Leidy Formation—New Name for a Pleistocene Glacio-Fluviatile-Lacustrine Sequence in Northwestern Wyoming

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

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Leidy Formation—New Name for a Pleistocene Glacio-Fluviatile-Lacustrine Sequence in Northwestern Wyoming

By J.D. LOVE

GEOLOGY OF THE TETON-JACKSON HOLE REGION, NORTHWESTERN WYOMING

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 932-D

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

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LEIDY FORMATION—NEW NAME FOR A PLEISTOCENE GLACIO-FLUVIATILE-LACUSTRINE SEQUENCE IN NORTHWESTERN WYOMING

By J.D. LOVE[1]

ABSTRACT

The Leidy Formation (new name) consists of about 400 ft to perhaps 900 ft of intertonguing till, fluviatile gravel, very fine sand, sandstone, and tan to red-brown lacustrine clay, claystone, and shale. The formation was deposited along at least 40 mi of the Gros Ventre River valley and adjacent tributaries in and adjacent to a lake impounded behind an ice dam at the mouth of the Gros Ventre canyon. Subsequent erosion and glaciation have removed the deposit from all but a few isolated localities. No conspicuous volcanic debris and no diagnostic fossils have been found. The presence of abundant, coarse, granitic till from the Wind River Range, 25–50 mi to the southeast, and normal magnetic polarity of the fine-grained strata suggest a Pleistocene age for the sequence. The fine-grained strata are environmentally significant because they support abundant selenium-converter plants that probably have an adverse affect on livestock and wildlife.

ACKNOWLEDGMENT

This paper has been greatly improved by Ann Coe Christiansen whose help and skill in editing are acknowledged with gratitude.

NAME AND DEFINITION

The Leidy Formation is here named after Mount Leidy, the highest peak (elevation 10,326 ft) in the Mount Leidy Highlands, Teton County, Wyoming. The type section is on the north side of the Gros Ventre River (fig. 1), 12 mi south-southwest of the peak. In an earlier publication (Love, 1956), the strata were lumped together as landslide and glacial deposits. Detailed geologic field work that started in 1955 and roadcuts made by the U.S. Forest Service in the late 1970's demonstrated that an unnamed glacio-fluviatile-lacustrine sequence more than 400 ft thick was present, remnants of which occur along the valley of the Gros Ventre River and its tributaries over a distance of at least 30 mi (Love, 1977, p. 592, depositional event 19). Therefore, a formal name for these strata is justified.

DISTRIBUTION AND THICKNESS

The mapped areas of outcrop of the Leidy Formation are along the Gros Ventre River valley and the North and South Forks of Fish Creek, tributaries of the Gros Ventre River (fig. 1). The Leidy Formation is preserved only in isolated outcrops, rarely more than 1.5 mi long, so correlation of individual beds is difficult except for the basal, rather homogeneous, quartzite gravel. The formation tilts westward at about 35 ft per mi. In the absence of specific data to the contrary, one interpretation of the deposit as a whole could be that the poorly consolidated and generally fine-grained strata overlying the basal gravel were laid down in "layer-cake" fashion, with the older units at the base and the younger at the top. Another interpretation is that some units low in the center of the valley may be inset and thus

[1]U.S. Geological Survey, Laramie, Wyoming.

