DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-642

Base from U.S. Geological Survey, 1959
10,000-foot grid based on Wyoming coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

SCALE 1:62 500

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Geology by G. M. Richmond in 1966–67; 1970; assisted in 1966 by K. L. Pierce, R. G. Baker, and W. M. Thomas

DESCRIPTION OF UNITS

HOLOCENE

LACUSTRINE DEPOSITS

lst Lake sediments—Gray to blue-gray, weathering buff, clayey silt (lst) underlying lake terraces that are 10, and 20–25 feet above Yellowstone Lake. Chiefly around the southern part of the lake. Deposits are mostly 3–6 feet thick, but are thicker at mouths of Chipmunk Creek and Grouse Creeks. Modern deltas of Chipmunk and Grouse Creeks are of similar material. Sandy gravel (lsg) consists of pebbles and locally cobbles, mostly of rhyolite, in a sandy matrix. Gravelly sand (lgs) is coarse to medium grained. Both are gray to buff, well sorted, and locally crossbedded. They form beach deposits around Yellowstone Lake and cap lake terraces, 10, 15, and 20–25 feet above the lake. The terraces are cut in older deposits of Pinedale or pre-Pinedale age, or bedrock. The sandy gravel (lsg) and gravelly sand (lgs) are mostly 2–10 feet thick, but in places, such as Wolf Point, Eagle Bay, Plover Point, and Elk Point, the sandy gravel forms thick bars and spits both at the level of successive terraces and in the modern lake. Sandy gravel also forms local beaches around Heart Lake.

ALLUVIAL DEPOSITS

fa Fine-grained humic alluvium—Dark- to light-gray or gray-brown silt, sand, and clay underlying swamps and depressions in Pinedale Till (pt) and kame deposits (pkg, pkgs, pksg). Also overlies Holocene stream gravel (sg) and Pinedale stream gravel (pg) on valley floors, and covers lake sediments (pl, plsg, lsg) in lagoonal depressions on lake terraces around Yellowstone Lake. Deposits are marshy, at least seasonally, and 2–30 feet thick.

sg Stream gravel—Buff to gray gravel, cobbles, and boulders in coarse sandy matrix; poorly sorted; 5–10 feet thick. Mapped only along flood plains, but occurs in channels of most streams and beneath fine-grained alluvium (fa) along many valley floors.

fg Fan gravel—Gray to buff, poorly sorted sand and angular gravel in alluvial fans. Mostly at mouths of small streams east of Heart Lake and along upper parts of valleys of Outlet and Surprise Creeks. Material is mostly of rhyolite tuff.

COLLUVIAL DEPOSITS

ta Talus deposit—Coarse angular blocks of rhyolite in sparse sandy matrix at base of rhyolite cliffs around Flat Mountain and locally along canyons of Surprise and Outlet Creeks. Very few deposits elsewhere. Deposits unstable, actively accumulating, sparsely vegetated and display very little soil development.

tf Talus-flow deposit—Coarse angular blocks of rhyolite forming lobate mass extending downslope from toe of a talus. Characterized by steep front and, locally by surface furrows arcuate downslope. Deposits occur only below north-facing rhyolite cliffs of Flat Mountain and ridge to southwest. They are unstable, and unvegetated, bear no soil, and may be partly active at present.

ls Landslide deposit—Large mass of debris, mostly derived from bedrock and till (pt) mantle that has slumped and flowed downslope from a steep arcuate headwall scarp. Material is clayey to sandy; contains numerous lake K-Ar and small clasts, mostly of tuff and rhyolite but locally of Mesozoic sandstone and limestone. Deposits characterized by steep hummocky topography, flow ridges, and depressions. Locally, they are dissected as much as 40 feet by present drainage.

EOLIAN DEPOSITS

es Eolian sand—Buff, medium to fine sand, forming small dunes or an irregular mantle. Deposits crossbedded. Mapped only at Rock Point and Dot Island, but occurs as small deposits on many wind-exposed bluffs around Yellowstone Lake. Deposits are mostly stable, and grass covered, and bear a very thin humic soil. However, some are active.

