Formation is folded into a broad west-northwest-trending syncline on the high divide separating Cottonwood, Twentyone, and Grass Creeks. An outlier of Tepee Trail strata on the Twentyone Creek–Wagonhound Creek divide also conforms with this trend, which intersects the strike of the underlying Aycross Formation at an angle of about 65° (pl. 1). The Aycross appears to have been refolded in several areas in the upper drainage of Twentyone Creek, and this refolding was probably coincident with the mild deformation of the Tepee Trail Formation.

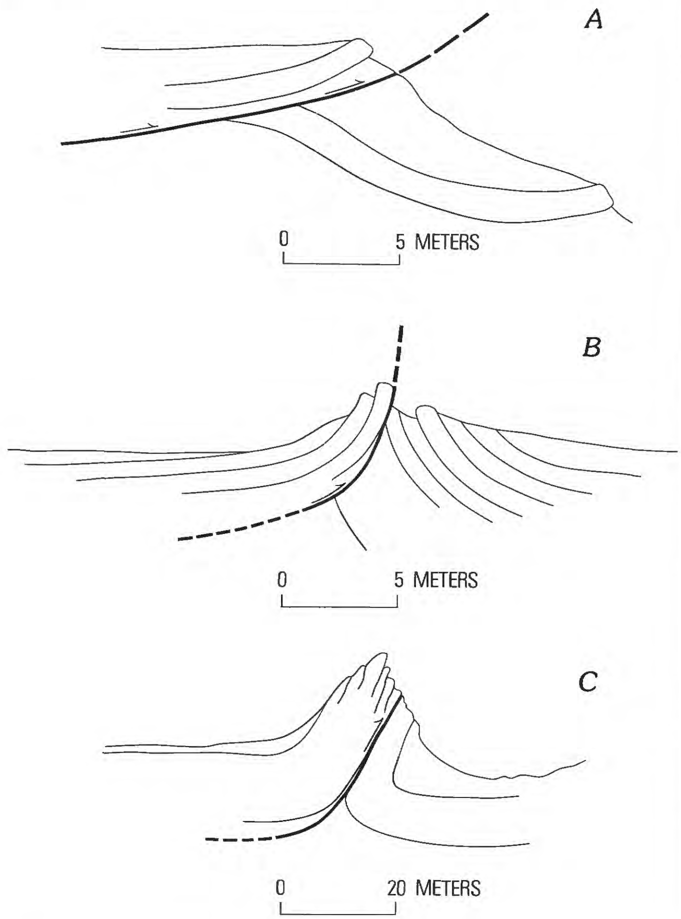


FIGURE 12.—Schematic cross-section geometries of a small-scale thrust fault. *A*, northeast of Vass quarry, SE¼SE¼SE¼NE¼ sec. 33, T. 44 N., R. 100 W.; *B*, on the Cottonwood Creek–Twentyone Creek divide, center of S¼S¼ sec. 23, T. 44 N., R. 100 W.; *C*, north of the Rhodes klippe, SW¼NE¼SW¼ sec. 17, T. 44 N., R. 99 W. The fault is variably present at or near the axis of a minor anticline in the Aycross Formation. Scale approximate.

NORMAL FAULTS

High-angle normal faults are numerous and transect nearly all exposures of the Aycross Formation. In areas of severe local deformation, sometimes as many as 30 separate normal faults were encountered in a square mile. Most of these features are of only local extent, show displacement of only a few meters, and were for the most part not mapped during the reconnaissance study.

Two trends are evident for high-angle normal faults; one to the northeast or east-northeast, and paralleling the trend of the principal fold axes, and a second at right angles to the structural grain, oriented to the northwest or north-northwest. The greatest displacement calculated for a normal fault is approximately 80 m in the SE¼ sec. 36, T. 45 N., R. 99 W., where the upper badland sequence of the Aycross Formation has been downthrown against the upper lacustrine sequence. This fault has an east-northeast bearing and parallels several normal faults mapped by Hewett (1926, pl. III) in the adjacent Grass Creek Basin Quadrangle. Hewett depicted these faults as offsetting both Aycross and Willwood strata ("Tertiary volcanics" and "Wasatch") in the Grass Creek Basin area, and it is likely that they do offset also in Twentyone Creek Quadrangle, though faulted contacts are not exposed there. Van Houten (1944, p. 200) observed that normal faults offset Willwood and "early basic breccia" near the head of Little Prospect Creek in the north part of T. 45 N., R. 99 W.

DETACHMENT FAULTING AND ASSOCIATED DISPLACED MASSES

One of the most important results of this study is the recognition and mapping of both large and small remnants (klippen) of detached masses of Eocene volcanic rocks. Similar masses were described briefly by Rohrer (1966a) and Wilson (1970, 1975); however, this study offers more detailed field evidence of their stratigraphy, stratigraphic sources, areal distribution, and age of displacement.

Rouse (1940, p. 1422–1423) was the first to remark on the presence of deformed rocks overlying horizontal rocks near the report area. For the Wood River drainage west of Noon Point, he observed:

> This deformation, reflected in the volcanic series but not in the underlying essentially horizontal Wasatch beds, presents a puzzling problem in this area where there are no intrusions. On the basis of the field work done to date all that can be said is that, after accumulation of the pyroclastics in this area, rather intense but extremely local deformation took place. This deformation may have resulted from the adjustment of the volcanic rocks at the mountain front subsequent to extrusion but prior to the lithification of the volcanic rocks.

Elsewhere, Rouse (1940), Hay (1954), and Wilson (1963, 1964a) have attributed some of this deformation to intrusions; but no intrusions have been recognized in the Owl Creek–Grass Creek area; and the hypothesis of local disharmonic folding does not satisfactorily account for all of the differentially deformed strata. Rohrer (1966a) believed that these masses in Adam Weiss Peak Quadrangle were remnants (klippen) of large scale detachment faulting (Enos Creek detachment fault), an interpretation that is endorsed here. Subsequently, Wilson (1970, 1975) mapped detachment fault contacts in the adjacent Soapy Dale Peak and Noon Point Quadrangles, and Rohrer (1966a) and Pierce (1978) have recognized allochthonous volcanic rocks capping Squaw Buttes, some 30 km to the northeast (secs. 23, 26, T. 48 N., R. 98 W.).

DEFINITION

Detachment klippen in the report area were recognized in the field on the following criteria:

1. They comprise outliers of intensely deformed rocks that invariably lie with structural discontinuity atop gently folded older rocks.
2. They are locally typified by plastic, rootless folding.
3. They are nowhere overlain by other rocks.
4. The folds and faults in individual klippen appear to bear no relation to those in adjacent klippen.
5. They are dispersed across a topography with relief of more than 600 m and variously fill valleys in or cap high divides on eroded Aycross rocks. Although underlying rocks were locally deformed by the upper plate, the differential topographic positions of the klippen did not result from gouging because many of the topographically lowest klippen lie atop and adjacent to relatively undeformed rocks.

Rohrer (1966a) and Wilson (1970) believed that all the Aycross (the former "Pitchfork") sequence in Adam Weiss Peak and Soapy Dale Peak Quandrangles is detached; the present study indicates that Aycross rocks in these areas, as in the study area, are in place. Detached masses do exist there, but they lie atop the gently folded Aycross Formation and are much more strongly deformed. Local anomalous dips in the Aycross occur proximal to detachment fault planes and reflect deformation caused by the overriding detached mass. The recognition that Aycross rocks in these areas are not detached (with certain minor exceptions) has critical implications for the age of detachment faulting of volcanic rocks.

DISTRIBUTION

Approximately 150 remnants of a detached mass (or masses) are dispersed from the North Fork of Owl Creek (pl. 1) in the south to the south flank of Carter Mountain on the north and from the head of Lake Creek (pl. 1) on the west to Adam Weiss Peak (Rohrer, 1966a) on the east. Two outlying detached remnants occur on the Squaw Buttes divide in the south-central Bighorn Basin. This distribution of klippen indicates that the area affected by detachment faulting was probably more than 1,500 km^2. The majority of the klippen lie within the mapped area (pl. 1).

COMPOSITION

Four types of allochthons were recognized in the report area, and these are distinguished by their composition and structural relations.

1. Variety 1 allochthons (klippen) are thick masses of heterogeneous lithology, composed of tuff, volcanic sandstone and conglomerate, volcanic flow breccia (lahar), tuff breccia, and andesitic lava flows; and they form the upper 300 m of rocks on the high divide between Lake Creek and the North Fork of Owl Creek, and a lesser portion of the divide between Lake and Cottonwood Creeks (pl. 1). These rocks (fig. 13) are virtually identical in gross lithology to adjacent in-place rocks of the lower and middle parts of the Tepee Trail Formation exposed in the drainage of Cottonwood Creek. Variety 1 masses are composed of steeply dipping to recumbent rocks that are roughly partitioned into blocks of similar structural grain by large normal faults. These faults do not extend into the underlying Aycross Formation.
2. Variety 2 allochthons are thinner masses (30–150 m) of green to brown volcanic wackes. Similar sandstones, although undeformed and generally not exceeding 10 m in thickness, occur in both the upper part of the Tepee Trail Formation and the lower part of the Wiggins Formation. Variety 2 masses are dispersed throughout much of the Twentyone Creek Quadrangle (pl. 1) and occur less frequently in adjacent parts of Milk Creek, Anchor Reservoir, Adam Weiss Peak, and Soapy Dale Peak Quadrangles (pl. 1; Rohrer, 1966a; Wilson, 1970). They vary in size from a few tens of meters in diameter to more than 3 km^2 in area (figs. 14–18). Deformation in these remnants is invariably greater than in the variety 1 masses, and discontinuous folds and faults accompanied by plastic folding are common.
3. Variety 3 allochthons are thin slivers of steeply dipping Aycross strata that lie above relatively undisturbed Aycross rocks. These remnants are rare and probably represent Aycross rocks that were dislocated by gouging due to horizontal movement of the detachment sheet above them, rather than detachment faulting involving the whole of the Aycross Formation. The last interpretation was suggested by both Rohrer (1966a) and Wilson (1970). The best example of this type of displaced mass is preserved on the divide separating the East and West Forks of Twentyone Creek (fig. 19).
4. Variety 4 allochthons consist of house-size blocks of andesitic volcanic conglomerate, nonvesicular porphyritic pyroxene basalt, andesitic basalt, agglomerate, and lahars. These are probably lag blocks that have been let down on relatively undisturbed rocks from a higher detached mass by erosion. Darton (1906, fig. X, A) illustrated a lag

4. Continued.
block of this sort in the upper drainage of the Middle Fork of Owl Creek, but did not comment on its origin. Blocks of this type are physically associated with a variety 2 klippe on the Prospect Creek–Twentyone Creek divide. Masursky (1952) mapped several of these blocks as intrusives in the Aycross Formation, but none of them are associated with vents, dikes, or other intrusive bodies. Most of them are situated in precarious positions on the faces of steep badland scarps (fig. 20).

DETACHMENT FAULT CONTACT

In the North Fork of Owl Creek region, the topographically highest fault contact of a variety 1 detached mass with the Aycross Formation is near the head of Lake Creek, at an elevation of about 2,560 m (pl. 1). The lowest exposure of this contact is west of the klippe comprising the chimney-like rocks in SW¼ sec. 34, T. 44 N., R. 100 W., at an elevation of about 2,040 m. In the intervening area, the allochthonous mass descends a gentle, eastward-sloping surface that is developed on the middle and upper parts of the Aycross Formation. For the most part, this contact is sharply defined (fig. 13) and presents little evidence of deep gouging. However, some deformation of underlying rocks has occurred in most areas, and this has locally interrupted the general southwest-northeast trend of folds seen elsewhere in the Aycross Formation.

The topographic positions of variety 2 klippen indicate that the detachment fault passed over a rugged topography in the area between Little Grass Creek and Cottonwood Creek (pl. 1, sec. *A–A'*), a topography similar to that which now exists, but one which was developed at slightly higher elevations. Here, the klippen variously cap some of the higher divides and fill parts of ancient valleys (fig. 15). Evidence of the gouging of underlying strata is common in the Twentyone Creek–Cottonwood Creek area (figs. 14, 16).

Rocks beneath detachment fault klippen in the mapped area are generally relatively undisturbed (figs. 17, 18), and there appears to have been no preferential structural grain developed in Aycross rocks by the movement of the detached mass. This interpretation contrasts with that of Rohrer (1966a) for rocks in Adam Weiss Peak Quadrangle. There is also no fault-plane breccia such as characterizes parts of the Heart Mountain detachment fault (Pierce, 1975), and the lower parts of the klippen are not noticeably shattered. Clastic dikes are rare, and where these occur they appear to have been injected downward, across the fault plane and into the Aycross mudstones. The absence of fault-plane breccia

FIGURE 13.—Detached Tepee Trail rocks (Ttd) constituting variety 1 klippe resting on gently folded middle Aycross strata (Ta) at west edge of Putney Flat in NW¼ sec. 3, NE¼ sec. 4, T. 43 N., R. 100 W., and SE¼ sec. 33, T. 44 N., R. 100 W. View to west. Detached Tepee Trail rocks in center distance are inclined about 40° to the south and closely resemble in-place lower Tepee Trail strata occurring elsewhere in the report area. Variety 2 klippen (Tud) in foreground. Normal and detachment fault contacts are designated by solid and dashed lines, respectively. Bar and ball on downthrown side of normal fault. Photograph by J. D. Love, July 16, 1978.

FIGURE 14.—The Rhodes klippe, a variety 2 allochthon (Tud) east of the Rhodes Ranch on the north side of Cottonwood Creek (center S½ sec. 17, T. 44 N., R. 99 W.). Klippe composed of about 90 m of detached, intensely folded volcanic wackes that lie atop about 60 m of the in-place basal Aycross Formation (Ta). Willwood sandstones and mudstones (Twl) form the structural terrace. View to northeast.

and the injection of clastic material downward probably reflects the plastic, incompetent nature of the underlying tuffaceous Aycross rocks.

Slickensides are common in all the klippen, but they are not noticeably more common near the plane of the fault. They show a bewildering variety of orientations, ranging from east-west to north-south, with dips from horizontal to vertical. None of these appear to be preferential; rather, they suggest (as do the discontinuous folds and faults) that internal cohesion of the mass was very weak during detachment faulting.

SOURCE AREA

The lithologies of variety 1 klippen so closely resemble those of the lower and middle parts of the Tepee Trail Formation in surrounding areas that they are almost certainly derived from that unit. Variety 2 klippen differ lithologically from variety 1 and probably came from higher stratigraphic sources.

The breakaway areas for the detachment fault were not recognized in the map area, nor were they seen in reconnaissance surveys to the west, in the upper drainages of Owl and Cottonwood Creeks. Wilson (1975) reported possible breakaway scarps for certain detachment fault remnants in the Wood River–Deer Creek region, about 20 km northwest of the mapped area. Though I disagree that all the remnants mapped by Wilson constitute detached rocks, some klippen do occur there and, together with displaced masses in the Soapy Dale Peak area, lie on the north side of the Grass Creek–Gooseberry Creek divide. Adam Weiss Peak and the numerous klippen in the Twentyone Creek–Cottonwood Creek area lie south of this divide. If all the klippen represent the same episode of detachment faulting, these spatial relations would indicate that part the detached mass originated on this divide or passed over or around it. In either case, it is possible that most of the breakaway area is no longer preserved because of the rapid headward erosion of Gooseberry Creek, Wood River, and their tributaries.

AGE OF DETACHMENT FAULTING

The age of detachment faulting of volcanic rocks in the southeast Absaroka Range is uncertain, but several lines of evidence indicate that it is considerably younger than the early or late-early to middle Eocene age demonstrated for the Heart Mountain fault farther north by Rouse (1937), and by Pierce (1941, 1957, 1963b). This interpretation is based on the following field evidence:

1. The topography preserved by the contacts of klippen with underlying Aycross rocks is remarkably similar to that in the area today and strongly suggests that detachment faulting occurred after the beginning of the presentday semiarid erosion period. This probably began in the Miocene, or later (McKenna and Love, 1972). The general northeast alinement of most of the klippen in the Twentyone Creek area results from the fact that these klippen sometimes fill ancient strike valleys.
2. The klippen lie on an erosion surface developed across all parts of the Aycross Formation (lower, middle, and upper). This erosion surface has a local relief across the map area of 630 m. Because the erosional unconformity at the Aycross Formation–Tepee Trail Formation contact has a maximum local relief of less than 20 m, it is impossible that detachment faulting took place at the time of the formation of this unconformity. Moreover, inclusion of Tepee Trail rocks in the detached mass clearly demonstrates that faulting occurred in post-Tepee Trail time.

   If the erosion surface on the Aycross Formation that was traversed by the detachment sheet was formed in post-Tepee Trail but pre-Wiggins time, it would require the removal of more than 1,100 m of rock at a time when principally aggradational conditions prevailed elsewhere. The planar nature of the Tepee Trail–Wiggins unconformity is certainly not consistent with an erosional episode of this magnitude. A post-Wiggins Tertiary age for detachment faulting would require the removal of a much thicker sequence of rocks (in excess of 2,150 m).
3. In no places are the klippen covered by younger rocks. The fact that klippen of Paleozoic rocks of the

FIGURE 15.—Vertical variety 2 allochthonous material (Tud) filling a deep valley in essentially horizontal Aycross rocks (Ta) in the upper drainage of Wagonhound Creek, NE¼NE¼NE¼ sec. 31, and NW¼NW¼NW¼ sec. 32, T. 45 N., R. 99 W. Twl, Willwood Formation. Detachment fault contact emphasized by heavy solid line, dashed where covered. View to north.

FIGURE 16.—Detail of detachment fault contact (dashed line) at the southeast margin of the Rhodes klippe (Tud). NE¼SW¼SE¼ sec. 17, T. 44 N., R. 99 W. Because the lower in-place Aycross beds (Ta) are relatively undisturbed beneath the main part of the detached mass, it is suggested that the upper plate collided with a topographic high in the Aycross Formation, turning up the leading edge of the upper plate (upper arrow), and locally deforming the underlying beds. Aycross strata at the middle arrow dip approximately 65° NW. Lower arrow depicts USGS Cenozoic fossil vertebrate locality D–1122 (1978), and people at this site give scale. View to northeast. Photograph by J. D. Love, July 16, 1978.

Heart Mountain fault are engulfed by rocks of the middle Eocene Wapiti Formation is the best line of evidence for the antiquity of that fault. In the mapped area, deformed klippen only occur atop eroded Aycross rocks along the front of the Absaroka Range where Tepee Trail and younger strata have been stripped off by erosion; highly deformed rocks are never found protruding from Aycross or Tepee Trail exposures in cliff faces.

SUMMARY OF CENOZOIC EVENTS

The onset of more or less continuous terrestrial sedimentation in the Bighorn Basin occurred in late Cody and Mesaverde (Campanian) times when alternating shale and beach or nearshore sandstone deposits record fluctuating marine strandlines. Meeteetse environments record the encroachment of swamps on shore areas, and by the beginning of Lance deposition (Maestrichtian), the sedimentary environment was almost exclusively fluviatile.

The Tertiary Period in the western Bighorn Basin area was characterized in the early part by accumulation of a thick sequence of fluviatile, volcanic, and some lacustrine rocks, and, later in the period, by the rather rapid excavation of the basin, following regional uplift.

In the southwestern Bighorn Basin, the systemic boundary is generally picked at a prominent but local angular unconformity between the Lance and Fort Union Formations. The base of the Fort Union is composed principally of lenticular sandstones and roundstone conglomerates that lie with angular unconformity atop tilted sheet sandstones and tabular mudstones of the Lance Formation. This contact shows that at least local warping and erosion followed deposition of the Lance; streams of the lower part of the Fort Union Formation were competent. Quartzite and weathered volcanic roundstones suggest that areas to the west and northwest of Yellowstone National Park were important source areas and that the intervening topography was low enough to accommodate the transportation of a large amount of sedimentary material. Higher levels of the Fort Union Formation are characterized by thick sheet

FIGURE 17.—Dugout klippe (Tud) in detachment fault contact with middle part of Aycross Formation (Ta), S¼ NE¼ sec. 7, T. 44 N., R. 99 W. The detached mass is almost wholly composed of strongly folded and shattered volcanic wacke and has a thrust contact (solid line) that is about 20° discordant with underlying rocks. Arrow parallels thrust contact. View to east.

sandstones, lenticular sandstones, and mudstones that indicate deposition on a broad alluvial plain. Pond and swamp deposits were formed locally on the flood basins, and channel sandstone geometries suggest that the major streams were large. Basinward, this principally alluvial environment gave way to broad areas of palustrine, coal swamp deposition. Minor incursions of a tongue of the Cannonball sea, Waltman lake, or another marine or brackish body may be indicated by Fort Union shales containing marine dinoflagellates in the Grass Creek Basin area (J. D. Love, oral commun., 1974), and by thicker shales of marine aspect in Fort Union rocks southeast of North Butte, Washakie County.

Following Paleocene times, the southwest Bighorn Basin underwent an episode of uplift and deformation of the border belt of sediments, and this was followed by a long period of erosion, during which time most of the lower Eocene Willwood Formation was deposited in the central part of the basin. Farther north, in the Greybull and Shoshone River areas, Willwood deposition was more continuous; and much if not most of the lower part of the formation is preserved. In the Clark's Fork Basin, sedimentation was probably continuous across the Paleocene-Eocene and Fort Union–Willwood boundaries.

Willwood rocks record a variety of alluvial and local paludal environments, and most of the formation was deposited on broad, open flood basins which allowed extensive development of alluvial soils. Fossil plants and vertebrates indicate a warm and humid climate, but paleosol morphologies indicate that climatic conditions became drier in late Willwood times, probably as a result of the slow rise of the Owl Creek and southern Bighorn Mountains (Bown, 1979a). Quartzites and vein quartz in Willwood rocks of the border area indicate source areas in the Targhee area and Washakie Range, respectively. Near the end of Willwood time, depression of the central Bighorn Basin area slowed and Willwood rocks overlapped the truncated border fold belt at the western margin of the basin. Tuffaceous material in upper Willwood strata indicates that volcanic activity had begun to the west in the Absaroka volcanic field.

