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SURFICIAL GEOLOGY and WATER RESOURCES of the TOBACCO and UPPER STILLWATER RIVER VALLEYS, NORTHWESTERN MONTANA

by

D. L. Coffin, Alex Brietkrietz, and R. G. McMurtrey
U. S. Geological Survey

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ABSTRACT

The U. S. Army Corps of Engineers is building Libby Dam on the Kootenai River in northwestern Montana. The reservoir will be about 90 miles long; about 40 miles will be in Canada, and about 50 miles will be in the United States

The study area includes about 50 miles of the Rocky Mountain Trench south of the international boundary. The trench, part of which is included in the reservoir, can be attributed to downfaulting between major longitudinal faults. Gravity data indicate that the trench has been filled by as much as 3,000 feet of low-density material. Deposits related to the last advance and retreat of the Cordilleran ice sheet form the most important aquifers and aquicludes. Ground water is not used extensively in the area, but some deposits should yield large quantities of water to wells. In the 1968 water year, about 110,000 acre-feet of ground water was discharged directly into a 10-mile reach of the Kootenai River.

Permeable sand and gravel deposits adjacent to Libby Reservoir will become saturated and provide additional reservoir storage. The results of an electric analog study are too crude to permit final estimates of bank storage, but the results show that the distribution of active bank storage along the reservoir will be mainly a function of the reservoir stage and the slope of the floor of the reservoir. The magnitude of active bank storage is controlled by the transmissivity and the storage coefficient of deposits adjacent to the reservoir.

INTRODUCTION

PURPOSE AND SCOPE

Investigation of the water resources of the Tobacco and upper Stillwater River valleys was begun in September of 1966 by the U. S. Geological Survey in cooperation with the Montana Bureau of Mines and Geology. The purpose of the study was to determine the occurrence of ground water, the extent of ground-water development, the chemical quality of water as related to use, and the effects of the proposed Libby Reservoir on the ground-water system.

To accomplish these objectives, basic data were collected and analyzed and are compiled in the appendix of this report. The basic data consist of the record of selected wells and springs (Table 6), drillers' logs (Table 7), water-level measurements (Table 8), chemical analyses of water (Table 9), and discharge measurements (Table 10). These data were related to the geologic framework of the area to define the occurrence of groundwater. Analog models were constructed to help in understanding the ground-water system and in estimating the future effects of Libby Reservoir.

ACKNOWLEDGMENTS

This report was made possible only through the excellent cooperation of landowners throughout the area. Special thanks are due Dr. H. D. Smiley, who allowed the installation of staff gages, test holes, and water-level recorders on his land. Well drillers William Lake and O. T. Thatcher supplied logs and gave freely the benefit of their many years of experience. Personnel of the U. S. Corps of Engineers provided geologic counsel and data about the reservoir that will form behind Libby Dam, which is now (1970) being constructed by that agency.

The assistance of Dean Kleinkopf and Penelope Miller of the U. S. Geological Survey in the reduction of gravity data and the computation of gravity cross sections is gratefully acknowledged.

PREVIOUS INVESTIGATIONS

No detailed geohydrologic studies have been made in the area, but the area is included in a comprehensive regional study of the Columbia-North Pacific watershed. The entire results of that study are not yet (1970) published, but Appendix V (Water Resources), has been published by the Pacific Northwest River Basins Commission (1969). Hydrologic data pertaining to the Kootenai River are published in Appendix V and in a report by the U. S. Army Corps of Engineers (1948). Streamflow records have been collected in the area since 1930 and are published annually by the U. S. Geological Survey. These records are summarized in Water-Supply Papers 1316 and 1736 (U. S. Geological Survey, 1955, 1964).

The most recent geologic studies (Johns, 1961, 1963) emphasize the structure and lithology of the Precambrian rocks throughout most of the area covered by this report. Alden (1953) described many of the glacial features and glacial deposits in the Tobacco and Stillwater valleys and along the Kootenai River. Daly (1912) mapped a strip along the international boundary.

The principal studies of the adjacent area in Canada are those of Garland and others (1961), who made a gravity survey of the Rocky Mountain Trench in southern British Columbia. Leech (1958, 1959, 1960) and Rice (1937, 1941) described the geology of the trench and adjacent areas.

LOCATION AND EXTENT

The study area is in the northwestern part of Montana in the Northern Rocky Mountains physiographic province (Fenneman, 1931, Fig. 82). The area, which extends about 50 miles southeast from the international boundary (Fig. 1), ranges from 2 to 18 miles in width and contains about 590 square miles. The principal town

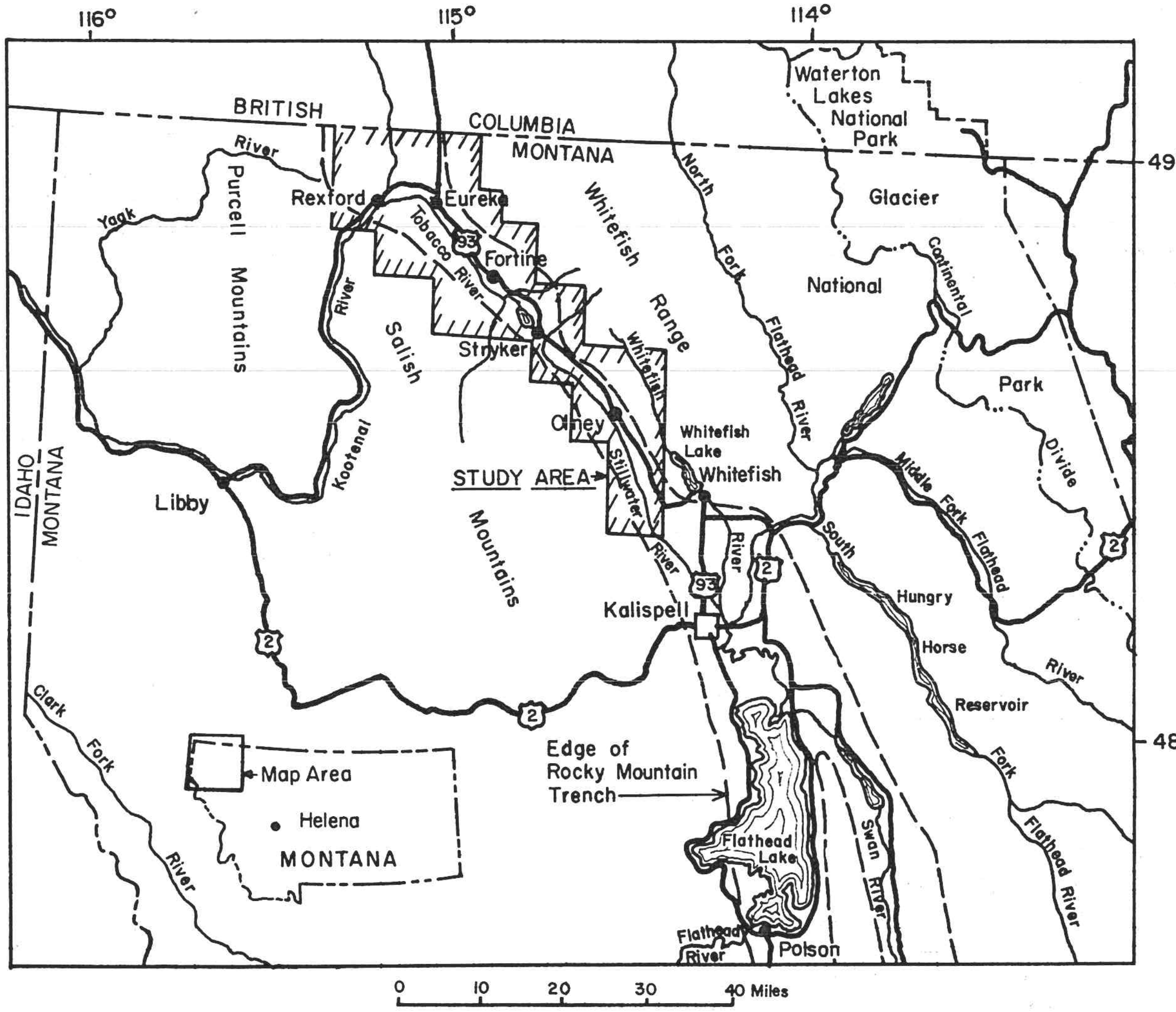

Figure 1.–Study area, principal towns, and drainage.

in the area is Eureka (population 1,229); nearby towns are Kalispell (population 10,151), Whitefish (population 2,965), and Libby (population 2,928). The area lies within Lincoln and Flathead Counties and includes parts of the Kootenai and Flathead National Forests and Stillwater State Forest.

WELL-NUMBERING SYSTEM

Wells and other locations are numbered in accordance with the U. S. Bureau of Land Management's system of land subdivision (Fig. 2). The first capital letter of the number indicates the quadrant of the principal meridian and base-line system in which the well is located; the letters begin with A in the northeast quadrant and proceed counterclockwise. The first numeral indicates the township, the second the range, and the third the section. Lower-case letters following the section number indicate, respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section. These subdivisions of the section are designated a, b, c, and d; the letters are assigned in counterclockwise direction, beginning in the northeast quarter. Where two or more locations are within the smallest subdivision, they are distinguished by consecutive numbers following the lower-case letters. For example, a well in the SW¼ SW¼ sec. 13, T. 31 N., R. 23 W., would be numbered B31-23-13cc.

TOPOGRAPHY

The Rocky Mountain Trench is the dominant topographic feature of the area. (See Fig. 1 and Pl. 1 for location of topographic and cultural features.) The trench is a narrow depression bordered by mountains on the east and west. It extends for more than 1,000 miles in a northwest direction from Montana to the Yukon Territory (Garland and others, 1961, p. 2495). The floor of the trench, 10 miles wide at the international boundary, narrows southward to about 2 miles at Stryker. The altitude of the floor is 2,700 feet at the international boundary, 3,200 feet at Stryker, and 2,900 feet at the south edge of the study area. The east wall of the trench is the steep west face of the Whitefish Range. On the west, the trench is bounded by the Salish Mountains south of the Kootenai River and by the Purcell Mountains north of the river. The adjacent mountains rise 4,000 feet above the floor of the trench on the east and 2,000 feet on the west.

The Tobacco Plains occupy the floor of the Rocky Mountain Trench between the international boundary and Eureka. The flat surface of the plains is interrupted by isolated drumlin-like hills and by kettle lakes 20 to 100 feet deep. The Kootenai River has cut a valley 1 mile wide and 200 to 300 feet deep on the west side of the plains. On the east, the plains end abruptly at the steep west face of the Whitefish Range. The Tobacco Plains contrast markedly to the irregular floor of the trench in other parts of the area. The land surface of the plains is more nearly level and timber is widely scattered. Except for the Tobacco Plains, the area is mountainous or hilly and is densely covered by pine, fir, spruce, and larch trees.

