Harebell Formation (Upper Cretaceous) and Pinyon Conglomerate (Uppermost Cretaceous and Paleocene), Northwestern Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 734-A

Prepared in cooperation with the Geological Survey of Wyoming and the Department of Geology of the University of Wyoming

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By J. D. LOVE

GEOLOGY OF GOLD-BEARING CONGLOMERATES IN NORTHWESTERN WYOMING

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The gold-bearing Harebell Formation and Pinyon Conglomerate contain many cubic miles of quartzite conglomerate from the now-buried Targhee uplift

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HAREBELL FORMATION (UPPER CRETACEOUS) AND PINYON CONGLOMERATE (UPPERMOST CRETACEOUS AND PALEOCENE), NORTHWESTERN WYOMING

By J. D. LOVE

ABSTRACT

The Harebell Formation of Late Cretaceous age crops out in an area of 265 sq mi (square miles) in Jackson Hole, northwestern Wyoming, and has a maximum thickness of about 11,000 feet. The Pinyon Conglomerate of latest Cretaceous and Paleocene age crops out in an area of 150 sq mi and has a maximum thickness of about 3,775 feet. Both formations contain thick zones of quartzite conglomerate from the same source; for this reason they are so similar that they have frequently been misidentified. No type section or reference section has previously been designated for either formation.

This report summarizes a comparison of differences and similarities of both formations and designates and presents a type section for the Harebell Formation and its conglomeratic Bobcat Member (a new name) and a principal reference section for the Pinyon Conglomerate. The chief differences between the two formations are in color, induration, and amount of volcanic debris. The Harebell is olive drab, has the greater induration, and contains abundant volcanic debris, especially in the northern sections. The Pinyon is light gray to light brown, has the lesser induration, and contains inconspicuous volcanic debris. A coal member, 50–140 feet thick, of early Paleocene age, is at the base of the Pinyon in the southeastern part of Jackson Hole. There is no such coal in the Harebell Formation.

Structural relations between the Pinyon and Harebell range from an angular unconformity of nearly 90° west of the Buffalo Fork thrust fault to near parallelism in the Box Creek downwarp. During deposition of the Harebell Formation, even in its uppermost part, brackish water repeatedly invaded the area. When the youngest strata were deposited, the oldest were 11,000 feet below sea level in the Box Creek downwarp. Major thrust faulting involved the Harebell Formation but ended before deposition of the Pinyon.

The discovery of an unabraded tooth of *Leptoceratops*, a small hornless dinosaur, 150 feet above the base of the Pinyon Conglomerate on Pinyon Peak is the basis for assigning a latest Cretaceous age to the basal part of the Pinyon Conglomerate. In the southeastern part of Jackson Hole, the Pinyon has Paleocene fossils at the base and at the top.

Gold is present in both formations, chiefly in quartzite conglomerate and sandstone. Preliminary analyses of the Harebell average 65 ppb (parts per billion) gold and have a maximum of 1,000; analyses of the Pinyon average 84 ppb and have a maximum of 8,700.

The source of the quartzite conglomerate in both formations is the recently named Targhee uplift, a now-buried uplift west and northwest of the Teton Range, beneath what is now the Snake River downwarp. The quartzite terrane of Precambrian and possibly Ordovician age in this uplift had an areal extent of 1,000 sq mi and provided a volume of quartzite conglomerate of 135 cu mi (cubic miles) to the Harebell Formation and 425 cu mi to the Pinyon Conglomerate. Of this, 40 cu mi of conglomerate in the Harebell Formation and 35 cu mi in the Pinyon are preserved in Jackson Hole.

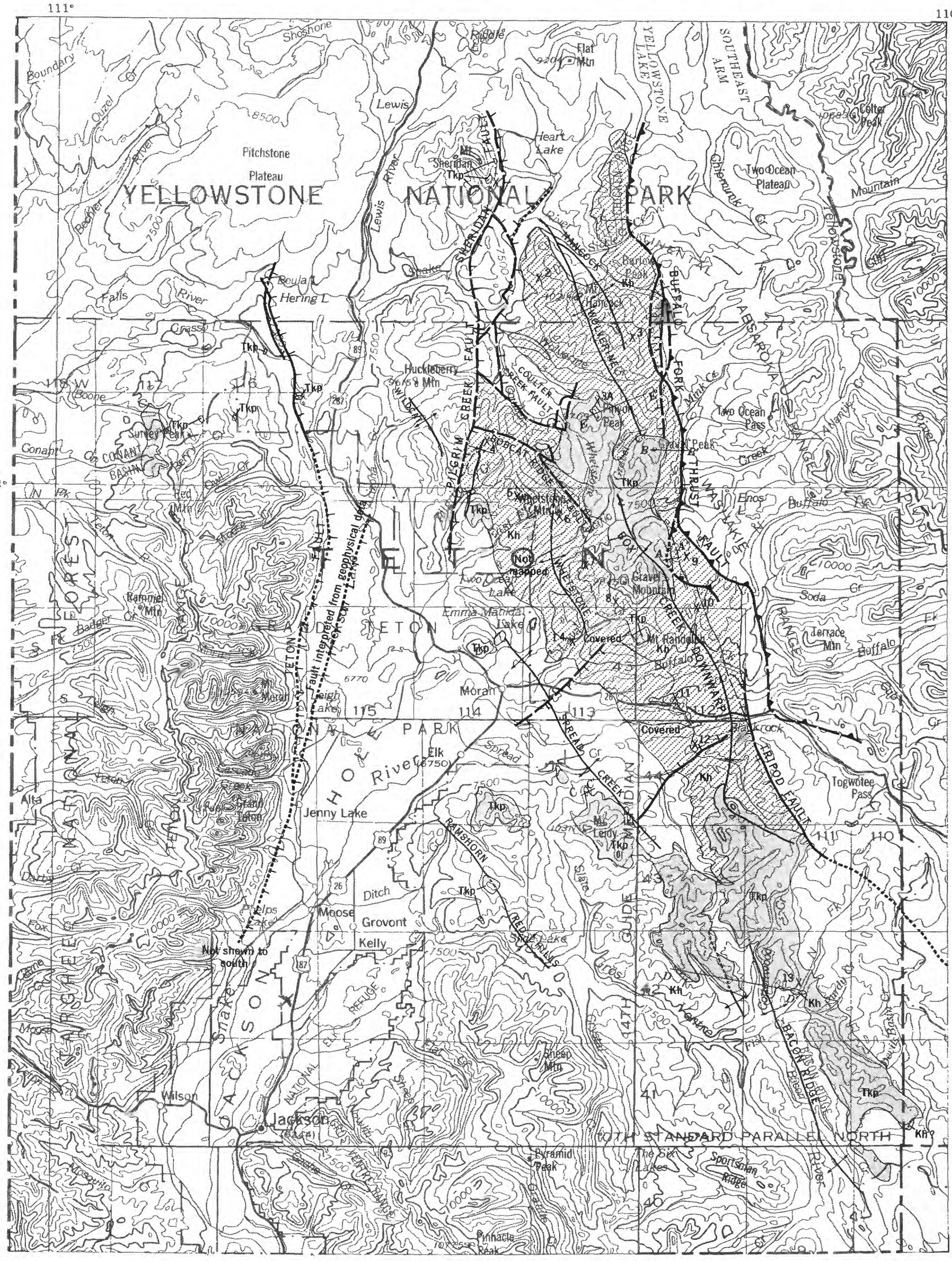
The climate during deposition of both the Harebell and the Pinyon was humid and warm. Large swift rivers flowed east and southeast from the Targhee uplift into Jackson Hole. Deposition was rapid in most places. Marine- or brackish-water incursions from the southeast were common while the Harebell Formation was being deposited but ceased prior to deposition of the Pinyon Conglomerate. Volcanism north and possibly northwest of Jackson Hole contributed much tuffaceous debris to the Harebell but little or none to the Pinyon.

INTRODUCTION

PURPOSE OF REPORT

The purpose of this report is to summarize new data, as well as old but previously unpublished data, on the Harebell Formation and Pinyon Conglomerate in northwestern Wyoming as an aid in distinguishing them in field mapping. The Harebell Formation crops out in an area of about 265 sq mi (square miles), and the Pinyon Conglomerate crops out in about 150 sq mi in northwestern Wyoming (fig. 1). The Harebell has a maximum thickness of about 11,000 feet; the Pinyon, about 3,775 feet. No type section or detailed description has previously been published for either formation. Both formations contain quartzite roundstone conglomerates of similar appearance and composition that were derived from a common source.

Some reasons for the paucity of detailed studies of these formations are: similarity of the conglomerates, remoteness of the areas where the sequences were first described, difficulty of access to key localities, mountainous topography, great thickness of


111°
110°
44°
YELLOWSTONE NATIONAL PARK
Pitchstone Plateau
Lewis L
Heart Lake
Flat Mtn
YELLOWSTONE LAKE
SOUTHEAST ARM
Colter Peak
Two Ocean Plateau
Mt Sheridan
Beula L
Hering L
Huckleberry Mtn
Barlow Peak
Mt Hancock
BUFFALO FORK THRUST
PILGRIM CREEK FAULT
COULTER CREEK FAULT
BOBCAT RIDGE
Two Ocean Pass
Survey Peak
CONANT BASIN
Whetstone Mtn
Not mapped
Two Ocean Lake
Gravel Mountain
Emma Matilda Lake
Rammel Mtn
Fault interpreted from geophysical data
TETON FAULT
Covered
Mt Randolph
Terrace Mtn
Mt Moran
Moran
Leigh Lake
GRAND TETON NATIONAL PARK
Blackrock
TRIPOD FAULT
Togwotee Pass
Elk (6750)
Jenny Lake
Grand Teton
Alta
SPREAD CREEK
RAMSHORN
Mt Leidy
Moose
Grovont
Kelly
Not shown to south
Sheep Mtn
BACON RIDGE
Wilson
Jackson
10TH STANDARD PARALLEL NORTH
Pyramid Peak
The Six Lakes
Sportsman Ridge
Pinnacle Peak
Tkp
Kh

the sequences, abundance of extensive landslides that distort areas of outcrop, complex structure, absence of accurate topographic and base maps until recent years, and lack of economic incentive. As a result, each worker who, by necessity, was involved with these strata made his own interpretations as to what constituted the Pinyon and what the Harebell; his decisions depended on where and how much he studied these rocks. Inevitably, therefore, a variety of usages developed, as well as even a question as to whether two formations were present, or only one (Bengtson, 1956, p. 158).

Gold has been known in the Pinyon Conglomerate since 1878 (O. H. St. John, in Hayden, 1883, p. 226), long before the formation was named, but not until 1965 was gold recognized in the Harebell Formation (Antweiler and Love, 1967). In 1966 a detailed study of the stratigraphy, structure, composition, and gold content of both the Harebell Formation and the Pinyon Conglomerate was initiated.

The mountains and basins of northwestern Wyoming are shown in figure 2. Their relations to the area of investigation and to adjacent pertinent features are given in figure 3.

EXPLANATION

Tkp

Tertiary and Cretaceous Pinyon Conglomerate

Kh

Cretaceous Harebell Formation
Dashed line indicates base of Bobcat Member

Contact
Dashed where approximately located

Normal fault
Dashed where approximately located; dotted where inferred. Hachures on downthrown side

Thrust fault with younger normal fault along same trace
Dashed where approximately located; dotted where inferred. Sawteeth on upper plate of thrust fault; hachures on downthrown side of normal fault

Anticline Syncline
Major folds, approximately located
Dotted where concealed

x6
Measured section described in report
X marks central location of section. Sections shown in figure 7

1. Mount Sheridan
2. Mount Hancock
3. Big Game Ridge
3A. Pinyon Peak
4. North Pilgrim Creek
5. East Pilgrim Creek
6. Whetstone Mountain
7. Pacific Creek
8. Gravel Mountain
9. Box Creek-Lava Creek divide
10. Box Creek Canyon
11. Rosies Ridge
12. North Fork Spread Creek
13. North Fork Fish Creek
14. Davis Hill

A —— A'
Line of section
See figures 13, 16, 19, 21 and 33

0 10 20 MILES

FIGURE 1 (left and above).—Geologic map of the Pinyon Conglomerate and Harebell Formation, Jackson Hole and vicinity, Wyoming. Geology by J. D. Love, 1945–70. Base from U.S. Geological Survey, Wyoming 1:500,000, 1964.

HISTORY OF INVESTIGATION

F. H. Bradley climbed Pinyon Peak (not named at that time) in 1872 and first observed the Pinyon Conglomerate in its type locality. He commented (in Hayden, 1873, p. 254–255) as follows:

> Ascending the high, sharp ridge on the west side of this valley [the head of the South Fork of Wolverine Creek] at least 500 feet high, we find its slopes to consist entirely of large and small well-rounded pebbles of variously-colored quartzites, up to the very summit, where this deposit is just pierced by an outcrop of the gray trachytic lavas and red basalt, partly vesicular, though mostly compact, which form the nucleus of the ridge. We here stood upon one of the highest points in that neighborhood, about 8,654 feet above the sea; so that we were entirely at a loss as to the source from which had flowed the large river which had distributed such immense amounts of gravel and sand. We could obtain no local data which should enable us to judge whether the stream had flowed northward or southward, but the general levels of the country would imply a northerly drainage. The deposit is evidently very ancient, but no considerable consolidation had taken place.

O. H. St. John (in Hayden, 1883) likewise observed and discussed the conglomerates and other strata, still unnamed as of that time, in both the Harebell Formation and the Pinyon Conglomerate. Somewhat more detailed observations were made by W. H. Weed (in Hague, 1896) who named the Pinyon Conglomerate, and by Hague (in Hague and others, 1899). No further investigations were made on these rocks for nearly half a century.

The present study was begun in 1945 and continued during parts of most subsequent field seasons through 1969. During that time, a reconnaissance geologic map (fig. 1) was made, and sections of the Harebell Formation, aggregating 75,000 feet, and of the Pinyon Conglomerate, aggregating 20,000 feet, were measured. Lithologic samples were collected at stratigraphic intervals of 10–100 feet from most sections. More than 10,000 samples were analyzed by the U.S. Geological Survey, chiefly for gold, silver, and mercury. Partial semiquantitative spectrographic analyses were made of several thousand. Other work included a study of thin sections and heavy-mineral separates of key beds and an examination of several hundred samples for fossils. These data have been used in studies of special aspects of the formations, such as distribution, characteristics, and values of gold (Antweiler, 1969 unpub. data; Antweiler and Sutton, 1970). Sedimentary structures, orientation of clasts, and petrography were studed by Lindsey (1969; 1970, unpub. data).

ACKNOWLEDGMENTS

Many persons have contributed to this study during the last 24 years. Chief among them was J. L. Weitz, who helped make many of the basic stratigraphic investigations in 1948, 1949, 1966, 1967, and 1968. J. C. Antweiler, whose stimulating, inquisitive, and perceptive research on gold in Jackson Hole in 1965 was a major factor in launching the northwest Wyoming conglomerate project in 1966, has been a constant source of ideas, encouragement, and indispensable data. D. A. Lindsey worked primarily on the petrography, orientation of rock fragments, and sedimentary structural features in both formations in 1967 and 1968 and provided data on these subjects for this report. Others who helped collect lithologic samples and fossils, who measured sections, and who assisted in field operations are: R. K. Hose, 1948 and

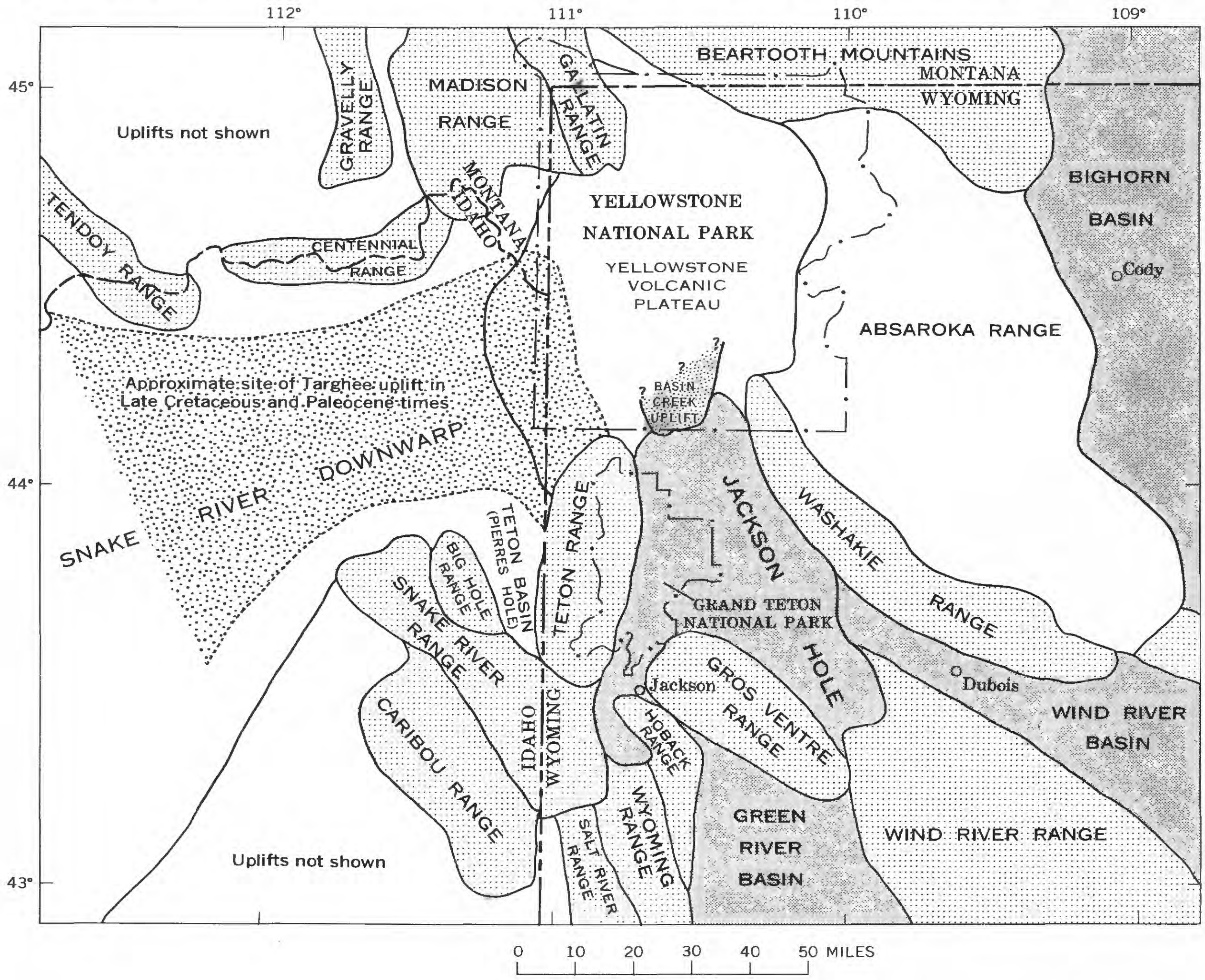


FIGURE 2.—Index map showing mountains, basins, and other features surrounding Jackson Hole. Folded and upfaulted mountains are emphasized by stipple and basins by shading. Inferred outline of Targhee uplift in latest Cretaceous and Paleocene times is shown by large dots enclosing random stipple.

1949; F. S. Fisher, 1966; J. A. Van Lieu, 1966; H. R. Bergquist, 1945 and 1947; D. C. Duncan, 1947; Mr. and Mrs. S. O. Reynolds, 1945, 1947, and 1948; and Emil and Larry Feuz, 1964, 1966, and 1968.

Paleontologists who identified the fossil collections are: R. W. Brown and J. A. Wolfe, leaves; E. B. Leopold and R. H. Tschudy, pollen; J. B. Reeside, Jr., D. W. Taylor, and T. C. Yen, mollusks; G. E. Lewis, vertebrate fossils; R. E. Peck, *Chara*; and E. G. Kauffman, brackish-water fossil *Mytilus* from the Harebell Formation. In addition, M. C. McKenna provided identifications of vertebrate fossils from the A.M.N.H. (American Museum of Natural History) dinosaur quarry in the Harebell Formation in stratigraphic section 11 and of mammals from beds overlying the Pinyon Conglomerate; he also led the A.M.N.H. 1969 field party that found *Leptoceratops* in the Pinyon Conglomerate on Pinyon Peak.

G. P. Zebal and Harvey French, using their data from planetable maps and sections, were of especial help in unraveling the stratigraphy of the Harebell Formation south of the Buffalo Fork. This report has

FIGURE 3.—Outline of geologic map area and relation of principal reference section of Pinyon Conglomerate and type section of Harebell Formation to regional features.

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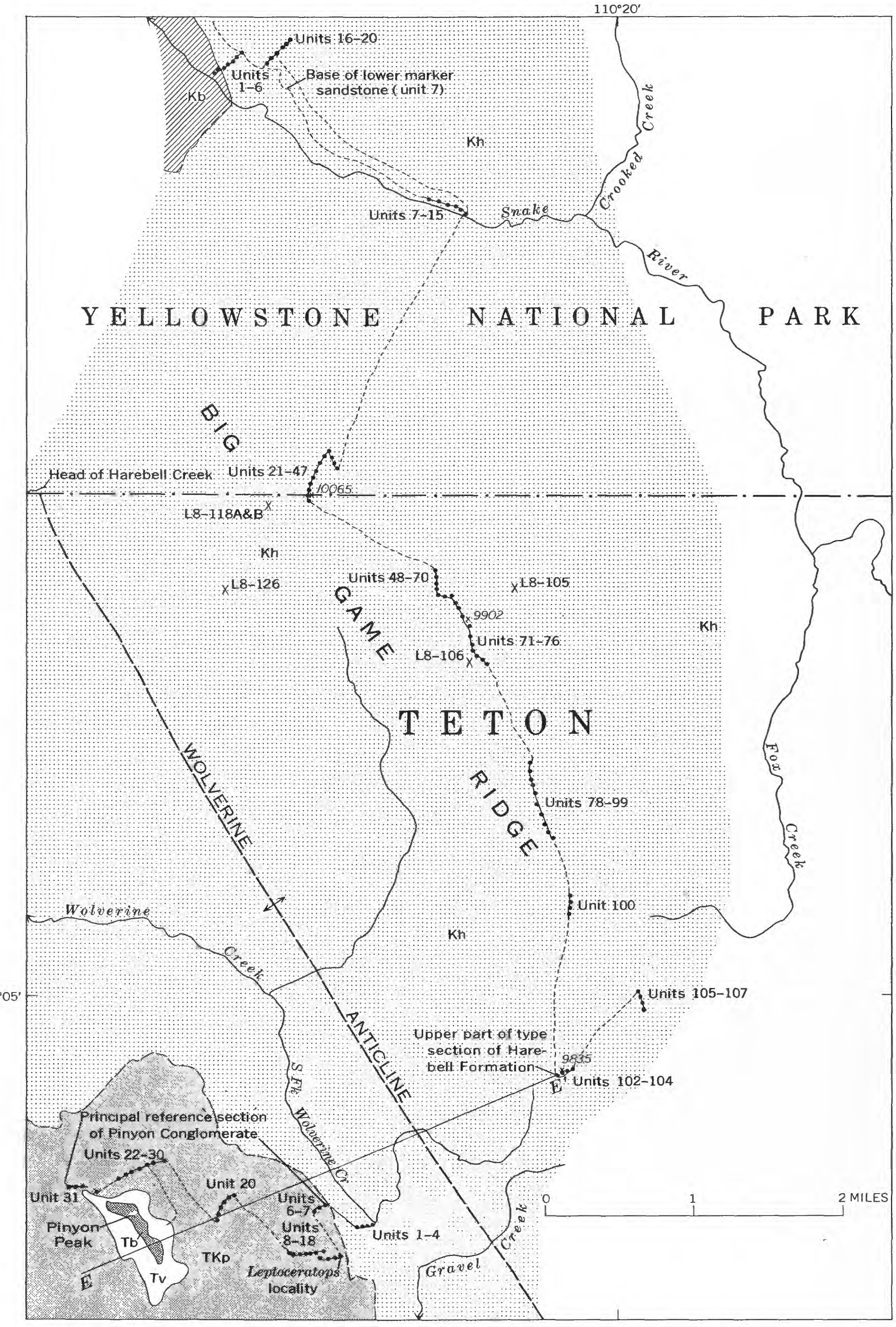


110°20'
Units 16-20
Units 1-6
Base of lower marker sandstone (unit 7)
Kb
Kh
Crooked Creek
Units 7-15
Snake
River
YELLOWSTONE NATIONAL PARK
BIG
Head of Harebell Creek
Units 21-47
10065
L8-118A&B
Kh
L8-126
Units 48-70
L8-105
9902
Kh
Units 71-76
L8-106
GAME
TETON
RIDGE
WOLVERINE
Fox
Creek
Units 78-99
Unit 100
Wolverine
Kh
Creek
44°05'
ANTICLINE
Units 105-107
Upper part of type section of Harebell Formation
9835
E'
Units 102-104
S Fk Wolverine Cr
Principal reference section of Pinyon Conglomerate
Units 22-30
Unit 20
Unit 31
Units 6-7
Units 8-18
Pinyon Peak
Tb
TKp
Tv
E
Units 1-4
Leptoceratops locality
Gravel
Creek
0
1
2 MILES

benefited from many stimulating discussions with W. L. Rohrer, who has done detailed mapping of the Pinyon Conglomerate and younger rocks along and east of the South Fork of Fish Creek.

HAREBELL FORMATION

NAME AND DEFINITION

The Harebell Formation was named (Love, 1956a) after Harebell Creek along the south boundary of Yellowstone National Park (fig. 4). No type section was designated at that time, but the type locality was described (p. 1900) as extending "from the head of the Snake River gorge southward over Big Game Ridge, about 2 miles east of Mount Hancock, and on across Wolverine Creek to the north base of Pinyon Peak."

