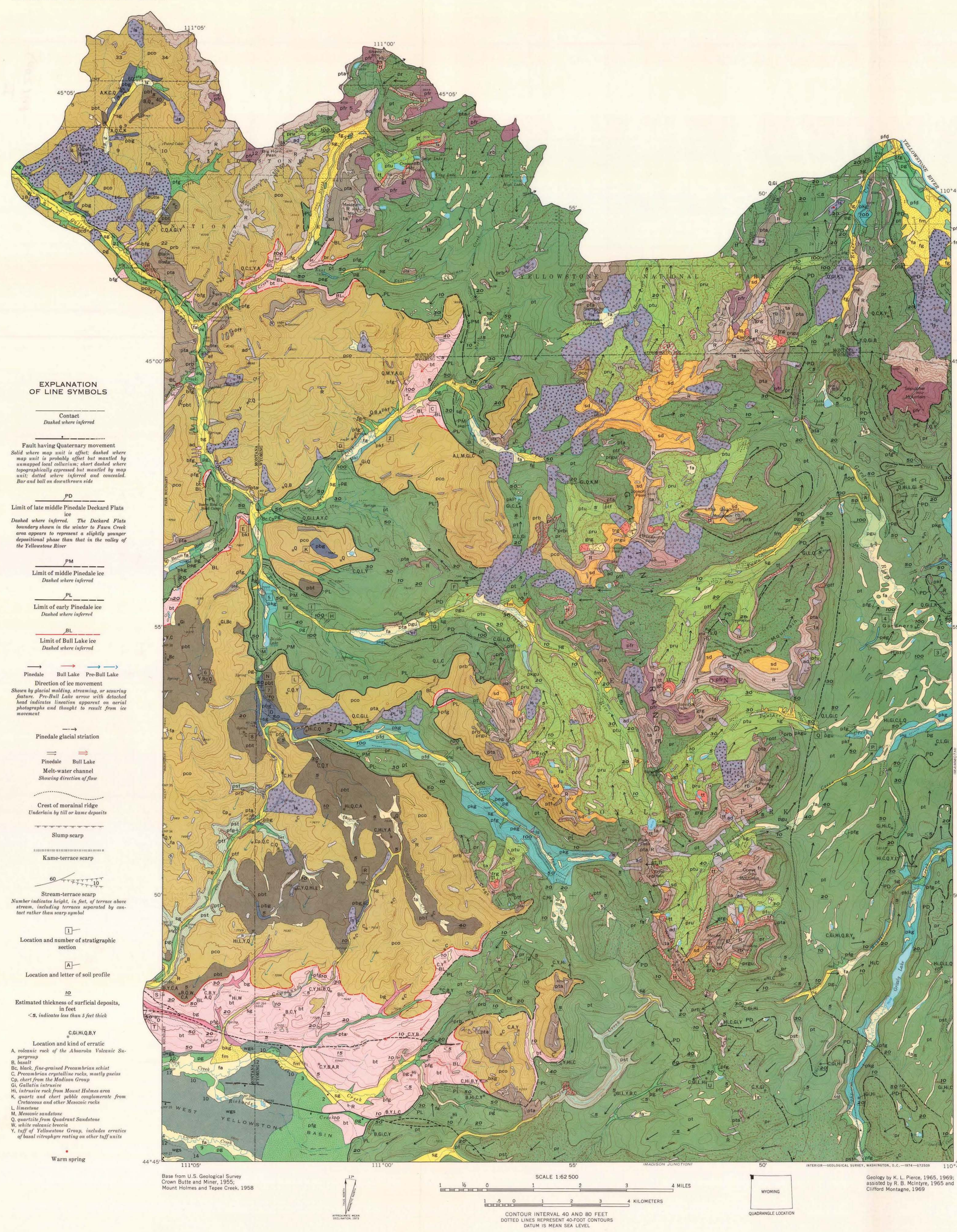
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



EXPLANATION OF LINE SYMBOLS

Contact
Dashed where inferred

Fault having Quaternary movement
Solid where map unit is offset; dashed where map unit is probably offset but mantled by unmapped local colluvium; short dashed where topographically expressed but mantled by map unit; dotted where inferred and concealed. Bar and ball on downthrown side

PD
Limit of late middle Pinedale Deckard Flats ice
Dashed where inferred. The Deckard Flats boundary shown in the winter to Fawn Creek area appears to represent a slightly younger depositional phase than that in the valley of the Yellowstone River

PM
Limit of middle Pinedale ice
Dashed where inferred

PL
Limit of early Pinedale ice
Dashed where inferred

BL
Limit of Bull Lake ice
Dashed where inferred

Pinedale Bull Lake Pre-Bull Lake
Direction of ice movement
Shown by glacial molding, streaming, or scouring feature. Pre-Bull Lake arrow with detached head indicates lineation apparent on aerial photographs and thought to result from ice movement

Pinedale glacial striation

Pinedale Bull Lake
Melt-water channel
Showing direction of flow

Crest of morainal ridge
Underlain by till or kame deposits

Slump scarp

Kame-terrace scarp

60 10
Stream-terrace scarp
Number indicates height, in feet, of terrace above stream, including terraces separated by contact rather than scarp symbol

1
Location and number of stratigraphic section

A
Location and letter of soil profile

10
Estimated thickness of surficial deposits, in feet
<5, indicates less than 5 feet thick

C,Gi,Hi,Q,B,Y
Location and kind of erratic
A, *volcanic rock of the Absaroka Volcanic Supergroup*
B, *basalt*
Bc, *black, fine-grained Precambrian schist*
C, *Precambrian crystalline rocks, mostly gneiss*
Cp, *chert from the Madison Group*
Gi, *Gallatin intrusive*
Hi, *intrusive rock from Mount Holmes area*
K, *quartz and chert pebble conglomerate from Cretaceous and other Mesozoic rocks*
L, *limestone*
M, *Mesozoic sandstone*
Q, *quartzite from Quadrant Sandstone*
W, *white volcanic breccia*
Y, *tuff of Yellowstone Group, includes erratics of basal vitrophyre resting on other tuff units*