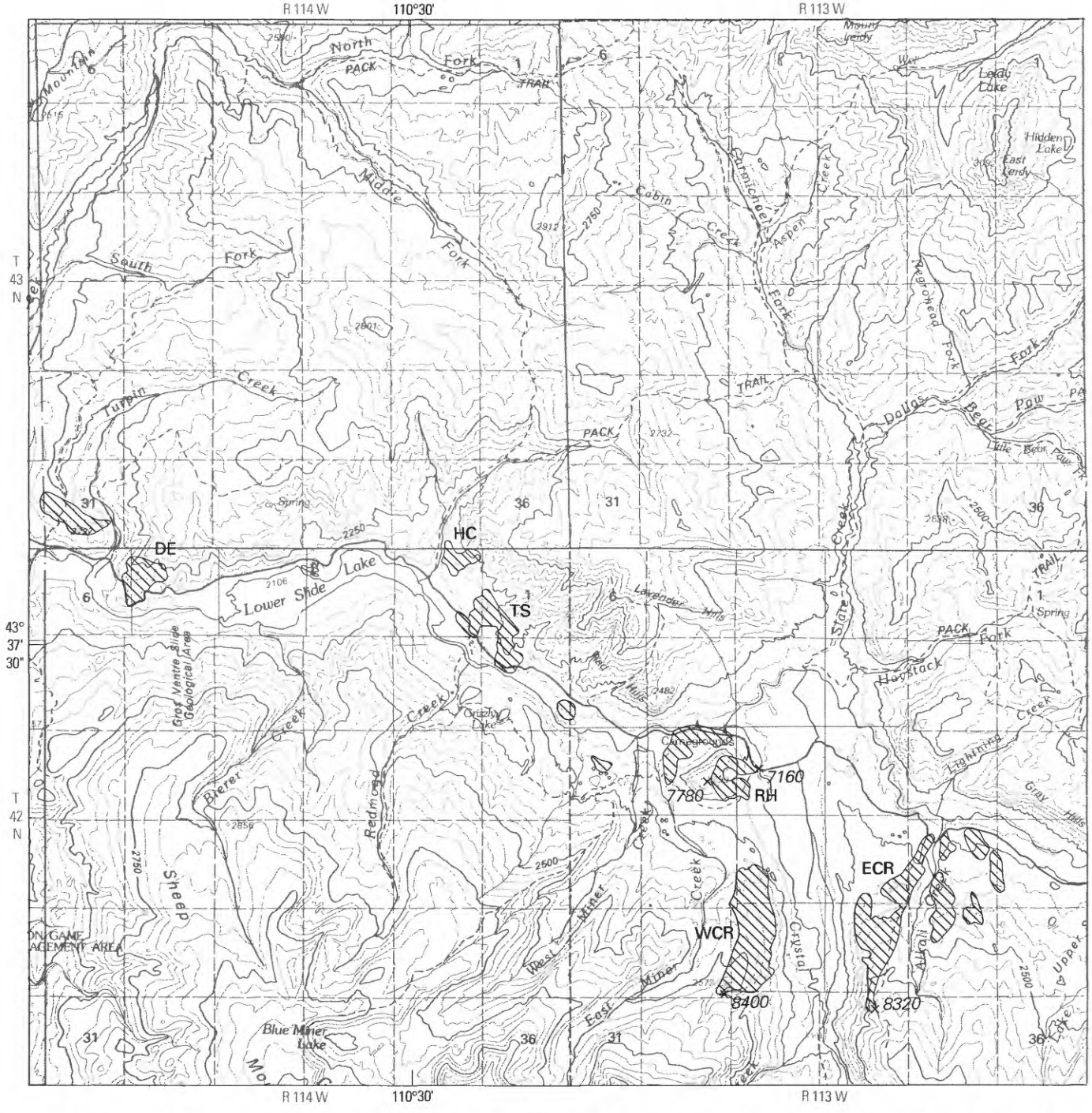
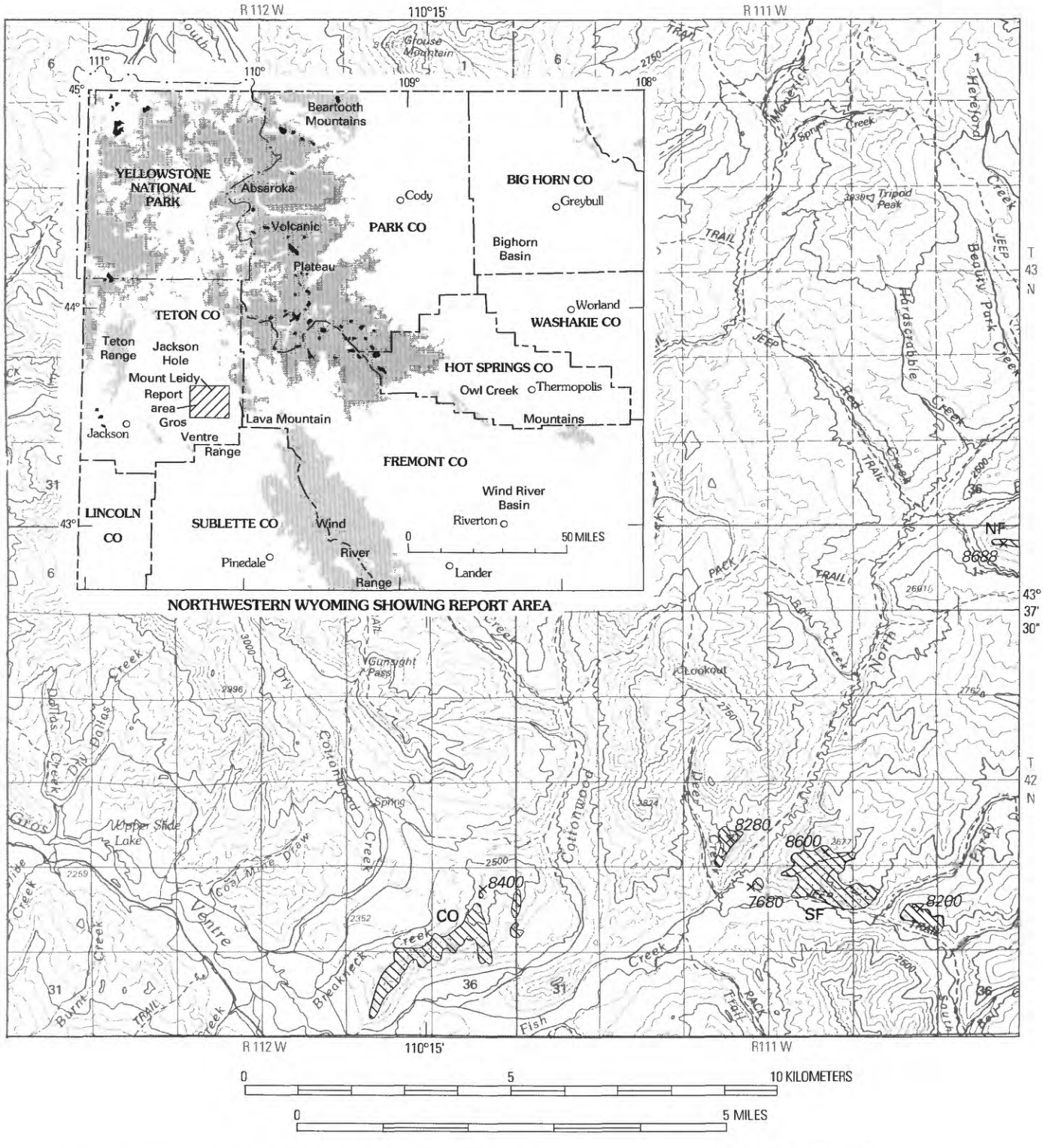


FIGURE 1 (above and facing page).—Localities of Leidy Formation described in text, showing selected elevations, in feet, of top and base of Leidy Formation. DE, Devils Elbow; HC, Horsetail Creek; TS, type section of the Leidy Formation; RH, Red Hills; WCR, West Crystal Creek; ECR, East Crystal Creek; CO, Cottonwood Creek; SF, South Fork Fish Creek; NF, North Fork Fish Creek. Light shading on index map indicates Precambrian rocks; dark shading indicates Tertiary and Quaternary volcanic rocks. Base from U.S. Geological Survey 1:100,000-scale Jackson Lake quadrangle, 1981; contour interval 50 m.

are younger than those high on the valley margins. If the latter is true, the actual original thickness of the Leidy Formation may never have been the cumulative thickness from the basal strata on the valley floor to the highest strata on the valley margins. If the first interpretation of thickness and depositional mechanics is accepted, the formation would be about 440 ft thick at the type section in



secs. 1 and 12, T. 42 N., R. 114 W. (fig. 2). The westernmost exposure, at the Devils Elbow locality, is a partial section that may be nearly 300 ft thick. At the South Fork Fish Creek locality (SF, fig. 1), the top of the Leidy Formation is at 8,600 ft and the bottom is at 7,680 ft.