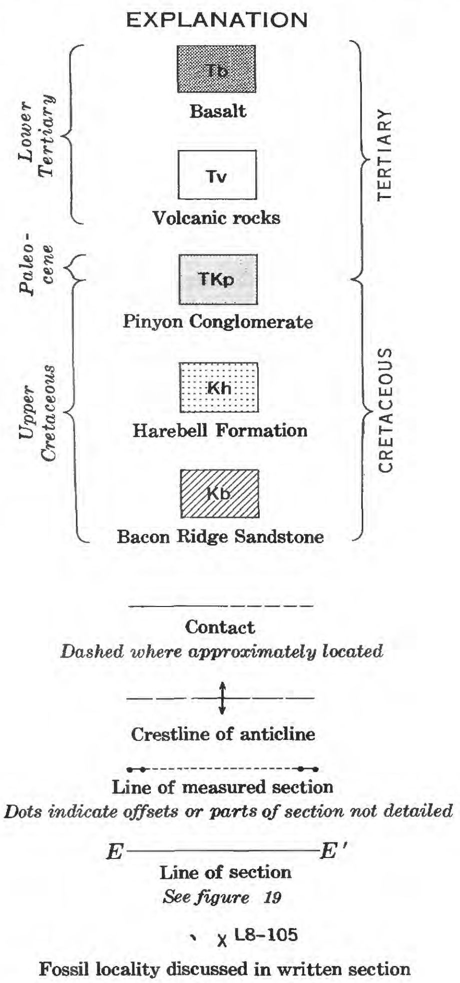


FIGURE 4.—Location of principal reference section of the Paleocene and Upper Cretaceous Pinyon Conglomerate (see also fig.19, cross section *E–E'*) and type section of the Upper Cretaceous Harebell Formation (see stratigraphic section 3). Base from U.S. Geological Survey Mount Hancock quadrangle, 1959.

The uppermost conglomeratic part of the formation is as much as 4,000 feet thick. It can be mapped separately in many areas and is designated the Bobcat Member (new name).

DISTRIBUTION AND THICKNESS

The distribution of the Harebell Formation is shown in figure 1. The type section (figs. 4, 5) extends from the Snake River southward to and along the top of Big Game Ridge. The type section of the Bobcat Member extends westward for 2½ miles from the bottom of the East Fork of Pilgrim Creek (fig. 6). The base of this section is about a mile southwest of Bobcat Ridge. The area of outcrop of the Harebell is about 265 sq mi, which is considerably more than that shown on the map accompanying the original description (Love, 1956a, fig. 1). This difference in interpretation arose because additional work has demonstrated that a large outcrop of conglomerate in the northern part of the mapped area, heretofore called Pinyon Conglomerate, is actually the Bobcat Member of the Harebell Formation. Many (but not all) of the measured sections on which this stratigraphic assignment is based are shown in figure 7.

The maximum thickness of the Harebell Formation is about 11,000 feet. All sections that were studied are only partial, and the thickest, section 2, is about 9,000 feet. Additional thicknesses of the formation are shown graphically in figures 7 and 13.

LITHOLOGY

Table 1 summarizes the composition and sedimentary features of the Harebell Formation and compares them with those of the Pinyon Conglomerate.

In the original description of the Harebell Formation, three facies were recognized: a fine-grained facies; a quartzite conglomerate sequence; and, in the southernmost part of the area, a conglomerate of Paleozoic sedimentary rocks. Between sections 3 and 12, the major thickness of fine-grained rocks is in the lower part of the formation. The upper more conglomeratic part is the Bobcat Member. Where the contact between them can be determined, it is shown as a dashed line on the geologic map (fig. 1).

Figure 5 shows the general appearance of the lower 2,000 feet of the formation at and north of its type section. The sequence is characterized by slope-forming monotonous sandstones, siltstones, and claystones. Details of lithology are illustrated by the type section for the formation.

Type section of Harebell Formation

[The base of the type section is exposed in the bottom of the Snake River Canyon about 1 mile southwest of Barlow Peak, southern Yellowstone National Park, and the top is exposed at the head of a north-facing cirque wall on the divide between Wolverine and Fox Creeks, 3½ miles south of the park boundary. The line of traverse, which extends southward from Snake River Canyon and along Big Game Ridge, is shown in figure 4. Some parts of the section were measured with Brunton compass and steel tape; several major intervals were computed, using the dips obtained in the field and the distances and elevations recorded on the topographic map of the Mount Hancock quadrangle. The structure is relatively uncomplicated along the line of section; beds dip 10°–15° SE. Descriptions and measurements are by J. D. Love and J. L. Weitz. Aiding in fossil collection and sampling were J. A. Van Lieu, R. K. Hose, Charles Nimick, and S. O. Reynolds. Thin sections were studied by D. A. Lindsey. Data were obtained during field seasons of 1945, 1948, 1949, 1964, and 1966. Fossils were identified by the following persons: D. W. Taylor and E. G. Kauffman, mollusks; R. W. Brown, leaves; R. H. Tschudy, pollen; and G. E. Lewis, dinosaur tooth.]

Top of section at erosion surface which is cut across Harebell Formation, on top of high north-facing cirque wall (elev 9,400 ft). An estimated thickness of 5,000 ft of younger beds 13 miles to the south (fig. 7) has been eroded from this locality.

	Thickness (feet)
Harebell Formation (part):	
107. Sandstone, drab, coarse-grained, massive to thick-bedded to crossbedded; at top is dense hard fine-grained crossbedded limy blue-gray sandstone which weathers to a rich dark brown and which looks petroliferous but has no odor; top sandstone is so hard that it forms the caprock of the hill	83
106. Conglomerate, dark-brown; composed of gray limestone and black shale pellets; forms conspicuous ledge	3
105. Sandstone, drab, coarse-grained, massive to thick-bedded, porous; forms lower part of big cliff	30
Offset 3,800 ft southwest to west edge of hill 9835 for units 102–104. This sequence can be traced across the offset area with some confidence; accuracy of correlation of offset beds is probably within 50 ft.	
104. Grit, brown; composed chiefly of limestone and clay balls as much as 1 in. in diam-	

FIGURE 5.—View looking northeast from top of Mount Hancock showing, at extreme right margin, the lower part of the type section of the Harebell Formation. Indicated are the unconformable contact between the Bacon Ridge Sandstone and Harebell Formation (A), Chicken Ridge and exposure of 3,000 feet of Harebell (B), Sickle Creek (C), Barlow Peak and exposure of 2,700 feet of Harebell (D), Cody Shale (E), and Southeast Arm of Yellowstone Lake (F).

Harebell Formation (part)—Continued	*Thickness (feet)*
eter; contains angular black chert and red quartzite fragments as much as ¼ in. long; part of unit is a hard brown sparkly highly biotitic sandstone that superficially resembles an igneous rock	3
103. Sandstone, olive-drab, very soft, silty	15
102. Sandstone, drab, coarse-grained, soft, porous, highly micaceous; forms weak ledge	20+
Offset 3,800 ft north to main line of section for underlying units.	
101. Beds in this interval were not sampled or described in detail; approximate thickness was computed from topographic map, aerial photographs, and dips taken in the field; the upper 600 ft is completely exposed in a precipitous north-flowing torrent gully 3,000 ft southwest of line of section and directly underlying unit 102 and consists of dark-gray to drab soft well-bedded siltstone and claystone interbedded with a few minor sandstone ledges; the lower part of sequence is drab soft siltstone and claystone with a lesser amount of thin-bedded hard fine-grained drab sandstone; apparently no quartzite pebble conglomerates are present, for the debris at the mouth of the gully contains no quartzite fragments	1,100±
100. Tuff, white, hard, siliceous; breaks into angular chips and plates; overlies creamy-white soft bentonite; harder layers look much like weathered Mowry Shale; abundant plant fragments were seen, but no well-preserved leaves; approximate strike N. 60° E., dip 12° SE	12±
99. Beds in this interval were not sampled or described in detail; thickness was computed; sequence is drab soft siltstone and claystone and thin beds of sandstone; no prominent hard beds	220±
98. Sandstone, light-gray, medium- to coarse-grained, hard, irregularly bedded; pepper-and-salt appearance; caps ridge; contains sparse large well-preserved leaves	20+
97. Claystone; drab in upper part; black and blocky in lower part	16
96. Siltstone, silty sandstone, and claystone; tawny brown in upper half, gray in middle, dark green in lower part	16
95. Sandstone and siltstone, drab, poorly exposed; top 1 ft is ledge of sandstone	33

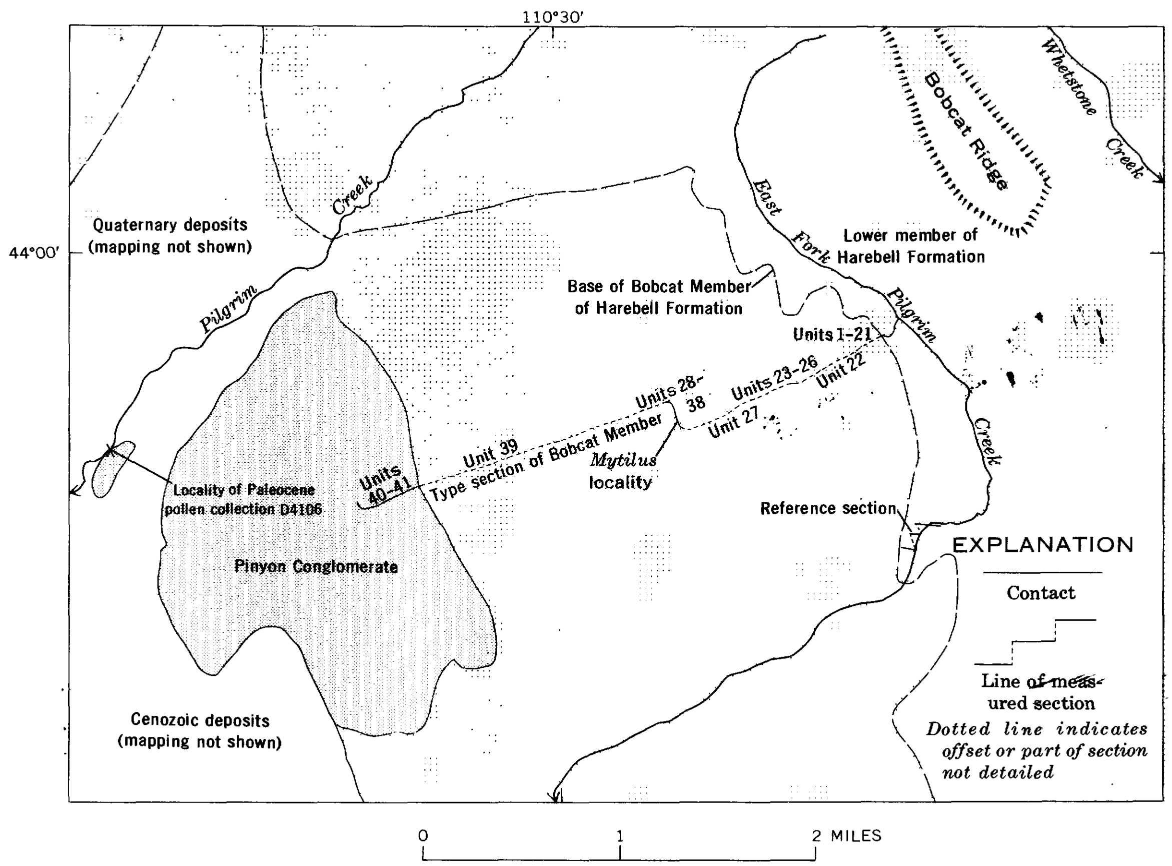


FIGURE 6.—Location of the type section of the Bobcat Member of the Harebell Formation. Base from U.S. Geological Survey Mount Hancock and Huckleberry Mountain quadrangles, 1:62,500, 1959 and 1956, and Two Ocean Lake and Whetstone Mountain quadrangles, 1:24,000, 1968 and 1965.

Harebell Formation (part)—Continued	*Thickness (feet)*
94. Sandstone, olive-drab; top 3 ft is a ledge of massive sandstone; middle is softer and poorly exposed; lower part hard and slabby; thickness is only approximate	45±
93. Claystone, black to drab, soft, blocky, poorly exposed; is present at top of high hill that breaks off northeastward into conspicuous escarpment; relation to unit 94 obscured; black claystone yielded a poorly preserved assemblage of Late Cretaceous pollen (USGS colln. D3864–B; R. H. Tschudy, written commun., Feb. 10, 1967)	15
92. Claystone, siltstone, and sandstone; top 15 ft is mustard-yellow cliff-forming evenly bedded sandstone; grades down to middle part which has many black and dark-gray claystone beds and drab thin sandstone and siltstone beds; lower part is drab to dark gray; a large indeterminate species of fresh-water clam, whose shells are as much as 4 in. long and ½ in. thick, and the fresh-water snail *Bellamya (Tulotomops)* n. sp. occur about 5 ft above the base in a carbonaceous sandstone (USGS colln. M2887; D. W. Taylor, written commun., Jan. 11, 1967); additional shell and plant fragments are in the overlying 30 ft of section; black claystone 20 ft above base yielded pollen of Late Cretaceous age (USGS colln. D3864–A; R. H. Tschudy, written commun., Feb. 10, 1967)	73

Harebell Formation (part)—Continued	*Thickness (feet)*
91. Sandstone, drab, poorly bedded to massive, hard, fine-grained; forms conspicuous ledge across face of scarp; thins southward	5–10
90. Sandstone and claystone in about equal amounts; sandstone is drab, fine grained, hard, ledgy, in 1–2-ft beds; claystone is drab to dark gray, soft, blocky; 4 ft below top in the southern part of the escarpment is a carbonaceous soft sandstone that contains abundant gastropods, most of which are high spired, and sparse pelecypods; USGS colln. M2886 contains the fresh-water clam *Plesielliptio*, the fresh-water(?) clam Corbulidae, and fresh-water snails *Bellamya (Tulotomops)* n. sp. and *Cleopatra* (D. W. Taylor, written commun., Jan. 11, 1967); this is the approximate horizon of a mollusk collection 3,500 ft southwest at station L8–114, which yielded the fresh-water clams *Sphaerium* and *Eupera*, the fresh-water snails *Viviparus*, *Reesidella*, and *Physa*?, and three indeterminate species (USGS Mesozoic loc. 27746; D. W. Taylor, writ- commun., 1963)	22
89. Claystone, olive-drab to dark-gray to black, soft	34
88. Sandstone, drab, fine-grained, hard, limy, ledgy, massive, lenticular	0–4
87. Claystone, tawny-yellow to black, soft, blocky; 2 ft of hard ledgy sandy siltstone	

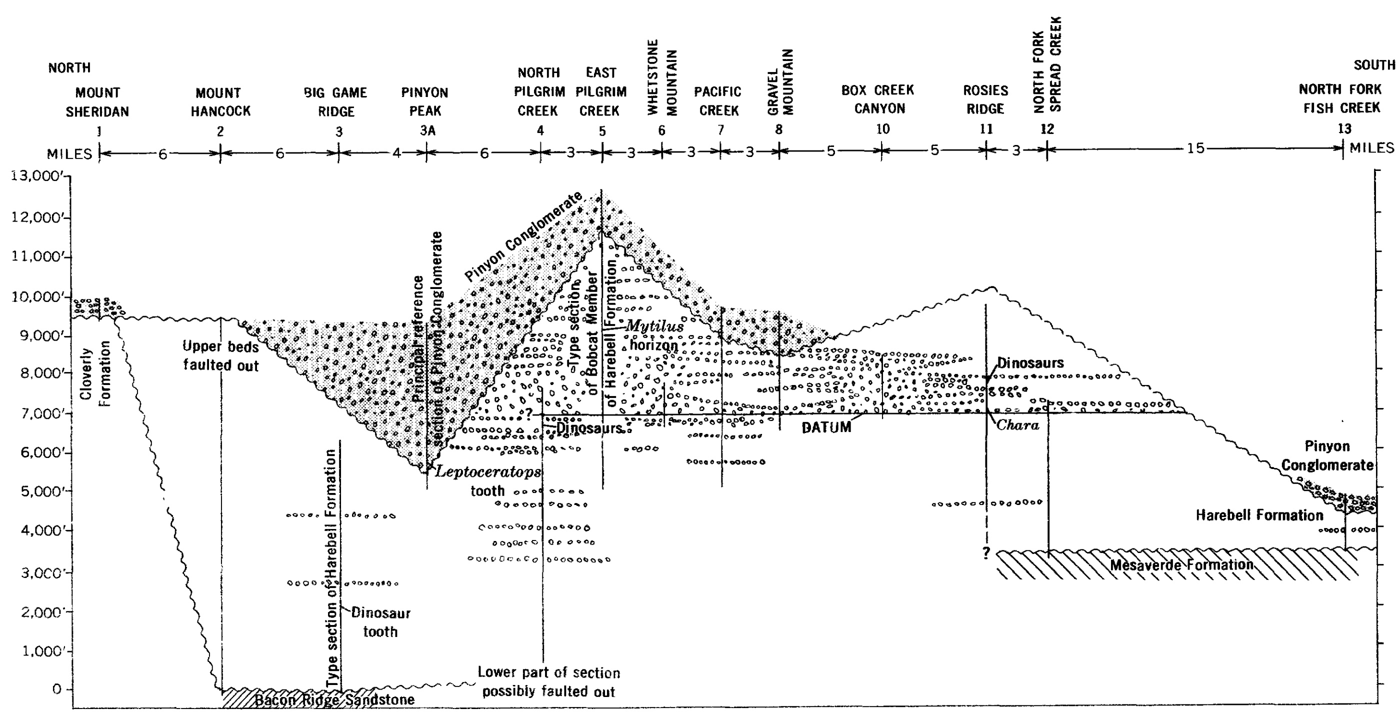


FIGURE 7.—Sections of Pinyon Conglomerate and Harebell Formation showing distribution of conglomerates and their relations to each other and to older Cretaceous rocks. Lensing of conglomerates is diagrammatic.

Harebell Formation (part)—Continued — *Thickness (feet)*

at base; top of unit cannot be determined where overlying lenticular sandstone pinches out — 40

86. Claystone, tawny-yellow to black, very soft, plastic, fine-grained, blocky; septarian concretion zone 10 ft below top — 50
85. Claystone, white to light-gray, bentonitic, very soft; exposed only in gopher mounds; top arbitrarily placed at color change to dark-gray claystone — 25±
84. Siltstone, blue-gray, very hard, silicified; has thin gray claystone partings; forms broad dip slope; breaks into sharp-edged rhombs; surface coated with secondary bright-cinnabar-red crystals of heulandite(?); sparse poorly preserved plant fragments and flat-spired silicified indeterminate land snails (USGS colln. M2888; D. W. Taylor, written commun., Jan. 11, 1967) — 3±
83. Sandstone, drab, soft, medium-grained; grades up to light-gray very soft poorly cemented sandstone; upper part is poorly exposed; top is a dip slope paved with hard blue-gray silicified siltstone of unit 84, all the way from the hilltop down to the bottom of the ravine at the base of the big exposure directly to the south — 35
82. Quartzite pebble conglomerate, brown, very hard, silicified; only a few pebbles more than 2 in. in diameter — 2
81. Claystone, dull green to drab, soft, finely blocky; contains a thin hard fine-grained silty sandstone in middle — 22

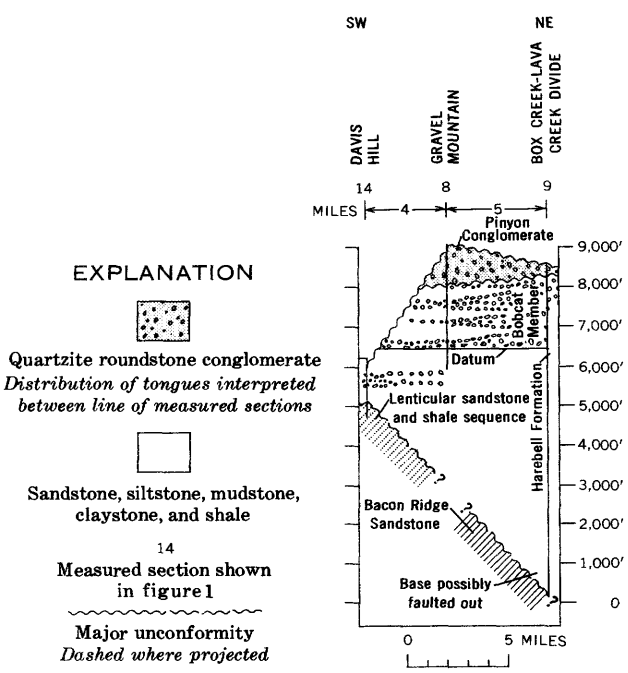


FIGURE 7.—Continued.

Harebell Formation (part)—Continued — *Thickness (feet)*

80. Sandstone, greenish-brown, brown-weathering, very hard, brittle — 1
79. Claystone, yellow to dark-gray, evenly bedded but highly blocky, and some gray hard siltstone beds; yellow septarian concretions as much as 2 ft in diameter about 15 ft above base; strike N. 60° E., dip 12° SE — 38
78. Sandstone, greenish-brown, rusty-weathering, hard, quartzitic; forms dip slope — 2
77. Beds not described or sampled; approximate thickness computed from topographic map, aerial photographs, and dips obtained in the field; chiefly drab shale and claystone with lesser amounts of hard green siltstone and very hard thin-bedded slabby sandstone — 575±
76. Sandstone, drab, fine-grained; upper half soft and silty; lower half hard — 4+
75. Claystone, mustard-yellow to dark-gray, finely blocky; exposures bare of vegetation; some marlstone; horizon of one of most prolific leaf localities in Harebell Formation; contains some gastropods, abundant beautifully preserved leaf fronds, crinkled ornate leaves, and large coarse-veined leaves 1 ft in diameter; USGS leaf colln. L8–106 contains *Sequoia dakotensis* Brown, *Cercidiphyllum ellipticum* (Newberry) Brown, *Trapa*? *microphylla* Lesquereux, *Dryophyllum subfalcatum* Lesquereux, *Ficus* sp. cf. *F. leei* Knowlton, and fragments of other dicotyledons (R. W. Brown, written commun., Nov. 15, 1948); a slightly lower horizon yielded USGS leaf colln. L61, which contains *Onoclea*? sp., *Ginkgo laramiensis* Ward, *Sequoia dakotensis* Brown, *Rhamnus* sp., and *Viburnum* sp. (R. W. Brown, written commun., Jan. 28, 1946); the gastropods have not been identified — 20
74. Sandstone, dark-gray, rusty-weathering, hard, fine-grained, irregularly bedded; abundant heavy minerals and other dark grains — 3
73. Claystone, mustard-yellow to dark-gray, soft, finely blocky; exposures bare of vegetation; strike N. 15° E., dip 10° SE — 20
72. Sandstone, drab, hard, slabby; forms top of low ridge — 5+
71. Beds not described or sampled; thickness computed; chiefly soft drab sandstone, siltstone, and claystone — 75±
70. Sandstone, greenish-drab, hard, slabby; forms dipslope on southeast top of hill 9902 — 1+
69. Claystone, mustard-yellow to dark-greenish-gray; several rusty sandstones in upper part — 80
68. Sandstone, grayish-drab; massive, except at top; breaks into huge conchoidally frac-

Harebell Formation (part)—Continued	*Thickness (feet)*
tured blocks; silty near top, coarse-grained in lower part	21
67. Claystone and siltstone, greenish-drab, soft, blocky	35
66. Sandstone, drab, rusty-weathering, hard, massive, fine-grained, ledgy	4
65. Claystone, mustard-drab to black, soft; forms bare rounded hard badlands; upper part is poorly exposed and probably sandy; a slabby green siltstone and claystone is 170 ft above base; a zone of shiny hard dark-red-brown heavy concretions is 80 ft above base; a crumbly leaf-bearing carbonaceous claystone 32 ft above base contains pollen of Maestrichtian age (USGS colln. D3863–B; R. H. Tschudy, written commun., Feb. 10, 1967); between 20 and 25 ft above base is a 4-ft. brown sandstone containing thick-veined leaves; a columnar-jointed heavy dense sandstone near base	215
64. Sandstone, greenish-brown, hard, dense, medium-grained; forms massive ledge at the top of which is the fresh-water clam *Sphaerium*? or Corbulidae? and the fresh-water snails *Bulinus*? and *Bellamya*? (USGS colln. M2890; D. W. Taylor; written commun., Jan. 11, 1967)	5
63. Claystone, green to mustard-dun to black, soft; blocky in part and silty, sandy, and slabby near top; ledges of hard siltstone 1 ft thick in lower part; sparse leaves are present, a fresh-water Mytilidae (E. G. Kauffman, written commun., Feb. 20, 1968) and the fresh-water snails *Viviparus*?, *Reesidella*, and a high-spired snail (USGS Mesozoic loc. 19665 (L61); D. W. Taylor, written commun., 1963)	43
62. Sandstone, drab, hard, coarse- to medium-grained, massive to thin-bedded to cross-bedded	5
61. Claystone, greenish-drab, soft, blocky	12
60. Sandstone, drab, hard; forms twin ragged ledges that have shale and siltstone partings in middle	4
59. Claystone, dark-green, drab, and yellowish-green, blocky, hard; sample from 5 ft above base yielded Late Cretaceous pollen (USGS colln. D3863–A; R. H. Tschudy, written commun., Feb. 10, 1967)	70
58. Sandstone, dull-greenish-drab, hard, massive, silty	2.5
57. Claystone, dull-green, blocky, hard	2.5
56. Siltstone, dull-green, hard, sandy, ledgy	1.5
55. Siltstone and claystone, drab, soft, poorly exposed	34
54. Sandstone, drab-gray; thin irregular bedding, hard; forms conspicuous ragged prominent ledge that has considerable lateral continuity; strike N. 35° E., dip 10° SE.; contains large palm fronds, *Sequoia*, and other leaves; this is the approximate horizon of USGS fossil colln. L8–105 in big north-facing exposure 2,500 ft to the east, which yielded two indeterminate species of fresh-water or brackish-water clams and the fresh-water snails *Viviparus*?, *Reesidella*, *Physa*?, and three indeterminate species (USGS Mesozoic loc. 27745; D. W. Taylor, written commun., 1963)	13
53. Largely covered; some exposures of drab soft claystone and siltstone	30
52. Sandstone, drab, fine-grained, slabby, irregularly bedded; forms lowest hard but inconspicuous ledge on big north-facing slope that overlooks Yellowstone National Park boundary trail	5
51. Covered interval; sequence exposed at northwest offset section (see discussion of unit 47), where it consists of interbedded silty greenish-gray sandstone, siltstone, and claystone; about 50 ft above base at the northwest offset section, a 5-ft ledge of hard poorly bedded sandstone yielded leaves of *Winchellia* sp. (USGS colln. L8–118–B; R. W. Brown, written commun., Nov. 15, 1948), small pelecypods, and large and small gastropods	212
50. Lower part covered; upper 5 ft is drab soft sandstone and dull-green hard blocky siltstone; many carbonized plant fragments; at the northwest offset locality the lower part of this unit is light- and dark-gray claystone and sandstone that yielded USGS leaf colln. L8–118–A from a 1-ft gray to brown slabby fine-grained carbonaceous sandstone about 45 ft above the base; identifiable leaves are *Sequoia dakotensis* Brown and *Celastrus* sp. (R. W. Brown, written commun., Nov. 15, 1948)	54
49. Sandstone, gray, hard; evenly bedded in part, ripple marked in part	4
48. Covered interval	12
Offset on top of unit 47, which is exposed in ravine about 400 ft north of Yellowstone National Park boundary pack traid, northwest 1 mile to top of hill 10065 on Big Game Ridge along the south boundary of Yellowstone National Park, for underlying section.	
47. Sandstone marker bed that bears a superficial resemblance to granite; light gray, very coarse-grained, hard; weathers into highly distinctive light-gray angular blocks that form rock glaciers in places on the north face of Big Game Ridge; matrix is silty but less so than for most sandstones in the Harebell Formation; many pebbles and cobbles of red, gray, black, brown, and white quartzite and other hard siliceous rocks up to 4 in. in diameter; unit has considerable lateral continuity in this area and was used in structural mapping; glaciers carried er-	

