UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Glacial Lake Devlin and the chronology of Pinedale Glaciation on the east slope of the Front Range, Colorado

By

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Abstract

Glacial Lake Devlin was dammed in a tributary valley 2.3 km upvalley from the limit of Pinedale Glaciation in North Boulder Creek valley, Boulder County, Colorado. Lake Devlin was about 2 km long, 200-460 m wide, and as much as 60 m deep. The distribution of till along North Boulder Creek indicates that lakes should have formed during both the Pinedale and Bull Lake Glaciations, but evidence that an older lake existed is not unequivocal. The shoreline of the Pinedale-age lake is relatively distinct and occurs at an altitude of about 2,975 m (9,760 ft).

Coring and augering at three localities revealed 36 m of lake sediment including, from the top down, 18 m of silt and clay rhythmites, 10 m of sand and gravel, and at least 8 m (bottom not reached) of clay with interbedded sand and gravel. The 10 m of sand and gravel is believed to be proglacial outwash of Pinedale age from three small glaciers in the upper part of the Caribou Creek drainage basin deposited before Caribou Creek was dammed. The underlying clayey sediment probably was deposited in a lake of pre-Pinedale age. Organic matter concentrated from core samples of the rhythmites provided nine ^{14}C ages that indicate that the latest phase of Lake Devlin persisted from about 22,400±1230 (DIC-870) to 12,180±240 (GaK-4834) ^{14}C years ago. Because Lake Devlin formed as ice of the Pinedale Glaciation was nearing its maximum expansion, this maximum expansion is inferred to have occurred within or relatively shortly after the interval between 23,000 and 21,000 years B.P.

INTRODUCTION

Lake Devlin was a glacier-margin lake of Pinedale age dammed near the lower limit of glaciation on the east slope of the Front Range in Boulder County, Colorado. Its history is important to the chronology of Pinedale Glaciation, because the existence of Lake Devlin was controlled by the glacier in the valley of North Boulder Creek. The sediment of Lake Devlin has provided radiocarbon ages that indicate when the glacier in North Boulder Creek valley neared its maximum position during the last glaciation and a minimum estimate of when it receded from that position. The pollen deposited with this sediment provides a record of the vegetation of the area and an estimate of treeline position during full-glacial conditions. The thick section of laminated silty-clay and clayey-silt bottom sediments of Lake Devlin are exceptionally usable for studies of paleomagnetism. They are magnetically strong and stable, and the laminations made it easy to recognize parts of the section that might have been deformed by coring.

This paper summarizes laboratory and field data for the sediment of Lake Devlin and reports the radiocarbon ages determined thus far. Other investigators--F. W. Bachhuber, E. E. Larson, Joseph Rosenbaum, and R. G. Baker--involved in this cooperative study have separate data on the vegetational and paleomagnetic history recorded in the sediment of Lake Devlin.

ORIGIN AND GEOMORPHOLOGY OF LAKE DEVLIN

Lake Devlin formed when the glacier descending the valley of North Boulder Creek advanced across the mouth of Caribou Creek, a tributary located near the lower limit of glaciation (fig. 1). The drainage basin of Caribou

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Figure 1.--NEAR HERE

Creek is small, about 5 km long and 4 km wide, and nestled well below the divides that separate it from adjacent watersheds. The ponded waters of this drainage basin had no outlet other than along the glacier margin. Lake Devlin no doubt fluctuated in size, but remained long enough at one level to form a shoreline, evident around most of its former perimeter at an altitude of about 2,975 m (9,760 ft). Lake Devlin was nearly 2 km long and varied in width from about 200 m to a maximum of 460 m in Devlins Park. The lake varied in depth from about 30 to 60 m, and was apparently deepest in Devlins Park near the present confluence of Caribou Creek and the creek from the Rainbow Lakes (fig. 2).

Figure 2.--NEAR HERE

Figure 1.--Map showing the location of Lake Devlin and adjoining areas that were glaciated during late Pleistocene time.

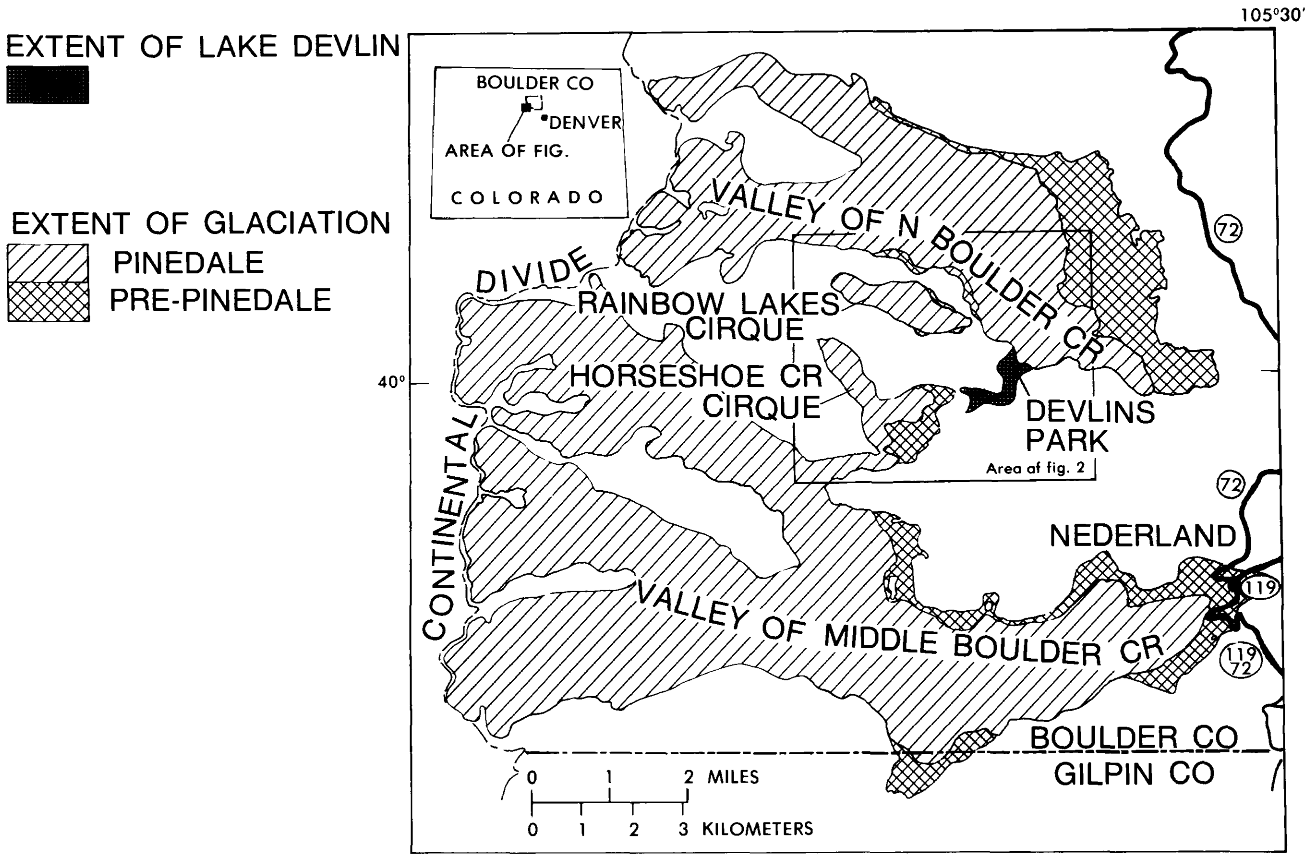
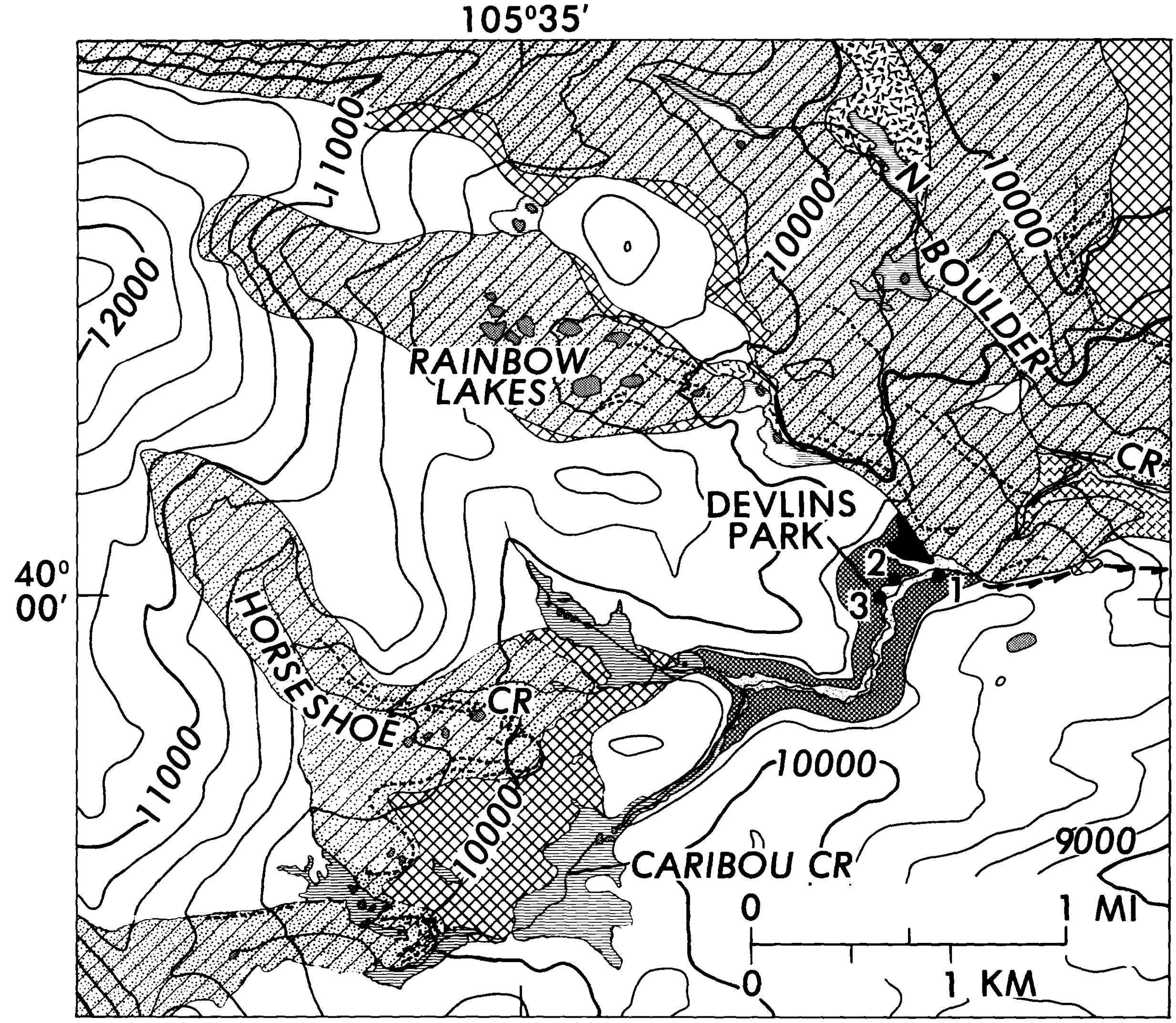