LITHOLOGY

TYPE SECTION

The lithology of the Leidy Formation is described in detail in the type section. The type section was

FIGURE 2.—Type section of Leidy Formation, secs. 1 and 12, T. 42 N., R. 114 W., Teton County, Wyoming. View is to the north, across Gros Ventre River (lower left corner). Dotted line indicates line of section; solid lines indicate formation contacts. Qls, Quaternary landslide debris derived from Leidy Formation; Qly, Leidy Formation; arrow, till in unit 24; Jm, Morrison(?) Formation; JTn, Nugget Sandstone; Tc, extensive outcrops of Chugwater Formation. Note the two roads across Leidy outcrops in middle of photograph; measured section is tied to them. Photograph by J.D. Love, June 1963.

described, sampled for pollen, and photographed in 1955, 1957–58, 1967, 1969, and 1984 by the author (figs. 2–4). It is poorly exposed and extensively slumped, partly because of the unlithified nature of the strata. Intertonguing with the fine-grained strata are several tills, some with erratics as much as 5 ft in diameter. These are chiefly of Paleozoic rocks from the Gros Ventre Range (6 mi to the south), Precambrian igneous and metamorphic rocks from the Wind River Range (40 mi to the southeast), and volcanic rocks from the Absaroka Range (25 mi to the northeast) (fig. 1).

The type section was hand-trenched wherever possible. The dark-gray shale marker bed (unit 9) strikes about 45° NE. and dips about 1° NW. This dip could be depositional or could perhaps be the result of regional westward tilting of this part of the Jackson Hole area. Samples for pollen, collected in 1958, were identified by E.B. Leopold (written commun., 1960). No megafossils were found except for sparse, unidentifiable leaf fragments at the Devils Elbow locality. Several samples for paleomagnetic determination were collected by D.W. Burbank, University of Southern California. In the type section below, unit 1 is oldest.

Type section of the Leidy Formation

[Measured with hand level and steel tape on the north side of the Gros Ventre River in secs. 1 and 12, T. 42 N., R. 114 W., Mount Leidy and Grizzly Lake 7 1/2-minute quadrangles, 1965, Teton County, Wyoming]

		Thickness (feet)
Leidy Formation (Pleistocene):		
28.	Claystone, reddish- to chocolate-brown, tough, containing 10 to 20 percent sand; pebbles of quartzite, chert, and red siltstone from Triassic Chugwater Formation in clay matrix. Unit overlaps a surface of high relief on north side of paleovalley cut in Chugwater Formation. Younger strata that may have once been present have been scoured away by ice and later erosion. Scattered clumps of *Astragalus bisulcatus* grow on unit but are not abundant. Pollen samples from 38 ft above base, from 35 ft above base, and from a chocolate-brown claystone in middle of unit are chiefly forms reworked from Cretaceous rocks	45
27.	Claystone, cocoa- to reddish-brown, soft, poorly exposed; mantled with much glacial debris. Probably no significant lithologic changes were missed because pits were dug about every 5 ft to in-place strata. In upper part, many angular, grit- to pebble-size clasts, chiefly of Precambrian quartzite and Paleozoic limestone and sandstone, embedded in claystone. *Astragalus bisulcatus* is abundant in lower 10 ft, sparsely present throughout remainder of unit. Top of unit is 30 ft north of wooden power pole	42
26.	Claystone and shale, dark-lead-gray, soft, fissile in part, very finely sandy; light gray near top. Four pollen samples are forms chiefly reworked from Cretaceous rocks. Main seleniferous unit; about 15 *Astragalus bisulcatus* bushes are in each 10-ft-square area (fig. 3); another unidentified vetch also grows selectively on unit	31
25.	Claystone, dark-gray, very fine grained, soft, plastic; thin partings of salmon-pink, very fine sand; lower part poorly exposed	16
24.	Till interbedded with sand and claystone, poorly exposed. Till is of angular erratics of Paleozoic rocks and some Precambrian granite that are as much as 6 ft in diameter. Sand is salmon pink and loose. Claystone is brick red and pebbly in upper part, gray brown in middle, and brick red at base. Pollen samples are reworked from Cretaceous shale. *Astragalus bisulcatus* grows on lower and middle parts but not on till	50
23.	Claystone and clay, dull-reddish-brown to gray, soft; monotonous sequence with only a few very fine sand and silt partings. Because of poor exposures, pits were dug at 3-ft intervals down to in-place strata. Pollen samples show forms reworked from Cretaceous rocks	33.5
22.	Sand, greenish-gray, very fine, homogenous; many dark grains; moderately clean. Concentration of plants having chevron-shaped leaves, unidentifiable without flowers	5.5

FIGURE 3.—Concentration of selenium-converter plant *Astragalus bisulcatus* on gray claystone of unit 26, type section of Leidy Formation. Note abrupt decrease in abundance of these plants at lithologic change marking top of unit (arrow). Photograph by J.D. Love, August 1984.