Harebell Formation (part)—Continued	Thickness (feet)
ratics of it up over Big Game Ridge and deposited them in boulder trains on the south side; thin section Wyo. 383 is of typical lithology and contains abundant volcanic plagioclase and quartz that show no strain shadows; thickness is somewhat variable, so maximum thickness is given	50±
46. Tripartite ledge of sandstone at top and bottom and quartzite pebble conglomerate in middle; unit forms ledges at top of exposure and continues as dip slope southward about 4,000 ft; at field station L8–126 are lenses of pink, gray, and black quartzite pebbles as much as 4 in. in diameter; many are fractured and recemented; thin section Wyo. 382 is of matrix and pebbles	22
45. Sandstone, gray, medium- to coarse-grained, soft, carbonaceous	26
44. Shale; upper part gray and silty, middle 2 ft black, lower part tan	5
43. Sandstone, gray, hard and soft, ledgy; upper part of unit is first ledge below top of exposure, varies in thickness from 15 to 20 ft, and lenses out ¼ mile to the east	38
42. Sandstone, gray, hard and soft, ledgy	24
41. Sandstone, gray, hard and soft, ledgy; medium grained thin bedded, with carbonaceous flecks	25
40. Largely covered; apparently underlain by soft sandstone and siltstone in units about 10 ft thick	43
39. Largely covered; at top is very fine grained gray ledge-forming sandstone that contains carbonaceous debris; underlain by carbonaceous shale and overlain by olive-drab clay shale; puffy brown to gray bentonitic shale forms rounded ridge in lower 20 ft	63
38. Claystone, gray, and plastic coaly shale	5
37. Sandstone, gray to olive-drab; forms small ledge; lenses out 30 ft east of line of section; yielded pollen of latest Cretaceous age (USGS colln. D3877–C; R. H. Tschudy, written commun., Feb. 10, 1967)	1
36. Covered interval across swale to lowest outcrop on main spur to south	42
35. Sandstone, gray, hard; forms western summit of prominent knob; strike east, dip 10° S	4
34. Covered interval	15
33. Sandstone, gray, brown-weathering, fine-grained, thin-bedded and slabby; forms weak ledge at eastern summit of prominent knob north of big scar	2
32. Covered interval; probably shale and siltstone	11
31. Sandstone, gray, brown-weathering, fine-grained, thin-bedded and slabby; forms weak ledge	2

Harebell Formation (part)—Continued	Thickness (feet)
30. Covered interval; probably shale and siltstone	15
29. Claystone, olive-drab, gray- and tan-weathering; yielded a tooth, probably of a theropod dinosaur of the Late Cretaceous family Deinodontidae (identified by G. E. Lewis, written commun., Nov. 4, 1966)	10
28. Sandstone and siltstone, dull-green; forms ledge; many plant fragments on upper surface	4
27. Shale, gray, hard; chippy in part; strike east, dip 8° S	14
26. Shale, gray, black to brown coaly shale at top	5
25. Sandstone, light-olive; weathering to yellow rounded slopes; top 3 ft is ledgy cross-bedded fine-grained sandstone	19
24. Claystone and shale, gray; sandy in part, rusty in basal 3 in.; this basal bed yielded well-preserved pollen assemblage of latest Cretaceous age (USGS colln. D3877–A; R. H. Tschudy, written commun., Feb. 10, 1967); 1-ft coal bed 10 ft above base; overlain by light-olive sandstone that weathers to yellow rounded slopes	30
23. Coal, black, impure	1.5
22. Shale, gray; contains a few lenses of ledgy fine-grained sandstone; 4-in. black to purplish-gray soft coaly clay shale in the middle of the unit is the site of a line of springs	50
21. Sandstone, light-gray, weathering olive-drab, hard, fine-grained, ledgy; some fragments of white tuff not in place but close	5±
Offset for underlying beds, except for units 16–20, 10,000 ft northeast from bare northeast spur of Big Game Ridge at elev 9,700 ft and 1,500 ft northeast of hill 10065 to the upstream end of the inner gorge of the Snake River Canyon approximately 1 mile downstream from the mouth of Crooked Creek. Units 16–20 are from southeast face of Barlow Peak, 8,000 ft northwest of Snake River Canyon.	
20. Beds between Big Game Ridge and Snake River Canyon not sampled or described in detail; thickness determined by subtracting thicknesses of units 16–19 from computed interval between top of unit 15 and base of unit 21; entire sequence is exposed on southwest side of Barlow Peak but only the upper part is exposed on Big Game Ridge north of locality of unit 21; sequence is chiefly sandstone, drab, with lesser amounts of drab to dark-gray siltstone, shale, and claystone; no conglomerates observed	700±
19. Sandstone, brown, medium- to fine-grained, very silty; in hard and soft coarsely bedded to massive layers	130
18. Shale, claystone, and siltstone, bluish- to greenish-gray; blocky in part	30

Harebell Formation (part)—Continued	Thickness (feet)
17. Sandstone, gray, clean to silty, fine-grained, slabby to massive; has pepper-and-salt appearance because of abundance of black grains; forms conspicuous ledge; strike N. 15° E., dip 14° SE	10
16. Sandstone, siltstone, shale, and claystone, dull-greenish-gray; monotonous sequence of interbedded lithologies; forms slope interrupted by weak ledges	500±
Underlying units described from Snake River Canyon.	
15. Upper of two marker sandstones in basal part of formation; gray to brown, massive in part; has minor claystone and siltstone breaks; makes cliffs at the upper part of the inner gorge of Snake River Canyon, approximately 8,000 ft southeast of the section on the southwest face of Barlow Peak; unit is silicified, hard, coarsely blocky, weathers into angular fractured cliffs; some beds at this locality are green, and much of unit is a coarse-grained secondarily silicified grit that contains highly rounded pebbles of quartzite, dense hard slate, and other siliceous rocks as much as 2 in. in diameter but commonly less than ½ in.; thin sections Wyo. 377, 378, and 379 are of representative types of sandstone and conglomerate; these show considerable tuffaceous debris	70
14. Shale, drab	15
13. Sandstone, yellow, soft	1
12. Shale and sandstone, drab; in about equal amounts	20
11. Sandstone, drab	20
10. Sandstone and shale, drab; in about equal amounts	17
9. Sandstone, drab, shaly	7
8. Shale, drab	18
7. Lower marker sandstone, gray to brown, hard, cliff-forming; described and sampled where it makes lower part of inner gorge of Snake River Canyon	77
Offset 8,000 ft northwest from bottom of Snake River Canyon to southwest face of Barlow Peak on base of unit 7 for underlying section.	
6. Sandstone, siltstone, and thin coaly shale beds, gray, soft; upper half of unit on Barlow Peak has brown very lenticular fine- to coarse-grained sandstone beds alternating with dark-gray shale, blocky siltstone, and claystone; lower half contains conspicuous dark-gray marlstone masses that weather bright yellow; these yielded *Trapa*-like leaves and small pelecypods from bottom of Snake River Canyon	300±
5. Bentonite, gray; has coaly partings	10
4. Sandstone, siltstone, and claystone, dark-gray; contains several coal beds, all less than 1 ft thick; one is 25 ft above base and others are lower; in bottom of canyon, this sequence contains leaves as large as 4×6 in. having scalloped margins	50±
3. Sandstone, brown, massive to poorly bedded; pepper-and-salt appearance, fine-grained; forms conspicuous ledge; strike N. 8° E., dip 17° SE	10
2. Sandstone, siltstone, shale, and claystone, drab, soft; has thin coal and bentonite beds; forms slope	200±
Total thickness of measured part of type Harebell Formation	6,276±

Contact between Harebell Formation and Bacon Ridge Sandstone. Areal relations indicate that this is an angular unconformity and that, in comparison with the Spread Creek section (fig. 17, section D; Love and others, 1951), about 4,000 ft of post-Bacon Ridge–pre-Harebell Upper Cretaceous strata is missing from the Snake River area.

Bacon Ridge Sandstone:	Thickness (feet)
1. Sandstone, light-gray, fine-grained, limy; massive in part, pepper-and-salt appearance; forms conspicuous bare cliff that extends up from river to main Snake River horse trail; is site of falls and potholes in river bottom; in middle, strike is N. 5° E., dip 23° E., and in slabby sandstone at base strike is N. 13° E., dip 20°SE.; oyster shells, small pelecypods, and fossil mud cracks occur at several horizons	130

TABLE 1.—*Comparison of data for the Harebell Formation and Pinyon Conglomerate*

[Statements are generalized. No single feature is known to be absolutely diagnostic of either formation]

Data	*Harebell Formation*	*Pinyon Conglomerate*
Color:		
Conglomerate	Light to dark brown	Generally lighter colored than conglomerates in Harebell.
Sandstone	Olive drab and dull green, weathers greenish-brown.	Light gray to light brown.
Siltstone, claystone, and shale.	Olive drab, dark green, dark gray, black.	Light green to light gray.
Lithologic composition:		
Conglomerate	About 90 percent quartzite roundstones; remainder siliceous volcanics, sedimentary rocks, granite.	Identical with that in Harebell.

TABLE 1.—*Comparison of data for the Harebell Formation and Pinyon Conglomerate*—Continued

Data	*Harebell Formation*	*Pinyon Conglomerate*
Lithologic composition—Continued		
Sandstone	Abundant volcanic quartz and plagioclase in lower half, which decrease in abundance southward; heavy minerals are tourmaline, zircon, green-brown hornblende, and garnet; many magnetite-rich sandstone beds throughout formation.	Volcanic debris rare. Green-brown hornblende and garnet. No magnetite-rich sandstones comparable in thickness or abundance to those in Harebell Formation.
Siltstone, claystone, and shale.	Dense, hard, brittle, silicified in some places. Many beds of bentonite and tuff.	Soft, blocky, not silicified. No bentonites and tuffs.
Cementation	Moderately well cemented in many places with calcareous and (or) siliceous cement.	Rarely as tightly cemented as Harebell Formation.
Features of clasts:		
Size	Rarely as large as 18 in. and decrease in size to southeast.	As large as 94 in., but these were much closer to source area than any known Harebell; generally, however, they are larger than those in the Harebell where both are the same distance from the source area.
Roundness	Highly rounded.	Highly rounded except near source area on northwest side of Teton Range.
Fracturing	Extensively fractured.	Generally less fractured than those in Harebell Formation.
Recementation	Recemented and fractures silicified in areas of tectonism.	Rarely extensively recemented.
Source of clasts	Quartzite is not from any adjacent exposed mountains and must have come from now-buried Targhee uplift; Paleozoic and Mesozoic clasts could have come from adjacent mountains or margins of Targhee uplift; welded tuff and Mesozoic igneous rocks probably came from an unknown western source in the Targhee uplift area.	Same source as for clasts in Harebell Formation.
Gold	Present throughout; values decrease in northern and southeastern areas of outcrop and in upper part of section.	Present throughout; values increase in southeastern and northwestern parts of outcrop area.
Fossils	Mollusks, *Chara*, ostracodes, pollen, leaves, wood, dinosaurs, acritarchs, dinoflagellates; some are exclusively Cretaceous; others could be Cretaceous or younger; some, like *Mytilus*, acritarchs, and dinoflagellates, represent very localized brief invasions of marine or brackish water; climate is inferred from fossils to have been warm and humid.	Mollusks, pollen, leaves, wood, mammals, and a single dinosaur tooth of *Leptoceratops*. Formation is bracketed by Paleocene fossils in southeastern part of area of outcrop. *Leptoceratops* is a Cretaceous dinosaur and was found 150 feet above the base of the principal reference section on Pinyon Peak. All fossils are from fresh-water or land environment; climate is inferred from fossils to have been warm and humid.
Relations to underlying rocks.	No visible angular unconformity, but one is inferred from regional relations; magnitude increases from southeast to northwest toward Targhee uplift.	Marked angular unconformity except in trough of Box Creek downwarp north of Buffalo Fork where the Pinyon is nearly parallel to the Harebell. In that area, however, the absence of the upper part of the Harebell suggests a major erosional unconformity.
Paleocurrent data	Streams flowed east-northeast to southeast into and across Jackson Hole from the Targhee uplift.	Same general stream direction as during deposition of Harebell Formation except in southeastern Jackson Hole where streams flowed south into northeastern part of Green River basin.

At Whetstone Falls (fig. 8), 2 miles southeast of section 6, the fine-grained facies is exposed along the gorge of Whetstone Creek for a distance of ¾ mile and consists of evenly bedded, hard, fine-grained, greenish-gray sandstone, siltstone, claystone, and shale. This locality is notable because of its unusually good exposures of soft strata and two beds of well-preserved leaves. Extensive collections, made in 1948, were lost before they could be identified and a small collection made in 1950 was identified as Paleocene by R. W. Brown (written commun., 1950). On this basis, these beds and the overlying conglomeratic rocks were mapped as Paleocene (Love and others, 1955; Love, 1956b). Additional collections were made in 1966 and 1969. These contained both Maestrichtian and Paleocene leaf types (USGS Paleobot. loc. 11049; J. A. Wolfe, written commun., Dec. 19, 1966, and April 8, 1970). Pollen from three claystones interbedded with the leaf-bearing strata yielded pollen which, though poorly preserved, is of Cretaceous age (USGS colln. D4444-A, C, and D; R. H. Tschudy, written commun., May 1, 1970).

The mollusk assemblage in the pollen-bearing strata includes the freshwater clams *Sphaerium*? or Corbulidae?, Unionidae or Quadrulidae, and *Eupera*? and the fresh-water snails *Viviparus*, *Lioplacodes*, *Reesidella*, and *Physa*? (USGS colln. 27739; D. W. Taylor, written commun. 1965).

A claystone interbedded with nearly flat-lying quartzite pebble conglomerate on Whetstone Mountain, 2 miles northwest of Whetstone Falls and 2,000 feet topographically higher than the gently dipping strata at the falls (how much higher in the stratigraphic succession the beds on Whetstone Mountain are is not known, but probably the amount is many hundred feet) yielded pollen of definite Late Cretaceous age (USGS colln. D4204-B; R. H. Tschudy, written commun., Jan. 22, 1969). The fine-grained

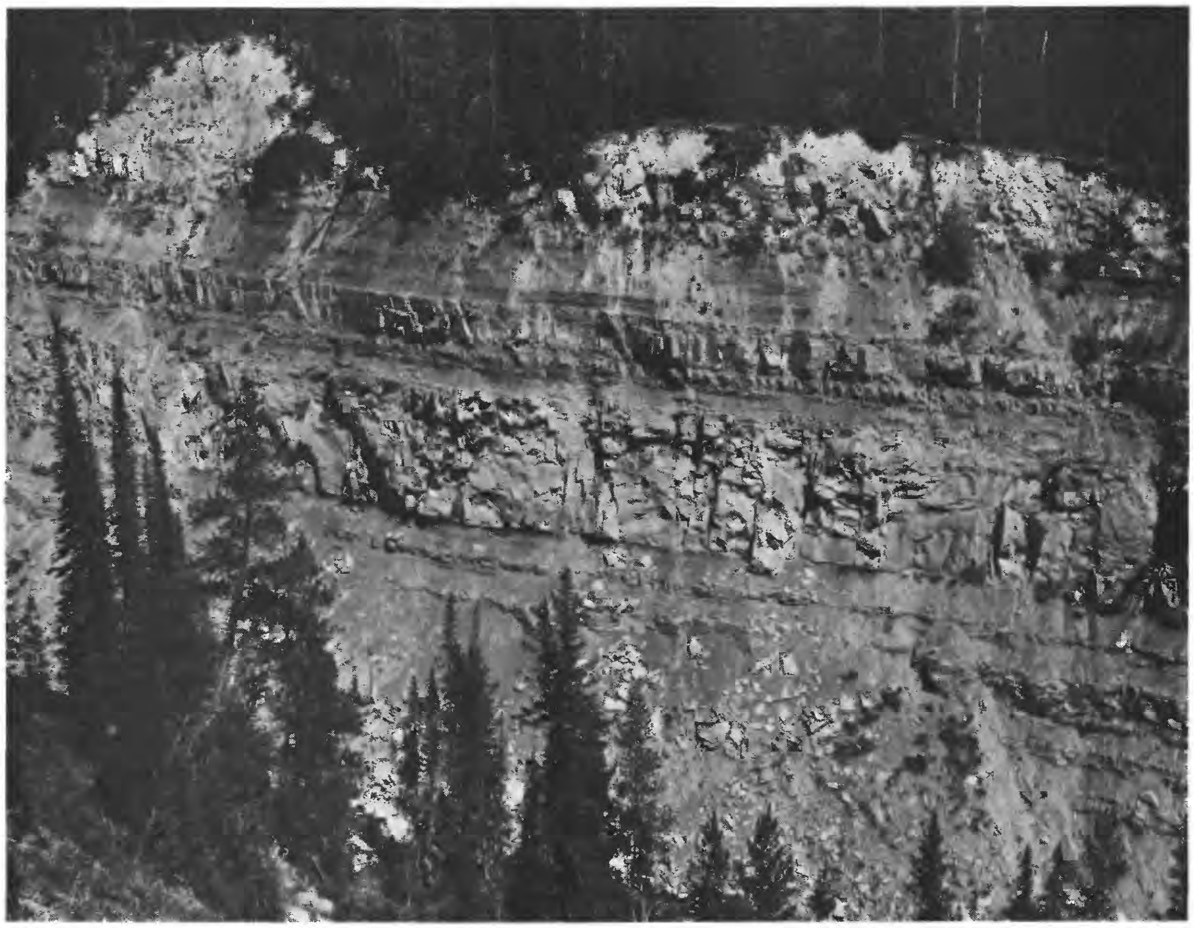


FIGURE 8.—Fine-grained facies in lower part of Harebell Formation, consisting entirely of evenly bedded sandstone, siltstone, shale, and claystone, near Whetstone Falls, 2 miles southeast of section 6. Thickness of visible section is about 120 feet. Leaf, pollen, and mollusk zone is in stata directly below area of lower right corner of photograph.

noncongloneratic strata at Whetstone Falls do not look like any beds in the type Pinyon or in the sections of the Pinyon farther southeast, but they do resemble beds in the type Harebell and are therefore assigned to the Harebell.

Beds of silty soft brown sandstone, some 100 feet thick and commonly crossbedded, are conspicuous throughout the middle and upper parts of the fine-grained facies. Many laminae and thin beds of magnetite-rich sandstone are present at various horizons. The concentrations of magnetite in some beds is such that a hand magnet can pick up chunks of sandstone several inches in diameter. These concentrations are lenticular and so thin that they do not constitute an economic resource.

Volcanic debris is common, especially in the lower half of the formation, but it decreases progressively in amount from north to south. Some sandstones in the lower middle part of section 4 contain a flood of quartz bipyramids; others have abundant volcanic plagioclase, and still others are characterized by a considerable volume of biotite. Farther southeast, in section 11, bentonites and biotite tuffs are common and conspicuous at several horizons below the base of the conglomeratic Bobcat Member.

Possibly because of the easily available silica in glass shards in the fine-grained volcanic debris, many of the claystone, siltstone, and shale beds are very hard and brittle. Some are secondarily silicified and contain silicified mollusks (for example, unit 84 in the type section).

Heavy minerals are common in the sandstones and consist chiefly of tourmaline, zircon, green-brown hornblende, and garnet. Sandstones in the lower part of sections 7 and 14 apparently contain as much gold, or perhaps more, than the quartzite conglomerates.

Quartzite conglomerate beds in the lower member are commonly less than 300 feet thick and are more lenticular than are those in the Bobcat Member. Lithologically, the conglomerates in both members are very similar so the description given in connection with the Bobcat Member is not repeated.

BOBCAT MEMBER

The Bobcat Member of the Harebell Formation is here named from Bobcat Ridge (figs. 1, 6, 18), a conspicuous topographic feature, south and southwest of which is the thickest, most complete, and least structurally complicated section of these rocks. The base of the member at its type section was formerly mapped as the base of the Pinyon Conglomerate (Love, 1956b), but subsequent studies indicated that is recognizable in the area between sections 4 and this mapping was not correct. The Bobcat Member 12 on the basis of (1) a persistent basal conglomerate, (2) the greater abundance of conglomerate, in contrast to the amount in the lower member, and (3) the general decrease in coarser fractions of volcanic debris (excluding roundstones). Details of lithology are presented in the type section of the Bobcat Member.

Type section of the Bobcat Member of the Harebell Formation

[The base of the section is at water level on the East Fork of Pilgrim Creek about a mile southwest of Bobcat Ridge. From this point, the line of section extends west-southwest for 2¾ miles to the top of the high point at 8,800 ft overlooking the north fork of Pilgrim Creek (fig. 6). A supplementary section of some of the lower beds was measured 1 mile south of the main section, along the East Fork of Pilgrim Creek. Some parts of the section were measured with Brunton compass and steel tape; several major intervals were computed, using dips obtained in the field and distances and elevations recorded on 1:24,000 topographic quadrangle maps (Whetstone Mountain and Two Ocean Lake). The structure is relatively uncomplicated along the line of section; beds dip about 20° SW. Descriptions and measurements are by J. D. Love and J. L. Weitz. Data on petrography and sedimentary structures were obtained by D. A. Lindsey, and many of the gold samples were taken by J. C. Antweiler. Fossils were identified by the following persons: D. W. Taylor and E. G. Kauffman, mollusks; E. B. Leopold and R. H. Tschudy, pollen; I. G. Sohn, ostracodes; R. A. Scott, seeds; J. A. Wolfe, leaves]

Top of section at erosion surface which is cut across Pinyon Conglomerate on high knife-edged ridge at 8,800 ft. Noncongloneratic beds containing Paleocene pollen (USGS colln. D4106, fig. 6) are present to the west along Pilgrim Creek and, although relations are somewhat obscured by landsliding, may be younger than the conglomerate.

	Thickness (feet)
Pinyon Conglomerate (part):	
41. Conglomerate, tan, loosely cemented; composed of red and gray highly rounded quartzite fragments and lesser amounts of dense hard siliceous volcanic rocks, black chert, granite, and siliceous Paleozoic rocks; forms east-facing slope broken by a few weak ledges; four strikes and dips taken; most consistent is strike N. 35° W., dip 20° SW.; imbrication of flattest roundstones shows that current moved directly east; 100 ft below top is a 25-ft zone that contains boulders 8–12 in. in diameter; several lenses of gray to rusty-brown coarse-grained crossbedded sandstone 1–2 ft thick	225
40. Conglomerate, tan; consists of quartzite roundstones as in unit 41 but intermittently exposed in lower reaches of torrent gullies draining this face	775±
Total thickness of measured and computed part of Pinyon Conglomerate	1,000±

Because of extensive landsliding, contact between the Pinyon Conglomerate and the Bobcat Member of Harebell Formation is only approximate and is arbitrarily put at the base of the lowest conglomerate exposures.