EXTENT OF LAKE DEVLIN
EXTENT OF GLACIATION
PINEDALE
PRE-PINEDALE
105°30'
40°
BOULDER CO
DENVER
AREA OF FIG.
COLORADO
VALLEY OF N BOULDER CR
CONTINENTAL DIVIDE
RAINBOW LAKES CIRQUE
HORSESHOE CR CIRQUE
DEVLINS PARK
Area of fig. 2
72
NEDERLAND
119
119
72
VALLEY OF MIDDLE BOULDER CR
BOULDER CO
GILPIN CO
0 1 2 MILES
0 1 2 3 KILOMETERS

Figure 2.--Map of surficial geology of the Lake Devlin area and location of core sites.



HOLOCENE

ALLUVIUM

HOLOCENE AND PLEISTOCENE

PEAT AND MUCK; INCLUDES SMALL AMOUNTS OF TILL AND OUTWASH LOCALLY

PLEISTOCENE

FLOOD AND SPILLWAY DEPOSITS

LACUSTRINE SEDIMENT OF LAKE DEVLIN, LOCALLY OVERLAIN ALONG MARGINS BY COLLUVIUM

DELTAIC SEDIMENT

OUTWASH OF PINEDALE AGE

TILL OF PINEDALE AGE; INCLUDES BEDROCK ALONG NORTH EDGE AND SW CORNER OF MAP AREA

TILL OF BULL LAKE AGE; MAY INCLUDE SOME PRE-BULL LAKE TILL LOCALLY

TERTIARY AND PRECAMBRIAN

IGNEOUS AND METAMORPHIC ROCKS UNDIFFERENTIATED

•2 CORE SITE

MORAINE CREST

SPILLWAY

The position of the shoreline of Lake Devlin is outlined at the downvalley end of the lake by remnants of a wave-cut terrace and on the west side of Devlins Park, where slopes are less steep, by beach deposits. The shoreline in Devlins Park is about 13 m above the former lake floor. At the upvalley end of the lake, the shoreline is nearly coincident with the level of the former lake floor itself. Although broadly incised by Caribou and Horseshoe Creeks to depths of 3 to more than 10 m, the former lake floor remains along the valley sides, like paired stream terraces. The surface of the sediments at the upvalley end of the lake is at nearly the same level as the surface of the segments of wave-cut terrace at the downvalley end, but the two surfaces do not join. The surface of the lake floor at the upvalley end of the lake descends gradually downvalley and becomes obscure about 600 m below the junction of Caribou and Horseshoe Creeks. The wave-cut terrace, which is especially distinct along the steep slope that bounds Devlins Park on the southeast, becomes obscure in an upvalley direction beginning about 500 m above the moraine dam where valley orientation changes from north-south to east-west.

Morey (1927) was the first to recognize remnants of the lake shoreline in Devlins Park, and Gilbert (1968) was the first to describe these remnants in detail (see table 1). Although the shoreline is about 13 m above the former

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Table 1.--NEAR HERE

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lake floor in Devlins Park, it is 14 to 20 m above present stream level. Caribou Creek and, to a lesser extent, the creek from the Rainbow Lakes have removed the upper 3 to 8 m of lake sediment over most of Devlins Park.

Table 1.--Height, width, origin and substrate (tabulated from Gilbert, 1968) of remnants of the shoreline of Lake Devlin along the perimeter of Devlins Park. (See fig. 1 for locations)

Location in park	Height above park floor (m)	Maximum width (m)	Origin and substrate
Northeast	16.7	24.4	Cut terrace in till of Pinedale age.
Southeast and east.	16.7	13.7	Cut terrace in colluvium 3.7-10.7 m thick.
Northwest and west.			
(upper)	16.5	19.2	Cut terrace in colluvium.
(lower)	15.2	16.7	Beach deposit of sand and gravel.

Preservation of the lake floor over such a broad area at its upvalley end is attributed to a cover of sand and gravel in this area. The sand and gravel were transported into Lake Devlin by proglacial streams from small glaciers at the heads of Caribou and Horseshoe Creeks (fig. 2). As much as 5 m of sand and gravel overlying lake bottom sediment are exposed along Caribou Creek 50 to 60 m upstream from its junction with Horseshoe Creek.

Boulders are common on the surface of the lake floor at the upvalley end of the lake, especially in the valley of Horseshoe Creek. The long axis of most boulders is less than 1 m, but for a few it is as much as 2 to 3 m. Some boulders are the product of mass movement, including minor landsliding from the valley sides. A wedge of colluvium occurs at the edge of the former lake floor in most places.