At the close of Willwood deposition, the central Bighorn Basin began a period of sporadic subsidence and a lake basin was developed, initiating deposition of the Tatman Formation. The western border belt, however, remained elevated and an unknown thickness of Willwood rocks was removed by erosion. Tongues of Willwood in Tatman rocks persist high up on the Squaw Buttes divide and demonstrate that fluviatile and lacustrine conditions fluctuated in the southern Bighorn Basin. At some time following deposition of the highest preserved Tatman rocks in the central Bighorn Basin, lacustrine environments were developed in and north of the report area. These reflect either the filling of the Tatman lake basin to the east or, more likely, depression of the western margin of the Bighorn Basin that continued sporadically throughout much of Tatman time. Relief along the western border of the basin was such that these lacustrine incursions were of only local extent, however, and a thick sequence of volcanic-derived sediments (the Aycross Formation) records a period of dominantly fluviatile deposition in the area.

The middle Eocene Aycross Formation received sediments from several areas to the west and northwest. The Owl Creek Mountains and Washakie Range contributed detrital quartz and chert, the Washakie Range probably supplied the vein quartz; quartzite pebbles and cobbles were derived from even farther west, indicating that relief in this direction was still relatively low, as it was in the Paleocene and early Eocene. The bulk of the detrital material in the Aycross, however, was derived from intrusive and extrusive igneous sources in more central areas of the Absaroka volcanic plateau. These sources remained active at least until the close of the Eocene, and probably until near the end of the Tertiary.

Aycross rocks were deposited on a surface of considerable relief; however, once strike valleys in older rocks had been filled, distributary streams became more stabilized and the local alluvial topography lessened.

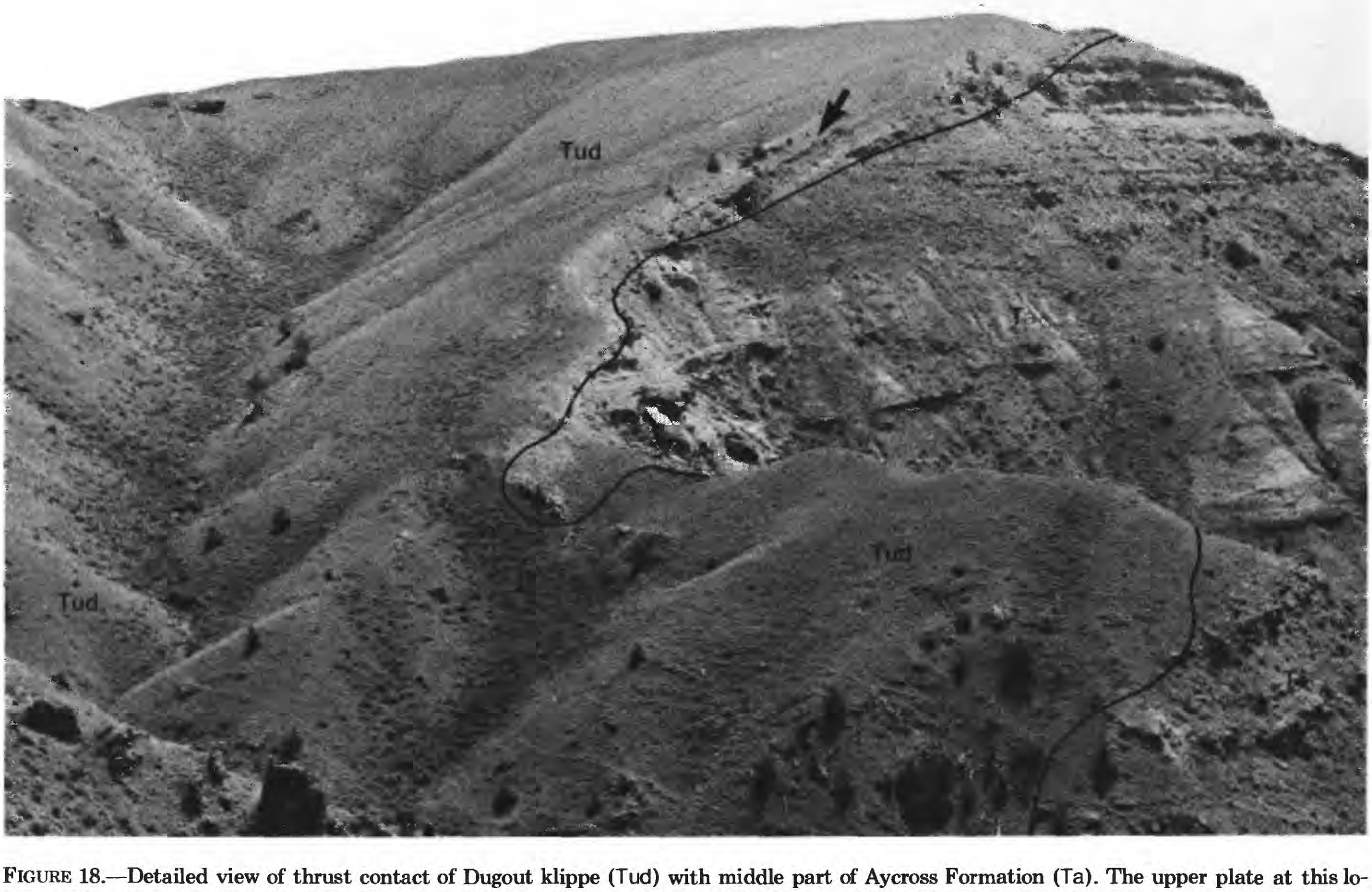


FIGURE 18.—Detailed view of thrust contact of Dugout klippe (Tud) with middle part of Aycross Formation (Ta). The upper plate at this locality appears to include some Aycross rocks (arrow) that were probably displaced beneath the mobile detached mass. View to southeast.

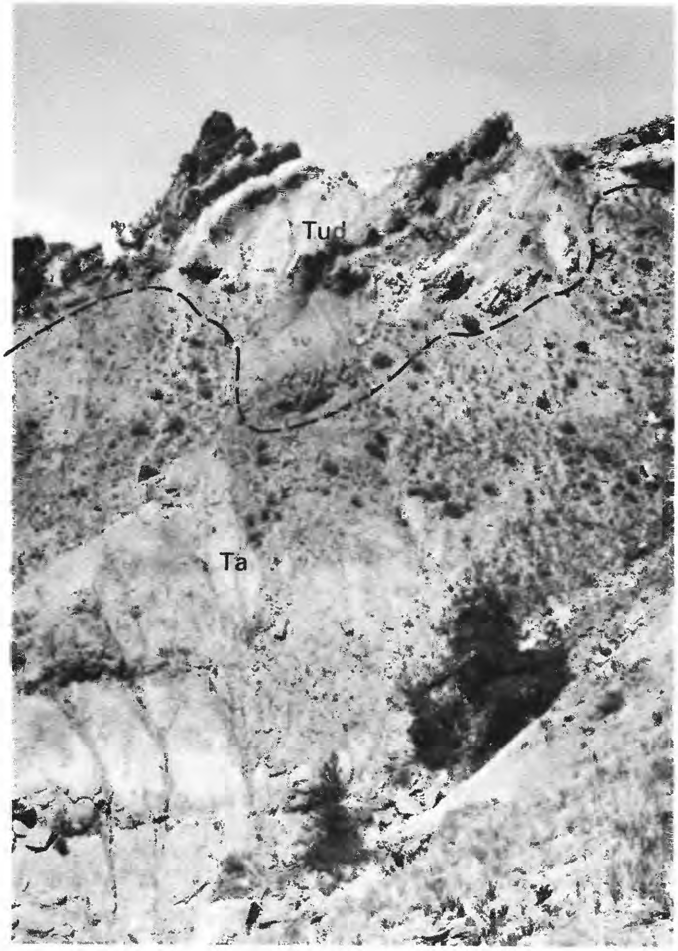


FIGURE 19.—Detached Aycross rocks (Tud) constituting variety 3 allochthon on divide separating West and East Forks of Twentyone Creek, NE¼NE¼SE¼SE¼NE¼ and SE¼SE¼NE¼SE¼NE¼ sec. 2, T. 44 N., R. 100 W. Detached rocks dip approximately 75° NW.; underlying rocks in place (Ta) are nearly horizontal. Dashed line emphasizes fault contact. These rocks, like those in figure 18, were probably displaced by gouging beneath the upper plate. View to north.

This change in distributary regimen is reflected in the persistent nature of many thick Aycross sandstones and the tabular geometry of the volcanic mudstones. The principal Aycross distributary streams were probably very large; mudstones were developed as overbank deposits on broad flood basins. Ponds developed in flood basin swales or in low-lying abandoned distributary channels. Wet intervals resulted in occasional influxes of coarse material and small-scale channeling.

At the close of Aycross time, the sedimentary prism must have resembled a large bajadalike drape of volcaniclastic rocks, abutting eruptive centers on the west, and descending gradually into the Tatman lake basin to the east. The climate continued to be warm temperate to subtropical and supported a large flora and fauna.

Uplift of most of the southern Absaroka region, probably due to renewed volcanic activity, occasioned folding and erosion of partially consolidated Aycross rocks; and the Tepee Trail Formation, another fluviatile volcaniclastic unit, was deposited on eroded Aycross rocks. Tepee Trail floras and faunas indicate change to a drier, less equable climate, perhaps occasioned by increased development of a Bighorn Basin rain shadow as accumulation of rocks in the Absaroka region increased local elevations and changed wind patterns. The Tatman lake basin or a younger lake basin was filled and dislocated to the southeast, possibly dividing it into a number of smaller lakes. Fluviatile conditions finally prevailed everywhere in the southern Bighorn Basin, and the "Tepee Trail" strata (of Tourtelot, 1957) were deposited above Tatman-like rocks in the Lysite Mountain area, during the late middle Eocene.

The expansion of the Absaroka volcanic field to the south and east is recorded in middle Eocene time by local folding and erosion of Tepee Trail rocks and by the influx of coarse volcanic-derived sediments, flows, and intrusives in the overlying Wiggins Formation. Development of the "chaos zone," a widespread, highly deformed horizon in the lower Wiggins Formation, may have occurred contemporary with deposition of these beds, or might reflect disharmonic folding, lahar development, or detachment faulting. The drier conditions of Tepee Trail time persisted into the late middle Eocene, and mirror conditions in intermontane basins throughout the Rocky Mountain region.

Wiggins strata are the youngest Eocene rocks preserved in the Absaroka Volcanic Supergroup. These were cut by the Washakie Needles dacite plug in late Eocene or early Oligocene times (L. L. Love, and others, 1976), or only latest Eocene according to Berggren, McKenna, Hardenbol, and Obradovich (1978, fig. 2). Outliers of Oligocene and Miocene rocks on the Bighorn Mountains to the east and similar downfaulted remnants 95 km to the west (J. D. Love and others, 1976) indicate that deposition, accompanied by volcanic activity, persisted both in the Bighorn Basin region and in the western Absaroka area well into late Tertiary times. The level of fill of sediments in the Bighorn area was at least as high as the subsummit surface of the Bighorn Mountains, and probably higher (McKenna and Love, 1972; Setoguchi, 1978; McKenna, 1980).

Regional uplift, commencing in the Miocene, resulted in the rapid excavation of the Bighorn Basin. This degradational regime is recorded by the removal of more than 2,000 m of early and middle Eocene rocks, and by the removal of unknown thickness of younger rock from the eastern Absaroka area alone, and in the development of numerous erosion surfaces on the Wiggins Formation

FIGURE 20.—Variety 4 allochthon (Qlb) situated on gently deformed Aycross rocks (Ta) in the drainage of the North Fork of Owl Creek, SW¼ NE¼NE¼SE¼ sec. 34. T. 44 N., R. 101 W. Block is approximately 25 m high. View to north.

and older rocks. By Pliocene or early Pleistocene times, erosion in the Bighorn Basin had reached the level of the Tatman Mountain surface, only 400 m above the adjacent valley floor of the present Greybull River. Rapid headward erosion developed a high scarp on the eastern front of the Absaroka Range that was met by several basinward-inclined planar erosion surfaces. The large differential relief, earthquakes associated with Pliocene-Pleistocene intrusive activity, differential loading of the volcanic pile due to rapid erosion, and possible wet conditions in the late Tertiary and early Quaternary, all contributed to large-scale basinward displacement (detachment faulting) of Eocene volcanic rocks. Following this faulting, essentially eastward alined drainages in the report area were captured by the headward erosion of south-flowing tributaries to Cottonwood Creek, and several hundred meters of allochthonous material and underlying Aycross rocks were removed. In the valleys of Wood River and Gooseberry Creek, erosion removed all allochthonous material between Adam Weiss Peak and Squaw Buttes and isolated Willwood and Tatman rocks of the Buffalo Basin rim from those of the western border area and Squaw Buttes divide.

VERTEBRATE PALEONTOLOGY

FOSSIL VERTEBRATE LOCALITIES

The first large and definitive collections of vertebrate fossils from the lower volcaniclastic sequence in the southeast Absaroka Range were obtained in the summer of 1977 by field parties of the U.S. Geological Survey and the University of Wyoming from rocks of the Aycross and Tepee Trail Formations exposed in a large area, principally delimited by the South Fork of Owl Creek on the south, and Grass Creek on the north. E. L. Simons (in Wilson, 1963) recorded the occurrence of vertebrate fossils from this volcaniclastic sequence on and adjacent to Carter Mountain, some 48 km to the north. (This collection is now under study by myself and others.) The collections made by the U.S. Geological Survey were recovered from 65 sites in the Aycross Formation and 8 in the superjacent Tepee Trail Formation. Thirty-seven of the Aycross localities are believed to occur in the lower parts of the various local sections, and 28 are probably from the upper part of the Aycross Formation. The majority of the fossils described in this report are, consequently, from lower Aycross rocks; specimens from stratigraphically higher (including Tepee Trail) levels have thus far been isolated finds of fragmentary teeth and bones.

Three localities in the lower part of the Aycross sequence are especially rich in fossil vertebrate remains and have been quarried, washed, and (or) screened. Clay Gall quarry (USGS fossil vertebrate loc. D–1018) is developed at the base of a thin, coarse-grained and conglomeratic channel sandstone in sec. 33, T. 44 N., R. 100 W., Hot Springs County, Wyo. The fossils, principally shell fragments of turtles, scales of *Lepisosteus* sp. (a garfish), crocodilian teeth, and rare mammal teeth and jaws, occur in a mud gall conglomerate developed at the base of the sandstone and in a green, tuffaceous, sandy mudstone sequence above the sandstone. An anthill situated on top of the latter unit yielded about a dozen mammal teeth.

The origin of the green tuffaceous sandy mudstone is unknown; however, the mud gall conglomerate is reminiscent of many fossil vertebrate concentrations in the Fort Union, Polecat Bench (Jepsen, 1940), and Lance Formations and their equivalents elsewhere in Wyoming. In these instances, the vertebrate material may have been concentrated at low points on flood plains during high water stages marking episodes of stream channel relocation. (See for example, Bown, 1979a.) Other Aycross localities, for example D–1039, also yield fossils from mud gall conglomerates. Exposures in the vicinity of Clay Gall quarry are poor, and the productive beds could not be located elsewhere.

Vass quarry (USGS fossil vertebrate loc. D–1034, fig. 21) is developed in a green, fine-grained, tuffaceous, sandy mudstone, in sec. 33, T. 44 N., R. 100 W., Hot Springs County, Wyo., about 0.8 km southeast of Clay Gall quarry. The stratigraphic position of Vass quarry relative to Clay Gall quarry is uncertain, but it is probably lower, as judged from local dips, which are principally to the northwest (toward Clay Gall quarry). Vass quarry appears to be near the exposed base of the upthrown side of a minor overthrust fault, an observation that complicates the relation of this site to other localities. Although outcrops are few in the area surrounding Vass quarry (the exposed portion of the quarry bed is about 20 m long), only a few centimeters of col-

FIGURE 21.—Vass quarry (USGS Cenozoic vertebrate locality D–1034) in the lower part of the Aycross Formation, NW¼NE¼SE¼ sec. 33, T. 44 N., R. 100 W. This site is the richest vertebrate quarry known in the report area. At level of man's head is dark-green sandstone that has yielded approximately 40 species of middle Eocene mammals, comprising nearly 500 teeth, 150 jaws, and 1 skull. View to north.

luvium obscure the productive bed laterally and the unit would probably be accessible for quarry operations for more than 200 m if this slopewash veneer were removed.

Vass quarry is the single most productive vertebrate locality yet discovered in the Owl Creek–Grass Creek area and has already yielded a diverse microfauna. More than one-half of the vertebrates described in this report come from this site (table 3), and its future potential appears to be considerable. The fossil remains are principally those of small mammals; however, fish and lacertilians are also well represented, and they occur with the mammals dispersed more or less at random throughout the approximate 50-cm thickness of the quarry bed.

The site was quarried for about 20 man-days and approximately 5 m^3 of matrix was screen-washed for small mammals. Both weathered and unweathered matrix requires two stages of kerosene preparation, each followed by drying intervals, prior to underwater screening. Washing was accomplished by agitation of the screen boxes in shallow pits, and most of the resultant kerosene-impregnated residue was later removed from the wash site and transported to local landfills. Water is scarce in the Owl Creek–Grass Creek area, and it is doubtful that large-scale screen washing operations can be undertaken there in the near future. Vass quarry is named for Mr. and Mrs. Hugh Vass, who kindly permitted us to excavate at the site, which is on their land.

Flattop quarry (USGS fossil vertebrate loc. D–1033, fig. 22) is a lag concentration of fossil vertebrates, principally mammals, developed at the top of a small flat-topped hill in sec. 12, T. 43 N., R. 101 W., Hot Springs County, Wyo. All the fossils recovered to date from Flattop quarry were found on the surface of a deeply weathered, buff, tuffaceous shaly mudstone or on adjacent exposures of the underlying unit, a hard, platy, purple-mottled, bluish-green volcanic sandstone. The contact of the buff and bluish-green volcanic units is undulatory at Flattop quarry (maximum observed relief is about 60–70 cm), and this undulation suggests that at least some of the fossils may have been concentrated in shallow swales by running water, although this is by no means certain.

No fossils were found in units either directly above or directly beneath the buff and bluish-green units, respectively, and the nature of the fossil occurrences suggests that Flattop quarry owes its current productivity to a lag formed by the prolonged weathering and gradual removal of the buff unit. Examination of the productive bed elsewhere in the vicinity of Flattop quarry resulted in the discovery of a few bone fragments, but not additional concentrations. Sweeping the deeply weathered matrix into piles with brooms revealed several additional specimens; however, Flattop quarry matrix has not been washed or extensively quarried, and the future potential of this site is unknown.

A few other localities have yielded fragmentary vertebrate remains from lithologies similar to those at Vass and Flattop quarries, but these apparent lithic-fossil associations (as well as that of mud gall conglomerates and bone) are not consistent enough to be very useful as aids in prospecting. For example, lithologies at localities D–1054, D–1059, and D–1062 resemble the Vass quarry bed and couplet lithologies at localities D–1045, D–1049, and D–1051 are similar to those at flattop quarry. More than 40 other, apparently identical, lithic units, however, proved to be barren.

Fossils were also obtained from several badland exposures of gray or variegated bentonitic tuffaceous mudstones (fig. 6), but these finds were generally limited to a single specimen per locality. Only two such U.S. Geological Survey sites (D–1050 and D–1052) are important. The locations of the most important U.S. Geological Survey localities in the Aycross Formation are depicted on the geologic map (pl. 1) and a synopsis of the known fauna at each is presented in table 3.

FIGURE 22.—Flattop quarry (USGS Cenozoic vertebrate loc. D–1033) in the middle part of the Aycross Formation on the north side of the North Fork of Owl Creek, NE¼NW¼NE¼ sec. 12, T. 43 N., R. 101 W. Most of the fossils were found as a lag deposit on the broad flat where the man is collecting, though the whole of the flat as far away as the light-colored hill (arrow) in the middle distance yielded some specimens. View to north.

SYSTEMATIC PALEONTOLOGY

The mammalian fauna of the Aycross Formation described in this report is presently known from one skull, 25 jaw fragments, approximately 250 isolated teeth, and about 200 postcranial bones, edentulous jaws, and broken teeth. A much larger collection obtained in 1978, will be described in another report. These collections are housed in the United States National Museum, Washington, D.C., and the U.S. Geological Survey in Denver. An undescribed collection exists at the University of Wyoming. The USNM and U.S. Geological Survey specimens represent at least 56 mammalian species (31 are identified) of 40 identified genera. Five new genera and seven new species are recognized in this collection, and two new genera and three new species are described in the following paragraphs. Bown (1979b) has recorded four new taxa of Aycross primates.

Class MAMMALIA
Subclass ?ALLOTHERIA
Order ?MULTITUBERCULATA
?multituberculate, gen. et sp. indet.

Referred specimen.—USGS 2000, fragment of lower (?) incisor.