Harebell Formation (part)—Continued
Bobcat Member (type)—Continued

Thickness (feet)

39. Beds in this interval were not sampled, measured, or individually described; approximate thickness was computed from topographic map and aerial photographs, using dips and strikes obtained from the few undisturbed outcrops; most of the surface area is a jumble of landslide and glacial debris surrounding a few ridges of conglomerate and sandstone in place; the abundance of landslide debris suggests that appreciable thicknesses of claystone, shale, and siltstone are present; this interval seems to be somewhat thinner to north and south; if there is any duplication by faulting, unit 39 would have to be part of the section below unit 34 and displacement would be at least 1,000 ft; a fault of this magnitude should be conspicuous on the ground and on aerial photographs, but no evidence of one was seen ---------- 1,900±
38. Sandstone, siltstone, claystone, and thin coal beds; sandstone is light gray, coarse to fine grained, and soft and constitutes lower part of unit; fossil horizon A is a gray blocky slightly limy siltstone 2.5 ft thick, above a 3-in. coal bed and 2.5 ft below fossil horizon B; horizon A contains flat-spired finely ribbed fresh-water gastropods and fragments of smoother much larger ones; one bone fragment collected; ferns and possibly *Sequoia* occur in fissile dark-gray carbonaceous shale and siltstone; in lighter gray more sandy siltstone are leaves as much as 3 in. wide that have toothed margins; fossil horizon B is the upper mollusk zone in carbonaceous gray siltstone; has sparse poorly preserved leaves, high- and low-spired fresh-water mollusks, sparse small clams as much as ¼ in. long; samples from horizons A and B yielded Late Cretaceous pollen, sparse acritarchs, *Veryhachium*, and *Tasmanites* (USGS colln. D4144–A, B; R. H. Tschudy, written commun., Apr. 11, 1968, and E. B. Leopold, written commun., Apr. 24, 1968) that suggest a very slight marine influence ---------- 20
37. Conglomerate, light-brown; has roundstones 2–4 in. in diameter; weathers to slope broken by weak ledges; sparse brown sandstone lenses; base not exposed but presumed to be at break in slope; this unit and unit 38 form the upper of two conspicuous closely spaced parallel white-appearing stripes visible for 20 miles from the floor of Jackson Hole ---------- 100±
36. Covered interval ---------- 30±
35. Sandstone, yellowish-tan, coarse-grained, very soft ---------- 15+
34. *Mytilus* shale zone; blue gray in lower part, carbonaceous and dark gray in upper; very hard and evenly bedded on fresh exposures; strike N. 35° W., dip 20° SW.; yielded numerous specimens of *Mytilus* (Kauffman, 1973), ostracodes common, sparse seeds and leaf fragments; the ostracodes were reported by I. G. Sohn and J. E. Hazel (written commun., Mar. 2, 1970) to be a large fresh- to brackish-water genus resembling the Early Cretaceous "*Paracypridea*" sp. (Sohn, 1969) and other forms that were unidentifiable; the seeds were not identifiable (R. A. Scott, written commun., Feb. 27, 1968); a suite of pollen samples from below, in, and above the *Mytilus* bed yielded Late Cretaceous pollen, *Veryhachium*, *Tasmanites*, acritarchs, and the alga *Pediastrum* (USGS collns. D4145–A, B; D4298–A–E; R. H. Tschudy, written commun., Apr. 11, 1968, and May 12, 1969; E. B. Leopold, written commun., Apr. 24, 1968) that suggest some marine or brackish-water influence ---------- 4
33. Sandstone, light-gray, massive to crossbedded; forms conspicuous white scar on southeast face of hill; this is the lower of two conspicuous parallel white stripes visible for 20 miles from the floor of Jackson Hole ---------- 17
32. Conglomerate and sandstone, light-brown; forms ragged slope; conglomerate is composed of highly fractured roundstones 1–2 in. in diameter; conspicuously fewer red quartzite fragments than in conglomerates lower in section ---------- 138
31. Conglomerate, light-brown; composed of quartzite roundstones in a coarse-grained brown sandstone matrix ---------- 3
30. Sandstone, drab, crossbedded, hard ---------- 2
29. Covered interval, possibly claystone and siltstone ---------- 30±
28. Shale and claystone, dull-gray; blocky in part, plastic in part, badly slumped; contains sparse flat-spired ribbed gastropods; split was barren of pollen ---------- 20+
27. Beds in this interval were not individually measured, sampled, or described; approximate thickness was computed from dips and strikes obtained in the field and from distances and elevations taken from the topographic map; area was traversed twice along the line of section, and general notations were made as to lithology; sequence is chiefly conglomerate except in the upper third, where there are some soft gray claystones, siltstones, and inconspicuous sandstones ---------- 950±
26. Conglomerate, brown, coarse; contains some boulders 15 in. in diameter, many have a conspicuous sheen; some boulders of dense

Harebell Formation (part)—Continued Bobcat Member (type)—Continued	*Thickness (feet)*
hard siliceous volcanic rocks noted	80+
25. Claystone, dark-gray, carbonaceous, soft, blocky; split was barren of pollen	6
24. Sandstone, drab, massive, coarse-grained; forms weak ledge; cobbles of quartzite are scattered throughout ledgy part, which is 10 ft above base; split was barren of pollen; strike N. 35° W., dip 20° SW	16
23. Conglomerate, brown, coarse; chiefly of highly rounded quartzite fragments that have a surficial sheen; many are 1 ft or more in diameter	78+
22. Beds in this interval were not measured, sampled, or described individually; thickness of unit was computed from dips and strikes obtained in the field and from distances and elevations taken from the topographic map; area was traversed in field along the line of section and general notations made as to lithology; sequence is conglomerate, except for a zone of gray sandstone, siltstone, and claystone near the base	800±
21. Conglomerate, light-brown, very coarse; contains many boulders more than 1 ft in diameter; sizes 6 in. to 1 ft are common; the top of this unit forms the apex of the high point at 8,910 ft and a dip slope to west; strike N. 35° W., dip 20° SW	97
20. Sandstone, drab; soft at base; overlain by 1-ft hard ledge, then soft sandstone grading up to greenish-gray siltstone that has carbonaceous partings	6
19. Conglomerate, light-brown; forms massive to thick-bedded cliff at top of east-facing scarp; no shale and only a few sandstone breaks; cliff face is not accessible for sampling unless climbing gear is used	260±
Total thickness of Bobcat Member of Harebell Formation	4,572±

Lower member (part):	
18. Claystone and sandstone; upper part is black plastic claystone; lower part is drab sandstone	25
17. Conglomerate, brown; composed of quartzite pebbles	22
16. Sandstone and claystone; sandstone is drab, soft, and is in lower part of unit; claystone is black and plastic, and has plant fragments and sparse crushed gastropods; split of black plastic claystone yielded pollen of Late Cretaceous age (USGS colln. D3859, sample 30; E. B. Leopold, written commun., Feb. 2, 1967)	11
15. Conglomerate, brown; composed chiefly of 2–4-in. quartzite roundstones	31
14. Claystone and shale, dark-gray, soft; interbedded with fine-grained evenly bedded sandstone	52

Harebell Formation (part)—Continued Lower member (part)—Continued	*Thickness (feet)*
13. Conglomerate in part, and covered intervals, possibly underlain by siltstone and soft sandstone	80
12. Sandstone, gray to drab, coarse- to fine-grained, moderately soft	80
11. Conglomerate, brown; composed of quartzite pebbles and cobbles	75
10. Shale, black, soft, fissile; 1-ft coaly shale bed 30 ft above base yielded pollen of Late Cretaceous age (USGS colln. D3859, sample 22; E. B. Leopold, written commun., Feb. 2, 1967); numerous 1–2-ft ledgy evenly bedded sandstones; top 1 ft is drab soft sandstone	94
9. Sandstone, gray, thin-bedded, fine- to medium-grained; forms slope	63
8. Conglomerate, brown; composed chiefly of highly rounded quartzite pebbles	32
7. Sandstone; brown in upper part, light-gray, evenly bedded near base, lenses out into channel of quartzite conglomerate	30
6. Shale, blue-gray, flaky, hard, very fine grained; sample of most fissile part, 5 ft above base, was barren of pollen	14
5. Sandstone, light-tan; so massive that it forms conspicuous smooth bare scarp on slope; coarse grained, hard; some large slightly ferruginous concretions, probably more limy than adjacent sandstone, although both effervesce freely; basal contact very sharp and even, and on it strike is N. 15° W., and dip 25° SW	42
4. Conglomerate, brown; composed of highly rounded quartzite pebbles and cobbles; weathers to conspicuous brown stripe that appears smooth from a distance and is the lowest widespread brown conglomerate layer above level of East Fork of Pilgrim Creek; many roundstones are severely crushed, and their surfaces on outcrop appear dull, but a moderate number are polished and some have a high sheen; Paleozoic sandstone pebbles noted but are not abundant	62
3. Sandstone, light-gray to brown, massive; contains sporadic sparse quartzite pebbles; coarse to very coarse grained; forms lowest smooth conspicuous white scar above East Fork of Pilgrim Creek	95
2. Conglomerate, brown; composed chiefly of quartzite roundstones, moderately coarse, many 6 in. to 1 ft in diameter, many are polished	60
1. Sandstone, drab to gray, and dark-gray fine-grained claystone; coarse-grained soft drab sandstone has conglomerate lenses; strike N. 20° W., dip 20° SW.; unit begins at creek level	4
Thickness of measured part of lower member of Harebell Formation	872

By offsetting on units 3 and 4, 1 mile northeast to the south end of Bobcat Ridge, and continuing the section eastward to the bottom of Whetstone Creek, another 1,000 ft of the lower member was measured and is shown in figure 7 but is not included here.

The basal part of the Bobcat Member and the upper part of the underlying strata in the Harebell Formation 1 mile south of the type section are shown in figure 9. A reference section of the lower part of this exposure follows.

Reference section of lower part of Bobcat Member and upper part of lower member of Harebell Formation

[The base of the reference section is at water level on the East Fork of Pilgrim Creek about 300 ft upstream from the middle of three right-angle bends in the creek. The top is in the middle of the big escarpment shown in figure 9. Although this section duplicates part of the type section of the Bobcat Member and underlying beds 1 mile to the north, it is presented because it provides a comparison of lithology and continuity of beds and furnishes additional pollen data. The line of traverse is shown in figure 6. Measurements were made with Brunton compass and steel tape. Soft shale beds at the base are somewhat distorted by landsliding, but the remainder of the section has a moderately uniform strike N. 25° W., dip 20° SW. Pollen samples were identified by R. H. Tschudy]

Harebell Formation (part)—Continued Bobcat Member (type)—Continued	*Thickness (feet)*
22. Conglomerate, light-brown; composed chiefly of quartzite roundstones ranging in size up to more than 1 ft in diameter but commonly of pebble to cobble size; many roundstones show intense crushing, hardest ones have high polish; large-scale crude stratification visible; exposure shown in upper middle part of figure 9; total thickness not measured	200+
21. Sandstone, rusty-brown, coarse-grained	5
20. Conglomerate, light-brown; composed chiefly of quartzite roundstones 2–4 in. in diameter	25
19. Sandstone and conglomerate, intertongued, limonite-stained, rusty-brown	10
Total thickness of measured part of Bobcat Member	240+

FIGURE 9.—About 1,000 feet of strata, largely quartzite conglomerate, in the Bobcat Member and underlying strata of Harebell Formation on East Fork of Pilgrim Creek in reference section accompanying stratigraphic section 5. Top of soft beds that form shelf extending diagonally across middle of exposure marks base of Bobcat Member.

Contact between Bobcat Member and lower member arbitrarily placed at this horizon. There is no definitive evidence of an angular or erosional unconformity, and the differentiation here is based entirely on the predominance of thick conglomerates above, and the presence of black and gray shales, olive-drab siltstones, and brown sandstones and conglomerates, in about equal amounts, below.

	Thickness (feet)
Lower member (part):	
18. Sandstone, blue-gray, massive; very distinctive because of its color, abundance of biotite, and doubly terminated quartz crystals; two brown hard highly contorted 2-ft sandstone ledges near top, separated by 1 ft of blue-gray sandstone; top ledge is conglomeratic	18
17. Claystone, dark-bluish-gray; very fine grained and laminated in part; blocky near base; forms prominent shelf in lower middle part of big exposure; sample from 32 ft above base was barren of pollen but contained abundant small fragile thin-shelled mollusks; sample from 16 ft above base was also barren of pollen	48
16. Conglomerate, brown, hard, tightly cemented; composed chiefly of quartzite roundstones	36
15. Sandstone, olive-drab, crossbedded, hard; contains leaf fragments and carbonaceous trash	1½
14. Conglomerate, brown, hard; composed chiefly of varicolored quartzite roundstones	2½
13. Sandstone, dark-gray and limonite-stained, coarse-grained, carbonaceous	1
12. Conglomerate, brown, hard; composed chiefly of varicolored quartzite roundstones	32
11. Sandstone and siltstone, dark-gray, carbonaceous; has coaly seams	1½
10. Conglomerate, brown, coarsely bedded; composed chiefly of varicolored quartzite roundstones, mostly pebbles and cobbles but some of boulder size; forms layered cliffs and slopes shown in lower right part of figure 9; not distinguishable from conglomerates in Bobcat Member	167
9. Sandstone, light-gray to drab, soft; silty shale lenses at top; sandstone intertongues with conglomerate, each tongue thin and sharply defined	10
8. Conglomerate, brown; on wet surfaces the array of bright-red, purple, green, black, brown, and pink roundstones gives the rock a remarkably gaily colored appearance; spectacular radial crush patterns involve roundstones	30
7. Shale, black, soft, fine-grained; three samples contained pollen of latest Cretaceous age (USGS colln. D4290A, B, C; R. H. Tschudy, written commun., May 12, 1969); samples also included dinoflagellates, acritarchs, and *Veryhachium* that suggest a slight marine influence	8

Harebell Formation (part)—Continued	Thickness (feet)
Lower member (part)—Continued	
6. Sandstone, olive-drab, soft; grades up through siltstone zone to overlying unit	5
5. Conglomerate, brown, coarse; contains many quartzite roundstones some as much as 1 ft in diameter, and a few are even larger	30±
Underlying beds distorted by landsliding and poorly exposed in part; thicknesses are only approximate, and descriptions are generalized.	
4. Shale, black, soft; hard brown leaf-bearing sandstone at base	5–10
3. Conglomerate, brown, coarse; chiefly quartzite roundstones	30
2. Shale, dark-gray, soft, plastic; interbedded with a lesser amount of drab sandstone; forms glide plane for landslide, so thickness is approximate; pollen sample from upper part	20±
1. Conglomerate, brown; composed chiefly of quartzite roundstones; forms big exposure on south side of creek	100±
Total thickness of measured part of lower member	550±

No older rocks are exposed at this locality.

Conglomerates in the Bobcat Member lens out within 10 miles north of section 4, and thus the member is not mappable in the Mount Hancock area (fig. 7, section 2). South of section 12, the member was removed by erosion prior to deposition of the Pinyon Conglomerate. In the vicinity of sections 11 and 12, the conglomerate facies thins rapidly southward and southeastward, and the overlying fine-grained strata are difficult to distinguish from those below the conglomerate. No evidence of a significant angular unconformity or disconformity, such as at the base of the Pinyon Conglomerate, was recognized at the base of the Bobcat Member.

The quartzite conglomerate of the Bobcat Member is characterized by highly rounded pebbles, cobbles, and boulders of red, black, green, brown, and light-gray dense quartzite embedded in a green, brown, or olive-drab coarse-grained sandstone matrix (fig. 10). In most places about 90 percent of the conglomerate is quartzite, and the remainder is red, green, black, gray, and brown dense siliceous welded tuff, porphyry, basalt, and other igneous rocks, deeply weathered gray granite that commonly disintegrated after deposition, and siliceous and calcareous Paleozoic sedimentary rocks such as chert, sandstone, dolomite, and limestone.

Many of the roundstones, especially where the sandstone matrix was so sparse that the larger rock

FIGURE 10.—Closeup of conglomerate and sandstone in Bobcat Member of Harebell Formation in stratigraphic section 11. Note extensive crushing of quartzite roundstones. This exposure is in a fresh roadcut on the north side of U.S. Highway 287.

fragments were originally in direct contact with one another, are complexly crushed: the harder, tougher ones have been pushed into the softer, more brittle ones. Crush scars formed in this manner are conspicuous. Also present are concentrically fractured impact scars acquired prior to deposition. The hardest and finest grained roundstones commonly exhibit a remarkably high polish on all sides. Microscopic examination shows the polish to be marked by parallel grooves. The rock surface appears fused and resembles slickensides. The polish may be a form of slickenside resulting from sliding of sand matrix across the surface of the roundstones during compaction under great pressure; it is not an outcrop phenomenon that could have resulted from Holocene wind abrasion, for it is just as abundant, or more so, on roundstones dug from beneath the surface of fresh outcrops.

The size of the roundstones varies considerably from place to place and in different parts of the section. In general, the size decreases southeastward from sections 4 and 5. Size rarely exceeds 18 inches, and the average range in most localities is 2–4 inches.

As mentioned previously, the thickest conglomerate is in section 5, where there are spectacular exposures of 1,000 feet of strata, almost entirely conglomerate, in a single face (fig. 9). In superficial appearance, this conglomerate resembles the Pinyon Conglomerate in the "Narrows" along the South Fork of Fish Creek, 4 miles southeast of section 13 (fig. 30). Close examination, however, shows that the conglomerate in the Bobcat Member is more tightly cemented and more severely crushed and the roundstones have a greater variety of colors. In fact, fresh wet exposures of conglomerate near the base of this exposure of the Bobcat Member show it

FIGURE 11.—Quartzite conglomerate and sandstone comprising units 32 and 33 in the type section of the Bobcat Member of the Harebell Formation in stratigraphic section 5, capped on right skyline by shale that, 2,000 feet along strike to the right, contains the brackish-water fossil *Mytilus*. Note man at lower right for scale.

to be the most extraordinarily colorful rock in the entire stratigraphic column of Jackson Hole. The interbedded fine-grained strata in the two formations in these compared sections are likewise conspicuously different. Those in the Bobcat Member are dark green to black, hard, and brittle in part, whereas those in the Pinyon are light green and gray and are very soft.

One of the most interesting and significant localities in the entire formation is the *Mytilus* bed, unit 34 in the type section of the Bobcat Member. The biota in this bed was studied by Kauffman (1973), and an interpretation of its environmental significance was made. Because of the enormous thickness of conglomerate below it (fig. 11), the fossils were first thought to be in the Pinyon Conglomerate. Additional work in that area, however, showed the horizon to be in the Bobcat Member of the Harebell. An interpretation of the unusual environment of deposition of thick conglomerates associated with fine-grained beds containing brackish-water fossils is discussed on page A32.

Associated with conglomerate beds 250 feet below the Bobcat Member in section 4 (fig. 12) and 800 feet above the base of the Bobcat Member in section 11 are sandstones that contain dinosaur remains. These occurrences are somewhat anomalous, because dinosaurs are commonly associated with sluggish streams and swamps rather than a high-energy environment such as that in which the conglomerates were deposited.

Another facies of the Harebell Formation, lithologically distinct from both members just described, is in stratigraphic section 13. The sequence at this locality contains conglomerate that is composed of Paleozoic and Mesozoic rock fragments. Isolated out-

FIGURE 12.—Dinosaur-bearing sandstone forming a dip slope on and intertonguing with quartzite conglomerate 250 feet below the base of the Bobcat Member of the Harebell Formation 2 miles southeast of Wildcat Peak in stratigraphic section 4. The conglomerates associated with the sandstone here indicate that dinosaurs at this locality lived in a high-energy environment of deposition.

crops occur at the east and west ends of section *D–D′* (figs. 1, 13). The stratigraphy and measured sections have been described elsewhere (Love and others, 1948; Love, Hose, and others, 1951). Conglomerate beds are sparse and lenticular, rarely more than 5 feet thick, and consist of rounded pebbles, cobbles, and sparse boulders as much as 1 foot in diameter of Paleozoic and Mesozoic sandstone, chert, silicified wood fragments, and lesser amounts of quartzite. Some of the wood has been identified as *Tempskya*, which has not been found in place in Jackson Hole but is in the Lower Cretaceous Aspen Shale and Wayan Formation of southeastern Idaho (Read and Ash, 1961). Much of this conglomeratic debris is less rounded than the quartzite fragments to the north and definitely was derived from an entirely different source, probably the rising ancestral Teton–Gros Ventre uplift.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The Harebell Formation overlaps rocks ranging in age from the Bacon Ridge Sandstone to the Meeteetse Formation (fig. 14), the unconformity increasing in magnitude from east to west, presumably all the way to the Precambrian core of the Targhee uplift (fig. 16). No local angular discordance was observed, but the amount of beveling can be determined in some places. For example, in section *D–D′* (fig. 13), approximately 780 feet of the Mesaverde Formation was eroded in the 6 miles between the North Fork of Fish Creek and the Dry Cottonwood Creek sections before the Harebell Formation was deposited (Love, Duncan, and others, 1948; Love, Hose, and others, 1951). In the type section the Harebell overlies the Bacon Ridge Sandstone, but 25 miles to the south between 4,000 and 5,000 feet of strata lies between the Bacon Ridge and the Harebell. Figure 16 was constructed on the basis of the regional data and the interpretations, described above, regarding the Targhee uplift. The unconformity at the top of the Harebell Formation is discussed in connection with the Pinyon Conglomerate.

The preponderance of quartzite conglomerate in the Bobcat Member and the past misidentifications of similar-appearing but younger conglomerate exposures in the region may raise questions regarding the formational assignment of the Bobcat Member.

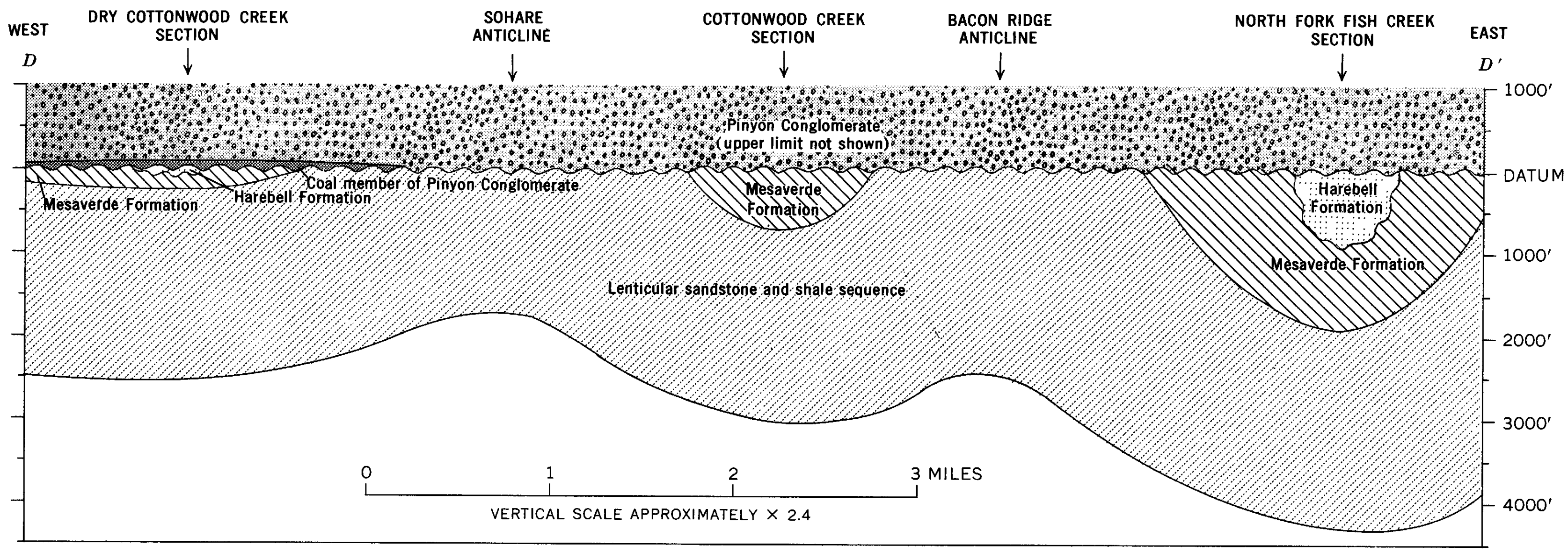


FIGURE 13.—Restored section *D–D′* across part of southeastern Jackson Hole during Paleocene time showing relation of Pinyon Conglomerate to previously folded Harebell Formation and older Cretaceous rocks. Stratigraphy is generalized from Love, Duncan, Bergquist, and Hose (1948), Love, Hose, Weitz, Duncan, and Bergquist (1951), and Love, Keefer, Duncan, Bergquist, and Hose (1951).

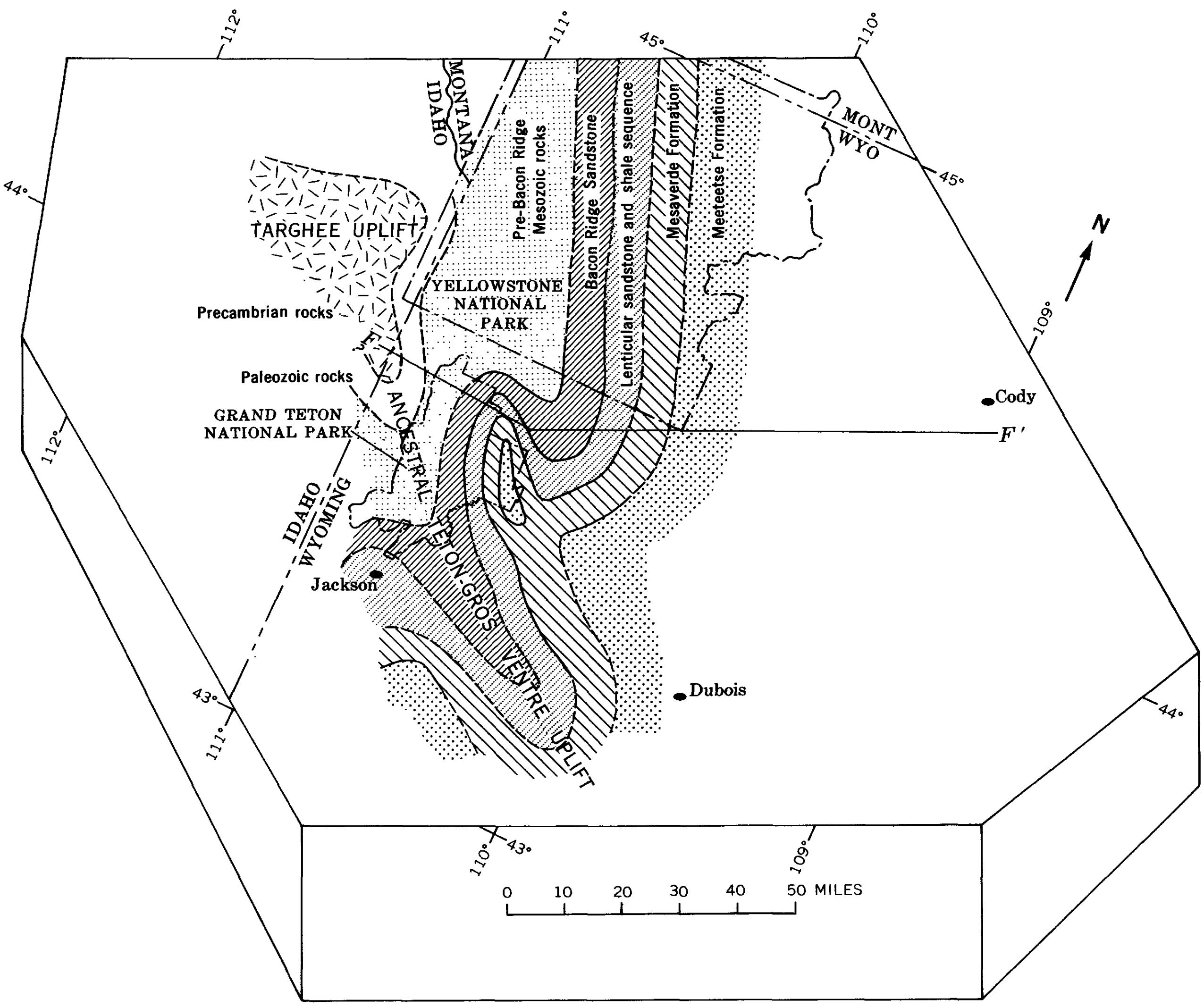


FIGURE 14.—Geology of area as it was at beginning of deposition of the Harebell Formation. Solid lines indicate adequate control; dashed lines are interpretive. Section *F–F′* shown in figure 16.