Warm spring

Base from U.S. Geological Survey
Crown Butte and Miner, 1955;
Mount Holmes and Tepee Creek, 1958

17°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1973

SCALE 1:62 500
1 ½ 0 1 2 3 4 MILES
1 .5 0 1 2 3 4 KILOMETERS
CONTOUR INTERVAL 40 AND 80 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

WYOMING
QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1974—G72509

Geology by K. L. Pierce, 1965, 1969; assisted by R. B. McIntyre, 1965 and Clifford Montagne, 1969

E X P L A N A T I O N

QUATERNARY

Holocene — Neoglaciation

Gannett Peak Stade
- GLACIAL DEPOSITS: gt — Till; grg — Rock glacier

Temple Lake Stade
- GLACIAL DEPOSITS: tt — Till; trg — Rock glacier

Holocene (Neoglaciation) — undivided
- ALLUVIAL DEPOSITS: fa — Fine-grained humic alluvium; sg — Stream gravel; fg, fm — Fan deposits (fg, *gravel*; fm, *muddy gravel*)
- COLLUVIAL DEPOSITS: sd — Solifluction deposit; ta — Talus deposit; tf — Talus-flow deposit; fr — Frost rubble; rb — Block rubble; ad — Avalanche debris

Pleistocene — Pinedale Glaciation

*Late Stade**
- GLACIAL DEPOSITS: ptu — Till; prgu — Rock glacier; pru — Rubble veneer
- ICE-CONTACT DEPOSITS: pkgu — Kame gravel
- ALLUVIAL DEPOSITS: pgu — Outwash gravel; pfd — Flood deposits
- COLLUVIAL DEPOSITS: pst — Scree deposit of tuff rubble; pta — Talus deposit; ptf — Talus-flow deposit; pfr — Frost rubble; prb — Block rubble

*Early and middle stade**
- GLACIAL DEPOSITS: pt — Till; pr — Rubble veneer
- ICE-CONTACT DEPOSITS: pkg — Kame gravel; peg — Esker gravel; pkf — Kame inwash fan gravel
- LACUSTRINE DEPOSITS: pkl — Ice-dammed lake silt
- ALLUVIAL DEPOSITS: pg — Outwash and stream gravel; pfg — Alluvial and outwash fan gravel
- COLLUVIAL DEPOSITS: pco — Colluvium

Landslide deposit — ls, *landslide deposit undifferentiated*; ef, *earth-flow deposit*

HYDROTHERMAL DEPOSITS: tr — Travertine

Bull Lake-Pinedale interval
- ALLUVIAL DEPOSITS: wgs — Sediments of West Yellowstone Basin

Bull Lake Glaciation
- GLACIAL DEPOSITS: bt — Till; br — Rubble veneer
- ICE-CONTACT DEPOSITS: bkg — Kame gravel
- LACUSTRINE DEPOSITS: bkl — Ice-dammed lake silt
- ALLUVIAL DEPOSITS: bg — Gravel; bfg — Fan gravel

Pre-Bull Lake glaciations
- GLACIAL DEPOSITS: pbt — Till
- ALLUVIAL DEPOSITS: pbg — Gravel

BEDROCK: R — Bedrock (*Includes rocks of Pleistocene to Precambrian age*)

*Denotes informal terminology

DESCRIPTION OF UNITS

NEOGLACIATION
GLACIAL DEPOSITS

gt, tt — Till—Gray, nonstratified, and unsorted angular rock debris in sparse matrix. Forms small end moraines 10-40 feet high in north-facing cirques. Gradational with and includes protalus ramparts. Gannett Peak Till (gt) forms a single morainal ridge incompletely covered with lichen, but little other vegetation. Temple Lake Till (tt) forms several slightly weathered morainal ridges covered with lichen, and local trees and grass. Thickness 10-40 feet.

grg, trg — Rock glacier—Glacier-shaped tongue of angular rock debris that heads in talus from cirque headwalls. Surface-flow ridges and furrows are convex downslope. Rubble is mainly resistant andesitic intrusive rocks. Deposits of Gannett Peak Stade (grg) have very steep, unstable fronts and are active, fresh, and barren. Deposits of Temple Lake Stade (trg) are inactive or less active with local unstable fronts, locally support trees, are more completely covered with lichens, and are locally overridden by Gannett Peak rock glaciers. Thickness 20-200 feet.

ALLUVIAL DEPOSITS

fa — Fine-grained humic alluvium—Silt and subordinate sand, clay, and plant material that underlies wet ground along drainages and in upland depressions; supports lush stands of tall grasses and sedges. Peaty at surface; locally includes marl at depth (stratigraphic section 5). Thickness 2-20 feet.

sg — Stream gravel—Sandy gravel with minor interbeds of sand and silt; forms alluvial flats 0-10 feet above the present streams; moderately sorted. Gravel is subrounded, 1-4 inches in diameter, and calcareous. Generally 10-30 feet thick, but in Gallatin River valley possibly 100 feet thick.

fg, fm — Fan deposits—Alluvial fans of boulders, cobbles, and pebbles in a sandy matrix below steep slopes. Fan gravel (fg) poorly sorted, crudely bedded; contains finer grained interbeds. Muddy fan gravel (fm) is very poorly sorted flood and mudflow deposits containing abundant fines. Mostly 10-50 feet thick.

