Names and Descriptions of New and Reclassified Formations in Northwestern Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 932-C

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

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Names and Descriptions of New and Reclassified Formations in Northwestern Wyoming

By J. D. LOVE

GEOLOGY OF THE TETON-JACKSON HOLE REGION, NORTHWESTERN WYOMING

GEOLOGICAL SURVEY PROFESSIONAL PAPER 932-C

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

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NAMES AND DESCRIPTIONS OF NEW AND RECLASSIFIED FORMATIONS IN NORTHWESTERN WYOMING[1]

By J. D. Love

ABSTRACT

Three new formations in northwestern Wyoming, Sohare (Late Cretaceous), Devils Basin (Paleocene), and Shooting Iron (Pliocene) are named, defined, and described. The name, Bivouac Formation (late Miocene), is abandoned, and the rock sequences that were included in the original Bivouac are discussed individually. They include, from the oldest to youngest: unnamed gravel (late Miocene), Conant Creek Tuff (early Pliocene), deposits of glaciation 1 (Pliocene), and Huckleberry Ridge Tuff (Pliocene).

The Sohare Formation consists of 3,000–5,000 ft of largely or entirely nonmarine olive-drab sandstone, shale, and thin beds of coal. The Devils Basin Formation consists of 600–1,600 ft of nonmarine gray sandstone, green and gray shale and claystone, and thin beds of coal. The Shooting Iron Formation is a brown, green, and pink lacustrine and fluviatile soft tuffaceous claystone, sandstone, and conglomerate sequence as much as 300 ft thick. All three of these newly named formations are moderately fossiliferous.

INTRODUCTION

During the process of compilation of the geologic maps of about thirty 7½-minute quadrangles in northwestern Wyoming, the Grand Teton National Park geologic map, the geologic map of the Driggs 1° × 2° quadrangle, and the newest version of the Wyoming geologic map (Love and Christiansen, 1985), it became apparent that new names should be introduced for several Cretaceous and Tertiary rock units and that individual components of one previously named formation should be reclassified. These rock units have been mapped, measured, and described during the interval from 1945 through 1982, so their validity, distribution, facies, and fossils are moderately well known. Their names and locations of type sections and supplementary sections are shown in figure 1.

ACKNOWLEDGMENTS

The stratigraphic work on the formations described here was launched in the 1940's, with the able assistance of H. R. Bergquist, R. K. Hose, J. L. Weitz, and D. C. Duncan. For more than 25 years, M. C. McKenna and his colleagues, by making slow, difficult, and careful vertebrate fossil collections, have contributed greatly to the understanding of the lower Tertiary rocks. W. L. Rohrer mapped the Sheridan Pass quadrangle and worked out some of the lateral facies changes in the Eocene and Paleocene strata. D. W. Taylor collected invertebrate fossils from several localities and provided identifications and correlations of faunal units. A. D. Barnosky collected and studied vertebrate fossils in the Shooting Iron Formation. J. C. Antweiler, in connection with gold studies of the Cretaceous and Tertiary rocks in Jackson Hole, was most helpful with many facets of field logistics and rock compositions. R. C. Casebeer of the U.S. Forest Service made available several magnificent air-oblique photographs of the southeastern Jackson Hole region. This paper has been greatly improved by a thorough review by Ann Coe Christiansen.

SOHARE FORMATION

NAME AND DEFINITION

The Sohare Formation is here named after Sohare Creek, a stream that drains the area about 2 mi north of the north end of the type section. In earlier publications on this region (Love, Duncan, and others, 1948; Love, Hose, and others, 1951; Love, Keefer, and others, 1951; Love, Weitz, and Hose, 1955; Love 1956c), the Sohare Formation was described as the "lenticular sandstone and shale sequence," underlain by the "coaly sequence." No formal names were assigned to these rocks because their regional mappability and their relations to older and younger rocks were not known. It has now been determined that the "coaly sequence" is only locally mappable and intertongues with the overlying strata. Hence, both units are here included in the Sohare Formation. Figure 2 shows the locality of the type section. It is in the northeastern part of the Upper Slide Lake 7½-minute topographic quadrangle.

[1]Submitted for publication in 1983 so that names could be used on Wyoming geologic map (Love and Christiansen (1985).

EXPLANATION

TERTIARY	Pliocene	Tsi	Shooting Iron Formation
	Paleocene	Tdb	Devils Basin Formation
CRETACEOUS	Upper Cretaceous	Ks	Sohare Formation
		Kb	Bacon Ridge Sandstone
			Sohare and Bacon Ridge Formations

● Type section or type locality

○3 Supplementary section

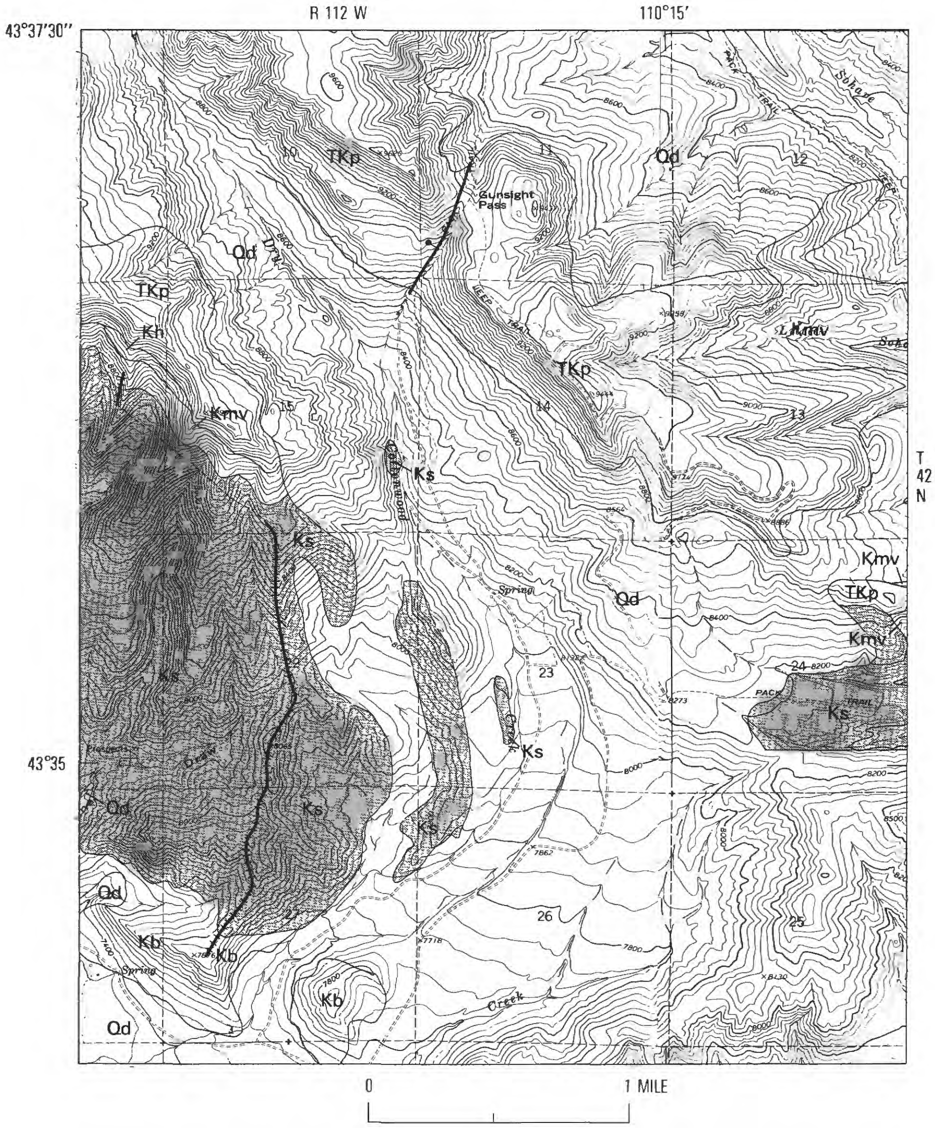
Locality designations:

Tbi	Bivouac Formation (abandoned)
Tsi	Shooting Iron Formation
Tdb	Devils Basin Formation
Ks	Sohare Formation
Kb	Bacon Ridge Sandstone

Contact

Faults—Dotted where inferred. Dashed where concealed. Sawteeth on upper plate of thrust. Bar and ball on downthrown block of normal fault

FIGURE 1.—Geologic map of northwestern Wyoming showing the locations of sections described in this report (modified from Love and Christiansen, 1985). Base from U.S. Geological Survey Wyoming topographic map, 1964–80, scale 1:500,000.



EXPLANATION

QUATERNARY		Qd	**Quaternary deposits**
TERTIARY	Paleocene	TKp	**Pinyon Conglomerate**
CRETACEOUS	Upper Cretaceous	Kh	**Harebell Formation**
		Kmv	**Mesaverde Formation**
		Ks	**Sohare Formation**
		Kb	**Bacon Ridge Sandstone**

Contact

Fault—Dotted where concealed. Bar and ball on downthrown side

Measured section—Dotted line connects offset part of section

FIGURE 2.—Line of traverse of measured type section of Sohare Formation. Geology from Love, Keefer, and others (1951) and mapping by J. D. Love in 1980–82. Base from U.S. Geological Survey Upper Slide Lake and Burnt Mountain 7½-minute topographic maps, 1965, scales 1:24,000.

DISTRIBUTION AND THICKNESS

The Sohare Formation is exposed in broad outcrops along the east side of Jackson Hole and is present on both flanks of the Gros Ventre Range to the south. Thicknesses vary from about 5,000 ft south of the Gros Ventre Range to an eroded edge just south of Yellowstone National Park. The type section in round numbers is about 3,200 ft thick; other thicknesses of measured sections are shown graphically on a chart (Love, Hose, and others, 1951).

LITHOLOGY

A detailed description of the lithology of the Sohare Formation is given in the type section. Figure 3 shows it in graphic form. The lithology of other sections in this general region has been presented elsewhere (Love, Hose, and others, 1951).

The Sohare Formation is largely, and perhaps entirely in some places, nonmarine. The upper 2,000 ft of the upper part of the sequence weathers to monotonous gray slopes (fig. 4) broken by irregular cliffs of sandstone. The sequence is characterized by thick channel deposits of sandstone as much as 50–100 ft thick that form gray and tan cliffs, but the sandstones lense out laterally in distances of a few hundred feet. These sandstones are separated by soft, gray shale, siltstone, and silty sandstone. A few beds of coal are present. Coals are much more numerous in the lower 900 ft and are especially abundant in the basal 500 ft. The continuity of the coal has not been established from one section to another. Several beds were mined in the early 1900's.

Associated with gray carbonaceous shales are numerous marlstone beds and concretions which are gray on fresh surfaces but bright ocher colored on weathered surfaces. Many of these marlstones contain abundant and well-preserved leaves. The coal member forms comparatively barren rounded hills with a banded appearance along broad outcrops between the Gros Ventre River and Mount Leidy (fig. 1).

TYPE SECTION

The type section of the Sohare Formation is adapted from a part of the published Dry Cottonwood Creek section (Love, Duncan, and others, 1948) and the graphic section (fig. 3) from Love, Hose, and others (1951, fig. 3), which also contains lists and horizons of identified fossils (table 1). It was measured by J. D. Love, D. C. Duncan, R. K. Hose, and H. R. Bergquist in August and September 1947. Major intervals were measured with plane table and alidade and smaller intervals with steel

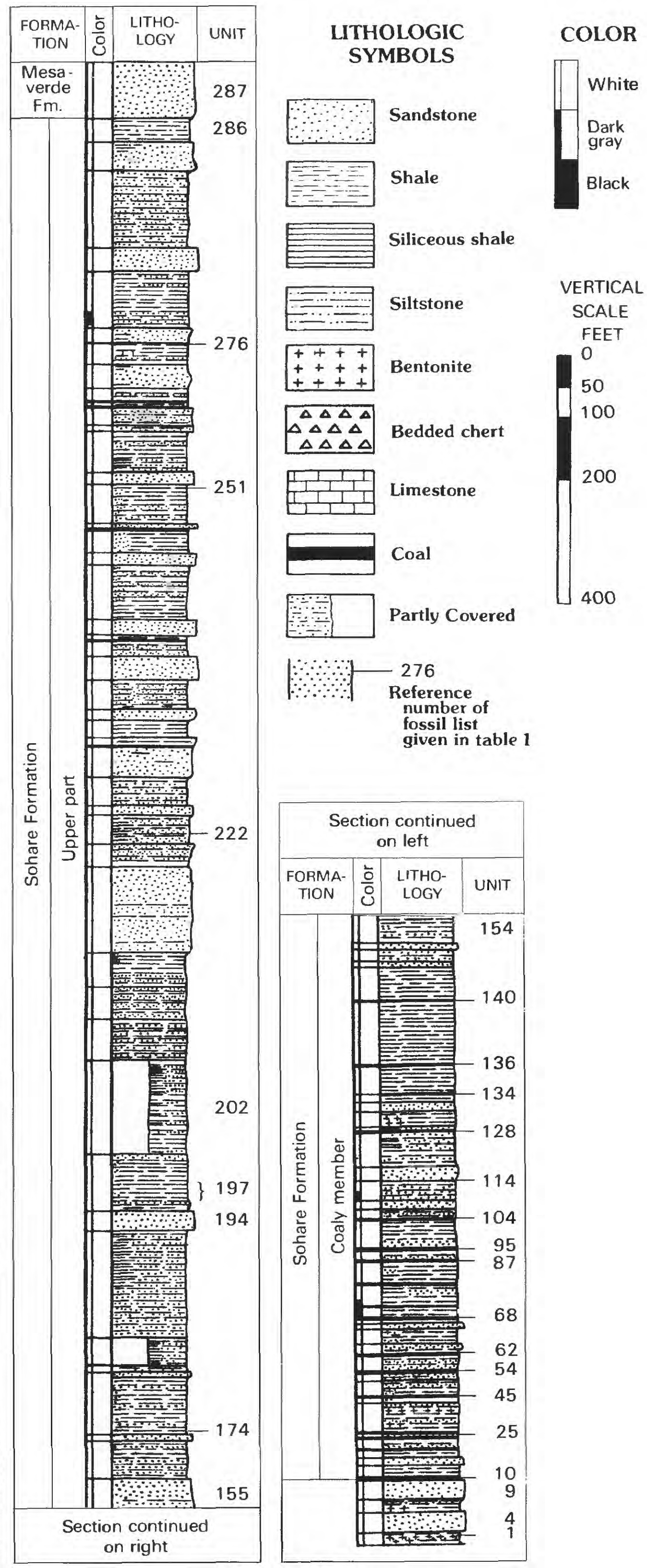


FIGURE 3.—Columnar type section of Sohare Formation (modified from Love, Hose, and others, 1951, Dry Cottonwood Creek section 5).

FIGURE 4.—View north-northeast at upper part of type section of Sohare Formation and associated rocks. Hachures mark line of plane-table traverse; dots, offset in traverse between units 281 and 280. Kc, Cody Shale; Kb, Bacon Ridge Sandstone; Ks, Sohare Formation; Kmv, Mesaverde Formation; Kh, Harebell Formation; Tpc, coaly member of Pinyon Conglomerate, which here is entirely of Paleocene age, marking basal part of Pinyon Conglomerate; Tp, upper part of Pinyon Conglomerate. Photograph by J. D. Love, August 1955.

tape. Dips range from 12° to 25° NE., with 17° being most consistent. Three-point dip control was obtained where practicable. Coal and bentonite beds were measured in inches. The total thickness of the formation was taken as the sum of the individual units, several of which are measured to tenths of feet. There is no intent to imply, however, that the thicknesses of major units or of the formation as a whole are accurate to this degree. Poorly exposed parts of the section were hand-trenched wherever possible. Unit 1 is oldest.

Marine mollusks were identified by W. A. Cobban, H. R. Bergquist, and J. B. Reeside, Jr.; nonmarine mollusks by D. W. Taylor and T. C. Yen; fossil leaves by R. W. Brown; fossils of the formation are listed in table 1.

Type section of the Sohare Formation

[Measured in secs. 15, 16, 22, and 27, T. 42 N., R. 112 W., Upper Slide Lake 7½-minute quadrangle, Teton County, Wyo. See figures 1 and 2 for maps of locality. Top of section is in east half of sec. 16, directly above prominent cliff-forming sandstone near base of good exposures]

	Thickness (feet)
Mesaverde Formation (part):	
288. Shale and claystone, light-greenish-gray, finely blocky in part, soft, fine-grained; 1-ft black carbonaceous layer 10 ft above base	4
287. Sandstone, light-gray, massive, soft, medium- to coarse-grained, porous; bright-colored grains; numerous dark grains; abundant gray limestone and clay pebbles in lower half; gray limestone concretions as much as 6 in. in diameter 5 ft below top; massive to poorly bedded, with some crossbedding; some hard finer grained ferruginous lenses; upper 11 ft very soft and forms slope; remainder forms the main conspicuous white cliff in the area	88

Type section of the Sohare Formation—Continued

[Contact between Mesaverde Formation and Sohare Formation arbitrarily placed at this horizon. Below this point the sandstones tend to be brown or darker gray and are much more lenticular and thinner than the sandstones above]

	Thickness (feet)
Sohare Formation:	
Upper part:	
286. Sandstone, shale, claystone, and siltstone; lower 14 ft is chiefly fine-grained, gray, very soft, silty sandstone; overlain by 1 ft of purplish-gray claystone; remainder is gray siltstone, claystone, and shale, interbedded; 1-ft black carbonaceous shale 5 ft below top	54
285. Sandstone, light-gray, weathering buff in part, medium-grained; bright-colored red, green, brown, and yellow grains; numerous dark grains; forms massive cliff but is thin bedded in part; some clay pellets in local lenses	29
284. Shale and sandstone; shale is lead gray to light gray; sandstone is light gray, fine grained, soft; abundant bright-colored grains; both shale and sandstone form slopes	41
283. Sandstone, gray, weathering light brown; fine-grained, hard, poorly bedded; numerous bright-colored grains; forms single brown ledge	7
282. Sandstone and shale interbedded in about equal amounts; sandstone is gray, fine grained, soft, numerous dark grains; form gray slope; 1-ft brown slabby sandstone 22 ft above base; shale is lead gray, with some almost black and some light-gray zones; 1-ft coal and coaly shale 49 ft above base	80
281. Sandstone, light-gray, massive, soft, porous; abundant bright-colored grains; abundant dark grains; forms lowest conspicuous smooth white cliff; 1-ft ledge of hard buff sandstone at top. This unit is 15 ft thick 1/4 mi east and 8 ft thick 3/4 mi east	36

Type section of the Sohare Formation—Continued

Sohare Formation—Continued Upper part—Continued	*Thickness (feet)*
[Section is offset on base of unit 281 3/4 mi northwest for overlying units]	
280. Shale, gray to tan, sandy; 2-ft brown limy sandstone 22 ft above base; fine-grained, gray, limy sandstone weathering brown, forming 1-ft ledges 35 ft and 46 ft above base	50
279. Shale, gray to dark-gray; minor amounts of tan sandy shale 21 ft and 39 ft above base; several 1-ft brown sandstone ledges; 1 ft of carbonaceous shale 10 ft above base	43
278. Sandstone, gray, weathering brown, hard, cross-bedded, fine- to medium-grained; abundant bright-colored grains; petroliferous odor on fresh fracture; forms conspicuous ledge where it crosses stream divide	7
277. Sandstone, gray, shaly, soft, friable	19
276. Shale, gray; at top is limy gray sandstone containing sparse leaves identified as *Araucarites longifolia* (Lesquereux) Dorf and fragments of ferns and dicotyledons (table 1)	19
275. Marlstone, yellow on weathered surface, gray on fresh surface, fine-grained, compact	2
274. Shale, gray	2
273. Sandstone, gray; lower 2 ft weathers to brown ledge.	3
272. Shale, gray	7
271. Sandstone, gray to tan; shaly near top and bottom; middle part forms ledge	31
270. Shale, interbedded with tan sandy shale	16
269. Sandstone, gray, lenticular; forms ledge	3
268. Shale, gray, interbedded with 2- to 4-ft beds of fine-grained friable sandstone	11
267. Coal, black, 8-in.; 3-in. carbonaceous shale at base and gray shale parting at top	1
266. Sandstone, gray, shaly, interbedded with an equal amount of dark-gray shale	8
265. Coal, black, 14-in.; 4-in. gray and brown shale at base and 1-in. gray shale at top	1.6
264. Sandstone, gray, fine-grained, friable; two limy sandstone ledges each about 1 ft thick; minor amount of gray shale in lower part	21
263. Shale, gray, sandy	3
262. Sandstone, gray, friable, fine-grained; lower 2 ft weathers to brown ledge	3
261. Shale, gray	2
260. Coal, black	0.5
259. Sandstone and shale, gray, interbedded in beds about 1 ft thick	5
258. Sandstone, gray to tan, friable	7
257. Shale, gray; 2-ft limy brown sandstone 9 ft above base	20
256. Shale, black, carbonaceous; coal partings	0.5
255. Shale, gray to tan, sandy	5
254. Sandstone, light-gray, friable	6
253. Shale, gray; interbedded at 2- to 6-ft intervals with friable shaly sandstone; 16 ft above base is a 2-ft brown limy sandstone	32
252. Sandstone, gray, friable; 1-ft thin-bedded ledge at base and another 17 ft above base	19
251. Shale, gray to tan, sandy; 1-ft thin platy sandstone ledges 24 ft, 30 ft, and 38 ft above base; reptile bone found in float 19 ft above base; well-preserved leaves at top (table 1)	41

Type section of the Sohare Formation—Continued

Sohare Formation—Continued Upper part—Continued	*Thickness (feet)*
250. Sandstone, gray; forms ledge	4
249. Shale, gray to tan; interbedded with fine-grained gray to brown limy sandstone	21
248. Sandstone, light-gray, medium-grained, lenticular	8
247. Coal, black, 16-in.; 3-in. brown carbonaceous shale at base; gray shaly sandstone parting at top	1.6
246. Shale, light- to dark-gray, sandy; 1-ft brown limy sandstone	33
245. Sandstone, light-gray, massive, lenticular; numerous dark grains; sparse bright-colored grains; poorly preserved plant fragments in brown bed at top	24
244. Shale, gray, sandy; some friable fine-grained sandstone with brown limy sandstone concretions	45
243. Shale, gray,sandy.	4
242. Sandstone, gray, fine-grained; 1-ft ledge in middle	5
241. Shale, gray; sandy in upper half; brown limy sandstone beds, each 1 ft thick, 10 ft and 17 ft above base	34
240. Sandstone, gray, massive, soft, friable; forms slope	9
239. Sandstone, gray, massive, lenticular; sparse clay balls and ferruginous concretions; forms cliff	14
238. Sandstone, gray, soft, friable; interbedded with lesser amounts of gray shale	9
237. Coal, 8-in.; 2-in. carbonaceous shale at base and 6-in. gray shale at top	1.3
236. Shale, gray; interbedded with fine-grained, friable, gray sandstone	29
235. Sandstone, light-gray, massive, lenticular; forms cliff	40
234. Shale, gray; interbedded with fine-grained gray sandstone; one 6-in. carbonaceous shale bed and a 2-ft brown limy sandstone	42
233. Sandstone, gray, massive; forms slope	11
232. Sandstone, gray, massive; lenticular; locally forms ledge	10
231. Shale, gray, sandy in part	24
230. Sandstone, gray, massive, lenticular; locally forms cliff	11
229. Shale, carbonaceous; contains coal partings	1
228. Sandstone, gray, shaly; 6-in. gray shale at top	11
227. Coal, 8-in.; 4-in carbonaceous shale at base	1
226. Sandstone, gray, fine-grained; sparse gray shale partings	17
225. Sandstone, light-gray, massive to thin-bedded, medium-grained; numerous dark grains	29
224. Shale, gray; interbedded with 2- to 4-ft beds of fine-grained, friable, light-gray sandstone	45
223. Sandstone, gray, massive to thin-bedded, medium-grained, lenticular; numerous dark grains	17
222. Sandstone, gray, fine-grained, shaly; interbedded with dark-gray shale; 3-ft sandy shale, weathering yellow, at base; 2-ft ledge of sandstone 36 ft above base; pelecypods in shale 20 ft above base	45
221. Sandstone, gray, fine-grained; 2-ft ledge at top	8