It is here assigned to the Harebell Formation, rather than to the Pinyon Conglomerate, for the following reasons: The Harebell Formation, despite its heterogeneity that is so characteristic of all terrestrial deposits, is a single unit, as defined here on the basis of both composition and bounding contacts. The rock body bounded by angular unconformities both above and below is characterized by abundant volcanic detritus (progressively decreasing toward the top), by greenish-brown colors that weather olive drab, and by dark-green sandstone, siltstone, and claystone. In contrast, the fine-grained strata of the Pinyon Conglomerate have lighter brown and gray colors and lack volcanic debris (table 1). The conglomerate in the Bobcat Member more closely resembles the lenticular conglomerate beds in the lower member of the Harebell, rather than the less-shattered and less indurated conglomerate in the Pinyon.

The presence of conglomerate is, of course, not the sole basis for rock-stratigraphic assignments in most Cretaceous and Tertiary terrestrial deposits, for all continental units are locally conglomeratic in proximity to the source. The occurrence, in both the Harebell and the Pinyon, of quartzite conglomerate from the same source, and perhaps the derivation of some of the younger conglomeratic debris from the older, make formational assignments difficult; however, as mentioned above, other criteria are available (table 1) even at localities where the angular unconformity between the two formations cannot be discerned. Moreover, where conglomerate beds in the Bobcat Member pinch out laterally, that is, southeastward, as shown in figure 7, the fine-grained rock body that is the lateral equivalent of the member is closely similar to the lower part of the Harebell Formation.

AGE AND CORRELATION

The Harebell Formation is of Late but not latest Cretaceous age. This age assignment is based on collections of Cretaceous pollen, leaves, acritarchs, dinoflagellates, dinosaurs, and *Chara*. Fossils of some kind are in almost all sections. Leaves are abundant and well preserved in many sections, especially 3 and 7. Many claystones and siltstones throughout the region contain mollusks, but these are fragile and thin shelled and commonly are crushed. The brackish-water *Mytilus* Zone has already been described. No definite remains of mammals have been observed, although some suspected of being mammal were found near the horizon of unit 15 in the type section. These were collected and submitted but were lost before they could be identified.

About 800 feet above the base of the Bobcat Member of the Harebell Formation in section 11 is a drab hard siltstone and sandstone interbedded with quartzite pebble conglomerate. The siltstone yielded a small collection of bones, teeth, and mollusks. The mollusks were identified by D. W. Taylor (written commun., 1963) as the fresh-water clams *Sphaerium* and *Eupera*, the fresh-water snails *Physa* or *Bulinus*, and an unidentified high-spired form, and the land snail *Pseudocolumna*. Vertebrate fossils collected from this bed by Wesley Gordon and associates in 1964 were identified by Richard Estes and M. C. McKenna (written commun., Oct. 19, 1964; Feb. 18, 1966; and Oct. 2, 1969) as follows:

At locality 3, the following vertebrate fossils were collected in 1964 by the American Museum of Natural History: *Prodesmodon* (plethodontid salamander, Aptian–Miocene), *Kindeleia* (amioid fish, Campanian–?Eocene), ceratopsian teeth (horned dinosaur, Maestrichtian), a ?camptosaur tooth, and an alligator (not useful here). In general, these remains are consistent with Maestrichtian age.

Dinosaur remains have also been found in association with conglomerates 250 feet below the base of the Bobcat Member of the Harebell Formation in section 4 (fig. 12). Concerning these, G. E. Lewis (written commun., Nov. 28, 1967) stated:

The datable fragments, out of several dozen, are of an edentulous dentary, of a predentate dinosaur about the size of the hadrosaurian ornithopods, with dental battery grooves less arcuate and more closely spaced than in *Triceratops*. The stratigraphic position is Upper Cretaceous.

A third locality (fig. 7, section 3) yielded one probable dinosaur tooth from a claystone about 2,300 feet above the base of the Harebell Formation (unit 29 in type section). Concerning it, G. E. Lewis (written commun., Nov. 4, 1966) stated: "The specimen is referred to one of the Upper Cretaceous Deinodontidae."

About 100 feet above the base of the Bobcat Member of the Harebell Formation, in section 11, is an olive-drab siltstone between two beds of quartzite cobbles and boulders. R. E. Peck and I collected abundant *Chara* from this siltstone; they were identified (R. K. Germundson and R. E. Peck, written commun., 1965) as follows:

Stellatochara mundula (Peck), *Amblyochara* cf. *A. begudiana* Grambast, ?*Harrischara* n. sp., *Mesochara* n. sp., ?*Chara* n. sp. These forms occur abundantly in the North Horn just west of Wales, Utah, in beds Spieker (personal communcation) considers Upper Cretaceous, and in the lower Willow Creek of Alberta. *Stellatochara mundula* ranges from Aptian through Upper Cretaceous.

GOLD OCCURRENCES

Gold in small amounts and invariably in very fine particles is present in most of the Harebell Formation. J. C. Antweiler, between 1965 and 1969, made a detailed investigation of the gold, with special emphasis on its grade, concentration, distribution, chemical characteristics, behavior in transport, and trace-element content. Final results are not yet available, but preliminary data on gold in the Harebell are reported by J. D. Love and J. C. Antweiler (in U.S. Geol. Survey, 1966, p. A4–A5), Antweiler and Love (1967), Antweiler (1969), and Antweiler and Sutton (1970). In summary, the first 141 samples of quartzite conglomerate and sandstone, collected principally from sections 7, 10, and 11, averaged 65 ppb (parts per billion) gold and had a maximum of 1,000 ppb. Gold values decrease in the northern and southeastern areas of outcrop and in the upper part of the formation. Sandstones in the lower middle part (section 7) and lower part (section 14) apparently contain as much gold as the richer conglomerates, and at these localities the magnetite contains an appreciable amount of gold. The gold is believed to have been derived from the Targhee uplift northwest of Jackson Hole.

TARGHEE UPLIFT — SOURCE OF QUARTZITE CONGLOMERATE AND GOLD

The source of the enormous volume of quartzite debris, most of which contains sparse small particles of gold, has been investigated in some detail because of the gold content. The presence of a now-vanished source uplift beneath the Snake River downwarp (fig. 2) west and northwest of Jackson

Hole has long been suspected (Love, 1956a; Eardley, 1960). By 1968, enough data had been obtained to permit an understanding of its dimensions and significance. It was then named the Targhee uplift (Love and Reed, 1968, p. 83), the name being derived from the Targhee National Forest, a large part of which is in the postulated area of the uplift in eastern Idaho and westernmost Wyoming. Figures 42 and 46 (Love and Reed, 1968) give a rough approximation of the extent of this uplift in latest Cretaceous and Paleocene times. Figure 15 of the present report includes additional information.

Regional studies were conducted to get a rough approximation of the original volume of sediment deposited east of the Targhee uplift during latest Cretaceous time in the area of figure 15. This volume, 3,200 cu mi (table 2), is based on data from unpublished isopach maps of the Harebell Formation in Jackson Hole and of the partial lateral equivalent, the Lance Formation, in the western part of the Bighorn Basin and northwestern arm of the Wind River basin. Only the areas containing uppermost Cretaceous rocks, part of which could have been derived from the Targhee uplift, were included.

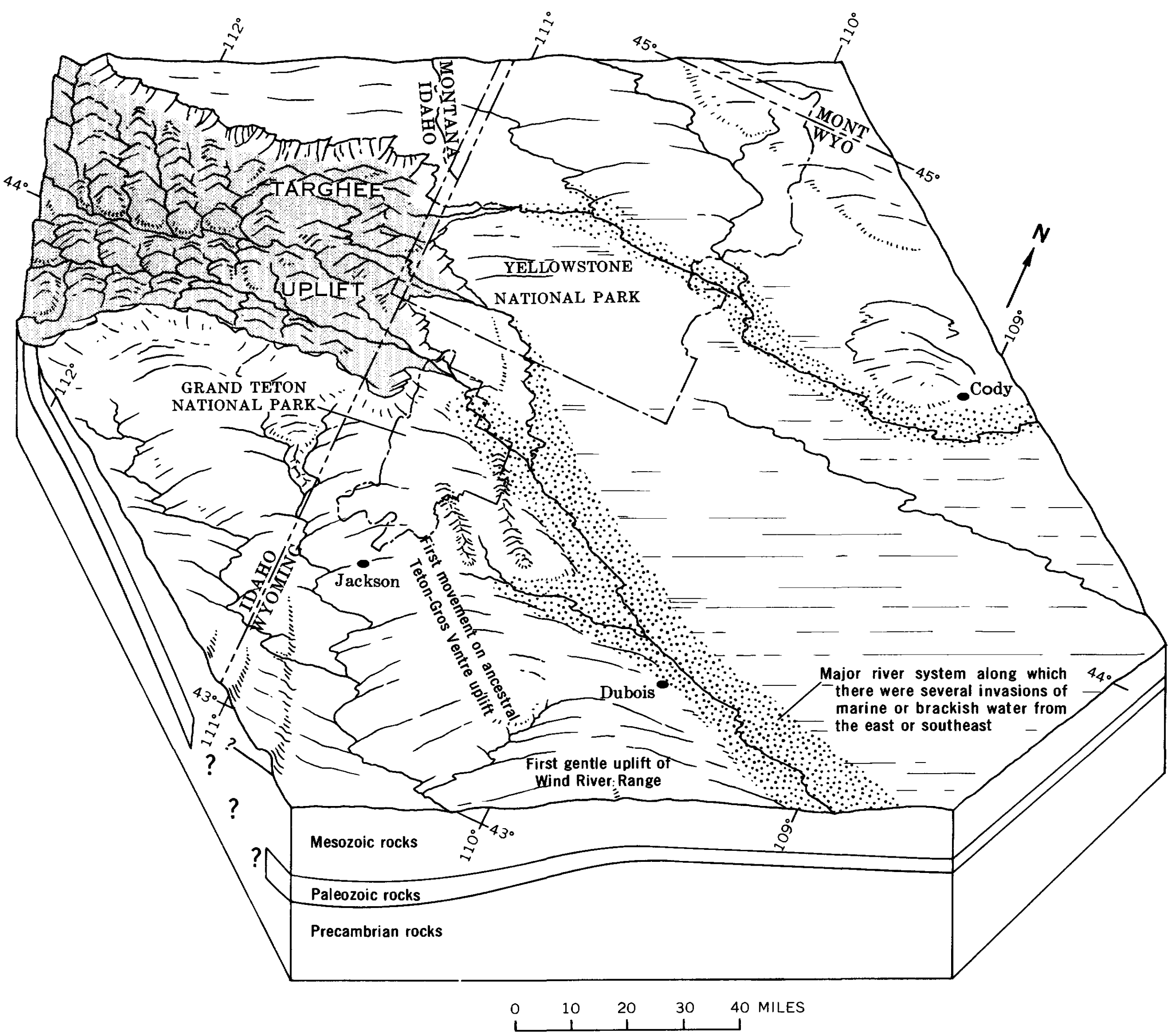


FIGURE 15.—Northwestern Wyoming and adjacent areas during deposition of Harebell Formation. Quartzite conglomerate facies derived from Targhee uplift is shown by stipple. Gray area is postulated Precambrian core of uplift. Precambrian metasedimentary rocks near the northwest corner of the block strike north-northwest and have steep dips. This is the basis for the diagrammatic representation of linear topography and trellis drainage throughout the exposed core area. Vertical exaggeration on near edge of block × 4.

TABLE 2.—*Estimated volumes of uppermost Cretaceous and Paleocene sediments and thicknesses of rocks stripped from Targhee uplift that were deposited as conglomerate*

Unit estimated	Harebell Formation (cu mi)	Pinyon Conglomerate (cu mi)	Remarks
Original volume of sediment in area of block diagrams (figs. 15 and 36).	3,200	3,400	Harebell volume includes Lance Formation in parts of Bighorn and Wind River basins; Pinyon volume includes Paleocene rocks above Pinyon Conglomerate in Jackson Hole and Fort Union Formation in part of Bighorn Basin but not Paleocene rocks in Wind River basin or south of Gros Ventre uplift where little, if any, of the sediment was derived from the Targhee uplift.
Original volume of quartzite conglomerate deposited in Jackson Hole.	135	425	
Volume of quartzite conglomerate still present in Jackson Hole.	40	35	
Thickness of rock debris derived from Targhee uplift necessary to account for conglomeratic part of formations.	[1] 700	[1] 2,000	Estimates based on assumption of 1,000 sq mi of Precambrian area on that part of Targhee uplift (as indicated on block diagrams) eroded by streams flowing exclusively into Jackson Hole. Sand and finer grained fractions are not considered.

[1] Feet.

The accuracy of this volume estimate may be questioned, as can the validity of many required assumptions, such as necessity for original continuity of these deposits across the present site of the Absaroka Range and the correlation of the Harebell with at least part of the Lance Formation. This estimate, nevertheless, has some use in reconstructing the size of the Targhee uplift and its relation to the depositional history during latest Cretaceous time.

The original volume of quartzite conglomerate in the Harebell Formation of Jackson Hole is estimated as about 135 cu mi (table 2). This figure is used as a guide in reconstructing the size of the parent area needed to furnish this amount of coarse debris. It seems reasonable to postulate a source area of at least 500 sq mi, and more likely 1,000 sq mi, underlain by quartzite. Immediately eliminated are the Paleozoic and Mesozoic rocks in mountains adjacent to Jackson Hole. The Flathead (Cambrian) and Tensleep (Pennsylvanian) Sandstones and the Quadrant (Pennsylvanian) Formation are the only ones in the Paleozoic sequence that are even moderately quartzitic, and this only in localized areas. These sandstones do not resemble, in physical appearance, variety of color, or degree of metamorphism, the quartzites in the conglomerates. No widespread quartzitic sandstones of consequence are in the Mesozoic sequence.

There is no 500-sq-mi or larger area of Precambrian quartzite in the cores of the Wind River, Gros Ventre, Teton, Centennial, Madison, Gallatin, Beartooth, or Washakie uplifts (fig. 2). In fact, quartzite is an uncommon lithology. Furthermore, except for the Washakie Range, uparching of these mountains and exposure of the Precambrian rocks took place chiefly in Paleocene and early Eocene times rather than prior to or during latest Cretaceous. The Washakie Range, as is discussed later, is believed to have risen, been thrust westward, and then deeply eroded after deposition of the Harebell Formation but before the end of Cretaceous time.

As mentioned earlier, imbrication of the flatter rock fragments in the conglomerates, orientation of channels and foreset beds, and increase in size of roundstones from southeast to northwest show that the transporting streams flowed east, east-northeast, and southeast across Jackson Hole (Lindsey, 1970). The size of the rock fragments and the volume of conglomeratic debris indicate that the transporting media were large vigorous rivers that drained a major upland to the west for a long period of time.

In the Lemhi Range, Idaho, 150 miles west-northwest of Jackson Hole and 50 miles west of the Centennial Range (fig. 2), are remnants of three quartzite sequences, each of which is several thousand feet thick. The oldest two, the Lemhi Quartzite, a gray-green sequence, and the Swauger, a purple to white quartzite (Ross, 1947), are in the Belt Supergroup of Precambian age; the youngest is the Kinnikinic, a nearly pure white quartzite more than 2,000 feet thick, of Ordovician age. A field examination of these shows that lithologically they compare closely with some of the roundstones in the Harebell Formation.

A thick sequence of Late Precambrian (younger than 750 m.y.) and Cambrian rocks containing many quartzites and quartzite conglomerates is known from southeastern Idaho and northern Utah, 100–200 miles southeast of Jackson Hole, and is younger than the Belt Supergroup (Crittenden and others, 1971). Many clasts in the Harebell Formation and Pinyon Conglomerate are composed of quartzitic conglomerate very similar to some of the conglomerates in this post-Belt sequence. It is possible, therefore, that a northern equivalent of these rocks, rather than a southern or eastern equivalent of Belt, was exposed at the surface of the Targhee uplift during latest Cretaceous and Paleocene times.

The Lemhi Range, however, is too far away from Jackson Hole to be the most likely source area, for boulders having the size and abundance of those observed in the Harebell could be transported that far only with great difficulty. In between are no present-day uplifts but, instead, there is the giant Snake River downwarp (Cohee, 1961), partly filled with Pliocene and Pleistocene igneous and pyroclastic rocks. Gravity maps and profiles show no evidence for or against a buried uplift underlying the northeastern part of this downwarp (Pakiser and Baldwin, 1961; LaFehr and Pakiser, 1962; Mabey, 1966). Nevertheless, all the currently available geologic evidence indicates that an uplift did exist there during latest Cretaceous and Paleocene times in the approximate location shown in figure 15.

Paleozoic and Precambrian quartzites were exposed in the core of the uplift as far back as Bacon Ridge time, for quartzite cobbles, as much as 18 inches long, are in the Bacon Ridge Sandstone in eastern Jackson Hole. The exposure of the Precambrian required a prior uparching and erosion of 10,000 feet of Paleozoic and Mesozoic strata (fig. 16).

Northwest of Rammel Mountain (fig. 1), on the west side of the Teton Range, Pliocene and Pleistocene rhyolitic rocks overlap Precambrian rocks, and there is no evidence of a west-dipping flank of Paleozoic strata. The Targhee uplift may have extended northwest from this part of the ancestral Teton Range and continued as far as the Lemhi Range. More specific evidence for the location of the southeast margin of the Targhee uplift is provided by the Pinyon Conglomerate and is discussed in connection with that formation.

Ryder (1967), who studied conglomerate facies of the Beaverhead Formation in the region of the Tendoy Range (fig. 2; northwest corner of fig. 15), Idaho and Montana, described the "Divide Quartzite Conglomerate Lithosome." This sequence consists of at least 15,000 feet of conglomerate in which Precambrian Belt-type quartzite clasts predominate. Current directions ranged from north in the southeasternmost area of conglomerate to northeast in the southwestern part. Pollen from presumed lateral-equivalent conglomerates at two localities within 5 miles north of the main mass of quartzite conglomerate range in age from early Late Cretaceous to late Late Cretaceous and (or) Paleocene. The "Divide Quartzite Conglomerate Lithosome" of Ryder is very similar to the quartzite conglomerates in the Harebell and may represent a partial temporal equivalent that was deposited by northward-flowing streams draining part of the quartzite core of the Targhee uplift. Therefore, on the basis of Ryder's work, the extreme northwest corner of figure 15 is shown to have a stream flowing north into the area of the "Divide Quartzite Conglomerate Lithosome."

Wilson (1970) added more details to the regional story of sedimentation northwest of the area shown in figure 15. He recognized that an uplift west of the southwest corner of Yellowstone National Park must have supplied a large volume of coarse clastic debris to the Beaverhead Conglomerate. He did not mention the Targhee uplift by name but showed the ancestral Beaverhead Range extending southeastward into the western part of the area of figure 15 (compare also his fig. 14 with fig. 46 in Love and Reed, 1968).

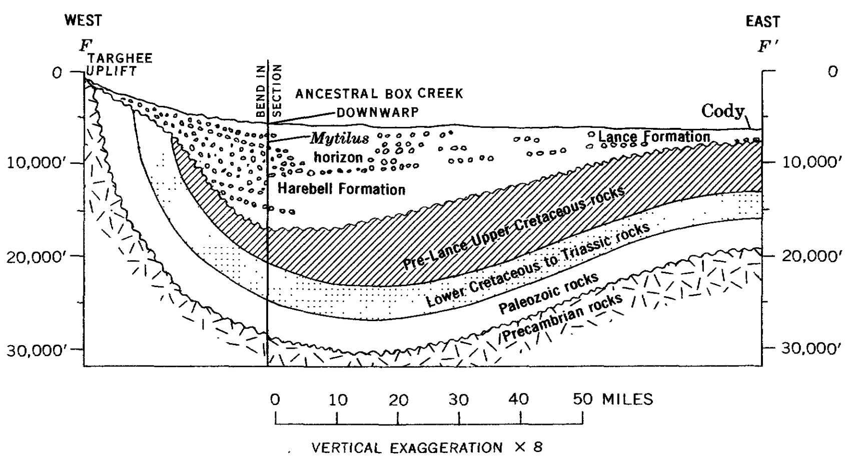


FIGURE 16.—Restored section *F–F'* extending east-northeast from the Targhee uplift to Cody at end of deposition of the Harebell and Lance Formations. Circles indicate major zones of conglomerate. Brackish-water *Mytilus* horizon is shown at bend in section. Line of section is shown in figure 14.

The southwest boundary of the uplift is unknown; its southern extent is limited by outcrops of Paleozoic rocks in the Big Hole and Snake River Ranges (fig. 2). Its northern extent is limited by the Centennial, Madison, and Gallatin Ranges, which have little quartzite. To the northeast, under the Yellowstone volcanic plateau, no data are available, but, inasmuch as the Harebell Formation is largely nonconglomeratic in the northernmost sections (fig. 7, sections such as 2 and 3) and still farther north (fig. 5), it is presumed that the uplift did not extend very far eastward into Yellowstone National Park.

My interpretation is that the Targhee uplift was broad; otherwise, streams would have had to flow lengthwise along a narrow steep-sided uplift. This seems highly unlikely. By considering the greatest possible breadth for the uplift within the confines of the nonquartzite-bearing mountain ranges, an area of quartzite outcrop of about 1,000 sq mi can be postulated. The accumulation of the 135 cu mi of quartzite conglomerate debris estimated to have been originally deposited in Jackson Hole requires removal of a 700-foot-thick source layer from a 1,000-sq mi area of the uplift. Probably an equal or greater amount of sandstone and siltstone was also derived from the same area. These total amounts given some measure of the height that the uplift must have been above the basin of deposition to the east. Conditions of deposition are discussed in connection with environmental interpretations.

Still unexplained is the source of the roundstones of fine-grained welded tuff, rhyolite, and other igneous rocks in the Harebell Formation. The presence of glass and the fresh appearance of the plagioclases suggest that the source rocks are of Mesozoic age. In size and sphericity the roundstones are comparable to the associated quartzite clasts, so they probably did not come from a greater distance. They may represent Mesozoic igneous and pyroclastic rocks that came up through the quartzite terrane of the Targhee uplift.

It is not known if any of the igneous or pyroclastic rock types in roundstones are related in age to the tuffaceous debris in the fine-grained facies of the Harebell Formation. The increasing abundance of this tuffaceous debris from south to north in Jackson Hole may indicate a northern source. Such a source might be present under the Yellowstone volcanic plateau. Otherwise, one must look about 100 miles north of the farthest north exposure of the Harebell to the Livingston Group, which is in part of comparable age to the Harebell. The Livingston Group contains abundant volcanic detritus, which is believed to have come from the Elkhorn Mountains (Roberts, 1963), about 100 miles north-northwest of the northwest corner of Yellowstone National Park. The abundance of only slightly abraded quartz bipyramids, however, in the sandstones in section 4 (fig. 7) and elsewhere in the Harebell Formation suggests that the coarser volcanic debris did not come from as far away as the Elkhorn Mountains.

A closer source, northwest or west of Yellowstone National Park, is suggested by the following data: On and northwest of Mount Everts in the northwestern part of the park, 55 miles north-northwest of the base of the type section of the Harebell Formation (figs. 4, 17), is a similar-appearing sequence of strata that was called Harebell Formation by Brown (1957). Later, these strata were named the Landslide Creek Formation by Fraser, Waldrop, and Hyden (1969, p. 34). In the area where Brown measured 634 feet of strata, they measured 654 feet, and the lithologic descriptions are so similar that there is little doubt that the same rocks were being discussed. Fraser, Waldrop, and Hyden described the sequence as follows:

> The formation, which is wholly continental in origin (mostly fluvial), comprises a sequence of dark-colored commonly conglomeratic sandstone interbedded with varicolored generally somber mudstone and claystone. A conspicuous volcanic component is present in all grade sizes: bentonite is present in virtually all fine-grained rock and in some coarse-grained rock; andesitic grains are common in nearly all sandstone and conglomerate; andesitic pebbles, cobbles, or boulders, which are rare or absent near the base and in the eastern part of the area, increase irregularly in abundance and average coarseness up section and northwestward in the area. Fragments of dinosaur bones are present locally, and land-plant debris is common throughout.