COLLUVIAL DEPOSITS

sd — Solifluction deposit—Stony mud on gentle and moderate slopes above timberline. Unsorted, nonbedded. Generally overlies shaly bedrock. Seasonally active, forming small terraces where emplaced by shallow flow during thaw. Contains more fine and fewer coarse particles than frost rubble (fr). Deposit 2-5 feet thick.

ta — Talus deposit—Angular rock rubble forming cones or aprons on steep slopes near timberline. Clasts commonly more than 6 inches across. Deposit bears little vegetation except lichens. Interstices void near surface, but silty matrix at depth. Active piecemeal accumulation from cliffs or positions upslope. Mostly 5-30 feet thick.

tf — Talus-flow deposit—Open rubble of angular rocks on moderate slopes. Mass movement shown by lobate form, deformation of turf at toe, and by unstable or recently turned rock fragments. Thickness 5-30 feet.

fr — Frost rubble—Rubble, mostly cobble-sized, with a fine-grained matrix on gentle slopes above timberline. Seasonal movement indicated by sparse or disrupted tundra and by thin azonal soil. Formed by frost mixing, sliding, and solifluction. Intermediate between solifluction deposit (sd) and block rubble (rb) in ratio of matrix to blocks. Thickness 3-6 feet.

rb — Block rubble—Large angular blocks; interstices void, although fine-grained matrix occurs near base of deposit. Barren; occurs near or above timberline on moderate to gentle slopes. Frost riven from underlying bedrock or from bedrock immediately upslope. Lichen cover incomplete. Thickness 3-10 feet.

ad — Avalanche debris—Boulder- to pebble-sized rock fragments in a fine-grained matrix; forms fan-shaped or lobate deposits at base of avalanche chutes. Deposits crudely bedded, unsorted to poorly sorted, locally very bouldery. Consists of debris transported by snow avalanche, slush flow, debris avalanche, and mudflow. Generally mapped only below active chutes where normal forest is replaced by small trees. Mostly 5-20 feet thick.

ls, ef — Landslide deposit—Nonsorted debris in a clayey matrix; forms lobate masses. Generally results from failure in shaly bedrock, but includes blocks of harder bedrock that overlies the shale. Most deposits have moved recently as indicated by fresh ridges, depressions, and slump scarps. Earth-flow deposits (ef) are especially clayey and characterized by smooth flow ridges and troughs parallel to periphery of deposit. North of Sportsman Lake, landslide appears glaciated by late Pinedale ice. Mostly 20-100 feet thick.

HYDROTHERMAL DEPOSITS

tr — Travertine—Light-gray, porous calcium carbonate that cements gravel 1.5 miles west of Fawn Pass. No modern deposition; vertical sections 10 feet thick exposed by erosion.

PINEDALE GLACIATION
GLACIAL DEPOSITS

ptu — Till—Similar to adjacent older Pinedale Till (pt) but slightly more bouldery and restricted to mountain valleys. Commonly forms three sets of well-defined end moraines 10-50 feet high and 0.5-5 miles downvalley from high, north-facing cirques. The B horizon, and the C_{ca} horizon if present, of soil profiles F, G, and Q look like those on nearby older Pinedale deposits, but are about 0.5 foot thinner. Along Panther and Fawn Creeks outer end moraines (ptu) are poorly expressed, significantly eroded, and may be older. Till of late Pinedale age probably occurs in headwaters of Gardner River, but no end moraines observed. Thickness 5-100 feet.

prgu — Rock glacier—Materials similar to younger Neoglacial rock glaciers (grg, trg), but form of deposit quite different; characterized by collapse depressions, largely obliterated flow features and rounded frontal-slope crest. Locally forested and mantled by humic soil. Thickness 10-50 feet.

pru — Rubble veneer—Similar to older Pinedale rubble veneer (pr), but scour features of enclosed bedrock areas fresher. Occurs upvalley from late Pinedale moraines.

pt — Till—Unsorted, nonstratified, compact mixture of roundstones, sand, silt, and clay deposited by glaciers. Stones mostly subrounded. Glacially striated and faceted clasts are common in deposit but are difficult to recognize on surface. South of Mount Holmes, the till is brown, sandy, noncalcareous, and rich in rhyolite tuff with lesser amounts of basalt, gneiss, and intrusive andesite. In northwestern corner of mapped area, brown, silty, noncalcareous; clasts mainly andesite boulders 0.3-1 foot in diameter. In central two-thirds of area, pinkish-gray to gray, clayey, and calcareous; most clasts <1 foot across and of intrusive andesite, limestone, and friable quartzite. Till mostly occurs as undulating ground moraine. In western part of area forms end moraines with hummocky topography and undrained depressions; ridges are 10-40 feet high, 20-200 feet wide, and slope as much as 20°. Crests of end moraines partly covered (10-30 percent) by protruding stones 0.5-1 foot across. End moraines along Grayling Creek studded with large boulders of gneiss from The Crags. End moraines elsewhere are not particularly bouldery, owing to a lack of boulder-forming bedrock and the abundance of fine-grained materials. Drumloidal topography conspicuous in and near Gardners Hole.
In central two-thirds of area, Western Brown Forest pedocal soils are formed on the calcareous, clayey till. The degree of apparent development is variable; in better developed profiles (soil profiles A, B, D, H, I, J, L, M, P, and U) the B horizon extends about 2-3 feet below the surface. Soil color, texture, and structure are weakly to perhaps moderately developed. Carbonate lenses and rinds in the C_{ca} horizon are as much as ¼ inch thick. On noncalcareous till brown podzolic soils mostly less than 2 feet thick are formed. Weathering rinds average less than 0.5 mm thick for each of about 20 suites of 10 or more glacially abraded intrusive andesites collected from the crests of the outermost to the innermost end moraines.
The till has been modified by frost heaving and, on slopes, by solifluction and creep. Till is commonly more than 20 feet thick along valley bottoms and at end moraines, but ground moraine mostly less than 5 feet thick on uplands and steep slopes.

pr — Rubble veneer—Thin mantle over bedrock of rubble in loose fine-grained matrix on glaciated uplands. Mostly weathered, especially by frost processes, from local bedrock, but contains some glacial erratics. Terrain underlain by rubble veneer (pr) gradational with and similar in appearance to much of that underlain by till (pt), but undisturbed glacial deposits are present only locally in glacial rubble areas. Includes discontinuous bands of solifluction debris, especially near tree line. Mapped areas include many small outcrops of glaciated bedrock. Uplands of Quadrant Mountain appear glaciated, but no erratics were found. Thickness 0-5 feet.