		Thickness (feet)
Leidy Formation (Pleistocene)—Continued:		
21.	Claystone, dark-red-brown to green, plastic, soft, very fine grained, very limy; contains white, clear crystals of gypsum(?)	24
20.	Claystone, dark-reddish-brown to green; appears wet on surface; very limy; abundant secondary clear crystals of gypsum(?)	3
19.	Claystone, dark-reddish-brown and green, mottled, very soft, plastic, limy, possibly gypsiferous; has hard crust on surface, poorly vegetated; supports some *Astragalus bisulcatus*	8
18.	Sand, tan, containing pea gravel in upper 2 ft; dark-brown and green, mottled plastic claystone in middle; tan at base	5
17.	Gravel, chiefly gray and red quartzite in rounded clasts 0.25–2 inches in diameter, rarely larger; has appearance of river gravel with little clay and silt	6.5
16.	Sand, rusty-brown, very soft, very fine; contains sporadic small, rounded quartzite pebbles. Lower 1 ft has white, salty bloom on outcrop that is licked by animals	2
15.	Claystone, dark-reddish-brown to brownish-gray, soft, plastic. Top is at top of abandoned upper road (fig. 2)	11
14.	Sand, gray, fine, clean, sparkly, loose; abundant black grains; 3-in-thick lens of coaly granules in middle	2.6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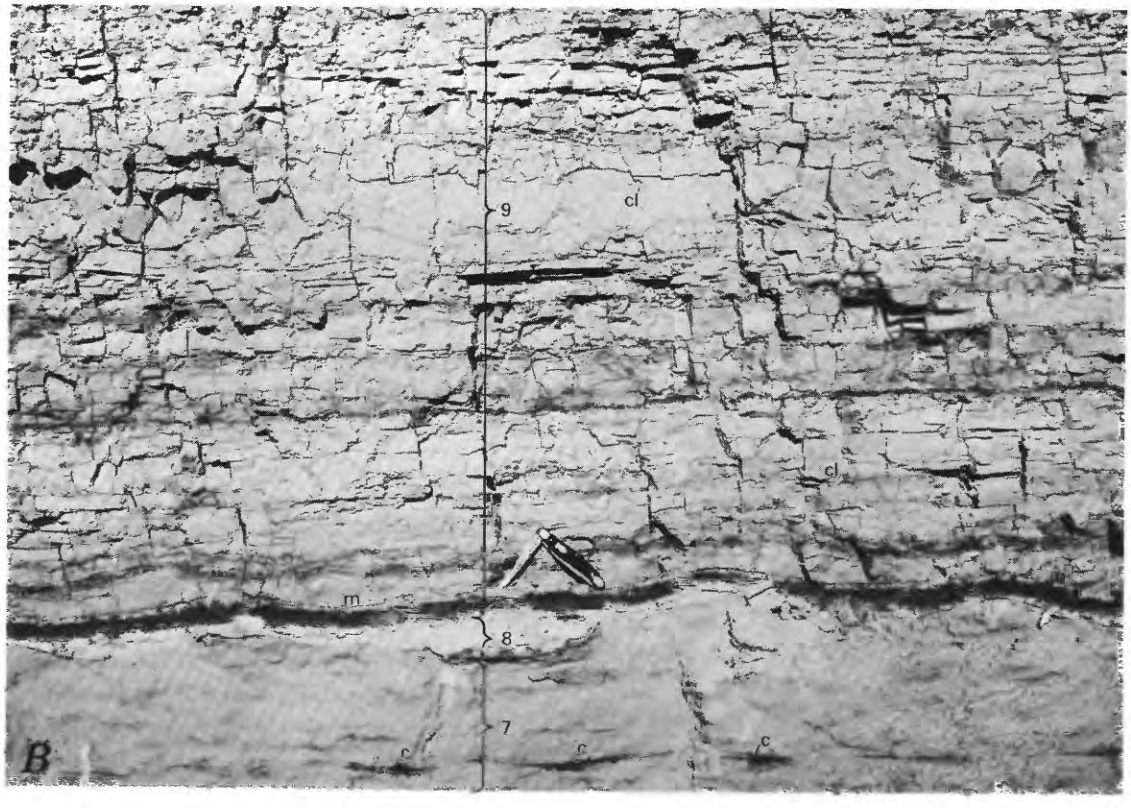
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FIGURE 4 (above and facing page).—Lower part of type section of Leidy Formation exposed near lower road shown on figure 2. Numbers refer to units of measured type section. 6, quartzite gravel; 7, sand with lenses of coaly debris; 8, sand (too thin to show in figure 4A); 9, shale and claystone; m, dark-gray shale marker bed; cl, laminated pink, yellow, and gray claystone; 10, sand and silt. Photographs by J.D. Love: *A* and *B*, September 26, 1969; *C*, August 26, 1955. *A*, Lacustrine and fluviatile strata; B, locality shown in figure 4*B*; Ab, selenium-converter plants of *Astragalus bisulcatus*; hammer shows scale. *B*, Detail of dark-gray shale marker bed, m; c, dark coaly debris; cl, claystone. *C*, Closeup of coarser laminae (as many as 20 per inch) and graded bedding in pink claystone of unit 9.