Type section of the Sohare Formation—Continued

	Thickness (feet)
Sohare Formation—Continued	
Coaly member—Continued	
87. Coal, sandstone, and shale beds, detailed as follows:	
Top: Coal ... 6 in.	
Shale, carbonaceous ... 12 in.	
Sandstone, gray ... 12 in.	
Shale, gray ... 18 in.	
Coal ... 24 in.	
Coal bone, with plant fragments weathering white ... 2 in.	
Coal ... 20 in.	
Sandstone, gray ... 7 in.	
Base: Shale, carbonaceous ... 2 in.	
Total: Coal, sandstone, and shale beds	9.2
86. Shale, gray	9
85. Shale, black	1
84. Shale, gray, sandy	6
83. Sandstone, gray, thin-bedded, limy; forms ledge	1
82. Shale, gray; 6-in. shaly sandstone in middle; brown marlstone nodules 2 ft below top	4
81. Coal, black; 2-in. carbonaceous shale at top and base	1
80. Shale, gray; sparse shaly sandstone partings	6
79. Sandstone, gray, shaly	6
78. Shale, gray	6
77. Marlstone, yellow, weathering gray, fine-grained	2
76. Sandstone, gray in lower part, tan near top, medium-grained, friable; two 3-in. partings of carbonaceous shale; 3-ft ledge at top	9
75. Shale, dark-gray, fissile	10.5
74. Sandstone, gray, fine-grained	2
73. Coal	0.5
72. Shale, brown, sandy	0.5
71. Sandstone, light-gray, fine-grained	2
70. Shale, dark-gray; lower 7 ft plastic, remainder fissile; sparse thin marlstone layers	17.5
69. Sandstone, gray to brown, fine-grained, shaly	1
68. Coal and shale beds, detailed as follows:	
Top: Coal ... 3 in.	
Shale, brown, carbonaceous ... 2 in.	
Base: Coal ... 7 in.	
Total: Coal and shale beds	1
67. Shale, gray; sandy at base	4
66. Sandstone, gray in upper half, tan and thin-bedded in lower half, fine- to medium-grained, friable	9
65. Shale, gray; sparse siderite and marlstone concretions; lower 3 ft sandy; upper half is about one-third bentonitic shale	26
64. Sandstone, gray, fine-grained, platy; forms ledge	6
63. Shale, gray	7
62. Coal, 14-in.; 2-in. carbonaceous shale at top and base	1.5
61. Shale, gray; 3-in. carbonaceous shale 1 ft above base and layer of marlstone nodules in middle	6
60. Sandstone, gray to tan, fine- to medium-grained; forms ledge	4
59. Shale, gray; parting of sandy shale at top; 6-in. carbonaceous shale 1 ft above base	6
58. Sandstone, light-gray, fine-grained	1.5
57. Marlstone, yellowish-brown	1
Type section of the Sohare Formation—Continued	
Sohare Formation—Continued	
Coaly member—Continued	
56. Shale, gray	3
55. Sandstone, gray, fine-grained	4
54. Coal, 13-in.; underlain by 8-in. brown carbonaceous shale	1.8
53. Shale, gray	2
52. Sandstone, light-gray, friable; sparse partings of shale; forms slope except for 1-ft ledge 10 ft above base	14
51. Shale, carbonaceous; 6-in. coal at top	1.5
50. Sandstone, gray, friable, fine-grained	3
49. Coal, 4-in.; underlain by 1-in. brown carbonaceous shale	0.4
48. Shale, gray	2
47. Sandstone, gray, friable; interbedded with 2- to 6-in. beds of bentonitic shale; sparse marlstone nodules	7
46. Shale, gray	5
45. Coal and shale beds, detailed as follows:	
Top: Shale, carbonaceous ... 1 in.	
Coal ... 8 in.	
Coal bone ... 2 in.	
Coal ... 13 in.	
Coal bone with plant fragments, weathering white ... 2 in.	
Coal ... 10 in.	
Base: Shale, carbonaceous ... 2 in.	
Total: Coal and shale beds	3.2
44. Shale, gray to brown, sandy	10
43. Sandstone, light-gray, fine- to medium-grained; at top is 1-ft brown siderite and marlstone concretion zone	8
42. Shale, gray; sparse nodules and thin layers of brown marlstone	2
41. Shale, carbonaceous	0.5
40. Bentonite, greenish-tan	0.5
39. Sandstone, gray, fine-grained, friable	2
38. Bentonite, black to dark-gray, impure	6
37. Sandstone, gray, friable, fine-grained; interbedded with gray bentonitic shale	6
36. Marlstone, brown to yellowish-brown	1.5
35. Bentonite, dark-gray to black, impure	2.5
34. Sandstone, tan, fine-grained, friable	2
33. Shale, gray	1.2
32. Sandstone, gray, thin-bedded, fine-grained, platy; 6-in. gray shale in middle	1.5
31. Shale, gray to tan, sandy	3
30. Sandstone, gray, fine-grained, thin-bedded	1.5
29. Marlstone, brown	0.5
28. Shale, dark-gray, bentonitic	6
27. Sandstone, gray, fine-grained, shaly, thin-bedded; 6-in. brown marlstone 6 in. above base	2.5
26. Shale, gray	4.5
25. Coal, shale, and sandstone beds, detailed as follows:	
Top: Shale, brown, carbonaceous ... 4 in.	
Coal ... 6 in.	
Coal bone, black, weathering white; abundant wood fragments ... 4 in.	
Coal, impure ... 2 in.	
Sandstone, gray, clayey, fine-grained ... 4 in.	
Coal ... 15 in.	

Type section of the Sohare Formation—Continued

		Thickness (feet)
Sohare Formation—Continued		
Coaly member—Continued		
25.	Coal, shale—Continued	
	Shale, brown, carbonaceous, micaceous ... 2 in.	
	Coal ... 2 in.	
	Shale, brown, carbonaceous ... 4 in.	
	Coal ... 9 in.	
	Base: Shale, brown, carbonaceous ... 4 in.	
	Total: Coal, shale, and sandstone beds	4.7
24.	Shale, gray	1
23.	Sandstone, gray, shaly	1
22.	Coal, shale, and sandstone beds, detailed as follows:	
	Top: Shale, brown ... 4 in.	
	Coal ... 8 in.	
	Sandstone, brown, fine-grained ... 4 in.	
	Coal, black, shaly cleavage ... 4 in.	
	Base: Shale, brown, carbonaceous ... 2 in.	
	Total: Coal, shale, and sandstone beds	1.8
21.	Shale, gray	2
20.	Sandstone, gray to tan, fine-grained, thin-bedded, soft; limy in part; shaly near top	8
19.	Shale, gray	2
18.	Marlstone, gray, weathering yellow-brown, lenticular	1
17.	Shale, gray	1
16.	Coal, shale, and sandstone beds, detailed as follows:	
	Top: Shale, brown, carbonaceous ... 12 in.	
	Sandstone, gray, fine-grained . 4 in.	
	Coal ... 10 in.	
	Coal bone ... 2 in.	
	Coal ... 6 in.	
	Base: Shale, carbonaceous ... 2 in.	
	Total: Coal, shale, and sandstone beds	3
15.	Shale, gray; contains sporadic nodules of brown marlstone	7
14.	Shale, brown, carbonaceous	1
13.	Sandstone, gray, fine-grained, thin-bedded, platy	15
12.	Shale, carbonaceous	2
11.	Shale, gray to brown; 2-in. bed of brown marlstone nodules 6 ft above base	11
10.	Coal and shale beds, detailed as follows:	
	Top: Shale, carbonaceous; laminae of coal ... 18 in.	
	Coal ... 30 in.	
	Shale, carbonaceous ... 1 in.	
	Coal ... 18 in.	
	Shale, brown, carbonaceous ... 3 in.	
	Claystone, gray, sandy ... 16 in.	
	Base: Coal ... 12 in.	
	Total: Coal and shale beds	8.1
	Total thickness of coaly member	915.1
	Total thickness of Sohare Formation	3,188.7

[Contact between coaly member of Sohare Formation and Bacon Ridge Sandstone arbitrarily placed at this point]

		Thickness (feet)
Bacon Ridge Sandstone:		
9.	Sandstone, gray, medium- to fine-grained, massive; abundant dark grains; two 2-ft ledges in upper part; remainder friable and forms slope. Brown ferruginous concretions contain as much as 14 percent zircon (R. S. Houston, oral commun., 1970)	29
8.	Shale, brown, carbonaceous	.5

Type section of the Sohare Formation—Continued

		Thickness (feet)
Bacon Ridge Sandstone—Continued		
7.	Sandstone, gray, friable	4
6.	Shale, gray, fissile; 6-in. black carbonaceous shale 1 ft below top; 3-in. brown carbonaceous shale at base	3.5
5.	Shale, gray, bentonitic; 2-in. bentonite at top	7
4.	Sandstone, gray, weathering brown in part, fine- to medium-grained, soft, porous, massive; numerous dark grains; locally forms cliffs; 0.4 mi east is a 3.5-ft fine-grained, lead-gray shale 9 ft below top	37
3.	Coal, 6-in.; underlain by 6-in. carbonaceous shale	1
2.	Shale, gray, blocky in part; abundant, poorly preserved plant fragments	6.5
1.	Bentonite, gray; interbedded with fine-grained tuffaceous thin-bedded sandstone; about 1 ft below top is a 2-in. layer containing small, thin-shelled pelecypods and high-spired gastropods, excellently preserved but very fragile (see table 1). This thin zone was followed for a distance of 4 mi to the southeast. It is probable that this zone and associated bentonitic beds may constitute an excellent marker zone. This is the highest stratigraphic occurrence of marine fossils discovered in this section	5

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The top of the Sohare Formation is picked to be at the base of the basal white cliff-forming sandstone of the Mesaverde Formation (fig. 4; unit 287 in the accompanying section; see also Love, 1973, fig. 20). The two formations probably intertongue, but this has not been adequately demonstrated because of poor exposures and lack of marker beds.

The contact between the Sohare Formation and underlying Bacon Ridge Sandstone was arbitrarily picked at the top of a conspicuous sandstone about 50 ft above a persistent bentonite bed containing marine invertebrate fossils. The formations probably intertongue. Detailed stratigraphic and paleontologic studies above and below the contact will be needed to determine the amount and nature of intertonguing.

AGE AND CORRELATION

The Bacon Ridge Sandstone underlying the Sohare Formation contains abundant marine fossils of middle Niobrara age (table 1; Love, 1956b, p. 80). The Sohare Formation contains many horizons with abundant and well-preserved floras of Late Cretaceous age (table 1), but the age has not yet been determined more precisely. No diagnostic fossils were found in the overlying Mesaverde Formation, other than that they are of Late Cretaceous age. The Sohare Formation and the underlying

TABLE 1.—*Fossils from the type section of the Sohare Formation and associated strata near Dry Cottonwood Creek*

[From Love, Hose, and others (1951). Leaders (---), no locality number or age not determinable]

Unit No. (fig. 3 and measured type section)	U.S.G.S. locality No.	Age	Fossils
			Upper part
276	---	Late Cretaceous.	Fragments of ferns and dicotyledons. Wood, not identifiable. *Brachyphyllum macrocarpum* Newberry. *Araucarites longifolia* (Lesquereux) Dorf. *Trapa*? *microphylla* Lesquereux. *Myrtophyllum torreyi* (Lesquereux) Dorf. *Sequoia brevifolia* Heer. *Anemia perplexa* Hollick. *Gleichenia pulchella* Knowlton.
251	---	Late Cretaceous.	*Anemia perplexa* Hollick. *Araucarites longifolia* (Lesquereux) Dorf. *Sequoia brevifolia* Heer. Palm fragment. *Myrtophyllum torreyi* (Lesquereux) Dorf. *Cercidiphyllum ellipticum* (Newberry) Brown.
222	22000	---	*Unio* sp. undet.
197	22001	Late Cretaceous.	*Viviparus* sp. undet. *Trapa*? *microphylla* Lesquereux.
194	---	Late Cretaceous.	*Equisetum* sp. Fern sp. *Araucarites longifolia* (Lesquereux) Dorf. Fragments of dicotyledonous leaves.
174	---	Late Cretaceous.	*Trapa*? *microphylla* Lesquereux.
			Bacon Ridge Sandstone
1	21120	Late Cretaceous, Niobrara	*Anomia* cf. *A. gryphaeiformis* Stanton. *Corbicula* sp. "*Tellina*" *modesta* Meek? "*Siliqua*" *huerfanensis* Stanton. *Eulimella*? *funicula* Meek. "*Melania*" aff. *M. insculpta* Meek.

Bacon Ridge Sandstone probably intertongue eastward with the marine upper part of the sandy facies of the Cody Shale as described by Keefer (1972, p. E16) in the western part of the Wind River Basin.

DEVILS BASIN FORMATION

NAME AND DEFINITION

The new name, Devils Basin Formation, is taken from Devils Basin Creek which flows southwestward into the South Fork of Fish Creek about 0.4 mi northwest of the main part of the type section (fig. 5).

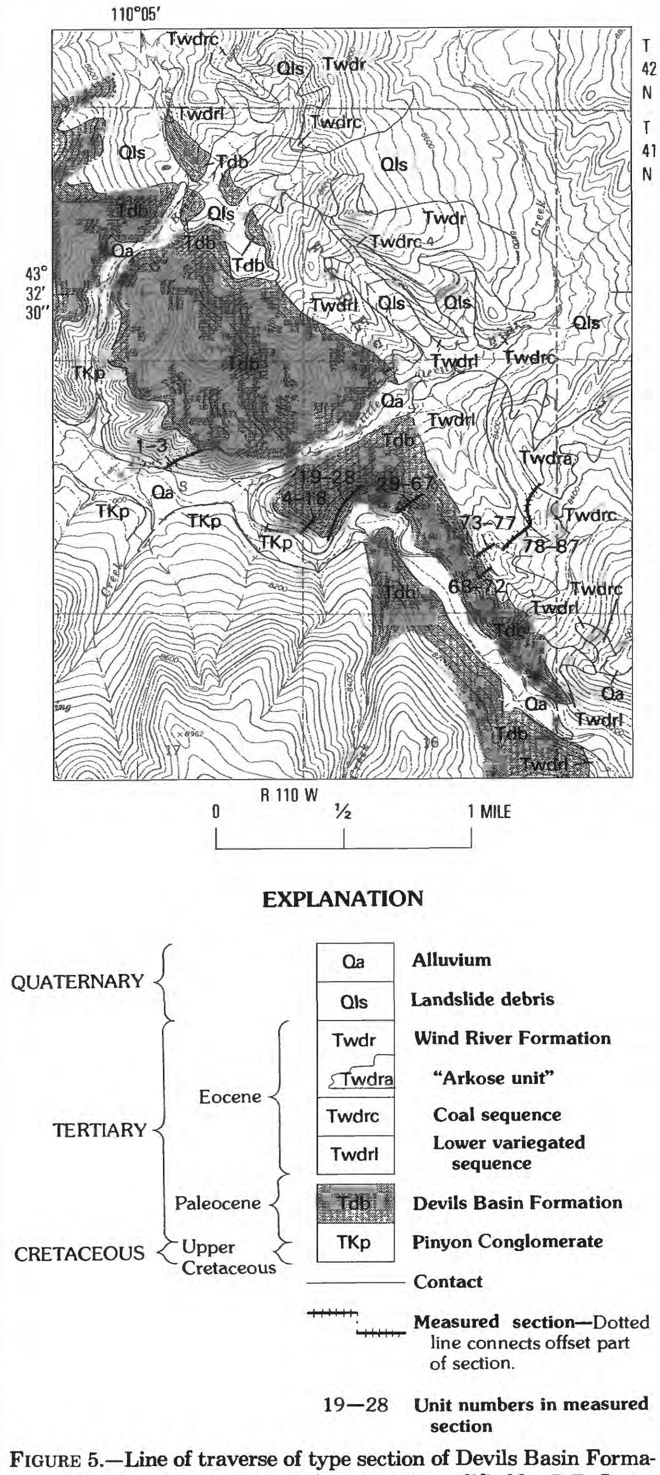


FIGURE 5.—Line of traverse of type section of Devils Basin Formation. Geology in part from Rohrer (1969), modified by J. D. Love, 1982. Base from U.S. Geological Survey Sheridan Pass 7½-minute topographic quadrangle map, 1965, scale 1:24,000.

The lower part of the section was measured and fossils collected July 10, 1945, by J. D. Love, and a generalized section was subsequently published (Love, 1947, section 14). There, and in many subsequent publications (for example, Love, Weitz, and Hose, 1955; Love, 1956b, c), these rocks were called the "greenish-gray and brown sandstone and shale sequence." No formal name was designated pending studies of the areal extent, age dating, and stratigraphic and structural relations of this sequence to overlying and underlying units. Now that these data are available, the Devils Basin Formation is here formally defined.

The area of the type section was mapped by Rohrer (1969) and called "Fort Union Formation." Separate studies were made by Love in 1960, 1963, 1966, 1981, and 1982. Poorly exposed units were hand-trenched where possible. Extensive vertebrate fossil collections were made from unit 19 during a period of many years by M. C. McKenna and associates (McKenna, 1980). Invertebrate fossils were identified by D. W. Taylor, J. B. Reeside, Jr., and T. C. Yen. Plant fossils were identified by R. W. Brown.

DISTRIBUTION AND THICKNESS

The exposed part of the Devils Basin Formation covers approximately 25 mi^2 (fig. 1) and is probably present in at least 75 mi^2 of the subsurface. The thickness of the type section is about 1,500 ft. Approximately 6 mi to the northwest on Purdy Creek (fig. 1), the formation is about 1,450 ft thick; on the North Fork of Fish Creek, 2 mi still farther north-northwest, it is about 1,150 ft; on Cottonwood Creek, 5 mi to the north, it is 600 ft; and it disappears under the Tripod thrust fault, 4 mi north of Cottonwood Creek. North of this point, the formation has not been recognized in Jackson Hole.

Within 5 mi to the south of the type section, the Devils Basin Formation is covered by younger strata or Quaternary deposits, or has been removed by erosion. However, 28 mi south of the type section, a roadcut on the north face of Black Butte has exposed about 15 ft of coal, carbonaceous shale, gray claystone, and tan fine-grained nonarkosic sandstone. These strata are similar to those in the Devils Basin Formation, dip 7° SW., and are about 400(?) ft above and 1 mi southwest of about 100 ft of Pinyon-type gold-bearing quartzite conglomerate that dips 30° SW. Presumably, the conglomerate dips under the coal and claystone sequence. Seven miles still farther south, along the northeast margin of the Green River Basin, the Gulf Oil Corporation New Fork Unit 1, sec. 5, T. 35 N., R. 110 W., penetrated about 2,000 ft of gray to green to brown siltstone, shale, and claystone, thin beds of coal, and gray sandstones like those at Black Butte and also in the Devils Basin Formation. This sequence in the well overlies about 400 ft of Pinyon-type quartzite conglomerate with some sandstones and shales. The conglomerate, in turn, overlies Upper Cretaceous rocks. Thus, if this correlation is correct, the Devils Basin Formation probably originally extended southward continuously from the type section into the Green River Basin.

LITHOLOGY

A detailed description of the lithology of the Devils Basin Formation is given in the type section. Throughout the surface exposures in the area shown in figure 1 the formation is characterized by gray, soft, highly lenticular poorly bedded sandstones, more evenly bedded gray and pale-green siltstones and claystones, thin-bedded brown to black carbonaceous shales, and thin beds of coal rarely more than 1–2 ft thick (figs. 6–10). Almost no conglomerate beds were observed. Many of the finer grained beds contain abundant freshwater mollusks, and a few have land snails and leaves. One bed (unit 16 in type section) has abundant vertebrate fossils. Of unique interest is a 2-ft limestone (unit 47 in type section; fig. 10) that has oil staining and a strong petroleum odor on fresh fractures.

TYPE SECTION

The type section of the Devils Basin Formation was measured with steel tape and pocket transit on the steep exposures along the east side of the South Fork of Fish Creek (figs. 5–10), secs. 8 and 9, T. 41 N., R. 110 W., Sheridan Pass quadrangle, Teton County, Wyo. The topographic map was used in major interval checks. All collections of fossils and rock samples are referenced to these measurements. Unit 1 is oldest.

Type section of the Devils Basin Formation

[Measured in secs. 8 and 9, T. 41 N., R. 110 W., Sheridan Pass 7½-minute quadrangle, 1965, Teton County, Wyo. See figures 1 and 5 for maps of locality. Top of measured section is in central east half of sec. 9 near the top of a hill, at the south end, near an altitude of 8560 ft]

	Thickness (feet)
Wind River Formation:	
[Units 87–85 are the lower part of the "arkose unit" of Rohrer (1969)]	
87. Arkose, yellow and tan, coarse, pebbly, soft; weathering into steep bare badland "hoodoos." Rohrer (1969) shows strike N. 30° W., dip 23° NE.	50+
86. Claystone, gray to brown, carbonaceous in part; puffy weathered surface suggests some bentonite content	15
85. Arkose, white, coarse, angular, soft; with abundant red-brown ironstone nodules at top	15
84. Shale, black, carbonaceous, soft, papery; abundant tiny ferruginous concretions. Some black shales weather with a bluish-white cast, suggesting oil shale. Several thin beds of coal are in lower part. This is Rohrer's (1969) "coal-bearing unit." His section 12 of the lower part of this unit was measured 300 ft east-southeast of line of section	125±

FIGURE 6.—Air-oblique view northeast across South Fork Fish Creek, showing type Devils Basin Formation and other Tertiary map units described by Love (1947) and Rohrer (1969). Hachured lines indicate line of measured type section; dots indicate offsets. TKp, Pinyon Conglomerate; Tdb, Devils Basin Formation; Twdrl, lower variegated sequence in Wind River Formation (variegated color absent south of Devils Basin Creek); Twdrc, coal sequence in Wind River Formation; Twdru, upper variegated sequence in Wind River Formation; Twdra, arkose tongue in Wind River Formation; Tac, Aycross Formation; Twi, Wiggins Formation; F, flora horizon; V, vertebrate fossil site in unit 16 ("Love quarry" of McKenna, 1980); M, horizon of mollusk collections. Photograph by R. L. Casebeer, Oct. 20, 1964.