Discussion.—This specimen is the only potential record of the multituberculates in this collection and appears to represent the inferior border of a large lower incisor. The most satisfactory comparisons were made with the large early Wasatchian eucosmodontid *Neoliotomus*; however, USGS 2000 differs from incisors of that genus in several probably significant respects. Among these are (1) the flatter inferior border, less

TABLE 3.—*Locality occurrences of identified vertebrate fossils from the Aycross Formation, Owl Creek – Grass Creek area, Hot Springs County, Wyoming*

Taxon	Locality No.																										
	D-1017	D-1018	D-1019	D-1023	D-1024	D-1025	D-1029	D-1031	D-1033	D-1034	D-1039	D-1040	D-1041	D-1042	D-1044	D-1045	D-1047	D-1049	D-1050	D-1052	D-1054	D-1055	D-1056	D-1057	D-1060	D-1061	D-1062	D-1064
Trionychid, indeterminate	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trionyx sp., s.l.	X	—	—	—	—	—	—	X	—	X	X	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	X	—
cf. *Plastomenus* sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—
cf. *Echmatemys* sp.	X	—	—	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	X	—	—	—	—	—	—	—
Echmatemys sp	X	—	X	—	—	X	—	X	—	X	X	—	X	—	X	—	X	—	X	X	X	—	—	—	—	—	—	X
cf. *Baena* sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	—	—	—	—	—	—
cf. *Baptemys* sp.	X	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
Baptemys sp., cf. *B. wyomingensis*	X	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—
Hadrianus sp.	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—
Kinosternine, indeterminate	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lacertilians, indeterminate	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crocodilia, indeterminate	—	X	—	—	—	—	—	—	X	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
?Multituberculata, gen. et sp. indeterminate	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peradectes sp., cf. *P. innominatus*	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peratherium knighti	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peratherium sp., cf. *P. marsupium*	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palaeictops sp., cf. *P. bridgeri*	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apatemys sp., cf. *A. bellus*	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Apatemys sp., cf. *A. bellulus*	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
?Didelphodontinae, gen. et sp. indeterminate	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scenopagus curtidens	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scenopagus edenensis	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scenopagus sp., cf. *S. priscus*	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Macrocranion* sp.	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
?Adapisoricid, gen. et sp. indeterminate	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Myolestes* sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nyctitherium serotinum	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Nyctitherium* sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Pontifactor* sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nyctitheriid, gen. et sp. indeterminate	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microchiropteran, gen. et sp. indet.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microsyops sp., cf. *M. elegans*	—	X	—	—	—	—	—	—	X	X	—	—	—	—	—	X	—	—	—	—	X	—	X	—	—	—	X	—
Uintasorex parvulus	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alveojunctus minutus	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Phenacolemur* sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Omomys carteri	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Shoshonius sp., cf. *S. cooperi*	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Absarokius* sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aycrossia lovei	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Strigorhysis bridgerensis	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Strigorhysis rugosus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
Gazinius amplus	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notharctus sp.	—	X	—	—	—	X	—	—	X	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—
Proviverroides piercei	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Patriofelis sp.	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viverravus gracilis	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viverravine, gen. et sp. indeterminate	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Uintacyon sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mesonyx sp., cf. *M. obtusidens*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Hyopsodus sp., cf. *H. paulus*	—	X	—	—	—	—	—	—	X	X	—	—	—	—	—	X	—	—	X	—	X	—	—	—	X	—	X	—
Trogosus sp.	—	—	X	X	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	X	—	—	—	—	—	—	—
Bathyopsis sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—
Orohippus sp	—	X	—	—	X	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Eotitanops borealis	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	X
cf. *Eotitanops* sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
cf. *Palaeosyops fontinalis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
cf. *Helaletes nanus*	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hyrachyus modestus	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	X	—	X	—	—
Antiacodon pygmaeus	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Leptotomus* sp. "A"	—	X	—	—	—	—	—	—	X	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Leptotomus* sp. "B"	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thisbemys corrugatus	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—
cf. *Thisbemys* sp.	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Pseudotomus* sp.	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	X	X	—	—	—	—	—	—
Reithroparamys sp., cf. *R. delicatissimus*	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microparamys sp. "A"	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microparamys sp. "B"	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Taxymys cuspidatus	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

keeled and less sharp ventromedial border, (2) The less curved crown, and (3) the greater mediolateral breadth. The Aycross specimen is eroded and the superior part of the tooth is missing.

If a multituberculate, USGS 2000 is the fifth record of a post-Wasatchian member of this ancient group. (Robinson and others, 1964; Black, 1967; West and others, 1977; M. C. McKenna, oral commun., 1977).

Subclass THERIA
Infraclass METATHERIA
Order MARSUPIALIA
Family DIDELPHIDAE

Peradectes sp., cf. P. innominatus (Simpson, 1928)

Referred specimens.—USNM 250571, 250577, 250578, 250579, 250580, 250582, 251515, 251577.

Discussion.—Setoguchi (1973) recommended the inclusion of *Peratherium innominatum* Simpson (1928) in *Peradectes*, a view that is endorsed here. The most complete known lower jaw is UW 984, a right P_3–M_4 (McGrew and others, 1959).

The Aycross teeth of *Peradectes* sp., cf. *P. innominatus* are closely comparable in morphology and size to both the type of the species and UW 984. Both of the latter specimens have extremely short molar talonids with respect to trigonid lengths. In this respect they resemble the Aycross specimens more closely than they do materials assigned to *Peratherium innominatum* by West (1973a). Moveover, some of West's specimens are markedly broader than are molars in the type of *P. innominatus*, UW 984, or the Aycross sample.

Measurements.—Given in table 4.

Peratherium knighti McGrew, in McGrew and others, 1959

Referred specimens.—USNM 250572, 250574, 250583, 250584, 250585, 250586, 251576, 251649, 251650.

Discussion.—The Aycross sample of *P. knighti* is virtually identical to comparable teeth of this species described by Setoguchi (1975) from late Eocene localities near Badwater, Wyo. Most Badwater and Aycross *P. knighti* is slightly smaller than known material from Tabernacle Butte.

Measurements.—Given in table 4.

Peratherium sp., cf. P. marsupium Troxell, 1923

Referred specimen.—USNM 250573.

Discussion.—This single lower molar is somewhat larger than the largest M_2 or M_3 of *P. knighti* ($L \approx 2.30$ mm), and somewhat smaller than that tooth in the type of *Peratherium marsupium* ($L=2.70$ mm). The most robust cusps in USNM 250573, however, argue for closer affinity to Troxell's species.

Measurements.—Given in table 4.

Infraclass EUTHERIA
Order PROTEUTHERIA
Superfamily LEPTICTOIDEA
Family LEPTICTIDAE

Palaeictops sp., cf. P. bridgeri (Simpson, 1959)

Referred specimens.—USNM 251452, 251453, 251454, 251573.

Discussion.—Van Valen (1967) incorporated Simpson's (1959) *Diacodon bridgeri* in *Palaeictops*, a procedure followed by Novacek (1977). Four specimens in the collection at hand appear to represent *Palaeictops bridgeri*; however, two specimens of molars make this assignment tentative because of their relative small size.

P_5 (traditionally P_4) is represented by two specimens, both of which have the paraconid well removed anteriorly from the protoconid, as in *P. bridgeri*; and the trigonids are, hence, not anteroposteriorly compressed as in *P. bicuspis* and *P. multicuspis*. P_5 is larger than in *P. bicuspis* or *P. matthewi* and is about equal in size to that tooth in *P. multicuspis* and the type of *P. bridgeri*. In USNM 251452, the P_5 metaconid appears to be closer to the protoconid than in the type of *P. bridgeri*; however, this may be an artifact of wear.

The molars are somewhat smaller than in the type of *P. bridgeri* and approach the size of *P. bicuspis*. The M_1 talonids are narrower than are the trigonids. From Novacek's (1977) measurements and from other data of mine, this not the case in at least some *P. biscuspis*. Rather, it is more typical of *P. multicuspis*, occurs in some *P. bridgeri*, and is the rule in *Prodiacodon*.

Measurements.—(mm): P_5L ($N=2$) = 4.10–4.30, P_5W ($N=2$) = 2.00–2.30; M_1L ($N=2$) = 3.00–3.10, M_1WTr ($N=2$) = 2.15–2.20, M_1WTa ($N=2$) = 2.05–2.10.

Superfamily APATEMYOIDEA
Family APATEMYIDAE

Apatemys sp., cf. A. bellus Marsh, 1872

Referred specimen.—USNM 251450.

Discussion.—West (1973b) included all earlier recognized Eocene species of *Apatemys* in a single species, *A. bellus* Marsh. Because relatively few apatemyid specimens are known and because precise stratigraphic control for most of these is poor at best, Bown (1979a) recommended that other named species be retained until a clearer picture of apatemyid interrelationships should emerge. (See also Bown and Schankler, 1981.)

Apatemyids are represented by only four teeth in the

TABLE 4.—*Measurements, in millimeters, of teeth of Aycross didelphids*

[nm, not measurable; leaders (- -), no tooth]

USNM No.	M_1L	M_1W	M_2L	M_2W	M_3L	M_3W	M_4L	M_4W	M^2L	M^2W	M^3L	M^3W
					Peradectes sp., cf. P. innominatus							
250578	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.40	1.85
250579	- -	- -	1.45	0.85	- -	- -	- -	- -	- -	- -	- -	- -
250580	- -	- -	1.50	0.85	- -	- -	- -	- -	- -	- -	- -	- -
250582	- -	- -	- -	- -	- -	- -	1.40	0.80	- -	- -	- -	- -
251577	- -	- -	- -	- -	1.50	0.80	- -	- -	- -	- -	- -	- -
					Peratherium knighti							
250572	2.00	1.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
250574	- -	- -	- -	- -	- -	- -	- -	- -	2.00	2.60	- -	- -
250583	[1]2.25	1.40	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
250584	- -	- -	- -	- -	2.00	1.10	- -	- -	- -	- -	- -	- -
250586	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	nm	2.35
251576	2.10	1.15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
251649	2.10	1.10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
251650	2.10	1.15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
					Peratherium sp., cf. P. marsupium							
250573	- -	- -	- -	- -	2.50	1.50	- -	- -	- -	- -	- -	- -

[1]May be M_2.

Aycross collection; however, because all of these are from a single quarry they appear to be separable into two species, on the basis of size. The two lower molars (both M_2) fit well with samples earlier ascribed to *Apatemys bellus* and *A. bellulus* and are here tentatively referred to those species.

Measurements.—(mm): M_2L = 2.35; M_2WTr = 1.60; M_2WTa = 1.50.

Apatemys sp., cf. A. bellulus Marsh, 1872

Referred specimens.—USNM 251449, 251451, 251592.

Discussion.—See previous section.

Measurements.—(mm): M_2 = 1.85; M_2WTr = 1.30; M_2WTa = 1.20.

?Superfamily PALAEORYCTOIDEA
?Family PALAEORYCTIDAE
?Subfamily DIDELPHODONTINAE
?didelphodontine, gen. et sp. indet.

Referred specimen.—USNM 251456.

Discussion.—This solitary tooth conforms well with P_4 in *Didelphodus absarokae* in nearly all respects, with the exception that there is no metaconid and the tooth is smaller than in that Wasatchian species. It differs from P_3 in *Didelphodus altidens* in the better basined talonid and stronger paraconid.

Measurements.—(mm): $P_{3 or 4}L$=2.45, $P_{3 or 4}W$=1.30.

Order INSECTIVORA
Suborder ERINACEOMORPHA
Family ADAPISORICIDAE
Scenopagus curtidens (Matthew, 1909)

Plate 2*A*, *B*

Referred specimens.—USGS 2001 (pl. 2*A*), USGS 2002 (pl. 2*B*), USNM 251463, 251464, 251466, 251471, 251581.

Discussion.—Although this species can be confidently identified in the Aycross collection by means of the lower teeth, the assignment of upper teeth, including a superb maxillary fragment preserving P^3-M^3 (USGS 2002) has been hampered by a relative lack of comparative material. Only one upper molar of *Scenopagus curtidens* has previously been described (Krishtalka, 1976a), upper teeth of *Talpavus* are unknown, and TTU-P 7051, the only referred P^4 of *Scenopagus priscus*, has been misplaced. Nevertheless, the upper teeth at hand are morphologically closest to those of *Scenopagus edenensis* and *S. priscus* but are intermediate in size. Because USGS 2002 is probably the most complete upper dentition of *S. curtidens*, the specimen is compared in detail with the well-known upper teeth of *Scenopagus edenensis*.

P^3 does not possess a parastyle as it does in *S. edenensis* (as, AMNH 56035), and P^4 has no hypocone as it has in the latter species. The parastylar shelf of P^4 is relatively larger and more rounded than in *S. edenensis* and the P^4 postparacrista is relatively longer than in some specimens of that species (longer than CM 6433, about the same as in AMNH 56035).

M^1 is transversely relatively broader than in *Scenopagus edenensis*, and this tooth approximates the length/breadth ratio seen in *S. priscus*. The M^1 paraconule is more labially situated beneath the paracone in USGS 2002 than in *S. edenensis* and closely resembles the condition in TTU-P 7060, M^1 of *S. priscus*. The conules are, however, weaker than in *S. priscus*, and on M^1 the paraconule is weaker than in *S. edenensis*. On M^2 the paraconule is weak to absent.

M^{1-2} appear to have a less strongly developed hypocone shelf in USGS 2002 than in *S. edenensis;* however, this shelf is strong in USNM 251466, and the teeth in the maxilla are more abraded. M_3 is relatively unreduced in *Scenopagus edenensis;* whereas M^3 is reduced relative to M^2 in USGS 2002, like the condition in *S. priscus*. M_3 is also reduced relative to M_2 in jaws of *Scenopagus curtidens*, suggesting that this relationship exists in the upper teeth and supporting the assignment of USGS 2002 to this species.

Lower teeth of *Scenopagus curtidens* in the Aycross sample are best represented by USGS 2001 (pl. 2*A*). In this specimen, the P_4 metaconid has been broken off. The talonid of P_4 is weakly developed but is stronger than in *Talpavus* and is about as strong as in *Plagioctenodon krausae* (Bown, 1979a)—and other *Scenopagus curtidens* (as, YPM 15254). P_4 is relatively small with respect to M_1, however, and in this character resembles the relationships seen in *Talpavus* and some *Plagioctenodon*. Both USGS 2001 and USNM 251464 differ from most *Scenopagus curtidens* in having a deep paracristid notch on P_4 separating the paraconid and protoconid on the labial side, more like the conditions in *S. edenensis* and *S. priscus*. In USNM 251464, the P_4 trigonid is a little longer and narrower than in other *S. curtidens* and does not have a labial bulge beneath the protoconid.

The M_{1-2} metaconids are not as tall and do not flare posterolingually as in *Talpavus nitidus* or as in *T.* sp., cf. *T. nitidus* of Krishtalka (1976a). The entoconids of M_{1-2} are not so lingually flared, and the M_1 talonid is less labially skewed than in other *Scenopagus curtidens*.

Measurements.—Given in table 5.

Scenopagus edenensis (McGrew, in McGrew and others, 1959)

Referred specimen.—USNM 251462.

Scenopagus sp., cf. *S. priscus* (Marsh, 1872)

Referred specimen.—USNM 251459.

Discussion.—Two teeth conform closely with specimens of *S. edenensis* and *S. priscus*, respectively, in terms of both size and morphology. *S. edenensis* and *S. priscus* occur together at Powder Wash, Utah, and *S. edenensis* and *S. curtidens* occur mutually at some Bridger Formation localities, so the occurrence of all three species at Vass quarry is probably not unusual.

Measurements.—Those of Aycross *Scenopagus* are provided in table 5.

cf. *Macrocranion* sp.

Referred specimen.—USGS 2007, 2008.

Discussion.—Krishtalka and Setoguchi (1977) described *Macrocranion robinsoni* as a new, late Eocene species from near Badwater, Wyo. *Macrocranion nitens* is a rare Wasatchian species. The two teeth at hand, if actually referable to *Macrocranion*, are the first record of this genus from the middle Eocene of North America and may prove, when better known, to represent a third species.

USGS 2007 is a P_4 about the size of that tooth in *Scenopagus edenensis* and hence larger than P_4 in either *M. nitens* or *M. robinsoni*. The tooth differs from P_4 in *Scenopagus edenensis* in having a paraconid more anteriorly removed from the metaconid and in having a deep valley separating the metaconid and protoconid. Both of these characters are diagnostic of *Macrocranion*; however, the talonid is more rounded posteriorly as in *Scenopagus*, not more squared as in *Macrocranion nitens*. The paracristid notch is only slightly higher than the talonid notch, as in *Macrocranion*. (See Krishtalka, 1976a.)

M_2 has a talonid that is both wider and longer than the trigonid as in *M. nitens*, but the cristid obliqua is more nearly parallel to the postvallid than in that species.

Measurements.—(mm): $P_4L = 2.05$, $P_4W = 1.30$; $M_2L = 2.15$, $M_2WTr = 1.55$, $M_2WTa = 1.70$.

?adapisoricid, gen. et sp. indet.

Referred specimen.—USNM 251470.

Discussion.—A probable adapisoricid approximately 15 percent smaller than *Scenopagus priscus* is represented by this specimen. No entoconid crest appears on M_2 as occurs in *Nyctitherium*, and the trigonids of M_{2-3} are more compressed anteroposteriorly than in that genus. The trigonid of M_3 is reduced relative to that for M_2 as in *Scenopagus priscus* and *S. curtidens*.

Measurements.—(mm): $M_2L = 1.25$, $M_2WTr = 0.90$, $M_2WTa = 0.85$.

TABLE 5.—*Measurements, in millimeters, of teeth of* Scenopagus *from the Aycross Formation*

[nm, not measurable; leaders (- -), no tooth]

USNM No.[1]	P_4L	P_4W	M_1L	M_1W	M_2L	M_2W	P^3L	P^3W	P^4L	P^4W	M^1L	M^1W	M^2L	M^2W	M^3W
							Scenopagus curtidens								
USGS 2001	1.60	1.05	1.85	1.60	1.80	1.60	- -	- -	- -	- -	- -	- -	- -	- -	- -
USGS 2002	- -	- -	- -	- -	- -	- -	0.85	0.80	1.60	1.85	1.70	2.35	1.55	2.40	1.05
251463	- -	- -	- -	- -	1.80	1.50	- -	- -	- -	- -	- -	- -	- -	- -	- -
251464	1.70	1.10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
251466	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.80	2.50	- -	- -	- -
251471	- -	- -	- -	- -	- -	- -	- -	- -	1.90	nm	- -	- -	1.70	2.70	- -
							Scenopagus edenensis								
251462	- -	- -	- -	- -	2.35	1.85	- -	- -	- -	- -	- -	- -	- -	- -	- -
							Scenopagus sp., cf. S. priscus								
251459	- -	- -	1.70	1.10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

[1]All USNM except USGS 2001, 2002.

Suborder SORICOMORPHA
Superfamily SORICOIDEA
Family GEOLABIDIDAE
cf. Myolestes sp.

Referred specimens.—USGS 2009, 2010, 2011.

Discussion.—An upper first molar (USGS 2009) is about the size of that tooth in *Scenopagus priscus* but differs from *Scenopagus* in its taller, more acute cusps, longer postmetacrista, smaller hypocone shelf, relatively higher prevalla and postvalla, stronger preparaconule and postparaconule and metaconule cristae, and stronger precingulum. In all of these features, the tooth resembles *Myolestes* and *Centetodon*, but most of these are equally applicable to *Batodon*, a Late Cretaceous form that M. C. McKenna (oral commun., 1976) has suggested might lie near the ancestry of *Centetodon*. Unfortunately, no upper teeth are known of either *Centetodon pulcher* or a new Bridgerian species under description by J. A. Lillegraven and M. C. McKenna (unpub. data, 1980). The specimen differs from TMM 40492-44 from the Chambers Tuff (De Ford, 1958) in Texas (also referred to a new species by Lillegraven and McKenna; same as *Centetodon* sp. C of Krishtalka and Setoguchi, 1977) in its smaller hypocone, less lingually continuous talon, larger parastylar area, and better developed preparaconule and postparaconule and metaconule cristae. From *Batodonoides* Novacek (1976), USGS 2009 differs in having a smaller parastylar area and the presence of a metaconule and metaconule cristae. No specimens of *Batodonoides* were seen, however, and comparisons were only made with figures and text descriptions.

USGS 2010, a P_4, is very narrow transversely as it is in *Myolestes*, *Batodonoides*, and a new Bridgerian species of *Centetodon* from Tabernacle Butte (J. A. Lillegraven and M. C. McKenna, unpub. data, 1980). The remainder of the morphology is virtually identical to that in *Myolestes* and various species of *Centetodon*, except that the P_4 paraconid is less cuspidate and arises somewhat higher on the face of the trigonid.

M_2 mirrors *Centetodon* in the low entoconid, acute cusps, projecting hypoconulid, and in the angle of the cristid obliqua.

The specimens at hand do not belong to any described species of *Centetodon*, nor do they appear to belong to undescribed Wasatchian material of the genus from the Willwood Formation in the Yale collection (Bown and Schankler, 1981). It is possible, however, that they belong to one of the several new forms currently under study by Lillegraven and McKenna.

Measurements.—(mm): M^1L = 1.60, M^1W = 2.15; P_4L = 1.45, P_4W = 0.70; M_2L = 1.55, M_2WTr = 1.00, M_2WTa = 0.90.

Family NYCTITHERIIDAE
Nyctitherium serotinum (Marsh, 1872)

Referred specimen.—USNM 250581.

Discussion.—This specimen, an M_2, is identical to that in CM 13722 (*N. serotinum*) from Powder Wash, Utah (Krishtalka, 1976b).

Measurements.—(mm): M_2L = 1.40, M_2W = 0.95.

cf. Nyctitherium sp.

Referred specimen.—USNM 250576.

Discussion.—This tooth has a relatively longer trigonid (more anterior paraconid) and a larger, more medial hypoconulid than do M_{1-2} of *Nyctitherium serotinum*. To some extent, these are similarities shared with some specimens of *N. velox*; however, there is no strong ectocingulid as is typical in that species.

Measurements.—(mm): M_1L = 1.60, M_1W = 1.00.

cf. Pontifactor sp.

Referred specimen.—USNM 251458.

Discussion.—This specimen, an M^2, is clearly of nyctitheriid morphology and, in the relatively small talon and absence of a lingual cingulum, more closely resembles *Pontifactor* than *Nyctitherium*. The labial border of the tooth is missing, however, and the presence of a mesostyle (a characteristic of *Pontifactor*) cannot be determined.

?nyctitheriid, gen. et sp. indet.

Referred specimen.—USNM 251461.

Discussion.—This tooth resembles closely the I_2 of *Saturninia grisollensis* described and figured by Sigé (1976, p. 31 and fig. 27), though the Aycross specimen has a relatively broader lingual basin. The second lower incisor of *Amphidozotherium cayluxi* (Sigé, 1976, fig. 95) is less similar. It is now probable that at least some North American and European nyctitheriids were using their enlarged, specialized medial incisors for similar purposes.

Order CHIROPTERA
Suborder MICROCHIROPTERA
gen. et sp. indeterminate
Plates 2*C*, 2*E*

Referred specimens.—USGS 2003 (pl. 2*C*), 2004 (pl. 2*E*).