Some conglomerates consist of andesite fragments as large as boulders. Chert and quartzite pebbles are common at many horizons. The formation rests with an erosional unconformity on older Cretaceous rocks. Regarding age and correlation, Fraser, Waldrop, and Hyden stated (p. 36):

> The Landslide Creek Formation is assigned to the Late Cretaceous on the basis of scattered dinosaur bone fragments from exposures northwest of Gardiner and a Cretaceous pollen assemblage collected by J. D. Love from the exposure west of Eagle Nest Rock (J. D. Love, written commun., 1961). Lithologically the formation resembles parts of the Cretaceous Livingston Group 40 miles north of Gardiner (Roberts, 1963) and to a lesser extent parts of the Cretaceous Harebell Formation 100 [actually 55] miles south (Love, 1956, p. 82). An approximate correlation with the upper three formations of the Livingston Group and with the Harebell Formation is suggested.

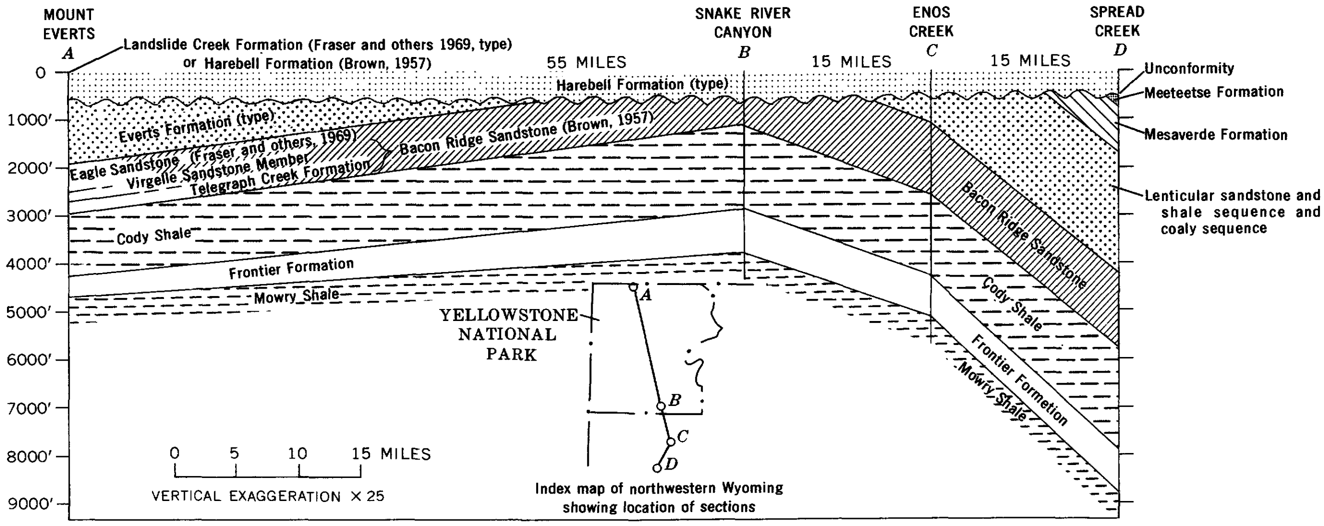


FIGURE 17.—Diagrammatic section from northern Yellowstone National Park to Jackson Hole showing regional unconformity between Harebell Formation and older Cretaceous rocks. Section *A* is adapted from measured sections by Brown (1957) and Fraser, Waldrop, and Hyden (1969); *B* is from J. D. Love and W. R. Keefer (unpub. data, 1972); *C* and *D* are from Love, Hose, Weitz, Duncan, and Bergquist (1951).

No reason was given for establishing a new name for these strata rather than using the name Harebell. Now there are two formations probably of the same age, whose type sections are 55 miles apart, and which have strikingly similar compositions. An unconformity is present at the base of each formation, and no known mountain barriers separated them at the time of deposition. They are both within Yellowstone National Park. It seems likely that the Landslide Creek Formation is merely a northern extension of strata in the lower part of the type section of the Harebell Formation. The marked increase in volcanic debris from south to north through Jackson Hole and across Yellowstone National Park and the size and abundance of andesite clasts suggest a volcanic source area somewhere west or northwest of Mount Everts.

INTERPRETATION OF DEPOSITIONAL ENVIRONMENT

Sediments in the Harebell Formation reflect extreme contrasts in high- and low-energy environments of deposition, not only laterally but also in the vertical succession of strata. The conglomerates certainly were deposited by powerful high-velocity rivers that flowed east and southeast into Jackson Hole from the Targhee uplift. Nevertheless, interbedded with the conglomerates are shales and claystones containing marine or brackish-water acritarchs and dinoflagellates and the mollusk *Mytilus*.

The flood of quartzite conglomerate in the lower part of the Bobcat Member is a reflection of some event whose influence lasted long enough to cause deposition of several thousand feet of coarse clastic debris. This event could have been a sudden rise of the Targhee uplift, a subsidence of the Box Creek downwarp, an increase in precipitation, or a combination of these. Less tuffaceous debris is present in the Bobcat Member than in the lower member, but bentonitic claystones occur in the upper part of section 11 and elsewhere near the top of the Bobcat Member.

Although the conglomerates persist through several thousand feet of stratigraphic thickness in sections 4, 5, 6, 9, and 10 (fig. 7), they lens out rapidly to the north, east, and southeast into fine-grained rocks. This lensing suggests that the position of the river system that flowed along the sinking Box Creek downwarp did not move very far laterally from the trough line. This downwarp probably was a northwestern continuation of the arcuate major trough of subsidence and deposition that extended through central Wyoming and on to the northeast (Love and others, 1963, fig. 4), where it may have connected with the latest Cretaceous seaway. This trough of active subsidence would be the most logical route along which the frequent invasions of marine and brackish water into Jackson Hole would have come. It was cut off permanently during latest Cretaceous time by the rise of an arch between the Wind River and Washakie Ranges.

Subsidence of the Box Creek downwarp must have been about as rapid as sedimentation, for even in the thickest and most conglomeratic sections (such as sections 4 and 5), there are thin beds that contain marine or brackish-water fossils. The brackish-water *Mytilus* Zone, consisting of 4 feet of fine-grained carbonaceous shale (fig. 7, section 5), was sampled in detail for microfossils. Concerning them, R. H. Tschudy (written commun., 1969) stated:

Veryhachium, *Tasmanites*, acritarchs, and dinoflagellates suggest marine or brackish conditions of deposition. The general paucity of marine forms suggests very little marine influence, possibly deposition on a delta. The paucity of palynomorphs in the rock as a whole, and their concentration in thin carbonaceous partings suggests rapid deposition followed by short periods during which organic material including palynomorphs settled out. This interpretation argue against any wholesale redeposition of Cretaceous palynomorphs in these rocks.

The swarms of fragile thin-shelled *Mytilus* in this same zone likewise argue against redeposition (Kauffman, 1973).

The presence of abundant leaves of tropical types at many horizons and of large dinosaurs is evidence that the climate was warm and humid; therefore, water sufficient to transport a large volume of coarse clastic sediment was no doubt available. By the time the youngest brackish-water strata in section 5 were being deposited, the oldest part of the Harebell Formation was nearly 11,000 feet below sea level in the trough of the Box Creek downwarp. Pertinent to the magnitude and rapidity of this subsidence are such questions as: What were the gradients of rivers flowing eastward and southeastward from the Targhee uplift, what was the height of the Targhee uplift above sea level, did the uplift rise, sink, or remain stable during Late Cretaceous time, what were the volumes of river water, and what were the mechanics of transport and deposition of the thick quartzite conglomerate beds? Answers to these questions must await more extensive regional studies.

PINYON CONGLOMERATE

NAME AND DEFINITION

The Pinyon Conglomerate was named by W. H. Weed (in Hague, 1896, p. 5), as follows:

They [Eocene sedimentary beds] have been designated the Pinyon conglomerate from the name of the mountain where they are best exposed. They consist of a series of conglomerate beds with local intercalations of sandstone, the formation resting unconformably upon the upturned Laramie (Cretaceous).

The "Laramie" strata referred to are part of the type section of the Harebell Formation. The setting of Pinyon Peak and exposures of conglomerate on it are shown in figure 18.

Hague (p. 5) also stated:

This material has accumulated to a thickness of nearly 600 feet, and is clearly a shallow-water, in-shore deposit, as it is far too coarse to have been transported to any great distance. As regards their age, these conglomerates have been provisionally referred to the Eocene period, since they were deposited subsequent to the Laramie upheaval and must have preceded the accumulation of volcanic rocks. * * * These gravels are the northern extension of much larger areas occurring in the Wind River Mountains.

Later, Hague (in Hague and others, 1899, p. 187) modified the name:

The conglomerate has been referred provisionally to the Eocene period, and has been regarded as a distinct geological formation, to which the name "Pinyon Peak conglomerate" has been given, after the locality where it is so characteristically exposed.

The name was subsequently changed back to Pinyon Conglomerate and its age to Paleocene (at the time Hague named the formation, the Paleocene Epoch had not been recognized) on the bases of vertebrate fossils in strata that directly overlie it (Love, 1947) and of invertebrate and plant fossils that underlie it (Love and others, 1948). During the summer of 1969, however, a tooth of *Leptoceratops*, a small hornless dinosaur of latest Cretaceous age, was found 150 feet above the base of the principal reference section of the Pinyon Conglomerate on Pinyon Peak (McKenna and Love, 1970). This indicates that at least the lowest 150 feet of the Pinyon Conglomerate in its type locality is of latest Cretaceous age.

DISTRIBUTION AND THICKNESS

Figure 1 shows the distribution of the Pinyon Conglomerate. The area of outcrop is about 150 sq mi. As stated in the discussion of the Harebell Formation, a large area of conglomerate, previously called Pinyon, south and southwest of Pinyon Peak, is now considered to be part of the Harebell.

North of Buffalo Fork, the top of the Pinyon Conglomerate is an erosion surface and no younger Paleocene rocks are present, so the original thickness of the conglomerate is not known. The type locality has the thickest section, about 3,775 feet. In the extreme southeastern part of the mapped area, the Pinyon is overlain by nonconglomeratic Paleocene rocks and has a thickness that decreases southeastward from 2,000 feet to about 200 feet at the extreme southeastern exposure.

LITHOLOGY

Table 1 summarizes the composition and sedimentary features of the Pinyon Conglomerate and compares them with those of the Harebell Formation.

No type section of the Pinyon Conglomerate was presented, either by Weed or by Hague, because, at

FIGURE 18.—Oblique aerial view southwest across Pinyon Peak area. Parts of the principal reference section of Pinyon Conglomerate (A) are indicated by dots. Other features shown are the lower Tertiary volcanic rocks (Tv), which unconformably overlie the Pinyon; Tertiary basalt (Tb), which caps Pinyon Peak (P); Whetstone Mountain (W) and Bobcat Ridge (BR), both of which are composed of Harebell Formation; and Grand Teton (T). Bare strip on right side of photograph is tornado path cut through trees during the late 1950's.

the time of their work (the 1880's to 1904), the concept of type sections had not been developed. After a lapse of 70 years, and also partly because there is such a discrepancy in figures for thickness of the conglomerate on Pinyon Peak (Hague's 600 feet versus my 3,775 feet), it is considered advisable to designate a principal reference section (American Commission on Stratigraphic Nomenclature, 1961, p. 653) on Pinyon Peak rather than to designate a type section. The principal reference section, whose location is shown in figures 4 and 18, is as follows:

[The section, on the east, north, and northwest spurs of Pinyon Peak (fig. 4), was measured, sampled, and described by J. D. Love and J. L. Weitz, using Brunton compass and steel tape; major intervals were computed from dips taken in the field, and distances and elevations were computed from the topographic map of the Mount Hancock quadrangle. Beds dip uniformly about 20° SW. Fossils were identified by the following persons: D. W. Taylor, mollusks; E. B. Leopold, pollen; Helen Duncan, Paleozoic fossils in boulders]

	Thickness (feet)
Volcanic rocks:	
32. Tuff and conglomerate, light-gray; not described here	200–400±

Angular unconformity. On Pinyon Peak the lower Tertiary volcanic rocks rest on 2,000–3,700 ft of Pinyon Conglomerate, whereas 1 mile northwest of the peak they directly overlie the Harebell Formation. These volcanic rocks were deposited in a steep-sided valley cut into the underlying Pinyon Conglomerate.

Pinyon Conglomerate:	*Thickness (feet)*
31. Conglomerate, light-tan, coarse-grained; rock fragments chiefly of highly rounded red and gray quartzite and some hard dense volcanic rocks and Paleozoic and Mesozoic cherts; sparse limestone and granite; some boulders 18 in. in diameter and many 12 in.; pollen sample of conglomerate matrix collected 100 ft below top; unit between the knife-edge crest of the north spur of Pinyon Peak and the west end of the northwest spur of the peak; thickness only approximate because of poor exposures and absence of beds that have reliable dip and strike; in the entire interval only conglomerate was observed, although dense timber and slumping of steep slopes could have concealed softer beds; top of unit probably was not original top of formation, and the amount removed by erosion cannot be determined; computed thickness is considered to be a minimum	1,100±
Underlying beds measured on north spur of Pinyon Peak, 2,000 ft north-northeast of VABM[1] 9,705 ft.	
30. Conglomerate, light-tan, coarse; roundstones are principally quartzite, chiefly red and gray, with only slight sheen on surface, and are embedded in a coarse-grained tan sandstone matrix; 50 ft below top, a green- and gray-mottled rounded chert boulder yielded brachiopods, crinoids, and the bryozoans *Rhombotrypella* and *Ascopora,* which are probably of Middle or Late Pennsylvanian age (identified by Helen Duncan, written commun., June 14, 1967)	152
29. Sandstone, brown; contains layers of black grains	2
28. Conglomerate, light-tan, coarse, chiefly of highly rounded fragments of red and gray quartzite	21
27. Sandstone, brown, ferruginous, carbonaceous, lenticular; strike N. 35° W., dip 22° SW	1
26. Conglomerate, light-tan, coarse, chiefly of highly rounded fragments of red and gray quartzite in a coarse-grained tan sandstone matrix	6
25. Sandstone, brown, coarse-grained; contains pebbles scattered throughout and thin conglomerate lenses; limonite staining conspicuous around chunks of carbonized wood	11
24. Conglomerate, light-tan; much coarser than overlying and underlying conglomerates; boulders more than 1 ft in diameter common	132
23. Sandstone, drab, crossbedded, ledgy; contains scattered pebbles and lenses of quartzite pebble conglomerate; abundant muscovite in matrix	7
22. Conglomerate, light-tan, coarse; contains many boulders and smaller roundstones of red and gray quartzite on which there is little sheen	25
21. Covered interval across valley from point at elevation 9,400 ft to base of unit 22; exposures in ravines to north of unit 22 suggest that entire interval of unit 21 is virtually all conglomerate	275±
20. Conglomerate, light-tan, coarse; contains many boulders, roundstones 1–10 in. in diameter consisting of highly rounded red and gray quartzite, and some red to gray dense volcanic rocks in a drab sandstone matrix; exposed in bottom of north-flowing torrent gully; a few 1-ft beds form rounded sandy ledges; in upper 175 ft, boulders 12 in. and larger are common (one at top of hill is 2 ft long); most are quartzite, but some cobbles as much as 6 in. in diameter are gray coarsely crystalline granite in which muscovite books were observed; 225 ft above base is an 8-in. boulder of black granite gneiss containing garnets and abundant biotite; 175 ft above base are several granite roundstones, pegmatite containing muscovite and large quartz and feldspar crystals, and some dense siliceous boulders composed of black angular fragments in a white matrix that give the rock the appearance of agglomerate; 100 ft above base, noted a 3-in. weathered granite pebble and a 10-in. tan dolomite boulder that has ghosts of small shells; pollen samples of conglomerate matrix taken 200, 100, and 25 ft below top were barren	440
19. Covered interval between elevation 9,100 ft on north-facing scar at base of unit 20 and top of unit 18; interval apparently is largely, and perhaps entirely, conglomerate	350
18. Conglomerate, tan; composed of red and light- to dark-gray quartzite and some dense hard siliceous volcanic rocks, cemented with coarse-grained brown sandstone; traces of inconspicuous polish on hardest roundstones; upper part has many boulders of white, red, and purple quartzite 15 in. in diameter	100
17. Siltstone, sandstone, and claystone, white, biotitic; appears tuffaceous; very poorly exposed	15
16. Chiefly conglomerate; partly covered; drab	

[1] Vertical angle elevation bench mark.

Pinyon Conglomerate—Continued — *Thickness (feet)*

silty blocky sandstone less than 10 ft thick at base of unit ____ 168

15. Conglomerate, tan; composed of roundstones of red and light- to dark-gray quartzite and some hard siliceous volcanic rocks, cemented with coarse-grained brown sandstone; traces of polish remain on hardest roundstones, but it is not conspicuous; poorly exposed in part ____ 215
14. Conglomerate, tan, coarse; poorly exposed in part; top 20 ft forms bench held up by many quartzite boulders 12–15 in. in diameter ____ 125±
13. Conglomerate, tan, coarse; poorly exposed in part; layer of large boulders at top forms ridge ____ 75
12. Partly covered interval; the lower 50 ft and top 50 ft are almost certainly conglomerate and the middle part probably is conglomerate ____ 325
11. Conglomerate, tan; chiefly red and gray quartzite roundstones 2–4 in. in diameter in a coarse-grained light-brown sandstone matrix ____ 25
10. Sandstone, gray to tan, coarse-grained, massive to crossbedded; forms upper part of relatively smooth bare slope and in places a cliff; some gray claystone lenses and pellets; sparse quartzite pebbles near base ____ 50
9. Limestone pellet conglomerate; greenish-brown, weathers dark brown; lenticular; crops out as ragged ledge having very uneven top and bottom; angular to rounded fragments of gray silty dense limestone as much as 3 in. in diameter, but commonly ¼–1 in., embedded in an olive-drab hard tightly cemented medium-grained sandstone matrix; sparse angular to rounded quartzite pebbles and granules; some dense brown fine-grained brittle hard claystone pebbles; unit yielded one poorly preserved clam shell 2 in. long and 1¼ in. from umbo to margin, one small lizard(?) scute, and one tooth of *Leptoceratops* ____ 0–3
8. Sandstone, gray to tan, coarse-grained, massive to crossbedded; forms lower part of relatively smooth bare slope that merges with a cliff; contains sporadic highly rounded quartzite pebbles; lenses of lead-gray soft blocky claystone ____ 47

Offset 1,800 ft north-northwest on base of unit 8 to bare northeast-facing exposure for underlying units.

7. Conglomerate, tan; red and gray quartzite roundstones most abundant, a few as much as 1 ft in diameter; lens of conglomerate near base and between sandstone layers thins from 10 to 2 ft within a horizontal distance of 10 ft, and underlying sandstone thickens from 1 ft where conglomerate is thickest to 5 ft where conglomerate is thinnest; this lowest conglomerate tongue grades into sandstone of underlying unit 6, 25 ft south of line of section; uppermost 5 ft of unit is about half sandstone and half conglomerate ____ 67
6. Sandstone, brown, crossbedded; black grains concentrated along bedding planes; forms smooth bare face ____ 37

Total thickness of measured and computed part of Pinyon Conglomerate ____ 3,774±

Approximate contact between Pinyon Conglomerate and Harebell Formation. Areal relations indicate that this contact is marked by an unconformity, but the underlying Harebell Formation is so badly slumped here that the contact is nowhere exposed. It is put at the top of the covered interval because in this general area the Pinyon Conglomerate is commonly more resistant, is better exposed, and consists almost entirely of conglomerate except for the basal sandstones, whereas the Harebell Formation here contains very few and very thin conglomerates (thick conglomerates appear, however, short distances to the west and southwest). Large slump areas develop characteristically on the soft claystones of the Harebell but there are only a few on the Pinyon. Offset 1,500 ft southeast for underlying beds. Units 1–5 are a lateral equivalent of part of unit 101 in the type section of the Harebell Formation about 3 miles to the northeast.

Harebell Formation (part):

5. Covered interval; probably underlain by soft drab claystone and siltstone and lesser amounts of sandstone ____ 200±
4. Claystone, dark-greenish-gray, hard, blocky; bare of vegetation; sparse but varied mollusk fauna of high- and low-spired gastropods and small ribbed pelecypods; contains fresh-water clams *Eupera* and *Sphaerium;* fresh-water snails *Valvata*?, *Bellamya*, *Reesidella*, *Cleopatra tenuicarinata* (Meek and Hayden), *Micropyrgus*? and *Bulinus*?; and the land snails *Grangerella*? and an indeterminate form (USGS colln. M2889; D. W. Taylor, written commun., Jan. 11, 1967) ____ 4
3. Sandstone, gray, medium- to coarse-grained, hard, ledge-forming, crossbedded; contains abundant black grains; forms bare stripe on upper hillside; strike N. 40° W., dip 20° SW ____ 15
2. Claystone, shale, and sandstone, drab to dark-gray to green, soft; sandstone is thin bedded; between 10 and 20 ft below top is 10 ft of hard blocky silicified green claystone; 25 ft above base of unit is black claystone 6 in. thick, which yielded Late Cretaceous pollen (USGS colln.

	Thickness (feet)
Harebell Formation (part)—Continued	
D3862; E. B. Leopold, written commun., Feb. 2, 1967)	185
1. Sandstone, drab, brown-weathering, hard, limy, fine-grained; base not exposed	4+
Total thickness of measured part of Harebell Formation	408±

Figure 19 shows the stratigraphic and structural relations of the principal reference section of the Pinyon Conglomerate to the type section of the Harebell Formation.

Conglomerate is not the only facies of the Pinyon. There is a thick sandstone facies on and west of Gravel Peak (fig. 1; fig. 33, section *B–B′*), 3 miles southeast of the principal reference section, and a coal member in southeastern Jackson Hole (figs. 13, 20).

Units 6, 8, 9, and 10, whose combined thickness is 137 feet, are the only major sandstones in the basal part of the principal reference section of the Pinyon. In contrast, 3 miles southeast on Gravel Peak, at least the basal 1,000 feet of the Pinyon is largely sandstone resting with an angular unconformity of 90° on the Harebell. The sandstones are tan, massive to crossbedded and medium grained and crop out in bare bulbous ledges 50–100 feet thick. No quartzite pebbles were observed near the unconformity, but there are lenses of blue-gray clay pellets and beds of dark-gray claystone. One claystone, 6 feet thick, in the basal 100 feet of the sequence, yielded small, fragile badly crushed mollusks. All pollen samples from these fine-grained beds were barren.

Lenses and beds of quartzite conglomerate appear higher in the Gravel Peak section; the uppermost 700 feet is chiefly conglomerate, with some beds of light-tan biotitic sandstone ranging in thickness from 10 to 50 feet. The thick basal sandstone facies continues west from Gravel Peak to the valley of Gravel Creek (fig. 1) but intertongues northward very rapidly with conglomerate. The distribution of the sandstone facies here suggests that some of the sand may have come from the Washakie Range to the east.

A coal-bearing sequence locally known as the coal member constitutes the basal part of the Pinyon Conglomerate near the west end of section *D–D′* (figs. 13, 20). This member has been described, and measured sections have been published (Love and others, 1948; Love, Hose, and others, 1951). It is lenticular and is known only from the southeastern part of the mapped area. In most places it is covered by debris from the overlying conglomerate but is well exposed at two localities: that shown in figure 20 and that at section *C–C′* (figs. 1, 21) 2 miles north of Mount Leidy. The thickness of the coal member at the locality of figure 20 is 50 feet, and north of Mount Leidy it is 140 feet. The member is composed of many thin coal beds, black coaly shale, gray to greenish-gray claystone and shale, and thin limonitic beds of sandstone. The chief significance of the coal member, as is discussed later, is that it contains Paleocene fossils. The additional Paleocene fossils known from rocks above the Pinyon Conglomerate definitely establish the age of the conglomerate in the southeastern part of the mapped area (fig. 1).

The coal member disconformably overlies the Harebell Formation at the Dry Dallas Creek locality (figs. 13, 20). North of Mount Leidy, the unconformity is nearly 90° (fig. 21).

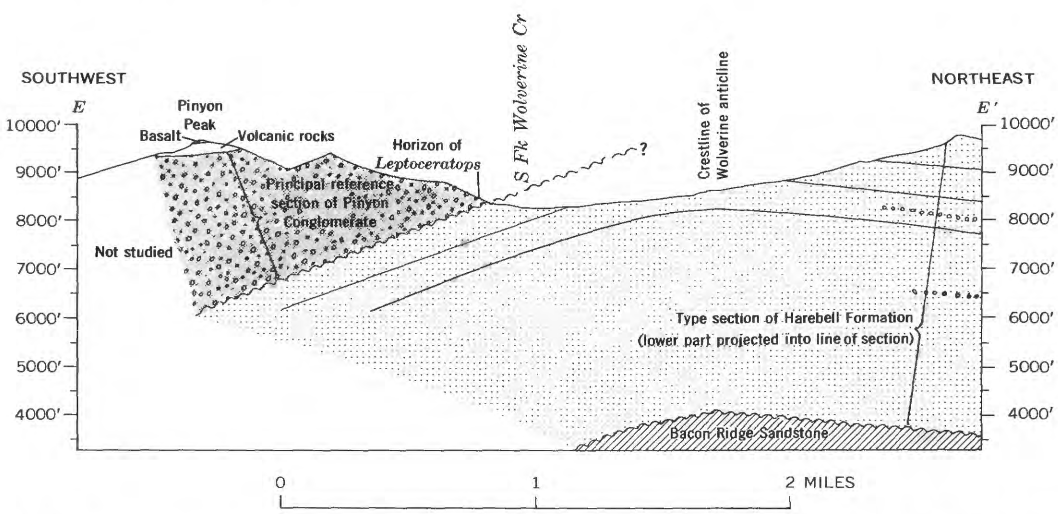


FIGURE 19.—Section *E–E′* through Pinyon Peak, showing relation of principal reference section of Pinyon Conglomerate to type section of the Harebell Formation. *Leptoceratops* horizon in Pinyon Conglomerate is indicated. Circles represent conglomerate.