The moraine dam that impounded Lake Devlin was several meters thick and plugged an opening that apparently was only tens of meters wide. Overflow drained eastward for about 0.7 km through a spillway that followed the margin of the damming glacier, and later, followed the moraine deposited by the glacier. The spillway was broad, as much as 20 m wide, and was situated on resistant, mostly massive, medium- to fine-grained igneous rock of Proterozoic age. A small channel cut in Boulder Creek Granodiorite east of and above the spillway described above may be a remnant of an older spillway.

SEDIMENTS OF LAKE DEVLIN

The sediments of Lake Devlin are divided into two categories: (1) bottom sediments of mostly silt and clay and (2) shoreline sediments of mostly sand and gravel, chiefly in deltas and beaches.

Bottom sediments

At least 36 m of lake sediment accumulated in Devlins Park. The thickest section is believed to be near Caribou Creek, a few tens of meters upstream from its junction with the creek from the Rainbow Lakes (site 2, fig. 2). At least 31 m of sediment exist beneath the park floor at this site, and about 5 m of section are exposed above stream level along the ridge between Caribou Creek and the creek from the Rainbow Lakes.

Six cores were taken at three sites (table 2; fig. 2) in Devlins

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Table 2.--NEAR HERE

Park. The objective at site 1 was to obtain material from basal lake beds for a ^{14}C age determination that would date the glacial advance that formed the lake. Two efforts with a hand-powered modified Livingston piston-sampler[1] failed to penetrate more than 7.5 m of section.

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[1]Use of trade names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 2.--List of cores obtained at the three sites in Devlins Park

Core		Date	Sampler	Interval cored (m)
1	1	7/24/71	Modified Livingston	0-7.0
2	1	10/03/71	Modified Livingston	7.0-7.5
3	2	7/21/72	Split-barrel	0-12.0
4	2	8/19/75	HRL-1[1]	0-14.0
5	2	9/15/75	HRL-2	12.3-16.0
6	3	10/20/75	HRL-3	0-15.3

[1]Thin-walled sampler designed after the Livingston by Rick Hoblitt, Joseph Rosenbaum, and E. E. Larson, Department of Geological Sciences, University of Colorado. A system different from that of the Livingston sampler was needed for controlling the piston. Each model of the HRL sampler had a different mechanism for releasing the piston when ready to core.

A 10-ton drilling rig with an hydraulically driven split-barrel sampler was used at site 2, the location of the thickest section according to resistivity data. The requirement that the samples be oriented so that their paleomagnetic properties could be studied precluded use of a rotary rig for coring, because segments of the unconsolidated sediment can separate and rotate differentially within the core barrel. The bulky, thick-walled, split-barrel sampler could not be forced deeper than 12 m, even with the powerful hydraulic system used. This sampler, unfortunately, also severely deformed the sediment, rendering it useless for palynological and paleomagnetic studies.

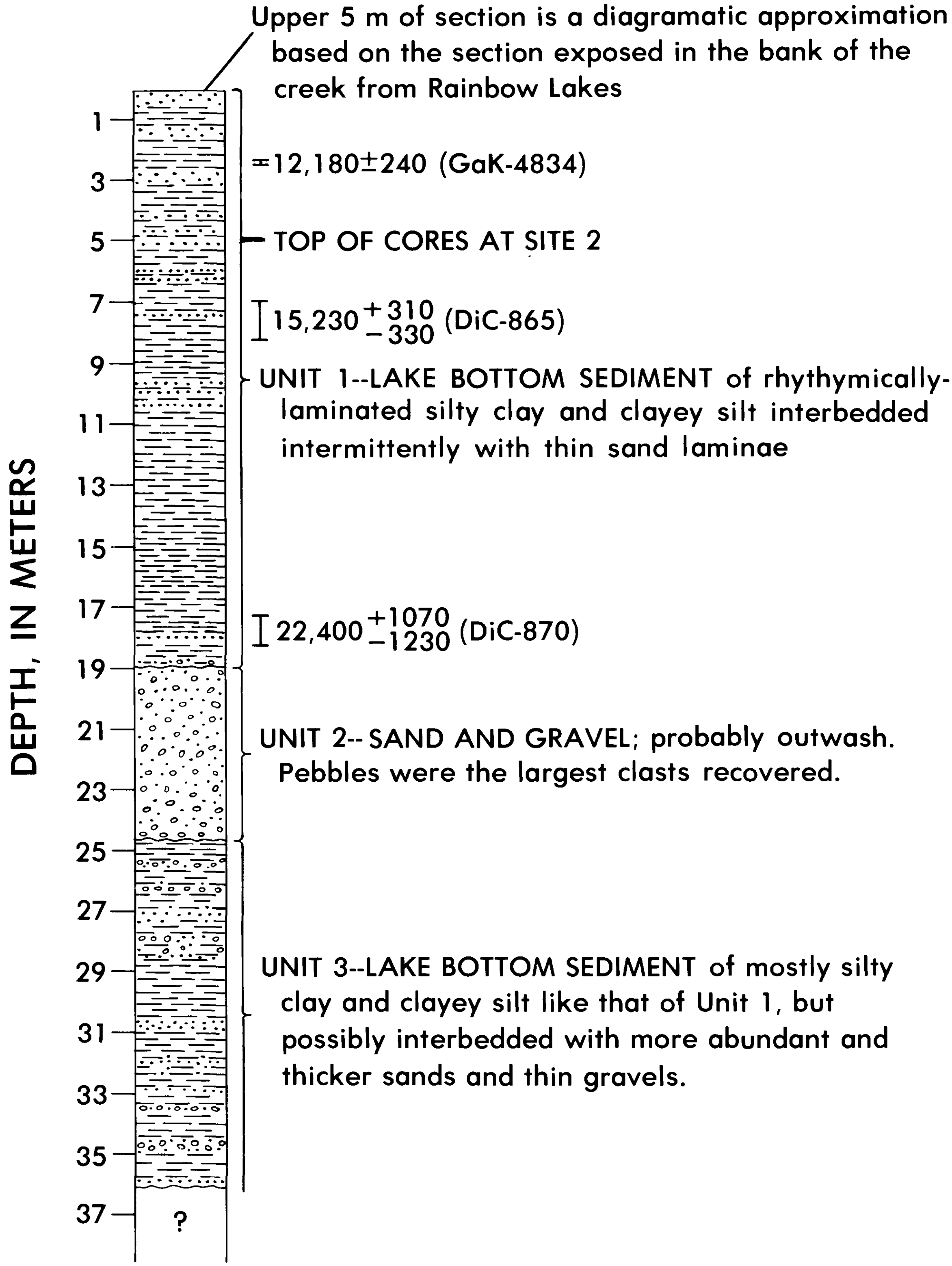
A second core was obtained at site 2 with a thin-walled sampler designed after the Livingston, but made larger and heavier to be used with an hydraulically driven system mounted on a three-quarter-ton truck. This boring managed to reach a depth of 14 m before a drill rod fractured and the sampler was lost. A third coring effort at site 2 reached a depth of 16 m, and penetrated the upper part of a unit of sand and gravel, the probable cause of the fracturing of the drill rod. This sand and gravel unit still poses a barrier to obtaining oriented cores from lower in the section. Attempts at keeping the noncoherent sand and gravel out of the hole by casing have been unsuccessful. The core barrel cannot be driven through even small thicknesses of sand and gravel at this depth. The thickness of the unit of sand and gravel and the nature of the sediment beneath it at site 2 (fig. 3)

Figure 3.--NEAR HERE

were determined by augering.

Figure 3.--Diagram showing stratigraphy and locations of grain-size samples and limiting ^{14}C ages at site 2 and at a nearby locality along the creek from the Rainbow Lakes that includes about 5 m of section lying above the level of site 2.