PINEDALE GLACIATION

GLACIAL DEPOSITS

pt Till and glacial rubble—Gray-brown to gray stony silty sand (pt), loose to compact; stones angular to subround. Deposits commonly thin, but range in thickness from less than 5 to more than 30 feet. Surface smooth to hummocky. Undrained depressions common in valley areas; many contain water. Ice-molded topography common on uplands. In eastern part of quadrangle, deposits are silty and contain abundant clasts of Eocene andesite and basalt. In western part, deposits are sandy. Clasts are mostly of rhyolite, but some are erratics of andesite and basalt and, west of Flat Mountain Arm, of sandstone and limestone. The soil on the till is commonly less than 12 inches thick and consists of a weakly oxidized horizon containing little or no clay. The uplands south of Flat Mountain are littered with thin glacial rubble (pr) consisting mostly of sand and locally derived fragments of rhyolite. Some stones are soled and faceted; a few are striated.

pr

ICE-CONTACT DEPOSITS

pkg Kame deposits—Buff to gray gravel containing a little sand (pkg), gravel with sandy matrix (pksg) and gravelly sand (pkgs) forming kame terraces having ice-contact frontal scarps and irregular hummocky upper surfaces. Deposits are 20 feet to more than 50 feet thick, are poorly sorted, and display numerous slump structures and minor faults. Locally they are covered with large boulders and till-like material derived from nearby till-covered slopes or former adjacent ice. Deposits mantle most slopes surrounding Yellowstone Lake between altitudes of 7,840 and about 8,000 feet—or between 110 and 270 feet above the lake. They also extend beneath younger lake deposits down to and below present lake level, and are exposed in lake bluffs in many places (for example: stratigraphic sections 37, 39, 40, 42, 43, 48, 72, and 74). Extensive deposits of unknown thickness occur in the area around Delusion Lake where they enclose numerous large and small kettles. The unnamed flat-topped upland west of Flat Mountain Arm is underlain mainly by these deposits, thick sections of which are exposed on its western slope. South of Flat Mountain, a sequence of kame terraces extends to an altitude of 8,450 feet, or 720 feet above Yellowstone Lake. To the south, ice-contact gravels extend continuously down the valley of Beaver Creek and form the promontory in Heart Lake. Small eskers (peg) composed of sandy cobble gravel are present in the valley of Chipmunk Creek.

pksg

pkgs

peg

LACUSTRINE DEPOSITS

Open lake sediments—Gray to blue-gray, varved, laminated, or massive silt (pl), gray to buff, deltaic crossbedded to massive, well-sorted, medium sand (psl) and gray to tan crossbedded beach sand and gravel (plsg) of former open-water levels of Yellowstone Lake, 60–65, 50–55, 40–45, and 30–35 feet above present lake level. The 60–65-foot terrace is the most continuous and commonly the broadest. At the south end of the lake, the deposits are mostly silt. Elsewhere, however, the silt commonly overlies or underlies lake sand above Pinedale Till or kame deposits (pkgs) in bluffs along the lakeshore (stratigraphic sections 10, 34, and 67). The beach deposits mantle the slopes up to the upper limit of the 60-foot terrace, and are thicker on terrace surfaces than on intervening slopes. The terrace floors beneath the beach deposits are cut in underlying sand and silt (pl, psl) or, where these deposits are lacking, in older Pinedale or pre-Pinedale deposits or bedrock. Along Grouse Creek (stratigraphic section 65) the sandy foreset beds of a delta, 60–70 feet above the lake, grade down into lake silt (pl) containing the 12,000-year-old Glacier Peak ash in its lower part and plant debris yielding a radiocarbon date of 9,060±300 years (W2041) in its upper part. At promontories around the lake or at the site of former embayments, such as Alder Lake, sand and gravel (plsg) form large longshore spits and bars, some 60 feet high, whose upper surfaces are at the level of corresponding terrace deposits. Similar deposits tie former islands to the mainland at the level of particular terraces, for example, southwest of Plover Point.

pl

psl

plsg

Ice-dammed lake sediments—Gray to blue-gray, weathering buff, varved, laminated, or massive silt (pkl) and massive to bedded, medium to fine sand (pksl). Thickness at least 20 feet, probably more. Deposits mantle slopes between 110 and 60 feet above south end of Yellowstone Lake. They form a broad, nearly continuous, undulating, ice-contact terrace 110 feet above the lake and a narrow discontinuous bench 80 feet above it. Elsewhere around the lake, slopes between 110 feet and 60 feet above the lake are mantled by poorly exposed gravel and sand beach deposits (pklb) 5–30 feet thick. East of the lake these deposits locally extend as high as 240 feet above it. Terraces formed of these deposits or cut in older kame terrace deposits (pksg, pkgs) or in bedrock occur 240, 200, 135, 120, 110, 90, and 80 feet above the east side of the lake. Only the 110-, 90-, and 80-foot terraces occur on the south and west sides. The 110-foot terrace is nearly continuous around the lake. The others are discontinuous.

pkl

pksl

pklb

ALLUVIAL DEPOSITS

pg Stream gravel—Gray to gray-brown, sandy; poorly sorted, poorly exposed; chiefly pebbles and cobbles; contains only a few boulders. Material predominantly of rhyolite in southwestern part of quadrangle; predominantly of andesite and basalt in eastern part. Deposits apparently formed mostly during recession of ice in late middle Pinedale time.

pfg Fan gravel—Gray to gray-brown, poorly sorted, sandy; locally bouldery. Lithologically like stream gravel (pg). Occurs along lower sectors of streams in southern and northeastern part of quadrangle.