Type section of the Devils Basin Formation—Continued

Wind River Formation—Continued	*Thickness (feet)*
[Units 71–83 compose Rohrer's (1969) "lower variegated unit." However, the strata are not variegated in this area, although they intertongue with variegated claystones 2 mi to the northwest]	
83. Marls, white to cream-colored, soft, light-weight; contain abundant ostracodes and well-preserved leaves. On outcrop, forms a conspicuous white stripe at base of overlying black shale	25
82. Shale, dark-gray, papery, soft	50
81. Partly covered interval. Somewhere in the lower 50 ft is a soft tan arkose interbedded with gray siltstone	

Type section of the Devils Basin Formation—Continued

Wind River Formation—Continued	*Thickness (feet)*
81. Partly covered interval—Continued and claystone. About 200 ft above base are turtle shell fragments. Entire unit is probably soft gray shale, siltstone, and claystone	300±
80. Arkose, tan, coarse, angular, apparently lenticular	10
79. Coaly shale, black and dark-gray, soft	10
78. Sandstone and siltstone, gray, soft, chippy in part	10
[Offset 200 ft southeast on top of unit 77 for overlying section]	
77. Sandstone, rusty to gray, hard, ripple-marked, ledgy; is "marker bed" that forms prominent ridge (figs. 6, 7) that can be traced for several miles to the	

FIGURE 7.—Air-oblique view north-northeast across South Fork Fish Creek, showing regional stratigraphic relations of Devils Basin Formation and other Tertiary map units described by Love (1947) and Rohrer (1969) and localities described in text. TKp, Pinyon Conglomerate; Tdb, Devils Basin Formation; Twdrl, lower variegated sequence in Wind River Formation; Twdrc, coal sequence in Wind River Formation; Twdru, upper variegated sequence in Wind River Formation; Tac, Aycross Formation; Twi, Wiggins Formation. Localities: A, Rohrer locality of vertebrate fossils of latest Paleocene age; B, several McKenna (1980) vertebrate-fossil sites of latest Paleocene and earliest Eocene ages; C, McKenna (1980) RIP locality, and D, "landslide locality" of vertebrate fossils of Lysite or Lost Cabin age; E, snail locality in Aycross Formation (Love, 1947); F, one of MacGinitie's (1974) "Coyote Creek flora" sites; G, flora horizon in Devils Basin Formation described by Love (1973); H, vertebrate fossil site ("Love quarry" of McKenna, 1980) containing fossils of middle Tiffanian age. Photograph by R. L. Casebeer, Oct. 20, 1964.

Type section of the Devils Basin Formation—Continued

	Thickness (feet)
Wind River Formation—Continued	
77. Sandstone—Continued northwest and at the type section forms a dip slope, timbered on the northeast side. Strike N. 30° W., dip 25° NE. Top of this unit is top of one of Rohrer's (1969) "ridge-forming units"	15
76. Claystone, shale, and siltstone, gray, lower half; becomes increasingly carbonaceous toward top and contains thin beds of coal less than 1 ft thick	50
75. Coal and carbonaceous shale consisting of two beds; conspicuous unit; separated by a coquina of white and brown mollusks of many types collected but not identified. Abundant wild roses mark coquina zone, whereas the upper and lower coals are nearly unvegetated. This makes a double stripe on outcrop that is visible on air photographs. The most prominent coquina bed in the middle is about 1 ft thick	12
74. Arkose, tan; fresh angular granite fragments; rests with sharp contact on dark-gray shale and incorporates small fragments of shale. This is the lowest coarse arkose from the Wind River Range 10 mi to the east	15
73. Shale, siltstone, and thin sandstones, gray, soft, slope-forming; sparse thin carbonaceous shale zones	135
[Offset 400 ft northwest for overlying section]	
72. Coal and coaly shale; coal is very impure, in beds less than 1 ft thick; about 3/4 of unit is shale. Equivalent to part of Rohrer's (1969) section 2, measured 1,000 ft to the southeast	16
71. Shale, dark-gray; interbedded with greenish-gray siltstone and gray, slabby, fine-grained sandstone; 1-ft coal about 10 ft below top	50
Total thickness of measured part of Wind River Formation	903±

[Arbitrary contact between Wind River Formation above and type Devils Basin Formation below (fig. 8). This is the top of Rohrer's (1969) Fort Union Formation]

	Thickness (feet)
Devils Basin Formation:	
70. Sandstone, white, uppermost marker bed; forms a conspicuous bed; consists of snowy-white poorly bedded sandstone; pyrite nodules common. One coal bed a few inches thick near base and another 6-in. bed 10 ft below top	85±
69. Siltstone and claystone, greenish-gray, soft, blocky	13
68. Shale, black to dark-gray, fissile, papery; abundant mollusks in two zones 15 ft and 23 ft above base. Many varieties of pelecypods and gastropods collected but not studied. Strike N. 25° W., dip 25° NE., at base of unit	32
[Offset 2,100 ft southeast on top of unit 67 for overlying section]	
67. Sandstone, chalky-white to limonite-stained; in ragged crossbedded ripple-marked ledges that form a conspicuous topographic escarpment with trees on back side	17
66. Shale and claystone, carbonaceous and coaly in lower 6 ft; remainder is dull green, soft, silty	16
65. Sandstone, soft, rusty-brown and gray; alternating with green to gray slightly carbonaceous shale. Some *Unio* shells in lowest sandstone	76
64. Shale, carbonaceous, and green shale and coquina beds of *Unio*, gastropods, and ostracodes. Collected, but preservation is poor; not studied. Pollen sample submitted but not studied	11
63. Sandstone, brown to gray; forms outcrops of irregular ledges and softer interbeds. In a 2-ft ledge in middle is a 6-in. zone of gray rounded limestone pellets and fossil-wood chips. No bones or shells seen, but lithology is similar to that at "Love quarry" (unit 16), where abundant vertebrate fossils were obtained	16
62. Coal and carbonaceous shale in lower 2 ft, grading up to blocky green claystone	5
61. Sandstone, light-gray, very soft, fine-grained, crossbedded	4
60. Shale, carbonaceous, and green shale and claystone; very soft	14
59. Sandstone, tan, very soft, muscovite-rich, sugary texture; small angular quartz grains	11
58. Shale, carbonaceous, and coal in lower 2 ft; green blocky claystone and shale in remainder	7
57. Sandstone, gray, nodular; some gray rounded limestone pellets, somewhat like the vertebrate fossil bed at "Love quarry" (unit 16)	5
56. Shale, carbonaceous, brown shale, papery shale, and dull-green blocky claystone. A 1.5-ft coal 15 ft above base	32
55. Sandstone, gray to drab, very soft; abundant muscovite; many pyrite nodules	67
54. Coaly shale and brown paper shale; a conspicuous bare unvegetated stripe on outcrop; abundant fossil plant fragments	3
53. Sandstone, gray; abundant varicolored grains; soft, porous, medium grained, abundant muscovite	14
52. Coaly shale, black, soft; interbedded with brown paper shale	3
51. Sandstone, tan; ledge-forming in part, poorly bedded; irregular concretionary lenses. Forms highest ledge on hill directly above bushy pine tree on line of section	27
50. Shale, carbonaceous, gray claystone, and thin sandstones; 1-ft coal 5 ft below top. Horizontal stump of carbonized wood 2 ft long and 1 ft in diameter at top of coal bed	25
49. Sandstone, tan, limy; forms ledge	4
48. Coal and brown paper shale. Main coal zone in this part of section. About half of unit is black shiny coal in beds 1–2 ft thick. The other half of unit is brown paper shale with abundant plant fragments	11
47. Limestone, brown, sandy, mottled, oil-stained; has a strong oil odor on fresh fracture. Weathered surface has a bluish-white bloom. Unit is very evenly bedded and forms a conspicuous thin ledge on outcrop at base of coal zone. Sample collected for oil analysis. Strike N. 30° W., dip 25° NE.	2
46. Sandstone, brown and gray, soft; contorted bedding	14
45. Claystone, dark-green, soft, finely blocky	3
44. Sandstone, gray to rusty-brown, concretionary, soft, irregularly bedded; 1-ft soft green shale 4 ft below top	15
43. Coal and carbonaceous shale; lowest of dark zones on outcrop above bushy pine tree (fig. 9)	8
42. Sandstone, light-gray, fine-grained, weakly slabby	8
41. Shale and claystone, light-greenish-gray, soft; grading up to carbonaceous shale at top	5
40. Sandstone, tan to gray; forms knobby concretionary ledges. Upslope to northwest, this unit has a bushy pine tree on it (fig. 9)	8

Type section of the Devils Basin Formation—Continued

Devils Basin Formation—Continued	*Thickness (feet)*
39. Claystone and shale, green to brown, carbonaceous; fine-grained sandstone and siltstone interbeds. Some moderately well-preserved leaves but matrix is so soft that they did not survive the trip to the laboratory. Pollen sample submitted but not studied	15
38. Sandstone, light-gray, soft, fine-grained, massive to slabby	7
37. Claystone, greenish-gray, soft, blocky, massive	11
36. Sandstone, light-gray to rusty-brown, soft, mostly massive, fine-grained. Upslope to the northwest, this unit crops out as a tan smooth sandstone with 2 pine trees on it (fig. 9)	54
35. Claystone, pale-greenish-gray, moderately soft, fine-grained, blocky; sparse carbonaceous zones containing poor plant fragments, but nothing worth collecting	9
34. Coal and coaly shale, dark-gray to black, soft	2
33. Claystone, pale-greenish-gray, massive, soft, blocky	9
32. Sandstone, gray to tan, massive in part, iron-stained, soft; 1-ft hard ledge in upper part	16
31. Shale, carbonaceous, rusty; 1-ft coaly shale at top	3
30. Sandstone, chalky-white to bluish-gray, fine-grained, soft, moderately clean	6
29. Shale, carbonaceous, gray to rusty-brown; silty in upper half, coaly in part. Lower of two carbonaceous zones shown in figure 9. Strike N. 15° W., dip 25° NE.	3
[Offset 900 ft southeast on top of unit 28 from near top of hill to creek level]	
28. Sandstone and claystone, green and gray, soft	10
27. Sandstone, tan, highly concretionary; some rounded balls 10 ft in diameter; highly lenticular	20±
26. Claystone, pale-green to dark-gray; some sandstone beds; basal bed is green claystone	40
25. Sandstone, gray to tan, mostly massive; forms big smooth cliff (fig. 8)	100±
24. Claystone, green, gray, and brown; thin carbonaceous shales; some lenticular gray sandstones	100±
23. Sandstone, light-gray, massive; lower of two big conspicuous sandstones; forms smooth cliff (fig. 8)	40
22. Coal, black, shiny, soft	1
21. Sandstone and shale, gray, soft; carbonaceous at top	10
20. Limestone, gray, hard, sublithographic	1
19. Shale, claystone, siltstone, sandstone, and thin coal beds. The sandstones are gray, fine grained to coarse grained, moderately well bedded. The shales and claystones are gray to greenish gray, sandy in part, very fine grained and fissile in part. About 6 carbonaceous shales and thin black shiny coal beds, each about 1 ft thick, all in a group near the middle of the sequence. Some of the sandstones are very limy and contain abundant gastropods and sparse tiny well-preserved pelecypods. Some of the shales are thinly laminated. The sandstones and shales are in about equal amounts, in beds 25–50 ft thick. A carbonaceous shale about 70 ft below the top contains several species of snails (table 3, USGS 20324). Directly below this horizon, a black shale yielded freshwater clams and snails (table 3, USGS 22268). About 100 ft below this fossil zone another carbonaceous sequence yielded a large assemblage of snails and one clam (table 3; USGS	

FIGURE 8.—View east-southeast at upper and middle parts of

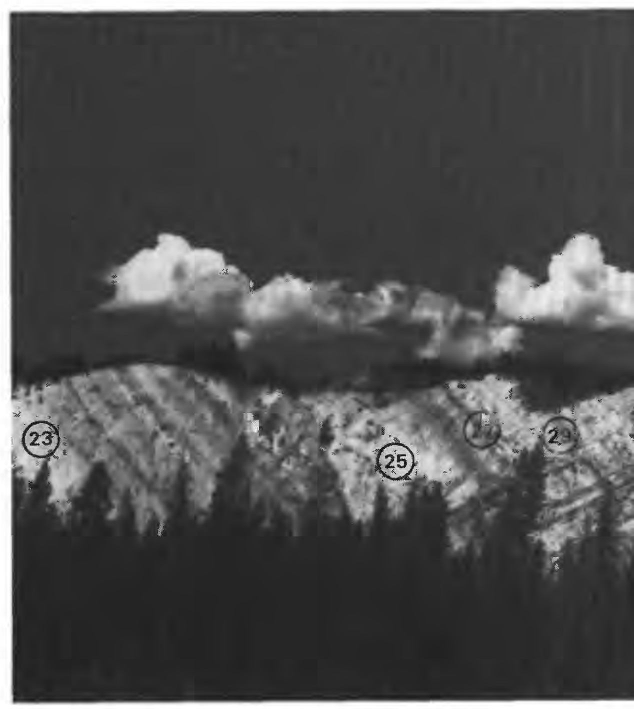
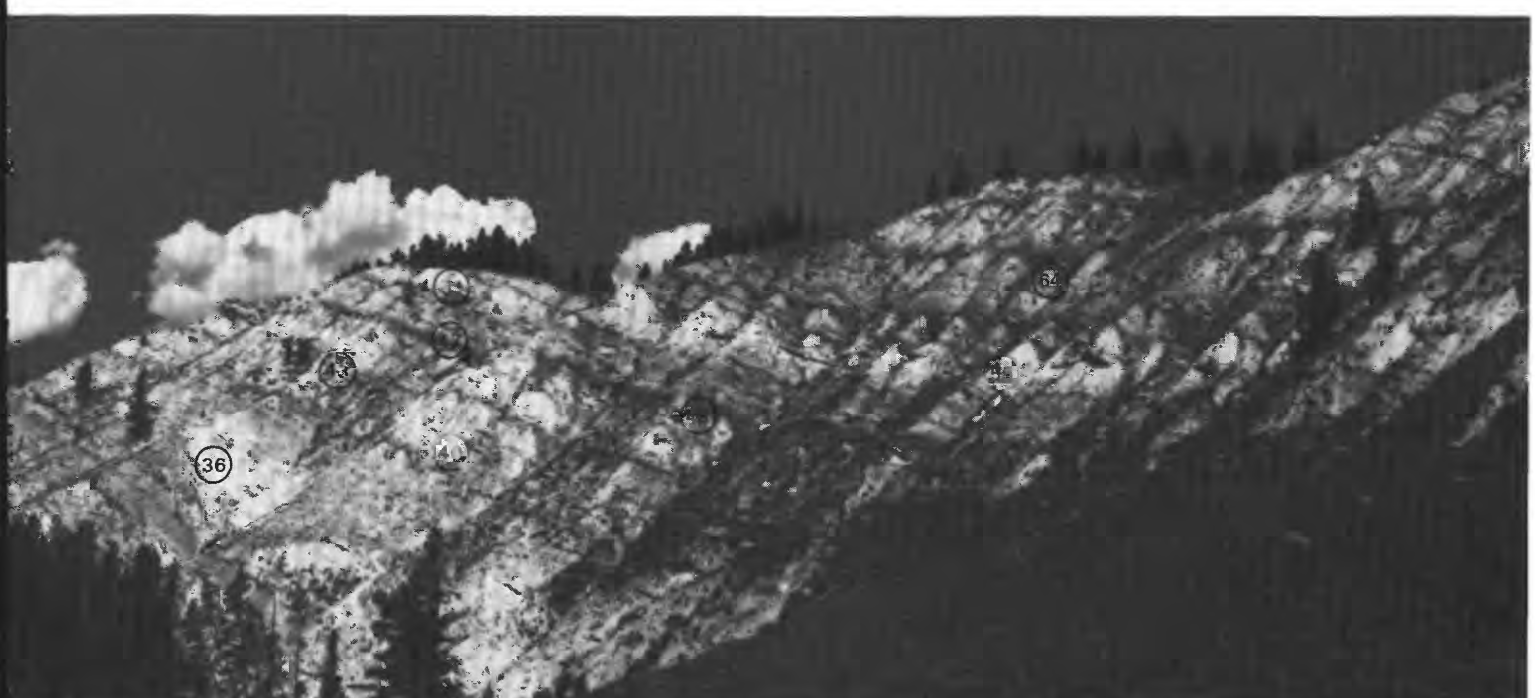


FIGURE 9.—View north-northwest at middle part of type

type section of Devils Basin Formation (Tdb) and the basal beds of the overlying Wind River Formation (Twdr). Numbers refer to unit numbers in the type section. Photograph by J. D. Love, July 29, 1981.



section of Devils Basin Formation. Numbers refer to unit members in the type section. Unit 47 is the oil-stained limestone. Photograph by J. D Love, Sept. 9, 1982.

Type section of the Devils Basin Formation—Continued

Devils Basin Formation—Continued	*Thickness (feet)*
19. Shale, claystone, siltstone—Continued 22269). The following additional collections were made by D. W. Taylor in 1963 from this zone (table 3): M2646—Massive ledge-forming sandstone. M2645—Platy gray carbonaceous sandstone 6 in. thick, 2 ft below M2646. M2644—Concretions from shaly mudstone, 15 ft stratigraphically below M2645	
Thickness of unit 19	190
[Offset 500 ft southeast on top of unit 18 from top of hill to creek level]	
18. Mudstone, bluish-gray, limy, very fine grained, very hard, brittle; conchoidal fractures; contains abundant fossil leaves in local concentrations, identified as *Taxodium occidentale* Newberry (=*Metasequoia occidentalis* Newberry, Chaney), *Cercidiphyllum arcticum* (Heer) Brown, *Vitis* sp., *Viburnum* sp. cf. *antiquum* (Newberry) Hollick, and a freshwater snail (table 3, USGS 22270)	2
17. Shale and sandstone, gray, soft	10
16. Sandstone lens, brown, coarse-grained; about 50 ft long; contains abundant limestone and clay pellets. This is the site and bed designated by McKenna (1980) as "Love quarry." Table 2 lists the vertebrate fossils (USGS 22271) found, and table 3 lists the invertebrate fossils (USGS 22271)	5
15. Sandstone, brown, coarse-grained; contains numerous dark grains	15
14. Sandstone, shale, and claystone; interbedded in about equal amounts. Shale is brown, claystone pale green, and sandstone pale yellow to pale green	100
13. Sandstone, tan; contains abundant large brown concretionary structures	30
12. Claystone and shale, greenish-brown, blocky, soft	50
11. Sandstone, tan, coarse-grained; numerous dark grains; one highly rounded quartzite boulder 8 in. in diameter near base of unit	30
10. Claystone and shale, green to brown; slightly carbonaceous in some zones	50
9. Sandstone, tan, fine to medium-grained	5
Approximate total thickness of type section of Devils Basin Formation	1,502±

[Contact between Devils Basin Formation and underlying Pinyon Conglomerate arbitrarily picked at top of highest major quartzite clast conglomerate bed (fig. 10). This is the same horizon used by Love (1973) but is higher than that previously picked (Love, 1947) at top of unit 1. Regional mapping indicated that the highest major conglomerate is the most useful horizon to separate the two formations]

Pinyon Conglomerate (part):	*Thickness (feet)*
8. Conglomerate, brown; consists of highly rounded clasts of quartzite and other hard siliceous rocks, with average size about 3 in., in a coarse-grained sandstone matrix. Abundant percussion scars are on pebbles, which are fractured and recemented. The matrix contains sparse small flakes of gold	75
7. Shale and claystone, pale-green, soft	20
6. Sandstone, tan, medium- to coarse-grained; forms cliff	50
5. Shale and claystone, pale-green, in lower third; sandstone and quartzite-clast conglomerate, tan to brown to gray in upper two-thirds	100
4. Shale and claystone, pale-green, sandy, soft	20
[Offset 2,800 ft southeast on top of unit 3]	
3. Sandstone, gray, moderately hard, medium-grained, porous; forms cliff; exposed at mouth of Devils Basin Creek	50
2. Sandstone, tan, pale-green shale and claystone, and thin lenticular quartzite-clast conglomerate, interbedded	200
1. Conglomerate, brown to tan; main body, composed chiefly of highly rounded quartzite clasts in a coarse-grained brown sandstone matrix; poorly bedded; contains few gray and tan sandstone lenses. The conglomerate matrix contains sparse small flakes of gold. (For appearance of this unit, see Love, 1973, fig. 30, about 2.5 mi down the South Fork Fish Creek from the mouth of Devils Basin Creek	1,000+
Approximate total thickness of measured part of Pinyon Conglomerate	1,515+

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The top of the type Devils Basin Formation is arbitrarily picked at the top of the highest prominent sandstone which also marks the base of the thick overlying soft carbonaceous and gray shale of the Eocene Wind River Formation. Within 2–3 mi to the north, this overlying somber sequence intertongues laterally with the lower variegated claystone and sandstone sequence in the Wind River Formation (Love, 1947; figs. 6, 7). There is probably no unconformity between these formations.

The contact between the Devils Basin Formation and the underlying Upper Cretaceous and Paleocene Pinyon Conglomerate is arbitrarily picked at the top of the highest major quartzite clast conglomerate (fig. 10). Regional mapping suggests that these two formations intertongue and that the contact is picked at different horizons from one locality to another. This is exemplified by the contrast between the sharp contact on the North Fork Fish Creek (fig. 11) and the transitional contact 9 mi north near the head of the South Fork Spread Creek. About 1 mi south of the head of South Fork the Devils Basin Formation disappears under the Tripod thrust fault. There is probably no time break or unconformity at the base of the Devils Basin Formation.