SECTION AT SITE 2, DEVLINS PARK, COLORADO



Work at site 3 was done to determine whether or not the paleomagnetic record of the sediment obtained at site 2 could be replicated at another site within the same basin. The succession of sediment at the two sites proved to be very similar, and the top of the unit of sand and gravel at site 3 was reached at a depth of 15.3 m.

Seventeen grain-size analyses (table 3) were made of the sediment

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Table 3.--NEAR HERE

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cored, mostly of that of the second core obtained at site 2. Almost all of the sediment is sticky, gray, rhythmically layered silty clay and clayey silt. Most rhythmites are 1 to 6 mm thick and consist of a pair of laminae; one dark-gray laminae, generally less than 2 mm thick, and one light-gray laminae, generally 2 to 4 mm thick, but ranging from 0.5 mm to as much as 20 mm in thickness. Layers of sand, most 12 to 20 mm thick, occur intermittently; in places, between about every 20 to 25 rhythmites. The thicker the sand layer, the coarser its texture. Sand laminae a few millimeters thick tend to be very fine to fine sand, whereas those 25 to 30 mm thick tend to be coarse to very coarse sand. As shown in table 3, the rhythmically-layered section is nearly half clay and half silt. Sand comprises only 0.5 to 5 percent of the rhythmites, most presumably from the sand laminae described above.

Table 3.--Grain-size analyses, percent organic matter, and pH of bottom sediments from Lake Devlin

Depth (m)	Site	Core No.	Sample No.	Type of bottom sediment	Textural Classification [1]	Percent [2] silt	clay	sand	Percent [3] organic matter	pH
2.74	4	-[5]	GRL-1340	Rhythmites	Silt Clay	46.8	48.4	4.8	1.35	7.2
2.00-2.25	2	4	GRL-2682	----do----	----do----	41.2	57.2	1.6	1.24	5.4
2.59-2.84	2	4	GRL-2683	----do----	----do----	46.2	51.2	2.6	0.95	5.0
4.21-4.23	1	1	GRL-771	Sand laminae	Sand	12.4	11.7	75.9	1.00	5.2
5.39-5.60	2	4	GRL-2684	Rhythmites	Clayey silt	50.1	47.5	2.4	0.78	6.3
7.10-7.40	2	4	GRL-2685	----do----	Silty clay	48.5	49.8	1.7	0.85	6.4
7.67-7.87	2	4	GRL-2686	----do----	Clayey silt	53.2	45.1	1.7	0.73	6.4
8.70-8.96	2	4	GRL-2687	----do----	----do----	50.0	48.8	1.2	0.94	6.3
10.55-10.85	2	4	GRL-2688	----do----	Silty clay	47.7	51.3	1.0	0.83	6.3
12.32-12.50	2	4	GRL-2689	----do----	Clayey silt	67.6	31.7	0.7	0.67	6.1
13.57-13.67	2	4	GRL-2305	----do----	----do----	50.0	49.3	0.7	0.57	6.2
14.80-15.00	3	6	GRL-2692	----do----	----do----	54.4	44.2	1.4	0.69	5.4
13.67-13.86	2	4	GRL-2304	Nonlaminated lake beds	----do----	66.6	27.5	5.9	0.47	6.5
13.87-14.25	2	5	GRL-2306	----do----	----do----	52.3	3.2	87.2	0.25	5.0
14.20-14.50	2	5	GRL-2690	Sand bed	Sand	9.6	1.2	95.1	0.31	5.2
14.60-15.30	2	5	GRL-2691	----do----	----do----	3.7	1.2	95.1	0.31	5.2
15.00-15.30	3	6	GRL-2693	----do----	----do----	16.8	4.4	78.8	0.25	5.7

[1] Textural classification of Shepard (1954).

[2] Percent sand, silt, and clay was determined by the sieve-pipette method.

[3] Percent organic matter was determined by the loss-on ignition method (2 hours at 450°C). Values were corrected for weight loss of clay minerals.

[4] Measurements were made with a Hack pH meter using a 1:2.5 sediment-to-water ratio.

[5] Sample not from core, but from bank of creek from Rainbow Lakes approximately 90 m upstream from its confluence with Caribou Creek, stratigraphically 2-3 m above the levels of the three core sites.

The pH of the rhythmically laminated beds ranges from 6.1 to 6.4, except within the upper 3 m of section at site 2, where values of 5.0 and 5.4 were recorded (table 3). A sample from the top of the rhythmically laminated section exposed in the bank of the creek from the Rainbow Lakes beneath a capping layer of sand and fine gravel had a pH of 7.2, the only sample that was not acid. The pH of two samples of nonlaminated lake beds at the bottom of the rhythmite section was 6.2 and 6.5, values similar to those of the rhythmites. However, two samples from the sand beneath the nonlaminated lake beds measured 5.0 and 5.2.

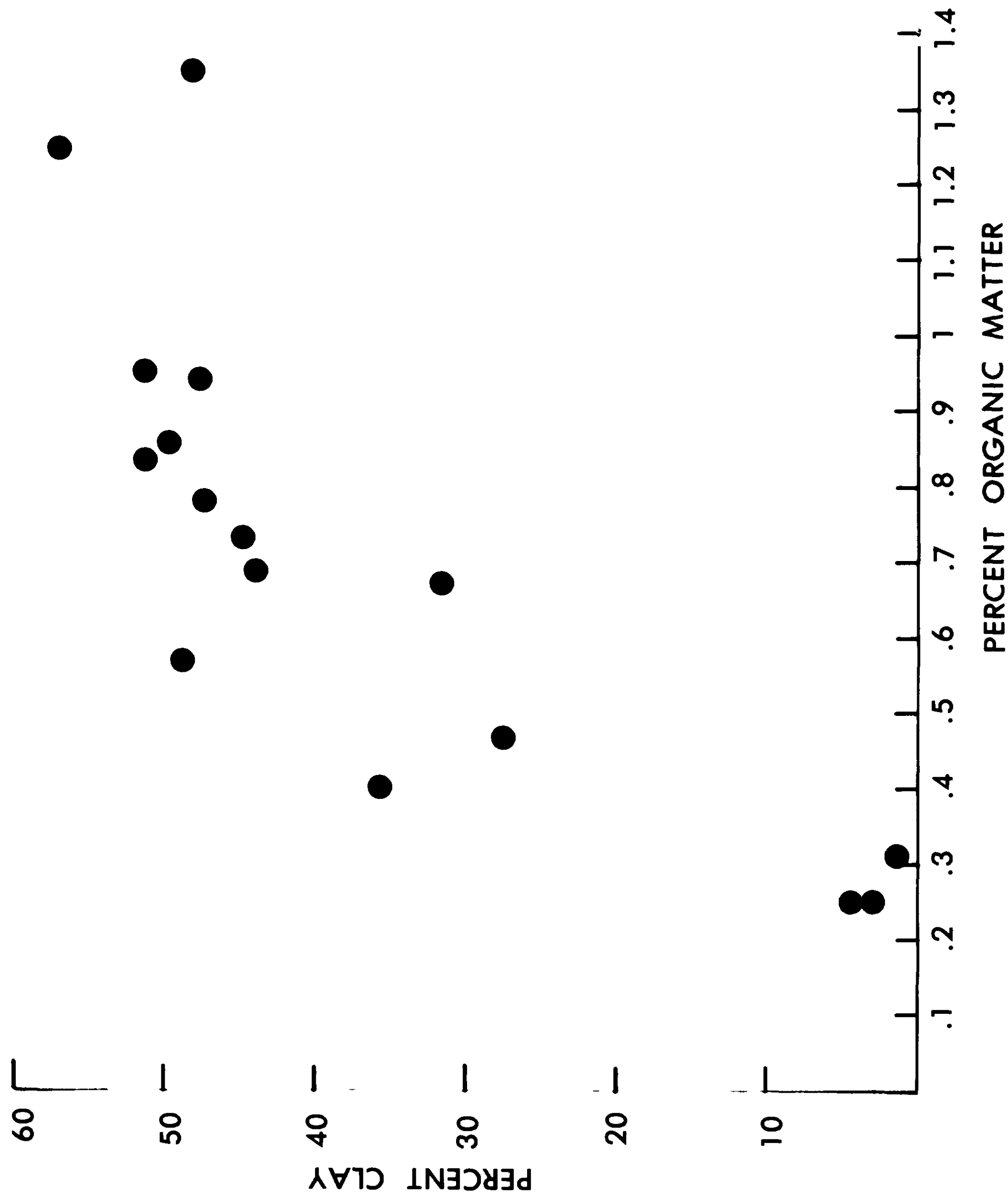
Finely subdivided, microscopic organic matter, although meager, exists throughout the lake bottom sediments of unit 1 (fig. 3). It tends to be more abundant in the more clay rich parts of the section (fig. 4A). The percentage