DRAINAGE

The project area is drained by the Kootenai River and tributaries of the Flathead River. The Kootenai River (spelled Kootenay in Canada) flows southward in the Rocky Mountain Trench from Canada to Rexford where it leaves the trench and flows southwestward to Libby. The river then turns northwestward and flows through Idaho and back into Canada, where it joins the Columbia. The Flathead River flows southward from Glacier National Park into Flathead Lake and joins the Clark Fork about 25 miles south of the lake.

The Tobacco River, tributary to the Kootenai River, drains the Rocky Mountain Trench between Stryker and Rexford. The Tobacco River is formed by the junction of Grave and Fortine Creeks. Grave Creek flows southwest from the Whitefish Range. Fortine Creek flows northeast from the Salish Mountains.

The Stillwater River drains the Rocky Mountain Trench south of Stryker. It rises in the Whitefish Range and flows southwest, entering the trench near Stryker, and then flows down the trench to the Flathead River near Kalispell.

The principal stream on the Tobacco Plains is Phillips Creek, which originates in Canada. Phillips Creek flows onto the Tobacco Plains near Roosville and empties into Sophie Lake. The creek is perennial almost to the international boundary, but south of the boundary it usually dries up in September or October and does not flow again until the snow begins to melt in the headwaters about the middle of May. Sophie Lake has no outlet, and local residents report that the lake has overflowed only twice in the last 30 years. Even then, the residents report, the water did not reach the Kootenai River but disappeared into a large "sinkhole" near the edge of the Kootenai River valley. Sophie Lake is the only stream-fed lake on the Tobacco Plains; the other lakes seemingly are sustained by ground water.

Indian Creek flows across the south end of the Tobacco Plains. Most of its water disappears by seepage before it reaches the Tobacco River. Runoff from the mountain front between Indian Creek and Phillips Creek disappears near the east edge of the Tobacco Plains.

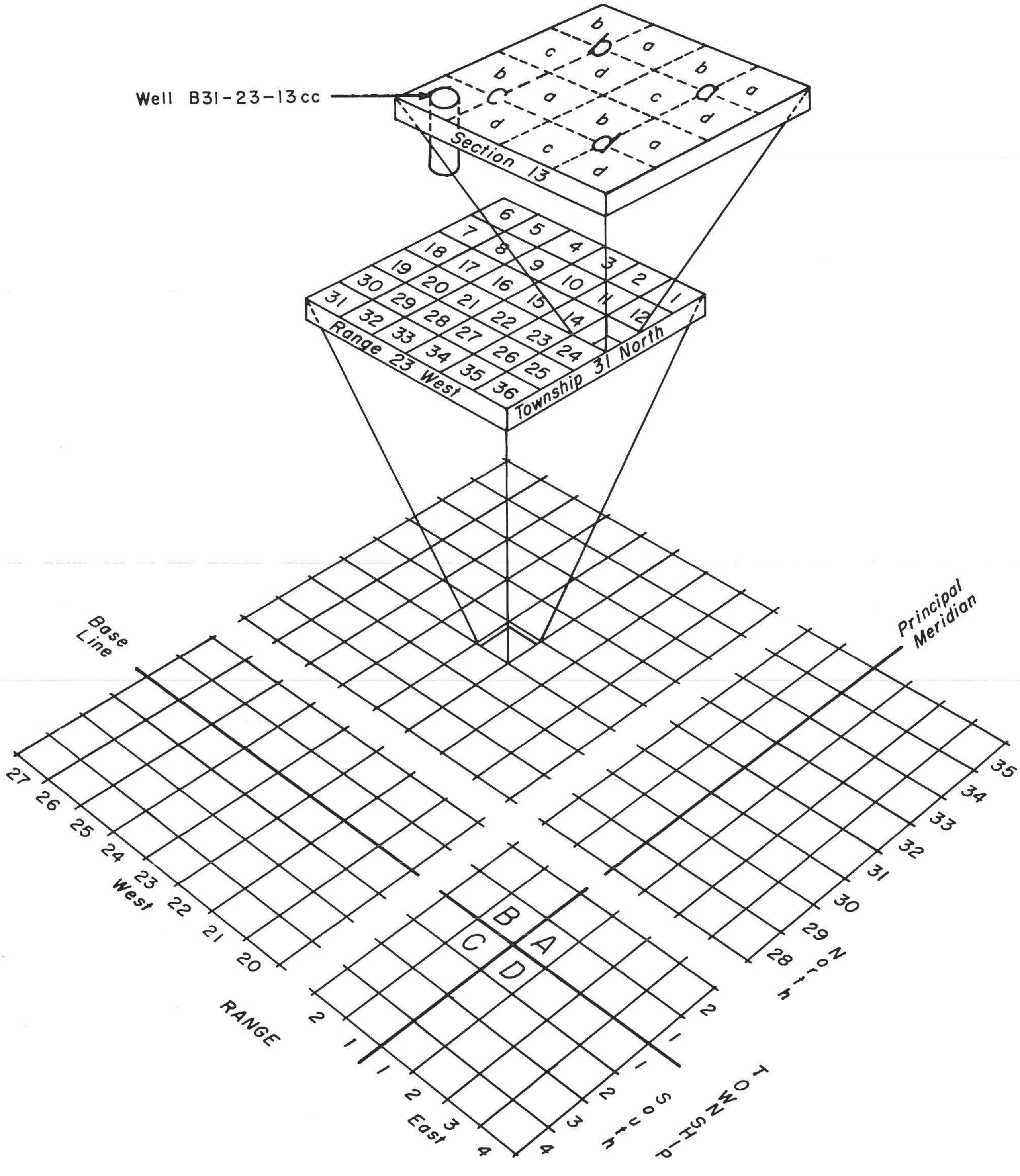

Figure 2.–Well-numbering system.

The Kootenai River is by far the largest in the project. Gaging-station records at Newgate, British Columbia, 0.9 mile north of the international boundary, show that from September 1930 to September 1968 the average discharge was 10,510 cfs (cubic feet per second), the maximum discharge was 98,200 cfs on May 28, 1948, and the minimum discharge was 994 cfs on February 7, 1936.

Records from the gaging station on the Tobacco River 6 miles above its mouth (B36-27-9cc) show that between September 1958 and September 1966, the average discharge was 277 cfs. For the same period, the maximum discharge was 2,320 cfs on June 9, 1964, and the minimum was 20 cfs on January 11, 1963.

A gaging station on the Stillwater River, 7 miles southwest of Whitefish (B30-22-34ca), was operated between September 1931 and September 1950. For this period the average discharge was 340 cfs, the maximum discharge was 4,330 cfs, May 26, 1948, and the minimum discharge was 40 cfs, December 24, 1944.

Grave and Fortine Creeks were gaged for a few years. The gage on Fortine Creek was about 5 miles southwest of Trego (B33-26-11aa). It was operated during water years 1947 through 1950, when average discharge was 93 cfs and the extremes were 1,810 cfs, May 16, 1950, and 5 cfs, September 7, 1949. The gage on Grave Creek was about 5 miles upstream from the confluence with Fortine Creek (B35-25-5cd) and was operated during water years 1923 and 1924. This record is not sufficient to determine the average discharge, but the recorded extremes were 690 cfs, June 11, 1923, and 18 cfs, April 1-5, 1924.

Crest-stage gages have been installed on five streams in the project area (Johnson and Omang, 1969). These gages are used to determine the yearly maximum stage and yearly maximum discharge from small drainage areas in Montana. The records from the crest-stage gages in the project area, summarized in Table 1, are an index to the maximum discharges that might be expected from the small drainage basins.

LAKES

About fifty lakes lie in the study area. The largest and deepest is Tally Lake, which covers 1,326 acres and is 450 feet deep, according to the U. S. Forest Service (written commun., 1968). The lakes are fed by small streams, but many of these streams flow only in response to snowmelt runoff. By late summer or fall, the lakes become warm and stagnant and contain a thick growth of aquatic plants. Some lakes have become completely filled by vegetation, and all that remains is a peat bog.

The lakes were formed as a result of glacial action. Most lakes fill depressions gouged out by glacial ice in till or Precambrian rocks, but in a few places natural drainages were dammed by till, and lakes formed behind these dams. Lakes on the Tobacco Plains fill depressions that may have resulted from the melting of large blocks of glacial ice. A man-made dam at Glen Lake has increased the size of the lake to provide storage for irrigation water.

Residents report that the average levels of most of the smaller lakes in the Tobacco and Stillwater drainages have risen a few feet in the last 50 years. This rise is confirmed by dead pine or fir trees that stand below the high-water mark of the lakes; the trees must have been drowned by the rising lake water. The rise in lake levels might indicate a climatic change but is more likely the result of changes in runoff characteristics caused by intensive logging during the last 50 years.

CLIMATE

Climatological data show that the climate of the Tobacco River drainage is markedly different from that of the Stillwater River drainage. At Eureka, on the south edge of the Tobacco Plains, the mean annual precipitation between 1961 and 1968 was 14.6 inches and the mean annual temperature was 45.2°F. At Olney, which is in the Stillwater River drainage, the mean annual precipitation between 1961 and 1968 was 22.5 inches and the mean annual temperature was 41.9°F. Climographs for

Table 1.–Summary of crest-stage gage records

Stream name	Location of gage	Drainage area (square miles)	Period of record (water years)	Greatest annual maximum		Least annual maximum	
				Date	Discharge (cfs)	Date	Discharge (cfs)
Fortine Creek	B33-26-11a	112	1947-68	5-16-50 5-20-54	1,810 1,810	5-23-68	377
Deep Creek	B35-25-30c	17.9	1959-68	6- 8-64	310	5-28-62	82
Unnamed tributary to Kootenai River	B35-29-11d	1.11	1959-68	5-22-67	12	May or June 1959 5-22-68	2 2
Rock Creek	B33-24-24b	6.18	1961-68	4-28-65	29	5-14-63	6
Spring Creek	B33-24-15b	3.86	1959-61	May or June 1959	12	6- 3-60	8

the two stations are compared in Figure 3, which is a plot of mean monthly temperature versus mean monthly precipitation. Each point represents the average conditions for the month, and lines connecting the points form a pattern whose location on the chart provides a summation of climate at the station. For example, the climate at Eureka would be generally classified as cool to warm and dry from March to November, but from November through February it is cold and humid.

The climatic differences between the Tobacco and Stillwater drainages are probably the result of orographic control. The Tobacco drainage lies in the rain shadow of the Purcell Mountains and the highest peaks of the Salish Mountains (Fig. 1). The Stillwater drainage also lies in the rain shadow of the Salish Mountains, but the mountain range is lower west of this drainage than west of the Tobacco drainage. Thus, the Tobacco drainage is more effectively shielded from eastward-moving storms. Many of the storms moving northward up the Rocky Mountain Trench do not cross the divide between the Tobacco and Stillwater drainages, and precipitation is restricted to the Stillwater side.

GEOLOGY

This section of the report discusses the geology of the study area as it relates to the occurrence and distribution of the most important water-bearing rocks. The first part describes the geologic setting, emphasizing the Rocky Mountain Trench. The second part describes the geologic history, emphasizing glacial and glacial-related events that have resulted in the formation of the most important water-bearing rocks. The third part discusses the geologic and hydrologic characteristics of the various water-bearing rocks.