		Thickness (feet)
	Leidy Formation (Pleistocene)—Continued:	
13.	Partly covered interval between two roads. Tan silt and gray and pale-purple, silty, very fine sand was dug out. Upper part may have some pebbble beds, but this can be determined only by deeper excavation. Abundant *Astragalus bisulcatus*.....	16
12.	Claystone, chocolate-brown to pink, soft, plastic, evenly bedded; thin silt and very fine sand partings. Upper 1 ft has white salty bloom; deer and elk have licked it so extensively that the top forms an overhanging ledge. Top of unit is at top of lower roadcut (fig. 2).....	7
11.	Gravel, gray; composed chiefly of rounded quartzite clasts, but some are of fresh granite, probably from Wind River Range because no granite is exposed on north flank of Gros Ventre Range; size of clasts rarely as much as 6 in; angular blocks of Paleozoic sandstone as much as 3 ft in diameter; lithified and limy at top.....	7
	Leidy Formation (Pleistocene)—Continued:	
10.	Sand and silt, brown, fine, thin-bedded. Top transitional. See figure 4A.....	3
9.	Shale and claystone, lead-gray to chocolate-brown and pink; thin interbeds of gray, very fine sand (fig. 4*B*). Laminated pink, yellow, and gray claystone with silty partings is shown in figure 4*C*. At base is a 1-in-thick, dark-gray, ripple marked shale marker bed (m, fig. 4*A*, *B*) that is continuous for 100 ft and dips 1° NW.....	3.5
8.	Sandstone, olive-drab, hard, ripple marked, very limy, fine-grained; forms thin ledge (fig. 4*B*).....	0.1
7.	Sand, light-tan, soft, fine, mostly clean; lenses of black coaly debris in upper part (fig. 4*B*); scattered pebbles of quartzite in lower 2 ft.....	4
6.	Gravel, gray; chiefly quartzite clasts 1–2 inches in diameter, very few larger than 4 in; some clasts of gray granite, probably from Wind River Range, have disintegrated in place. Top of unit is just above road level of lower road (figs. 4*A*, 2).....	20.±
5.	Sand, light-tan, clean in part, silty and clayey in part, soft. Pollen samples from thin, pink clay 2 ft below top of unit, from 1-in-thick, pink, waxy claystone 6 ft above base, and from clayey sand containing carbon chunks that do not look like coal, 5 ft above base. A 4-in-thick layer of sandy siltstone, licked by animals for salt, is 3 ft above base.....	11
4.	Gravel, gray, unlithified; chiefly of rounded quartzite redeposited from the Pinyon Conglomerate, but sparse angular clasts of Paleozoic and Mesozoic rocks are rarely larger than 1 ft in diameter; is more till-like than the basal gravel (unit 2).....	28
3.	Sand, light-brown, silty, evenly bedded; partings of very fine grained, dark-brown to pink claystone...	2
2.	Gravel, gray, unlithified; smaller clasts are predominantly quartzite from the Pinyon Conglomerate; larger clasts of Mesozoic sandstone from Cretaceous formations (including Mowry Shale) and the Jurassic Sundance Formation; larger clasts also of Paleozoic limestone and Precambrian granite, probably from Wind River Range; many clasts larger than 2 ft in upper part; those in lower part are 1–2 inches in diameter. Looks more like a fluviatile deposit than till (no striated boulders seen). Contains some very small gold flakes.....	52
	Total measured thickness of Leidy Formation	438.7

[Contact between Leidy Formation, which is essentially horizontal, and Morrison(?) Formation, which strikes N. 55° W. and dips 45° NE., is very sharp. The gravel of unit 2 was deposited on a very irregular surface.]

		Thickness (feet)
	Morrison(?) Formation (Jurassic?)	
1.	Sandstone, greenish-gray, porous, nonglauconitic, nonsparkly. Forms prominent 50-ft-high cliff above Gros Ventre River; 100 ft east of Leidy type section, the sandstone is overlain by 15 ft of red and green nonglauconitic claystone, also part of the Morrison(?) Formation.....	50.+

DEVILS ELBOW LOCALITY

At the Devils Elbow locality (DE, fig. 1), the Leidy Formation is about 300 ft thick but is too poorly exposed to be described in detail except for the basal part, which was well exposed in a roadcut in 1984 when the data for figure 5 were collected. The roadcut was extensively modified in 1988 by the U.S. Forest Service and no longer appears as diagrammed. This exposure was especially important because it showed the intertonguing of till with the fluviatile-lacustrine strata. The till consists of large and small erratics, chiefly of highly rounded quartzite derived from the Pinyon Conglomerate but also includes angular fragments as much as 5 ft in diameter of Paleozoic and Mesozoic rocks that are embedded in a structureless, hard, limy matrix of pebbles, granules, and sand. Soled and striated erratics are common.

The clay and pebble sequence shown in figure 5 is a poorly bedded deposit of small, rounded pebbles in a matrix of dull-brown to gray, colloidally fine, plastic clay; this combination is characteristic of the Leidy Formation at all outcrops. The clay sequence is brown, reddish brown, and greenish gray, invariably fine, waxy, and plastic. The sand is tan and fine and forms a moderately continuous bed that dips about 7° NW.; it has not been determined if this is an initial attitude or one acquired by westward tilting of the Jackson Hole area in Pleistocene and Holocene time.

Overlying the strata exposed in the roadcut is nearly 100 ft of brown and gray clay and possibly some sand and gravel. *Astragalus bisulcatus* is abundant. Above this interval is 35 ft of sand (fig. 6) that is gray, medium, moderately well sorted, and homogeneous; it contains abundant sparkly grains and numerous chunks of coaly debris. This sand has been extensively quarried. It does not support *Astragalus bisulcatus*.

The remainder of the section overlying the sand is mostly brown and pink clay and silt that support abundant *Astragalus bisulcatus*. A 10-ft zone of clay, about 50 ft above the sand, contains some fossil leaf impressions too poor to be identified. The uppermost part of the Leidy Formation at this locality overlaps the Triassic Chugwater Formation; the Leidy was deposited on a surface of much higher relief than is now present but, despite this, very little locally derived coarse clastic debris from the adjacent slope is incorporated in it.

RED HILLS LOCALITY

The remnant of the Leidy Formation at the Red Hills locality is plastered on the east face of the Red Hills (RH, fig. 1); the relief on the base of the Leidy is about 560 ft in a horizontal distance of 2,200 ft. If the Leidy is essentially horizontal, its thickness here would be a minimum of 560 ft. The lowest part of the formation is at or slightly below the present Gros Ventre River valley floor, and the top is eroded away. Exposures are poor, and the formation is heavily mantled with glacial debris. Most of the sequence here is apparently soft, plastic, colloidally fine, gray to pink clay. Pollen samples were collected from near the top but yielded reworked Cretaceous forms. There are probably coarse clastics in the basal part but, if present, they are difficult to distinguish from younger glacial debris. An active landslide has stripped much of the Leidy claystone from the steep slope on the Chugwater Formation against which it was deposited. *Astragalus bisulcatus* is so abundant at some horizons in the middle and upper parts that it is difficult to walk without stepping on individual plants.