ICE-CONTACT DEPOSITS

pkgu — Kame gravel—Similar to Pinedale kame gravel (pkg) but deposited within area occupied by late Pinedale ice.

pkg — Kame gravel—Buff to gray, moderately well sorted gravel and gravelly sand commonly having ice-contact frontal scarps. Upper surface displays irregular terraces, ridges, and kettles. Irregularly bedded with abrupt vertical and lateral changes in grain size, including local sand and silt beds. Gravel mostly less than 6 inches in diameter; composed of limestone, sandstone, intrusive andesite, and, locally, Precambrian crystalline rocks. Locally overlies unweathered Pinedale Till (stratigraphic section 1). Thickness 20-100 feet.

peg — Esker gravel—Sinuous ridge of well-sorted gravel deposited by subglacial stream. More gravelly and better sorted than kame gravel. Mostly 10-30 feet thick.

pkf — Kame inwash fan gravel—Similar to kame gravel (pkg) but more uniformly bedded and sized. Deposited behind ice dam near stratigraphic section 2 and soil profile P. Mostly 10-30 feet thick.

LACUSTRINE DEPOSITS

pkl — Ice-dammed lake silt—Gray, bedded, calcareous silt. Occurs where glacier from Gallatin River valley dammed lower Fan Creek, and upstream where glacier from East Fork valley dammed the drainage to the south. Mostly 10-30 feet thick.

ALLUVIAL DEPOSITS

pgu — Outwash gravel—Similar to older Pinedale outwash gravel (pg) but associated with end moraines of late Pinedale age. Soil profile G has weak B horizon over C_{ca} horizon marked by caliche coatings ¼ inch thick on pebbles. Mostly 10-30 feet thick.

pfd — Flood deposits—Buff, coarse bouldery gravel; poorly to moderately sorted; poorly bedded; boulders mostly of basalt and gneiss and have percussion spalls. Deposits form large longitudinal bars, giant ripple marks, and sharp bars and swales. In the Yellowstone River valley, deposits extend from river level 200 feet upslope to flood-ripped and resedimented fronts of alluvial fans. Probably of late Pinedale age. Much smaller deposits along Grayling Creek form boulder-studded terraces and a bar-and-swale topography. Probably of late Pinedale age. Thickness 20-100 feet.

pg — Outwash and stream gravel—Gray to buff, moderately sorted gravel with sandy matrix; underlies terraces 5-15 feet above streams and abandoned melt-water channels; stones subrounded to rounded, mostly 1-6 inches in diameter. Except in southwest corner of mapped area, roundstones are, in order of decreasing aboundance: carbonate rocks, intrusive andesite rocks, friable quartzite, sandstone, and gneiss. Silty alluvial mantle has infiltrated gravels to aid in forming a weak soil with a "color" B horizon 1-2 feet thick underlain by a moderately developed caliche 1-2 feet thick. Thickness 5-30 feet.

pfg — Alluvial and outwash fan gravel—Mostly similar to Neoglacial fan gravel (fg) but bulk of deposit accumulated in Pinedale time; locally incised by modern streams. In southwest part of area forms outwash fan of moderately sorted pebble gravel which extends west from Pinedale end moraines and laps over sediments of West Yellowstone Basin (wgs). Mostly 10-50 feet thick.

COLLUVIAL DEPOSITS

pco — Colluvium—Locally derived rock rubble in an abundant fine-grained matrix. In western part of area mapped beyond limits of Bull Lake and Pinedale Glaciations, but contiguous with areas of pre-Bull Lake till (pbt). Mostly stable with a weakly developed soil 1-3 feet thick. Deposits locally include a younger active surface layer. Mostly 3-8 feet thick.

pst — Scree deposit of tuff rubble—Small-pebble-sized fragments of stony rhyolite forming sheets over tuff bedrock and aprons or cones farther downslope. Generally covered by open forest; includes surface material that slides and tumbles downhill against trees and other obstacles. Thickness of sheets 0-5 feet; of aprons and cones 5-30 feet.

pta — Talus deposit—Rubble of angular rocks as large as 4 feet in diameter. Forms aprons and cones on steep slopes, generally below cliffs. Fine-grained matrix commonly extends to surface where soil is weak, humic, and 1-3 feet thick. Deposit inactive and generally covered with trees or grass. Thickness 5-50 feet.

ptf — Talus-flow deposit—Similar to younger, Neoglacial talus flow (tf) but inactive and partly vegetation-covered.

pfr — Frost rubble—Similar to younger, Neoglacial frost rubble (fr) but covered by turf except for protruding large blocks of lichen-covered rubble; virtually stable. Occurs in dry open areas near timberline. Mostly 2-5 feet thick.

prb — Block rubble—Similar to younger, Neoglacial block rubble (rb), but inactive and below timberline. Interstices open at surface; deposits well drained, and vegetation sparse except for heavy lichen cover. Mostly 3-8 feet thick.

DEPOSITS OF THE PINEDALE-BULL LAKE INTERVAL
ALLUVIAL DEPOSITS

wgs — Sediments of West Yellowstone Basin—Gray sand and fine gravel forming coalescing alluvial fans of low gradient. Deposit coarsens eastward towards source. Incised 10-20 feet by modern streams and original slope of surface of deposit modified by tectonic tilting. Deposit well bedded with beds 1-2 feet thick: cross-stratification in beds at low angles; gravel commonly openwork. Eastern contact with outwash fan of Pinedale gravel (pfg) mapped at edge of recognizable Pinedale channel morphology.
Clasts are dominantly stony rhyolite but to southwest, in West Yellowstone quadrangle, obsidian clasts become dominant. Highly permeable; upper surface generally dry supporting sparse stand of lodgepole pine. Weakly developed soil has admixed windblown silt in upper 12-18 inches. Occurs inside loop of early Bull Lake moraines and is overlain by early Pinedale outwash. Mostly 40-100 feet thick.