A clear interpretation of geology is necessary to an understanding of a hydrologic system. Subsurface geologic or hydrologic data are scarce in the project area; therefore, this report is based on a study of surficial geology. Until more subsurface data are available, conclusions concerning the hydrologic system must be regarded as tentative, to be modified as more data accumulate.

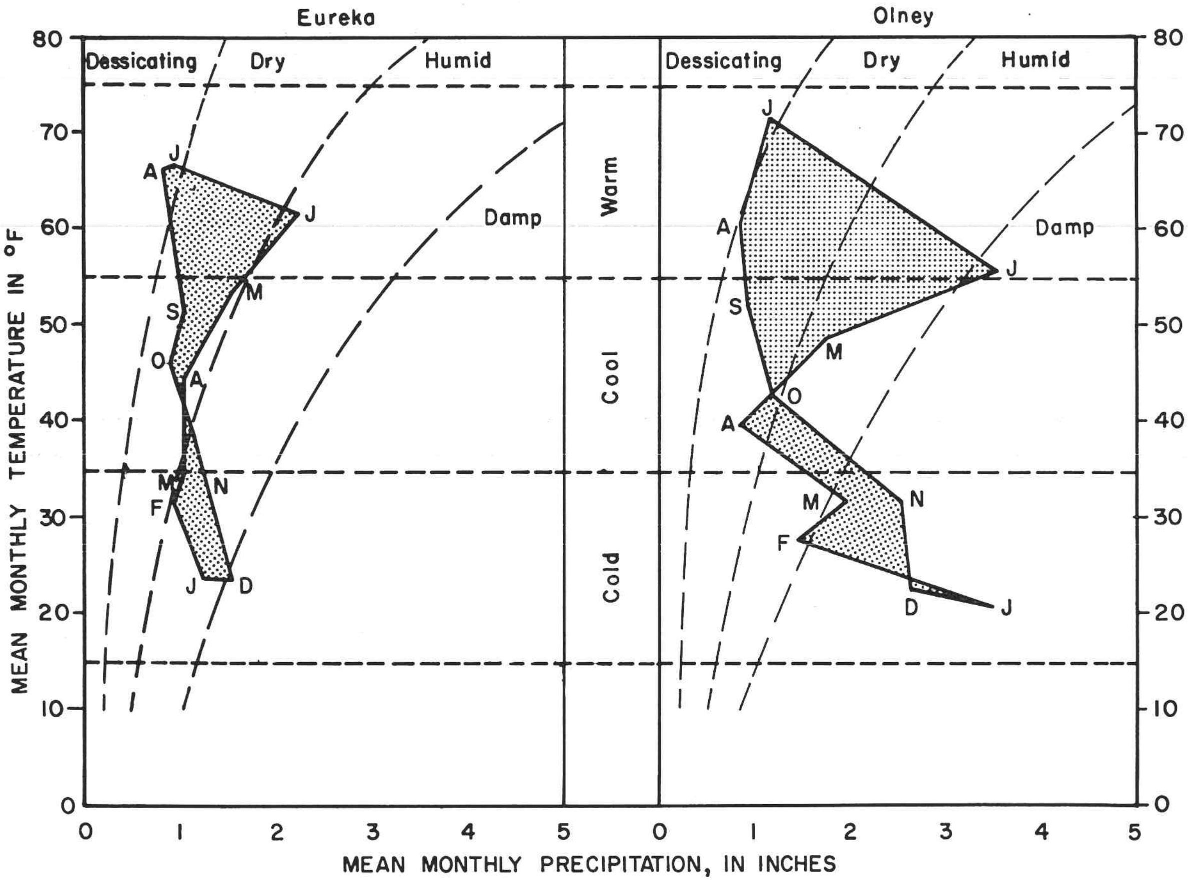

Figure 3.—Climographs for Eureka and Olney.

GEOLOGIC SETTING

In the study area, the Rocky Mountain Trench (Fig. 1) is bordered on the east and west by major longitudinal gravity faults. Leech (1959, p. 14) observed that south of lat 49°30′ N. the trench seems to be due to downfaulting between the longitudinal faults and that the faults lack significant strike-slip displacement. The gravity measurements made by Garland and others (1961) as well as gravity measurements made during this study indicate that the trench contains a series of basins, which are thought to be filled with low-density material. These basins, which are 2 to 7 miles long, may represent downfaulted blocks between faults transverse to the major longitudinal faults (Garland and others, 1961, p. 2504). Gravity measurements indicate that the low-density material in the basins may be as much as 3,000 feet thick in the study area. Garland and others (1961, p. 2501) estimated slightly less than 4,000 feet of fill in the trench near lat 49°15′ N. Konizeski and others (1968, p. 15) estimated, from a gravity study, about 4,800 feet of fill in the trench near the mouth of the Swan River valley, about 90 miles southeast of Eureka. Between the basins, the fill in the trench thins significantly. Precambrian rocks are exposed almost clear across the trench near Stryker.

Precambrian rocks of the Belt Supergroup form the walls of the trench in the study area except for a small area near Roosville, where rocks of Paleozoic age are exposed. Johns (1961, Pl. 1, 4; 1963, Pl. 1) showed that the Precambrian rocks dip to the east on each side of the trench. Displacement along the longitudinal faults forming the trench is unknown in most places in the project, but Johns (1963, p. 42) reported vertical displacement of about 4,000 feet on a fault forming the east side of the trench near Stryker. Daly (1912, p. 601) suggested that Paleozoic limestone exposed on the trench floor east of Roosville would require a net relative vertical displacement of 10,000 feet. The average net displacement may exceed the 4,000 feet reported near Stryker; it is probably thousands of feet.

GEOLOGIC HISTORY

The trench began to form during the Laramide revolution, as did many of the other structural features in northwestern Montana. Ross (1959b, p. 102) and Johns (1963, p. 48) postulated that major faulting took place in the latter part of the Paleocene or in the Eocene Epoch, and that minor movements have continued through the Tertiary Period. During and after the formation of the trench, debris from the adjacent mountains began to fill the depression. The type of rocks deposited in the study area during the Tertiary Period is unknown, as the rocks are not exposed and no deep-test-hole logs are available. Gravity measurements, however, indicate as much as 3,000 feet of fill. Most of this fill probably was deposited during Tertiary time.

Tertiary rocks exposed in the Canadian part of the trench are the Miocene lake deposits reported by Rice (1937, p. 25) slightly north of lat 49°30′ N. Older Tertiary rocks either are covered or have not been recognized. Exposures of rocks older than Wisconsin age in the study area are few because glacial deposits mantle the floor of the trench.

Glaciers occupied the Rocky Mountain Trench repeatedly during the Pleistocene Epoch. Richmond (1965, p. 217, 222) recognized five major periods of Pleistocene glaciation in the Rocky Mountains of the United States. Richmond and others (1965, p. 234) recognized three glaciations of the Rocky Mountain Trench from study of glacial deposits near Kalispell and Polson. The Flathead lobe of the Cordilleran ice sheet moved southward from Canada in the trench, and it was joined by valley glaciers. Because the project area was glaciated at least three times, glacial deposits are extensive, but the erosional and depositional effects of the last glacial advance and retreat have obscured or eradicated earlier deposits.

Deposits related to the last, or Pinedale, glacial advance and retreat form the major aquifers and aquicludes in the study area. The interrelation of deposits can best be understood by considering the sequence of events that caused their deposition.

As the ice last moved southward down the trench (Fig. 4), it ground and polished the hard Precambrian rocks. Unconsolidated rocks in the trench were partly removed and ground up to form a mixture of sandy clay and cobbles (till). Beneath the ice, the till was mounded into streamlined drumlin-shaped hills on the floor of the trench and plastered against the lower walls (Fig. 4). The maximum advance of the ice sheet during the early stage of Pinedale time was about 60 miles south of Eureka (Richmond and others, 1965, Fig. 1), but middle and late Pinedale advances extended to Polson and Big Draw.

After reaching its southern limit, the ice front began to recede northward. The rate of recession was not uniform, and as the recession slowed or stopped, recessional moraines formed. The principal recessional moraine in the area is near Stryker, on the divide between the Stillwater and Tobacco Rivers (Alden, 1953, p. 127). Water from the melting ice carried some of the till southward, sorting and depositing it as outwash in the Stillwater valley and as deltaic deposits in the waters of

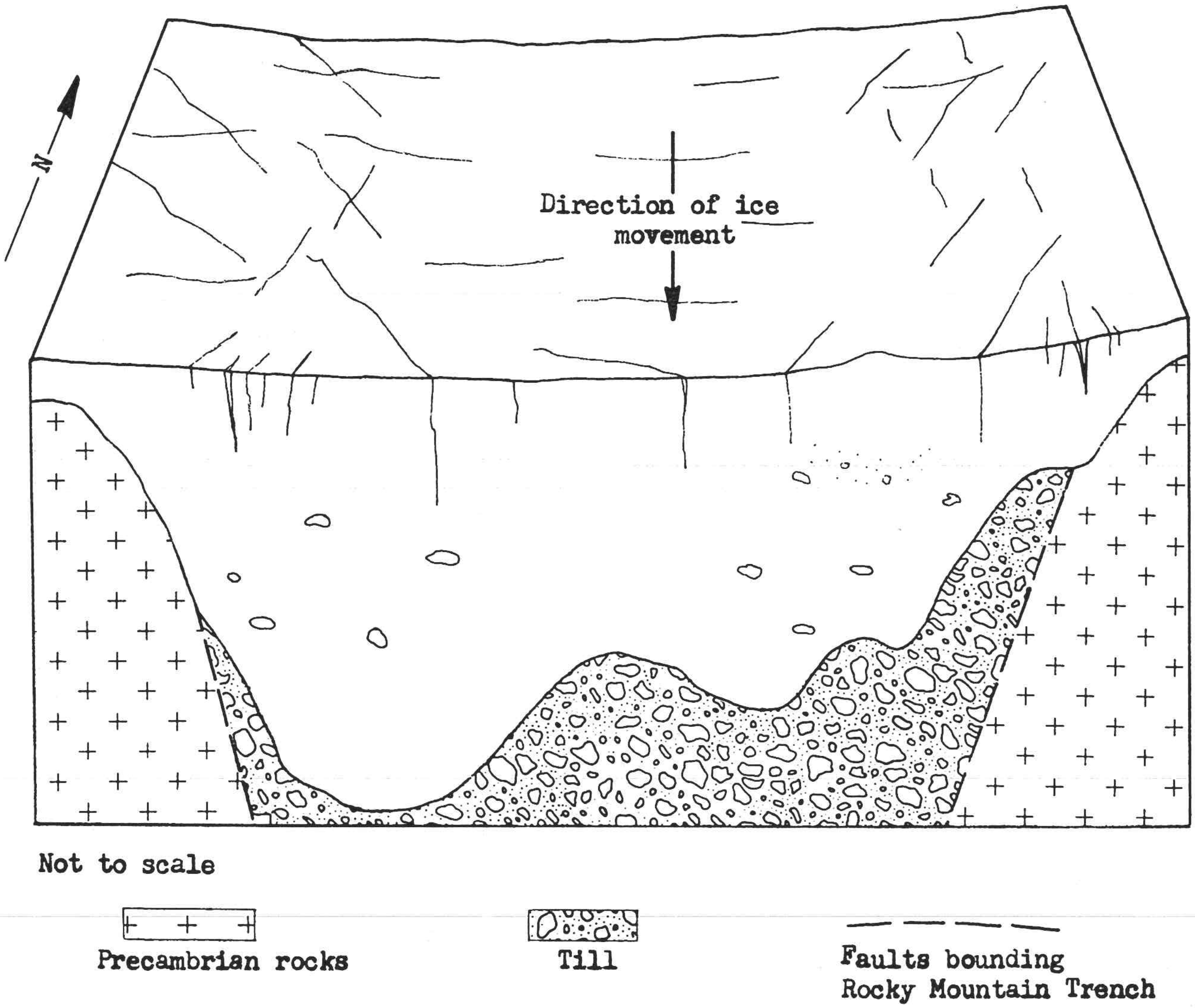

Figure 4.–The last ice sheet to fill the Rocky Mountain Trench in the study area.