AGE AND CORRELATION

The Devils Basin Formation is of late Paleocene (middle Tiffanian) age (McKenna, 1980, p. 327). This age assignment is based on a large and varied assemblage of vertebrate fossils from "Love quarry" (unit 16; table 2)

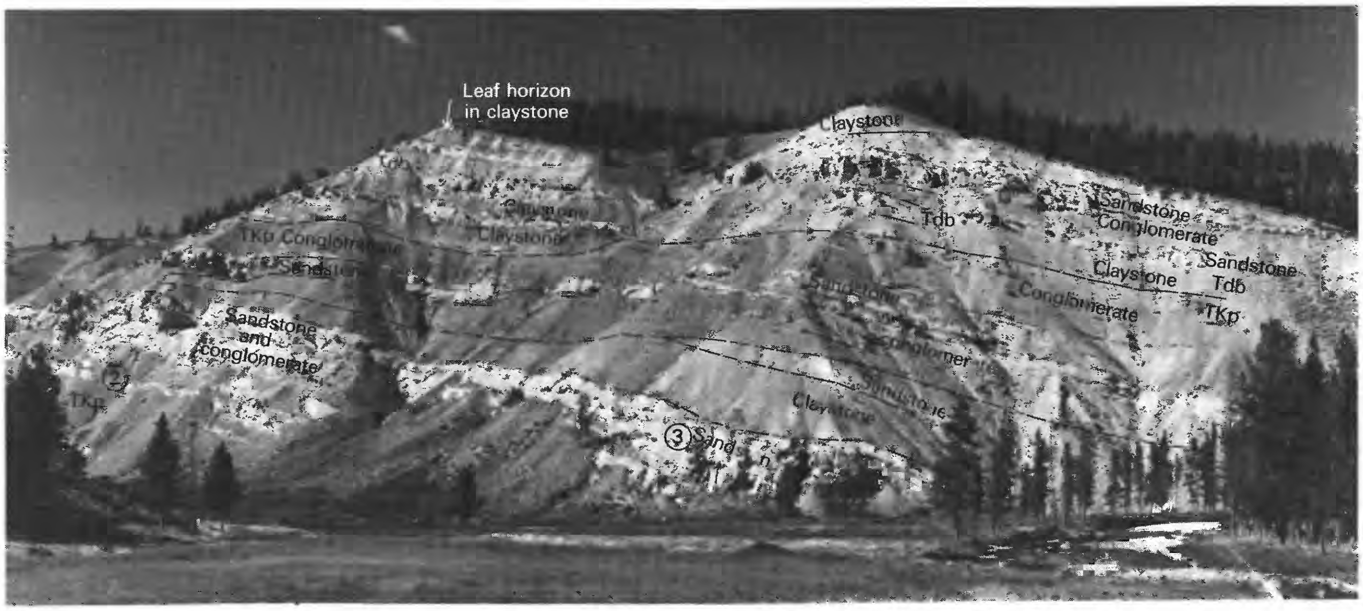


FIGURE 10.—View north across South Fork Fish Creek north of the mouth of Devils Basin Creek, showing contact relations of basal beds of type Devils Basin Formation (Tdb) and Pinyon Conglomerate (TKp). Site is shown at bracket in figure 6. Numbers refer to unit numbers in type section of the Devils Basin Formation. Green and gray sandstones and claystones, similar to those in the Devils Basin Formation, are interbedded with quartzite-clast conglomerate in the upper part of the Pinyon Conglomerate. Photograph by J. D. Love, Aug. 22, 1966.

FIGURE 11.—Contact between upper 150 feet of Pinyon Conglomerate (TKp) and Devils Basin Formation (Tdb) in the Burnt Mountain 7½-minute quadrangle, Teton County. View is east across North Fork Fish Creek, directly upstream from mouth of Harness Gulch (barely visible at right margin). Devils Basin Formation subdivided as follows: A, tan sandstone (15 ft); B, green claystone (10 ft); C, tan sandstone (75 ft); D, gray sandstone and siltstone (30 ft); E, gray siltstone (30 ft); F, tan sandstone (7 ft); G, green claystone (10 ft); H, gray sandstone (20+ ft). Photograph by J. D. Love, July 20, 1945.

TABLE 2.—*Middle Tiffanian (late Paleocene) vertebrate fossils from "Love quarry," unit 16 in type section of Devils Basin Formation*

[USGS collection No. 22271. Identified by McKenna (1980). For location, see figures 1, 6, and 7]

Fish	Primates:
Amphibian	*Zanycteris paleocenus*
Crocodilian	?*Paromomys depressidens*
Turtle	*Ignacius frugivorus*
Glyptosaurine anguid lizard	*Carpodaptes hobackensis*
cf. *Odaxosaurus* or	*Plesiadapis rex*
Proxestops jepseni	Carnivora:
Multituberculata:	*Didymictis* sp.
Neoplagiaulax fractus	Condylarthra:
Ectypodus powelli	*Thryptacodon antiquus*
cf. *Prochetodon cavus* or	*Mimotricentes subtrigonus*
Ptilodus sp.	*Phenacodus grangeri*
Small eutherians:	*Phenacodus* cf.
Mckennatherium cf. *M. ladae*	*P. brachypternus*
Leptacodon sp.	*Ectocion* (including
cf. *Litolestes notissimus*	*Gidleyina*) sp.
cf. *Elpidophorus elegans*	*Protoselene* cf. *P. opisthacus*
?*Mixodectes* sp.	*Promioclaenus*
?*Prodiacodon* sp.	cf. *P. aquilonius*
Propalaeosinopa thomsoni	*Litomylus* sp.

near the base of the type section, and on vertebrate fossils of late(?) Tiffanian or Clarkforkian (earliest Eocene-latest Paleocene) age in a drab claystone sequence near the base of the Wind River Formation (fig. 7, loc. A). This site is 2 mi northwest of the type Devils Basin Formation (McKenna, 1980). In addition to the vertebrate fossils, the Devils Basin Formation has yielded fossil leaves at several localities (Love, 1947) and many zones of mollusks, the most significant of which and their localities are listed in table 3.

The Devils Basin Formation is the same age as part of the Fort Union Formation of the Bighorn Basin (McKenna, 1980), the same age as part of the Shotgun Member of the Fort Union Formation in the Wind River Basin (Keefer, 1965), and the same age as the lower part of the Hoback Formation (Dorr and others, 1977), 25 mi to the southwest in the Green River Basin, on the opposite side of the Gros Ventre Range. Each of these sequences was deposited largely or entirely in a separate basin of deposition and under different environmental conditions. Active tectonism around these other basin margins resulted in floods of locally derived debris with many and varied facies. In contrast, the Devils Basin Formation represents an interval of quiet sedimentation. Possibly correlative strata were penetrated by the Gulf well along the northeast margin of the Green River Basin 28 mi south of the type Devils Basin Formation—as previously mentioned. The relation of strata in the Gulf well to the Hoback Formation, 25 mi west of the well, is not known, but the source of sediment at the two sites was not the same.

Shortly after Paleocene time, in all directions from this basin of deposition very complex tectonic events occurred and have disguised or obliterated much of the late Paleocene history.

SHOOTING IRON FORMATION

NAME AND DEFINITION

The Shooting Iron Formation is named after the Shooting Iron Ranch which is adjacent to the type section (figs. 1, 12–16), in the South Park area of southern Jackson Hole, southwest of the town of Jackson. The fossiliferous type section was mapped (Love and Albee, 1972) and called "lacustrine deposits near Shooting Iron Ranch (Pleistocene)." (See discussion herein on age and correlation for current assignment of this unit to the Pliocene.) A second fossiliferous section, with a different, deep-water lacustrine invertebrate fauna (fig. 1, loc. Tsi3; figs. 17, 18), near Botcher Hill north of Jackson, was mapped and described as "unnamed Pleistocene strata" (Love and Taylor, 1962). A third fossiliferous section along Boyle Ditch has a land snail assemblage (fig. 1, loc. Tsi4; figs. 19–21); this third section had been called the uppermost part of the type Teewinot Formation (Love, 1956a, b, c; Taylor, 1966). Later, after detailed mapping showed that the uppermost part was a different sequence, it and the adjacent lacustrine deposits were called "lacustrine deposits like those at the Shooting Iron Ranch (Tertiary)" (Love, 1975). A fourth fossiliferous section (fig. 1, loc. Tsi5; fig. 22) was mapped on the east side of Jackson Hole and is here referred to as Old Miller Cabin reference section. An unfossiliferous remnant was mapped at an elevation of nearly 10,000 ft on the Gros Ventre Range (C. M. Love and J. D. Love, 1978; fig. 23) and called "strata like those at the Shooting Iron Ranch (Pliocene);" this section is here referred to as the Granite Creek Divide reference section (fig. 1, loc. Tsi6).

In addition to these remnants, at least eight other small outcrops and two drill holes show similar strata. Possibly more than one formation is represented by these remnants, but their distinctive lithology suggests that they are all related to the same episode of deposition.

DISTRIBUTION AND THICKNESS

Except for one small outcrop of dubious correlation, on the west shore near the north end of Jackson Lake, all known occurrences of the Shooting Iron Formation are in southern Jackson Hole and on the top and west

TABLE 3.—*Invertebrate fossils in the Devils Basin Formation, Teton County, Wyoming*

[Fossils identified by D. W. Taylor (1975). Query (?) indicates identification uncertain; leaders (...), not found]

	U.S.G.S. collection numbers									
	20324	22266	22267	22268	22269	22270	22271	M2644	M2645	M2646
Freshwater clams										
Plesielliptio mendax (White)	...	...	...	...	?	...	?	...	X	X
Sphaerium sp. indet	...	X	X	...	...	...	...	...	...	...
Pisidium sp. indet	...	...	...	X	...	...	...	...	...	...
Eupera sp. indet	...	...	X	X	...	...	...	...	...	...
Freshwater snails										
Payettiidae, n.g. b and n. sp.	...	X	X	...	...	...	...	...	...	...
Valvata sp. indet	...	X	X	...	...	...	...	...	...	...
Bellamya sp. indet	X	...	X	...	X	...	...	X	X	X
N. Gen. A of the Lioplacinae	...	...	...	...	X	...	X	...	X	...
Reesidella nana (White)	...	X	X	...	...	...	X	...	...	...
Cleopatra multistriata (Meek & Hayden)	?	...	X	...	X	...	...	...	X	X
Cleopatra tenuicarinata (Meek & Hayden)	...	...	...	...	...	...	...	...	X	...
Micropyrgus? sp. indet	?	X	X	X	X	...	...	...	...	X
Pleurolimnea tenuicosta (Meek & Hayden)	X	...	X	...	X	...	?	...	...	X
Physa cf. *P. bridgerensis* Meek	...	...	...	...	X	X	X	...	...	X
Land snail										
Indeterminate	X	...	...	...	...	...	...	...	...	...

COLLECTION LOCALITIES

U.S.G.S. Collection No.	Field No.	Remarks
20324	L–2c	SW¼ sec. 9, T. 41 N., R. 110 W. (fig. 5). Unit 19 in type section. Collectors: H. R. Bergquist and J. D. Love, 1945. Cited by Love (1947, section 14; 1956a, p. 85).
22266	L–39	SW¼SW¼ sec. 21, T. 43 N., R. 111 W. Cutbank on east side of Cottonwood Creek; section 9 of Love (1947). About 100 ft above Pinyon Conglomerate. Collectors: H. R. Bergquist and J. D. Love, 1945. Cited by Love (1947; 1956b, p. 85).
22267	B–4	Southwest corner sec. 11, T. 42 N., R. 111 W. Gray shaly-weathering claystone at bend in creek, on east side of North Fork of Fish Creek about 2.75 mi above junction with South Fork of Fish Creek. Section 10 of Love (1947); about 275 ft above Pinyon Conglomerate. Collectors: H. R. Bergquist, 1945; D. W. Love, J. D. Love, and D. W. Taylor, 1961. Cited by Love (1947; 1956b, p. 84).
22268	L–2d	SW¼ sec. 9, T. 41 N., R. 110 W. (fig. 5). Unit 19 in type section. Black shale between localities 22269 and 20324 and just below 20324. Section 14 of Love (1947). Collectors: H. R. Bergquist and J. D. Love, 1945. Cited by Love (1947; 1956b, p. 85); Love, Keefer, Duncan, Bergquist, and Hose (1951, sheet 2).
22269	L–2b	SW¼ sec. 9, T. 41 N., R. 110 W. (fig. 5). Unit 19 in type section. About 0.25 mi southeast of mouth of Devils Basin Creek on north side of Fish Creek; section 14 of Love (1947). Collectors: H. R. Bergquist and J. D. Love, 1945. Cited by Love (1947; 1956b, p. 85); Love, Keefer, Duncan, Bergquist, and Hose (1951, sheet 2).
22270	L–2	SW¼ sec. 9, T. 41 N., R. 110 W. Section 14 of Love (1947). Collectors: H. R. Bergquist and J. D. Love, 1945. Cited by Love (1947; 1956b, p. 85); Love, Keefer, Duncan, Bergquist, and Hose (1951, sheet 2).
22271	L–2a	SW¼ sec. 9, T. 41 N., R. 110 W. Section 14 of Love (1947). Collector: J. D. Love, 1945. Cited by Love (1947; 1956b, p. 85); Love, Keefer, Duncan, Bergquist, and Hose (1951, sheet 2). Subsequent collection by M. C. McKenna, D. W. Taylor, and others, 1963.
M2644	T63–94	SW¼ sec. 9, T. 41 N., R. 110 W. Concretions from shaly mudstone, about 15 ft stratigraphically below locality M2645. Collector: D. W. Taylor, 1963.
M2646	T63–93	Same locality as collection M2644. Massive ledge-forming sandstone, 2 ft stratigraphically above locality M2645. Collector: D. W. Taylor, 1963.
M2645	T63–92	Same locality as collection M2644. Platy gray carbonaceous sandstone about 6 in. thick, 2 ft stratigraphically below locality M2646. Collector: D. W. Taylor, 1963.

flank of the Gros Ventre Range. The thickest section, about 300 ft, was penetrated in a well drilled for water at the Dejanikus property west of Jackson (fig. 1, loc. Tsi2). Other partial sections are much thinner; the type section at Shooting Iron Ranch is nearly 70 ft; the reference sections are (1) at Botcher Hill, 25 ft; (2) at Boyle Ditch, 155–160 ft; (3) at Old Miller Cabin, 56 ft; and (4) at Granite Creek Divide, 72 ft. Although precise records were not kept on the Jackson town water wells, the well farthest north, about 2,000 ft north of the town boundary, encountered pink tuffaceous claystone typical of the Shooting Iron Formation at a depth of more than 150 ft.

LITHOLOGY

Measured reference sections (figs. 12–16), Botcher Hill (figs. 17, 18), Boyle Ditch (figs. 19–21), Old Miller Cabin (fig. 22), and Granite Creek Divide (fig. 23) show the lithology and outcrop appearance of the Shooting Iron Formation. As expected in lacustrine and lake-margin deposits surrounded by mountains, lithology varies considerably at and between each locality, depending on the nature of locally available clastic debris. Most clasts in the conglomerates are locally derived. Several distinctive lithologies are present at most localities, and these help distinguish the Shooting Iron Formation from the underlying stratigraphic units: (1) Many beds contain abundant, brightly colored (red, green, yellow, brown, black, and so on) sand grains, mostly of volcanic-rock fragments or minerals; (2) most outcrops have beds, lenses, and blebs of bright-lemon-yellow and (or) bright-green bentonitic claystone; and (3) red and green very soft bentonitic claystones are common. The source of most volcanic debris is not known, but the andesite at the Botcher Hill locality must have been from the north end of East Gros Ventre Butte because its lithology is identical to that of the outcrop of andesite across the fault. The petrography of other volcanic constituents has not been studied in detail.

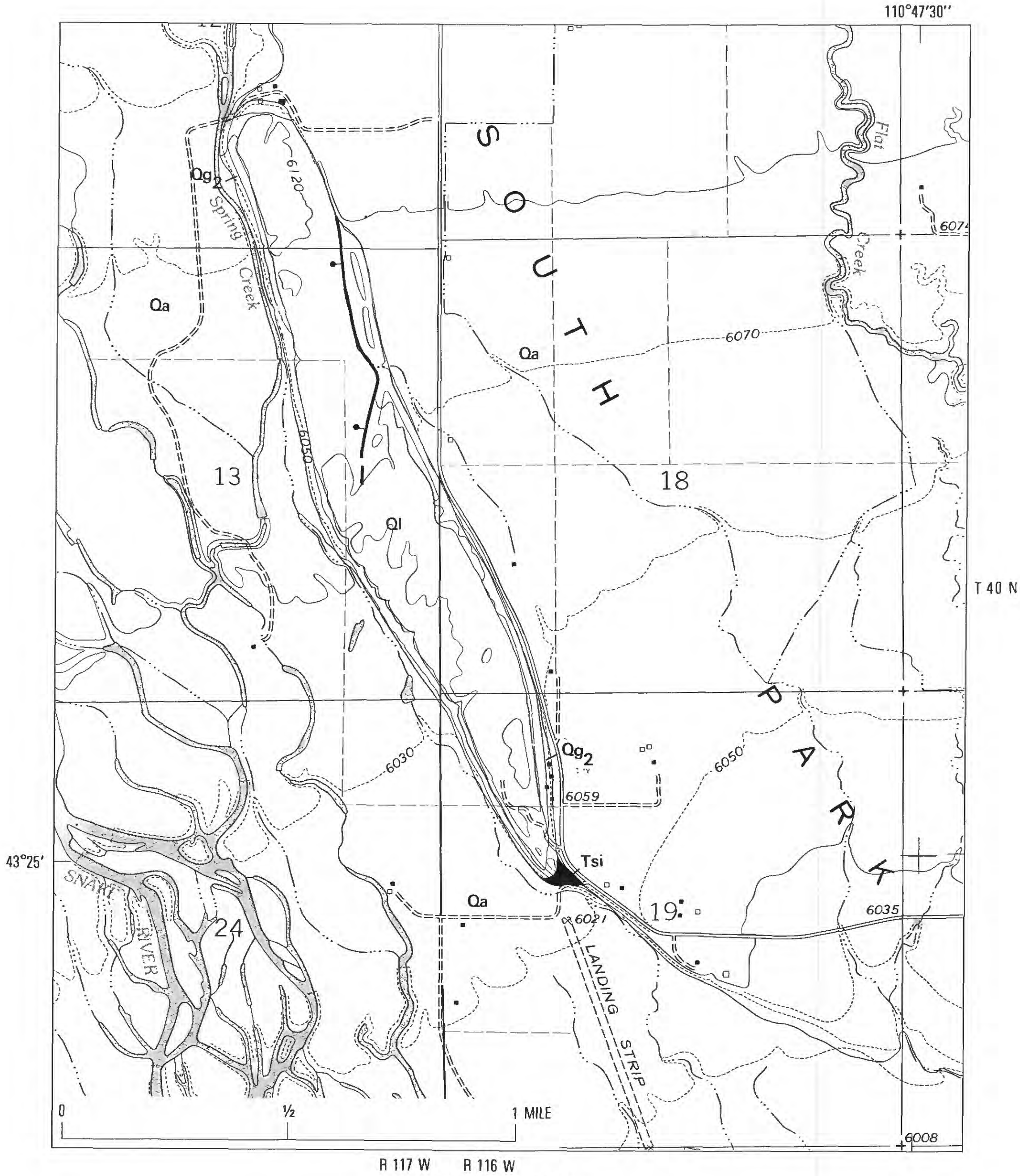
TYPE SECTION

The type section of the Shooting Iron Formation (fig. 12) was measured with steel tape along a fresh roadcut in sec. 19, T. 40 N., R. 116 W., 500 ft west of the Shooting Iron Ranch buildings. (For geology, see Love and Albee, 1972.) The section was measured by J. D. Love, Sept. 5, 1957, with supplementary studies in 1963, 1969, and 1978. Exposures are at the south end of an elongate hill (fig. 13) locally known as "Martha's Mountain," after Martha Hufsmith who lived at the Shooting Iron Ranch at the time the section was first described. Strike is about east-west, dip 12° north. Mollusks were identified by D. W. Taylor. Many samples were collected for pollen and diatom study, but no reports have been made. Unit 1 is oldest.

Type section of the Shooting Iron Formation

[Measured in sec. 19, T. 40 N., R. 116 W., Jackson 7½-minute quadrangle, Teton County, Wyo. Section is along a roadcut 1,500 ft east of the west line and 2,000 ft south of the north line of sec. 19. See locality Tsi1, figure 1]

	Thickness (feet)
Pleistocene glacial deposits:	
20. Outwash debris from glaciation 2 (Love and Albee, 1972 numbered the glaciations, with 1 the oldest); boulder- to sand-size clasts, coarsely stratified, composed chiefly of quartzite roundstones; considerably slumped; contains sparse high-spired gastropods, too few to provide a ^{14}C age determination	25+
Shooting Iron Formation:	
19. Claystone, dark-gray, tough, plastic, very fine grained; looks like an underclay	2.0
18. Sandstone, greenish-gray, fine-grained, silty; soft limonite stain at top. Contains sparse mollusk shell fragments	0.4
17. Conglomerate, reddish-gray, fine-grained; average clast size less than 1 in.; crudely stratified, much red rock; looks like basal part of unit 10. Many clasts are of hard volcanic rock; few are of quartzite. Some lenses of sandstone are as much as 2 ft thick in lower part. Conglomerate has sand matrix; many flat pebbles, few more than 2 in. long. Yellow iron stain in top 1 ft	12
16. Claystone, chocolate-brown, blocky, soft; abundant moderately well preserved mollusks in upper 3 in. Fossil zone C (figs. 14, 15)	1.5
15. Siltstone and very fine grained sandstone, reddish-brown on fresh surfaces, massive, soft; grades up to overlying unit	3
14. Conglomerate, reddish-gray, fine-grained; average size of clasts 1 in. or less, rounded; composition about the same as in lower part of unit 10. Conglomerate has a sand matrix and contains thin lenses of sandstone	5
13. Claystone, green, finely blocky, plastic when wet, soft. Contains sparse mollusks	1
12. Sandstone, light-green, mottled rusty, very fine grained, silty	2
11. Sandstone, brown, medium-grained, soft, massive; many black and red grains	2.5
10. Conglomerate, rusty-brown, soft, poorly cemented; coarse sand matrix. Contains a variety of rounded pebbles, average less than 1 in. in size, rarely as much as 4 in. except near the top where they reach 8 in. Some clasts of Amsden chert, red Chugwater siltstone, many volcanic rocks; sparse quartzite. Several beds of siltstone	13
9. Siltstone, light-gray, sandy, massive, soft; forms a parting between two conglomerate beds	1.5
8. Conglomerate, rusty-brown, soft, poorly cemented; coarse sand matrix; a variety of rounded pebbles with average size less than 1 in., rarely as much as 4 in.; chiefly Precambrian, Paleozoic, and Mesozoic rock clasts, with some volcanic rocks. Some rounded coal fragments	7.5



EXPLANATION

QUATERNARY		Qa	Alluvium and flood-plain deposits
		Ql	Loess
		Qg2	Deposits of glaciation 2
TERTIARY	Pliocene	Tsi	Shooting Iron Formation

Contact

Fault—Dashed where approximately located. Bar and ball on downthrown side

FIGURE 12.—Type locality of the Shooting Iron Formation. Geology from Love and Albee (1972). Base from U.S. Geological Survey Jackson 7½-minute quadrangle, 1963, scale 1:24,000.