Discussion.—USGS 2004 is an M^3 about the size of that in living *Myotis lucifugus* and closely resembles M^3 in that species, with the exception that the Aycross specimen is transversely broader. There are also resemblances to M^3 in *Icaronycteris*? *menui* Russell, Louis, and Savage (1973) of the French early Eocene. USGS 2003 is an M_2 of an unknown mammal, probably a microchiropteran. The tooth also bears some similarity to M_2 in some of the earliest shrews. The trigonid is slightly more compressed anteroposteriorly than in the shrew *Domnina gradata*, and the prevallid and cristid obliqua are less oblique. The entoconid is very large and is connected to the metaconid by a well-developed entocristid. The cristid obliqua joins the postvallid lingual to the anteroposterior midline of the tooth, and the hypoflexid is, consequently, very broad. The ectocingulid is continuous with the precingulids and postcingulids but fades somewhat beneath the hypoconid. The configuration of this molar is also remarkably similar to M_1 or M_2 in living tupaiids.

Measurements.—(mm): USGS 2003, M_2L = 1.90, M_2W = 1.25;, USGS 2004, M^3L = 0.90, M^3W = 1.25.

Order PRIMATES
Suborder PLESIADAPIFORMES
Family MICROSYOPIDAE
Subfamily MICROSYOPINAE
Microsyops sp., cf. M. elegans (Marsh, 1871)

Referred specimens.—USNM 251487-251508.

Discussion.—Teeth of *Microsyops* in the Aycross collection reflect considerable variability in size and span the ranges of *M. elegans* and *M. scottianus* in both size and morphology, supporting Szalay's (1969a) suggestion that the two species may come to be regarded as synonymous. USNM 251499 and 251503 even reach the lower part of the size range for *Microsyops annectens*; however, all other teeth are too small to be included in either that species or in *M. lundeliusi*.

P^4 in the Aycross specimens has no mesostyle and only a very small foldlike metaconule, much as in some *M. scottianus* (as, AMNH 14703). The presence of a metaconule appears to be quite variable, and this cusp is absent on USNM 22117. (See Szalay, 1969a, pl. 44, 1–2.) The molars are nearly identical in morphology with those of *M. scottianus* and *M. elegans*, and the two aberrantly large specimens noted above do not have the markedly bunodont cusps or wrinkled enamel that characterize some cheek teeth of *Microsyops annectens*.

Measurements.—Given in table 6.

Subfamily UINTASORICINAE
Uintasorex parvulus Matthew, 1909

Referred specimens.—USNM 250592, 251447, 251580.

Discussion.—These teeth do not differ appreciably from comparable teeth of *Uintasorex parvulus* described by Szalay (1969b). A lower incisor, although slightly larger, compares favorably with that in AMNH 55664 (Szalay, 1969b, figs. 4, 5) and is probably too small to belong to the new taxon described below.

Measurements.—(mm): M_1L = 1.10, M_1W = 1.00.

Alveojunctus, gen. nov.

Etymology.—Latin *alveus*=hollow, and latin *junctus*=unite or connect; in reference to the joined trigonid and talonid basins on the lower molars.

Type.—*Alveojunctus minutus*, sp. nov. and only known species.

Diagnosis.—P_4 relatively longer than in *Niptomomys* or *Uintasorex* and metaconid strong to absent. P_4 entoconid larger and taller than in latter two genera and posterior part of tooth rounded, not straight. P_4 paraconid cristidlike to cuspidate, larger than in *Niptomomys* and about as large as in *Uintasorex*. Postvallid

TABLE 6.—*Measurements, in millimeters, of teeth of* Microsyops *sp., cf.* M. elegans *from the Aycross Formation*

[nm, not measurable; leaders (- -), no tooth]

USNM No.	P_4L	P_4W	M_1L	M_1W	M_2L	M_2W	M_3L	M_3W	
251487	4.30	3.00	3.80	3.22	4.25	3.60	5.30	3.30	(composite)
251489	4.00	2.90	4.15	3.05	4.10	3.10	- -	- -	(composite)
251493	4.20	3.00	- -	- -	- -	- -	- -	- -	
251499	- -	- -	- -	- -	4.90	3.65	- -	- -	
251502	- -	- -	- -	- -	4.25	3.30	- -	- -	
251503	- -	- -	- -	- -	4.70	3.70	- -	- -	
251504	4.05	2.70	- -	- -	- -	- -	- -	- -	
251507	- -	- -	- -	- -	- -	- -	5.20	3.20	

USNM No.	P^4L	P^4W	M^1L	M^1W	M^2L	M^2W	M^3L	M^3W	
251488	4.30	5.10	- -	- -	4.50	5.40	- -	- -	(composite)
251490	- -	- -	- -	- -	4.55	5.50	- -	- -	
251492	3.95	4.60	- -	- -	- -	- -	- -	- -	
251494	- -	- -	- -	- -	- -	- -	4.50	nm	
251495	- -	- -	- -	- -	- -	- -	4.40	5.10	
251497	- -	- -	4.45	5.45	- -	- -	- -	- -	
251505	4.25	5.30	- -	- -	- -	- -	- -	- -	
251508	- -	- -	- -	- -	- -	- -	nm	4.50	

slope of P_4 gentle, not steep as in *Niptomomys* or *Uintasorex* and resulting in much larger talonid basin. P_4 entoconid and M_1 metaconid and entoconid with tendency to wear flat.

P_4 60 percent larger than in *Niptomomys*, 100 percent larger than in *Uintasorex*; M_1 35 percent larger than in *Niptomomys* and 60 percent larger than in *Uintasorex*. M_1 with trigonid open posteriorly, protocristid absent, and trigonid and talonid basins joined, in contrast to both *Niptomomys* and *Uintasorex*. M_1 trigonid short, not taller than entoconid as in latter two genera, and M_1 metaconid and entoconid very large and attenuated anteroposteriorly, larger than protoconid and taller than hypoconid or protoconid. Entocristid absent on M_1 and talonid notch narrow and acute.

Talonid basins of P_4–M_1 very broad (relatively broader than in *Niptomomys* or *Uintasorex*) and cristids obliqua confluent with labial margin of protoconid. Hypoflexid absent on P_4, minute on M_1. P_4-M_1 have no cingulids.

Alveojunctus minutus, sp. nov.

Plate 2*D*

Etymology.—Latin *minutus*=small.

Holotype.—USGS 2005 (pl. 2*D*), right M_1.

Locality.—USGS fossil vertebrate locality D-1034 (Vass quarry), Aycross Formation (lower part of local section), middle Eocene, sec. 33, T. 44 N., R. 100 W., Hot Springs County, Wyo.

Hypodigm.—The type and the following specimens: USNM 250589, 250593, 250594, 251446, USGS 2006 (pl. 2*D*), all from Vass quarry (topodigm); possibly also FMNH-PM 28689 (West and Dawson, 1973, fig. 30), Cathedral Bluffs Tongue of Wasatch Formation, early Bridgerian (middle Eocene).

Diagnosis.—Only known species.

Measurements.—(mm): M_1L (type) = 1.75, M_1W = 1.25; P_4L (N=5)=1.90–2.10, P_4W (N=5)=1.00–1.20; ?M_3L = 1.90, ?M_3W = 1.45.

Discussion—Alveojunctus is one of the most distinctive of the uintasoricine microsyopids. The type specimen, an isolated M_1, is so unusual and aberrantly specialized that erection of a new genus based on this specimen is only warranted by its quarry association with several unusual specimens of uintasoricine-like P_4's, and the recognition of a similarly shaped lower molar (?M_3) in another collection.

In spite of the distinctive morphologies of P_4 and M_1, allocation of the new taxon to the Uintasoricinae appears to be warranted by (1) its relatively small size, (2) the molarized P_4 talonid, (3) the cuspidate M_1 paraconid, (4) the relatively broad basins of the molars, and (5) the connate hypoconulid and entoconid but poorly developed hypoconulid-entoconid notch.

West and Dawson (1973) assigned a third lower molar to cf. *Niptomomys* sp. but described the unusual confluence of the trigonid and talonid basins and observed that the specimen may belong to a new uintasoricine taxon. This specimen, although larger, closely resembles the type of *Alveojunctus minutus* and is here tentatively referred to that species. The M_3 has no paraconid as occurs in the type of *Alveojunctus* (an M_1).

Alveojunctus does not closely resemble *Uintasorex montezumicus* Lillegraven (1976), either of two probably new uintasoricines from the Tepee Trail Formation (M. C. McKenna, oral commun., 1977), or UCMP 95949, an undescribed uintasoricine from upper Wasatchian rocks of the Washakie Basin (D. E. Savage, oral commun., 1971).

Family PAROMOMYIDAE

cf. Phenacolemur sp.

Referred specimens.—USNM 250587, 250588.

Discussion.—These lower molars have deeper basins and relatively taller hypoconids and entoconids than in *Ignacius* and are not so smoothly sculptured as in that form. (See Bown and Rose, 1976.) The teeth are in the size range of *Phenacolemur jepseni* and of undescribed "Lysite" *Phenacolemur* from the Willwood Formation of the Bighorn Basin (T. M. Bown and D. Schankler, unpub. data, 1980), and they fall in the lowest part of the range of measurements for Gray Bull *Phenacolemur praecox* (including *P. citatus*; Bown, 1979a). The specimens are too large to occlude with upper teeth of *Ignacius mcgrewi*.

The Aycross specimens are the first described teeth of cf. *Phenacolemur* from middle Eocene rocks although West (1972) has observed that the genus probably occurs in Bridger Formation ("B") localities. *Ignacius mcgrewi*, another paromomyid, is known from the middle Eocene part of the Cathedral Bluffs Tongue of the Wasatch Formation in the northern Green River Basin (West and Dawson, 1973), and from the so-called "Tepee Trail" Formation near Badwater, Wyo. (Robinson, 1968). *Ignacius*-like paromomyids also occur in the upper Eureka Sound Formation (Eocene) on Ellesmere Island (West and others, 1977).

Suborder HAPLORHINI

Infraorder TARSIIFORMES

Family OMOMYIDAE

Subfamily OMOMYINAE

Omomys carteri Leidy, 1869

Referred specimen.—USNM 250598.

Discussion.—This tooth (an M^2) has a shallower ectoflexus than M^2 of most specimens of *O. carteri* (for example, YPM 13229) but otherwise closely conforms with that species. The pericone shelf is more distinct, but the lingual cingulum is less well developed between the pericone and talon than in YPM 11584 (type of "*Palaeacodon vagus*").

Measurements.—(mm): M^2L = 2.45, M^2W = 3.60.

Shoshonius sp., cf. S. cooperi Granger, 1910

Referred specimens.—USNM 250599, 251448, 251579.

Discussion.—Szalay (1976) believed that teeth of *Shoshonius* and *Washakius* could be distinguished by the well-developed upper molar mesostyles, P^{3-4} metacones, and relatively constricted M_{2-3} trigonids in *Shoshonius*. Mesostyles do occur on upper molars referred to *Washakius* (for example, UW 10275; Szalay, 1976, fig. 96), and metacones can exist on P^{3-4} in both genera. However, the development of both of these features is certainly more pronounced in materials ascribed to *Shoshonius*.

The assignment of the Aycross specimens to *Shoshonius* is based on the strong M^2 mesostyle and the construction of P^3. The latter tooth appears to have a smaller parastyle and a greater degree of posterior emargination in *Shoshonius* and, in these characters, resembles the condition in USNM 251579. The Aycross M_2 (USNM 250599) has the metastylid closely appressed to the metaconid as in most *Washakius*; however, the talonid structure is more reminiscent of that in *Shoshonius* materials available to me.

Measurements.—(mm): M_2L = 2.25, M_2W = 1.95; P^3L = 1.80, P^3W = 2.25; M^2L = 2.00.

Subfamily ANAPTOMORPHINAE

cf. Absarokius sp.

Referred specimen.—USNM 251517.

Discussion.—This tooth appears to have had a relatively broad talonid as in *Anaptomorphus* and *Absarokius witteri*, and it exhibits faint crenulations as occur in both *A. witteri* and *Aycrossia lovei* (Bown, 1979b). The talonid basin appears to have been less bowl-shaped than in *Anaptomorphus*. The paraconid is closer to the metaconid than in *Aycrossia lovei*, and the tooth is larger than in that species. The enamel is considerably less crenulated than in *Strigorhysis* and resembles the faint crenulations in the type of *Absarokius witteri*, the only other Bridgerian specimen of *Absarokius*. Better knowledge of the manifestation of enamel crenulation in worn teeth of *Strigorhysis bridgerensis* may later necessitate reference of this specimen to that genus.

Aycrossia lovei Bown, 1979b

Referred specimens.—USNM 250595, 250596, 250597, 251518.

Discussion.—The I_2 and M_2 at hand are virtually identical to USNM 250566 and 250562, respectively (Bown, 1979b), and the M_2 extends the known occurrence of *Aycrossia* to Clay Gall quarry, as well as Vass quarry.

P_3 differs from that in the type specimen in the longer and more rounded lingual border and resultant greater posterior emargination. The less posterior emargination in the type was treated as a diagnostic character in this taxon, and it now appears to be a variable feature of the tooth.

USNM 250596 is tentatively referred to I^2 of *Aycrossia*. The anterior cristid is shorter and the heel is less raised than in I_2, but otherwise the teeth are similar in construction.

Measurements.—(mm): I_2L = 1.10, I_2W = 1.15; M_1L = 2.45, M_1W = 2.00; I^2L = 0.90, I^2W = 0.90; P^3L = 1.70, P^3W = 2.00.

cf. Strigorhysis bridgerensis Bown, 1979b

Referred specimens.—USNM 251516, 251519.

Discussion.—Both specimens of M_1 (combined in USNM 251516) lack the talonids; however, the postvallid enamel is highly rugose, a condition typical of M_{2-3} in *Strigorhysis*, but one that is unknown in more complete materials of *Aycrossia*. M_1 was unknown at the time of description of *Strigorhysis*. The specimens closely resemble M_1 in *Aycrossia* in the possession of large, posteriorly deflected metaconids, oblique postvallids, and in the presence of a parastylid.

M_3 differs from that tooth in both *Strigorhysis* and *Aycrossia* in the absence of an anterolabial shelf and in the consequent narrowing of the trigonid and hypoflexid regions. The enamel is very strongly crenulated as it is in *Strigorhysis*, and the presence of the anterolabial shelf is probably a variable character, as it appears to be in populations of the notharctine *Pelycodus*.

Measurements.—(mm): M_3L = 2.60, M_3W = 1.65.

Suborder STREPSIRHINI
Infraorder LEMURIFORMES
Family ADAPIDAE
Subfamily NOTHARCTINAE
Notharctus sp.

Referred specimens.—USNM 251480–251485.

Discussion.—Gingerich (1979) has recently reviewed the middle Eocene species of *Notharctus* and recognized four species on the basis of molar size and the degree of symphyseal fusion. Although additional morphological criteria are desirable, particularly to aid in the identification of samples of isolated teeth, such a synthesis does not appear to be forthcoming. Robinson (1957), following earlier workers, utilized M_3 morphology, presence or absence of an M_1 paraconid, and presence or absence of a twinned P^4 paracone as aids in distingushing species of *Notharctus*. It nevertheless appears that middle Eocene species of *Notharctus* are closely knit: I find that all of these characters are probably interspecifically variable and, coupled with the rather sizable overlap in tooth dimension between subjacent and superjacent populations, not usefully diagnostic.

In the absence of more meaningful criteria for identification, it is impossible to assign the Aycross *Notharctus* sample to a species. USNM 251483, an M_3 from low in the local Aycross section, is approximately equal to size to M_3 in the type of Gingerich's *N. robinsoni* and differs from that tooth only in the absence of the small paraconid. Five additional teeth of *Notharctus* were recovered from localities that are probably higher in their local sections. These teeth appear to represent a larger species of *Notharctus*; M_1 and M_2 most closely resemble their counterparts in AMNH 11461, the type of *N. pugnax*.

According to Gingerich (1979), *Notharctus robinsoni* occurs in the Bridger "A" faunal interval near Opal, Wyo., in the Eocene Huerfano Formation of Colorado and, possibly, from the Foster Reservoir locality at the base of Carter Mountain in the Bighorn Basin. The age of the Foster Reservoir assemblage is uncertain, but it is probably of middle Eocene age (E. L. Simons, in Wilson, 1963).

Notharctus pugnax is most common in early Bridgerian ("B") rocks of the Bridger and Green River Basins, Wyo. The Aycross specimens are much too small to belong to late Bridgerian *Notharctus robustior* and differ in both size and morphology from comparable teeth of *Smilodectes*.

Measurements.—(mm): M_1L = 6.00; M_2L = 7.00, M_2W = 5.50; M_3L = 7.60, M_3W = 4.50; P^3L = 3.90, P^3W = 5.75; M^1L = 6.30, M^1W = 7.45; M^2W = 8.70.

Order CREODONTA
Family HYAENODONTIDAE
Subfamily HYAENODONTINAE
Tribe PROVIVERRINI
Proviverroides, gen. nov.

Etymology.—Greek *eides*, like; in allusion to similarities shared with *Proviverra*.

Type.—*Proviverroides piercei*, sp. nov. and onlv known species.

Diagnosis.—M^{1-3} paracones well separated from metacones as in *Proviverra* and *Arfia*, not connate as in *Tritemnodon* and *Prototomus*. M_{1-3} with well-basined talonids in contrast to latter two genera and about as in *Proviverra* and *Arfia*. Molar trigonids relatively short and broad as in *Proviverra*, not tall or linguolabially compressed as in *Tritemnodon*. P_{3-4} paraconids much larger and these teeth relatively longer and with better basined heels than in *Proviverra, Arfia, Tritemnodon*, and *Prototomus*. Heel of P_4 not raised as in *Prototomus* and this tooth broad and robust, not relatively slender and trenchant as in *Proviverra* and *Tritemnodon*. Molars robust as in *Arfia* and some *Proviverra*, not relatively gracile as in *Tritemnodon* and *Prototomus*.

Proviverroides piercei, sp. nov.
Plates 2*F*, 3*A*, *B*

Etymology.—For William G. Pierce, in acknowledgment of his many contributions to the geology of the Bighorn Basin region.

Holotype.—USGS 1984, mandibular fragments with left P_3–M_3, right P_3 and M_3; right maxillary fragment with M^{1-3} and metastylar area of P^4, left M^3; two canine fragments (pls. 2*F*, 3*A*, *B*). Collected by M. C. Campbell; only known specimen.

Locality.—USGS fossil vertebrate locality D–1033 (Flattop quarry), Aycross Formation (lower part of local section), middle Eocene, sec. 12, T. 43 N., R. 101 W., Hot Springs County, Wyo.

Diagnosis.—Large hyaenodontine, size of *Proviverra major.* Measurements of teeth follow (in mm): Depth of ramus beneath M_2 (lingual side)=18.5, beneath P_4=16.6; P_3L=8.70, P_3W=3.70; P_4L=10.25, P_4W=5.00; M_1L=8.90, M_1WTr=5.25, M_1WTa=5.45; M_2L=9.60, M_2WTr=6.60, M_2WTa=5.65; M_3L=10.10, M_3WTr=5.80, M_3WTa=4.55; M^1L=9.50, M^1Wa=9.60, M^1Wp=11.8; M^2L=9.30, M^2Wa=11.15, M^2Wp=14.00, M^3L=6.40, M^3Wa=11.40, M^3Wp=8.70.

Discussion.—*Proviverroides piercei* is a relatively large hyaenodontid that is typified by relatively low crowned but broadly basined lower molars and by elongate P_{3-4} that are broad and possess strong paraconids and well-basined talonids. The molar talonids are better developed and more basined than in *Prototomus*, *Tritemnodon*, *Proviverra*, or *Cynohyaenodon* and resemble most closely molars of *Arfia*. The general molar configuration (especially the low trigonids) is, however, closer to that of *Proviverra* than of *Arfia,* and P_{3-4} contrast sharply with those teeth in both of the latter genera.

The combination of several characters, for example, low-crowned and well-basined molars, P_3 morphology, robusticity of cheek teeth, and well-separated M^{1-3} paracones and metacones (Van Valen, 1965), demonstrate the closer affinity of *Proviverroides* to *Proviverra* than to *Prototomus* or *Tritemnodon*. Moreover, the molar trigonids are not linguolabially compressed as in *Tritemnodon* and, to a lesser extent, *Prototomus*.

P_{3-4} are the most diagnostic teeth and alone serve to distinguish *Proviverroides* from *Proviverra.* Both teeth have well-developed paraconids that serve to lengthen them, and both possess relatively more distinct talonid cusps. The anterior elongation of P_4 in *Proviverroides* gives the tooth a somewhat *Tritemnodon*-like configuration when viewed from the labial side. P_4 is, however, a much broader tooth in *Proviverroides*, and the protoconid has a broad, flat postvallid surface. In both *Tritemnodon* and *Proviverra*, the protoconid is trenchant with a shearing, bladelike postvallid.

The upper molars of *Proviverroides* appear to be relatively wider at the lingual margin and relatively narrower transversely than in *Proviverra* specimens examined by me. These developments toward more massive, compact teeth seem to parallel those in *Arfia.* In early Wasatchian *Arfia*, however, the metacone is confluent with the metastylar shelf by means of a long, unbroken postmetacrista. In *Proviverroides*, as in *Proviverra*, *Prototomus*, and *Tritemnodon*, the postmetacrista is broken by a deep inflection immediately posterolabial to the metacone; and the "carnassial" development of M^{1-2} is more apparent than in *Arfia*.

The M^2 metastylar shelf is more sharply inflected labially than in *"Sinopa" (Proviverra) minor* (of Wortman, 1902) and is developed about as in *Tritemnodon.* M^3 has a well-developed metacone as has *Proviverra grangeri* (Matthew, 1906), but M^3 is relatively larger with respect to M^2 than in that taxon.

Proviverroides is most closely related to *Proviverra* among known hyaenodontids but has divergently developed robust, nontrenchant, and basined posterior premolars. These specializations, together with the large, low-crowned molars, decrease the emphasis on shear and have paralleled, to some extent, the condition in *Arfia.*

Family OXYAENIDAE
Subfamily OXYAENINAE
Patriofelis sp.