glacial Lake Missoula.* This lake, which was formed by an ice dam in the Clark Fork valley east of the Montana-Idaho boundary, backed water over as much as 2,900 square miles (Pardee, 1910). Near the close of Pleistocene time, the lake level was at an altitude of 3,200 feet (Richmond and others, 1965, p. 234). Deltaic deposits laid down by the Stillwater River during the last ice retreat interfinger with fine-grained lake-bottom deposits at an altitude of about 3,000 feet. Water from melting ice formed smaller lakes in Good and Logan Creek valleys (north of Tally Lake) and deposited outwash west of Lower Stillwater Lake (Pl. 1).

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*Glacial Lake Missoula filled and drained several times, and one or more of these lakes may have extended up the Flathead Valley into the areas described in this report and in the earlier report on the Kalispell Valley (Konizeski and others, 1968). During the last glacial advance (late Pinedale), however, the ice of the Flathead lobe still filled the valley when glacial Lake Missoula drained (Alden, 1953, p. 165). The highest lake-bed silt deposits near Kalispell were formed in an ancestral Flathead Lake rather than in an arm of glacial Lake Missoula (Richmond and others, 1965, p. 236). As the Polson moraine is compound, representing two stages of Pinedale advance (Richmond and others, 1965), any other lake-bed silt of Pinedale age that may underlie the highest beds presumably was likewise deposited in ancestral Flathead Lake. During two Bull Lake stages of glaciation, the Flathead lobe extended even farther south (Richmond and others, 1965) and must have blocked glacial Lake Missoula from entering the Kalispell area, even though the lake levels then were higher than during the last Pinedale advance. Therefore, the Montana Bureau of Mines and Geology prefers to interpret the lake-bed silt deposits in the Kalispell-Eureka areas as deposits of ancestral Flathead Lake (and glacial Lake Kootenai) rather than of glacial Lake Missoula. So little is known about pre-Wisconsin glaciation, however, that the possibility of silt deposition in pre-Wisconsin stages of glacial Lake Missoula in this area cannot be excluded.

Continued recession of the ice front left deposits of poorly sorted outwash and kame deposits near Dickey Lake. Water must have been ponded between the ice front and the Tobacco-Stillwater divide after the ice front had receded northwestward to some point between Grave Creek and Eureka. The lake thus formed extended to the Tobacco-Stillwater divide and far up the Fortine Creek drainage, as shown by lacustrine deposits on the floor of Fortine Creek valley. Outwash was deposited higher on the valley sides.

When the main ice front receded northward into Canada, water from the lake between the ice front and the Tobacco-Stillwater divide merged with glacial Lake Kootenai, which was formed by an ice dam in the lower Kootenai valley (Alden, 1953, p. 151). The length of the lake is unknown, but if the glacial ice had retreated as far north as Canal Flats, 80 miles into British Columbia, before the ice dam was destroyed, the lake would have been about 350 miles long. Water may have been impounded in the lake during earlier glaciations, but the last glacial advance obscured any evidence of earlier lakes.

Glacial Lake Kootenai existed long enough that at least 400 feet of sediment accumulated in the Tobacco Plains area. Lake sediment in this area rests on till. Not completely covered by lake deposits are the low drumlins that projected above the floor of the ancient lake. Depressions in the surface result from the melting of ice blocks that were surrounded by lake deposits. The lake surface rose to an altitude of about 2,700 feet, the altitude of the highest deltaic deposits.

Streams drained into the lake from the adjacent mountains and from valley glaciers that remained after the main body of ice in the trench had receded northward. These streams eroded some of the till and some of the deposits left by the melting ice. The detrital loads of the streams were probably first deposited as outwash at the foot of the walls of the trench. This outwash was poorly sorted, but continued reworking by the streams resorted the material and carried much of it into the lake (Fig. 5). When the material reached the lake, it was again sorted—the silt and clay remained in suspension in the turbulent water near the mouths of tributaries, but settled out in the quieter water. Gravel was deposited near the mouths of the streams, sand and gravel a little farther out, and sand carried to the edge of the quiet water intermixed and interfingered with the silt and clay settling from the turbid lake water. The sand and gravel formed deltas radiating from the mouths of the major tributaries. In the Tobacco Plains area, the major tributaries were from the east, as no deltaic deposits are found on the west side of the trench. Thus, a typical east-west geologic section across the trench (Pl. 1) shows silt and clay of the lake-bottom deposits interfingering and grading eastward into sand and gravel of the deltaic deposits, which in turn interfinger and grade eastward into gravel and cobbles of the outwash deposits. The top of the lake-bottom deposits is at an altitude of 2,600 to 2,650 feet, and the highest deltaic deposits are at an altitude of about 2,700 feet.

Alden (1953, p. 152) reported several lowerings of glacial Lake Kootenai due to melting of ice dams in the lower Kootenai Valley. In the study area, however, evidence remains only of the final lowering of the lake outlet to an altitude below 2,000 feet. When the ice dam was destroyed, the waters of glacial Lake Kootenai drained into the Columbia River. The Kootenai River occupied the lowest part of the lake floor, which was the area of the lake-bottom deposits, and has since cut down through these deposits 200 to 300 feet. This entrenchment formed an inner valley, as much as 2 miles wide, below the general level of the Tobacco Plains (Fig. 6, Pl. 1). Within the inner valley, the Kootenai River has formed several gravel terraces and deposited as much as 50 feet of gravel beneath the flood plain.

GEOLOGIC AND HYDROLOGIC CHARACTERISTICS

Metasedimentary Rocks

All the metasedimentary rocks exposed in the study area belong to the Belt Supergroup of Precambrian age. The rocks were assigned by Johns (1961, 1963) to four groups designated, from oldest to youngest, pre-Ravalli, Ravalli, Piegan, and Missoula. These major groups were suggested by C. P. Ross (1959a). Johns (1961, p. 11) reported the aggregate thickness of the Belt Supergroup as almost 30,000 feet. Most of the rocks are fine grained, being principally argillite, impure limestone, and quartzite. Near the base of the Missoula Group is a lava flow, the Purcell Basalt, which is 700 feet thick in the Purcell Mountains and consists of a lower basic flow and an upper acidic flow separated by about 75 feet of thin-bedded greenish-gray argillite and quartzite (Johns, 1961, p. 23). The lithology, stratigraphy, and structure of the Precambrian rocks were described in detail by Ross (1959b) and Johns (1961, 1963).

The metasedimentary rocks yield water to wells and springs only from fractures. The yield to wells is generally less than 10 gpm (gallons per minute), but the aggregate discharge from areas underlain by these rocks is sufficient to sustain the base flow of many streams.

Sedimentary Rocks

Sedimentary rocks crop out only in a small area along the international boundary ¼ mile east of Roosville.

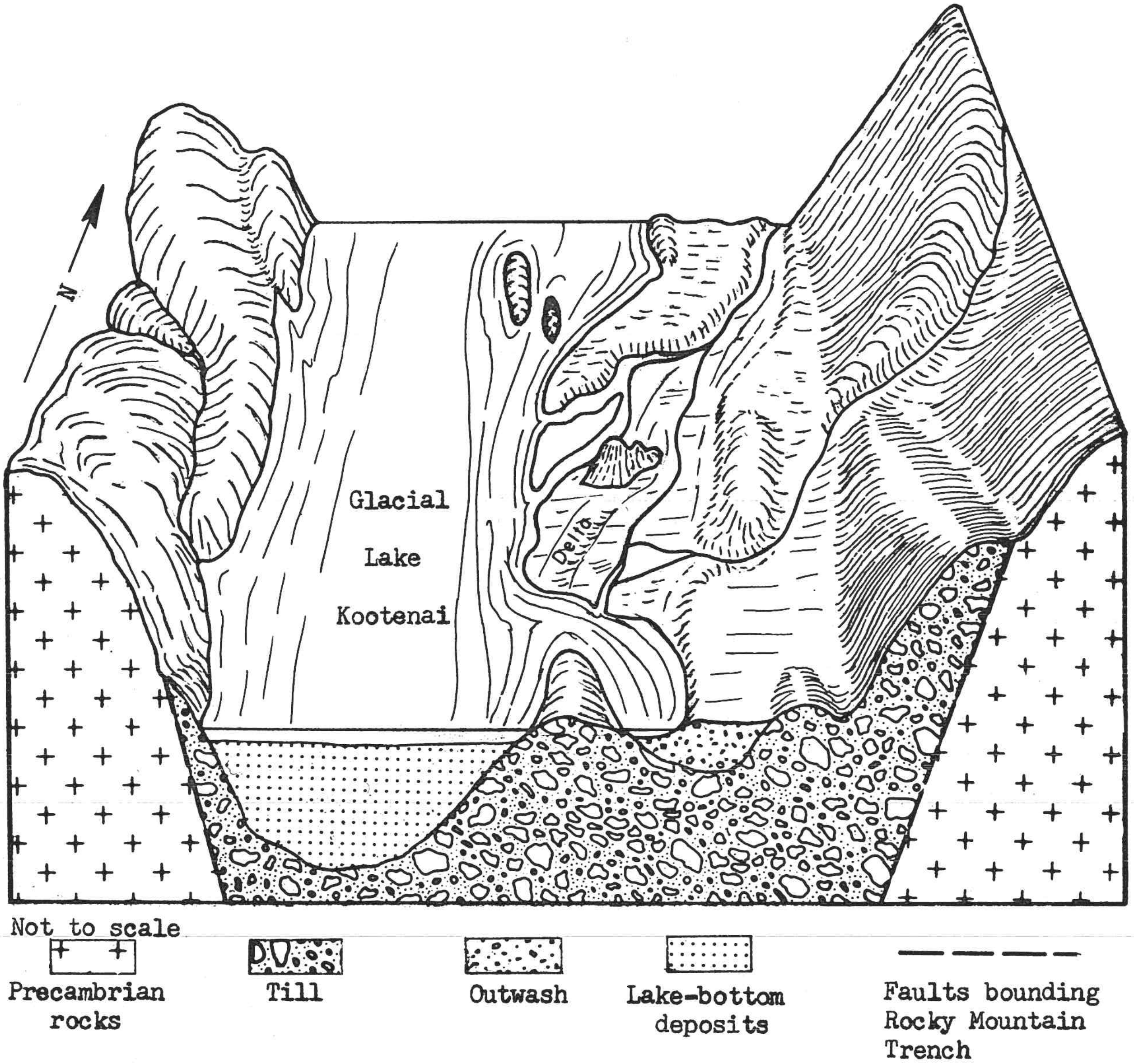


Figure 5.–Glacial Lake Kootenai in the study area.