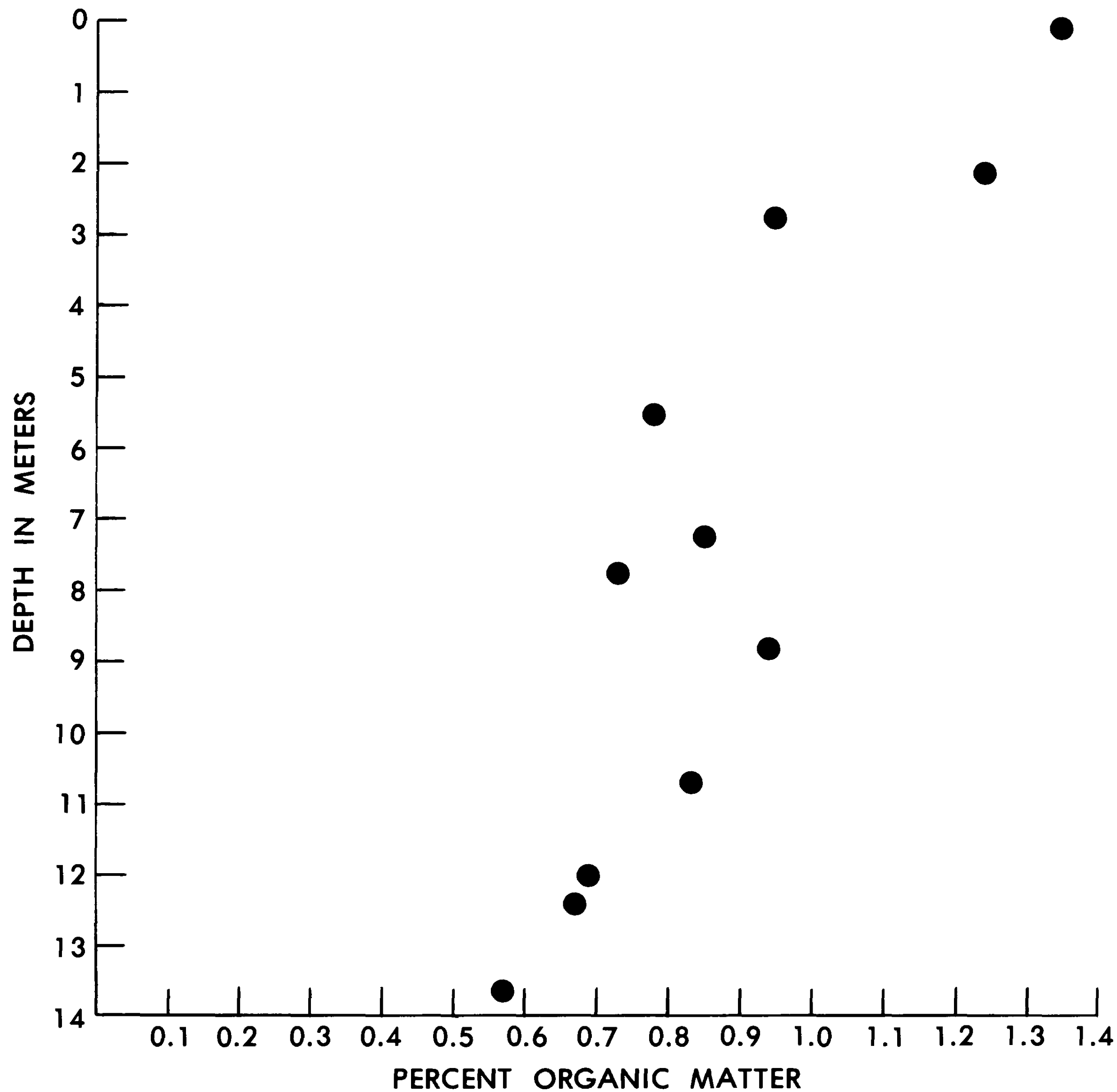
Figure 4.--NEAR HERE

of organic matter measured in samples from three sandy intervals was 0.25, 0.25, and 0.31, respectively; whereas, in ten samples of rhythmites, it ranged from 0.57 to 1.35 (table 3). The percentage of organic matter also varies with position in the section, increasing progressively upward, except for a couple of minor fluctuations (fig. 4B).

The presence of the microscopic organic matter is important, because it can be separated and concentrated for ^{14}C age determinations. The origin of the organic matter has not been determined. Presumably, it consists of pollen, possibly algae, and possibly planktonic anaerobic bacteria deposited in the manner described by Dickman (1979).

Figure 4.--_A_, Percent organic matter tends to increase with clay content. _B_, Percent organic matter increases upward in the rhythmically laminated section at site 2.


PERCENT CLAY
60
50
40
30
20
10
PERCENT ORGANIC MATTER
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
1.1
1.2
1.3
1.4


DEPTH IN METERS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4
PERCENT ORGANIC MATTER

Shoreline Sediments

Less is known about the shoreline sediments of Lake Devlin, because they were not part of the section cored and they are exposed in only a few places. Most shoreline sediments are overlain locally by colluvium. Hence, only the deltaic deposits, which are more extensive and dissected by streams, were examined in detail.

Deltaic sediments were deposited where Caribou Creek, Horseshoe Creek, and the creek from the Rainbow Lakes entered Lake Devlin. As landforms, the deltas are inconspicuous, especially those at the upstream end of the lake where shallower water resulted in thinner accumulations that grade gradually downvalley over lake-bottom sediments. Post-depositional erosion and colluviation from valley sides also may have helped obscure the margins of the deltas at the upvalley end of Lake Devlin.

Little can be said about the primary structures of the deltaic deposits, because only a few exposures exist. Colluvium from the deposits themselves conceals details of stratification in the stream cuts and also on the steeper slopes of the thicker, more prominent delta formed where the creek from the Rainbow Lakes entered Lake Devlin. Although stratification is obscured, it is obvious that the deltaic deposits are coarse, especially those at the upvalley end of the lake. Colluvium derived from the deltaic deposits at the upvalley end of the lake consists of about 25 percent clasts, mostly subrounded pebbles and cobbles, in a sandy matrix. A small exposure on an undercut slope along Caribou Creek 50 to 60 m upstream from its junction with Horseshoe Creek reveals that the unstratified gravelly colluvium is derived from discrete beds of sand and gravel.