FIGURE 20.—View northeast at Upper Cretaceous and Paleocene rocks at west end of section *D–D'* (figs. 1, 13), between head of Dry Dallas and Dry Cottonwood Creeks. Stratigraphy of this locality was described by Love, Duncan, Bergquist, and Hose (1948) and Love, Hose, Weitz, Duncan, and Bergquist (1951) and was mapped by Love, Keefer, Duncan, Bergquist, and Hose (1950). Indicated are Pinyon Conglomerate (Tp); coal member of Pinyon Conglomerate, top and base marked by arrows (Tpc); Harebell Formation, top and base marked by arrows (Kh); white sandstone cliff in Mesaverde Formation (Kms); mollusks and *Chara* Zone in Mesaverde Formation (Kmi); leaf bed in Mesaverde Formation (Kml).

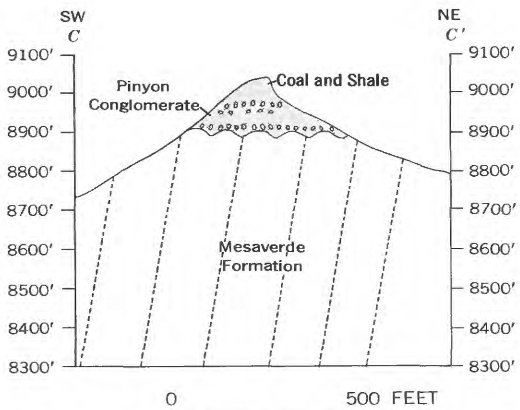


FIGURE 21.—Cross section *C–C'* (fig. 1) showing angular unconformity between intertongued coal and conglomerate facies of Pinyon Conglomerate and Mesaverde Formation 2 miles north of Mount Leidy on west flank of Spread Creek anticline. Dotted lines show dip of beds in Mesaverde Formation.

Roundstones in the Pinyon Conglomerate are almost identical with those described from the Harebell Formation in color, composition, degree of rounding, polish, and abundance of percussion and crush scars. The amount of fracturing is commonly less in the Pinyon (fig. 22; compare with fig. 10), and the sandstone matrix is light tan to rusty brown, whereas in the Harebell it is commonly olive drab and more silty. The size of roundstones in the Pinyon is generally larger than those in the Harebell. An extreme example is in the middle of a 2,000-foot section of the Pinyon at the northwest margin of the Teton Range, west of Survey Peak (fig. 1), where a rounded boulder of white quartzite measuring 54×48×30+ inches (fig. 23) was observed. Another boulder nearby, of quartz-pebble conglomerate, embedded in the Pinyon, measured 62×94×? inches (the base of the boulder could not be uncovered in the time available). A boulder 2 feet in diameter is in unit 18 of the section on Pinyon Peak. No boulders of these dimensions were found in the Harebell

FIGURE 22.—Pinyon Conglomerate in fresh roadcut at top of section, overlying Sohare anticline (cross section *D–D'*, fig. 13). Most roundstones are red, brown, white, purple, and green quartzite, but the black shiny one at center of left margin is chert. Disintegrated boulder above point of hammer is gray granite. Crush scars give roundstones a dappled appearance. Note fracturing of roundstones and amount of sandstone matrix. Compare with closeup photograph of conglomerate in Harebell Formation (fig. 10).

Formation. It should be emphasized, however, that no outcrops of Harebell are known west of the Pilgrim Creek fault (fig. 1), whereas several outcrops of Pinyon, including those having the largest boulders, are preserved west of the fault. In sections about equidistant from the inferred Targhee uplift, most Pinyon boulders are larger.

The Pinyon Conglomerate on the northwest side of the Teton Range rests with a 25° angular unconformity on the Madison Limestone (fig. 24). These relations warrant an expanded discussion because of the evidence they provide concerning the southeast margin of the Targhee uplift. If the strata in this exposure were rotated to their position at the time of deposition of the Pinyon, the Madison would dip 25°–30° E., probably directly off the east flank of the Targhee uplift. The conglomerate (fig. 25) in the position indicated by the arrow in figure 24 contains many angular to rounded fragments of fossiliferous Mississippian limestone, Permian phosphorite and black shale, Triassic red siltstone, and Jurassic oolitic limestone. Muscovite-rich gray granite is fairly common. The softest of these rocks could not have survived intact had they been transported more than a very short distance, perhaps of a mile or two. Therefore, it is inferred that this locality marks the eastern margin of the Targhee uplift where it joins the ancestral Teton fold.

The northernmost exposures of the Pinyon Conglomerate are at and near section 1 (figs. 1, 7), south of Mount Sheridan in Yellowstone National Park (Love and Keefer, 1969). The Pinyon Conglomerate is 450 feet thick at section 1 (fig. 26) and rests with an angular unconformity on the Cloverly and Morrison(?) Formations, undivided. This section is on the Basin Creek uplift, and in the 6 miles between it and section 2, at least 15,000 feet of rocks was eroded away after the end of Harebell deposition and before the beginning of deposition of the Pinyon Conglomerate (fig. 7). In these northermost exposures, where the Pinyon is largely coarse conglomerate, there is a minimum of sandstone matrix; many boulders are 1 foot or more in diameter. As a result of adjacent igneous activity, much of the conglomerate has been drastically altered so that its original features are obscured (Love and Keefer, 1969).

Outcrops of the Pinyon Conglomerate are, in many localities, awesome piles of roughly stratified roundstones that form bare steep slopes and cliffs broken by only a few ledges of lenticular sandstone. On Gravel Mountain (fig. 7, section 8; fig. 27), for example, approximately 1,000 feet of section, virtually all conglomerate, is exposed in a single face. Significant depositional features can be observed in three dimensions on both sides of the mountain in one of the best displayed conglomerate deposits in the country. How much more conglomerate has been eroded from the top of the section cannot be determined.

On the south slopes of Mount Randolph, the Pinyon Conglomerate rests with angular unconformity across the truncated edges of conglomerate in the basal part of the Bobcat Member of the Harebell Formation (fig. 28). Still farther southeast, more and more abundant highly lenticular beds of sandstone appear within the conglomerate. Figure 29 shows some of these in a characteristic exposure 2 miles southeast of section 13 (fig. 1). Two miles still

FIGURE 23.—Quartzite boulder measuring 54×48×30+ inches in Pinyon Conglomerate on Boone Creek Ridge northwest of the Teton Range, 2 miles west of Survey Peak. Note crescent-shaped percussion scars.

farther southeast, in the "Narrows" along the South Fork of Fish Creek, is one of the most spectacular exposures of the Pinyon Conglomerate (fig. 30). It was compared earlier in this report (p. A22) with the section of conglomerate in the Bobcat Member of the Harebell Formation on the East Fork of Pilgrim Creek (fig. 9). The volume of quartzite conglomerate in the Pinyon on the South Fork of Fish Creek is even more impressive when one considers that it all has come a minimum of 60 airline miles from the nearest quartzite source in the Targhee uplift and that the actual stream distance traveled may have been nearly twice that.

The southeasternmost exposures of the Pinyon Conglomerate (fig. 31) are very significant from the standpoints of facies and age. Along the South Fork of Fish Creek, about 6 miles southeast of section 13 (fig. 1) are excellent exposures that show the relation of the Pinyon Conglomerate to younger rocks. This section has been described previously (Love, 1947, sections 13 and 14). From the top of the Pinyon Conglomerate upward, the mappable units consist of an unnamed greenish-gray and brown sandstone and shale sequence that contains Paleocene vertebrate fossils at locality V (fig. 31), a lower variegated sequence containing Paleocene and earliest Eocene vertebrate fossils, a coal-bearing sequence that contains abundant mollusks of earliest and early Eocene age (D. W. Taylor, written commun., 1967), and an upper variegated sequence containing fossil mammals of early Eocene age.

A detailed view of the section at locality X in figure 31 is shown in figure 32. In my original study of this specific section (Love, 1947, section 14), I put the top of the Pinyon at the top of the main mass of conglomerate shown in the lower left corner of the photograph. Rohrer (1969) found that the most convenient mapping horizon is at the top of the highest conglomerate shown in the upper middle part of the photograph. Therefore, on the basis of Rohrer's work, the contact has been moved up to that horizon. This section demonstrates the relation of the various rock types to the contact between the Pinyon Conglomerate and the younger sequence. Significant thicknesses of the other lithologies are below the highest conglomerate. As can be seen in figure 31, the Paleocene vertebrate fossil locality is in strata

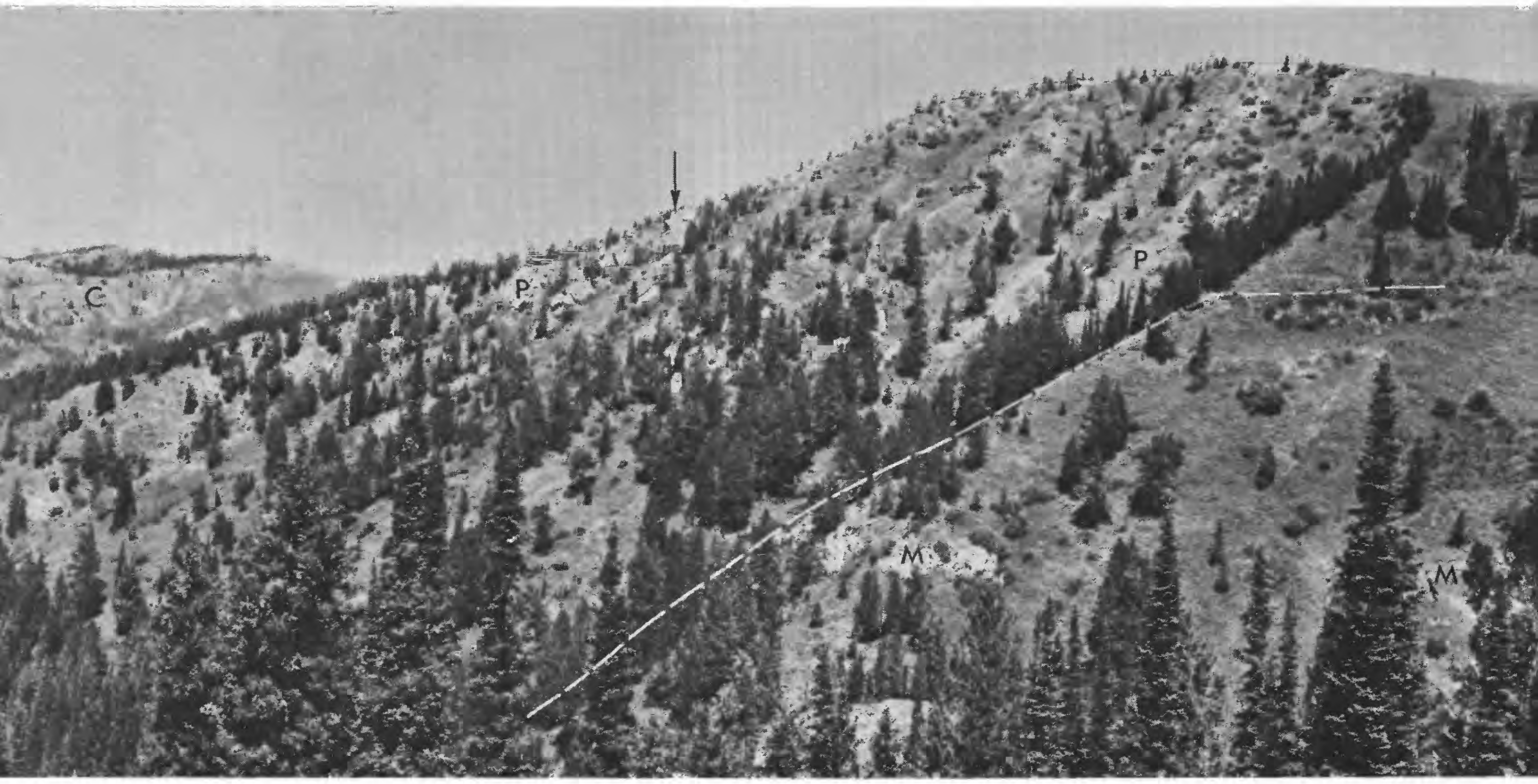


FIGURE 24.—View north showing Pinyon Conglomerate (P) overlapping Madison Limestone (M) on the northwest side of the Teton Range, along the southeast margin of Conant Basin. The Pinyon dips 25° W. (left) and lies with a conspicuous angular unconformity on nearly horizontal light-colored ledges of Madison Limestone. Arrow indicates site of figure 25. Eocene pyroclastic rocks and quartzite conglomerate (C) at upper left dip west at nearly the same angle as the Pinyon.

just above the highest conglomerate. This fossil locality is discussed on p. A45.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

Because the Targhee uplift and the drainage systems that flow east from it were significantly affected by tectonic events during latest Cretaceous and Paleocene times, discussion of these features is deferred until after that of the stratigraphic and structural relations of the Pinyon Conglomerate.

The similarity of quartzite conglomerates in the Harebell to the Pinyon Conglomerate and the fact that they are nearly accordant in the trough of the Box Creek downwarp (in some places conglomerate overlies conglomerate) led to much confusion as to which conglomerates were Harebell and which were Pinyon. Therefore, a special effort was made to study and illustrate localities where the relations are unequivocal and then to extend the data to less clear-cut areas. Doubtless some misinterpretations still remain in figure 1.

Figure 7 shows the regional relations of the Pinyon to the Harebell and also to rocks older than the Harebell. The local relations in the reference and type sections of the Pinyon and Harebell are presented in section *E–E′* (fig. 19). Figure 33 (sections *A–A′* and *B–B′*) shows two localities where the angular unconformity approaches 90°, west of the Buffalo Fork thrust fault (fig. 1). Local relations in the southern part of the area are shown in section *D–D′* (fig. 13). The basal coal member of the Pinyon Conglomerate, which overlies the Mesaverde Formation with an angular unconformity of nearly 90°, 2 miles north of Mount Leidy (fig. 21, section *C–C′*) has been discussed.

These sections, and additional localities where the relatively undeformed Pinyon Conglomerate rests on highly folded and faulted rocks ranging in age from Mississippian to Late Cretaceous, indicate that a major episode of Laramide tectonism occurred after deposition of the Harebell and before deposition of the Pinyon Conglomerate. During this relatively short span of time, two major structural features rose and were denuded of 15,000–20,000 feet of strata. The Washakie Range rose and was thrust westward, along the Buffalo Fork thrust fault (figs.

FIGURE 25.—Part of an exposure of Pinyon Conglomerate nearly 2,000 feet thick along the northwest margin of the Teton Range 3 miles southwest of Survey Peak. Many roundstones are of Paleozoic and Mesozoic soft strata, but Precambrian quartzite from the Targhee uplift predominates.

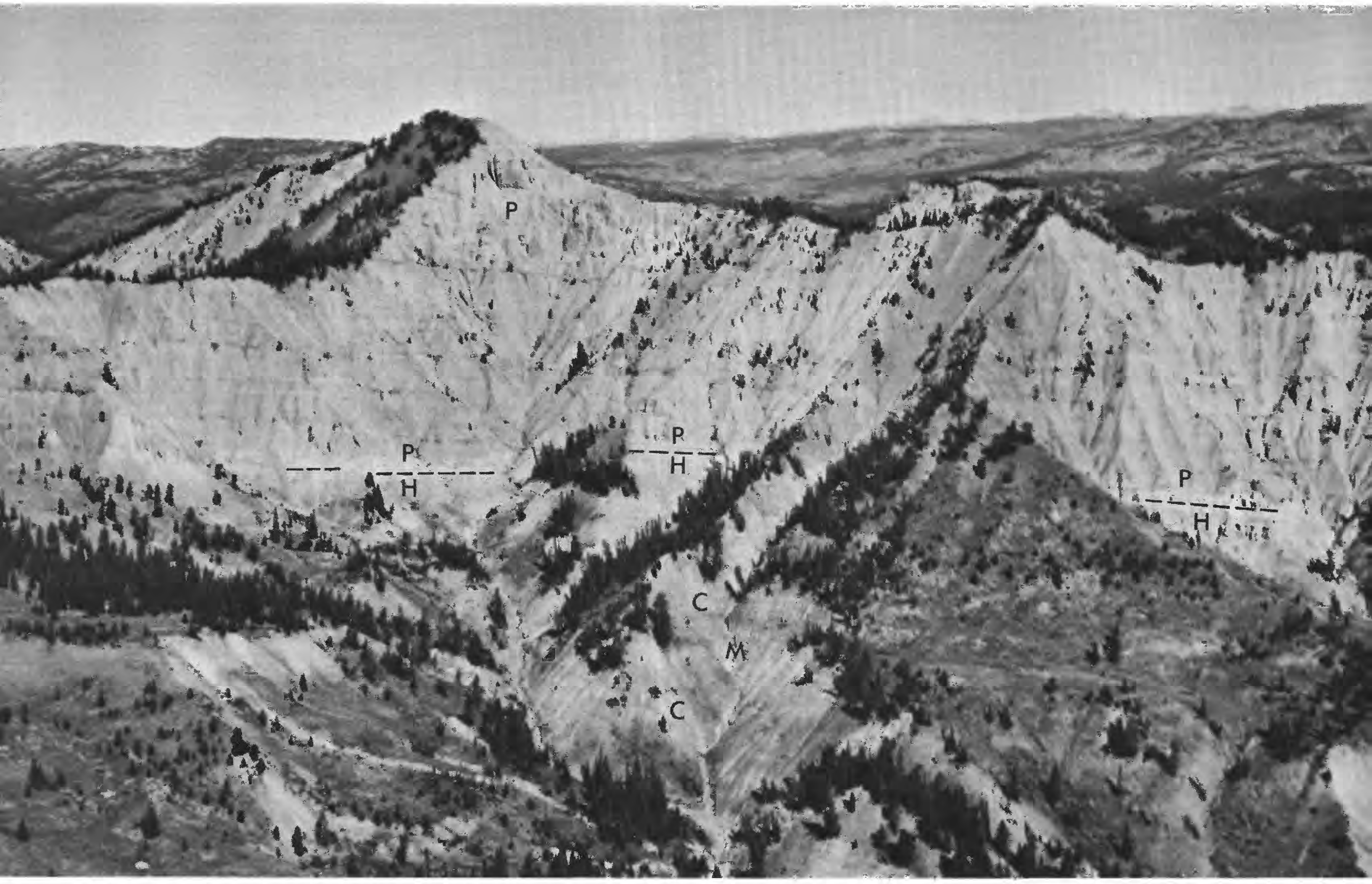


FIGURE 27.—Oblique aerial view of southwest face of Gravel Mountain at stratigraphic section 8. Indicated are about 1,000 feet of Pinyon Conglomerate (P); Harebell Formation (H), containing several quartzite conglomerate beds (C) nearly 100 feet thick; and several claystones, one of which yielded Cretaceous marine or brackish-water acritarchs (M). Photograph by P. E. Millward.

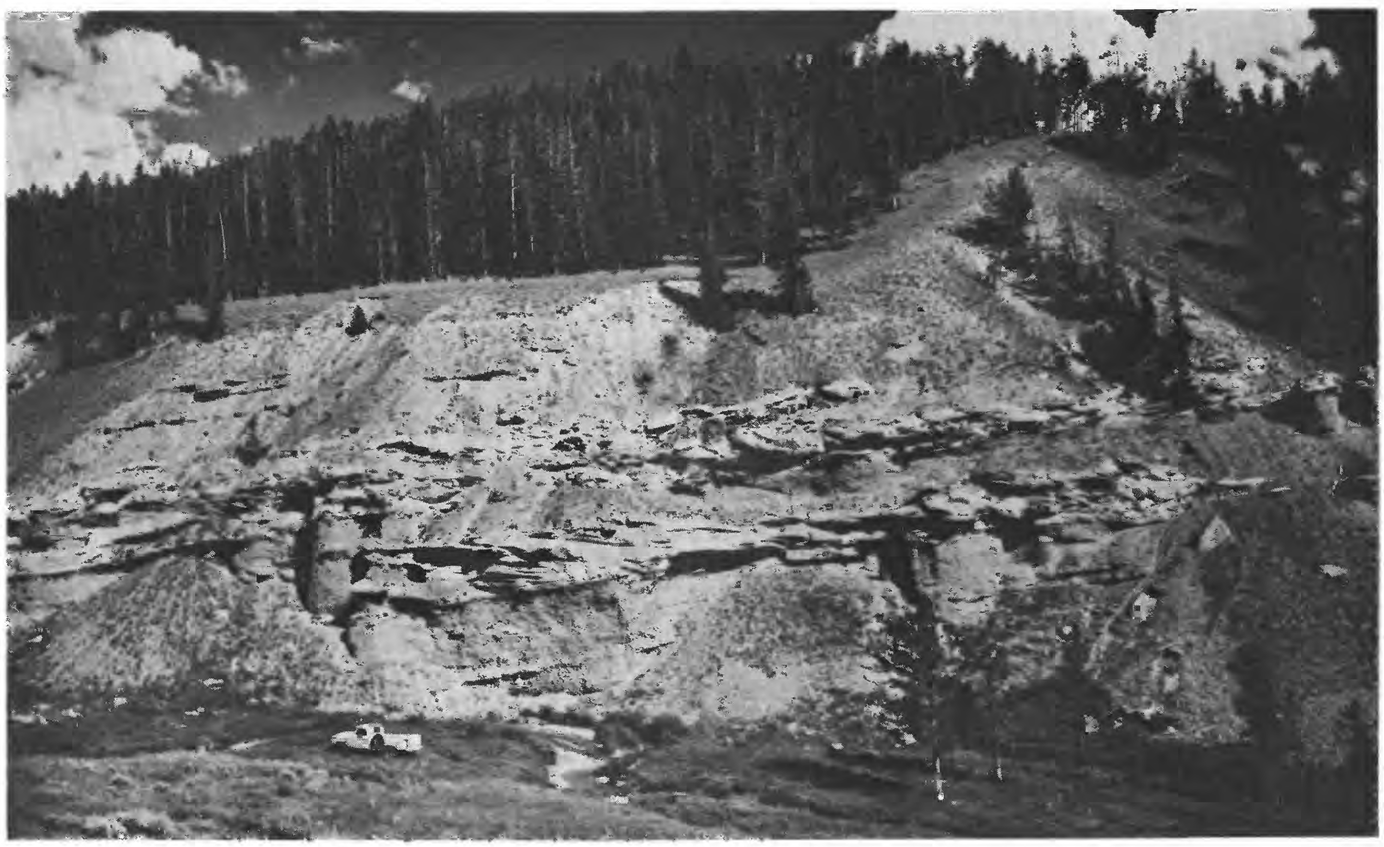
1; 33, section *B–B′*; 34), over the Harebell Formation and was eroded, probably to the Paleozoic rocks. The Basin Creek uplift (figs 2; 7, section 1) rose and was eroded at least to Lower Cretaceous and Jurassic(?) rocks (fig. 26) and probably to older strata. Lesser anticlines, such as Spread Creek and Red Hills (fig. 1), were folded, thrust southwest, and eroded to Cretaceous and Triassic rocks, respectively.

Figure 34 shows in cross section the relations of the Pinyon Conglomerate to older rocks across the deep part of the Box Creek downwarp. Figure 35 is a reconstructed geologic map showing exposed rocks that flanked major uplifts and downwarps at the beginning of deposition of the Pinyon Conglomerate.

In areas where younger Paleocene rocks overlie the Pinyon Conglomerate (figs. 30, 31), the contact between them is marked only by the cessation of deposition of conglomerate. No physical break has been demonstrated. Inasmuch as the Pinyon Conglomerate has never been severely deformed in Jackson Hole, it is concluded that the major compressional episode of the Laramide Revolution in this area ended in latest Cretaceous time before deposition of the conglomerate. Later movements did, of course, occur. The nearly vertical Tripod fault (fig. 1; Love, 1947) on the east side of Jackson Hole is thought to have been active in early Eocene time. The mountains of the Gros Ventre Range were ris-

◀ FIGURE 26.—Contact (indicated by line) between highly silicified Pinyon Conglomerate and Cloverly and Morrison(?) Formations undivided; Mount Sheridan measured section 1.


P
G
H
H
H
H
H



◀ FIGURE 28.—View north toward Mount Randolph showing an angular unconformity between the Harebell Formation and Pinyon Conglomerate. Indicated are sparsely vegetated conglomerates in the Bobcat Member of the Harebell (H) which dip about 15° to right, overlain by nearly horizontal Pinyon Conglomerate (P); in the distance is Gravel Mountain (G), the visible part of which is composed of Pinyon Conglomerate.

ing during the early Eocene but did not reach their present proportions until later.

AGE AND CORRELATION

The presence of a tooth of *Leptoceratops*, a small hornless dinosaur of latest Cretaceous age, 150 feet above the base of the Pinyon Conglomerate in the principal reference section (unit 9), necessitated a revision of the age of this part of the formation (McKenna and Love, 1970). The interpretations considered were that (1) the strata are post-Cretaceous in age but the dinosaur tooth was redeposited from older rocks, (2) the tooth represents a dinosaur that survived from Cretaceous into Paleocene time, and (3) the specimen indicates Cretaceous age for the enclosing strata. It was concluded that the lower part of the Pinyon Conglomerate at this locality is of Cretaceous age.

Although no fine-grained beds were observed in the upper part of the principal reference section, pollen samples were collected from matrix of the conglomerate in units 20 and 31. They were barren.