COLLUVIAL DEPOSITS

pta Talus deposit—Angular blocks of rhyolite in sandy matrix. Forms coalescing cones of debris at base of cliffs along Surprise and Outlet Creeks. Deposits are inactive, stable, forested, and bear a thin soil like that on Pinedale Till.

pkls Kame landslide deposit—Mass of debris, derived from bedrock and overlying till (pt) mantle, that has slumped and flowed downslope. Deposits characterized by steep hummocky topography, including collapsed kettlelike depressions and melt-water drainageways that extend around arcuate heads of individual slump masses. They occur on both sides of the valley of Grouse Creek in southcentral part of quadrangle. Consist mostly of clasts and large masses of tuff in a silty to clayey matrix. They grade northward into kame terrace deposits (pkgs). These relations and their morphology suggest that the slides took place over stagnant ice and were subsequently modified by collapse of ice and melt-water activity.

SACAGAWEA RIDGE-BULL LAKE INTERGLACIATION

LACUSTRINE DEPOSITS

fu Sediments of Flat Mountain Arm—Lacustrine silt, sand, and

fl gravel deposits disconformably underlying the Aster Creek rhyolite flow (Ra) (K-Ar age, about 150,000 years) along the north shore of Flat Mountain Arm. The deposits are divided into an upper unit (fu) and a lower unit (fl), separated by the Shoshone Lake Tuff Member (Christiansen and Blank, 1972) (Rst) (K-Ar age about 155,000 years), but are about 40 feet thick. Sediments of the upper unit (fu), are compact but not hard. They consist of blue-gray, chocolate-weathering, laminated, pumiceous lake silt, 4–8 feet thick, overlying medium to fine, massive to weakly bedded, pumiceous sandy silt, 6–25 feet thick (stratigraphic sections 54, 55, 56, 58 and 60). The sandy silt overlies dark-gray-brown, hard, massive to finely laminated silt, 5–12 feet thick, which in turn overlies well-rounded manganese-stained sandy gravel, composed mostly of rhyolite and 1–3 feet thick. The basal gravel rests disconformably on the Shoshone Lake Tuff Member. The tuff rests with slight disconformity on the sediments of the lower unit (fl). These consist of compact, hard, blue-gray, chocolate-weathering, massive to laminated, pumiceous silt, 5–8 feet thick, overlying green, blue-gray, or rust-brown, hard, compact, medium to fine, pumiceous silty sand, 6–25 feet thick (stratigraphic sections 53, 57, and 59). The silty sand rests on a basal gray to rust-brown, hard, compact, crossbedded, well-rounded, sandy gravel and poorly sorted sand, 2–5 feet thick. The basalt gravel and sand grades laterally westward into dark-gray to pinkish-brown, compact, sandy to silty, unsorted and unstratified till-like diamicton containing angular to well-rounded pebbles and cobbles of rhyolite and andesite, fragments of Cretaceous quartzite and limestone, chunks of bedded lake silt and reworked silicified concretions of lake silt. This diamicton is probably till, but might be a landslide deposit derived from Flat Mountain to the south. All of the sediments of the lower unit contain small pyrite crystals and are locally hydrothermally altered.

BEDROCK

Re Rhyolite flows and tuff—Three Quaternary rhyolite flows

Rw and a tuff crop out in the northwestern and western parts

Ra of the quadrangle (see index map). Outcrops of the in-

Rst dividual flows and of the tuff have been mapped because of their significant stratigraphic relations to Quaternary sedimentary deposits in this and adjacent quadrangles. The Elephant Back rhyolite flow (Re) (K-Ar age about 150,000 years) overlies the West Thumb rhyolite flow (Rw) (K-Ar age also about 150,000 years). The West Thumb rhyolite flow is locally overlain by lake sediments (s-bl) containing a pumice (K-Ar age about 150,000 years) (stratigraphic section 19) that was probably deposited during eruption of the Elephant Back rhyolite flow. Younger Bull Lake Till overlies these lake sediments in places (stratigraphic section 33). The Aster Creek rhyolite flow (Ra) (K-Ar age about 150,000 years) overlies the upper sediments of Flat Mountain Arm. The Shoshone Lake Tuff Member (Rst) (K-Ar age about 155,000 years) occurs between the upper and lower units of the sediments of Flat Mountain Arm. (K-Ar dates were determined by J. D. Obradovich).