Referred specimen.—USNM 251550.

Discussion.—The trigonid of this M_1 is elongate as in *Patriofelis* and *Ambloctonus* and contrasts with the more squared geometries of *Palaeonictis* and some *Oxyaena.* The trigonid cusps are linguolabially compressed and the talonid is trenchant and unicuspid as in *Patriofelis* (Denison, 1938), not basined or with a well-developed hypoconid as occurs in *Ambloctonus.*

Damage to the trigonid makes a specific assignment difficult. The tooth is smaller than M_1 in *Patriofelis ulta, P. ferox,* and *P. compressa* and may have been about the size of that tooth in the small *"Patriofelis" coloradensis* (M_1, unfortunately, is absent in the type). Matthew (1915), however, referred the latter species to *Ambloctonus.*

Order CARNIVORA
Family MIACIDAE
Subfamily VIVERRAVINAE
Viverravus gracilis Marsh, 1872
Plate 3*C, D*

Referred specimen.—USNM 251648 (pl. 3*C, D*).

Discussion.—The solitary specimen referred to this species corresponds almost exactly in molar morphology and in M_1 measurements (given by Matthew, 1909, and Robinson, 1966) for the type of *Viverravus gracilis*. These measurements are smaller than those recorded for *V. gracilis* by West (1973a) or for *V.* cf. *gracilis* by Simpson (1959) but fit well with the size range of the Huerfano sample (Robinson, 1966). The specimen has larger teeth than has *Viverravus minutus* and considerably smaller teeth than *V. sicarius*.

M_1 has a well-basined talonid with a large, flattened hypoconulid and a twinned entoconid. M_2 likewise has a well-basined heel, not so acutely trenchant as in *V. minutus*, and the entoconid is, like that on M_1, twinned.

Measurements.—(mm): Depth of ramus beneath M_1 (lingual side) 5.00; $M_1L=5.25$, $M_1WTr=3.15$; $M_2L=4.10$, $M_2WTr=2.20$.

viverravine, gen. et sp. indet.

Referred specimens.—USGS 1985, 1986, 1987.

Discussion.—A possible new viverravine taxon is represented by these three teeth from Vass quarry. M_1 differs from that tooth in *V. acutus* and *V. gracilis* in having a relatively longer talonid, in a more trenchant and anterolingually attenuated paraconid, and in a relatively larger carnassial (prevallid) shearing surface.

A fragment of a P_3 and a complete presumed P_4 are hesitantly referred to the same taxon as the molar. P_3 differs from that tooth in species of *Viverravus* in having the origination of the anterobasal cusp higher on the anterior face of the protoconid. P_4(?) is more elongate and trenchant than in *Viverravus*, and the anterior face of the protoconid slopes more gently than in P_4 of the latter genus. The anterior (paraconid) lobe is relatively longer than in *Viverravus*, causing the protoconid to occur in the middle of the tooth and not toward the anterior margin. The principal talonid cusp of P_4 is more completely separated from the protoconid than in *Viverravus* and occurs lower on the crown. The anterior extension of the tooth, its large length-to-breadth ratio, the gently sloping posterior margin of the protoconid, and the trenchant protoconid give the tooth a somewhat *Tritemnodon*-like configuration when viewed from the labial side.

These three teeth probably represent a new viverravine; however, this cannot be established with certainty as no serial dentition is known. P_3 and M_1 could be referred to a new species of *Viverravus*, but P_4(?) is clearly divergent. The general configuration of the tooth is more miacid than hyaenodontid and more viverravine than miacine. All the specimens are about the same size as their presumed counterparts in *Viverravus minutus*.

Measurements.—(mm): $(?)P_4L=4.75$, $(?)P_4W=1.60$; $M_1L=4.60$, $M_1WTr=2.05$, $M_1WTa=1.85$.

Subfamily MIACINAE

Uintacyon sp.

Plate 4*A*

Referred specimen.—USGS 1983, skull with left I^{1-3}, P^3–M^2, right P^2–M^2; fragments of left femur, left ulna, left pelvis, and phalanges (pl. 4*A*).

Discussion.—USGS 1983 is probably the finest specimen of *Uintacyon* presently known. Detailed description of the skull and postcranial bones is beyond the scope of this report but would doubtless contribute greatly to the anatomy of this rare genus.

The postcranial bones indicate that *Uintacyon* sp. was about the size of the living kit fox (*Vulpes macrotis*); however, the limb elements are bulkier and suggest that they belong to a more heavily built animal. The rostrum of the skull has been slightly crushed laterally and the cranium is somewhat flattened. The rostrum and palate are broad, and the rostrum is slightly shorter than the cranium. The general proportions of the cranium are about as in *Viverravus minutus*, but the palate is relatively broader and the face is relatively shorter, as in *Vulpavus* and *Vassacyon*. The sagittal crest, though damaged, is robust and distinct and the occipital–lambdoidal crest is very robust.

The premaxillary has been damaged and is largely missing on the right side, but there does not appear to have been so long a diastema between I^3 and the canine as in *Vulpavus*, nor a diastema between I^2 and I^3 as in *V. ovatus*. The premaxillary was also probably less acutely curved than in *Vulpavus*.

The anterior three premolars are closely spaced, more so than in *Vulpavus*, and P^1 (preserved by alveolus only) was relatively larger than in species of that genus that retain this tooth. P^1 was single rooted, whereas P^{2-3} are double rooted and linguolabially compressed teeth and lack protocones, as in *Miacis*. Guthrie (1971) believed that a protocone may have been present on P^3 in *Uintacyon asodes*, but this is uncertain because most of the crown is missing in the only described upper dentition.

Upper teeth of *Uintacyon* are at best poorly known, and it is ironic that the only known skull cannot, for that reason, be confidently assigned to a species. The teeth are much smaller than expected for the unknown uppers of *Uintacyon major* Matthew (1909) and are smaller than known upper teeth of *U. vorax*. Teeth of both *U. edax* (from figure of Wortman, 1901, reprint edition p. 26) and *U. massetericus* are too small. P^4 and M^1 are similar in morphology and length to these teeth in *Uintacyon asodes* from the fauna of the Lost Cabin Member of the Wind River Formation (Guthrie, 1971), and the cheek teeth are also about the appropriate size to occlude with those in the unique mandible of *U. jugulans*.

Among the generic diagnostic characters cited by Matthew (1915) for *Uintacyon*, the carnassiform P^4, small P^4 parastyle, moderately elongate M^{1-2} parastyles, smaller M^1 metacones than paracones and absence of a good postprotocrista duplicate the condition in USGS 1983. The absence of the postprotocrista and hypocone on M^1 are features that, in part, serve to distinguish *Uintacyon* from most morphologically heterogeneous specimens attributed to *Miacis*. *Miacis* also generally has a more continuous lingual cingulum on M^{1-2}, a stronger M^2 ectoflexus and metacone and, in at least some specimens, an M^3. (See, for example, AMNH 15176, the type of *Miacis latidens*, where this tooth is represented by broken alveolar borders posterior to M^2.) In 1909, Matthew (p. 346) believed M^3 to be present in

Uintacyon; however, by 1915 (p. 29, 31) he questioned its presence in this genus. Its absence in USGS 1983 demonstrates that the tooth had, indeed, been lost in at least one species, although in *Uintacyon* sp., cf. *U. massetericus* from the early Wasatchian No Water fauna (Bown, 1979a), M^3 was retained (as, UW 9766).

The morphology of P^4 in USGS 1983 is strikingly close to that in the type of *Miacis latidens*, even though the molars are dissimilar. In both, the parastyle is reduced relative to the condition in *Oödectes*, and the carnassial is highly developed. In USGS 1983, however, the protocone shelf has been somewhat reduced posterolingually, lengthening the postvallum. The carnassial appears to be more transverse and less oblique (and hence less advanced) than in *Miacis parvivorus* (AMNH 11500) or than in USGS D-1069-1, an undescribed *Uintacyon*-like miacine from rocks of early Wasatchian age in the Clark's Fork Basin.

Measurements.—(mm): Length of skull (unrestored)=78.8; length of braincase (lambdoid crest to anterior confluence of sagittal crest)=35.6; palatal width (M^2–M^2)=34.7; palatal length=40.4; I^1–M^2 (unrestored)=38.8; canine alveolus L=5.00, W=4.90; P^1 alveolus L=3.20, W=2.30; P^2L=3.80, P^2W=1.60; RP^3L=4.60, RP^3W=2.65; RP^4L=8.40, RP^4W=9.40; RM^1L=5.90; RM^1W=9.50; RM^2L=2.95, RM^2W=6.05; LP^3L=4.50, LP^3W=2.55; LP^4L=8.65, LP^4W=9.50; LM^1L=6.20, LM^1W=9.50; LM^2L=2.85, LM^2W=6.15

Order MESONYCHIA
Family MESONYCHIDAE
Mesonyx sp., cf. M. obtusidens Cope, 1872
Plate 4*B*

Referred specimen.—USGS 1988 (pl. 4*B*).

Discussion.—This specimen conforms closely with P^4–M^2 in AMNH 12643, a specimen figured by Matthew (1909, p. 494, fig. 94). The P^4 metacone appears to be somewhat closer to the paracone than in the latter specimen, and all the teeth of USGS 1988 are about 15 percent smaller.

Measurements.—(mm): P^4L=10.40, P^4W=11.10; M^1L=14.40, M^1W=13.60; M^2L=13.00, M^2W=14.40.

Order CONDYLARTHRA
Family HYOPSODONTIDAE
Hyopsodus sp., cf. H. paulus Leidy, 1870
Plate 5*A*

Referred specimens.—USNM 251521, 251530–251533, 251534 (pl. 5*A*), 251535–251547, 251568.

Discussion.—These specimens correspond closely in size with teeth of late Bridgerian *Hyopsodus lepidus* and in size and morphology with those of early Bridgerian *H. paulus*. Trigonid widths of M_{1-3} fall in the upper part of the range of Gardner Butte *Hyopsodus* and in the lower range of Black's Fork (lower Bridger Formation) *Hyopsodus* samples studied by Robinson (1966), as well as those for *H. paulus*. They also agree fairly well with some middle and late Wasatchian Willwood specimens in the Yale samples studied by Gingerich (1976), but differ from those and from most other Wasatchian *Hyopsodus* in the frequent occurrence of a metastylid on the lower molars. G. L. Jepsen (in Van Houten, 1944; and in Hay, 1956) observed that this cusp is common in Bridgerian *Hyopsodus*, including *H. paulus*, but is rare to absent in Wasatchian species.

Only one maxilla fragment (pl. 5*A*) and only one ramal fragment were recovered, and it is uncertain if the isolated teeth belong to the same species as the jaws, in spite of their close approximation in both size and morphology. M^3 is relatively large with respect to M^2 and has a large hypocone as it has in all *H. paulus* examined by me. (See also Gazin, 1968, pl. 6–1.) Aycross *Hyopsodus* consequently has a larger M^3 to M^2 ratio than in *H. despiciens* (a larger form) or most *H. lepidus*.

Two specimens of lower teeth from Vass quarry (USNM 251540 and 251543) are abnormally small (table 7) and may prove to belong to a second species when larger samples of *Hyopsodus* teeth are available.

Measurements.—Given in table 7.

Order TILLODONTIA
Family ESTHONYCHIDAE
Subfamily TROGOSINAE
Trogosus sp.

Referred specimens.—USNM 251525–251529.

Discussion.—Aycross tillodonts are thus far represented only by fragments of incisors, one of which (USNM 251529) is associated with a left M^3. This molar resembles *Trogosus* more closely than *Tillodon*, but heavy wear has obscured much of the morphology.

The parastyle is large as in Huerfano *Trogosus grangeri* Gazin (1953) and is followed posteriorly by a deep anterolingual-posterolabial fold as in that species. M^3 and the most complete of the incisors are slightly larger than those of *Trogosus hyracoides*, *T. grangeri*, *T. castoridens*, and *T. hillsi*, and are somewhat smaller than in many *T. latidens*. The best of the incisor fragments, however, compares favorably with a specimen assigned by G. L. Jepsen to *Trogosus ?latidens* from the "early acid breccia" (locality A-4 of Van Houten, 1944, p. 202–203).

Order DINOCERATA
Family UINTATHERIIDAE
Subfamily BATHYOPSINAE
Bathyopsis sp.

Referred specimen.—USGS 1989.

Discussion.—This specimen is referable to *Bathyopsis* by virtue of its small size, by the reduced paraconid crest and paraconid, and in the absence of an entocristid. The

TABLE 7.—*Measurements, in millimeters, of teeth of* Hyopsodus *sp., cf.* H. paulus *from the Aycross Formation*

[nm, not measurable; leaders (- -), no tooth]

USNM No.	P_4L	P_4W	M_1L	M_1W	M_2L	M_2W	M_3L	M_3W	
251531	3.20	2.25	4.20	2.90	- -	- -	- -	- -	(composite)
251533	- -	- -	- -	- -	4.60	3.40	- -	- -	
251536	- -	- -	- -	- -	4.70	3.50	- -	- -	
251538	- -	- -	4.10	3.10	4.25	3.50	4.60	3.00	
251540	- -	- -	3.50	nm	- -	- -	- -	- -	
251541	3.10	2.40	- -	- -	- -	- -	- -	- -	
251543	- -	- -	- -	- -	3.55	3.00	- -	- -	
251546	- -	- -	4.30	3.70	- -	- -	- -	- -	

USNM No.	P^2L	P^2W	P^3L	P^3W	P^4L	P^4W	M^1L	M^1W	M^2L	M^2W	M^3L	M^3W
251530	- -	- -	- -	- -	- -	- -	3.40	4.40	- -	- -	- -	- -
251531	- -	- -	- -	- -	2.80	4.20	- -	- -	- -	- -	- -	- -
251532	- -	- -	- -	- -	- -	- -	3.30	4.65	- -	- -	- -	- -
251534	2.40	1.70	2.30	3.00	2.50	3.70	3.30	4.15	3.65	4.90	3.30	4.30
251536	- -	- -	- -	- -	- -	- -	- -	- -	3.80	5.10	- -	- -
251537	- -	- -	- -	- -	2.50	3.50	- -	- -	- -	- -	- -	- -
251540	- -	- -	- -	- -	2.60	3.70	- -	- -	- -	- -	- -	- -
251541	2.30	2.50	- -	- -	- -	- -	- -	- -	3.50	4.80	(composite)	
251545	- -	- -	- -	- -	2.40	3.65	- -	- -	- -	- -	- -	- -
251547	- -	- -	- -	- -	- -	- -	- -	- -	3.85	5.40	- -	- -

strong development of a shelflike heel on which the hypoconid and entoconid cannot be distinguished is reminiscent of the condition in cf. *Bathyopsis fissidens* (Gazin, 1952) and *Uintatherium*. The cristid obliqua joins the metastylid as in *Probathyopsis*, *Prouintatherium*, and many other *Bathyopsis* (contrary to Wheeler, 1961, p. 63).

M_2 is equal in size to M_2 of *Prouintatherium hobackensis* and is smaller than most *Bathyopsis fissidens* or *B. middleswarti*.

Measurements.—(mm): $M_2L=15.30$, $M_2WTr=9.10$, $M_2WTa=10.20$; $M_3WTr=13.85$.

Order PERISSODACTYLA
Suborder HIPPOMORPHA
Superfamily EQUOIDEA
Family EQUIDAE
Orohippus sp.

Referred specimens.—USNM 251472–251479, 251551, 251561.

Discussion.—Of the five generally recognized species of *Orohippus* that occur in Bridgerian rocks, the Aycross sample more closely resembles those from the early Bridgerian (*Orohippus pumilus*, *O. major*) than those from the late Bridgerian (*O. agilis*, *O. sylvaticus*). *Orohippus progressus* is known from both early and late Bridgerian localities but is significantly smaller than the Aycross specimens.

The P^{3-4}, diagnostic for species of *Orohippus*, are unknown in this collection; however, the P_3 possesses a very small entoconid that is smaller than that in most specimens of *Orohippus agilis* or *O. pumilus* and is only slightly better developed than in *Hyracotherium*. The upper molar conules are much stronger than in late Bridgerian *O. agilis*, and the trigonids of the lower molars are not as narrow as in either the latter species or *O. sylvaticus*. The M_2, however, is narrowest at the trigonid as it is in both *O. sylvaticus* and *O. progressus*.

A single specimen of M^1 has a faint mesostyle developed at the juncture of the postparacone and premetacone cristae in contrast to *Hyracotherium*, but this cusp is not confluent with the ectocingulum as it is in most other *Orohippus*. The mesostyle is developed about as well as in all the specimens of *Orohippus major* and *O. agilis* examined by me and is weaker than in either *O. progressus* or *O. sylvaticus*. West (1973a) observed a very weak mesostyle in some specimens of *Orohippus* cf. *O. pumilus* in the New Fork and Big Sandy (Bridger Formation) collection and the teeth at hand closely resemble those specimens.

With respect to the measurements of lower molars of samples of *Orohippus* given by Kitts (1957) and West (1973a), the Aycross M_1 specimens are intermediate between *Orohippus sylvaticus* and *O. agilis*; M_3 falls at the upper end of the observed range for *O. pumilus*; and is within the ranges for both *O. agilis* and *O. sylvaticus*.

Measurements.—(mm): $P_2L=7.20$, $P_2W=3.00$; $P_3L=7.90$, $P_3W=4.80$; M_1L $(N=3)=8.00–8.80$, M_1W $(N=3)=5.70–5.80$; $M_2L=9.00$, $M_2W=6.20$; $M_3L=10.90$, $M_3W=5.50$; $M^1L=8.60$, $M^1W=9.35$.

Superfamily BRONTOTHERIOIDEA
Family BRONTOTHERIIDAE
Subfamily PALAEOSYOPINAE
Eotitanops borealis (Cope, 1880)
Plate 5*B*

Referred specimens.—USGS 1990–1992, 1993 (pl. 5*B*), 1994.

Discussion.—These specimens, all individual teeth, fall into the lower part of the observed range for teeth of *Eotitanops borealis* (see Osborn, 1929), and an M^2 (USGS 1991) is virtually identical in size and morphology with that in Osborn's (1913) type of *E. "gregoryi"* (=*E. borealis*, AMNH 14839). An M^1 (pl. 5*B*) has more strongly crenulated enamel than in any other specimens of *E. borealis* examined by me.

Measurements.—(mm): $P^4W=13.40$; $M^1L=15.20$, $M^1W=18.30$; $M^2L=16.00+$, $M^2W=19.50$.

cf. Eotitanops sp.

Referred specimens.—USGS 1995, 1996.

Discussion.—Two specimens of P^4 are considerably larger than those of *Eotitanops borealis* from lower in the local Aycross section but resemble last upper premolars of that animal more than they do those of the larger *Palaeosyops*.

Measurements.—(mm): $P^4L=14.00$, $P^4W=20.00+$.

cf. Palaeosyops fontinalis (Cope, 1873)
Plate 5*C*

Referred specimen.—USGS 1997 (pl. 5*C*).

Discussion.—cf. *Palaeosyops fontinalis* is represented by three associated maxillary fragments that preserve the canine, P^{3-4}, dP^4, M^{1-2} (P^3, dP^4, and M^1 are damaged). The permanent teeth in this specimen closely resemble those in YPM 16450, *P. fontinalis*, from the Huerfano Formation (Robinson, 1966, pl. VIII-1), but the M^2 mesostyle is somewhat broader and more rounded at the base and the tooth has a less distinct paraconule.

Measurements.—(mm): $M^1L=22.50$, $M^1Wp\approx25.70$; $M^2L=30.00$, $M^2Wa=33.00$, $M^2Wp=29.50$.

Suborder CERATOMORPHA
Superfamily TAPIROIDEA
Family HELALETIDAE
cf. Helaletes nanus (Marsh, 1871)
Plate 5*E, F*

Referred specimens.—USNM 251562, ?251561, ?251563, USGS 1998 (pl. 5*E, F*).

Discussion.—Radinsky's (1963) revision of the North American Tapiroidea has, to a considerable extent, clarified the picture of tapiroid dental anatomy, systematics, and evolution. It remains difficult, however, to consistently distinguish dentitions of some of the earlier and more generalized helaletids, particularly those of *Heptodon* and *Helaletes.* This is because (1) existing diagnoses are largely based on characters of the upper teeth, particularly the antemolar dentition, and (2) all the characters applied to the diagnoses of upper molars and lower cheek teeth form part of a continuum and are not, strictly speaking, diagnostic for either genus. For example, P^{2-4} are premolariform in *Heptodon* but maybe either premolariform or semimolariform in *Helaletes nanus* (Radinsky, 1963, p. 28 and fig. 10). The M^{1-2} metacones are "slightly convex to flat; not shortened and not as lingually displaced as in later helaletids" (Radinsky, 1963, p. 28), in *Heptodon.* In *Helaletes*, the M^{1-2} metacones are "slightly convex to flat, slightly shortened" (Radinsky, 1963, p. 40).

The M^3 metacone in *Heptodon* is "not as reduced as in later helaletids" and in *Helaletes* is "not as reduced as in *Colodon*" (a later helaletid; Radinsky, 1963, p. 28, 40). P_{3-4} were observed to have relatively high trigonids in *Heptodon*; whereas, they are "low" in *Helaletes*, and in both genera P_{3-4} have long paralophids and a P_4 entoconid.

From my examination of dentitions labeled *Heptodon* and *Helaletes nanus* in the AMNH collections, I find, as suggested by the above paraphrased diagnoses, that all these characters are variable and intergrade between the two genera.

P_1 appears to be absent in all *Helaletes* where this is determinable; whereas, the tooth is certainly present in at least some *Heptodon*. *Helaletes intermedius* also persistently has more molariform P^{2-4} than either *Heptodon* or *Helaletes nanus*. Neither of these criteria is adequate for generic separation. Specimens referred to *Heptodon* are exclusively middle and late Wasatchian in age, and specimens referred to *Helaletes nanus* are restricted to Bridgerian ("B–D") age. The specimens at hand are hesitantly assigned to Bridgerian *H. nanus* with the recognition that this assignment increases the variability attributed to an already highly variable taxon.