BULL LAKE GLACIATION
GLACIAL DEPOSITS

bt — Till—Unsorted, nonstratified compact mixture of roundstones, sand, silt, and clay beyond limit of Pinedale Till. Forms bulky moraines with subdued slopes and scarce boulders at surface. Closed depressions generally absent. East of Gallatin Range, subsurface till in stratigraphic sections 3 and 4 is pinker than the overlying Pinedale Till and is probably of Bull Lake age. On north side of West Yellowstone Basin, forms smooth, bulky moraines, mantled by 1-4 feet of windblown silt, and containing much basalt, rhyolite tuff, and Precambrian rocks. On the end moraines shown in the southwest corner of the map soil profiles S and T are 3-4 feet thick with moderate to strong texture, color, and structure development. Along Fan Creek, soil profile C has a moderately well developed B horizon about 3 feet thick. Till mostly 20-100 feet thick.

br — Rubble veneer—Similar to Pinedale rubble veneer (pr) but generally thicker, more weathered and stable.

ICE CONTACT DEPOSITS

bkg — Kame gravel—Similar to Pinedale kame gravel (pkg), but more deeply weathered and eroded. Mapped in southwest part of area where both deposits include inwash increment. Thickness 5-20 feet.

LACUSTRINE DEPOSITS

bkl — Ice-dammed lake silt—Pinkish-tan, massive-bedded silts grading into till where glacier from Bacon Rind Creek dammed Gallatin River. Thickness 5-10 feet.

ALLUVIAL DEPOSITS

bg — Gravel—Mapped only in southwest part of area. Includes both outwash and inwash. Mantled by colluvium; interior of deposit not exposed.

bfg — Fan gravel—Similar to Neoglacial fan gravel (fg). Mapped only in northwest part of area: more deeply incised (about 50 ft) than Pinedale fan gravel (pfg). Soils locally deep and have strong caliche. Unit largely mantled by thick colluvium from adjacent hillsides. Thickness 20-50 feet.

PRE-BULL LAKE GLACIATIONS
GLACIAL DEPOSITS

pbt — Till—Unsorted, nonstratified, compact mixture of roundstones, sand, silt, and clay on benches in western part of area beyond Bull Lake and Pinedale Till. Generally recognized by erratics. Morainal form generally absent as in the area near stratigraphic section 6 but subdued ridges locally preserved. Original upper surface eroded and disrupted by frost action. Locally mantled by as much as 2 feet of silt. Where partly preserved, relict soil (soil profiles K, R) distinguished by B horizon about 2 feet thick with strongly developed structure, color, and clayey texture. Striated stones of rhyolite tuff from the Yellowstone Group occur in till beneath pre-Bull Lake ice-contact sand and gravel (stratigraphic section 7, 8). In Daly Creek drainage basin in northwest corner of mapped area, erosion of segments of moraines and subdued expression of cirques suggest that the till (pbt) is of pre-Bull Lake age. Along neighboring Black Butte Creek, a formless deposit containing abundant boulders of Precambrian rock, not known to crop out upvalley, is mapped as pre-Bull Lake till (pbt) but might be a Tertiary conglomerate. Thickness 5-50 feet.

ALLUVIAL DEPOSITS

pbg — Gravel—Moderately sorted gravel and deposits of kame sand and lake sediments. Eroded, and mantled by colluvium and alluvial fans. Pre-Bull Lake age suggested by association with pre-Bull Lake till (pbt), height above present drainage, and post-depositional weathering or burial of original deposit. Kame sand leached at soil profile 0 to depth of 90 inches. Kame sand at stratigraphic section 7 has a moderately developed soil 2-4 feet thick under 2 feet of windblown silt. Relict soil on outwash at soil profile K has B horizon more than 2 feet thick with strong reddish colors, clayey texture, and strong structure. In northwest corner of mapped area, coarse outwash(?) containing Precambrian clasts occurs as much as 60 feet above Gallatin River; mantled by colluvium and alluvial-fan deposits and locally deeply weathered. Thickness 20-100 feet.

R — BEDROCK
(After U.S. Geological Survey map I-711, 1972) Pinkish gneisses of Precambrian age are exposed low at the south end of the Gallatin Range and also in and south of The Crags. Paleozoic limestones and shales crop out from the south end of the range to the Gallatin River-Panther Creek area. Upper Paleozoic quartzite forms the uplands near Quadrant Mountain. From Fawn Pass north to Electric Peak and in the northeast part of the mapped area, Mesozoic shales and sandstones predominate. However, near Sepulcher Mountain and from Fan Creek to the north map boundary, andesitic volcanic and sedimentary rocks of the Absaroka Volcanic Supergroup crop out. Andesitic laccoliths, stocks, and sills cut the Mesozoic sedimentary rocks in the Electric Peak-Joseph Peak-Indian Creek area, and a biotitic stock crops out near Mount Holmes. Precambrian and Paleozoic rocks crop out along the west boundary of the area, and volcanic rocks of the Absaroka Supergroup occur south of The Crags. Quaternary rhyolite tuff of the Yellowstone Group underlies much of the partially dissected terrain east, south, and west of the Gallatin Range. Quaternary basalt flows locally mantle the tuff.

SURFICIAL GEOLOGIC HISTORY

INTRODUCTION

The mapped area covers the northwestern corner of Yellowstone National Park. The glacially sculptured Gallatin Range extends from the south-central part northward, where it encompasses the entire northern map boundary. Its peaks rise several hundred feet above timberline to altitudes mostly between 10,000 and 10,550 feet. Electric Peak is 10,992 feet in altitude. Dissected benches flank the range at altitudes between 7,600 and 8,000 feet. The lowest places are at elevations of 5,200 feet along the Yellowstone River to the northeast, 6,800 feet along the Gallatin River to the northwest, and 6,600 feet in the West Yellowstone Basin to the southwest.

PLEISTOCENE GLACIATIONS

Great icecaps repeatedly covered most of Yellowstone Park during Pleistocene time. These glaciations are (from oldest to youngest): pre-Bull Lake (which probably included several full-scale glaciations), Bull Lake, and Pinedale. During the Pinedale, and probably the Bull Lake and pre-Bull Lake glaciations, ice accumulated in cirques along the Gallatin Range and, more significantly, in a large icecap on plateaus to the east and southeast. A smaller icecap formed in the uplands at the head of Specimen Creek. In addition, glaciers advanced eastward into this map area from the Madison Range and down the valley of the Yellowstone River from sources east of the map area.