R Undivided bedrock—Two tuffs of the Yellowstone Group—one 600,000 years old, the other 2 million years old—underlie most of the lower slopes east of Yellowstone Lake and the southeast quarter of the quadrangle (R. L. Christiansen, written commun., 1970). Eocene mudflow rock, basalt, and andesitic rocks underlie the higher hills east of Yellowstone Lake, The Promontory, and the southeastern part of the quadrangle east of Grouse Creek (H. J. Prostka and H. W. Smedes, written commun., 1970). Mesozoic rocks, mostly shale, sandstone, and limestone, underlie most of Chicken Ridge in the southern part of the quadrangle and crop out locally north, west, and southeast of Flat Mountain (W. R. Keefer, written commun., 1970).

DEPOSITS EXPOSED ONLY IN STRATIGRAPHIC SECTIONS

HOLOCENE

co Colluvium—Buff to gray-brown massive, unsorted, silty sand, locally containing isolated stones. Deposits 1–4 feet thick; exposed along bluffs of Yellowstone Lake in stratigraphic sections 3, 10, 11, 12, 13, 14, 20, 36, 46, 48, 65, 66, 67, 72, and elsewhere.

BULL LAKE–PINEDALE INTERGLACIATION

b-pl Lake silt—Blue-gray, weathering brownish, massive to laminated compact silt. Locally contains pumice or pumiceous sand beds. Overlain by Pinedale Till (pt) at stratigraphic sections 1, 7, and 9; overlies Bull Lake Till (bt) at stratigraphic section 3. Also occurs in stratigraphic sections 24, 29, 30, 33, 38, 52, 63, 64, 70, 71, 72, 79, 82, and elsewhere in bluffs around Yellowstone Lake.

b-psl Lake sand—Blue-gray to gray, weathering buff, massive to weakly bedded, compact, medium- to fine-grained. Locally contains pumice or reworked pumice layers. Bedding locally involuted. Overlain by Pinedale Till (pt) at stratigraphic section 6, 28, 29, 30, 31, 47, and 81; overlies Bull Lake kame gravelly sand (bkgs) or Bull Lake Till (bt) at stratigraphic sections 30, 80, 81, and 82.

BULL LAKE GLACIATION

bl Lake silt—Blue-gray compact, contorted varved silt. Contains striated stones and erratics of andesite and basalt. Occurs beneath Pinedale Till (pt) and overlies Bull Lake Till (bt) at stratigraphic sections 26 and 32.

bks Kame sand and kame gravelly sand—Gray to blue-gray,

bkgs crossbedded, locally deltaic sand (bks) and gravelly sand (bkgs); sharp changes in texture, poorly sorted within beds. Displays slump and fault structures. Locally contains reworked pumice layers. Overlain by Pinedale Till (pt) at stratigraphic section 78 and by lake silt (b-pl) or sand (b-psl) of Bull Lake-Pinedale interglacial interval at stratigraphic sections 79, 80, 81, and 82. Overlies Bull Lake Till (bt) at stratigraphic section 81.

bt Till—Blue-gray, weathering buff, hard, compact, massive, stony silty till. Contains angular to rounded clasts that are mostly of Eocene andesite and basalt on east side of lake; mostly of rhyolite containing minor amounts of andesite and basalt on south side of lake; mostly of rhyolite and minor amounts of andesite and basalt on west side. Occurs beneath Bull Lake kame deposits (bkgs) or lake beds (bl) which are overlain by Pinedale Till (pt) at stratigraphic sections 26, 30, 32, 80, and 82. Also occurs at stratigraphic sections 18, 19, and 33.

INTRA-BULL LAKE INTERVAL

b-bl Lake silt—Blue-gray, brownish-weathering, laminated silt with local thin sandy layers. Contains pumice bed 0.3–1.2 feet thick. Deposits observed only at stratigraphic sections 66, 67, 68, and 69. Pumice at stratigraphic section 67 has been K-Ar dated as about 103,000 years old.

SACAGAWEA–BULL LAKE INTERGLACIATION

s-bl Lake silt and sand—Blue-gray, weathering buff, silt (s-bl),

s-bsl and massive to laminated pumiceous sand (s-bsl); underlies Bull Lake Till (bt) at stratigraphic sections 19 and 33; contains a pumice bed (K-Ar age, about 150,000 years) at stratigraphic sections 20, 21, 22, 23, and 24. Overlies West Thumb rhyolite flow (Rw) (K-Ar age, about 150,000 years) at stratigraphic sections 19 and 33.

STRATIGRAPHIC SECTIONS

Units separated by slashes, are shown in descending order; numbers (where shown) represent thickness, in feet. Sections demonstrate stratigraphic relations of units vertically exposed and thus too small to be shown on the map.