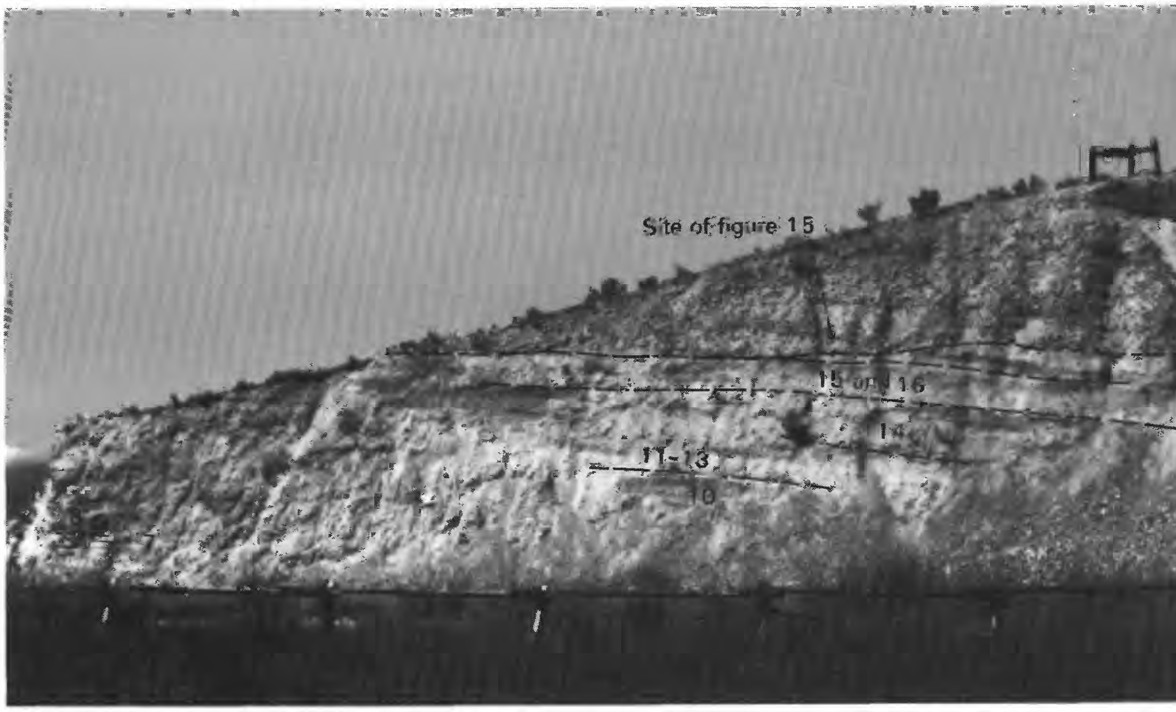


FIGURE 13.—View west at most of type section of Shooting Iron Formation on east side of Martha's mountain (fig. 1

Type section of the Shooting Iron Formation—Continued

Shooting Iron Formation—Continued	*Thickness (feet)*
7. Siltstone and very fine grained sandstone in lower half, light-brown to tan, massive, blocky, sparsely fossiliferous. Upper half grades to silty claystone, slightly darker brown than below; abundant mollusks. Fossil zone B (fig. 16). Both high- and low-spired gastropods are present. Thickness uneven because of truncation by overlying conglomerate	4.0–7.5
6. Claystone, dark-brownish-gray; almost black near top, silty, limy, plastic near top. Abundant shells throughout, both gastropods and the clam *Pisidium*. Fossil zone A (fig. 16)	3.4
5. Sandstone, olive-drab, soft, poorly cemented; coarse grained where sampled but grades to siltstone and fine-grained sandstone 20 ft to west. Abundant red and black grains and appears to be a volcanic sandstone	2
4. Claystone and siltstone, pink and brown; pink is the finest textured; interbedded	2.2
3. Siltstone and sandstone, brown, fine-grained, massive, soft; 1-in. pink claystone bed at base	1.4
2. Sandstone, brown, with red partings, medium-grained, soft, poorly cemented, homogeneous, massive; abundant red, black, and clear grains; probably a volcanic sandstone; a remarkable rock because of the brightly colored grains, similar to sandstones in the correlative sequence to the northeast	1
1. Claystone, reddish-brown, tough, slightly gritty; carves easily into coherent blocks with knife	1+
Total thickness of exposed part of Shooting Iron Formation	66.4–69.9

Underlying rocks not exposed below level of roadcut.

BOTCHER HILL REFERENCE SECTION

The Botcher Hill reference section (fig. 1, loc. Tsi3; fig. 17) of the Shooting Iron Formation was measured with steel tape and level by J. D. Love, Aug. 15, 1961, in sec. 11, T. 41 N., R. 116 W., Teton County. At the time of measurement, the strata were exposed in fresh roadcuts (fig. 18) but by 1983 most of the exposures were obliterated by slumping and vegetation cover. Photographs, geologic maps, cross section, fossils, and stratigraphy of this section were discussed by Love and Taylor (1962), and the strata were called Pleistocene. With the revision of the Pliocene-Pleistocene boundary to conform to the world time scale, these strata are now assigned to the Pliocene. Mollusks were identified by D. W. Taylor. Post-Shooting Iron strata are included in the measured section in order to show the complex stratigraphic relations. Units are numbered consecutively with 1 the oldest.

loc. Tsi1). Numbers refer to unit numbers in measured section. Sites of figures 14 and 15 are indicated. Five-foot fence post on skyline shows scale. Photograph by J. D. Love, Sept. 5, 1957.

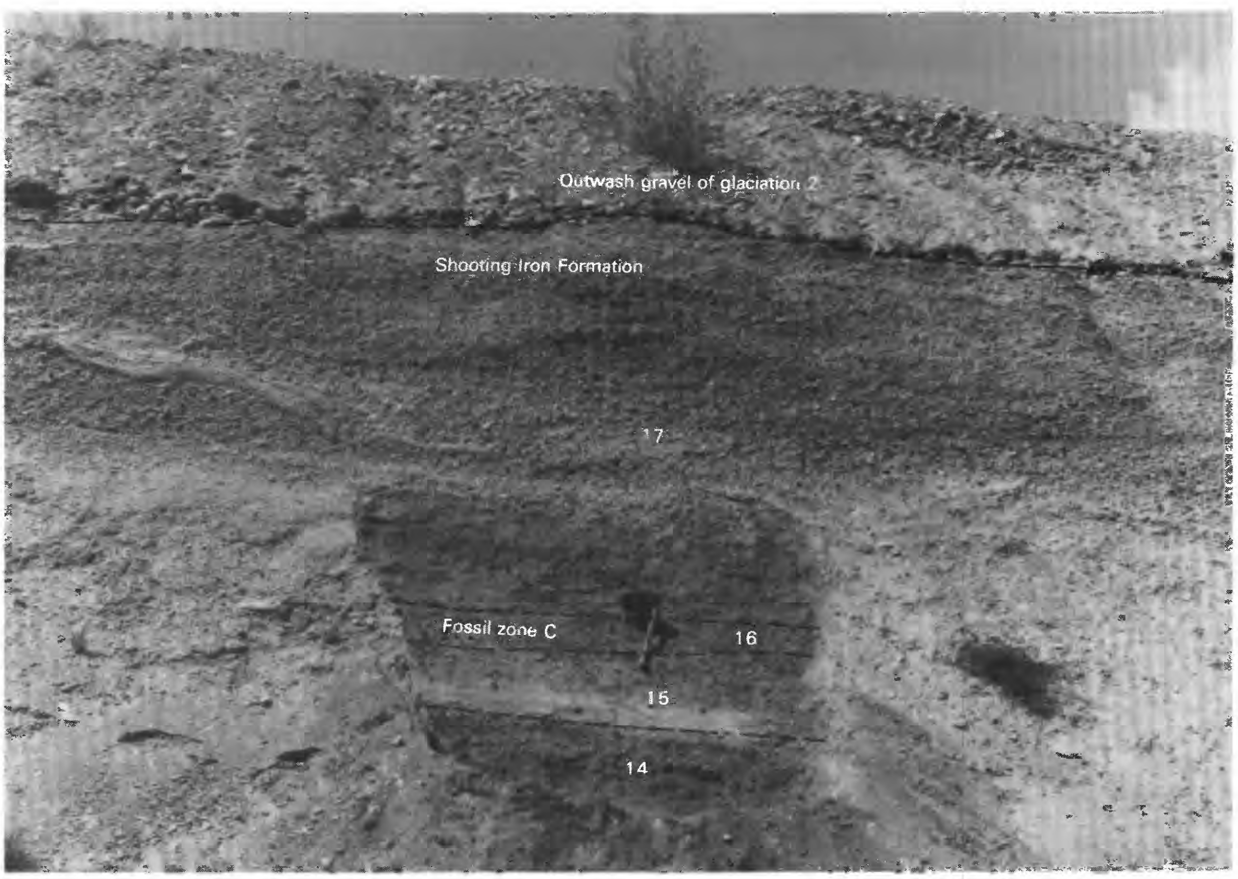


FIGURE 14.—Detail of lithology in upper part of type section of Shooting Iron Formation. Site of photograph is indicated on figure 13. Numbers refer to unit numbers in measured section. Twenty-inch shovel handle shows scale. Photograph by J. D. Love, Sept. 5, 1957.

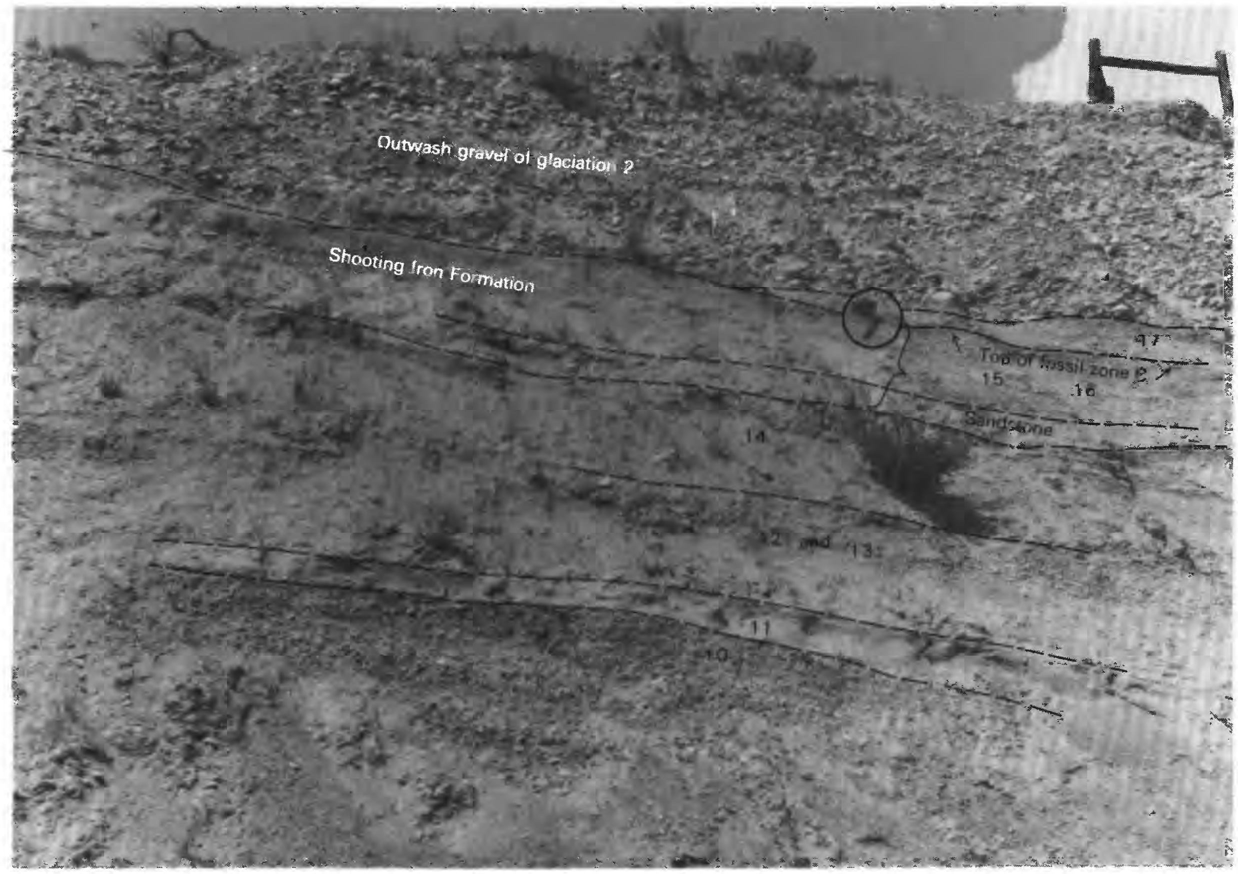


FIGURE 15.—Detail of lithology in middle part of type section of Shooting Iron Formation in roadcut near south end of Martha's mountain shown in figure 13. Numbers refer to unit numbers in measured section. Twenty-inch shovel handle (in circle) shows scale. Photograph by J. D. Love, Sept. 5, 1957.

Botcher Hill reference section of Shooting Iron Formation

[Measured in sec. 11, T. 41 N., R. 116 W., Gros Ventre Junction 7½-minute quadrangle, 1968, Teton County, Wyo. Section was measured in roadcut in 1961, 1,400 ft south of the north line and 1,000 ft east of the west line of sec. 1]

	Thickness (feet)
Pleistocene loess deposits:	
18. Loess, light-gray to brown, mostly homogeneous. The top 5 ft is a mixture of brown soil and loess, underlain by 7 ft of loess, then 1 ft of dark-gray soil or loess, then 2 ft of gray loess, then 1 ft pupillidae snail zone, whose shells yielded a ^{14}C age of 19,000±600 years B.P. (Field No. L63-90; Lab. No. W-1560; Meyer Rubin, written commun., 1965; see also Love and others, 1965, p. 40). Below this is 8 ft of gray loess. Sequence has a slight dip to east or northeast	24
[Angular unconformity; about 25 ft of underlying sequence is cut out southward within a horizontal distance of 100 ft]	
Outwash of glaciation 3:	
17. Silt or soil, brown, dusty; loesslike in part, in 1-ft massive beds containing pebble, cobble, and boulder lenses, chiefly of volcanic rock fragments, interbedded with about an equal number of lenticular 1-ft beds of gravel; some andesite boulders as much as 2 ft in diameter are present, but the average clast size is about 2 in.	10

Botcher Hill reference section of Shooting Iron Formation—Continued

	Thickness (feet)
Outwash of glaciation 3—Continued	
16. Soil, dark-brown; massive in lower 2 ft, merges up into dark-gray and black soil in upper 1 ft; sporadic volcanic rock fragments ranging in size from granules to boulders; one 2-in. black obsidian clast noted; sparse bone fragments, including end of a large ulna of *Bison bison*. Strike N. 20° E., dip 15° SE.	3
15. Gravel; chiefly Pinyon-type quartzite clasts and some angular volcanic rock fragments	0–1
14. Clay, silt, sand, and gravel; at base is 3 in. of medium, gray, shard-bearing unconsolidated sand; overlain by 3 in. of dusty silt and laminated pink to green fine-grained claystone; remainder of unit is crossbedded sand, gravel lenses, thin-bedded sand and silt, and dusty massive loesslike silt; is lowest prominent ledge above basal slope of sequence	3
13. Gravel, unconsolidated; reddish-brown to black porphyritic andesite boulders as much as 3 ft in diameter, angular to subrounded, in matrix of smaller volcanic rock fragments and Pinyon-type rounded quartzite clasts; flattish boulders are	

FIGURE 16.—View north at lower strata in type section of Shooting Iron Formation. Promontory at right margin of photograph is same as at left margin of figure 13. Numbered units and fossil zones are described in measured section. Conspicuous grooves are bulldozer scour lines, not bedding. Heavy dashed line, fault; arrows indicate direction of movement. Twenty-inch shovel handle (in circle) shows scale. Photograph by J. D. Love, July 24, 1963.

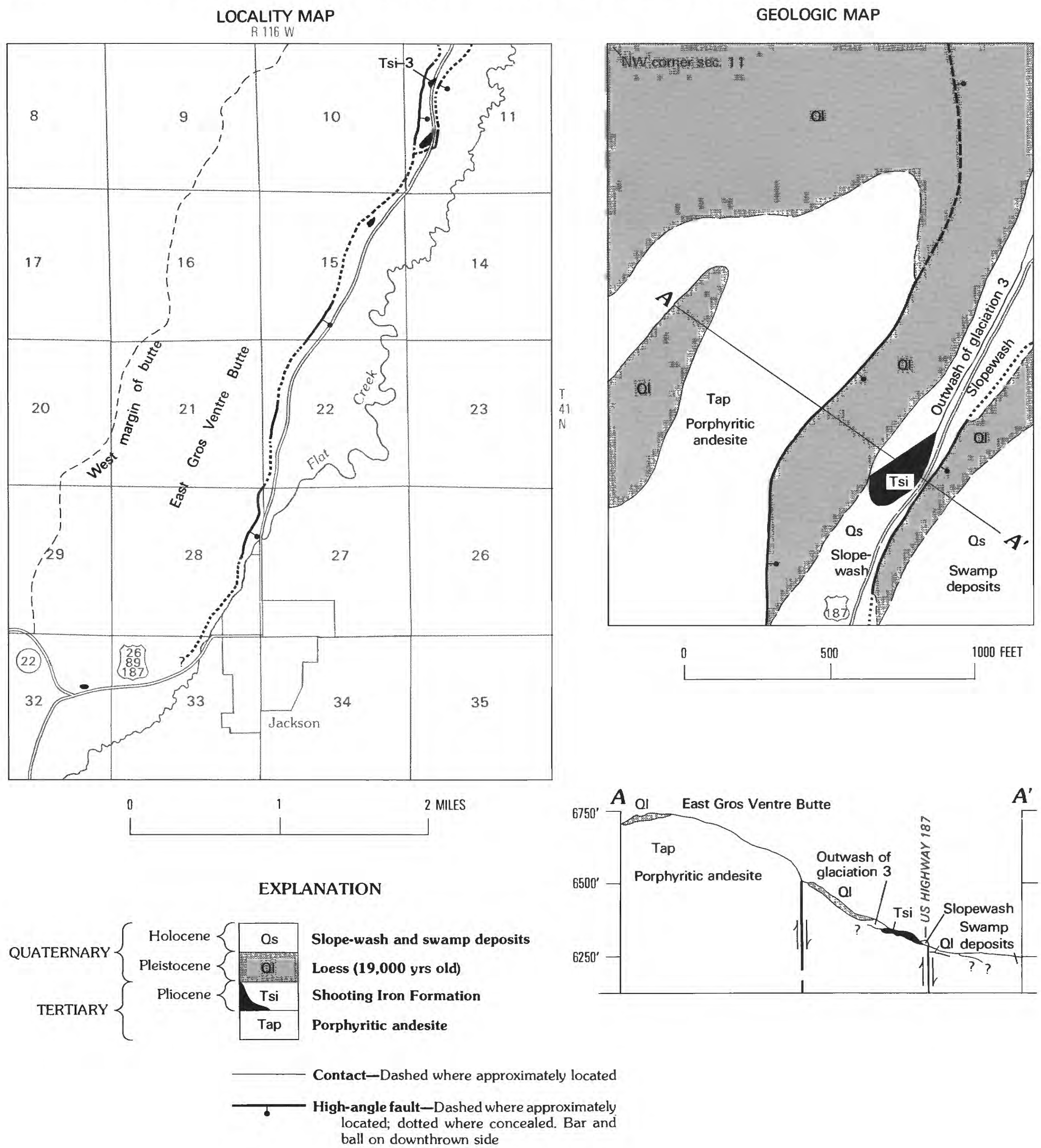


FIGURE 17.—Geologic sketch map and cross section of Shooting Iron Formation at Botcher Hill reference section (fig. 1, loc. Tsi3; fig. 18), and other sites along east margin of East Gros Ventre Butte. Modified from Love and Taylor (1962).

FIGURE 18.—Deep-water lacustrine beds at Botcher Hill reference section (fig. 1, loc. Tsi3) in Shooting Iron Formation, folded into gentle anticline delineated by main fossil zone (unit 6) and downfaulted against porphyritic andesite (Ta). Also shown are other unit numbers in measured section, outwash gravel of glaciation 3 (Qo_3), and younger loess (Ql) having a ^{14}C age of 19,000 years. From Love and Taylor (1962). Photograph by J. D. Love, Aug. 15, 1961.

Botcher Hill reference section of Shooting Iron Formation—Continued

Outwash of glaciation 3—Continued	*Thickness (feet)*
oriented, indicating depositing stream flowed south	10
Total thickness of glaciation 3 outwash and associated deposits	26–27

[Angular unconformity; about 10 ft of underlying sequence is cut out within a horizontal distance of 50 ft]

Shooting Iron Formation:	
12. Claystone, siltstone, sandstone, and conglomerate, intertongued, in about equal amounts, olive-drab, soft, massive; most fragments are angular, of red and black porphyritic andesite; size ranges from grit to small pebbles	5
11. Claystone, olive-drab, soft, blocky, finely pebbly; scattered red and black angular porphyritic andesite fragments	1
10. Grit, brown; composed of brown, red, and black angular fragments of andesite in tan soft sand matrix	0.3–0.6
9. Claystone, brownish-green, soft, blocky; sparse gastropods and pelecypods at base; gray limestone nodules as much as 3 in. in diameter at top; scattered grit- to pebble-size angular fragments of andesite throughout	2
8. Siltstone, light-rusty-gray, soft, massive; velvety appearance on surface	1
7. Conglomerate; black porphyritic andesite cobbles, pebbles, and grit fragments	0.3
6. Claystone, olive-drab, blocky, very soft; a layer of pelecypod shells at base and scattered in lesser numbers throughout unit; individual shells are as	

Botcher Hill reference section of Shooting Iron Formation—Continued

Shooting Iron Formation—Continued	*Thickness (feet)*
6. Claystone—Continued long as 3 in.; both valves are together, suggesting quiet water at time of burial. Unit is marked by dotted line in figure 18, showing that strata are gently folded into a north-trending anticline. Contains freshwater clam *Anodonta?* and freshwater snails *Valvata utahensis* Call and *Carinifex newberryi* (Lea) (Love and Taylor, 1962)	0.5–1
5. Grit, dark-reddish-brown, soft; composed of deeply weathered angular fragments of coarse porphyritic andesite; some fragments are 4 in. in diameter; matrix is olive-brown siltstone and sandstone	0.5
4. Claystone, dull-brownish-gray, blocky, soft; velvety sheen on surface; sporadic fragments of deeply weathered red porphyritic andesite as much as 6 in. in diameter; 1-in. layer of white limestone nodules that are hollow in center, with contraction cracks; sparse mollusks	1.3
3. Grit, dark-reddish-brown, soft; composed of deeply weathered angular fragments of coarse porphyritic andesite; most fragments are grit size, but some are 4 in. in diameter; matrix is olive-brown siltstone and sandstone	2
2. Siltstone, light-rusty-brown to gray, homogeneous, very soft, bedded; velvety sheen on surface; dusty when dry; contains sporadic granules and pebbles of porphyritic andesite	6
1. Conglomerate, siltstone, and claystone, dark-brown, soft, massive; 50 percent of unit is composed of angular to rounded fragments of dark-red and black porphyritic andesite as much as 6 in. in diameter but commonly grit size; remaining 50 percent is claystone and siltstone	4.5
Total thickness of measured part of Shooting Iron Formation	24.2–25.2

Underlying strata not exposed.

BOYLE DITCH REFERENCE SECTION

This section (figs. 19–21; fig. 1, loc. Tsi4) was measured by J. D. Love on Sept. 9, 1952, and was considered to be part of the type Teewinot Formation (Love, 1956a, b). Additional studies were made in 1964. The base of the section is on the southeast bank of Boyle Ditch, southeast of an old cabin site on the east edge of a meadow, about 1/4 mi northeast of the National Elk Refuge hay barn; the top is directly upstream from the headgate where the ditch goes into the pipeline, SE1/4 sec. 25, T. 42 N., R. 116 W., Teton County. Pollen samples were collected by and for E. B. Leopold in 1952, 1958, and 1962; vertebrate fossils identified by D. W. Taylor, C. W. Hibbard, and A. D. Barnosky (1985), and mollusks by D. W. Taylor. Sparse ostracodes are present. General strike is N. 16° E., dip 7° W. Unit 1 is oldest.