PRE-BULL LAKE GLACIATIONS

The featureless, deeply weathered till (pbt) on the uplands around stratigraphic section 6 is probably the oldest in the area. It overlies and contains fragments of the Huckleberry Ridge Tuff, which is 2 million years old (Christiansen and Blank, 1972). Its relation to the 0.6-m.y.-old Lava Creek Tuff is not known. Other deposits of pre-Bull Lake till, outwash gravel, and kame gravel (see stratigraphic sections 6, 7, and 8, and soil profiles O and R) overlie and contain fragments of the 0.6-m.y.-old tuff which they therefore postdate. Most of the till surface, especially along Daly Creek, preserves visible but subdued, glacial morphology.

A south-southeast lineation of the terrain apparent on aerial photographs suggests that a large pre-Bull Lake ice mass flowed southward from Grayling Creek into the West Yellowstone Basin. This glaciation probably represents the youngest pre-Bull Lake—the Sacagawea Ridge Glaciation—for kame morphology is locally preserved and scour features are observed on aerial photographs paralleling the present topography. In the northwest corner of the mapped area, terrace gravels (pbg) 60 feet above the Gallatin River contain cobbles and boulders of diverse rock types (including abundant Precambrian rocks); they may represent outwash of a pre-Bull Lake glaciation whose end moraines have since been obliterated.

At stratigraphic sections 7 and 8 and soil profile 0, glaciofluvial and lacustrine deposits represent the stagnation of probable Sacagawea Ridge glaciers. During such stagnation Grayling Creek may have flowed northward across the low divide.

BULL LAKE GLACIATION

Bull Lake deposits in the map area occur primarily on the north side of the West Yellowstone Basin where bulky but subdued morainal ridges overlie tuff of the Yellowstone Group. Till and locally sandy gravel form these moraines. The till contains abundant basalt and tuff and some metamorphic, sedimentary, and intrusive rocks; these constituents demonstrate a source at the south end of the Gallatin Range. The moraines slope west very gently; the orientation of ice-molded topography just south of the mapped area and obsidian erratics in the till (near soil profile T) indicate that a very large glacial lobe flowed from near the present Madison Canyon (south of mapped area) northwestward into the mapped area, where it joined smaller glaciers descending Gneiss and Maple Creeks. The deposits thicken west of the mapped area toward the terminal moraines at The Narrows of Hebgen Lake about 6 miles west of the area.

In the northwestern part of the area, subdued Bull Lake moraines occur just downvalley from fresher Pinedale moraines. A Bull Lake age for these moraines is suggested by the development expressed in soil profiles C and E. The Bull Lake age of the till along Bacon Rind, Fan, and Specimen Creeks is not certain, because neither the weathering nor the morphology could be reliably compared.

Bull Lake glaciers did not extend as far as Pinedale glaciers along the Gallatin River, Grayling Creek, or in the area just east of the Gallatin Range. (A possible exception is the morainal loop where soil profile N is slightly better developed than other profiles on Pinedale deposits.)

East of the Gallatin Range, a pinkish till of probable Bull Lake age occurs beneath grayish Pinedale Till in the cores of drumlins (stratigraphic sections 3, 4). The pink till lacks erratics of Precambrian gneiss found in the Pinedale Till (stratigraphic section 3). This lack shows that the pink till comes from nearby parts of the Gallatin Range, whereas the Pinedale comes from places as distant as the south end of the Gallatin Range. Therefore the influence of the Bull Lake icecap on glaciers flowing eastward from the Gallatin Range was less than that of the Pinedale icecap.

BULL LAKE-PINEDALE INTERVAL

The sediments of West Yellowstone Basin (wgs) were deposited after the Bull Lake end moraines and before the early Pinedale end moraines. The sediments may be glacially derived; they form large alluvial fans rich in obsidian built by the Madison River and smaller fans rich in stony rhyolite built by Cougar, Gneiss, and Maple Creeks. (The Madison River is south of the mapped area.) Rapid deposition and an abundant supply of material are indicated by planar bedding, the openwork texture of the sediments, and the estimated thickness of about 100 feet.

PINEDALE GLACIATION

Early Pinedale advance—The Pinedale Glaciation left the most prominent record on the present landscape. While early Pinedale glaciers formed in cirques and advanced down valleys in the Gallatin and Madison Ranges, an icecap tens of miles across grew on the plateaus to the east and southeast of the Gallatin Range, eventually becoming several thousand feet thick. Glacial striations and streaming show that this icecap poured around the south end of the Gallatin Range and drained down Maple, Gneiss, and Grayling Creeks. East of the Gallatin Range, drumloidal topography and bedrock scour and striations show the ice to have been so thick that it flowed north-northeast oblique to the Gallatin Range front. Glacial molding and scour show that this flow was essentially undeflected by both topographic obstacles 500 feet high and the valley glaciers from the Gallatin Range (as shown by drumloidal topography across the valley mouths). Fresh glacial striations and scour features occur at altitudes of 8,800 feet on Sepulcher Mountain. For the 12 miles parallel to glacial flow features from Grizzly Lake to Sepulcher Mountain, a presumed gradient of 100 feet per mile is reasonable. Therefore, above Grizzly Lake (alt. 7,508 feet) the icecap probably reached an altitude of 10,000 feet and was about 2,500 feet thick. In Gardners Hole, thick Pinedale and older deposits were molded beneath thick Pinedale ice into pronounced drumloidal topography. This ice was probably well in excess of 1,000 feet thick. This northward-flowing ice converged with ice at equal height on the east (Mammoth quadrangle) to form the Yellowstone Valley glacier whose terminus was 30 miles downvalley from the northeastern corner of this map.