WEST CRYSTAL CREEK LOCALITY

The Leidy Formation, 1–2 mi south of the Red Hills locality, on the west side of Crystal Creek (WCR, fig. 1), consists largely of glacial debris and gravel having a maximum thickness of about 400 ft. Below the bare surface of till and gravel, about 10 ft of gray to dull-pink, plastic, soft, very fine clay is exposed in a pull-away landslide scar on the east side of the outcrop. The entire formation is poorly exposed in broad, rounded slopes; the base is everywhere hidden by slump or younger glacial debris. The till and gravel in the Leidy Formation are chiefly of subrounded clasts of Madison Limestone (Mississippian) from the Gros Ventre Range to the south, but there are also large erratics of Permian chert and Pennsylvanian Tensleep Sandstone, very sparse Precambrian granite from the Wind River Range to the southeast, and rounded quartzite cobbles and boulders from the Pinyon Conglomerate across the Gros Ventre River valley to the north. No volcanic rocks from the Absaroka Range to the northeast were found. Some of the boulder beds are pink and support sparse stands of *Astragalus bisulcatus*. The zone of waxy, soft clay is at an elevation of about 8,080 ft, 350 ft higher than the top of the clay at the Red Hills locality. The strata at the West Crystal

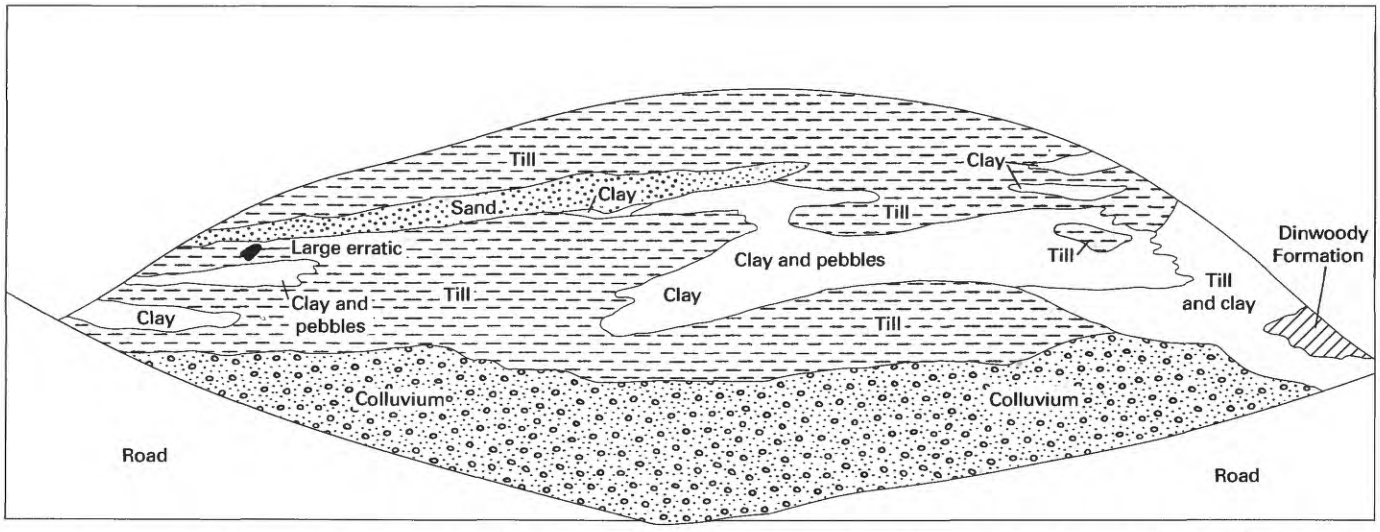

FIGURE 5.—Diagram of south-facing roadcut at Devils Elbow locality (DE, fig. 1) showing the intertonguing relations of the lacustrine-fluviatile strata and glacial deposits in the Leidy Formation. The till contains abundant striated and soled erratics, chiefly of quartzite from the Pinyon Conglomerate and Paleozoic and Mesozoic rocks. Approximately 70 ft of strata are exposed above road level. Diagram sketched from a photograph taken August 6, 1984; roadcut extensively modified in 1988 by the U.S. Forest Service.

Creek locality were deposited on a very irregular terrain cut into Paleozoic and Mesozoic rocks.

EAST CRYSTAL CREEK LOCALITY

On the east side of Crystal Creek (ECR, fig. 1), the Leidy Formation is at approximately the same elevation as on the west side and, likewise, is almost entirely gravel and till, but there are also tiny exposures of soft, plastic, red and gray clay. The till and gravel contain considerably more quartzite clasts from the Pinyon Conglomerate than the strata at West Crystal Creek; otherwise, the composition here is comparable to that at the West Crystal Creek locality.

COTTONWOOD CREEK LOCALITY

Seven miles to the east of the East Crystal Creek locality, on the west side of Cottonwood Creek (CO, fig. 1), the Leidy Formation unconformably overlies the Upper Cretaceous Sohare Formation and consists of about 75 ft of fluvial gravel containing clasts generally less than 1 ft in diameter but with a maximum size of about 3 ft. These clasts, chiefly from the Pinyon, are rounded quartzite clasts but include

FIGURE 6.—Leidy Formation at Devils Elbow locality (DE, fig. 1). Upper part of gray, medium sand, 35 ft thick, about 100 ft above roadcut shown in figure 5. Dark layers near base of photograph are concentrations of coaly debris. Photograph by J.D. Love, September 6, 1962.

lesser amounts of Eocene Absaroka Volcanic Supergroup rocks, Mesozoic sandstone, and Precambrian rocks from the Wind River Range. Overlying this fluvial gravel is about 60 ft of till containing huge, angular erratics, 4 ft or more in diameter; the erratics are mainly Paleozoic rocks in an unsized and unsorted matrix of many rock types. Overlying the till is 2 ft of dark-gray-brown, very fine, plastic clay similar to that in the type section. The clay is overlain by 20–30 ft of gray, fine, soft, loose, even-textured sand. Above the sand is 10 ft of lead-gray to tan, soft, plastic clay and silt. Overlying the clay is 50 ft or more of tan, fine, loose sand. *Astragalus bisulcatus* is common on many of the beds.