USGS 1998 (pl. 5*E, F*) preserves P^{3-4}, M^2, and P_4–M_3 of the cheek teeth of a small helaletid tapiroid. P^{3-4} are essentially premolariform with no hypocone as typically occurs in *Helaletes intermedius*, *Dilophodon*, and more advanced tapiroids. The metaloph is perpendicular to the anteroposterior axis of the tooth and joins the lingual border of the protocone, much as in UW 3189 (*H. nanus*) and YPM 12578 (*H. nanus;* Radinsky, 1963, fig. 10). UW 3189, however, is much smaller than USGS 1998, and

P^{3-4} have much stronger metalophs. USGS 1998 lacks the raised longitudinal postprotocone crista found in more advanced *H. nanus* (as, AMNH 11467). The relative length of the M^2 metaloph is well within the ranges for both *Heptodon* and *Helaletes nanus* in the American Museum collection.

P_4 has a small entoconid, as do both *Heptodon* and *Helaletes*. (Compare AMNH 15656, *Heptodon*, and AMNH 13124, *Helaletes nanus*.) The obliqueness of the M_{1-3} hypolophid is approximately equal in both genera to the condition in USGS 1998; and M_3 in the latter specimen has a large hypoconulid. This cusp, apparently absent in *Dilophodon*, is relatively larger in specimens of *Heptodon* than in *Helaletes nanus*.

USGS 1998 is intermediate between *Helaletes nanus* and *H. intermedius* in size but in morphology more closely resembles the former species. The specimen is also only slightly smaller than comparable teeth of *Heptodon posticus*. P^{3-4} are among the largest and least molarized of these teeth now referred to *Helaletes nanus*.

USGS 1998 possibly represents P^1 of cf. *H. nanus*. The tooth is double rooted and linguolabially compressed as observed by Radinsky (1963) for *H. nanus*, but it has three cusps, the anterior and posterior of which are small digitations of the crown (as in UW 3189 and *Dilophodon leotanus*).

Measurements.—(mm): $P_4L=9.00$, $P_4W=6.20$; ?$P^1L=5.10$, ?$P^1W=3.40$; USGS 1998: $P^3L=8.70$, $P^3W=10.30$; $P^4L=9.10$, $P^4W=11.50$; $M^2L=11.60$, $M^2W=13.50$ (all left side); $P^3L=8.80$, $P^3W=10.60$; $P^4L=9.30$, $P^4W=11.30$ (both right side); $P_4L=9.10$, $P_4W=6.90$; $M_1L=11.10$, $M_1W=7.20$ (both left side); $P_4L=9.30$, $P_4W=7.00$; $M_1L=11.20$, $M_1W=7.20$; $M_2L\geq11.80$, $M_2W\geq8.00$; $M_3W=8.30$.

Hyrachyus modestus (Leidy, 1870)

Plates 5*D*, 6*A*

Referred specimens—USNM 251555, 251564 (pl. 5*D*), 251566 (pl. 6*A*), ?251569.

Discussion.—*Hyrachyus modestus* molars from the Aycross fauna are slightly larger than most comparable teeth of this species from the Huerfano fauna or from Bridger Formation "A" or "B" levels but are too small for inclusion in *H. eximius*. A specimen of P_4 (USNM 251555) is smaller than the range of measurements for this tooth in *H. modestus* given by Wood (1934) but is significantly larger than P_4 in most Bridger Formation specimens assigned to that species in the University of Wyoming collection. All of the above specimens are within the size ranges given by Radinsky (1967) for Bridger Formation "B" *H. modestus*.

A second P_4 of *Hyrachyus* (donated to the American Museum of Natural History) was recovered from near the type area of the Aycross Formation on the Bitterroot Ranch, east of Dubois, Wyo. This specimen (AMNH 104822) is much larger than the tooth from the Owl Creek area Aycross Formation and may represent *H. eximius*.

M_2 (pl. 5*D*) retains a small hypoconulid fold. Morris (1954) believed that the presence of this cusp on M_3 was a "primitive" character and observed that it is unknown in post-early Bridgerian molars of *Hyrachyus*.

Measurements.—(mm): $P_4L=12.60$, $P_4W=9.70$; $M_2L=19.80$, $M_2W=14.60$; $M^2L=19.25+$, $M^2Wp=20.20$.

Order ARTIODACTYLA
Family DICHOBUNIDAE
Antiacodon pygmaeus (Cope, 1875)

Referred specimens.—USNM 251520, 251522.

Discussion.—M^2 (USNM 251520) does not differ appreciably from that tooth in AMNH 12043 (*A. pygmaeus*) described by Sinclair (1914). The M_2 is larger than in most samples of *A. pygmaeus* from the Bridger Formation (Robinson, 1966; West, 1973a) and Huerfano Formation (Robinson, 1966) and is also larger than in specimens assigned to *Antiacodon vanvaleni* by Guthrie (1971) from the Lost Cabin Member of the Wind River Formation. The tooth has a well-developed paraconid in contrast to *Microsus*, but this cusp is smaller than the metaconid as in *Antiacodon vanvaleni*. In *A. pygmaeus* from both the Bridger and Huerfano Formations (for example, AMNH 55202 and 17490, Robinson, 1966, pl. X, 1–2), the paraconid is the larger cusp. It is likely, but not certain, that both the paraconid construction and large size of USNM 251522 are within the range of variation for *A. pygmaeus*.

Measurements.—(mm): $M^2W=6.10$; $M_2L=5.50$, $M_2W=4.60$.

Order RODENTIA
Suborder SCIUROMORPHA
Family ISCHYROMYIDAE
cf. Leptotomus sp. "A"

Plate 6*D*–*G*

Referred specimens.—USNM 251609, 251610, 251612 (pl. 6*D*), 251614, 251624 (pl. 6*F*), 251629 (pl. 6*G*), 251633, 251637, 251638 (pl. 6*E*).

Discussion.—This large paramyine occurs at four localities in the Aycross Formation of the Owl Creek area. The specimens most closely resemble teeth of *Leptotomus* but are smaller than the smallest teeth of *L. sciuroides*, a species that Wood (1962) observed to be the smallest of the genus.

Nelson (1974) reported an undescribed species of *Leptotomus* from the middle Eocene part of the Fowkes Formation of western Wyoming, and the specimens at hand closely match his description and measurements, although I have not seen Nelson's specimens. The teeth are closest to those of *Leptotomus guildayi* Black (1971) from the "Tepee Trail" Formation near Badwater, Wyo., but they differ from that species in (1) their smaller size, (2) a trace of a hypocone on P^4, (3) the presence of a more bulbous and cuspate mesostyle on P^4 and M^1, (4) the more squared anterolingual borders of the upper molars, (5) the presence of a small accessory cusp at the lingual base of long molar precingulae, and (6) the lesser degree of emargination of the anterior border of P^4. This latter character gives the tooth a less anteriorly concave aspect than in P^4 of *L. guildayi*.

It is probable that these teeth represent a new species of *Leptotomus*, but serially associated teeth are desirable to diagnose one.

Measurements.—(mm): P^4L (N=4)=2.20–2.70, P^4W (N=4)=2.85–3.15; M^1L=2.45, M^1W=2.70; M^2L=2.55, M^2W=2.60; M^3L=2.40, M^3W=2.20; M_2L=2.85, M_2W=2.50.

cf. Leptotomus sp. "B"

Plate 6*B*

Referred specimens.—USNM 251615, 251636 (pl. 6*B*).

Discussion.—This probable second species of *Leptotomus* is characterized by teeth that are lower crowned and larger than in *L. guildayi*; and the M^{1-2} metacones are more excavated anterolingually than in other species of *Leptotomus*. This construction has resulted in a broad, shallow trigon basin between the protoloph and metaloph. Both the protocone and hypocone are shelflike and elongated anteroposteriorly. The mesostyle is a large, single cusp and the metaconule is larger than the paraconule. The protoloph is connected to the protocone shelf in USNM 251615 but is not in USNM 251636. The metaloph does not reach the protocone.

Measurements.—(mm): $M^{1 or 2}L$ (N=2)=3.45–3.65, $M^{1 or 2}W$ (N=1)=3.65.

Thisbemys corrugatus Wood (in McGrew and others, 1959)

Plates 6*I*, 7*A*

Referred specimens.—USNM 251594 (pl. 6*I*), 251618, 251639 (pl. 7*A*), 251641, 251643.

Discussion.—The stronger enamel corrugation, larger molar parastyles, short M^2 metaloph, and distinct hypocone serve to place these specimens in *Thisbemys corrugatus* (A. E. Wood, in McGrew and others, 1959; Wood, 1962); but the Aycross Formation specimens differ from Bridger Formation specimens in a few relatively minor respects. P^4 (USNM 251641) has a steeper internal protocone slope and somewhat more rounded paracone and metacone. The M^2 protocone is more rounded lingually than in much Bridger Formation *T. corrugatus*, and the angle formed by the juncture of the preparacrista and postparacrista is more obtuse, less acute than in that species. (See CM 9929, Bridger "C.") In this feature the teeth are developed more as in *Pseudotomus* and *Leptotomus*. Tooth sizes fit well with those given by Wood (1962) for Bridger Formation *T. corrugatus*.

Measurements.—(mm): P^4W=4.50; M^2L=3.60, M^2W=4.20; P_4L=3.50, P_4W=2.90 (estimated); M_1L=3.90, M_1W=3.70; M_2L=4.35, M_2W=3.30.

cf. Thisbemys sp.

Plates 6*C*, 7*B*

Referred specimens.—USNM 251604 (pl. 7*B*), 251642 (pl. 6*C*).

Discussion.—A second *Thisbemys*-like rodent is represented by two teeth from Flattop quarry. The teeth are low crowned and larger than teeth of *T. nini* and about the size of *T. plicatus*. The paraconule, however, is larger than in that species although the metaconule is also very large. The conules are pyramidal in occlusal outline, not rounded as in *Leptotomus*. The enamel corrugation is not so strongly developed as in *T. plicatus* specimens figured by Wood (1962) but is about the same as in AMNH 12505 (from Bridger "B").

The lower molar is also less corrugated than in *T. plicatus*, but both of the Aycross specimens are strongly worn. The lower molars possess two deep furrows that border the mesoconid and enter the talonid basin. The anterior of these is parallel to the trigonid mure, and the posterior furrow is oriented posterolingually. The hypoflexid is squared and denticulate as in most species of *Thisbemys*. The mesoconid is large and is better developed than in *Thisbemys uintensis*.

These specimens differ enough from described species of *Thisbemys* to question their assignation to that genus. However, among specimens available for comparison, they most closely resemble *T. plicatus* teeth from the Blacks Fork Member of the Bridger Formation (Bridger "B").

Measurements.—(mm): M^1L=3.60, M^1W=4.50; M_1L=4.00, M_1W=3.70; M_2L=4.30, M_2W=4.15.

cf. Pseudotomus sp.

Plate 7*C*–*E*

Referred specimens.—USNM 251597 (pl. 7*E*, top), 251600, 251601, 251602 (pl. 7*D*), 251603 (pl. 7*E*, bottom), 251613, 251616, 251623 (pl. 7*C*).

Discussion.—Few specimens have been referred in the past to this enigmatic genus, and consequently few specimens were available for comparison. Dawson (1968) observed that Bridgerian *Pseudotomus* was not satisfactorily distinguishable from *Ischyrotomus*, and I agree with this observation. Dawson referred material from

Powder Wash (early Bridgerian, Utah) to *Pseudotomus* on the basis of the multiple conules on the upper molars. This feature was also believed by Wood (1962) to be a diagnostic character, even though multiple conules occur frequently in *Leptotomus* (as, *L. burkei*).

The Aycross specimens possess multiple conules on the upper molars. Aside from this feature, no published diagnoses are adequate to distinguish teeth of *Pseudotomus* from those of *Ischyrotomus*, although teeth referred to the former genus are typically much larger than their counterparts in either *Ischyrotomus* or *Leptotomus*.

The specimens at hand fall into two size ranges; the smallest specimens (USNM 251597, 251602, 251623) fit the known range for *Pseudotomus robustus*, whereas the largest teeth are clearly larger than that species. (See measurements in Wood, 1962 and Dawson, 1968.) Even the largest specimen, however, is dwarfed by CM 13893, an $M^{1 or 2}$ assigned by Dawson (1968) to *Pseudotomus* sp., although the morphology of that specimen is close to that of USNM 251603 from the Aycross Formation.

P_4 and the lower molars are, likewise, essentially the same as those of *P. robustus* (for example, CM 9697 and AMNH 55952, Bridger "B"), although faint enamel crenulations are present on the lower molars. As in *P. robustus*, the hyocone is less distinct and the metaconule is smaller and less isolated than in *Leptotomus*.

Measurements.—(mm): M^1L=5.50, M^1W=5.70, M^2L=5.70, M^2W=6.40; P_4L (N=2)=5.80–6.75, P_4W (N=2)=5.50–6.10; M_1L=5.10, M_1W=5.30; M_2L=6.60, M_2W=6.20; M_3L=7.00, M_3W=5.50.

Subfamily REITHROPARAMYINAE

Reithroparamys sp., cf. R. delicatissimus (Leidy, 1871)

Plate 7*F*

Referred specimens.—USNM 251588 (pl. 7*F*, middle), 251595 (pl. 7*F*, top), 251617 (pl. 7*F*, bottom), 251627.

Discussion.—The only upper molar here tentatively referred to *Reithroparamys delicatissimus* is strongly worn but has the bilophodont pattern and a double metaconule as is typical of that species. The lower molars are virtually identical to those of Bridger Formation *R. delicatissimus* described by Wood (1962) and are smaller than either *R. huerfanensis* or *R. matthewi*. Two cristids extend from the protoconid to the metaconid (not one as in *R. matthewi*) and the hypolophid is strong; both features are developed as in *R. delicatissimus*. The mesoconid, however, forms part of the ectolophid and is not discrete as Wood (1962) has observed for that species. The distinct, isolated mesoconid is developed about as in *R. matthewi*. The protoconid and metaconid are relatively more separated than in most *Paramys*, and a crest extends from the entoconid into the talonid basin as is typical in *Reithroparamys*.

Measurements.—(mm): $M_{1 or 2}L$ (N=2)=2.50–2.75, $M_{1 or 2}W$ (N=2)=2.50–2.60; M_3L=2.70, M_3W=2.15.

Microparamys sp. "A"

Plate 7*G–L*

Referred specimens.—USNM 251582, 251586 (pl. 7*I*), 251589, 251619, 251620 (pl. 7*G*), 251621, 251635 (pl. 7*L*), 251640 (pl. 7*H*), 251645 (pl. 7*J*), 251647 (pl. 7*K*).

Discussion.—The highly distinctive genus *Microparamys* is probably represented by two species in the Aycross collection. The specimens at hand belong to a medium-sized species, slightly larger than *M. minutus* and about the size of late Eocene *M. dubious*.

The diminutive size, the strong precingulum, the separation of the precingulid from the protoconid, the distinct mesostylid or metastylid and mesoconid, and the isolation of the entoconid from the postcristid are all characters that unite these teeth with *Microparamys*. The metaloph, however, is well developed, in contrast to the diagnosis of *Microparamys* given by Wood (in McGrew and others, 1959). This metaloph is attached to the protocone as in *M. dubious* and with no incipient commissure with the hypocone as occurs in "*Microparamys*" *wyomingensis* (=*Paramys*, according to West, 1969). P^4 and the upper molars possess a distinct mesostyle in contrast to those teeth in *M. dubious* (Dawson, 1974), and the hypocone is discrete on M^{1-2} as in *M. minutus* (small or absent in *M. dubious*). The upper molars are not so quadrate in occlusal outline as in the specimen of *M. minutus* figured by Dawson (1968, fig. 9).

The lower molars conform well with Dawson's description (1966, p. 100–101) for *M. dubious*, and there is no entostylid as occurs in *M. minutus* (as, CM 19566; Dawson, 1968, fig. 15). This cusp has variously been called the metastylid, the mesosytlid, or the entostylid in reference to its seemingly variable development on the posterolingual slope of the metaconid, in the talonid notch, or on the entocristid, respectively. In the terminology of Dawson (1966, p. 101, footnote), the cusp in *Microparamys* sp. "A" is a mesostylid.

This species appears to be closest to Uintan *Microparamys dubious*, but the small sample is insufficient to be confidently assigned to either that species or *M. minutus*. Left and right dP^4 are represented by USNM 251619 and 251635, respectively.

Measurements.—(mm): $LdP^4L=1.25$, $LdP^4W=1.20$; $RdP^4L=1.35$, $RdP^4W=1.40$; $P^4L=1.15$, $P^4W=1.40$; $M^{1 or 2}L$ (N=4)=1.30–1.40, $M^{1 or 2}W$ (N=4)=1.40–1.60; M^3L (N=2)=1.40–1.50, M^3W (N=2)=1.50; $M_{1 or 2}L$ (N=2)=1.50, $M_{1 or 2}W$(N=2)=1.45–1.60.

Microparamys sp. "B"

Plate 7*N, O*

Referred specimens.—USNM 251585 (pl. 7*N*)51634 (pl. 7*O*).

Discussion.—A very small species of *Microparamys* is represented by only two specimens, both from Vass quarry. The lower molar is about the size of M_1 or M_2 in *Microparamys wilsoni*, but the P^4 is smaller and does not have a mesostyle as was observed in that species by Wood (1962, fig. 55*E*). The $M_{1 or 2}$ mesoconid is very large with a low lingual crest as in *M. wilsoni*; however, the tooth has no metastylid as occurs on M_1 in the type specimen. In other respects, this species is very close to poorly known upper Bridger Formation *Microparamys wilsoni*, especially so in details of loph development on P^4.

Measurements.—(mm): $P^4L=0.75$, $P^4W=1.00$; $M_{1 or 2}L=1.00$, $M_{1 or 2}W=0.95$.

Family SCIURAVIDAE

Taxymys cuspidatus, sp. nov.

Plates 6*H*, 7*M*

Etymology.—Reference to the more cuspate development of P^4–M^3 than in other species of *Taxymys.*

Holotype.—USGS 1999, fragment of right maxilla with P^3–M^3 (pl. 6*H*).

Locality.—USGS fossil vertebrate locality D–1034 (Vass quarry), Aycross Formation (lower part of local section), middle Eocene, sec. 33, T. 44 N., R. 100 W., Hot Springs County, Wyo.

Hypodigm.—The type and USNM 251590, 251605, 251626, 215628, 251632, upper teeth (topodigm); possibly also USNM 251587, 251591 (pl. 7*M*), 251611, 251625 (pl. 7*M*), 251631, 251644, 251646, lower teeth.

Diagnosis.—Smaller than *Taxymys lucaris* or *T. progressus.* P^4 with distinct hypocone and with no mesostyle as occurs in most specimens of latter two species. M^{1-2} mesostyles attached to paracone by anterior mure, not isolated. P^4-M^2 protoconule and metaconule distinct, cuspate, and with less well developed protoloph and metaloph than in other *Taxymys.* M^{1-2} protocone larger with respect to hypocone than in *T. lucaris* or *T. progressus.*

Measurements.—Given in table 8.

Discussion.—*Taxymys cuspidatus* appears to be the most generalized known member of this genus in its lesser degree of bilophodonty, more cuspate conules, and large protocone. All other published specimens referred or referable to *Taxymys* are late Bridgerian in age, and no specimens in the hypodigm of *T. cuspidatus* preclude this species from the possible ancestry of *T. lucaris.*

The early sciuravids are imperfectly known; the family is in need of general review. *Dawsonomys, Tillomys,* and *Pauromys* are only positively known from lower teeth, and lower teeth of *Taxymys* are extremely rare. (Upper teeth of *Pauromys perditus* and *P. schaubi* are unknown; both Dawson (1968) and Nelson (1974) have described upper teeth of *Pauromys* sp.) Nevertheless, the type specimen and referred upper teeth of *Taxymys cuspidatus* conform most closely with those of *Taxymys lucaris* among the sciuravids.

The upper teeth of *T. cuspidatus* are quite brachydont, more rounded, less bilophate, and more basined than are those of *Sciuravus.* From *Pauromys* sp. (Dawson, 1968), they differ in the absence of a mesocone, in the construction of the mesostyle, in the better developed conules, and in the retention of two anterior cusps on referred specimens of P_4.

Seven lower teeth representing P_4–M_3, are tentatively referred to *Taxymys cuspidatus* on the basis of their size, their association with the remainder of the topodigm of the species, and their general sciuravid construction. M_1(?) is strongly worn, but M_2 and several specimens of M_3 resemble somewhat these teeth in *Sciuravus bridgeri* Wilson (1938), another sciuravid whose upper dentition is unknown or unrecognized. USNM 251591 (an M_2, pl. 7*M*) is close to YPM 13464 (*S. bridgeri*, probably an M_1) in the rhomboid occlusal outlines of both teeth, in broad, deep central fovea, in continuous hypoconulid-entoconid shelf, in the short entoconid, and in having a lingual mesolophid connecting the entoconid and the mesoconid. M_3 of *T. cuspidatus*, however, is unlike that of *Sciuravus bridgeri* (for example, YPM 13465, 13556–2) in having a much stronger and more transverse mesoconid and in having a postprotocristid that swings anteriorly in front of the metaconid at the anteroposterior midline of the tooth, and not posteriorly behind the metaconid. M_3 of *T. cuspidatus* also lacks the metastylid that occurs in *S. bridgeri*, and M_{2-3} of *T. cuspidatus* have a stronger metalophid, reminiscent of the bilophid trigonid in *Reithroparamys delicatissimus.*

Wilson (1938, p. 299) suggested that *Sciuravus bridgeri* may represent the unknown lower teeth of *Taxymys lucaris.* That this does not seem very likely is in-

TABLE 8.—*Measurements, in millimeters, of teeth of* Taxymys cuspidatus, *sp. nov., from the Aycross Formation*

[Leaders (- -), no tooth]

USNM No.[1]	P^3L	P^3W	P^4L	P^4W	M^1L	M^1W	M^2L	M^2W	M^3L	M^3W
USGS 1999	0.55	0.55	1.35	1.70	1.75	1.80	1.90	2.00	1.90	1.90
251605	- -	- -	- -	- -	- -	- -	1.70	1.75	- -	- -
251590	- -	- -	- -	- -	- -	- -	- -	- -	1.75	1.80
251632	- -	- -	- -	- -	1.70	1.80	- -	- -	- -	- -
251628	- -	- -	- -	- -	- -	- -	1.75	1.85	- -	- -
251626	- -	- -	- -	- -	- -	- -	1.70	1.80	- -	- -

USNM No.	P_4L	P_4W	M_1L	M_1W	M_2L	M_2W	M_3L	M_3W
251611	- -	- -	- -	- -	- -	- -	2.05	1.55
251591	- -	- -	- -	- -	1.80	1.75	- -	- -
251587	1.30	1.20	- -	- -	- -	- -	- -	- -
251631	- -	- -	- -	- -	- -	- -	2.00	1.65
251625	- -	- -	- -	- -	- -	- -	1.85	1.60
251646	- -	- -	- -	- -	- -	- -	2.15	1.70
251644	- -	- -	1.75	1.50	- -	- -	- -	- -

[1]All USNM except USGS 1999.

dicated by (1) the differences in the lower teeth here referred to *T. cuspidatus*, (2) the absence of other *Taxymys*-like upper molars in rocks of early Bridgerian age, and (3) the absence of *Sciuravus bridgeri*-like lower teeth in rocks of late Bridgerian age.