Leech (1960) identified these rocks as Upper Devonian and Mississippian. Johns (1961, p. 19) described the exposure as 300 feet of tan to light-red calcareous quartzite overlain by a dark-gray fossiliferous limestone, the total thickness of the section being about 1,850 feet. Because of poor exposures, structural and stratigraphic relations in the sequence and its relation to older rocks are not clear. These Paleozoic rocks are included with the Precambrian rocks on Plate 1.

Semiconsolidated Rocks

Alden (1953) examined several exposures near Olney that he thought may be of Tertiary or early Pleistocene age. These exposures are in cuts along the Great Northern Railway south of Olney (B32-23-17). A 10- to 15-foot bed of yellowish-gray crossbedded medium to coarse sand is overlain by 10 to 15 feet of thinly laminated yellowish-gray silty clay, which contains black carbonaceous material and the impressions of plant stems and of coniferous needles. Specks of micalike minerals in the clay and its light specific gravity suggest that a part is volcanic ash. The clay is overlain by gray till, which has been forced into vertical crevices in the clay, probably during the last advance of the Cordilleran ice sheet. The crevices decrease in width from 2 or 3 feet at the top to 3 or 4 inches at a depth of 6 feet. Although the clay must predate the last advance of the ice, how much older it is remains unknown, because no diagnostic fossils have been found and exposures are very few and small. The clay could have been deposited in a

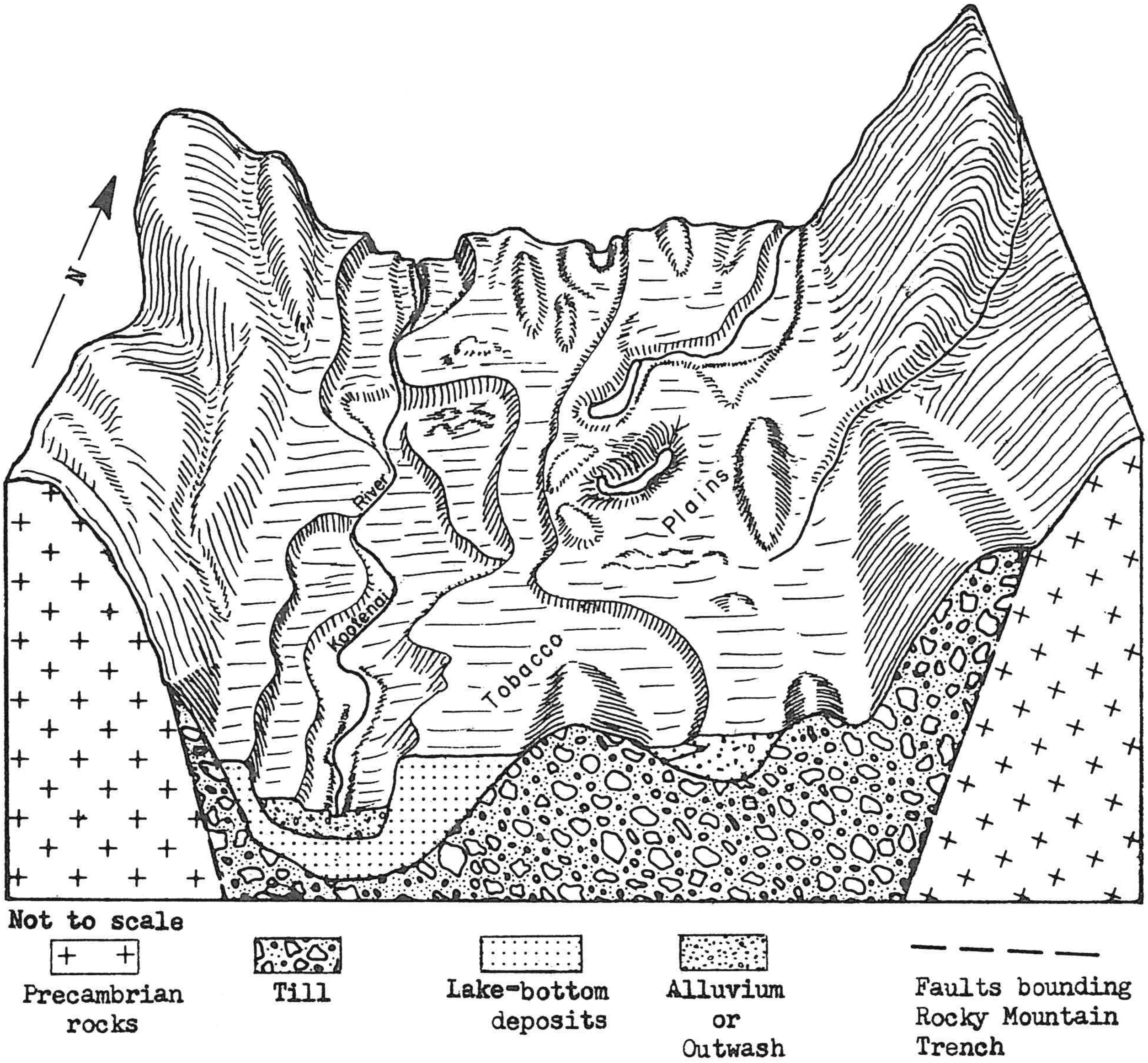


Figure 6.—The Tobacco Plains and Kootenai River valley.

glacial lake during Bull Lake or early to middle Pinedale time, but the deposits are lightly cemented and seem older than deposits that have been definitely related to the Wisconsin glacial lakes. Rocks similar to those south of Olney crop out northeast of Eureka (B37-26-32), and along the north side of the Elk River 14 miles north of the international boundary. The occurrence of these similar deposits at widely separated places in the Rocky Mountain Trench suggests that they may be related to filling of the trench during the Tertiary Period rather than to filling of a glacial lake in Pleistocene time.

An exposure along the Great Northern Railway tracks (B32-23-34) about 5 miles southeast of Olney reveals about 15 feet of sand and gravel unconformably overlain by 15 feet of till. A rusty stain coats the sand and gravel, giving the exposure a decidedly yellow tinge, even when seen from a distance. The lower 15 feet is well-sorted fine to medium gravel, which contains beds of fine to very coarse sand. The beds of sand and gravel are massively crossbedded and firmly cemented; the unit has weathered to a steep slope covered by a few inches of gravel. A continuous bed of "bentonite" extends along the base of the exposure. The lithology and color of material at this exposure differ greatly from the silty clay exposed south of Olney, but the outcrops are too far apart to permit determination of structural or stratigraphic relations.

Sand and gravel like that in the exposure southeast of Olney should yield water freely to wells. A well (B31-23-3db1) about a mile south of the exposure is reported to have penetrated rocks that were stained about the same color as the exposure. In that well, clay and gravel penetrated at a depth of 262 to 348 feet was reported to be dark yellowish orange. The well is reported to yield 3 gpm with 262 feet of drawdown and is completed with an open-end casing at 348 feet. If the sand and gravel penetrated by the well correlates with that exposed, it should yield more water to a properly constructed well. Perhaps the beds of clay alternate with beds of gravel, thus restricting movement of water to the open end of the casing. Much more hydrologic testing would be necessary to evaluate the water-bearing potential of the semiconsolidated deposits. If well-sorted deposits of sand and gravel are extensive beneath the till, however, they should yield significant amounts of water to wells. Because the outcrops are too small, semiconsolidated rocks are not shown on Plate 1.

Unconsolidated Deposits

Till.—Till is widely exposed in the project area. Most of it was deposited beneath the last ice sheet to advance across the area. Almost everywhere the till forms smooth elongated hills trending southeast. The thickness of the till varies greatly in short distances because of an uneven distribution of the glacial debris beneath the ice; where till is shown on Plate 1, it is believed to be at least 10 feet thick. Drumlins of till rise 200 feet above the surface of the Tobacco Plains. In general, the till is an unsorted mixture of detrital material ranging in size from clay to boulders. Clay- and silt-size materials predominate, but the percentage composition of the till varies widely. Near outcrops of Precambrian rocks, the till includes a large percentage of boulders and cobbles derived from the outcrops. Farther from the outcrops the clay content increases and the size of pebbles and cobbles decreases. East of Eureka and also near Dickey Lake, the till is almost entirely clay and sand containing only a few pebbles. Many of the rounded cobbles and boulders have shallow grooves and scratches, which would easily wear off if the rocks were transported far by streams. These markings help to distinguish till from deposits of poorly sorted outwash.

In road or stream cuts, till forms steep slopes, but if saturated by water the till may slide. Along the Tobacco River the till seems more compact than in other places and weathers to buttress-like spires and pinnacles. Slopes of most outcrops are covered by weathered-out gravel, giving the impression that the till contains more large rocks than is actually the case. Till is light gray and weathers to white.

In most places till is nearly impermeable, but where the clay and silt content decreases, the till can yield as much as 2 gpm to large-diameter wells. A few springs issue from the till, but the flows are less than 5 gpm and the springs go dry during most summers. Few drilled wells obtain water from till, and drillers usually log till as clay or as clay and boulders. The principal hydrologic effect of till is to impede the downward movement of water, thus increasing runoff or allowing water to accumulate in overlying more permeable deposits.

Outwash.—Outwash is derived from the erosion of till by melt water. Streams that carried sediment loads from till deposits separated the clay and silt-size particles from the larger size fraction. The fine-grained detritus was carried into lakes. Sand, gravel, and cobbles were deposited along streams and near lake shores. These coarse-grained deposits form terraces along the Tobacco and Stillwater Rivers and other streams.

The composition and average grain size of outwash depends on how far it was carried by streams. When carried only a short distance the outwash retains considerable clay and has a wide range in grain size. When carried farther, it loses most of its clay and is relatively uniform in grain size. Outwash is normally poorly sorted in the higher parts of a drainage basin, but is better sorted at the lower altitudes. Typical poorly sorted outwash is exposed in a gravel pit ½ mile northwest of Dickey Lake (B34-25-9). About 20 feet of sand and gravel containing as much as 30 percent clay is exposed in the wall of the pit. Sorting is generally poor, although lenses of sand or of gravel are scattered throughout the exposure. Most sand and gravel is coated with clay, as much as one-fourth inch thick on the underside of some pebbles. In places, the clay, sand, and gravel are so thoroughly intermixed as to leave only tiny voids, but in other places the clay does not completely fill the spaces between pebbles, and voids are as large as a quarter of an inch. Pebbles and cobbles are subrounded to well rounded and have no scratches or grooves.