SOUTH FORK FISH CREEK LOCALITY

The composition of the Leidy Formation on the South Fork of Fish Creek (SF, fig. 1) is especially significant. The basal strata rest unconformably on the Sohare Formation (Upper Cretaceous) on a spur about 150 ft topographically above the adjacent flood plain at the junction of the North and South Forks of Fish Creek (at elevation 7,680 ft, fig. 1). Here, the basal bed consists of about 5 ft of highly rounded granite boulders, more like stream boulders than glacial erratics, as much as 4 ft in diameter, intermixed with highly rounded quartzite gravel from the Pinyon. Above the basal boulder bed are 15 ft of soft, tan clayey sand, overlain by 5 ft of angular boulders of black basalt scoria and andesitic rocks that are as much as 3 ft in diameter. These boulders are overlain by a 10-ft unit of tan, clayey sand.

About 250 ft higher on this spur is a remnant of the upper part of the Leidy Formation. Cretaceous sandstone occupies the interval between these outcrops. At the base of the upper section is about 100 ft of quartzite gravel derived from the adjacent Pinyon Conglomerate that is exposed to the east and north. This gravel is intermixed with boulders of gray to pink granite, as much as 4 ft in diameter, which become more abundant and larger near the top of the section. One 4-ft boulder of hard, tuffaceous sandstone from the Aycross Formation (middle Eocene), which crops out 15 mi to the northeast, was observed. Above this boulder bed is 30–40 ft of tan to pink, loose, medium sand and some clay beds. Capping these is a till of giant granite boulders, one of which measured 8×6×5 ft, and sparse, much smaller, Paleozoic clasts. No volcanic clasts were seen. The granitic debris at this locality was carried 20–25 mi northwestward by ice and water from the Wind River Range. No granite source is exposed on the north side of the Gros Ventre Range. The debris from the Wind River source merged with volcanic debris that was brought by ice and water 10 mi southwestward from Lava Mountain and the Absaroka Range. (See discussion of the deposit on the North Fork Fish Creek.)

NORTH FORK FISH CREEK LOCALITY

One remnant of the Leidy Formation, about 120 ft thick, is preserved on the west end of a narrow spur between Squaw and Papoose Creeks east of the North Fork of Fish Creek (NF, fig. 1). At the base is about 10 ft of carbonate-cemented, quartzite pebble conglomerate with clasts of only 1–2 in; this conglomerate unconformably overlies coaly strata in the Wind River Formation (lower Eocene). Above this is 25 ft or more of bright-red, green, and gray clay, silt, sand, and tuff reworked from middle Eocene rocks. Overlying these strata is a 13-ft layer of jumbled, angular, red and black basalt boulders, some as much as 5 ft in diameter, which were probably derived from basalt flows on Lava Mountain, 10 mi to the northeast, and dated at about 500,000 years B.P. (Love and Love, 1983, p. 15). This boulder bed has characteristics typical of till, but it could be a debris flow. Above the boulder bed to the top of the deposit is about 65 ft of pale-green, very fine, sticky clay and pebbly sand containing sporadic boulders of basalt.

SOURCES OF SEDIMENT AND CONDITIONS OF DEPOSITION

A preliminary attempt was made to compile an isopach map using the data on figure 1 and using 19 points from the exposed base and top of the Leidy Formation along 30 mi of the Gros Ventre River valley and the North Fork of Fish Creek. This isopach map shows that the river that deposited the basal fluvial gravel followed the present course of the Gros Ventre River between the junction of the North and South Forks of Fish Creek and the Devils Elbow locality. Most quartzite clasts were probably derived from the Paleocene and Upper Cretaceous Pinyon Conglomerate, which is extensively exposed north and east of the Gros Ventre River in the Mount Leidy area and along Fish Creek. However, Lagas (1984), who studied the glacial deposits in the lower part of the Gros Ventre valley, thought that the source of the basal quartzite gravels was Jackson Hole and that they backfilled the valley.

Glacial erratics indicate that ice flowed into the Fish Creek drainage from granitic terrain in the Wind River Range to the southeast and from the Paleozoic rocks of the Gros Ventre Range to the south (fig. 1). Precambrian rocks are not exposed north of the topographic crestline of the Gros Ventre Range (Simons and others, 1988). Ice also advanced southwestward from the Eocene volcanic terrain of the Absaroka Range and the Quaternary basalt of Lava Mountain, crossed the drainage divides at the heads of Cottonwood Creek and North Fork Fish Creek, and flowed down the Fish Creek valley. It then merged with ice from the Wind River and Gros Ventre Ranges.

The base of the Leidy Formation on the South Fork Fish Creek is at an elevation of about 7,740 ft, whereas 15 mi downstream, to the west at the Red Hills locality, the base is at 7,160 ft. This indicates that the paleovalley at the beginning of Leidy deposition had a gradient only slightly steeper along this stretch of the Gros Ventre valley than exists today (40 ft vs. 35 ft per mi).

What happened in the deeper part of Jackson Hole during deposition of the Leidy Formation is not well understood, but it seems likely that a glacier more than a thousand feet thick occupied the area between the Devils Elbow locality and the Teton Range, 10 mi to the west, and almost certainly dammed the Gros Ventre River valley west of the Devils Elbow locality. If the "layer-cake" interpretation, described previously, is correct, perhaps 800 ft or more of very fine clay and associated glacio-fluviatile deposits composing the Leidy Formation were deposited upstream from (east of) that ice dam. The clay probably was derived in large part from Cretaceous and Tertiary shale and claystone to the east. The presence of abundant Late Cretaceous pollen at several horizons in the type section of the Leidy helps substantiate this interpretation.