CORRELATION OF THE AYCROSS MAMMALS

The known mammal fauna of the Aycross Formation of the southeastern Absaroka Range is a heterogeneous one, but one clearly of Bridgerian (middle Eocene) age. Age-diagnostic faunal elements indicate that the best correlation is probably with early Bridgerian ("A" and "B") faunas of southwestern Wyoming. Most important in this assignment are specimens referred to *Microsyops* sp., cf. *M. elegans*, *Hyopsodus* sp., cf. *H. paulus*, and *Antiacodon pygmaeus*. These species, as currently understood, occur only in rocks of early Bridgerian age. *Eotitanops borealis* and *Palaeosyops fontinalis* are also dominantly early Bridgerian (Bridger "A") or older, and *Trogosus* sp., *Hyrachyus modestus*, and cf. *Helaletes nanus* are most abundant in early Bridgerian faunas, though they do also occur in younger rocks.

Assignment of the Aycross collection to either a Bridger "A" or Bridger "B" equivalent is presently impossible, and the distinction between these fanuas is doubtful elsewhere, including the type area in southwestern Wyoming. McGrew and Sullivan (1970) believed that the mutual occurrence of *Palaeosyops fontinalis*, *Bathyopsis middleswarti*, and a "distinct size group of *Notharctus*," (?*N. robinsoni* of Gingerich, 1979) was diagnostic of the Bridger "A" fauna. The paucity of *Hyopsodus* in Bridger "A" rocks and the apparent absence of uintatheres in Bridger "B" rocks, however, seem to indicate that the possibility of environmental control suggested by those authors is responsible, because both are relatively common in rocks younger than Bridger "A" and Bridger "B", respectively. Robinson (1966) believed that *Palaeosyops fontinalis* was exclusively Wasatchian, and *Bathyopsis middleswarti* is known only from the Bridger "A".

Little faunistic change is observed in successively higher collections from the Aycross Formation in the Owl Creek–Grass Creek area; however, the three most important localities are in the lower part of the formation and no rich localities have yet been found in the upper part of this sequence. Approximately 30 specimens have been recovered from the superjacent Tepee Trail Formation, including large titanotheres and tapiroids, but the collection is largely fragmentary teeth and bones and remains to be identified. The broader areal distribution and age significance of the mammals described in this report may be briefly summarized.

ORDERS MULTITUBERCULATA (?), MARSUPIALIA

The only specimen of a possible multituberculate cannot be identified to genus and is of no utility in correlation. Gazin (1976) noted the occurrence of *Peradectes innominatus* ("*Peratherium*" *innominatum*) and *Peratherium marsupium* in both lower and upper levels of the Bridger Formation. *Peratherium knighti* occurs in the upper Bridger, and both this species and *P. marsupium* have close relatives in Duchesnean rocks on

Lysite Mountain, in the eastern Owl Creek Mountains, Wyo. (Setoguchi, 1975). *Perathium knighti* may also occur in rocks of early Bridgerian age (West and Dawson, 1973). These species are apparently not useful for correlation within the middle Eocene.

ORDER PROTEUTHERIA

The only known Aycross leptictid appears closest in morphology to late Bridgerian *Palaeictops bridgeri* from Tabernacle Butte, although the small size of the molars indicates that this sample may represent an early variant of that species that also shares crossing similarities with Wasatchian *P. bicuspis* and *P. multicuspis*. Too little is known about the variation in Eocene *Apatemys* to make this animal useful in faunal correlation, and the questionable didelphodontine premolar cannot confidently be assigned to a genus.

ORDER INSECTIVORA

The species of *Scenopagus* span all of the Bridgerian, and *S. curtidens* and *S. priscus* probably also occur at some late Wasatchian localities (Krishtalka, 1976a). *S. edenensis* is alone apparently restricted to the Bridgerian. *Macrocranion* is best represented in Wasatchian rocks, but it has one known middle or late Eocene occurrence (Krishtalka and Setoguchi, 1977). The Aycross specimen does not appear to represent a described species. *Myolestes dasypelix* is otherwise known only from the lower Bridger Formation (Gazin, 1976). Its ally, *Centetodon* (sensu stricto), is principally known from post-Bridgerian rocks, but J. A. Lillegraven and M. C. McKenna (unpub. data, 1980) have recorded additional Bridgerian species, and undescribed forms are also known from the Wasatchian Willwood Formation (Bown and Schankler, 1981). *Nyctitherium serotinum* is apparently an ubiquitous Bridgerian insectivore, and cf. *Pontifactor* sp. is not age diagnostic (the type is from the Bridger "D" level), because a closely related form occurs in rocks of early Wasatchian age (Krishtalka, 1976b; Bown, 1979a).

ORDER PRIMATES

Microsyops elegans appears to be represented at several localities and is otherwise restricted to lower Bridger ("A" and "B") levels. The Aycross specimens also resemble late Wasatchian *M. scottianus*, a possible synonym of *M. elegans*. *Uintasorex parvulus* otherwise occurs only in late Bridgerian and Uintan localities, but *Alveojunctus minutus* probably also occurs in the early Bridgerian part of the Cathedral Bluffs Tongue of the Wasatch Formation (West and Dawson, 1973). *Phenacolemur*, a typically Wasatchian genus, is not positively known from other rocks of Bridgerian age but has close relatives that persist into the Uintan.

Omomys carteri is unknown at pre- and post-Bridgerian localities and is most abundant in the lower Bridger Formation. *Shoshonius* is otherwise a late Wasatchian genus, but a specimen of an Aycross omomyid possesses a strong M^2 mesostyle, the single most diagnostic feature in distinguishing *Shoshonius* from closely similar *Washakius*. "*Shoshonius*" *laurae* (late Bridgerian of Tabernacle Butte, Wyo., G. G. Simpson, in McGrew and others, 1959) is probably a synonym of *Washakius insignis*, as suggested by Szalay (1976). *Absarokius* is also a typically Wasatchian omomyid; whereas, *A. witteri* is probably Bridgerian. The sole Aycross specimen is only tentatively referred to this genus. *Aycrossia*, *Strigorhysis*, and *Gazinius* (Bown, 1979b) are known only from the southeast Absaroka Aycross Formation but are clearly advanced over their Wasatchian anaptomorphine counterparts. Several specimens of *Notharctus* sp. probably belong to either *N. robinsoni* (for example, Gingerich, 1979) or *N. pugnax*, both of which are apparently restricted to the early Bridgerian.

ORDERS CREODONTA, CARNIVORA, AND MESONYCHIA

Proviverroides piercei may have been derived from *Proviverra*, a Wasatchian and Bridgerian genus. The sole tooth of *Patriofelis* is smaller than that in most other *Patriofelis* and cannot be assigned to a species. *Viverravus gracilis* and *Uintacyon* are known from rocks of both early and late Bridgerian ages, as is *Mesonyx* sp., cf. *M. obtusidens*, the only mesonychid.

ORDERS CONDYLARTHRA, TILLODONTIA, AND DINOCERATA

Hyopsodus paulus is apparently restricted to the early Bridgerian and *Bathyopsis* is thus far known only from lower Bridger ("A") localities and from rocks of late Wasatchian age. *Trogosus* is most common in the lower part of the Bridger Formation.

ORDERS PERISSODACTYLA AND ARTIODACTYLA

Orohippus specimens more closely resemble *O. pumilus* and *O. major* from the early Bridgerian than they do younger species. *Eotitanops borealis* occurs in both late Wasatchian and early Bridgerian faunas but is perhaps more diagnostic of the former. Both *Palaeosyops fontinalis* and *Antiacodon pygmaeus* are confined to the early middle Eocene. *Helaletes nanus* and *Hyrachyus modestus* are most common in early Bridgerian faunas and their equivalents, but both are known in younger rocks; and *Hyrachyus modestus* has been found in the Lost Cabin Member of the Wind River Formation (late Wasatchian, Wood, 1934; Guthrie, 1971).

ORDER RODENTIA

Leptotomus, *Pseudotomus*, *Thisbemys*, and *Microparamys* species range throughout the Bridger Formation and its equivalents elsewhere; however, *Leptotomus* species from the Aycross appear to be smaller and more generalized than other described species. Aycross *Thisbemys corrugatus* is smaller than specimens of this taxon from the upper Bridger Formation, and *Thisbemys* sp. is perhaps closest to *T. plicatus*, a dominantly early Bridgerian species. The *Microparamys* material is not diagnostic, but the smaller form resembles *M. wilsoni* from the upper Bridger Formation. Wood (1962) has recorded *Reithroparamys delicatissimus* from both upper and lower levels of the Bridger Formation. *Taxymys cuspidatus* is smaller and more generalized than either *T. lucaris* or *T. progressus*, both of which are late Bridgerian.

CORRELATION WITH THE TYPE AYCROSS FORMATION

Wood, Seton, and Hares (1936) briefly described fossil mammals from two different levels of the Aycross Formation in its type area in the northwestern Wind River Basin. The stratigraphically highest faunal assemblage (Duncan Ranch fauna) is clearly of late Bridgerian age, probably near the Bridger "C" age attributed to it by Wood, Seton, and Hares. These fossils are definitely younger than any from localities thus far sampled in the Aycross Formation of the Owl Creek–Grass Creek area; the two areas have only *Hyrachyus* cf. *modestus* in common (The remainder of the Duncan Ranch fauna includes *Patriofelis ferox*, *Hyrachyus eximius*, *Uintatherium* cf. *mirabile*, *Telmatherium* cf. *cultridens*, *Telmatherium* cf. *validum*, and cf. *Tillotherium*.) McKenna (1972, p. 91) observed that the upper fauna from the type area of the Aycross Formation is "Bridgerian" and is close to that from referred lower Tepee Trail rocks at the summit of Togwotee Pass.

A second collection, obtained "more than a hundred feet lower," contains *Desmatotherium guyotii*, *Eotitanops borealis*, *Palaeosyops* cf. *major*, *Patriofelis*, and an "isectolophid." Wood, Seton, and Hares (1936, p. 394) believed that these fossils suggest a "Lower Bridger age, possibly equivalent to Bridger A." Only *Eotitanops borealis* and an indeterminate species of *Patriofelis* are held in common between the lower fauna in the type area of the Aycross and the rocks in the southeast Absaroka Range; however, barring environmental considerations, *E. borealis* is probably sufficient to assign both collections, in the light of associated material, to the early Bridgerian.

Three additional specimens from near the type area of the Aycross Formation (Bitterroot Ranch, sec. 32, T. 42 N., R. 104 W., Fremont County, Wyo.) were obtained in 1977, but they do little to assist further in the correlation of the type area. These specimens are cf. *Palaeosyops* sp. (probably not *P. fontinalis*), *Hyrachyus* sp., cf. *H. eximius*, and *Phenacodus* sp. (possibly a new species). *Hyrachyus eximius* occurs in both early and late Bridgerian faunas but is most common in the latter. *Phenacodus* is rare in post-Wasatchian faunas but persists until at least the late Bridgerian. (See, for example, West and Atkins, 1970.)

POST-WILLWOOD MAMMALS FROM WEST OF CODY, WYOMING

Jepsen (1939), Demarest (1940), and Van Houten (1944) have recorded four localities that yielded mammal teeth from exposures of tuffaceous rocks: (1) in the Ishawooa Hills (probably secs. 31 and 32, T. 50 N., R. 105 W., and secs. 5, 6, T. 49 N., R. 105 W.), and (2) east of Aldrich Creek (probably sec. 12, T. 49 N., R. 105 W.), adjacent to the drainage of the South Fork of Shoshone River. Localities A2, A4, and A5 of Van Houten (1944, p. 202) were believed to be in the early acid breccia and early basic tuff (of Rouse, 1935), and locality B1 was in the early basic breccia. All these localities probably occur in the Wapiti Formation of Nelson and Pierce (1968). These collections contain teeth of the following mammals (identified by G. L. Jepsen, unless otherwise noted):

Locality A2
- ?tillodont, incisor fragment

Locality A4
- *Microsyops* sp., right M^1
- *Hyopsodus* sp., left P_3, left M_{1-2}
- ?*Pseudotomus* sp., fragment of upper molar (larger than *P. coloradensis*, identified by Bown)
- *Trogosus*? *latidens*, right incisor, P_4, M_3
- ?taeniodont, incisor fragments
- titanothere tooth fragments (specimens now apparently lost)

Locality A5
- Large ischyromyid, incisor fragment
- *Pseudotomus coloradensis*, left P_4 (identified by A. E. Wood, 1962, p. 179)

Locality B1
- *Microsyops* sp., left M^2
- *Didymictis* sp., left M^2
- ischyromyid, incisor fragment

Jepsen (1939; and in Van Houten, 1944) believed that these mammals indicate a late early Eocene or middle Eocene age, noting that the *Didymictis*, *Hyopsodus*, and titanothere teeth are suggestive of the younger age. *Didymictis* is actually more representive of the Wasatchian. Wood (1962) gave the known distribution of *Pseudotomus coloradensis* as "lower Eocene," including PU 14687a (from the Wapiti Formation) in the hypodigm of that taxon. Although this collection is admittedly rather small to determine a reliable age, some of these faunal elements clarify the age of their Wapiti Formation localities in the light of the larger Aycross assemblage discovered some 57 km to the south.

Wapiti Formation *Microsyops* is represented by two upper molars, PU 14693 and 18634. The former specimen is longer anteroposteriorly (M^2L=4.85 mm, M^2W=5.40 mm) than any *Microsyops* in the Aycross collection described previously, and the tooth is absolutely much larger than in any Wasatchian *Microsyops*. As Szalay (1969a, p. 272) determined for *Microsyops* sp. from the Carter Mountain local fauna (YPM loc. 3), the Wapiti specimens are approximately intermediate in size between *M. elegans* (including *M. scottianus*) and *M. annectens*. *Microsyops elegans* is elsewhere apparently restricted to the early Bridgerian and *M. annectens* to the late Bridgerian. (See Szalay, 1969a; Gazin, 1976.)

The associated teeth referred by G. L. Jepsen (in Van Houten, 1944) to *Trogosus*? *latidens* are those of a very large tillodont, clearly both much larger and more advanced than any known Wasatchian form. The type specimen of *Trogosus*? *latidens* (YPM 11085) is inadequate but, as Gazin (1953) recognized, the larger tooth size appears to be distinctive. *T.*? *latidens* elsewhere appears to be restricted to middle Eocene rocks (Gazin, 1953, 1976).

PU 14692, a left M^2 referred by Jepsen (1939) to *Didymictis*, is, as observed by Jepsen, also markedly larger than any known late Wasatchian species and differs from M^2 in *D. latidens* in the larger size, in being less transverse, and in the possession of a continuous lingual cingulum. G. T. MacIntyre, in a note accompanying the specimen, has observed that "* * * if [the tooth is] *Didmictis*, then [it is] *D. vancleveae* * * *, a species described by Robinson (1966) from the upper faunal zone of the Huerfano Formation. The type of *Didymictis vancleveae* was not seen, but if this assignment is correct, Wapiti *Didymictis* has its closest counterparts in rocks of probable early Bridgerian age in southern Colorado.

PU 16133, 18632, and 18634 are teeth of a species of *Hyopsodus* much larger than those of *Hyopsodus* sp., cf. *H. paulus* from the Aycross Formation. G. L. Jepsen's comments (in Van Houten, 1944; and in Hay, 1956) on the frequency of occurrence of the metastylid in Wasatchian and Bridgerian *Hyopsodus* are equally valid today, and the presence of this cusp in PU 16133 indicates a strong probability that the teeth are post-Lost Cabin in age. PU 16133, an M_2, is the only complete *Hyopsodus* tooth from the Wapiti Formation, and its size (M_2L=5.2 mm, M_2W=4.1 mm) is just above the maximum recorded by Gazin (1968) for late Bridgerian ("C" and "D") *H. despiciens*. *Hyopsodus* teeth of this size, however, are well known in Wasatchian rocks (as, *Hyopodus browni* and *H. powellianus*), and the presence of the metastylid, although suggestive, is not definitive.

Although the age of the Wapiti Formation mammals is still open to some debate, the known collection is clearly of greater Bridgerian than Wasatchian aspect. The specimens of *Microsyops* are nearly definitive in this regard, but the possibility remains that unkown ecological factors exist that bias this determination. *Microsyops* in the Wapiti has a close relative if not a conspecific in the lower Carter Mountain fauna, an assemblage that was earlier also hesitantly included in the late early or early middle Eocene (E. L. Simons, in Wilson, 1963; Radinsky, 1963; Szalay, 1969a). None of the Wapiti mammals are typically Wasatchian, and none would be unexpected finds in the Aycross Formation. The probability is that the Wapiti Formation mammals and certainly lower Carter Mountain collections (J. G. Eaton, oral commun., 1980) are also early middle Eocene in age.

MAMMALS FROM THE TATMAN FORMATION

A small collection of vertebrate remains, including six mammal teeth, was recovered in 1970 by David Parris from two localities in the type Tatman Formation in secs. 20 and 21, T. 50 N., R. 97 W., Big Horn County, Wyo. (See Rohrer, 1964b.) Mr. Parris has kindly forwarded this collection to me for inclusion in this report. The basal Tatman Formation intertongues with the upper part of the underlying Willwood Formation on the Tatman Mountain table and on the Squaw Buttes divide (Van Houten, 1944; Bown, 1979a), and the preserved part of the Tatman is approximately 220 m thick on Tatman Mountain (Rohrer, 1964b). *Lambdotherium* is known from several Yale Peabody Museum localities in at least the upper 100 m of the Willwood Formation, demonstrating that the Tatman localities are late Wasatchian in age, or younger (Wood and others, 1941; Van Houten, 1945; Schankler, 1980; Bown, 1980).

The localities, designated 1 and 2 by Parris, occur in the upper and lower parts of the preserved Tatman sequence, respectively, and contain the following mammals:

Locality 1
- PU 20760, *Paramys copei*, right M^2 (identified by Parris)
- PU 20762, *Microsyops scottianus*, right M_1 (identified by Parris)

Locality 2

PU uncatalogued, cf. *Hyopsodus* sp., right M^3

PU uncatalogued, cf. *Hyopsodus* sp., right M^2

PU uncatalogued, *Hyopsodus* sp., talonid of left $M_{1 or 2}$

PU 20763, *Microsyops scottianus*, right M^1 (identified by Parris)

The teeth of *Microsyops* are too large to belong with *M. latidens* but fit the observed ranges of measurements given by Szalay (1969a) for both *Microsyops scottianus* and *M. elegans*. Parris assigned the specimens to the former species but recognized that they might equally well belong to the latter. The teeth are smaller than teeth referred to *Microsyops* sp., cf. *M. elegans*, from the Aycross Formation or *Microsyops* sp. from Carter Mountain.

Regarding the specimen of *Paramys*, Parris (written commun., 1977) noted that "a favorable comparison" was made "with the RM^2 of PU 13433" (*Paramys copei*). The hypocone is very small, which is contrary to Wood's (1962) *P. copei bicuspis* and *P. copei major*; and the mesostyle is a single cusp in contrast to *P. copei bicuspis*. Both the protoconule and metaconule are simple, single cusps. *Paramys copei* is most common in Wasatchian rocks but probably occurs also in the upper part of the Huerfano Formation of southern Colorado, in rocks called either early Bridgerian or "Gardnerbuttean" by some authors. McKenna (1976) has suggested that the faunal distinctiveness of the Gardner Butte local fauna is not as great as formerly believed and what differences do exist might reflect ecologic, not stratigraphic controls. McKenna believed the Gardner Butte local fauna to be late Wasatchian.

The Tatman mammals, if assessed at either end of their known range extremes, equivocally indicate late Wasatchian or earliest Bridgerian ages for the formation. The relative small size of the *Microsyops* teeth (with respect to Aycross materials) and the absence of *Paramys copei* in known rocks of early Bridgerian age in Wyoming, however, suggest to me that the Vass quarry fauna is probably slightly younger than (or ecologically different from) either of the Tatman Mountain localities. Although this interpretation is borne out in part by the extensive erosional unconformity between the Willwood and Aycross Formations in the Owl Creek–Grass Creek area and by the absence of volcanic material in the central Bighorn Basin Tatman Formation, it does not preclude the possible temporal equivalence of some Tatman and Aycross strata if lacustrine rocks on Lysite Mountain or in the mapped area of this report were ever contiguous with upper Tatman rocks now eroded away in the central Bighorn Basin. (See discussions herein and in Van Houten, 1944; Love, 1964; Rohrer, 1966a; Rohrer and Smith, 1969; Bay, 1969.)

FAUNAL SUMMARY

Vertebrates obtained from Aycross rocks in the southeastern Absaroka Range comprise an early Bridgerian (early middle Eocene) fauna, most closely correlated with the well-known Bridger Formation "A" and "B" assemblages of southwest Wyoming. Similar faunas have also been obtained from parts of the Green River Formation of southwest Wyoming and eastern Utah, the type area of the Aycross Formation of the western Wind River Basin, the upper part of the Huerfano Formation of southern Colorado, and the Wapiti Formation of the northeast Absaroka Range. The dominantly lacustrine Tatman Formation of the central Bighorn Basin has yielded a few teeth that are probably older than the stratigraphically lowest collections of mammals from the Aycross Formation of the report area.