Thirty miles to the south-southeast, a gray claystone in the coal member at the locality shown in figure 20 (Love and others, 1948, p. 12, unit 387; also fig. 13, section *D–D′*) yielded the fresh-water clams *Sphaerium* and *Eupera*; fresh-water snails *Valvata bicinta* Whiteaves, *Viviparus meeki* Wenz, *Paleancyclus radiatus* Yen, Physidae?; and the land snails *Pseudocolumna* and *Oreohelix (Radiocentrum)* (D. W. Taylor, written commun., 1960). Taylor considered these to be of Paleocene age. This mollusk-bearing unit yielded the following pollen and spores of early Paleocene age (E. B. Leopold, written commun., 1960; USGS Paleobot. loc. D1513):

Abietinaepollenites cf. *A. dunrobinensis* Couper
Deltoidospora hallii Miner
Laevigatosporites haarti Potonié & Venitz
Cyathidites australis Couper
Ulmoideipites tricostatus Anderson
Momipites tenuipolus Anderson
Classopollis torosus Reiss
Alnipollenites versus Potonié (P_5 type)
Cicatricosisporites dorogensis Potonié & Gelletich
Densoisporites perinatus Couper
Liliacidites hyalaciniatus Anderson

A sample collected by D. A. Lindsey from one of the coal beds below the gray claystone (USGS Paleobot. loc. D4281), shown in figure 20, likewise yielded excellent palynomorphs of Paleocene age. An early Paleocene age for the assemblage is probable, according to R. H. Tschudy (written commun., 1969), because of the absence of *Carya* and other late Paleocene species.

M. C. McKenna collected vertebrate fossils of probable late Paleocene (early Tiffanian of Wood and others, 1941) age from the greenish-gray and brown sandstone, shale, and claystone sequence overlying the Pinyon Conglomerate (fig. 31). He (written commun., 1965) graciously provided the following list of identified forms: *Prochetodon cavus*, *P.* n. sp., *Ptilodus wyomingensis*, *Plesiadapis* sp., *Bessoecetor* sp. cf. *B. thomsoni*, hyopsodont cf. *Promioclaenus*, and hyopsodont cf. *Protoselene*.

The conglomerate, therefore, lies between beds that contain fossils of probable late Paleocene age and the coal member that yielded early Paleocene fossils.

Eight miles southwest of the principal reference section of the Pinyon Conglomerate, unfortunately in an area surrounded by landslides (fig. 6), three pollen samples were obtained from a 50-foot section of dark-gray hard sandstone, siltstone, and carbonaceous shale, the lithology of which is not typical of either Pinyon or Harebell. On the basis of regional relations, the pollen horizons are interpreted to be about 1,000 feet above the base of the Pinyon. Concerning these poorly preserved palynomorphs (USGS colln. D4106–A–C), R. H. Tschudy (written commun., Jan. 17, 1968) stated:

> None of these samples yielded identifiable characteristic Late Cretaceous palynomorphs. The specimens found were either long ranging or known only from the Paleocene. If these samples represent the Paleocene, as I think they do, then the part represented must be low in the Paleocene sequence.

In the framework of regional correlation, the Paleocene part of the Pinyon Conglomerate is almost certainly a time equivalent of the Fort Union Formation in the Wind River basin (Keefer, 1965), although little or no physical connection is apparent between the two deposits. The part of the Hoback Formation above the conglomerate marker beds in the area south of the Gros Ventre Range (Dorr,

◀ FIGURE 29.—Intertongued sandstone and quartzite conglomerate in Pinyon Conglomerate on east side of Purdy Creek 2 miles southeast of stratigraphic section 13. Note man above and to right of truck for scale.

1958) is likewise a partial time equivalent of the Pinyon, but the only physical connection between the deposits was probably along the extreme northeast margin of the Green River Basin at about lat 43° N., long 110° W. (figs. 2, 36). On outcrop at that locality the southernmost occurrence of Pinyon Con-

FIGURE 30.—View northeast across the "Narrows" along the South Fork of Fish Creek, 4 miles southeast of stratigraphic section 13, where about 1,000 feet of Pinyon Conglomerate that contains minor amounts of sandstone and claystone is exposed. Car roof at bottom and man (in circle) at lower left beside dead trees indicate scale.

FIGURE 31.—Oblique aerial view northeast across South Fork of Fish Creek (in foreground) showing Tertiary mappable units described by Love (1947). Indicated are Devils Basin Creek (DB); site of middle Paleocene vertebrate fossils, leaves, and mollusks (V; listed in Love, 1947, section 14); Pinyon Conglomerate (TKp); green and gray sandstone and shale sequence (Ts); stratigraphic section shown in figure 32 (X); USGS Paleocene leaf and mollusk locality L66–87 (L); lower variegated sequence containing Paleocene and earliest Eocene vertebrate fossils (Tlv); coal sequence (C); upper variegated sequence containing early Eocene vertebrate fossils (Tuv); Wiggins Formation in Absaroka Range (Twi). Photograph by R. C. Casebeer.

glomerate has a pebble size noticeably smaller than that on the South Fork of Fish Creek to the north. Imbrication shows that streamflow was from north to south. In an adjacent more complete subsurface section (Gulf Oil Corp., New Fork 1, sec. 5, T. 36 N., R. 110 W.), quartzite pebble conglomerates intertongue with gray sandstone, claystone, and thin coal beds. This section has a total thickness of about 500 feet, of which 350 feet is conglomerate.

FIGURE 32.—View north across South Fork of Fish Creek at mouth of Devils Basin Creek, showing exposure at X, figure 31. Green and gray sandstone and claystone is interbedded with conglomerate in upper part of Pinyon Conglomerate (TKp). What appears to be an angular unconformity at lower right is partly the result of perspective and partly of deposition of conglomerate in a channel cut across the underlying sandstone and claystone. The green and gray sandstone and claystone sequence (Ts) has the same sandstone and claystone lithology as that within the Pinyon and contains middle Paleocene vertebrate fossils 1,500 feet to the right of the area of the photograph. (See fig. 31, loc. V.) More than 600 feet of section is visible.

GOLD OCCURRENCES

Gold is present in small amounts in most parts of the Pinyon Conglomerate and is somewhat more abundant in the southeastern and northwestern areas of outcrop. Most of it is believed to have come from the Targhee uplift. Of special interest is the high silver content of the gold in the Pinyon Conglomerate as contrasted with the low silver content in gold from the Harebell Formation (Antweiler and Sutton, 1970).

The volume of Pinyon Conglomerate still present in Jackson Hole is estimated to be about 35 cu mi (table 2). Preliminary data on gold in the Pinyon are given in a summary of investigations made by J. D. Love and J. C. Antweiler (in U.S. Geol. Survey, 1966, p. A4–A5) and in reports by Antweiler and Love (1967) and Antweiler and Sutton (1970). In summary, the first 665 samples, chiefly from south of the Buffalo Fork, averaged 84 ppb gold and had a maximum of 8,700 ppb.

INFLUENCE OF TARGHEE, WASHAKIE, AND BASIN CREEK UPLIFTS ON PINYON SEDIMENTATION

The latest Cretaceous and Paleocene history of the Targhee uplift was reconstructed by Love and Reed (1968, fig. 46). Key data used in this reconstruction are the overlap of the Pinyon Conglomerate onto the Madison Limestone near the junction of the Targhee uplift with the core of the ancestral Teton–Gros Ventre uplift (fig. 24), the size and composition of the boulders (figs. 23, 25) on outcrops along the northwest side of the Teton Range, the nature and volume of the Pinyon Conglomerate in Jackson Hole, and the overlap of unfolded Pinyon Conglomerate across sharp old folds such as the Red Hills anticline in southeastern Jackson Hole (fig. 1). Figure 36 of the present report incorporates additional details.

The original volume of Pinyon Conglomerate and its lateral equivalents deposited east of the Targhee uplift within the area of figure 36 is estimated to have been about 3,400 cu mi (table 2). This figure does not include Paleocene rocks in the Wind River basin, which were separated from Jackson Hole by a rising arch between the Wind River and Washakie Ranges. Also not included is the tremendous volume of Paleocene clastic debris in the northern part of the Green River Basin because most of the debris in

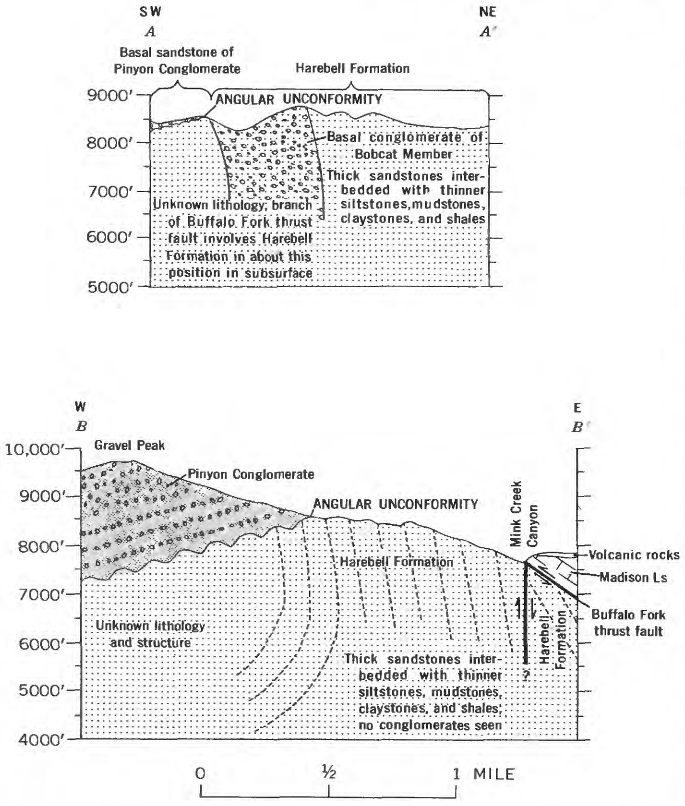


FIGURE 33.—Cross sections showing relation of Pinyon Conglomerate to Harebell Formation. Lines of section are shown on geologic map (fig. 1). Section *A–A'* is at north end of Gravel Ridge; *B–B'* is from Gravel Peak to Mink Creek. Circles represent conglomerate.

that area was derived from a western source south of the Targhee uplift.

The question arises as to where the hundreds of cubic miles of sediment stripped from the rising uplifts (such as the Washakie) in and adjacent to Jackson Hole was redeposited. Very little of this debris remained in Jackson Hole; otherwise, the Pinyon would include abundant locally derived clasts. The three areas where the debris probably went are the Bighorn, Wind River (before its connection with Jackson Hole was blocked), and Green River Basins. The fact that little debris remained in Jackson Hole indicates something of the magnitude of the rise of the Targhee uplift during Paleocene time and the power of the rivers originating in it that extended across Jackson Hole. Sedimentary features indicate that at least one river flowed east-northeastward into the Box Creek downwarp (Lindsey, 1970), then turned southward around the southeast end of the ancestral Gros Ventre uplift and entered the northeast margin of the Green River Basin (fig. 36). Another flowed eastward into the Bighorn Basin.

The original volume of quartzite conglomerate deposited in the Pinyon of Jackson Hole is estimated to have been about 425 cu mi (table 2), and this figure is used in reconstructing the size and the amounts of rise and erosion of the Targhee uplift during this interval of deposition.

While the Harebell Formation was being deposited, the area of the Precambrian core of the Targhee uplift was estimated to have been about 1,000 sq mi. Almost certainly it was somewhat larger during Pinyon deposition. For the estimated 425 cu mi of quartzite debris to have been originally deposited in the Pinyon Conglomerate of Jackson Hole (table 2) would have required removal of a 2,000-foot-thick layer of rock from 1,000 sq mi of the up-

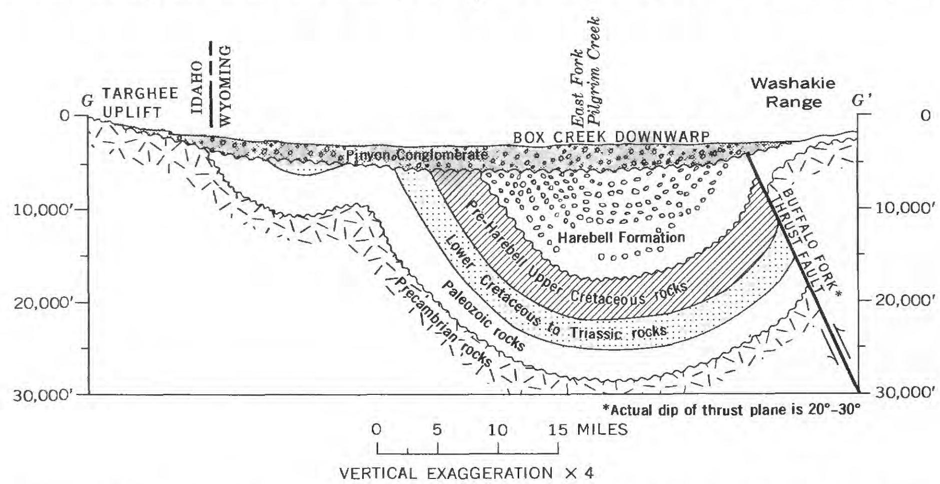


FIGURE 34.—Restored section from the Targhee uplift to the Washakie Range showing relation of Pinyon Conglomerate to older rocks during the latter part of Paleocene time. Circles indicate major zones of conglomerate. Line of section is shown in figure 35.

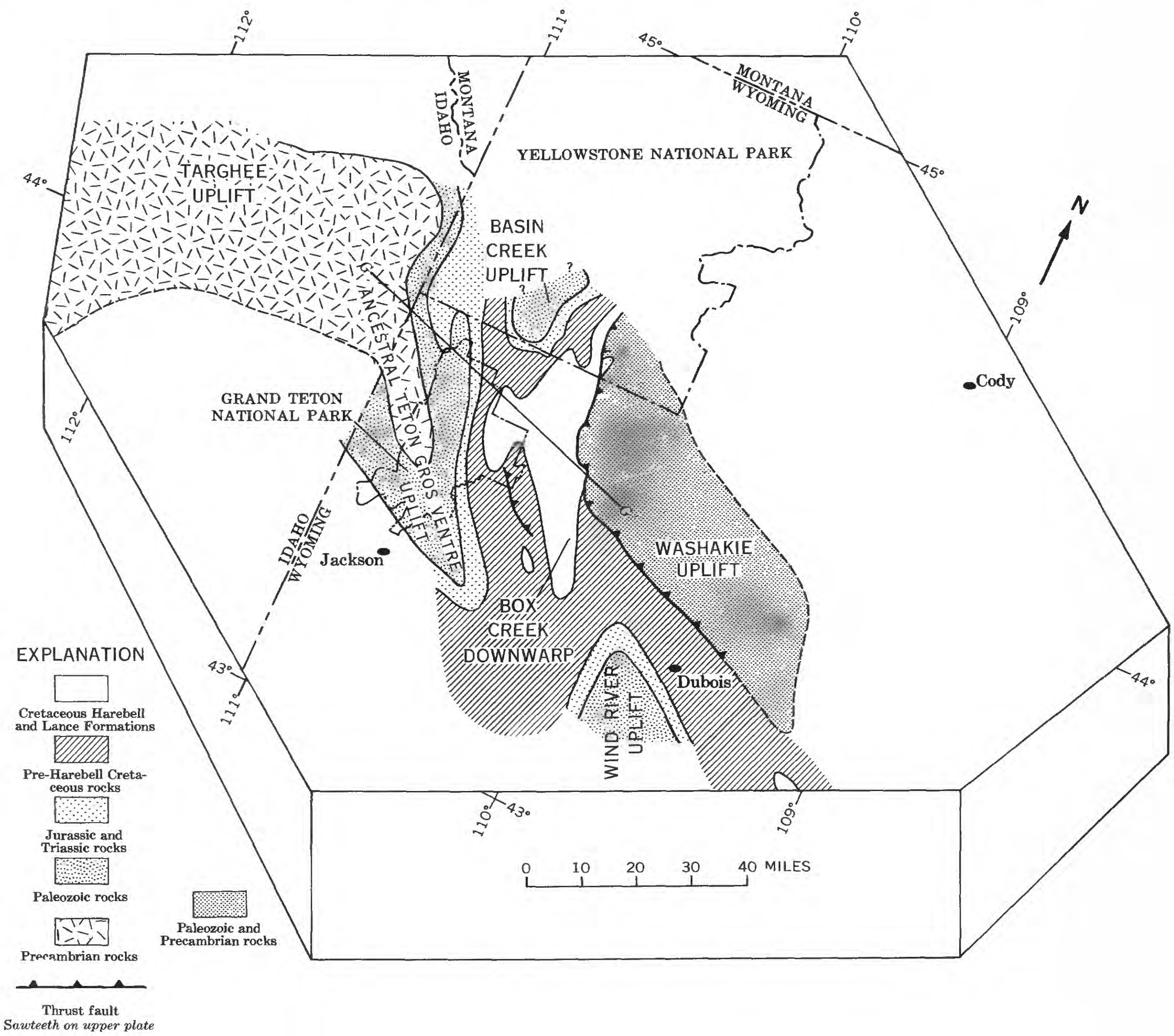


FIGURE 35.—Northwestern Wyoming and adjacent areas at beginning of deposition of Pinyon Conglomerate.

lift. As was described in connection with the Harebell, during Pinyon deposition probably an equal or greater amount of sand- and silt-size debris was derived from the same area at the same time as the conglomerate.

The chief difference in relations of the Targhee uplift to the Box Creek downwarp (and the area of Jackson Hole in general) at the times of deposition of the Harebell Formation and the Pinyon Conglomerate is that during deposition of the Harebell the Box Creek downwarp sank at least 11,000 feet, whereas during Pinyon deposition there is no evidence that it sank more than about 4,000 feet. Thus, the deposition of a layer 2,000–4,000 feet thick of rock from the Targhee uplift, with the boulder size increasing (rather than decreasing) as sedimentation continued, suggests that the Targhee uplift rose considerably more in Pinyon time than in Harebell, and also that it continued to rise throughout deposition of the Pinyon Conglomerate.

Several remnants of quartzite conglomerate extend south along the present crest of the Teton Range as far as Red Mountain (fig. 1; not shown on geologic map because they are too small). The one on Red Mountain was discovered by Blackwelder (1915, p. 201), who considered the possibility that it might be Pinyon Conglomerate. Later workers (Edmund, 1951, p. 58; Horberg and others, 1955, p. 508) thought the quartzite boulders were of glacial origin. A projection of the dips and strike of the Pinyon

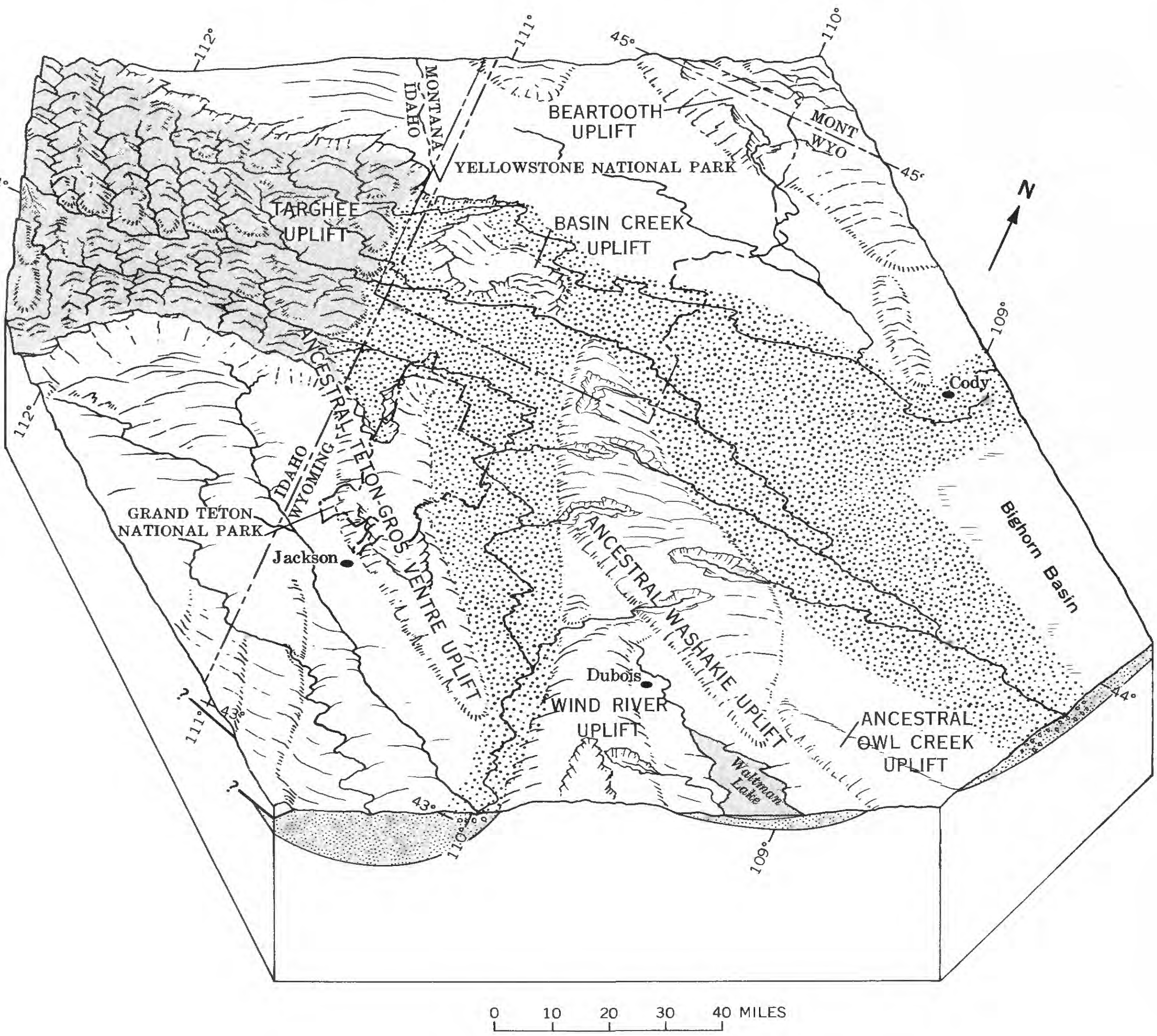


FIGURE 36.—Northwestern Wyoming and adjacent areas during deposition of Pinyon Conglomerate. Quartzite conglomerate facies derived from Targhee uplift is shown by dots. All Paleocene rocks are patterned on edges of block. Circles indicate conglomerate. Gray area is postulated Precambrian core of uplift. Vertical exaggeration on near edge of block × 4. Cretaceous thrust faults on lower left margin of block are not shown.

outcrops shown in figures 24 and 25 indicates that remnants of Pinyon Conglomerate could be expected in the observed locations. Blackwelder noted that the boulders retained the characteristic polish of those in the Pinyon Conglomerate. Edmund (1951) noticed glacial striae on them, but I did not observe any. The striae might have been cut by slight shifting of a nearly static icecap. However, Red Mountain is above the general level of Pleistocene ice in the northern Tetons. In adjacent places where the quartzite boulders have been moved by ice, the boulders quickly lost their polish. Furthermore, as ice tends to flow downhill, and Red Mountain is one of the highest points (about 10,200 ft) in the area, a higher source for the boulders in Pleistocene time would be hard to find. Therefore, Blackwelder's interpretation that these boulders are remnants of Pinyon Conglomerate is considered to be correct.

These various bits of evidence indicate that the Pinyon Conglomerate lapped well up onto the Paleozoic core of the ancestral Teton uplift. The Targhee uplift to the west must have been considerably higher in order for this debris to have moved downhill to its present positions. The altitude of remnants on Red Mountain is above 10,000 feet, yet the Snake River downwarp directly to the west is about 5,500 feet; this indicates how much the original topographic relations of the two areas have been reversed by later movements.

FIGURE 37.—Fossil log 39 inches in diameter embedded in Pinyon Conglomerate about 500 feet above base, 300 feet southeast of Placid Oil Co. Govt. 1 oil test, sec. 14, T. 42 N., R. 112 W.

The paucity of sandstone and finer grained strata in the Pinyon Conglomerate throughout most of the Jackson Hole area, except near Gravel Peak on the east side (fig. 33, section *B–B′*) and in southeastern Jackson Hole (figs. 29, 32), suggests that stream gradients were high and volumes of water large all the way from the Targhee uplift to the Green River and Bighorn Basins.

As mentioned earlier, between the time of deposition of the Harebell Formation and Pinyon Conglomerate, the Washakie Range rose and was denuded of 15,000–20,000 feet of strata and the Basin Creek uplift lost about 15,000 feet (figs. 7, 36). Except in the Gravel Peak area, where at least 1,000 feet of sandstone may have been locally derived in part from the Washakie Range, nearly all the debris from these two uplifts was carried out of the area, and, therefore, had little effect on the composition of the Pinyon Conglomerate. Similarly, the ancestral Teton–Gros Ventre uplift, on the north flank of which is the Red Hills anticline (fig. 1) that is known to have been stripped to the Lower Cretaceous before Pinyon deposition, apparently supplied only an inconspicuous amount of debris to the conglomerate.

INTERPRETATION OF DEPOSITIONAL ENVIRONMENT

The coal member of the Pinyon Conglomerate indicates that for a brief interval in early Paleocene time some nonconglomeratic Paleocene strata were deposited in very localized coal swamps. No evidence has yet been found of a marine or brackish-water environment. During the remainder of the time represented by Pinyon deposition, the environment was one in which layer after layer of quartzite gravel was deposited (fig. 27) by rivers so powerful that most fine-grained sediment was carried out of the area. Despite the harshness of this terrain, it was not entirely devoid of life. Tree stumps, one of which is 39 inches in diameter, occur about 500 feet above the base of the conglomerate in the Dry Cottonwood Creek locality (figs. 37; 13, section *D–D′*); and, in the same area and part of the section, small fragile land snails (*Grangerella* cf. *G. phenacodorum*, and other types; D. W. Tayor, written commun., 1963) are present in claystone lenses within the conglomerate. The fossils both below and above the conglomerate suggest a warm humid climate and abundant water.

Tuffaceous debris is conspicuously sparse in the fine-grained strata interbedded with the Pinyon Conglomerate, in contrast to abundant tuff in the Harebell. Apparently the volcanism to the north that produced the tuffs in Late Cretaceous time was no longer sufficiently active to have much effect on the composition of the Pinyon.

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