1. 20 pkgs /5pt /6b-pl.
2. 30 psl, deltaic/10 pl.
3. 2 co / 2 plsg / 31 b-pl, pumiceous / 2.1 bt.
4. 4 lsg / 15 pl, varved / 10 pksl / 15 pt, lacustral.
5. 30 psl / 5 pl, varved / 6 pt.
6. 25 psl / 10 pl / 6 pt / 5 b-psl, massive.
7. 10 pl / 5 pt / 8 b-pl / 10 Rw.
8. 4 lsg / 8 pksl / 4 pt / 10 Rw.
9. 10 psl / 10 pt / 8 b-pl / 2 Rw.
10. 3 co / 2 lsg / 12 pl / 18 psl / 10 pt.
11. 4 co / 0.5 lsg / 4.5 psl / 3 pl / 15 pt.
12. 3 co / 2 lsg / 13 pl / 8 pt.
13. 3 co / 2 lsg / 20 psl / 4 pt.
14. 3 co / 4 lgs / 20 psl.
15. 4 lsg / 20 psl, deltaic.
16. 13 psl / 8 pt / 2 Rw.
17. 3 lsg / 10 pl, altered / 3 pl / 2 pt / 5 pt, lacustrine.
18. 3 lsg, cemented / 10 pl, altered / 3 pt, cemented.
19. 5 bt / 5 s-bsl / 2 Rw.
20. 2 co / 3.5 lsg / 18 b-psl, deltaic / 10.2 s-bsl, pumiceous / 1.2 pumice, K-Ar age 150,000 years / 1.8 s-bsl / 4 s-bl.
21. 3 lgs / Pinedale boulder line / 20 b-psl, deltaic / 13 s-bl, containing 1.5 pumice, K-Ar age 150,000 years.
22. 3 lgs / 15 b-psl / 17 s-bl, containing 1.3 pumice, K-Ar age 150,000 years / 6 s-bsl.
23. 3 lgs, cemented / 10 b-psl / 20 s-bl, containing 2.5 pumice, K-Ar age 150,000 years.
24. 8 pl, varved / 20 psl / Pinedale stone line, rusty / 10 b-pl, massive / 7 b-psl, pumiceous / 8 s-bl / 1 pumice, K-Ar age 150,000 years.
25. 3 co / 2 pl, varved / 8 pt / 2 bl, contorted, striated erratic stones.
26. 1 co / 2 lsg / 8 pl / 14 pt / 6 bl, containing erratic stones / 6 bt.
27. 3 lgs / 16 pl, varved / 8 pt / 2 bl, contorted, striated stones.
28. 3 co / 18 pl, varved / 3 pt / 2 b-psl / 3 bl, contorted, striated stones.
29. 3 lgs / 4 pl / 3 pt / 4 b-psl / 5 b-pl / 4 b-psl / 2 bl, contorted, striated stones.
30. 1 co / 2 lgs / 3 pl / 4 pt / 8 b-pl / 3 b-psl / 5 bt, clayey, erratics.
31. 8 lgs / 12 pt / 3 b-psl, pebbly / 3 Rw, with fracture fillings of b-psl.
32. 2 lgs / 20 pl / 10 pt / 2 bl / 3 bt.
33. 3 es / 2 lgs / 12 bt / 5 s-bl / 3 Rw.
34. 10 lgs / 2 pl / 4 psl / 3 Rw.
35. 10 psl / 80 pkgs / 10 b-pl.
36. 2 co / 3 lsg / 4 pt and crumpled psl / 8 psl, deltaic / 4 psl / 4 pl.
37. lsg / pl / pksg.
38. pksg / b-pl.
39. pl / pksg.
40. pksg / pt.
41. lgs / pl / pt.
42. 8 lgs / 6 psl / 6 pl, varved / pksg.
43. 3 lgs / 6 psl / 40 pl, varved / pkgs.
44. 6 lgs / 11 psl / 4 pl.
45. 6 lgs / 6 psl / 7.6 pl.
46. 3 co / 15 pkgs / 20 pt.
47. 3 co / 15 pkgs / 15 pt / 15 b-psl.
48. 3 co / 10 lgs / 3 pkgs.
49. 15 es / 8 co / 10 pksg / 6 pl / 10 pt.
50. 6 lsg / 4 pl.
51. 3 lsg / 7 pt.
52. 10 lgs, diatomaceous / 2.3 pl / 0.02 Glacier Peak ash / 1.5 pl, varved / 0.5 pksg.
53. pkgs / Rst / tf.
54. 20 Ra / 9.8 fu / 2 Rst.
55. 25 Ra / 20 covered / 8.2 fu / 2 Rst.
56. 2 pt / 20 fu / 9.5 Rst.
57. 20 Rst / 25 fl.
58. 20 Ra / 36 fu / 2 Rst.
59. 30 Rst / 8.2 fl.
60. 30 Ra / 4.6 fu / 40 Rst.
61. 8 pksg / 15 pkl.
62. 2 lsg / 3 psl / 6 pt.
63. pksl, deltaic / b-pl.
64. pksl, deltaic / b-pl.
65. 1.3 co / 4.6 fa / 9.2 psl, deltaic / 7.7 psl / 8 pl / 0.013 Glacier Peak ash / 9.5 pl, varved / 1 pt.
66. 2 co / 15 b-psl / 0.9 pumice / 20 b-pl.
67. 2 co / 4 pl / 1.5 psl / 4 pksg / 4.5 pt / 18 b-pl / 1 pumice / 14 b-pl.
68. 5 psl / 6 pksg / 1.5 pt / 26 b-pl / 0.3 pumice / 3 b-pl.
69. 10 pg / 3 pt / 10 b-pl.
70. 15 pg / 20 b-pl.
71. 5 pg / 15 b-pl.
72. 5 co / 5 pg / 5 psl / 10 pkg / 10 b-pl.
73. plsg / pt.
74. pkl / pksg.
75. 60 pksg, deltaic.
76. lsg / pl.
77. 1 lsg / 2 pt / 2 b-psl / 2 pumice.
78. 10 lsg / 4 pt / 18 bks, containing two reworked pumice layers.
79. 10 lsg / 8 b-pl / 10 bkgs, containing two reworked pumice layers.
80. 10 pl / 0.6 diatomite / 6 pl / pt - boulder zone / 9 b-psl, containing reworked pumice layer / 12 bkgs / 2 bt.
81. 4 pt / 20 b-psl containing reworked pumice layer / 15 bkgs.
82. 3 pt / 15 b-pl / 25 b-psl / 3 bkgs / 3 bt.
83. 10 lsg / 3 pt.
84. 6 lsg / 2 pt.
85. 2 pl / 3 pt.
86. 6 plsg / 34 pksg.