Aycross mammals are dominated by the primates (12 species), insectivores (10 or 11 species), and rodents (9 species); however, these small mammals were largely obtained from quarries that yield fewer specimens of the larger perissodactyls or carnivorans. The representation of the Omomyidae (7 or 8 species of 6 or 7 genera—the higher figure indicated by the presence of *Washakius* in the 1978 collection) is the greatest for any single Bridgerian fauna, and the diversity of the anaptomorphines (5 species in 4 genera) is larger than in any other post-Wasatchian assemblage. By contrast, only 4 species and 3 genera of these primates occur in the Bridger Formation, which is the best collected sequence of this age in North America. Elsewhere, anaptomorphines are rare elements in middle Eocene faunas, whereas they are thus far the most abundantly represented primate subfamily in the Aycross Formation of the report area.

Eotitanops is only questionably present in other middle Eocene faunas, and it is more characteristic of the late Wasatchian, as is the uintathere *Bathyopsis*. *Palaeosyops fontinalis*, believed to be one of the index taxa for the Bridger "A" fauna by McGrew and Sullivan (1970), occurs in the Aycross fauna associated with mammals more diagnostic of a Bridger "B" age. *Shoshonius*, another omomyid, is otherwise known only from rocks of late early Eocene age. This overlap of diagnostic forms, coupled with the presence of at least five new genera and seven new species (see also Bown, 1979b), a probable multituberculate, and a bat in the Aycross fauna, mammals as yet unknown or rare in other middle Eocene rocks, indicates that Black (1967) was correct in his belief that later Eocene rocks along the margins of the Rocky Mountain intermontane basins record faunal environments not developed, preserved, or discovered elsewhere.

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PLATES 2–7

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PLATE 2

[Figures *A–D* and *F* are stereophotographs]

FIGURES *A*, *B*. *Scenopagus curtidens* (p. 44).

A. Occlusal view of USGS 2001, right P_4–M_2 (× 11).

B. Occlusal view of USGS 2002, right P^3–M^3 (× 11).

C. Microchiropteran (?), gen. et sp. indeterminate (p. 47).

Occlusal view of USGS 2003, left M_2 (× 12).

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Occlusal views of USGS 2006 (top), right P_4, and USGS 2005 (bottom), right M_1 (type specimen) (both × 11).

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F. *Proviverroides piercei*, gen. et sp. nov. (p. 50).

Occlusal view of USGS 1984 (maxillary part of type specimen), right P^4–M^3 (× 2).

INSECTIVORA, PRIMATES, CHIROPTERA, AND CREODONTA

PLATE 3

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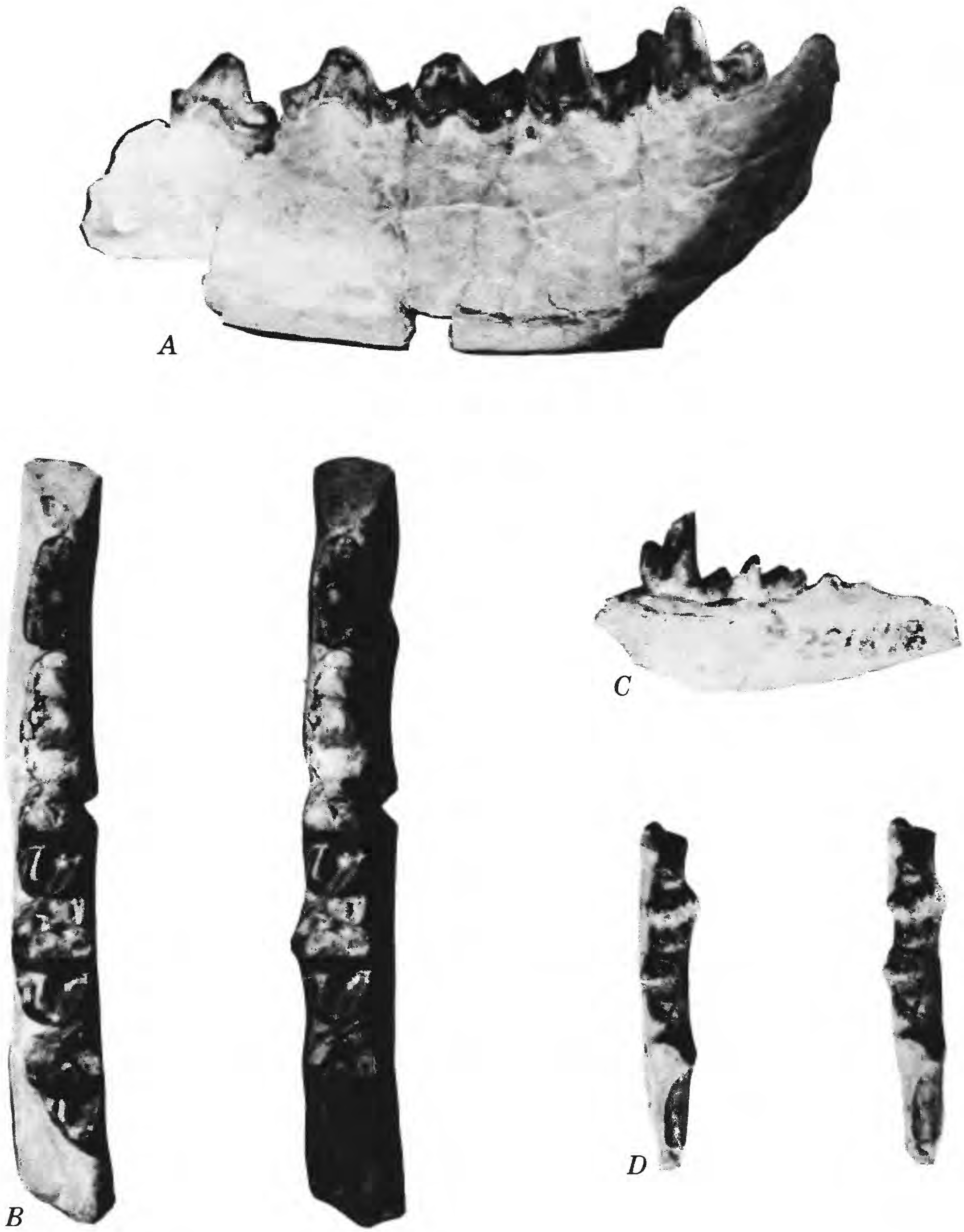

CREODONTA AND CARNIVORA

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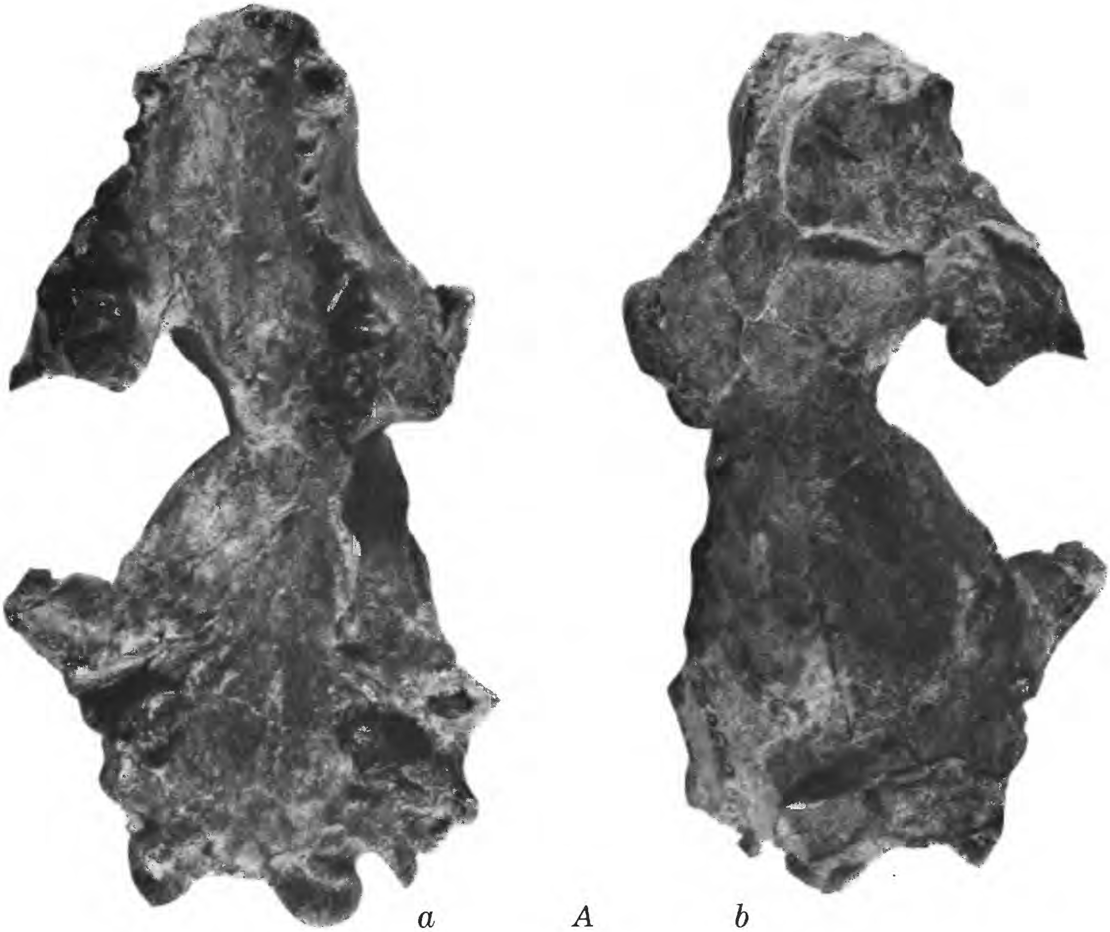
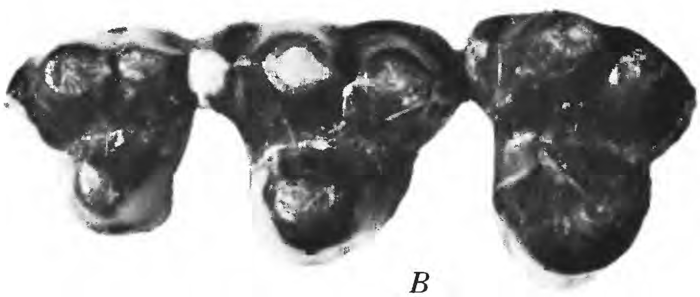


a *A* *b*



B

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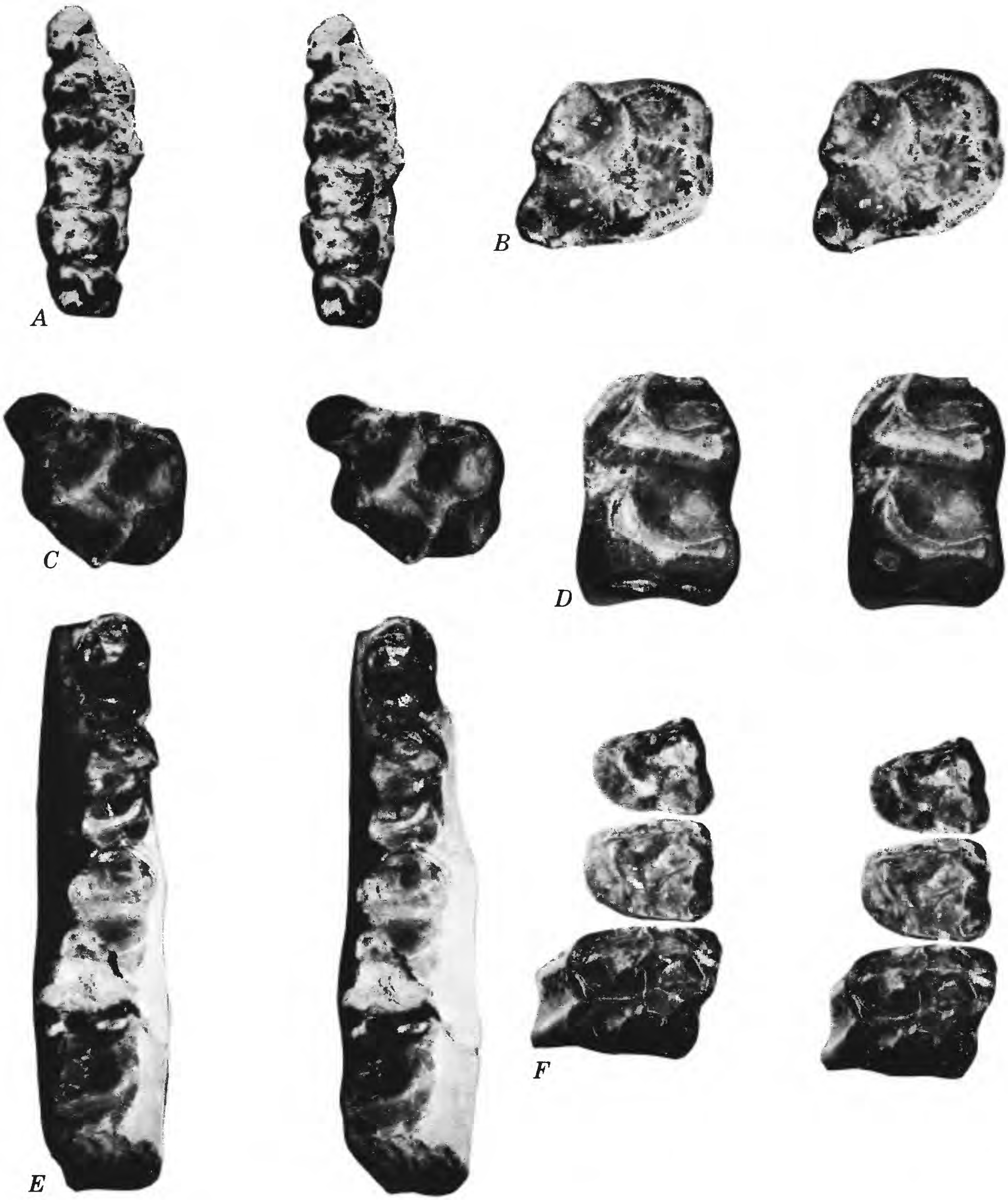

CONDYLARTHRA AND PERISSODACTYLA

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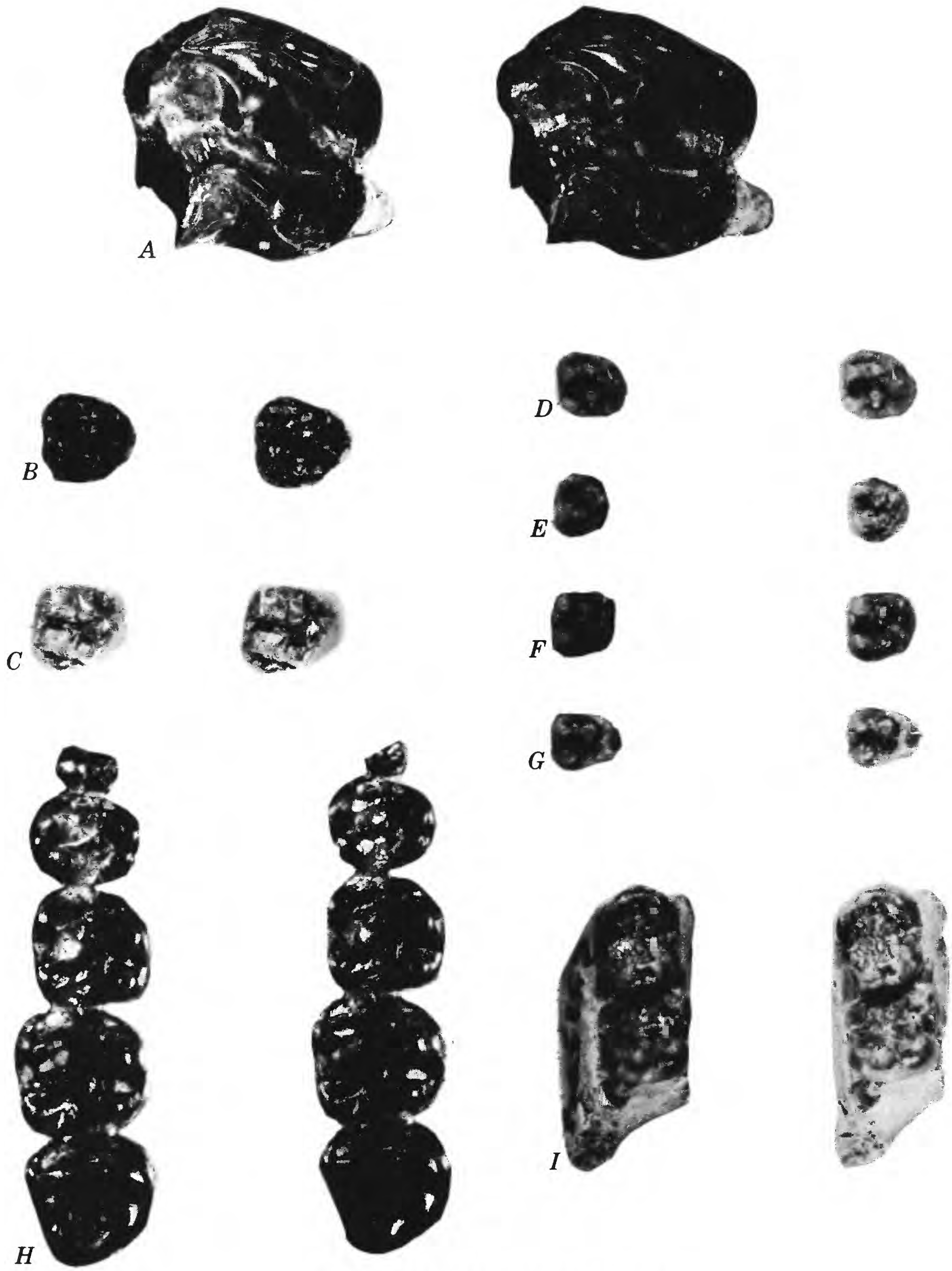

PERISSODACTYLA AND RODENTIA

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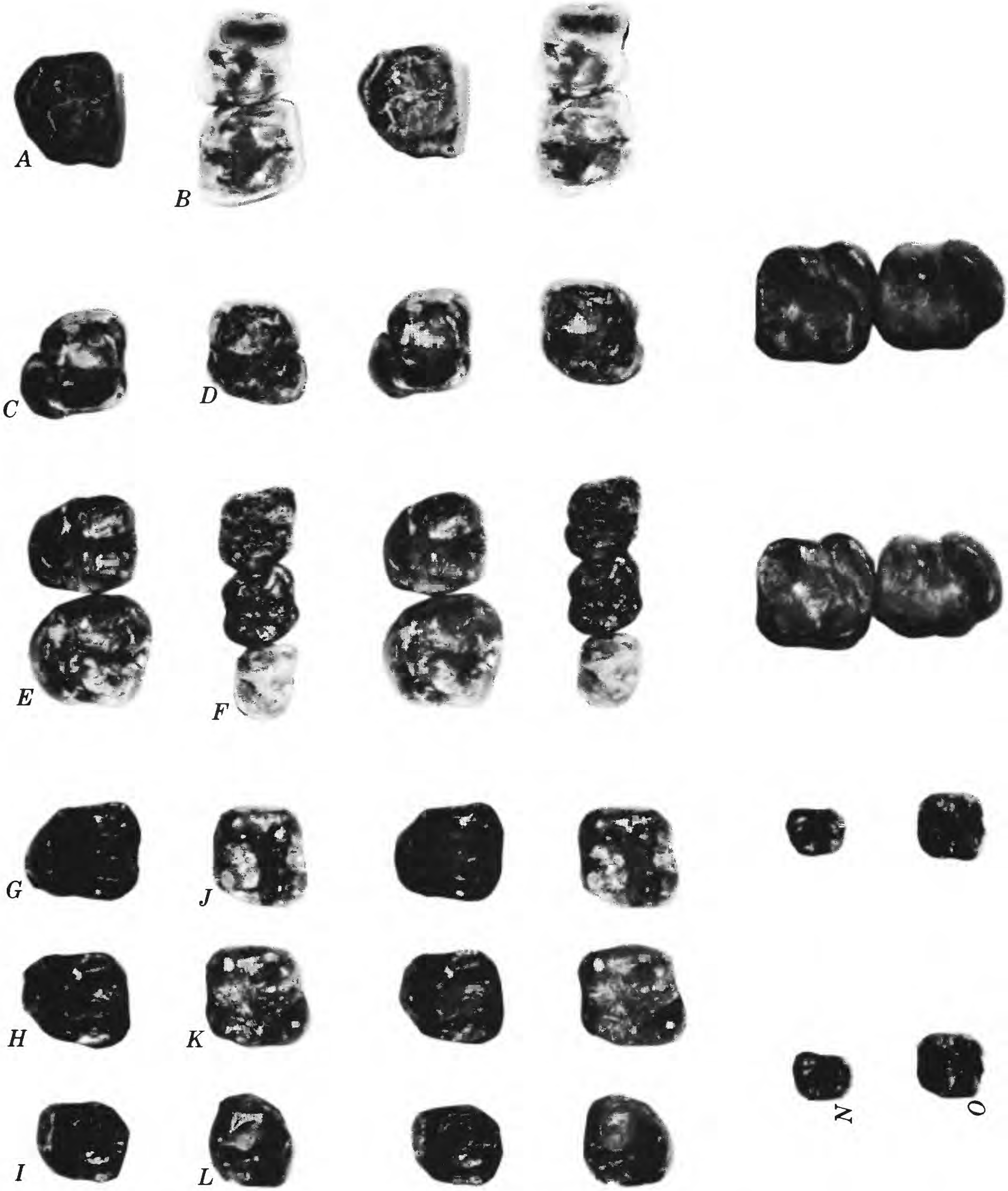

RODENTIA