A deposit of well-sorted outwash crops out on the Tobacco Plains (B37-27-10). Material in this deposit ranges from pebbles to 10-inch cobbles. The median grain size is about 3 inches. Medium to very coarse sand is interspersed between larger grains. Bedding is not well developed but is graded. All the gravel is well rounded and spherical; the sand is subrounded to rounded. The principal difference between the two deposits of outwash is the nearly complete absence of clay in the Tobacco Plains deposit (B37-27-10). Outwash exposed in B37-27-35 is even better sorted. Deposits near the ancient shoreline of glacial Lake Kootenai are about 50 percent fine to very fine gravel and 50 percent medium to very coarse sand.

The lithology of the outwash indicates that it should be capable of storing and transmitting relatively large volumes of water. Where the outwash contains clay, its transmitting and storing capacities would be considerably reduced, but sandy or gravelly outwash should yield large quantities of water to wells properly constructed and developed.

Drillers report 10 to 100 feet of outwash beneath the Tobacco Plains. As much as 100 feet is exposed along some terraces, and places probably will be found where outwash is more than 100 feet thick.

Much of the outwash along the Tobacco River and beneath the Tobacco Plains is probably drained. Outwash along the Stillwater River and southwest of Lower Stillwater Lake is not topographically much above the streams and should supply water for many uses. A few domestic and stock wells obtain water from the outwash, but these wells extend only 1 to 5 feet into the outwash and are open-end construction; therefore neither maximum yield to wells nor the hydrologic properties could be accurately determined. Hydrologic properties assumed for the outwash and other deposits are shown in Table 5.

Deltaic deposits.—Streams that drained into glacial lakes deposited part of their loads as deltas. The deltaic deposits grade into and interfinger with the outwash deposits on their shoreward side; lakeward they grade into and interfinger with lake-bottom deposits. Deltaic deposits of glacial Lake Kootenai are clearly defined on the Tobacco Plains (Pl. 1), but deltaic deposits of glacial Lake Missoula in the Stillwater valley are not well defined and on Plate 1 were not differentiated from the outwash deposits.

The mapped deltaic deposits weather to smooth rounded slopes. Outcrops have beds of both sand and gravel, but in general grain size is related to the distance from the shore line of glacial Lake Kootenai. Deltaic deposits north of Tetrault Lake (B37-27-28ab) are well rounded, crossbedded, very permeable pebble gravel. Deltaic deposits near the west end of Tetrault Lake (B37-27-28bc) were transported farther and are medium to very coarse sand and a small amount of very fine gravel (Fig. 7). The log of test hole B37-27-28cb shows the interfingering of the deltaic deposits and lake-bottom deposits and describes both types of deposits. Both of these deposits are probably more thinly bedded and better sorted than the log indicates, because individual thin beds could not be detected during the drilling.

Test hold B37-27-28cb

Land-surface altitude: 2,600 feet.

Depth to water below land surface: 111.06 feet, July 12, 1967.

Bailed for 2 hours at 9 gpm. At the end of bailing the water level had been drawn down 1.0 foot. Casing is slot perforated between 174 and 178 feet and between 184 and 190 feet.

Log

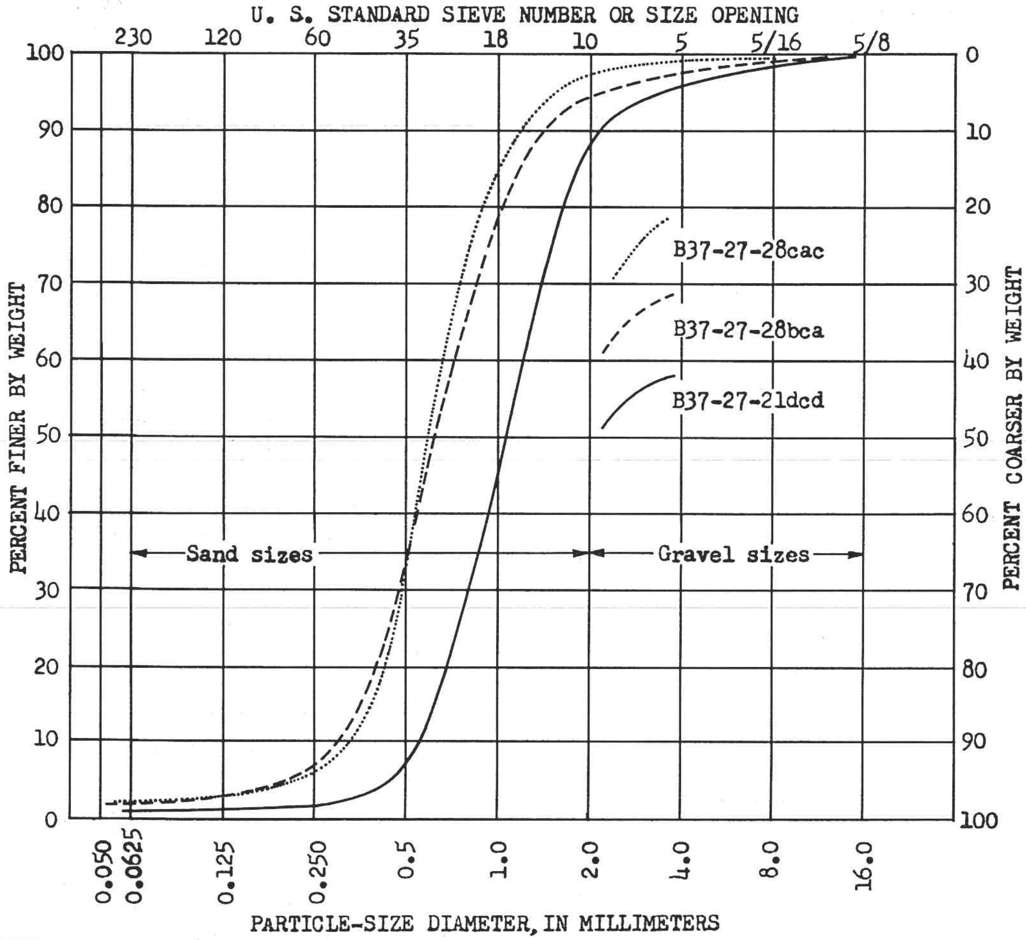
	Thickness (feet)	Depth (feet)
Lake-bottom deposits:		
Sand, very fine to very coarse, mostly fine to medium, angular to subrounded; contains clay and a few pebbles	38	28
Sand, very fine to very coarse, mostly medium to very coarse, angular to rounded; contains very fine to medium well-rounded gravel	12	40
Deltaic deposits:		
Gravel, very fine to very coarse, mostly very fine to fine, rounded to well rounded, and medium to very coarse sand. Steady loss of drilling fluid below 40 feet and complete loss below 50 feet	19	59
Lake-bottom deposits:		
Sand, very fine to very coarse, mostly fine to medium, angular to rounded; contains clay and very fine to medium gravel	16	75
Deltaic deposits:		
Gravel, very fine to medium, mostly medium, well rounded, and medium to very coarse sand. Steady loss of drilling fluid	22	97
Sand, medium to very coarse, subrounded to well rounded; contains clay to fine sand, and very fine to fine gravel	20	117
Sand, very fine to very coarse, angular to rounded, poorly sorted; contains silt, clay, and some very fine gravel	14	131
Sand, medium to very coarse, subrounded to rounded, and very fine to fine well-rounded gravel; contains silt to fine sand	4	135
Lake-bottom deposits:		
Sand, medium to very coarse, angular to well rounded, well sorted	10	145
Till:		
Silt, clayey; contains sand and gravel	13	158
Clay, silty, gray; contains sand, pebbles, and cobbles; poorly sorted	15	173
Cobbles and boulders, matrix is clay and sand	3	176
Outwash (?):		
Gravel, very fine to very coarse, rounded to well rounded, and very fine to very coarse sand; contains cobbles. Water level rose to 106 feet below land surface	3	179
Till (?):		
Clay, silty, gray; and sand, gravel, and cobbles. Drills very hard	4	183
Outwash (?):		
Gravel, very fine to very coarse, rounded to well rounded, and sand; contains cobbles and clay. Hole is making water between 183 and 188 feet	21	204
Till (?):		
Clay, silty, gray; contains sand, gravel, and cobbles	11	215

Outwash (?):		
Sand, very fine to fine, angular, well sorted	9	224
Sand, very fine to very coarse, angular to rounded, and brownish-yellow clay; contains very fine to medium gravel	26	250
Till (?):		
Clay, silty, light yellowish brown; contains sand to medium gravel	28	278
Clay, silty, light yellowish brown, and very fine to very coarse sand; contains fine gravel	17	295
Clay, sandy, light yellowish gray, and very fine to very coarse sand; contains very fine to very coarse gravel and cobbles. Well is making some water between 310 and 315 feet	45	340

Deltaic deposits of glacial Lake Missoula are poorly exposed. One highway cut (B31-23-3), exposes well-sorted deltaic sand and gravel interfingering with well-sorted lake-bottom sand and silt.

Deltaic deposits are capable of storing and transmitting large volumes of water. At most places on the Tobacco Plains the deposits are above the water table. No wells are known to tap the deposits in the Stillwater drainage. The hydrologic characteristics, therefore, remain unknown.

Lake-bottom deposits.–Lake-bottom deposits accumulated in the relatively quiet water of glacial Lakes