The sediments at the top of the Leidy Formation and incorporated glacial debris deposited in and adjacent to the lake had approximately the same maximum elevation. The maximum elevation of remnants at the West Crystal Creek locality is 8,400 ft, at Cottonwood Creek 8,400 ft, at South Fork Fish Creek 8,600 ft, and 6 mi farther north, on North Fork Fish Creek, 8,700 ft. The top of the Leidy Formation farthest to the west is probably somewhat lower now than when originally deposited because of the westward downtilting of the Jackson Hole area along the Teton fault (Love, 1977) later in Quaternary time.

The eastern remnants of the Leidy Formation contain more glacial debris and less lacustrine sediment than their western counterparts. The top of the glacio-fluvatile deposit probably increased in altitude toward the source in the Wind River Range due to normal stream gradients. Although many cubic miles of debris were removed by later glaciation and erosion when the valley was reexcavated, there apparently was no more than 150 ft of deepening of the pre-Leidy valley floor in post-Leidy time.

The number of ice advances from the Gros Ventre Range to the south, from the Wind River Range to the southeast, and from the Absaroka Range to the northeast, and the thickness of ice at any given time during deposition of the Leidy Formation are not easily determined because of poor exposures and discontinuous remnants of Leidy deposits. Two conspicuous tills from the Wind River Range merge near the South Fork Fish Creek locality, but it is not known how they correlate with other tills in the region.

ENVIRONMENTAL SIGNIFICANCE

Astragalus bisulcatus is the only selenium-converter plant on the Leidy Formation. This species requires selenium to grow well. Most of the selenium is probably recycled from the Sohare Formation and Cody Shale, although lesser amounts may have come from the Mowry Shale, Cloverly and Morrison(?) Formations, and the Eocene strata east of the forks of Fish Creek. In addition to indicating the presence of selenium, this plant has important environmental significance. One question that has been raised is whether this species is indigenous to the area. During the summer of 1933, O.A. Beath, the selenium chemist at the University of Wyoming, assigned the author to search for selenium-converter plants of any species along the Gros Ventre River valley. After a week of looking, H.F. Eppson, chemist, University of Wyoming, and the author found only a few plants of *Astragalus bisulcatus*, all on the Sohare Formation near the mouth of Cottonwood Creek. None was observed on sediments recognized in this report as the Leidy Formation. The seeds were probably brought into the region from some other seleniferous area by way of baled hay, cars, or cattle because the plants themselves cannot spread across broad natural nonseleniferous barriers. During the next 57 years, this species spread progressively along seleniferous strata, laterally from where these strata cross the U.S. Forest Service access road along the Gros Ventre River valley. Each selenium-converter plant converts a halo of selenium from a chemical form that is unavailable to most of the common, normally nonseleniferous plant types to a chemical form that is available to nearly all plants

(Beath, 1982). Thus, the originally nonseleniferous plants at these sites became secondarily seleniferous.

Each June, about 3,000 cattle are driven across the Leidy Formation at the Devils Elbow and Horsetail Creek (DE, HC, fig. 1) localities (Fred Kingwill, U.S. Forest Service, oral commun., 1985) and spread out from there eastward into the headwaters of Fish Creek. The cattle return across the same downstream localities in September and October. Chronic selenium poisoning, as indicated by "sledrunner" hoofs, weight loss, patchy hair, and low birth rate, have been observed in some of the cattle that have spent the summer on this range (correspondence from O.A. Beath to Rod Lucas, January 1957). The area east of the type section of the Leidy Formation is winter range for elk. The type section and the Red Hills locality are likewise winter range for bighorn sheep. The elk in this area have an unusually low birth rate, and some exhibit greater nervousness and a higher incidence of ulcerated livers and tooth decay than elk in nonseleniferous areas (Dr. Margaret Altmann, University of Wyoming, oral commun., 1955). The effect of selenium on humans in this area has not been documented.

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The Leidy Formation rests with angular unconformity on strata ranging in age from Pennsylvanian to early Eocene. The relief on this unconformity is steeper than the present land surface. The only deposits known to overlie the Leidy Formation along and adjacent to the Gros Ventre River valley are younger tills of Pleistocene age.

AGE AND CORRELATION

The Leidy Formation is of Pleistocene age. No diagnostic megafossils or microfossils have been found. The ice-margin environment may have been too harsh to permit extensive development of fauna and flora. Samples from units 5–26 of the type section contain the following palynomorphs, as identified by E.B. Leopold (Report F-58-32-D, written commun., April 28, 1960):

Sporites arcifer Thiergart
Triplanosporites sinuosus Pflug
Gleicheniidites senonicus Ross
Deltoidospora halli Miner
Foveosporites canalis Balme
Inaperturopollenites dubius Potonie
Pityosporites labdacus Potonie
Classopollis cf. *torosus* Reiss
Triporopollenites endoplicatus (Stanley, 1960 dissert.).

"Units C, D, and E [units 15, 21, and 23 in type section] contain substantial amounts of these pollen—about 60 to 100 grains per 20-gram sample of sediment. Only 6 or 8 grains that could be interpreted as Quaternary pollen forms were found among these 7 samples. Because the stratigraphy indicates a Quaternary(?) age [for the Leidy Formation], the contained pollen must be interpreted as rebedded. The assemblage listed above suggests a Lance age for the source sediments."

Paleomagnetic determinations by D.W. Burbank, University of Southern California (oral commun., 1985) of samples from the type section of the Leidy Formation have normal magnetic polarity, compatible with an age of less than about 750,000 years B.P. No volcanic ash has been found in the Leidy Formation.

The till intertonguing with the fluviatile-lacustrine strata (fig. 5) in the Leidy Formation represents a glaciation that is younger than the Pliocene till (Love, 1989; also called diamicton by Pichmond, 1986, p. 86) under the Huckleberry Ridge Tuff at Signal Mountain in Grand Teton National Park and is older than, or perhaps contemporaneous with, some of the ice that dammed the mouth of the Gros Ventre River valley. The correlation of this and other Pleistocene glaciations in Jackson Hole with the Bull Lake glaciation at Bull Lake, Wyoming, the Pinedale glaciation at Pinedale, Wyoming, and older glaciations in the Wind River Range to the southeast has not been firmly established.

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