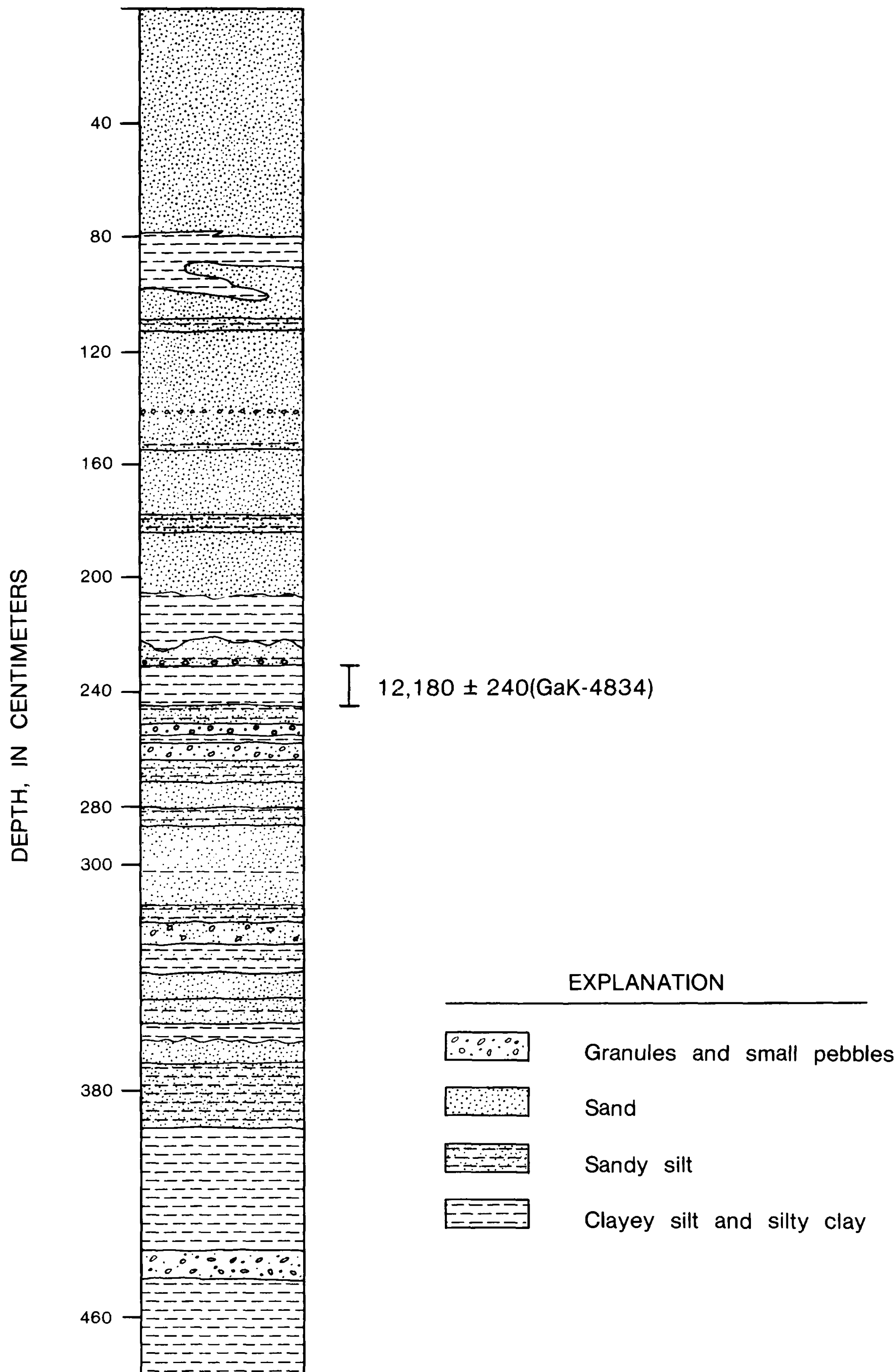
At the exposure on Caribou Creek, 4.3 m of interbedded sand and pebble- and cobble-sized gravel overlie lake bottom sediments consisting of laminated, cross-stratified clayey silt, silt, and silty fine sand, the upper 3 m of which are exposed. The cross-stratified laminae dip northwest at 11^{o}-22^{o}. Although valleys are incised 5 to 10 m into the deltaic and lake floor sediments at and upstream from the junction of Caribou and Horseshoe Creeks, the lake bottom sediments are concealed by a wedge of colluvium derived from the overlying deltaic sediments.

A flat-topped ridge parallels the south side of the creek from the Rainbow Lakes, from near where this stream enters Devlins Park to its confluence with Caribou Creek. The ridge is a few tens of meters wide and ranges from 4 to 6 m in height above the creek from the Rainbow Lakes. The sediment beneath the surface of this ridge consists of interbedded small pebble-granule gravel, sand, silt, and clay. Sand dominates the upper 2 m of this section, whereas laminated clayey silt and silty clay dominate the lower 2 m (fig. 5). The uppermost clayey silt and silty clay are the source of the

Figure 5.--NEAR HERE

12,180 $\pm$ 240 yr B.P. (GaK-4834) ^{14}C age used to estimate the time of termination of Lake Devlin. The ridge has been interpreted to be a remnant of a small delta (Morey, 1927, p. 41-42), as either a bar formed from reworked delta sand or a younger delta built onto the main delta after the lake had drained to a lower level (Gilbert, 1968, p. 28-30), and as a remnant of the original lake floor capped by nearshore and delatic sand (Madole and others, 1973, p. 5).

Figure 5.--Section of sediment beneath a remnant of the floor of Lake Devlin measured in an undercut slope on the south side of the creek from the Rainbow Lakes approximately 90 m upstream from its confluence with Caribou Creek.



DEPTH, IN CENTIMETERS
40
80
120
160
200
240
280
300
380
460
500
12,180 ± 240(GaK-4834)
EXPLANATION
Granules and small pebbles
Sand
Sandy silt
Clayey silt and silty clay

The upper several meters of the original floor of Lake Devlin have been eroded from most of Devlins Park. The ridge south of the creek from the Rainbow Lakes is believed to be a remnant of the original lake floor isolated by dissection as illustrated schematically in figure 6. The occurrence of

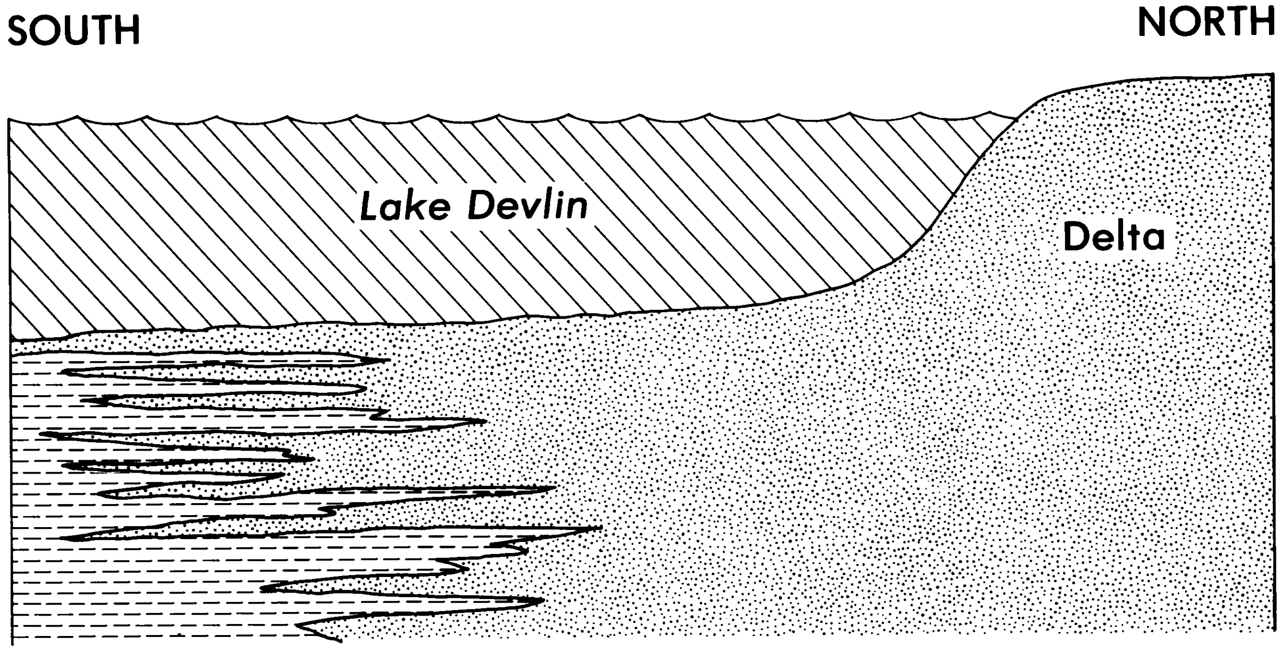
Figure 6.--NEAR HERE

rhythmites interbedded with sand and small pebble-granule gravel (fig. 5) is interpreted as an intertonguing of lake-bottom sediment with the distal edges of bottom-set beds of the delta. Gilbert (1968, p. 30) found that cross-stratified sediment in the ridge dipped uniformly south, as do the cross-stratified beds in the delta north of the creek from the Rainbow Lakes, but at much lower values; less than 5° as opposed to 18°-20°. Possibly, the preservation of the original lake floor at this locality is due to the capping layer of porous sand and fine gravel.