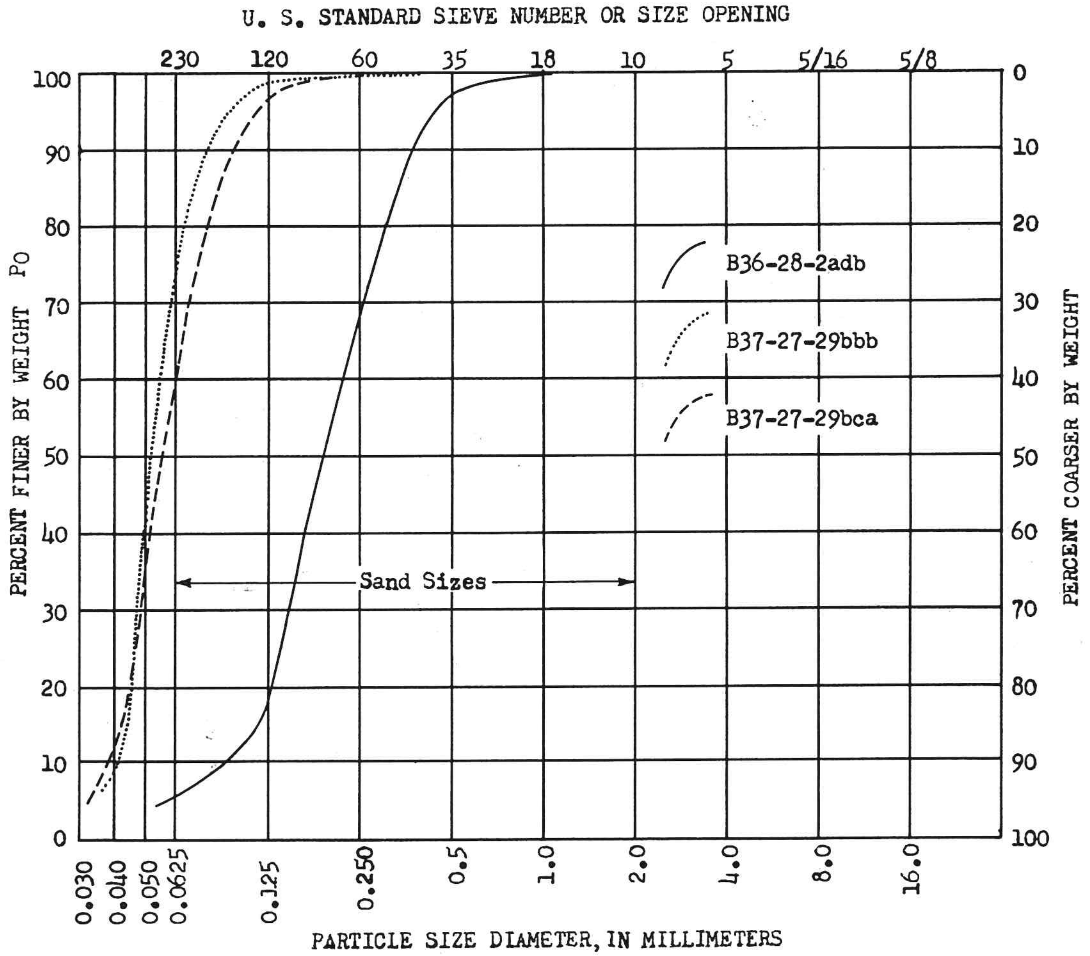
Location	Clay sizes	Silt sizes	Sand sizes					Gravel sizes		
	<0.004	0.004-0.0625	V.fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1	V.coarse 1-2	V.fine 2-4	Fine 4-8	Medium 8-16
B37-27-28cac	2.2		0.6	3.2	27.5	51.5	12.4	1.6	1.0	
B37-27-28bca	2.1		0.9	3.7	27.2	44.5	15.8	3.5	1.8	0.5
B37-27-21dcd	1.1		0.2	0.4	5.3	37.9	42.5	8.8	2.7	1.1

Figure 7.–Particle-size distribution curves of deltaic deposits.

Kootenai and Missoula. The sediments generally range from clay to very coarse sand, but silt and very fine sand predominate (Fig. 8). The silt is interbedded with layers of clay and fine sand. Beds of sand are slightly less than 1 inch to 4 inches thick. Beds of clay are as much as 1 foot thick but most are less than 1 inch thick. The lake-bottom deposits are fine to very coarse sand in the area where they interfinger with the deltaic deposits.

The maximum thickness of the lake-bottom deposits in the Tobacco Plains area is unknown. Bluffs along the Kootenai River expose as much as 300 feet of lake-bottom deposits, and Konizeski and others (1968, p. 8) reported more than 600 feet of glaciolacustrine silt and sand in the Kalispell Valley.

No wells in the project area are known to obtain water from the lake-bottom deposits. When saturated, the fine material "runs" into the casing. Drillers report that drilling through the deposits causes problems as the sand "heaves" into the open end of the casing and may lock the tools. The hydrologic characteristics of the deposits are unknown, but they transmit water, as shown by springs issuing from the deposits in sec. 8, 17, and 20, T. 37 N., R. 27 W. The maximum discharges of the springs range from 0.98 to 17.4 cfs.



Location	Clay sizes	Silt sizes	Sand sizes					Gravel sizes		
	0.004	0.004-0.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5 - 1	V. coarse 1 - 2	V. fine 2 - 4	Fine 4 - 8	Medium 8 - 16
B36-28-2adb	5.6		12.5	49.5	30.1	2.3				
B37-27-29bbb	57.2		23.5	1.2	0.1					
B37-27-29bca	61.2		35.5	2.7						

Figure 8.–Particle-size distribution curves of lake-bottom deposits.

Alluvium.—Alluvium is material eroded from older rocks and deposited along the rivers and streams. Its composition differs widely between drainage basins and even within a basin, depending on the composition of the source rocks. In the study area, alluvium along the larger streams is mostly sand and gravel. Alluvium along the smaller streams and along the Stillwater River south of Olney contains a large percentage of clay and silt.

The alluvium shown on Plate 1, for example at B35-26-29c, as small patches surrounded by till or Precambrian rocks, is fine grained and contains a large percentage of decayed plant material. Also, where the alluvium crops out in relatively wide areas along Young and Good Creeks, it contains a large percentage of organic material. The composition of the alluvium along the Kootenai River is shown in the following log of test hole B37-27-7ccd. The relation of the alluvium to the underlying deposits is shown in the section on Plate 1.

Test hole B37-27-7ccd

Land-surface altitude: 2,357 feet.
Depth to water below land surface: 50.00 feet, July 8, 1967.
Bailed at 9 gpm for 2 hours. At the end of bailing, no drawdown was detectable.
Casing is perforated from 130 to 139 feet.

Log

	Thickness (feet)	Depth (feet)
Alluvium:		
Gravel, very fine to very coarse, well rounded, and medium to very coarse, angular to well-rounded sand; contains cobbles to 6 inches in diameter	35	35
Gravel, medium to very coarse, well rounded, well sorted. Complete loss of drilling fluid between 35 and 44 feet	9	44
Lake-bottom deposits:		
Sand, very fine to fine, subrounded to well rounded, moderately well sorted; contains silt	16	60
Sand, very fine to medium, subrounded to rounded	10	70
Sand, very fine to fine, subrounded to rounded; contains silt	14	84
Clay, silty, light tan	1	85
Sand, very fine, and gray silt	11	96
Sand, very fine to medium, subrounded to rounded; contains silt	18	114
Sand, very fine to coarse, subrounded to well rounded, poorly sorted; contains a few well-rounded pebbles	2	116
Deltaic deposits (?):		
Gravel, very fine to coarse, well rounded, and medium to very coarse well-rounded sand	2	118
Sand, medium to very coarse, subrounded to well rounded; contains a few pebbles and inch-size pieces of black carbonaceous material	7	125
Silt, clayey, gray	3	128
Gravel, fine to very coarse, subrounded to well rounded; contains sand	12	140

Wells that tap the alluvium yield sufficient water for domestic and stock use. Because wells in the study area extend only a few feet into the alluvium, the hydrologic characteristics are not known. These characteristics undoubtedly vary considerably depending on the clay and silt content. The alluvium along the Kootenai River seems to be very permeable, as no drawdown was detectable in test hole B37-27-7ccd after 2 hours of bailing at 9 gpm. Permeability of this alluvium is also indicated by fluctuations of water level in this well, which closely follow stage fluctuations of the Kootenai River (Fig. 9). River stage shown on Figure 9 was measured daily at Rexford, about 7 miles downstream from the well. The well is 1,270 feet east of the river (section, Pl. 1). The average difference between the water-surface altitude in the well and that in the river is less than 1 foot.

HYDROLOGY

For the purposes of discussion, the project area is divided into two principal regions. The first region is drained by the Tobacco and Stillwater Rivers and the second is the Tobacco Plains. The plains region has little surface drainage, but ground water discharges into the Kootenai River. Hydrologic data are sparse throughout the project area. Most of the field effort was spent in collecting data from the Tobacco Plains. Thus, the following discussion is generalized for the Tobacco and Stillwater drainages and slightly more detailed for the Tobacco Plains.

TOBACCO RIVER AND STILLWATER RIVER DRAINAGES

Precipitation

Precipitation was recorded from 1961 through 1967 at Olney in the Stillwater River drainage and at Fortine in the Tobacco River drainage. The average monthly precipitation at Olney ranges from 0.85 inch in August to 3.56 inches in January; at Fortine the range is 0.87 inch in February to 2.42 inches in May. At Olney, precipitation from October through March accounts for about 60 percent of the average yearly total of 22.5

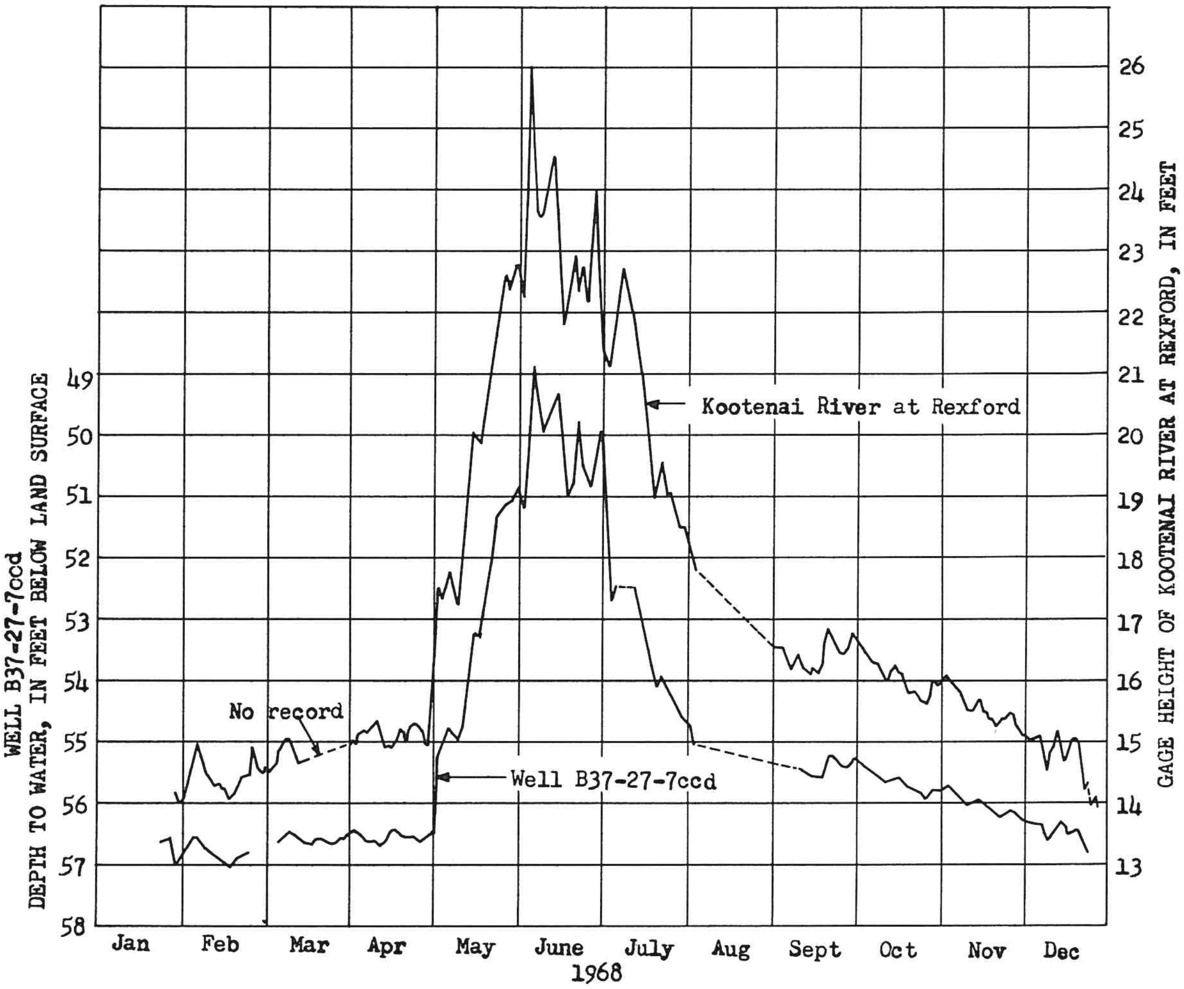


Figure 9.–Hydrographs of the Kootenai River and well B37-27-7ccd.

inches; at Fortine, precipitation during the same months accounts for about 50 percent of the average yearly total of 16.4 inches. Precipitation from May through July accounts for about 30 percent of the yearly total at Olney and 40 percent at Fortine. At both stations, the remaining 10 percent of the total is nearly evenly distributed in April, August, and September.