SURFICIAL GEOLOGIC HISTORY

INTRODUCTION

The Frank Island quadrangle is in south-central Yellowstone National Park and includes most of Yellowstone Lake. The hills to the northeast are foothills of the Absaroka Range, and The Promontory at the south end of the lake is geologically also a part of that range. Chicken Ridge, in the southern part of the quadrangle, is the north end of a range of folded and faulted pre-Quaternary sedimentary rocks that extends far to the south. The east-facing escarpment that trends northwest from Chicken Ridge to Flat Mountain is a Quaternary fault scarp. The South and Southeast Arms of Yellowstone Lake appear to have been excavated along fault blocks. Heart Lake lies in a structural trough downfaulted to the west. Flat Mountain Arm lies along the southern inner margin of a large caldera (see small map) which collapsed after eruption of a tuff of the Yellowstone Group about 600,000 years ago. The areas north of Flat Mountain Arm and north of West Thumb represent the east edge of the Central Plateau of Yellowstone National Park. The highest points in the quadrangle are Overlook Mountain (9,221 feet), Channel Mountain (8,745 feet), and Flat Mountain (9,204 feet).

PLEISTOCENE GLACIATIONS

Although great icecaps covered most of Yellowstone National Park and adjacent areas during several glaciations in Pleistocene time (Richmond, 1970), deposits of only the last two, the Bull Lake (older) and the Pinedale (younger), have been identified in this quadrangle. During each glaciation, cap ice developed on the high plateaus of the Absaroka Range to the southeast and flowed north along the upper valley of the Yellowstone River into the basin of Yellowstone Lake. Here the ice accumulated to a thickness of about 3,000 feet and flowed across the Continental Divide to the southwest into the drainage of the Snake River and Jackson Hole. During the Sacagawea Ridge-Bull Lake interglaciation, which preceded the Bull Lake Glaciation, the basin of Yellowstone Lake was occupied by an open lake whose extent and level were affected by a violent eruption of tuff coincident with the collapse of a caldera immediately west of the quadrangle in West Thumb and by subsequent outpouring of rhyolite flows. Following these events, the lake was 370 feet above present Yellowstone Lake. During the interglaciation separating the Bull Lake and Pinedale Glaciations another open lake formed in the basin at a level about 250 feet above present Yellowstone Lake.

SACAGAWEA RIDGE-BULL LAKE INTERGLACIATION

Deposits of the Sacagawea Ridge-Bull Lake interglaciation crop out in several places in the bluffs surrounding Yellowstone Lake. They are best exposed along the north side of Flat Mountain Arm (fu, fl), where they are informally designated as sediments of Flat Mountain Arm. Here, the lower unit (fl), comprises a basal till-like diamicton, which may represent the Sacagawea Ridge Glaciation, and associated crossbedded gravelly sand. These deposits are overlain by lake sand and silt (stratigraphic sections 58,57, and 59). In this quadrangle, the ancient lake occupied the area of present Yellowstone Lake, the area between Flat Mountain Arm and West Thumb and probably the area north of West Thumb. The highest deposits of the ancient lake are now about 20 feet above present Yellowstone Lake whose elevation is 7,733 feet. The ancient lake may have drained northwest through an area now covered by younger rhyolite flows (Norris Junction quadrangle) and across the old caldera rim at the site of present Madison Canyon.