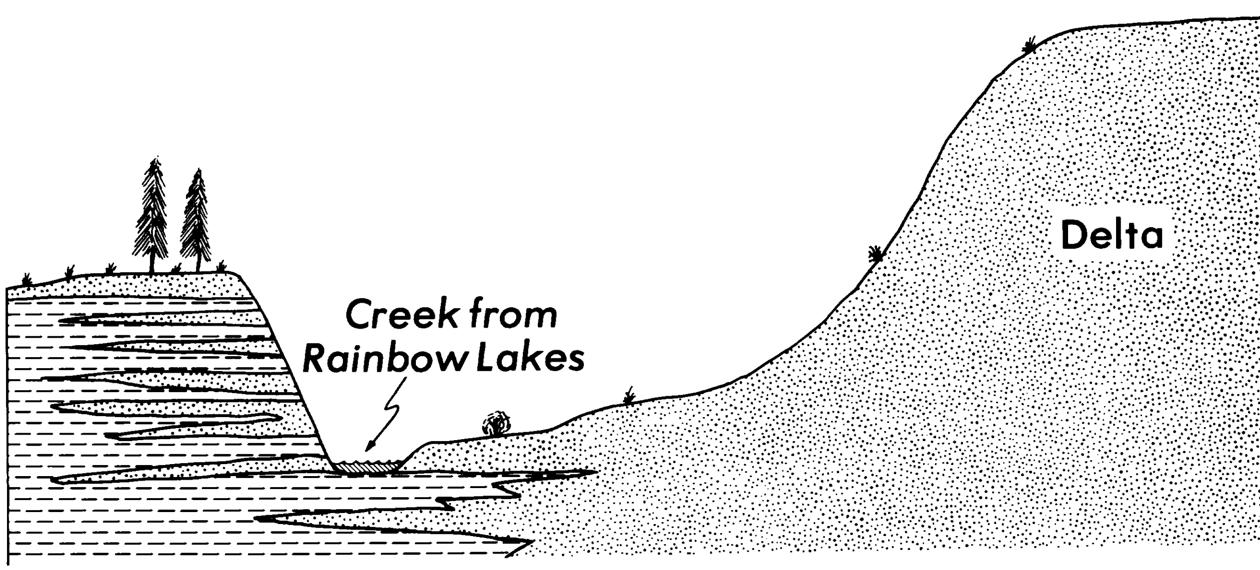
The delta that formed where the creek from the Rainbow Lakes entered Lake Devlin is much thicker than those at the upvalley end of the lake, and it contains a much smaller percentage of large pebbles and cobble-sized clasts. Much of the sediment resembles grus, consisting chiefly of coarse sand and granules derived from granitic rocks. As elsewhere, colluvium conceals the stratification of the undisturbed deposit. A small pit in the deposit on the southwest near the creek from the Rainbow Lakes exposed thin, cross-stratified beds of sand and pebble gravel. Gilbert (1968) reported small-scale crossbedding in a pit, now obliterated, on the east edge of the deposit.

The upper surface of the delta is about 18 to 20 m above the creek from the Rainbow Lakes. Deltaic sediment extends down nearly to the level of the creek and probably intertongues with lake bottom sediment throughout most of the subsurface section, in the way suggested in figure 6.

Figure 6.--An interpretation of the stratigraphic relations between the sediment in the flat-topped ridge on the south side of the creek from the Rainbow Lakes and that in the delta formed where the creek from the Rainbow Lakes entered Lake Devlin.



LATE PLEISTOCENE



PRESENT

HISTORY OF LAKE DEVLIN

Nine ^{14}C ages for organic matter concentrated from rhythmically layered silty clay and clayey silt indicate that Lake Devlin lasted for about 10,000 years; beginning about 22,400 $\pm$ 1,230 (DIC-870) ^{14}C years ago and ending about 12,180 $\pm$ 240 (GaK-4834) ^{14}C years ago. Organic matter for ^{14}C age determinations was concentrated from the lake sediment according to the method described by Kihl (1975a, 1975b). The low carbon content of the lake sediment made it necessary to use about 1 m of section to concentrate enough organic matter for a ^{14}C age. A half meter of section would have sufficed, if the entire core had been available. The core, however, had been split longitudinally, and half was used for studies of pollen content and paleomagnetic properties. The ^{14}C ages obtained are presumed to be an average for the sample interval, and therefore, to be the approximate age for the sediment at the midpoint of each sample interval.

Samples DIC-865 to DIC-871 are from site 2, core 2. Their ages are reasonably consistent (older with increased depth), except for DIC-867 and DIC-868 (fig. 7). The cause of the anomalous ages for these samples is

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Figure 7.--NEAR HERE

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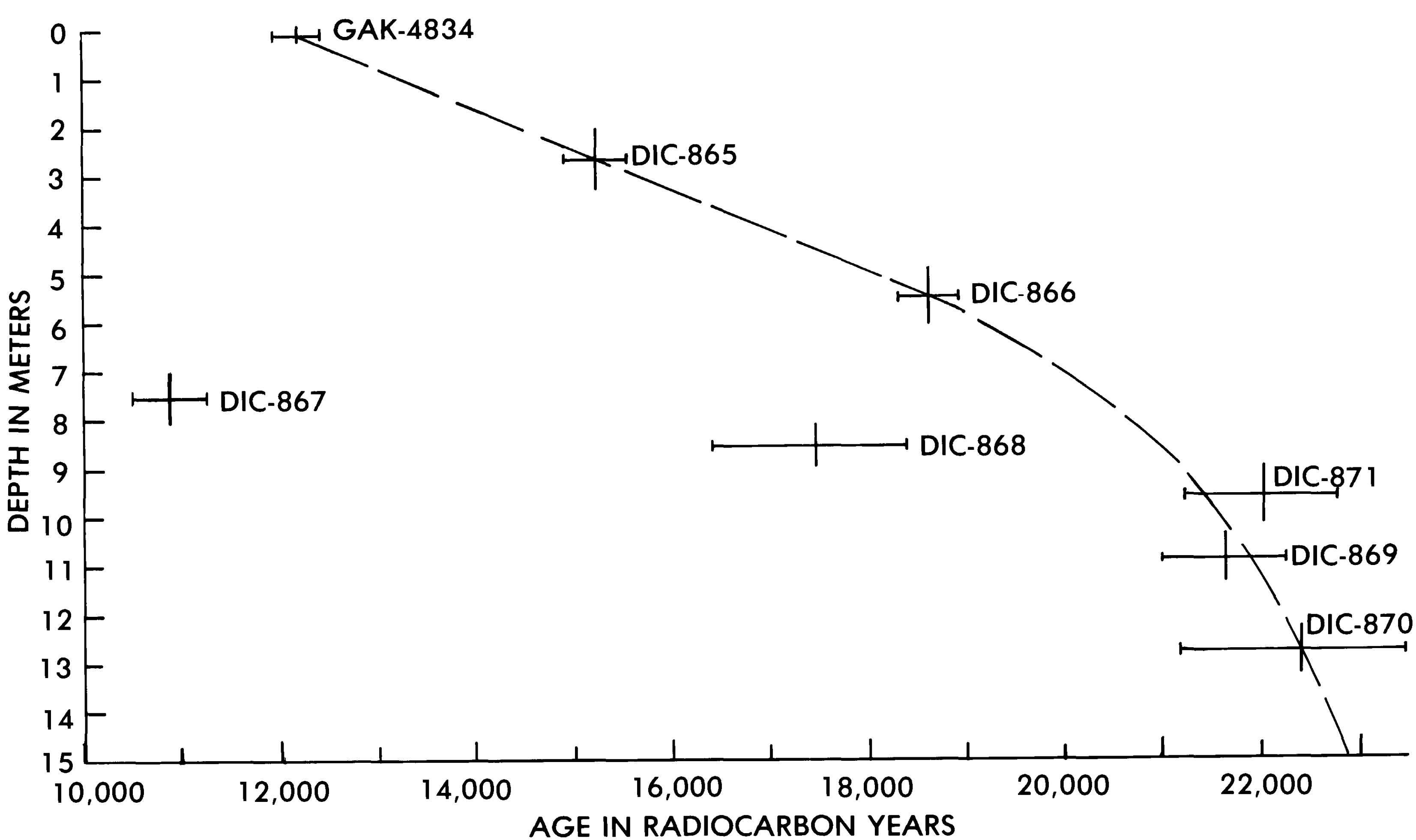
unknown, but may be related to contamination resulting from the decomposition of organic matter in the cores while they were in storage. Sample DIC-867 gave off a putrid odor throughout all stages of its preparation. Prior to preparation, the samples were stored in a freezer, which was unplugged accidentally for a time. The length of time that the cores were thawed is unknown, but it was probably weeks rather than days. Decomposition of material used in sample DIC-867 is believed to have begun when the core was thawed.