Boyle Ditch reference section of the Shooting Iron Formation

[Measured in SE¼ sec. 25, T. 42 N., R. 116 W., Gros Ventre Junction 7½-minute quadrangle, Teton County, Wyo. Top of section is on SE. bank of Boyle Ditch directly upstream from the headgate where the ditch goes into the pipeline]

	Thickness (feet)
Till of glaciation 2:	
35. Till, chiefly boulders of Paleozoic rocks and Pinyon-type rounded quartzite in hard white to pink very limy matrix	10+
Shooting Iron Formation:	
34. Claystone, pink, dense, blocky, smooth-weathering, tough; upper 8 ft mottled, limonitic, with some silty layers; thin bedded in part; stands in vertical wall of ditch; sparse ostracodes	20+
33. Claystone, gray, plastic, sticky, smooth, homogeneous, very fine grained, nonswelling, blocky; sparse ostracodes	14±
32. Siltstone, rusty-brown and gray, very limonitic, soft, clayey; grades up to overlying unit	1.3
31. Sandstone, dark-gray-brown, limonite-stained, very soft, almost uncemented, crossbedded, fine-grained; abundant red and black grains throughout	3.5
30. Siltstone, drab; limonite stain, sandy in part, clayey in part, soft, blocky	3.8
29. Claystone, dull-gray, very soft, blocky, sticky when wet	1.8
28. Siltstone, gray, rusty-stained; clayey in lower part, finely sandy in upper; very soft, blocky	1.8
27. Claystone, gray, weathers almost white, smooth, sticky, very fine grained, slightly calcareous to noncalcareous, blocky; forms conspicuous light-colored layer between two limonite-stained layers; one 5-in. rounded quartzite boulder embedded in claystone	1.5
26. Claystone, dull-gray; very fine grained and sticky in lower 3 ft; grades up to limonite-stained siltstone in top 1 ft; blocky, very soft	4
25. Siltstone, light-gray, very soft; interbedded with about equal amounts of drab, very fine grained sandstone, all thin bedded; some gray silty claystone layers; 2-in. limonitic silty very fine grained sandstone at top	6.5
24. Claystone, light-gray, limy, blocky; fine-grained and sticky in lower part, more silty in upper	1.8
23. Sandstone, rusty-brown and gray, limonite-stained, very soft, fine-grained, massive, homogeneous; abundant red and black grains	1.2
22. Claystone, gray, soft, sticky, dense, blocky, homogeneous	7
21. Claystone, pink, dense, blocky, fine-grained, homogeneous, laminated in part, ripple-marked (fig. 19)	12±

[Offset northeast, upstream from below weir in Boyle Ditch on unit 20 for this and older units]

20. Varved shale; bright-orange-red, brown, and gray laminae, 10–50 per inch; darker gray toward base; graded bedding (fig. 20). Sparse mollusks in lower part	1.6
19. Pumicite(?), gray, very fine grained, sparkly; laminated in lower half, massive in upper; soft, crumbly, dusty when dry, impure	0.5
18. Claystone, pale-pink, smooth, massive, blocky, very fine grained, homogeneous	2
17. Unit with variable lithology, chiefly light-drab very soft fine-grained sandstone with some granule and pea-gravel lenses. Upper 1 ft is thin-bedded crossbedded very soft fine-grained sandstone. Sparse mollusks in lower part	3.2–7

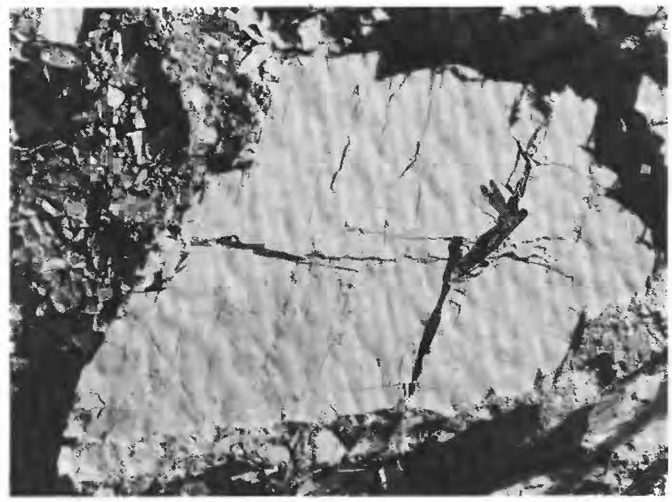


FIGURE 19.—Ripple-marked surface on pink claystone of unit 21 in Boyle Ditch reference section (fig. 1, loc. Tsi4) of Shooting Iron Formation. Photograph by J. D. Love, Sept. 9, 1952. The site has since been destroyed.

Boyle Ditch reference section of the Shooting Iron Formation—Continued

	Thickness (feet)
Shooting Iron Formation—Continued	
16. Sandstone and conglomerate, rusty-drab to light-tan, very soft, almost unlithified; about 2 ft of pea gravel at top and base, rest fine- to medium-grained sandstone, crossbedded. This is the approximate horizon from which Hibbard got a fragment of horse leg bone and Barnosky (1985) found *Pliophenacomys primaevus*. Pebbles rarely more than 1 in. in diameter, chiefly black chert and white and gray limestone	6.7
15. Sandstone, grading up to sandy siltstone, pale-greenish-drab, soft, crumbly. Basal 2 in. is coarse-grained sandstone with shiny light-brown pellets, abundant gastropods and fish or frog bones, abundant shards, angular grains of obsidian. Remainder of unit is essentially unfossiliferous, poorly bedded but flaky, clayey near top	3.7

[The following section of unit 17 was measured 150 ft southwest of main section shown in figure 21, along the southeast side of Boyle Ditch where the unit is much thicker than in the main section; Cs is at top]

17–Cs. Siltstone to very fine grained sandstone, light-gray, faintly bedded, soft, dusty when dry, crumbly, moderately fossiliferous throughout. About 50 ft south of main section, it is crossbedded fine-grained sandstone in lenses, with abundant small high-spired gastropods	2.5
17–Bs. Claystone, pale-green, soft; sparse mollusks	0.2
17–As. Siltstone, light-tan, sandy, massive, very soft; sparse high-spired gastropods throughout but more common near top	3

[The following section of units 15–19 was measured 200 ft southwest of main section along the southeast side of Boyle Ditch (fig. 20) and shows the continuity of some units and variability of others]

19–A. Pumicite(?), gray, as in main section but hard	0.4
18–A. Claystone, pale-pink, as in unit 18	2
17–Ac. Sandstone, olive-drab, clean, very fine grained; 1-in. granule sandstone at top; equivalent to part of subunit 17–Cs	3.5

FIGURE 20.—View east across ditch at upper part of the Boyle Ditch reference section (fig. 1, loc. Tsi4) of the Shooting Iron Formation. Numbers correspond to unit numbers in measured section. Unit 20 is varved shale; 19, pumicite(?); 18, pink claystone marker bed; 17, siltstone and sandstone; 17a, green claystone; 16a, conglomerate; 16b, sandstone; 16c, conglomerate and sandstone; 15, sandstone. Bedding-plane surface on unit 20 is shown in figure 19. Twenty-inch shovel handle (in circle) shows scale. Photograph by J. D. Love, Aug. 18, 1964.

Boyle Ditch reference section of the Shooting Iron Formation—
Continued

Shooting Iron Formation—Continued	*Thickness (feet)*
17–Ab. Same as subunit 17–Bs	0.3
17–Aa. Same as subunit 17–As	3
16–Ac. Pea gravel	1
16–Ab. Sandstone, pale-green and rusty-brown, fine-grained	2.5
16–Aa. Basal conglomerate, pea gravel size	1.6
15–A. Sandstone and sandy siltstone as in unit 15 of main section. Upper 2 ft exposed above ditch water level. Total thickness not known	2+

[Underlying units are in main section (fig. 21)]

14. Claystone, gray, sticky when wet, very fine grained, smooth, blocky, soft	0.3
13. Sandstone, olive-drab, very soft, massive, poorly cemented; silty in upper part, fine to medium	

Boyle Ditch reference section of the Shooting Iron Formation—
Continued

Shooting Iron Formation—Continued	*Thickness (feet)*
13. Sandstone—Continued grained in lower part; numerous shards in lower part; contains abundant low- and high-spired gastropods in lower 3 in	1
12. Claystone marker bed, dark-gray to black, very heavy, sticky, plastic, very fine grained, smooth; forms tough unit; looks like black claystone in unit 18 of Old Miller Cabin section; irregular top and base probably the result of squeezing of plastic mass; appears black on outcrop but is actually dark gray; upper half lighter colored and becomes brownish gray at top. Figure 21 shows appearance and relation of this and associated units 6–20 in erosion scar cut by Boyle Ditch, south side	2
11. Sandstone, dark-grayish-brown, very soft, almost uncemented, massive, medium-grained, "pepper-and-salt" appearance; some red grains	1.5
10. Siltstone, dull-gray, clayey and sandy, very soft, blocky	0.3
9. Sandstone, gray, "pepper-and-salt" appearance, medium-grained, almost uncemented, massive; bed of white fibrous pumice chunks as large as 1/2 in. in a 2-in. bed at base. Some carbon chunks	1.7
8. Siltstone, light-greenish-gray, soft, crumbly to flaky; limy, poorly bedded, and sandy in upper 1 ft; contains a prolific snail fauna looking like that in unit 6, with color marking in flesh-pink bands; matrix does not break down readily in water. Less fossiliferous in top 1 ft. Some frog or fish bones	4
7. Conglomerate, rusty-brown to gray; irregular channeled base and a somewhat more even top; consists chiefly of subrounded black chert and gray Madison Limestone clasts, white limestone from the Teewinot Formation, rounded quartzite, probably from the Pinyon Conglomerate, sparse obsidian and rhyolite clasts in a coarse-grained poorly cemented limonitic sandstone matrix. Appears nearly massive. Clast size rarely exceeds 3 in., average about 1 in. Some large gastropod shell fragments. Imbrication and bedding structures indicate that current came from north. Thin section (WYO–406, USGS collection) of a gray pebble with concentric structure represents a common rock type and is made up of oolites and pisolites in a carbonate matrix. Source of rock not known	7–12
6. Claystone and siltstone, light-gray, dense, plastic near top, sandy near base; contains abundant mollusks; this is upper part of Taylor's land snail bed (Taylor, 1966); does not break up in water when wet; massive, structureless. Many gastropods retain original shell color. Also one of the fossil mammal horizons containing *Ophiomys meadensis* (fig. 21; table 4). Average strike N. 16° E., dip 7° W.	2.5
5. Sandstone and pea gravel conglomerate, rusty-brown; about 1/3 gravel of subrounded black and gray chert, quartzite, and some volcanic rocks rarely as much as 1 in. in diameter, in lenses; grades southwestward along outcrop in 50 ft to coarse-grained greenish-brown limonite-stained soft unconsolidated sandstone. In upper half, gastropods are common and rock breaks down in water. This is the lower part of Taylor's land snail and fossil mammal bed (table 4; Taylor, 1966; Barnosky, 1985)	4

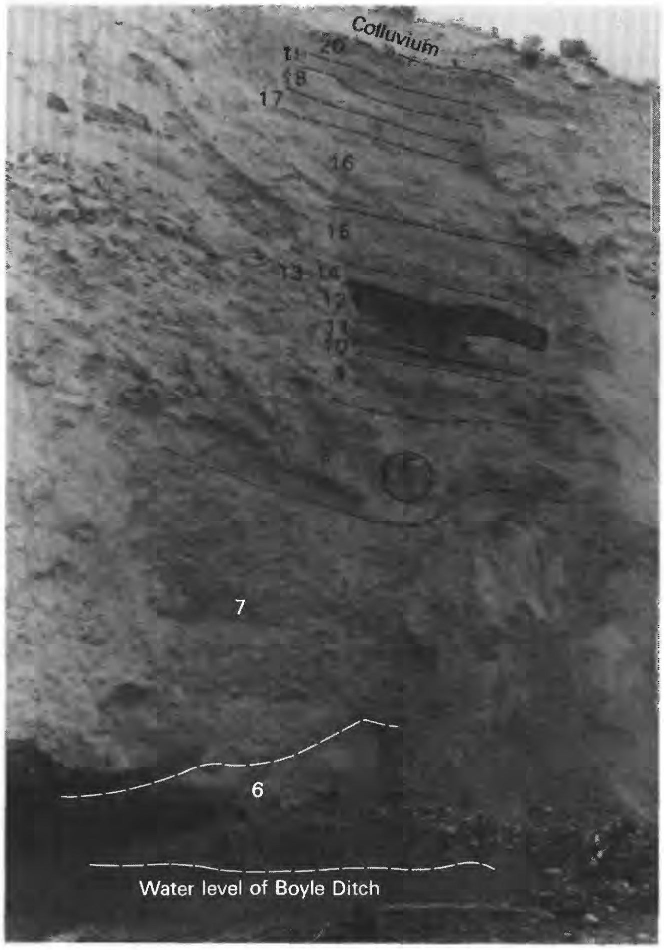


FIGURE 21.—Fossiliferous lower part of Boyle Ditch reference section (fig. 1, loc. Tsi4) of the Shooting Iron Formation on south bank of the ditch. Numbers refer to unit numbers in measured section. Unit 6 is the chief fossil land snail horizon from which three mammal teeth were collected by D. W. Taylor; a more extensive collection of teeth was made by A. D. Barnosky (table 4). Twenty-inch shovel handle (in circle) shows scale. Photograph by J. D. Love, Aug. 18, 1964.

Boyle Ditch reference section of the Shooting Iron Formation—Continued

	Thickness (feet)
Shooting Iron Formation—Continued	
4. Claystone and siltstone, pale-greenish-gray to dull-green, hard, massive, dense, coarsely blocky, largely noncalcareous	6.5
3. Claystone, pale-pastel-pink and green, plastic, tough, nonswelling, fine-grained, blocky; 1-in. limonite zone at top	5
2. Siltstone and claystone, pale-green, with pink blotches, very soft, nonplastic, blocky	7
1. Sandstone, greenish-drab, with limonite blotches, medium-grained, massive, soft, almost unlithified, "pepper-and-salt" appearance, limy.	

Boyle Ditch reference section of the Shooting Iron Formation—Continued

	Thickness (feet)
Shooting Iron Formation—Continued	
1. Sandstone—Continued	
There is little likelihood of the underlying section being exposed without major deepening of Boyle Ditch, because directly upstream the entire section is cut off by landslide. Probably not much more than 50–100 ft of section between unit 1 and Teewinot Formation. Average strike is N. 16° E., dip 7° W.	3.5+
Total thickness of measured part of Shooting Iron Formation (partial section—base not exposed and top eroded)	154.2–163

OLD MILLER CABIN REFERENCE SECTION

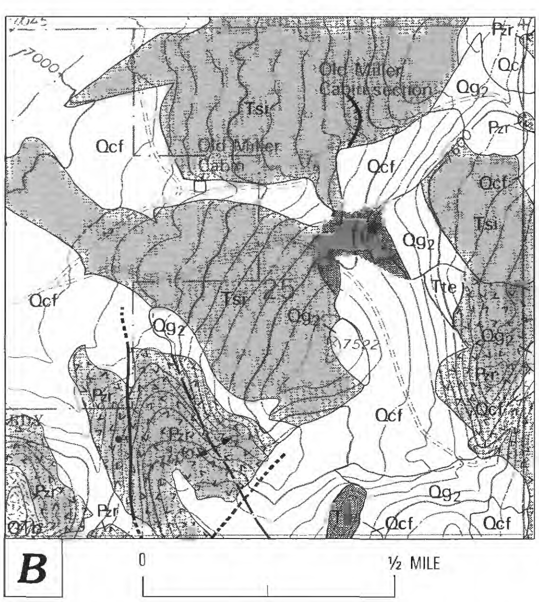
The following section was measured on the south-facing bare slope about 1/4 mi east uphill from Old Miller Cabin (fig. 1, loc. Tsi5; fig. 22). The main fossil zone (unit 14) is about 900 ft south of the north line, and 1,500 ft west of the east line of sec. 25, T. 42 N., R. 115 W., Teton County. The section was described by J. D. Love, Aug. 27, 1963. Generalized strike is N. 10° W., dip 10° W. The fossil site is shown on a polaroid photograph and in Kodachrome color, both in the field notes. Claude Hibbard collected fragmentary vertebrate fossils (table 4). Invertebrate fossils were lost before they could be identified. Unit 1 is oldest.

Old Miller Cabin reference section of the Shooting Iron Formation

[Measured in sec. 25, T. 42 N., R. 115 W., Blue Miner Lake 7½-minute quadrangle, 1968, Teton County, Wyo. Section begins 1,850 ft west of east line and 1,250 ft south of north line]

	Thickness (feet)
Shooting Iron Formation (top eroded):	
18. Claystone, dark-brown, weathering black, extraordinarily tough, plastic, very fine grained; has big desiccation cracks. Original thickness not known because this unit forms the cap on the dip slope. No younger beds present at this site	1+
17. Claystone, siltstone, and sandstone, dark-gray at base, green in remainder; soft, with tough plastic very fine grained claystone matrix; sand grains are red, green, black, and cream colored. Thin light-pinkish-gray marlstone partings in lower 1 ft. One large fossil leg bone of a horse(?) (table 4), on surface near top of unit, is 1½ in. in diameter, 5 in. long, with part of joint	5
16. Marlstone, light-pinkish-gray, blocky, granular, porous; some mollusk fragments. Black claystone parting in middle	0.4
15. Claystone, dark-gray, dense, plastic, blocky; plant fragments and crushed mollusks	0.2

A. View northwest showing reference section (fig. 1, loc. Tsi5). Key units described in measured section are indicated. Vehicle is on unit 17 which contains mammal bones. A, limestone in Teewinot Formation (late Miocene). Photograph by J. D. Love, Aug. 27, 1963.



EXPLANATION

QUATERNARY
- Qcf — **Colluvium and fan deposits**
- Qg2 — **Drift and outwash deposits of glaciation 2**

QUATERNARY–TERTIARY
- QTb — **Basalt**

TERTIARY
- Pliocene: Tsi — **Shooting Iron Formation**
- Miocene: Tte — **Teewinot Formation**

PALEOZOIC
- Pzr — **Paleozoic rocks**—Includes Phosphoria Formation (Permian), Tensleep Sandstone (Pennsylvanian and Mississippian), Amsden Formation (Mississippian), and Madison Limestone (Mississippian)

Contact

Fault—Dotted where concealed. Bar and ball on downthrown side

Anticline

Measured section

B. Geologic map of sec. 25, T. 42 N., R. 115 W., showing site of Old Miller Cabin reference section. Geology by J. D. Love, 1951–71 and 1975. Base from U.S. Geological Survey Blue Miner Lake 7½-minute quadrangle, 1968, scale 1:24,000.

FIGURE 22.—OLD MILLER CABIN REFERENCE SECTION OF SHOOTING IRON FORMATION

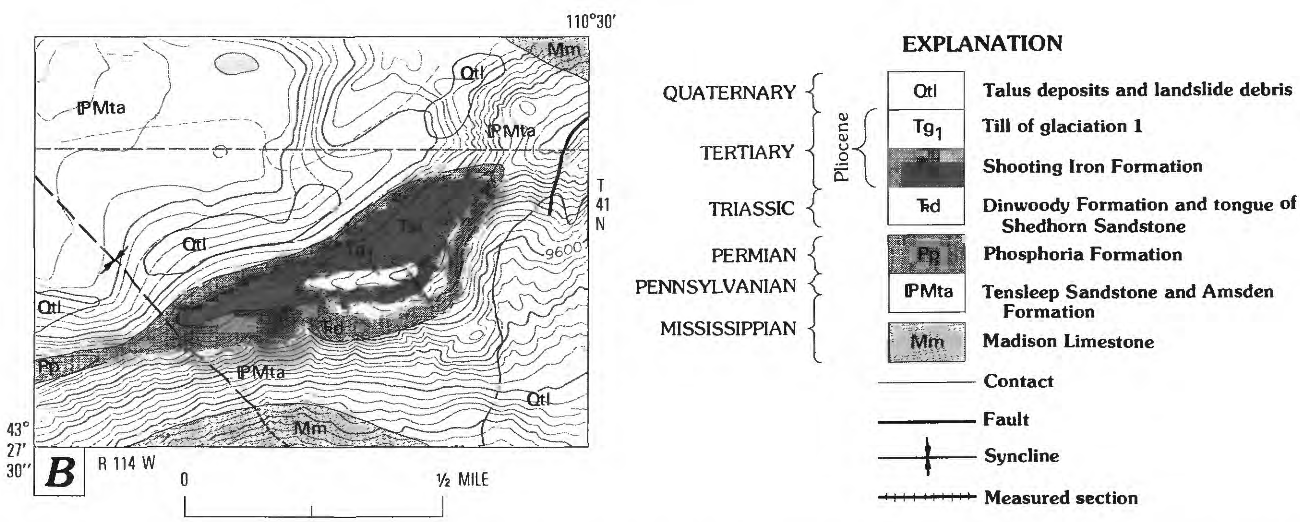
Old Miller Cabin reference section of the Shooting Iron Formation—Continued

Shooting Iron Formation—Continued	*Thickness (feet)*
14. Marlstone, light-pinkish-gray, soft to hard, thin-bedded; several beds of very peculiar granulitic material, all calcareous, with masses of what look like fish bones. Some bony material present. Abundant crushed high- and low-spired gastropods as long or wide as 1 in. and *Pisidium*. Main fossil zone. (Collection NR-63-12, received in Washington, Dec. 16, 1963, lost before it could be identified.) Some carbonized rush stems as long as 6 in. and as wide as 1 in., but no leaves seen	0.7
13. Claystone and siltstone, pale-green, sandy, soft, blocky; varicolored sand grains in a waxy very fine grained matrix; 2-in. bed of pale-pinkish-gray marl with fragmentary mollusks in middle	4
12. Conglomerate, grit, and sandstone, green, soft; green waxy claystone matrix and rounded limestone pebbles in lower part, grading up to grit with varicolored soft and hard rounded granules of black, red, and green in lemon-yellow to green claystone matrix, and at top a pale-green sandstone with claystone matrix. Grades up to overlying unit	5±
11. Claystone, dark-lead-gray, tough, plastic, very fine grained; colloidal matrix; numerous carbonized plant chunks and impressions as large as 1 in.; no leaves and no invertebrates seen	0.4
10. Claystone; pale green near base, red brown in middle, and green and red mottled near top. Sporadic rounded limestone pebbles in upper 6 in. and distinctive grit in top 2 in. Pollen and diatom samples from middle; lithologic sample of grit for petrographic study. Rounded limestone pebbles as large as 2 in. in conglomeratic part; grit has black obsidian(?) and soft and hard, red, green, and other color granules	1.6
9. Sandstone, rusty-tan, very soft, fine- to medium-grained; abundant angular red, orange, green, and black grains	1
8. Claystone, pale-green, with pink tinges, soft, blocky; waxy colloidally fine matrix, many red grains. Grades up to overlying unit	0.7
[Offset 100 ft to east on top of unit 7 for underlying section]	
7. Claystone, dark-brick-red; fine grained in lower part, sandy, with varicolored grains in upper, very soft, blocky	2
6. Sandstone, siltstone, and claystone, olive-drab; all with colloidally fine-grained matrix, blocky to fissile, very soft; many waxy claystone pellets and granules of harder rocks; many red and black grains; looks tuffaceous. Grades eastward to a red unit in distance of 10 ft	3
5. Conglomerate; yellowish-olive-drab in lower part, becoming gray near top; coarse in lower part, grit near top; sandstone matrix except near top where it is clayey; conglomerate has rounded to angular fragments, which are chiefly of Madison Limestone and as much as 1 ft in diameter	2.3
4. Claystone, lead-gray to olive-drab, very fine grained to silty; fissile in part; interbedded with olive-drab siltstone and very fine grained soft loose slightly pebbly sandstone	1.2
3. Conglomerate, gray, coarse; 1- to 3-ft boulders of Madison Limestone in olive-drab to yellow sandstone matrix at most horizons; some very fine grained gray claystone matrix near top. This unit forms a coarse boulder layer along lip of draw below red slope on south-facing outcrop	6
2. Sandstone, yellowish-olive-drab with gray partings, very soft and crumbly; waxy claystone matrix, finely pebbly; appears shardy, particularly in gray part; grades up to conglomerate of unit 3	1.3
1. Conglomerate, gray, coarse, soft, with tan clayey and sandy matrix; roundstones 2–3 in. in diameter, angular to subrounded, largely Madison Limestone, with lesser amounts of Tensleep Sandstone. No Precambrian, Tertiary volcanics, or Pinyon-type rounded quartzite seen. Probably derived directly from dip slopes to east. Base not exposed but unit appears to rest directly on Phosphoria Formation here and to southwest on conglomerate of the Teewinot Formation. Probably not much more than 50 ft more section below this horizon, as red staining appears up draw near Phosphoria outcrop	20±
Total thickness of measured part of Shooting Iron Formation	55.8±

GRANITE CREEK DIVIDE REFERENCE SECTION

The Granite Creek Divide reference section (fig. 1, loc. Tsi6; fig. 23) of Shooting Iron Formation was measured by J. D. Love with steel tape and level; lithologic samples were taken for analysis, July 24, 1975. The section is in the NE¼ of the Turquoise Lake 7½-minute quadrangle, at an elevation of approximately 10,000 ft. The geology of the area is shown on a map (C. M. Love and J. D. Love, 1978). A brief note on the significance of the site has been published (J. D. Love, 1976 [1977], p. 71). Unit 1 is oldest. Field note locality is L75-59.