The icecap east of the Gallatin Range dammed valley glaciers in the range, causing them to thicken and flow westward across divides such as Fawn Pass and Bighorn Pass (note flow arrows), where they greatly augmented flow from local glaciers formed within the Gallatin and Grayling drainages. Part of the glacier in the valley of the Gallatin River flowed across the low divide into Fan Creek, where it extended both upvalley (to soil profile D) and downvalley. Lake sediments and gravel (stratigraphic section 2) were deposited along Fan Creek upstream from this ice dam. The Pinedale glacier advancing down Bacon Rind Creek forced the Gallatin River to the eastern side of its valley, where it is now locally incised into bedrock.

A small icecap on the uplands in the north-central part of the area flowed both south into the forks of Specimen Creek and north out of the mapped area.

Outwash from Pinedale glaciers (pg) accumulated along the major valleys near present stream levels and in addition it probably forms the flood plains (sg, fa) of many streams. A large Pinedale outwash fan (pfg) was built across the eastern part of the sediments of West Yellowstone Basin (wgs).

Middle Pinedale advances and stagnation—After the early Pinedale advance, the ice receded and readvanced to the middle Pinedale limit (PM). Middle Pinedale glaciers at their maximum were about nine-tenths the size of those of the early Pinedale.

Abundant recessional moraines in the Gallatin River valley show that the glaciers receded intermittently after the middle Pinedale maximum. Near Divide Lake, glaciofluvial gravels washed around ice blocks which melted, forming kettles in which fine-grained humic marly sediments accumulated. In a kettle near Divide Lake (stratigraphic section 5) an air-fall layer of volcanic ash one-fourth inch thick was deposited after 1.6 feet of a total of 16.4 feet of sediment accumulated. Preliminary petrographic examination by R. E. Wilcox (written commun., 1970) indicates this ash to have the petrographic characteristics of two informally named ash beds—the Glacier Peak ash bed (about 12,000 years old) and the recently discovered set J from Mount St. Helens (between 8,000 and 12,000 years old; Mullineaux and others, 1972). When the ash at stratigraphic section 5 was deposited about 8,000-12,000 years ago, the Gallatin glacier had receded from the middle Pinedale glacial maximum, ice-blocks in kettles had melted, and one-tenth of the sediment now in the kettle had accumulated.

The widespread, thick kame gravels along Grayling Creek are related to the icecap near the south end of the Gallatin Range and not simply to the glaciers from the small cirques of Grayling Creek. When the icecap so diminished that inflow into the deep valley of Grayling Creek ceased, the thick ice mass in that valley stagnated, and much fluvioglacial material was deposited.

The last widespread and well-defined advance or standstill of middle Pinedale ice is here referred to as the Deckard Flats advance or standstill (PD). Ice from east of the Gallatin Range flowed down the Gardner River, combined with ice coming down the Yellowstone Valley, and terminated near the mouth of Reese Creek in the northeast corner of the area.

Pinedale frost activity and colluviation—The cold and moist Pinedale climate gave rise to much frost activity and mass wasting. In areas not glaciated in Pinedale time, downslope movement of Pinedale colluvium (pco) and frost rubble (pfr) occurred on moderate to gentle slopes, as did the accumulation of some talus (pta) and block rubble (prb). During glacial recession when areas scoured and steepened by Pinedale ice became exposed, frost wedging of outcrops produced talus or scree (pta, pst) and block rubble (prb). Over much of the area mapped as till or rubble veneer, frost action, solifluction, and creep have caused mixing and downslope movement of unconsolidated materials.

Pinedale floods—Glacially dammed lakes east of the mapped area released at least two floods with waters up to 200 feet deep down the Yellowstone River. Longitudinal bars as much as 1 mile long and 50 feet high occur in the northeast corner and just east of the area. Just north of elevation point 5179 "giant ripple marks" form ridges 50 feet apart, studded with boulders 3-5 feet across. The flood-ripped fronts and transverse scour bars on the lower parts of successively deposited alluvial fans of Reese Creek attest scour by two separate floods. A smaller flood along Grayling Creek deposited boulders as much as 10 feet in diameter which form a bar-and-swale topography with about 8 feet of relief above the sharp bend in the creek.

Late Pinedale glacial advance—In late Pinedale time following middle Pinedale recession, glaciers readvanced from high, well-protected cirques to termini 1 to about 5 miles downvalley. Icecaps and icefields were apparently absent in the mapped area. Three distinct sets of late Pinedale end moraines, representing three phases of glacial advance and recession, are found in the valleys of the Gallatin River, Indian Creek, Panther Creek, and Fawn Creek.

PINEDALE AND HOLOCENE LANDSLIDES

Landslides are common in the northern two-thirds of the mapped area. Most are caused by failure in Mesozoic shales and show fresh morphologic form and other evidence of modern movement. Earthflows display streaming and lobate flow patterns which indicate movement as slow viscous flow rather than as quasi-rigid blocks. Scarps formed by the incipient movement of large masses of bedrock are conspicuous on Sepulcher Mountain and Quadrant Mountain.

In the northwestern part of the mapped area, slides beyond the limits of glaciation probably started moving considerably before Pinedale time. Slides near the Gallatin Range crest probably started moving during middle and late Pinedale deglaciation.

NEOGLACIATION

No glaciers were probably present in the map area during the Altithermal interval about 7,000 to 4,000 years ago. Subsequently, small cirque glaciers and rock glaciers formed in high well-protected cirques. The glaciers deposited one to three rubbly morainal ridges. Temple Lake moraines average 9,000 feet in altitude; rock glaciers average 8,720 feet. Till or rock glaciers of Gannett Peak age occur in about half the cirques with Temple Lake deposits; end moraines average 9,220 feet in altitude, and the rock glaciers, 9,030 feet. Trees are yet to be established on Gannett Peak moraines, indicating the moraines as being less than several hundred years old. Gannett Peak rock glaciers are actively advancing, locally over less active or inactive Temple Lake ones, as in the cirques of Electric Peak. Temple Lake rock glaciers have generally stagnated; locally they are still moving, but were formed in Temple Lake time.