Because the Lake Devlin area is well within the crystalline core of the Front Range, far removed from areas of sedimentary rocks, it is unlikely that the ^{14}C ages of its sediment are influenced by either the hard-water effect (Deevey and others, 1954; Broecker and Walton, 1959) or to redeposition of organic matter eroded from older rocks (Nambudiri and others, 1980). The amount of carbonate that might have reached the area in dust and rainwater from semiarid lowlands is considered to have had a negligible effect, if any, on the ^{14}C ages of the lake sediment. Likewise, the soil parent material, vegetation, and quantity of precipitation received does not allow carbonates to accumulate in the soil, to be transported later into the streams and lakes of the area.

Figure 7.--^{14}C ages from core 2, site 2. The vertical lines denote the interval used to obtain each sample, and the horizontal lines are the one-sigma standard deviation for each age determination. The curve fitted to the age determinations suggests that the rate of sedimentation during the first 2,000-3,000 yrs of Lake Devlin's existence was four to five times greater than during the next 7,000 years.


GAK-4834
DIC-865
DIC-866
DIC-867
DIC-868
DIC-871
DIC-869
DIC-870
DEPTH IN METERS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
10,000
12,000
14,000
16,000
18,000
20,000
22,000
AGE IN RADIOCARBON YEARS

Apparently nearly half of the bottom sediment of Lake Devlin was deposited during the first 2,000 to 3,000 years of its existence (fig. 7). Rhythmites were counted in core segments from an interval at site 1 that is approximately equivalent to the interval between 6 and 9 m at site 2 (fig. 7). The rhythmites, pairs of dark- and light-colored laminae, ranged from 2.75 to 5.90 per cm thick and averaged about 4/cm. If the rhythmites are varves, sedimentation varied from 1 m/275 yr to 1 m/590 yr. The range in rate of sedimentation calculated for this interval (fig. 7) is from 1 m/500 yr to 1 m/800 yr. According to figure 7, the rhythmites were counted in an interval wherein sedimentation rate was changing from a maximum of about 1 m/250 yr near the bottom of the section to 1 m/1200 yr near the top of the section. No attempt was made to evaluate the effect of compaction on the rates of sedimentation estimated. If compaction increases with depth, the rate of sedimentation estimated for the first 2,000 to 3,000 years would have been even greater than 1 m/200 to 1 m/300 yrs.

Inasmuch as Lake Devlin was an ice-margin lake, its history is linked to the local glacial history. The lake began when a Pinedale-age glacier, descending the valley of North Boulder Creek, blocked the mouth of Caribou Creek, which is located about 2.3 km from the downvalley limit of Pinedale Glaciation. Later, the lake drained after the glacier had receded upvalley from the mouth of Caribou Creek, and the lateral moraine left behind was breached by the impounded water. During its existence, the lake was fed by sediment-laden meltwater from small glaciers at the heads of Horseshoe Creek, the creek from the Rainbow Lakes, and a small body of ice that spilled over from the Middle Boulder Creek glacier into the head of Caribou Creek (figs. 1, 2).

Deposits of two glaciations, Pinedale and Bull Lake, occur extensively along the valley of North Boulder Creek and over smaller areas at the heads of the streams comprising the Caribou Creek drainage basin (figs. 1, 2). The distribution of these deposits indicates that an ice-margin lake also should have formed here during Bull Lake time. As yet, however, lake deposits of Bull Lake age have not been identified positively, although the sediment beneath unit 2 at site 2 (fig. 3) may be of Bull Lake age.

Unit 2 (fig. 3) represents a different environment of deposition than does the overlying section of rhythmites, but the kind of environment and its age are matters of speculation. Unit 2 could be any of the following: (1) outwash of late Bull Lake age deposited by proglacial streams during deglaciation, after the ice-margin lake of that time had drained; (2) outwash of Pinedale age deposited by proglacial streams from expanding glaciers before Caribou Creek was dammed; (3) shallow-water lake deposits of either late Bull Lake age or Pinedale age; (4) an interglacial fluvial deposit; or (5) a combination of the above.

I favor the interpretation that unit 2 is outwash of Pinedale age for two reasons. First, an outwash-producing system existed before the drainage basin was dammed in Pinedale time. The damming formed a sediment trap in which the coarsest part of the outwash would have been the first to aggrade. As the lake expanded, the bedload fraction of the outwash was deposited progressively farther upvalley, whereas the suspended load continued into the lake and ultimately settled to form the rhythmites. Second, the uppermost beds of Lake Devlin have been eroded from most of Devlins Park during the 12,000 years since the lake drained. It is probable that an even greater part of the lake beds of Bull Lake age were eroded, inasmuch as they were exposed to erosion for a longer time. Exhumation of the older beds would have been especially great near the downvalley end of the lake where Caribou Creek descends precipitously to North Boulder Creek. Hence, even if outwash was deposited over lake beds during Bull Lake deglaciation, it probably would have been eroded in the vicinity of site 2.

The formation of Lake Devlin was nearly contemporaneous with the maximum expansion of ice during the Pinedale Glaciation. Consequently, glaciers of Pinedale age are inferred to have been nearing their maximum expansion in this area between 23,000 and 21,000 years B.P. Whether or not the draining of Lake Devlin coincided closely with the disappearance of ice from the vicinity of the junction of Caribou Creek and North Boulder Creek is debatable. Judging from information obtained elsewhere, the two events probably did not coincide.

Glaciers probably began to recede from their terminal positions in this area before 13,000 yrs ago (Madole, 1976; Nelson and others, 1979), and had disappeared completely or nearly disappeared before 11,000 yrs ago (Madole, 1980). This suggests that the moraine dam held until long after ice had receded from the junction of Caribou and North Boulder Creeks. Likewise, it held during retreats and readvances that probably occurred between 23,000 and 13,000 yrs ago. The longevity of the moraine dam is attributed, at least in part, to its thickness and short span; the broad, stable spillway; and possibly to the fact that it may have retained an ice core for a long time. The distinct shoreline in Devlins Park attests to the fact that the lake persisted for a remarkably long time at approximately the same level.

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