A. View southwest near head of Granite Creek at site of reference section (fig. 1, loc. Tsi6). Photograph by J. D. Love, July 24, 1974.



B. Geologic map of part of the NE¼ of the Turquoise Lake quadrangle, showing site of Granite Creek Divide reference section. Geology from C. M. Love and J. D. Love (1978). Base from U.S. Geological Survey Turquoise Lake 7½-minute quadrangle, 1965, scale 1:24,000.

FIGURE 23.—GRANITE CREEK DIVIDE REFERENCE SECTION OF SHOOTING IRON FORMATION

Granite Creek Divide reference section of the Shooting Iron Formation

[Measured in unsurveyed area, 1,300 ft south of the north line of T. 40 N. and 1,700 ft west of the east boundary of the Turquoise Lake 7½-minute quadrangle, Teton County, Wyo. Section is on a south-facing slope about 1,800 ft above Granite Creek]

	Thickness (feet)
Till of glaciation 1:	
15. Lag deposits of till draped across underlying exposures of Shooting Iron Formation. The dominant lithology of the erratics is sandstone and limestone, locally derived from the Tensleep Sandstone and Madison Limestone. Some are as much as 5 ft in diameter. There are a few highly rounded quartzite erratics as much as 1 ft in diameter; several retain surface polish and percussion scars. There are sparse highly rounded erratics of Absaroka Volcanic Supergroup, chiefly andesite and basalt, rarely more than 0.15 ft in diameter. Both the quartzite and volcanic rocks are foreign to this part of the Gros Ventre Range; neither is known in the underlying Shooting Iron Formation. These erratics must have been brought in by ice from a source area at least 20-30 mi to the northeast and now 1,000-3,000 ft lower in elevation. They had to travel across the Gros Ventre Range through passes with a present minimum elevation above 10,300 ft. There is no clear-cut soil development in or on the till. The erratics have sunk down into the underlying red plastic clay of the Shooting Iron Formation	0-10
Shooting Iron Formation:	
14. Conglomerate, sandstone, and claystone, gray to red, soft; apparently with a bentonitic matrix as indicated by swelling cracks on the surface. Some fresh pink granite cobbles, probably from the south or southwest. No quartzite or volcanic clasts seen	12±
13. Claystone, pink, soft; bright red grains. In middle is a 3-in. greenish-gray sandstone with brightly colored grains	3
12. Partly covered interval. Poor exposures of very soft conglomerate, sandstone, and claystone	17
11. Sandstone, dull-green; limonite and bright-lemon-yellow staining, very soft; brightly colored red, green, orange, and brown sand grains in a bentonitic claystone matrix	1
10. Claystone, dull-pink; bright-lemon-yellow bentonite partings; soft	0.5
9. Conglomerate; forms lower ledgy unit in photograph (fig. 23). Clasts are less than 2 ft in diameter in lower 10 ft and as much as 3-4 ft in a zone overlying the lower ledge, decreasing in size again toward top of unit. Most clasts are Madison Limestone and Tensleep Sandstone, probably locally derived. No granite, quartzite, or volcanic clasts seen. Matrix is sandstone, tan, glauconitic in part, limy	22
8. Claystone, creamy-tan, bentonitic, sticky, plastic; white limy nodules as much as 0.15 ft in diameter	2
7. Claystone, brown, sandy and silty, soft, blocky; brightly colored sand grains	0.25

Granite Creek Divide reference section of the Shooting Iron Formation—Continued

	Thickness (feet)
6. Sandstone, brown, coarse-grained, very soft; consisting of a great variety of very brightly colored red, green, orange, and brown grains	0.5
5. Claystone and siltstone, brown, sandy, blocky, soft; abundant red grains	0.5
4. Covered interval; probably underlain by very soft sandstone, siltstone, and claystone	3
3. Boulder conglomerate, chiefly of Tensleep Sandstone; clasts rounded, as much as 1 ft in diameter. Strike N. 45° E., dip 10° NW.	10
Approximate total thickness of Shooting Iron Formation	71.75-81.75
Angular unconformity.	
Dinwoody Formation—part (Triassic):	
2. Siltstone, brown, in part dolomitic, platy, hard. Dip almost horizontal or very slightly to north	116
Tongue of Shedhorn—part (Triassic)	
1. Sandstone, brown, hard, quartzitic	8
Phosphoria Formation—part (Permian):	
— Coquina of brachiopods and other fossils; silicified, in dolomitic matrix; forms marker ledge in photograph (fig. 23)—Not measured.	

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The Shooting Iron Formation lies with angular unconformity across all older rocks ranging in age from Paleozoic and Mesozoic to late Miocene. No younger strata except glacial debris, outwash deposits, and loess overlie it.

AGE AND CORRELATION

Table 4 lists the fossils identified from the Shooting Iron Formation. Most of the snails are terrestrial except for those at the Botcher Hill reference section (loc. Tsi3) which are lacustrine. The Boyle Ditch reference section (loc. Tsi4) is especially significant because it not only has the largest assemblage of terrestrial mollusks but also has four species of fossil mammals of late Pliocene (Blancan) age. Regarding the mollusks, Taylor stated (1966, p. 84):

> The mollusks from locality [Tsi4] all belong to living species so far as they are identified, although the *Menetus* may represent an extinct species. Four species (*Lymnaea montanensis*, *Hawaiia minuscula*, *Oreohelix peripherica* and *O.* cf. *O. yavapai* are living in nearby areas but not in Jackson Hole. The lacustrine snail *Menetus* occurs in Blancan assemblages in Star Valley and in the Glenns Ferry Formation [in Idaho], but is now practically confined to the Pacific Coast area. Perhaps its disappearance over a wide area of Idaho and Wyoming will prove to have regional stratigraphic value.

TABLE 4.—*Fossils from the Shooting Iron Formation*

[Mollusks were identified by D. W. Taylor (Taylor, 1966, and written commun., 1959; Love and Taylor, 1962). For field and USGS/USNM numbers, see those references. Vertebrate fossils from loc. Tsi4 were identified by A. D. Barnosky (written commun., 1983), and from loc. Tsi5, by C. W. Hibbard (written commun., 1963). Leaders (----) indicate not found]

Species	Localities (shown in fig. 1)			
	Tsi1	Tsi4	Tsi3	Tsi5[1]
Mollusks				
Anodonta? sp. indet	----	----	X	----
Pisidium compressum Prime	----	----	X	----
Valvata humeralis Say	X	X	X	----
Valvata utahensis Call	----	----	X	----
Carinifex newberryi (Lea)	----	----	X	----
Pisidium casertanum (Poli)	----	X	----	----
Pisidium obtusale (Lamarck)	----	X	----	----
Fossaria obrussa (Say)	----	X	----	----
Lymnaea montanensis (Baker)	----	X	----	----
Lymnaea cf. *L. elodes* Say	X	X	----	----
Planorbula cf. *P. campestris* (Dawson)	X	----	----	----
Planorbidae n. gen. and sp.	X	----	----	----
Promenetus umbilicatellus (Cockerell)	----	X	----	----
Menetus sp. indet	----	X	----	----
Aplexa hypnorum (Linnaeus)	----	X	----	----
Vertigo gouldi (Binney)	----	X	----	----
Vertigo modesta Say	----	X	----	----
Pupilla muscorum (Linnaeus)	X	X	----	----
Vallonia cyclophorella Sterki	X	X	----	----
cf. *Succinea* (2 spp.)	X	X	----	----
Discus cronkhitei (Newcomb)	----	X	----	----
Discus shimeki cockerelli Pilsbry	X	----	----	----
Hawaiia minuscula (Binney)	----	X	----	----
Oreohelix peripherica (Ancey)	----	X	----	----
Oreohelix cf. *O. yavapai* Pilsbry	----	X	----	----
Oreohelix n. sp	X	----	----	----
Stagnicola palustris (Muller)	X	----	----	----
Anisus pattersoni (Baker)	X	----	----	----
Pisidium sp. indet	X	----	----	----
Vertebrates				
Pliopotamys near *meadensis*	----	X	----	----
Pliophenacomys primaevus	----	X	----	----
Ophiomys meadensis	----	X	----	----
Ondatra cf. *O. idahoensis*	----	X	----	----
Synaptomys sp	----	X	----	----
Horse?	----	----	----	X
Turtle	----	----	----	X

[1]Mollusk collection submitted to Washington, D.C., received by D. W. Taylor, acknowledged Dec. 16, 1963, and given collection number NR-63-12. Lost before it could be identified.

Regarding the fossil mammals from this site, A. D. Barnosky (written commun., 1983[2]) stated:

[2]Barnosky (1985) published a detailed description of the vertebrate fossils and their age and correlation.

Three of the taxa, *Pliophenacomys primaevus, Ophiomys meadensis,* and *Ondatra* near *idahoensis,* clearly show affinities to late Blancan species of the Great Plains, and fourth, *Synaptomys,* possibly does. The fauna implies that Jackson Hole was included in an eastern biogeographic province in the late Pliocene, which contrasts with its position within the western province today.

With reference to the freshwater mollusks at the Botcher Hill locality (Tsi3), Love and Taylor (1962, p. D138) stated:

Of the five species of mollusks found in the lacustrine sequence, *Valvata utahensis* and *Carinifex newberryi* live in either lakes or large slow-moving streams, whereas the other three may also live in small creeks only a few feet wide. * * * Two species found in the laucustrine sequence (*Carinifex newberryi* and *Valvata humeralis*) live in Lake Tahoe, California-Nevada, at depths between 120 and 300 ft (Hanna and Smith, 1938). Lake Tahoe has an area of about 300 sq mi, a maximum depth of 1,628 ft, and a mean depth of about 800 ft according to Hutchinson (1957). The former lake in Jackson Hole might have been of the same order of magnitude.

Taylor (oral commun., Mar. 25, 1965) stated that he thought the *Carinifex* beds in the Botcher Hill reference section were younger than the strata containing the terrestrial fauna at the Boyle Ditch section, and at the type section. Inasmuch as the *Carinifex* strata are known from only one site, and no younger strata have been identified, there is no way of determining the extent of the Shooting Iron lake. Subsequent extensive glaciation could have removed most or all of these soft lacustrine strata from a large part of Jackson Hole.

The Shooting Iron Formation at the Boyle Ditch section was originally included in the upper part of the Teewinot Formation and was dated as middle Pliocene (Love, 1956a) but areal mapping later showed that it was lithologically and faunally very different from the Teewinot and much younger than the upper strata of that formation, which are 9.2 Ma (Mega-annum, million years; Evernden and others, 1964). The revised stratigraphic time scale includes any rocks older than 5 Ma in the Miocene. The age relations of the Shooting Iron Formation to Pliocene rocks farther north in Jackson Hole are not known. Possibly, some or all of the red claystone sequence between the lower Pliocene Conant Creek Tuff and the Huckleberry Ridge Tuff (2.02±0.08 Ma) on Signal Mountain (at loc. Tbi, fig. 1), 20 mi north of the Boyle Ditch section, may be part of the Shooting Iron Formation. The subsurface extent of remnants of the Shooting Iron can only be determined by drilling and by study of drill cuttings. In much of Jackson Hole, however, no drill cuttings have been saved as of 1983, so the subsurface data prior to that time have been lost.

Taylor (1966, p. 84-86) described and collected Blancan-age mollusks and fossil mammals from an unnamed reddish-brown and green sequence of soft claystone, sandstone, and conglomerate exposed in a series of roadcuts approximately 35 mi south-southwest of the type section of the Shooting Iron Formation in the Star Valley area. The strata at these two localities are probably of the same age and have similar lithology but were deposited in different structural basins.

BIVOUAC FORMATION (ABANDONED NAME) AND ASSOCIATED TEEWINOT FORMATION, UNNAMED GRAVEL, CONANT CREEK AND HUCKLEBERRY RIDGE TUFFS, AND PLIOCENE GLACIAL DEPOSITS

NAMES AND DEFINITIONS

The Bivouac Formation was named and defined from exposures on the northeast flank of Signal Mountain (fig. 1, loc. Tbi, and fig. 24; Love, 1956a, p. 1911–1913). The formation originally included several units that later mapping has shown to be separate formations. This necessitates the abandonment of the name Bivouac Formation. Table 5 shows the changes in nomenclature and present age assignments of the rocks on Signal Mountain.

The evolution of nomenclature and the various changes in age assignments of rocks on Signal Mountain are summarized as follows:

1. All rocks above the Teewinot Formation on Signal Mountain were included in the type Bivouac Formation (Love, 1956a).
2. Christiansen and Blank (1972) mapped the rhyolitic rocks in Yellowstone National Park and correlated the Huckleberry Ridge Tuff of that area with the upper rhyolite welded tuff forming the prominent ledge on Signal Mountain. In Yellowstone National Park, many dates showed the tuff to be 1.9 Ma. A sample previously collected from the base of the tuff in the U.S. Bureau of Reclamation Jackson Lake (Moran) Dam rock quarry at the south end of the dam had been dated as 2.5 Ma (R. W. Kistler, written commun., June 1, 1964; date used in Love and Reed, 1968). R. L. Christiansen considered the date on Signal Mountain to be wrong, and the Huckleberry Ridge Tuff to be Pleistocene in age. Subsequently, however, new decay constants were used to recalculate the 1.9-Ma age and the tuff was redated at 2.02±0.08 Ma (J. D. Obradovich, oral commun., 1980; Love and A. C. Christiansen, 1980). This puts the tuff into the Pliocene (the age cutoff being 1.65 Ma—Richmond and Fullerton, 1986).

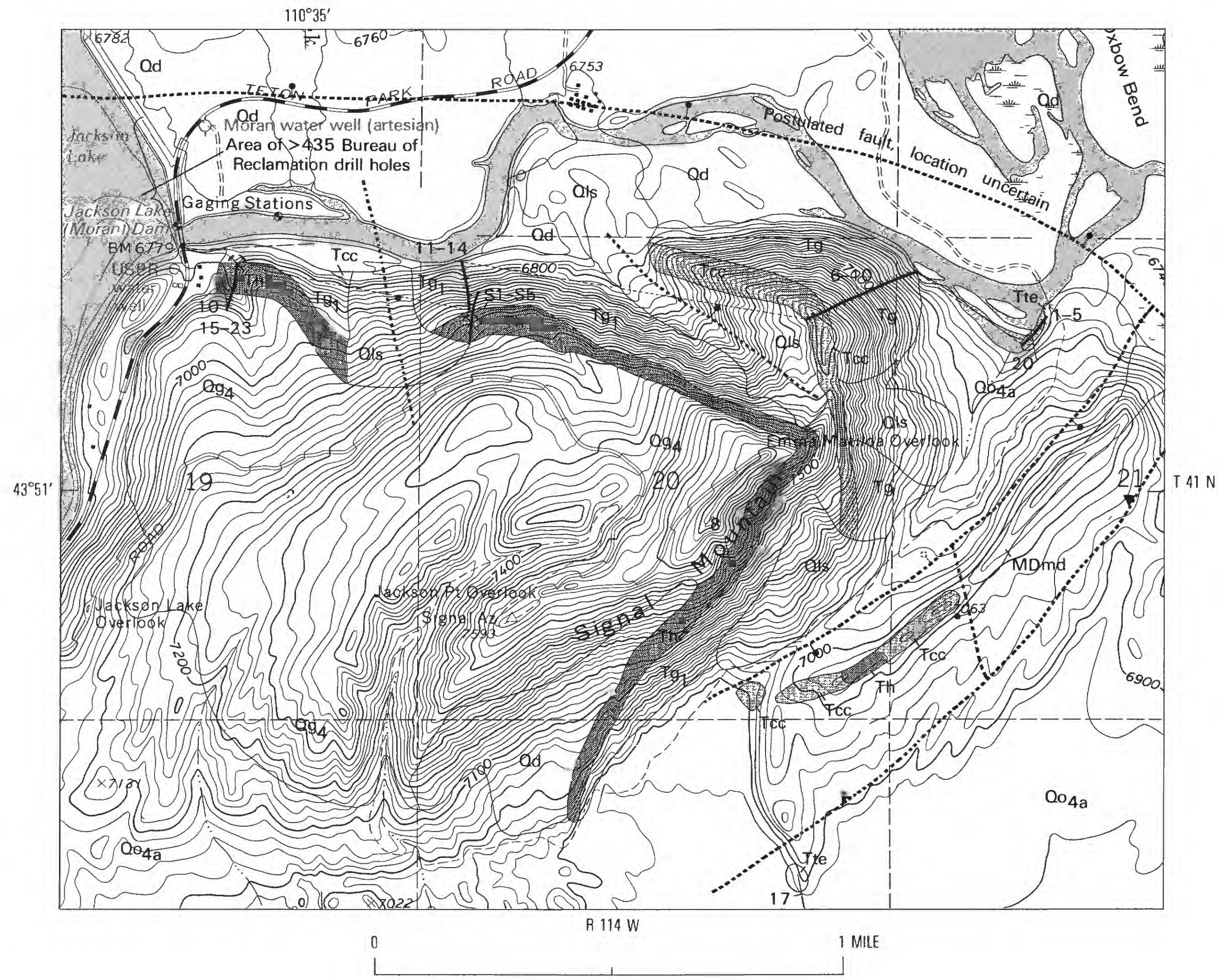
TABLE 5.—*Changes in nomenclature and present age assignments of rocks on Signal Mountain*

Love (1956a)	Love (this report)	Age assignment
Glacial deposits	Deposits of glaciation 4	Pleistocene.
Bivouac Formation	Huckleberry Ridge Tuff (75 ft); 2.02 Ma.	Late Pliocene.
	Deposits of glaciation 1 and associated gravel (300–450 ft).	Pliocene.
	Conant Creek Tuff (200± ft); 4.2 Ma.	Early Pliocene.
	Unnamed gravel (1,000–1,200 ft).	Late Miocene.
Teewinot Formation	Teewinot Formation; 9.2 Ma near top.	Late Miocene.

3. R. L. Christiansen identified and mapped the Conant Creek Tuff below the Huckleberry Ridge Tuff on Signal Mountain (written commun., 1972). This tuff, exposed on the north and east sides of Signal Mountain, was correlated with the Conant Creek Tuff on the northwest side of the Teton Range (R. L. Christiansen and Love, 1978). In the type section, this tuff was dated by K-Ar method as 5.78±0.08 Ma and by fission-track method as 4.2±0.7 Ma. The latter date is considered more reliable because it compares with the K-Ar ages of 4.1±0.1 Ma to 4.8±0.3 Ma (Morgan and others, 1984) on tuffs in the Kilgore area of eastern Idaho, which have the same composition and lithology as the Conant Creek Tuff, and are believed by Morgan and R. L. Christiansen to be the Conant Creek Tuff (L. A. Morgan, oral commun., 1985).
4. Between the Huckleberry Ridge and Conant Creek Tuffs is 300–450 ft of till-like gravel that is unsized, unsorted, unstratified, and contains striated and soled quartzite boulders in a noncalcareous clay matrix. This unit is more like till than like a fluvial deposit and because it was bracketed between the two dated tuffs, it was called a Pliocene glacial deposit (Love, 1976, p. 70–71).
5. Below the Conant Creek Tuff and above the Teewinot Formation (late Miocene) is 1,000–1,200 ft of unnamed gravel.

DISTRIBUTION AND THICKNESS

The Teewinot Formation is exposed 1 mi north, 1,000 ft east, and 2,000 ft south of Signal Mountain. The thickness of the Teewinot in this area is not known, but



EXPLANATION

QUATERNARY	Pleistocene and Holocene	Qd	**Alluvial gravel, colluvium, and swamp and flood-plain deposits**
		Qls	**Landslide debris**
	Pleistocene	Qo_{4a}	**Outwash gravel forming terraces graded to Jackson Lake moraine**
		Qg_4	**Drift and outwash deposits of glaciation 4**
TERTIARY	Pliocene	Th	**Huckleberry Ridge Tuff**
		Tg_1	**Till of glaciation 1**
		Tcc	**Conant Creek Tuff**
	Miocene	Tg	**Unnamed gravel**
		Tte	**Teewinot Formation**
DEVONIAN AND MISSISSIPPIAN		MDmd	**Madison Limestone and Darby Formation**

Contact

Concealed normal fault—Bar and ball on present downthrown side; dotted bar and ball on postulated original downthrown side

Concealed thrust fault—Sawteeth on overriding block

Strike and dip of beds

6–10 **Measured section**—Dotted line connects offset part of section. Numbers indicate units described in text

Quarry site

Figure 24.—Geologic map of Signal Mountain area showing locations of described sections of Miocene and younger strata. Geology by J. D. Love, 1983. Base from U.S. Geological Survey Moran 7½-minute quadrangle, 1968, scale 1:24,000.

it probably is not much more than 300 ft, based on the distance and dip between the exposures along the Snake River and the Hominy Peak Formation (middle Eocene) to the east.

The unnamed gravel has been identified only on Signal Mountain, where it is estimated to be 1,000–1,200 ft thick. The overlying Conant Creek Tuff, 200–250 ft thick, is present on Signal Mountain, in subsurface sections to the north, and on Pilgrim Peak 5.5 mi to the north.