The lower unit (fl) is overlain by a pumiceous tuff, the Shoshone Lake Tuff Member, which is about 40 feet thick and consists of weakly welded to loose material. The tuff has a K-Ar age of about 155,000 years. The caldera associated with eruption of the tuff occupies the circular part of West Thumb in the West Thumb quadrangle adjacent to the west and developed either at the edge of the lake or beneath its waters.

The upper unit of the sediments of Flat Mountain Arm (fu) consists of a thin basal gravel overlain by lake sand and silt, and has a maximum thickness of about 35 feet (stratigraphic sections 54, 55, 56, and 58). The deposits show that the lake rose over the tuff and attained a somewhat higher level than in pre-tuff time. Though affected by faulting, the lake beds are now at a maximum height of about 50 feet above present lake level. The extent of the lake was probably less than that of the pre-tuff lake, as it was modified by changes in the terrain resulting from deposition of the tuff, and by collapse of the caldera of West Thumb. During this time, the lake may have drained southwest to Heart Lake across the divide now covered by the Aster Creek rhyolite flow (see small map).

The lake was next changed by the eruption of the Aster Creek (Ra) and West Thumb (Rw) rhyolite flows (see small map), both K-Ar dated at about 150,000 years. The Aster Creek flow poured from the present Continental Divide near the west edge of the quadrangle southward across the area west of Beaver Creek to Heart Lake, and northeastward across the peninsular area between Flat Mountain Arm and West Thumb. It covered the entire area of present Flat Mountain Arm, as shown by an exposure on the south side of the arm. The West Thumb rhyolite flow (Rw) poured into the northwestern part of the quadrangle and forms the present northwest margin of Yellowstone Lake in that area. Its base is below present water level. To the north, in the Canyon Village quadrangle, a lobe of the West Thumb rhyolite flow extended across the ancient lake in the area of present LeHardys Rapids and impinged against the upland to the east. The dam thus formed raised the waters of the lake to an altitude of about 8,100 feet, or about 370 feet above present lake level. This lake drained across the dam and northward into a shallow successor lake of the Yellowstone River (Canyon Village quadrangle) which lead across the north rim of the old caldera. Deposits of this lake (s-bl, s-bsl) occur locally in bluffs along the northwest shore of Yellowstone Lake and are well exposed. At stratigraphic sections 19, 20, 21, 22, 23, 24, and 33 they consist of silts and pumiceous sands and contain a pumice bed K-Ar dated at about 150,000 years. Locally, they overlie the West Thumb rhyolite flow (stratigraphic sections 19 and 33). The pumice was probably deposited during the eruption of the Elephant Back rhyolite flow (Re) into the northwest corner of the quadrangle across the surface of the West Thumb rhyolite flow. The Elephant Back flow also has a K-Ar age of about 150,000 years but, like the pumice, is clearly somewhat younger than the West Thumb flow. The deposits of the Sacagawea Ridge-Bull Lake interglaciation (s-bl, s-bsl) are separated from lake deposits or till of the Bull Lake Glaciation by a disconformity (stratigraphic sections 22, 23, 24, and 33).

BULL LAKE GLACIATION

Bull Lake Till (bt) crops out in bluffs around Yellowstone Lake (stratigraphic sections 3, 19, 26, 30, 32, 33, and 81), but is not exposed extensively enough to be mapped. The presence of abundant erratics of andesite and basalt in Bull Lake Till on the west side of the lake indicates that the ice was derived from the Absaroka Range east and southeast of the lake. However, the abundance of reworked lake silt in the till at some localities (stratigraphic sections 2, 81, and 82) and its high content of reworked pumice and obsidian at others (stratigraphic sections 32 and 33) show that the ice derived most of its load from older Quaternary lacustrine and tuffaceous deposits, such as those of the Sacagawea Ridge-Bull Lake interglaciation, that underlie the lake basin. Flat Mountain Arm and the basin of Delusion Lake were probably excavated in these deposits by the Bull Lake ice. The local blue-gray unoxidized character of the till further suggests that the till may have been deposited under water.