NEOGLACIAL COLLUVIATION

Frost riving continues to produce extensive talus deposits below glacially steepened cirques and other cliffs in the Gallatin Range, especially in hard, well-jointed intrusive rocks. Avalanche debris is accumulating at the base of avalanche chutes by processes ranging from snow avalanches to torrential floods. Solifluction occurs in muddy deposits when the ground thaws from the surface down, thus forming a soupy slurry of rocks and mud (sd) that flows on very gentle slopes. Solifluction and frost heaving together produce rubble (fr). Frost heaving is forming block rubble (rb).

HOLOCENE ALLUVIATION AND EROSION

Most streams in the area now flow within a few feet of their Pinedale level. Although little downward erosion is evident, the streams have reworked and transported Pinedale alluvium in addition to new material supplied from the slopes. Along Specimen Creek and Reese Creek, alluvial fans of poorly sorted debris have coalesced below cliffy slopes.

In Gardners Hole, the larger streams have cut trenches across low points in the drumloidal topography.

QUATERNARY FAULTING

Most Quaternary faults on the map cut rhyolite tuff of the Yellowstone Group and are drawn according to mapping by R. L. Christiansen (U.S. Geol. Survey, 1972). In the West Yellowstone Basin, a fault scarp 10 feet high cuts the outwash fan of Pinedale gravel (pfg).

REFERENCES

Christiansen, R. L., and Blank, H. R., Jr., 1972, Volcanic stratigraphy of the Quaternary rhyolite plateau in Yellowstone National Park: U.S. Geol. Survey Prof. Paper 729-B, 18 p.
Mullineaux, D. R., Hyde, J. H., and Rubin, Meyer, 1972, Preliminary assessment of upper Pleistocene and Holocene pumiceous tephra from Mount St. Helens, southern Washington: Geol. Soc. America Abs. with Programs, v. 4, no. 3, p. 204-205.
U.S. Geological Survey, 1972, Geologic map of Yellowstone National Park: U.S. Geol. Survey Misc. Geol. Inv. Map I-711.

SOIL PROFILES

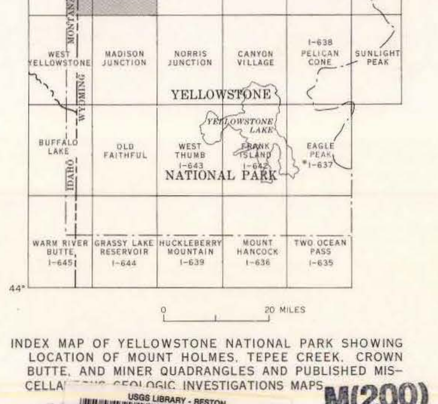
Soil horizons, separated by slashes, are shown in descending order; numbers give depth in inches below surface. Symbols A, B, and C refer to soil horizons; B_1, B_2, and B_3 refer to subdivisions of B horizon; and C_{ca} refers to carbonate zone in C horizon. Modifiers "moderate" and "strong" show how well structure of B horizon is developed, or how well caliche is developed in C_{ca} horizon. Where no modifier is given, property is weakly developed: the B horizon would generally be regarded as a "color B," or the C_{ca} horizon is developed in calcareous parent material and carbonate has simply been rearranged with only minor translocation.

A. 0-3A/3-27B/27-43 C_{ca}.
B. 0-3A/3-31B/31->46C.
C. 0-6A/6->42B, moderate.
D. 0-5A/5-22B/22-35 C_{ca}, very weak.
E. 0-6A/6-25B, moderate/25->44C_{ca}.
F. 0-6A/6-15B, moderate/15->30C.
G. 0-10A/10-30B/30-40 C_{ca}, moderate.
H. 0-5A/5-34B/34->48 C_{ca}.
I. 0-7A/7-22B/22-33 C, leached/C_{ca}.
J. 0-8A/8-30B/30->45 C_{ca}.
K. 0-6A/6-12B, modern/12->32B, relict, strong.
L. 0-8A/8-22B/22->40 C_{ca}.
M. 0-9A/9-33B/33->44 C_{ca}.
N. 0-8A/8-15B_1/15-37B_2, weak to moderate/C.
O. 0-20A, colluvial/20-50B/50-90C, leached/C_{ca}.
P. 0-3A/3-30B/30->65 C_{ca}.
Q. 0-5A/5-20B/20-23 C_{ca}/C.
R. 0-20A, colluvial/20->50B, strong, relict.
S. 0-6A/6-54B, moderate/C.
T. 0-22A/22-32B, strong/C.
U. 0-3A/3-28B/28-41 C_{ca}/C.

STRATIGRAPHIC SECTIONS

Units, separated by slashes, are shown in descending order; numbers show thickness in feet. Letter symbols represent map units; where unit is not a map unit, lithology is described.

1. 2 soil/20 pkg/30 pt/R.
2. 3 soil/15 pkf/10 pkf, sandy.
3. 2 soil/38 pt, grayish/15 bt?, reddish.
4. 21 pt, tan/2 soil?/18 bt, brown and pink.
5. 16 fa, marly (with volcanic ash at 14.8 feet)/pkg?.
6. 1 silt, windblown/3 soil/>5 pbt.
7. 2 silt, windblown/4 soil/5 pbg, sandy/>3 pbt.
8. 5 pfg or bfg/2 oxidized gravel/5 sand, gray/15 pbt/R.



INDEX MAP OF YELLOWSTONE NATIONAL PARK SHOWING LOCATION OF MOUNT HOLMES, TEPEE CREEK, CROWN BUTTE, AND MINER QUADRANGLES AND PUBLISHED MISCELLANEOUS GEOLOGIC INVESTIGATIONS MAPS

SURFICIAL GEOLOGIC MAP OF THE MOUNT HOLMES QUADRANGLE AND PARTS OF THE TEPEE CREEK, CROWN BUTTE, AND MINER QUADRANGLES, YELLOWSTONE NATIONAL PARK, WYOMING AND MONTANA

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