The Pliocene deposits of glaciation 1, 300–450 ft thick, have been recognized only on Signal Mountain. They may, however, be related to similar very old tills on Blacktail Butte, 16 mi to the south-southwest, and on the Gros Ventre Range in the Granite Creek Divide reference section (loc. Tsi 6, fig. 1; see reference section of Shooting Iron Formation, unit 15), 27 mi to the south.

The Huckleberry Ridge Tuff, 75–100 ft thick, is present on Signal Mountain, in subsurface sections to the north, on Pilgrim Peak 5.5 mi to the north, and on Shadow Mountain 7 mi to the south.

LITHOLOGIES

The following generalized stratigraphic section describing the four units included in the original Bivouac Formation and the uppermost part of the Teewinot Formation incorporates data from outcrops on the north and east sides of Signal Mountain and U.S. Bureau of Reclamation core and drill holes in the vicinity of the Jackson Lake (Moran) Dam. Because of geographic and geologic constraints and limited exposures, this does not represent a single continuous section, but a series of correlated partial sections that are tied together into a generalized sequence.

Signal Mountain section

[Top of section is in the U.S. Bureau of Reclamation Jackson Lake Dam rock quarry about 800 ft southeast of the south end of the Jackson Lake Dam in SE¼ sec. 19, T. 45 N., R. 114 W., Moran 7½-minute quadrangle, Teton County, Wyo.]

	Thickness (feet)
Deposits of glaciation 4 (Pleistocene):	
23. Till; composed chiefly of erratics of many rock types from the Teton Range, Yellowstone National Park, the Absaroka Range, and the Pinyon Peak area (fig. 1), plastered on the top and flanks of Signal Mountain. These are lag deposits from ice that overrode Signal Mountain. This ice was probably 2,000–3,000 ft thick on the adjacent floor of Jackson Hole	0–100
Huckleberry Ridge Tuff (Pliocene) (fig. 25):	
22. Varved clay, sand, and gravel, unindurated; dips parallel to underlying welded tuff (strike N. 10° W., dip 10° W.). At base is gray clayey sand overlain by quartzite boulder gravel with abundant rhyolite and mafic clasts. Above this is pink very finely laminated (with as many as 50–75 laminae per inch) tough clay, overlain by gravel containing persistent gray sand layers. Pink clay was sampled for diatoms, but none was found. The varved clay must have been deposited horizontally and tilted by later movement	15
21. Rhyolite welded tuff, light-pinkish-gray, fine-grained; sparse clear euhedral to subhedral quartz phenocrysts in upper part (thin section WYO-654[1] from top of unit); darker gray and with more phenocrysts in middle; very dark gray, dense, and with sparse phenocrysts near base (thin section WYO-647, basal 1 ft; WYO-648, 2 ft above base; WYO-649, 6 ft above base). Top of unit appears weathered	60–75
20. Tuff, salmon-pink, light-weight, massive; scattered clear crystals; irregular base and top (fig. 25)	0.5–1.8
19. Pumicite; brown in lower 6 in., red in middle, and purple near top; irregular top with lenticular light-purplish-tan layer at top; well bedded, coarse grained, soft, with large glassy crystals in clayey matrix. Thin section WYO-741 and heavy mineral separate LHM-16	2
18. Claystone, candy-striped red and white (fig. 26); forms conspicuous bed across center of outcrop; minutely laminated, with perhaps 40 laminae per inch; is noncalcareous, has smooth soapy feel, and is very fine grained; a peculiar brown bed 1/4 in. thick with white specks near top; sampled for pollen and diatoms but none found by Leopold and Lohman. Thin section WYO-740	0.25
17. Claystone and shard bed, gray in lower part; conspicuous 1-in. brown layer near top which has a red parting at its base; laminated; layer just below the red parting sampled for pollen and diatoms but none found by Leopold and Lohman	0.3
16. Pumicite and claystone (figs. 25, 26), completely intermixed; salmon pink at base, grading up to various shades of pale brown, pale pink, and pinkish gray; evenly bedded; shards are large, angular, and embedded throughout the clayey matrix; gradational base and top. Coarsest part is thin section WYO-739 and heavy mineral separate LHM-15. Sample (Love No. 1), has 9.16 percent K_2O and age of 2.5 Ma (R. W. Kistler, written commun., June 1, 1964) on sanidine	1.3
15. Claystone; layered in 1/2- to 1-in. beds, cream-colored at base, overlain by brown, then gray and gray-brown speckled beds, then salmon pink, then gray speckled, then pale pink, then gray-brown speckled, then cream colored, then brownish gray at top; all but gray beds are smooth and waxy; gray layers contain black and red grains and shards; a remarkably laminated unit, noncalcareous throughout; sampled for pollen and diatoms, but none found by Leopold and Lohman. X-ray sample LW-1116 shows the rock to be more than 75 percent kaolinitic clay;	

[1]Thin sections and heavy mineral separates are in USGS files.

FIGURE 25.—Huckleberry Ridge Tuff. Sedimentary rocks in the basal part below welded tuff (unit 21) and above deposits of glaciation 1 (unit 14). Numbers refer to unit numbers of Signal Mountain section at U.S. Bureau of Reclamation Jackson Lake Dam rock quarry. Photograph by J. D. Love, Sept. 9, 1958, of northeast corner of quarry.

Signal Mountain section—Continued

Huckleberry Ridge Tuff—Continued — *Thickness (feet)*

15. Claystone—Continued
spectrographic analysis shows above-average amounts of niobium, lead, and zinc 0.5

Approximate total thickness of Huckleberry Ridge Tuff 79.85–96.15

[Offset to landslide-exposed part in sec. 20, 2,800 ft east of the Jackson Lake Dam quarry. Section was measured below the outcropping ledge of the tuff (unit 2) in a steep avalanche chute on the north side of Signal Mountain (figs. 24, 27). The section was exposed at the headwall of a landslide pull-away scarp in 1975 but subsequently has been obscured by slumping. Section was measured, photographed, and sampled by J. D. Love, June 15, 1975. A supplementary section of the soft basal units of the Huckleberry Ridge Tuff below the continuous ledge-forming unit 21 is included here to show the lateral variations in these softer strata]

Huckleberry Ridge Tuff:

S5. Welded tuff, lavender, crystal-rich, hard, blocky, moderately dense. Thin section WYO-653 from 2 ft above base. This unit and overlying tuff was extensively quarried by the U.S. Bureau of Reclamation 50 ft south of this site for riprap on the Jackson Lake Dam, more than 60 years ago, before the present Jackson Lake Dam quarry site was opened .... 10+

S4. Obsidian, dark-brown to black, porous; a frothy

Signal Mountain section—Continued

Huckleberry Ridge Tuff—Continued — *Thickness (feet)*

S4. Obsidian—Continued
mass of semicompacted oriented shards forming a bed that breaks into angular blocks 1

S3. Obsidian sand, black, only slightly lithified, bedded; composed of coarse, angular loose shards 1

S2. Pumicite, dark-reddish-orange; composed of very coarse large shards, quartz crystals, and angular obsidian fragments; bedded. Thin section WYO-651 .... 1–1.5

S1. Pumicite, pale-gray, bedded; irregular blobs and discontinuous layers of plastic bentonite(?) and rusty-orange claystone. Shards are moderately small. At base is 0.1-ft pinkish-brown soft plastic clay. Strike N. 10° E., dip 7° W. 2.5

Thickness of part of the Huckleberry Ridge Tuff .... 16+

Base of Huckleberry Ridge Tuff.

Deposits of glaciation 1 (Pliocene):

14. Till, brown to gray, hard, compacted; stands in a vertical face, unstratified; composed of highly rounded to angular unsized, unsorted, and unoriented clasts of many rock types. Composition is the same as for unit 12............ 4

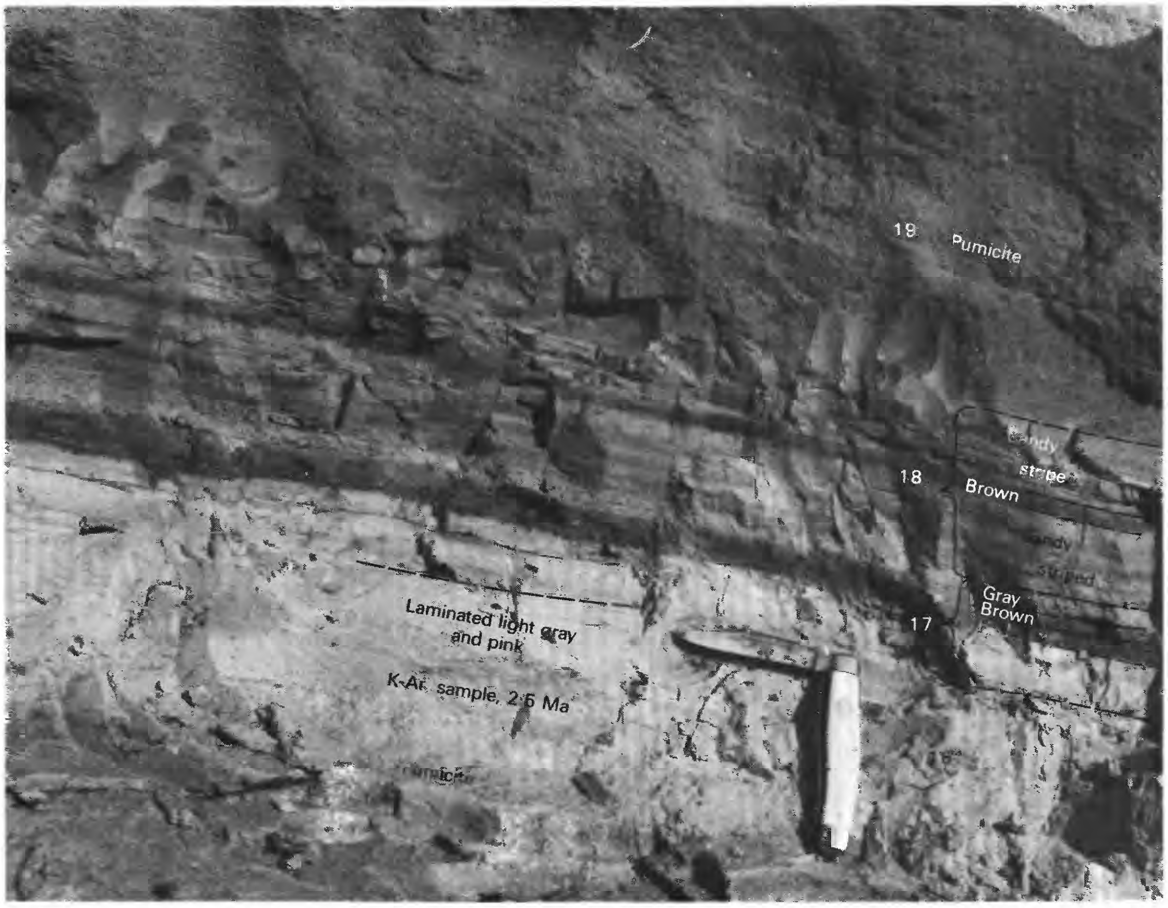


FIGURE 26.—Detail of candy-striped strata in basal part of Huckleberry Ridge Tuff at the same site and with the same unit numbers as shown in figure 25. Photograph by J. D. Love, Sept. 9, 1958.

Signal Mountain section—Continued

Deposits of glaciation 1 (Pliocene)—Continued — *Thickness (feet)*

13. Sandstone, brown, pepper-and-salt, coarse angular grains, moderately indurated. Thin section WYO-652 .... 0.5
12. Till, dull-pinkish-brown when wet, gray when dry; composed of highly rounded to angular unsized, unsorted, and unoriented clasts of many rock types, completely intermixed, with no evidence of stratification. No sand or clay lenses in entire unit. Some zones have a clay matrix in which boulders are embedded and others have a sand matrix. Clast size averages about 0.2 ft but some boulders are as large as 1.2 ft. Composition is about 75 percent quartzite clasts, highly rounded, with percussion scars still preserved. About 20 percent are mafic volcanic rocks, chiefly andesite and basalt like that in the Colter (Miocene) and Hominy Peak (middle Eocene) Formations exposed 4–6 mi to the north. About 5 percent of clasts are rhyolite, possibly from the underlying and adjacent

Signal Mountain section—Continued

Deposits of glaciation 1 (Pliocene)—Continued — *Thickness (feet)*

12. Till—Continued
Conant Creek Tuff. Most of the volcanic clasts are rounded and so deeply weathered in place that they fall apart when removed. No Mesozoic or Paleozoic clasts were observed. The clay and sand matrix is consistently noncalcareous. The upper 10 ft of the unit is so tightly compacted that it stands in a vertical face. Striated, soled, plucked, and faceted boulders of quartzite are present but sparse, and were obtained in place so the till origin of the deposit seems at least moderately substantiated 74
11. Covered interval. As nearly as can be determined from outcrops and core-drill data from more than 435 U.S. Bureau of Reclamation holes near the Jackson Lake Dam, the interval is largely conglomerate similar to that in unit 12. The U.S. Bureau of Reclamation 1954 water well south of the Jackson Lake Dam penetrated 92 ft of section below the welded tuff unit (unit 21, this report) in the Huckleberry

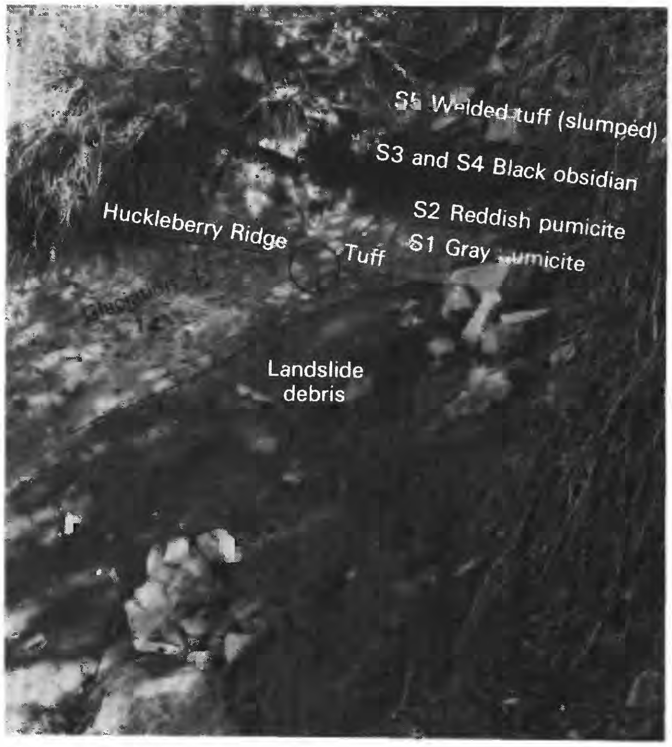


FIGURE 27.—Headwall of landslide, exposing basal beds of Huckleberry Ridge Tuff in contact with deposits of glaciation 1 (unit 14). Site is on north side of Signal Mountain. Twenty-inch shovel handle (in circle) shows scale. Numbers refer to units listed in Signal Mountain section. Units S1–S5 are units of the Huckleberry Ridge Tuff of differing lithology than those seen in the quarry part of the section: S1, gray pumicite; S2, reddish-orange pumicite; S3 and S4, black obsidian; S5, welded tuff (slumped). Photograph by J. D. Love, June 15, 1975. Section has since been obscured by landslide debris.

Signal Mountain section—Continued

Deposits of glaciation 1 (Pliocene)—Continued	*Thickness (feet)*
11. Covered interval—Continued Ridge Tuff. Only 13 samples of cuttings were collected for this 92-ft interval, too few to be very helpful. A microscopic examination shows the lithology to be about the same as described in unit 12, with only traces of sand and brown clay. Most of this interval in the well would probably be a lateral equivalent of unit 12. Poor exposures of red clay on the ridge north of Emma Matilda Overlook on Signal Mountain, directly above the Conant Creek Tuff, might be a remnant of the Shooting Iron Formation described earlier in this report or they might be a clay zone within this till sequence	220–370
Approximate thickness of deposits of glaciation 1	298.5–448.5

Signal Mountain section—Continued

[Contact between glacial deposits and Conant Creek Tuff not well exposed on surface but very sharp in U.S. Bureau of Reclamation drill holes in the dam area. The following description combines data from outcrops supplemented by data from U.S. Bureau of Reclamation core holes near the Jackson Lake (Moran) Dam (Gilbert and others, 1982; J. D. Gilbert, written commun., 1983)]

Conant Creek Tuff (Pliocene):	*Thickness (feet)*
10. Welded tuff, brown, highly vesicular, porous; forms brown ragged ledges on outcrops on north and east sides of Signal Mountain	25–50
9. Tuff and pumicite, tan to pink, soft; interbedded with gravel of quartzite and volcanic clasts	75–100
8. Welded tuff, brown to pink, hard	35
7. Tuff and pumicite, gray and pink, soft, porous, permeable. Base not exposed and not reached in core holes; probably not much thicker	65+
Approximate thickness of Conant Creek Tuff	200–250+

[Contact between Conant Creek Tuff and unnamed gravel not exposed]

Unnamed gravel (Miocene):

6. Conglomerate, tan, soft; poorly exposed on northeast slope of Signal Mountain (fig. 28). Sequence consists dominantly of boulder conglomerate of highly rounded quartzite clasts with lesser amounts of mafic volcanic rocks that weather to crumbled fragments. Clasts are embedded in a coarse, soft, almost unlithified, sand matrix. This sequence has not been drilled and there are no good natural exposures so details of lithology and sedimentary features are not known. The estimated thickness of the unnamed gravel is based on dips in the overlying Conant Creek Tuff and underlying Teewinot Formation nearby and on topography and horizontal distance between outcrops of bracketing strata. A small outcrop of fossiliferous Teewinot Formation, 1,200 ft horizontally south of the Conant Creek Tuff on the valley floor of Jackson Hole south of Signal Mountain suggests that the unnamed gravel is much thinner there.

Estimated thickness of unnamed gravel 1,000–1,200

Contact between the unnamed gravel and Teewinot Formation not exposed (position inferred).

[Section exposed along south bank of Snake River about 1,000 ft east of east base of Signal Mountain (fig. 28)]

Teewinot Formation (part) (Miocene):	
5. Claystone, white, hard, light-weight, possibly diatomaceous	6
4. Pumicite, white, hard, limy. Strike N. 10° W., dip 20° W	2
3. Claystone, pale-green, hard, massive; conchoidal fractures	15
2. Pumicite, white, fine-grained, very soft	10
1. Claystone, greenish-gray, hard, massive, siliceous	10

Base of measured and estimated section. Underlying rocks not exposed.

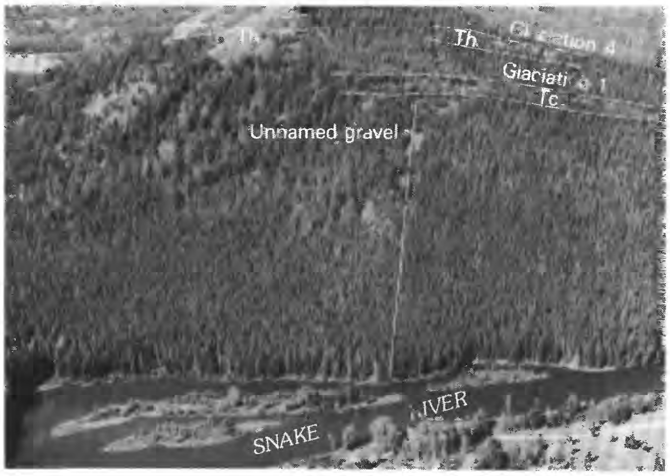


FIGURE 28.—Air-oblique view south at north face of Signal Mountain showing relations of Pleistocene deposits of glaciation 4, upper Pliocene Huckleberry Ridge Tuff (Th), Pliocene deposits of glaciation 1, lower Pliocene Conant Creek Tuff (Tcc), and unnamed gravel (upper Miocene). Photograph by W. B. Hall, J. D. Love, and T. H. Walsh, July 7, 1972.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

A major unconformity is present regionally at the top of the Teewinot Formation. Exposures of the overlying unnamed gravel are too limited and too poor to indicate its relation to the overlying Conant Creek Tuff, but, elsewhere, the Conant Creek unconformably overlaps rocks ranging in age from Miocene to Eocene and possibly older. The Pliocene deposits of glaciation 1 are inferred to have unconformities at both top and bottom. The overlying Huckleberry Ridge Tuff is the youngest lithified sequence in the Signal Mountain area, and elsewhere overlaps rocks ranging in age from Miocene to Paleozoic. The only post-Huckleberry deposits in this area are unconsolidated Quaternary glacial and fluvial material.

AGE AND CORRELATION

The Teewinot Formation is late Miocene in the revised Tertiary time scale that places the Miocene-Pliocene boundary at 5 Ma. A K-Ar age from the upper part of the type section of the Teewinot is 9.2 Ma (Evernden and others, 1964). Originally, it was called middle Pliocene (Love, 1956a) on the old time scale. The Teewinot Formation at the site 1,000 ft south of Signal Mountain yielded a few mollusks and 45 species of diatoms (K. E. Lohman, written commun., 1955, diatom loc. 4216).

The unnamed gravel, which was the basal unit of the original Bivouac Formation, was called late Pliocene(?) on the old time scale; however, because the unnamed gravel lies between upper Miocene and lower Pliocene formations, the Teewinot and Conant Creek, the gravel is probably of late Miocene age.

The Conant Creek Tuff in its type section on the northwest side of the Teton Range (fig. 1) has been dated by K-Ar method as 5.78 ± 0.08 Ma and by fission track method as 4.2 ± 0.7 Ma (Christiansen and Love, 1978) and was called Pliocene. The younger age is considered to be more reliable (see previous discussion). On the revised time scale, the Conant Creek Tuff is considered to be early Pliocene.

No age is available for the deposits of glaciation 1, but inasmuch as they are bracketed by Pliocene rocks (Conant Creek Tuff below and Huckleberry Ridge Tuff above), the deposits are assigned to the Pliocene.

The Huckleberry Ridge Tuff in and near Yellowstone National Park was dated on the basis of 17 K-Ar samples from the welded tuffs as about 1.9 Ma (Christiansen and Blank, 1972; R. L. Christiansen, written commun., 1975), with a range from 1.81 to 2.17 Ma. Using the revised decay constants (Steiger and Jager, 1977), the 1.9-Ma age of the Huckleberry Ridge Tuff is recalculated to be 2.02 ± 0.08 Ma (J. D. Obradovich, oral commun., 1980; Love and A. C. Christiansen, 1980). Inasmuch as the Pliocene-Pleistocene boundary has been placed at 1.65 Ma by Richmond and Fullerton (1986), the Huckleberry Ridge Tuff becomes Pliocene. The 2.5 Ma age from sanidine in pumicite below the base of the welded tuff, in unit 16 of the measured section at the Jackson Lake Dam quarry (R. W. Kistler, written commun., June 1, 1964), may represent an eruptive phase of the Huckleberry Ridge Tuff older than the welded tuff in the Yellowstone area, or possibly the sample could have been slightly altered. The sample came, however, from a fresh quarry face below the zone of weathering. The Pliocene-Pleistocene boundary of 2.5 Ma was used in many publications (for example, Love and Reed, 1968; Love, Reed, and others, 1973) and at that time the formation was called Pleistocene.

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