The distribution of outcrops of Bull Lake Till shows that an icecap filled the basin of Yellowstone Lake in Bull Lake time. End moraines formed by the icecap lie outside Yellowstone National Park beyond those of the subsequent Pinedale Glaciation. Bull Lake ice was therefore more extensive than Pinedale ice and was also thicker. The history of recession of the ice is not well documented in this quadrangle. Slumped and faulted ice-contact gravel (bkgs) and crossbedded lake sand (bks), locally containing beds of reworked pumice (stratigraphic section 79) and overlain in places by younger lake deposits and (or) Pinedale Till (stratigraphic sections 78, 80, 81, and 82), represent a recessional phase of the glaciation on the east side of the lake. On the west side, varved lacustrine silts on Bull Lake Till and under Pinedale Till (stratigraphic section 32) were also deposited as Bull Lake ice receded from the area. Associated deposits of contorted irregularly bedded silt, containing striated stones and erratics of basalt and andesite, that underlie massive or laminated lake deposits (b-pl, b-psl) beneath Pinedale Till (stratigraphic sections 25, 26, 27, 28, and 29) were probably formed during recession of the Bull Lake ice. The Bull Lake Glaciation ended at sometime prior to about 70,000 years ago, the age of the Pitchstone Plateau Rhyolite flow (Map I-639) which, though in the path of Bull Lake ice, has no Bull Lake deposits on it.

INTRA-BULL LAKE INTERVAL

The Bull Lake Glaciation is subdivided into two stades, separated by a nonglacial interval (Richmond, 1965). In this quadrangle a sequence of lake silts (b-bl) exposed at stratigraphic sections 66, 67, 68, and 69 are believed to represent deposits of an open lake during this interval because they contain a pumice bed K-Ar dated at about 103,000 years. No till of the late stade of Bull Lake Glaciation was found on them, but they are truncated by a disconformity overlain by Pinedale Till. In the Canyon Village quadrangle, the Hayden Valley and Solfatara Plateau rhyolite flows, both K-Ar dated at about 105,000 years, are locally overlain by deposits of late Bull Lake age.

BULL LAKE–PINEDALE INTERGLACIATION

Deposits of the Bull Lake-Pinedale interglaciation are insufficiently exposed to be mapped, but crop out beneath Pinedale Till or ice-contact deposits around the lake and in drainages from the south. Most are massive to laminated silts and fine sands (b-psl, b-pl) recording deep-water conditions (stratigraphic sections 3, 6, 7, 20, 21, 22, 23, 24, 28, 29, 30, 77, 79, 80, 81, and 82). Though the level of the lake cannot be determined in this quadrangle, huge deltas of similar material, stratigraphically between Bull Lake Till and Pinedale Till, attain altitudes up to about 7,980 feet, or 250 feet above present Yellowstone Lake, in the Eagle Peak (Map I-637) and Two Ocean Pass (Map I-635) quadrangles, adjacent to the east and southeast, respectively. This lake was impounded, as before Bull Lake Glaciation, by the lava dam in the area of LeHardys Rapids to the north in the Canyon Village quadrangle. The dam, however, was about 120 feet lower than during the Sacagawea-Bull Lake interglaciation. Plant material from deposits of the lake, along Solution Creek (stratigraphic section 35), has a radiocarbon age >38,000 years (W2012). Similar material from deposits near the mouth of Solution Creek (stratigraphic section 36) that has a radiocarbon age of 29,000± 1,000 years (W2583) were crumpled by overriding ice of the Pinedale Glaciation. Wood from delta deposits of the lake in the Eagle Peak quadrangle (Map I-637) yielded a radiocarbon age of >42,000 years (W2197) and >45,000 years (W2411). The lake is therefore considered to have existed from the end of Bull Lake Glaciation at sometime prior to 70,000 years ago to a time somewhat less than 29,000 years ago.

PINEDALE GLACIATION

Early in Pinedale time, glaciers formed in the higher parts of the Absaroka Range southeast of the quadrangle and coalesced westward into a large mass, which flowed north down the upper valley of the Yellowstone River into the basin of Yellowstone Lake. Here the ice became a center of local accumulation and developed into a cap which, in this quadrangle, spread southwest across the uplands enclosing Delusion Lake and overrode and crumpled preexisting lake beds 29,000 years old and older along Solution Creek (stratigraphic sections 35 and 36). The cap gradually thickened and eventually overrode the divides surrounding the basin. In the eastern part of the quadrangle it must have attained a maximum thickness of over 3,000 feet, for it overrode the crest of the Absaroka Range to the east. In the southwestern part of the quadrangle it flowed across the Continental Divide, across the basin of Heart Lake, and, at its maximum, merged with glaciers from the Teton Range in the basin of Jackson Hole.

STAGNATION OF THE PINEDALE ICECAP

During deglaciation, one and locally more readvances of the ice took place, but their end moraines lie outside the limits of this quadrangle. As the surface of the icecap lowered, uplands such as Flat Mountain and Overlook Mountain began to emerge and melt waters flowed between the ice and adjacent slopes. A high melt-water channel (altitude 8,700 feet) extends across the Continental Divide just north of Overlook Mountain,