Precipitation from October through March usually accumulates as snow that begins to melt in late March or early April. By late May or early June, runoff is at its peak. Summer precipitation may occur as rainstorms lasting several days or as brief intense thunder showers.

Ground-water Flow to Streams

A small part of the precipitation that reaches the land surface soaks into the ground. Large parts of the drainage areas of the Tobacco and Stillwater Rivers are underlain by till or by Precambrian rocks, both of which are only slightly permeable. These rocks can absorb and release only small amounts of water per unit area, but their total outcrop area is large, and therefore the total contribution to streams is sufficient to help sustain base flows. Outwash deposits and alluvium cover a relatively small percentage of each drainage basin, but these deposits are capable of absorbing and releasing relatively large volumes of water per unit area.

An index of the ground-water discharge to streams is given by miscellaneous discharge measurements (Table 2). The measurements were made in the fall, three weeks after the last precipitation and before the streams had begun to freeze. From ground-water inflow, Grave Creek gained 7.8 cfs in 6 miles between the project boundary and the mouth of Fortine Creek. The Tobacco River gained 14.3 cfs in 9 miles between the junction of Grave and Fortine Creeks and the gaging station at B36-27-9ddb. Unmeasured tributary inflow was estimated to account for about 2 cfs of the 14.3 cfs. The gain from ground water (about 1.3 cfs per mile) seems to be fairly evenly distributed along the Tobacco River and Grave Creek.

Table 2.—Miscellaneous discharge measurements in the Tobacco and Stillwater River basins

Stream	Location of measurement	Date	Discharge (cfs)	Stream gain between measurements (cfs)	Remarks
Grave Creek	Lat 48°50′12″ N., long 114°50′10″ W. (unsurveyed)	10-18-66	44.1		
Glen Lake Ditch	B35-25- 6ccc	10-18-66	24.2		Diverts from Grave Creek
Grave Creek	B35-26-15bcc	10-18-66	27.7	7.8	Slightly above junction with Fortine Creek
Fortine Creek	B35-26-15bcc	10-18-66	24.2		Slightly above junction with Grave Creek
Therriault Creek	B36-26-33cdb	10-18-66	9.78		Tributary to Tobacco River
Tobacco River at gage	B36-27- 9ddb	10-18-66	76.0	14.3	
Stillwater River	B34-25-25d	11- 9-66	22.0		
Stillwater River	B32-23-18a	11- 9-66	52.4	30.4	
Stillwater River	B31-23-10a	11- 9-66	109	56.6	

The Stillwater River gained 30.4 cfs in 13 miles between Stryker and Olney and gained 56.5 cfs in 14 miles between Olney and the southern boundary of the project area. Tributary inflows account for about 4 cfs of the 30.4 cfs and about 10 cfs of the 56.6 cfs. The gain from ground-water inflow is about 2 cfs per mile between Stryker and Olney and about 3 cfs per mile between Olney and the southern boundary. The larger gain per mile in the Stillwater River is probably due to the greater average precipitation in the Stillwater River basin and to the greater percentage of permeable outwash along the Stillwater River. Much of the 4 cfs per mile gain between Olney and the southern boundary probably originates from the large area of outwash southwest of Lower Stillwater Lake (Pl. 1).

The Tobacco and Stillwater Rivers receive ground water throughout the year except, perhaps, during the last part of May and the first part of June when river stage is high. If the river stage is higher than the water level in the adjacent aquifer, water from the river may flow into the aquifer. The amount of water entering the aquifer from the river is probably small, because the aquifers too have been recharged from snowmelt and rain, and therefore contain the most water during May and June. In the last part of June, the river stages decrease, and ground water discharges into the river.

Water Use

The Tobacco and Stillwater drainage basins have few wells. Most of the wells provide water for domestic and stock supplies and are completed only a few feet into the water-bearing zone. Most casings are open at the bottom and have no perforations. Well yields are reported to be adequate for domestic and stock supplies, and irrigation wells undoubtedly could be constructed in places underlain by outwash or alluvium. Landowners have little interest in drilling irrigation wells, probably because land suitable for irrigation would have to be cleared of timber and because surface-water supplies are adequate for irrigating hay, which is the principal crop. During this study, 56 wells were inventoried in the Tobacco and Stillwater drainages (Pl. 2). No water-use data are available, but the total withdrawal of water from wells probably is less than 200 acre-feet annually in the Tobacco and Stillwater drainages. Many homes are supplied from springs or from small streams tributary to the Tobacco and Stillwater Rivers.

Eureka and Fortine are supplied principally from surface-water sources, Eureka from St. Clair Creek and Fortine from Deep Creek. The St. Clair Creek supply is supplemented by water diverted from Grave Creek. A municipal well was drilled to supplement the water supply at Eureka, but the yield of the well is reported to be small and the well is seldom used. Part of Eureka is supplied by a private water system that pumps water from two wells on the north side of town. Well B36-27-14ab is reported to be 127 feet deep and to yield 75 gpm with 40 feet of drawdown. Well B36-27-14ba is reported to be 141 feet deep and yields 135 gpm with 100 feet of drawdown. The U. S. Public Health Service (1963) reported the average plant output of the municipal water supply at Eureka as 250 acre-feet annually. The average output of the Fortine water system is not reported, but the 1960 population served was 130 compared with 1,230 at Eureka. The municipal water use at Fortine would probably be about one-tenth that of Eureka.

The largest irrigation system in the project diverts water from Therriault and Grave Creeks to Glen Lake. From Glen Lake, a ditch distributes water to about 1,400 acres at the south end of the Tobacco Plains.

TOBACCO PLAINS

Precipitation

The weather station at Eureka is about a mile north of town at the southern edge of the Tobacco Plains; therefore, the record is representative of the Tobacco Plains. The average annual precipitation from 1961 to 1967 was 14.6 inches; June (2.42 inches) had the greatest precipitation, and August (0.84 inch) the least. Monthly precipitation averages about 1 inch during February, March, April, July, September, October, and November. During January, May, and December, precipitation ranges between 1.25 and 1.58 inches per month. Precipitation from September through May may be either rain or snow. The ground does not remain snow-covered for longer than about a month, except during unusually cold winters. Average monthly temperatures are above freezing except during December and January, when the average temperature is 23°F. Lakes on the Tobacco Plains are usually ice covered during January and February.

The mountains east and west of the Tobacco Plains receive considerably more precipitation and the temperatures are lower than in the valley. No permanent snow fields remain in the mountains, but snow does not melt from sheltered places until August.

Recharge

Precipitation on the Tobacco Plains is absorbed or evaporated and transpired. Little water runs off the area because the outwash, lake bottom, and deltaic deposits are permeable and absorb most of the water not evaporated or transpired. Areas underlain by these deposits lack a well-developed drainage pattern. In areas underlain by till, precipitation runs off and is absorbed by adjacent more permeable deposits.

The amount of precipitation that is absorbed differs from place to place depending on the type of underlying deposit, topography, and vegetal cover. A hydrograph for well B37-27-28cb shows little correlation with well B37-27-33dc or with precipitation records at Eureka (Fig. 10). The water-level rise in well B37-27-28cb during June and July is probably due to recharge from Phillips Creek and Sophie Lake. Well B37-27-33dc is separated from the major hydrologic effects of Sophie Lake and Phillips Creek by an outcrop of till (Pl. 1). In this well the water level begins to rise in May, probably in response to precipitation.

Phillips Creek and Sophie Lake are important sources of recharge to the ground-water reservoir beneath the Tobacco Plains. Phillips Creek originates east of the Rocky Mountain Trench in Canada. It enters the trench about 1.5 miles north of the international boundary, flows south across the boundary, and empties into Sophie Lake. During the fall, winter, and early spring, the flow of Phillips Creek varies between 10 and 20 cfs at the point where the creek enters the trench. The flow decreases steadily downstream because of seepage losses. At the boundary the flow is less than 5 cfs from September to May. In mid-May, snowmelt increases the flow to 100 cfs or more at the boundary. This snowmelt reaches Sophie Lake and causes the water level to rise 10 to 15 feet. By the end of June the flow of Phillips Creek decreases and the level of Sophie Lake begins to drop because of infiltration from the lake into the adjacent aquifers. Water from Sophie Lake and Phillips Creek moves into the aquifer system and causes a water-level rise in Tetrault Lake about 20 days after the rise in Sophie Lake. The water-level rise in well B37-27-28cb, 0.2 mile west of Tetrault Lake, occurs about 24 days after the rise in Sophie Lake. The small lakes near Sophie Lake have a shorter lag time, but discharge from springs along the edge of the Kootenai River valley does not begin to increase until about a month after Sophie Lake begins to rise. The water-level changes caused by Phillips Creek and Sophie Lake are shown in Figure 10.

The rate of seepage from Sophie Lake can be estimated from the stage hydrograph. For example, on June 29, 1967, the lake level began to drop, indicating that inflow was less than seepage. Inflow to the lake on June 29 was 52 cfs or 104 acre-feet, but lake storage decreased about 4 acre-feet; therefore about 54 cfs was seeping from the lake.

During the summer of 1967, discharge was measured in Phillips Creek at the international boundary and at a bridge 2.2 river miles downstream (Fig. 11), and staff-gage readings were taken at Sophie and Tetrault Lakes. The creek began to flow at the boundary on May 21; discharge measurements (Table 10, appendix) were begun on June 6 and were continued to September. The discharge record was extended by estimating the flow between May 21 and June 6. Between May 21 and September 1, about 1,900 acre-feet infiltrated in the 2.2-mile reach. About 4,900 acre-feet flowed past the bridge (B37-27-15aaa) between May 21 and July 26 when the creek dried up at the bridge. Sophie Lake rose 11.4 feet between May 21 and June 29. By July 26 the lake level had fallen 2.4 feet. The surface area of the lake is 210 acres, so the net rise of 9.0 feet between May 21 and July 26 indicates a temporary increase in lake storage of about 1,900 acre-feet. The difference between flow past the bridge and the temporary increase in storage is about 3,000 acre-feet; that amount must have infiltrated from the lower reach of Phillips Creek and from Sophie Lake.

Evaporation from the lake is probably less than 420 acre-feet per year. The nearest evaporation pan is in the

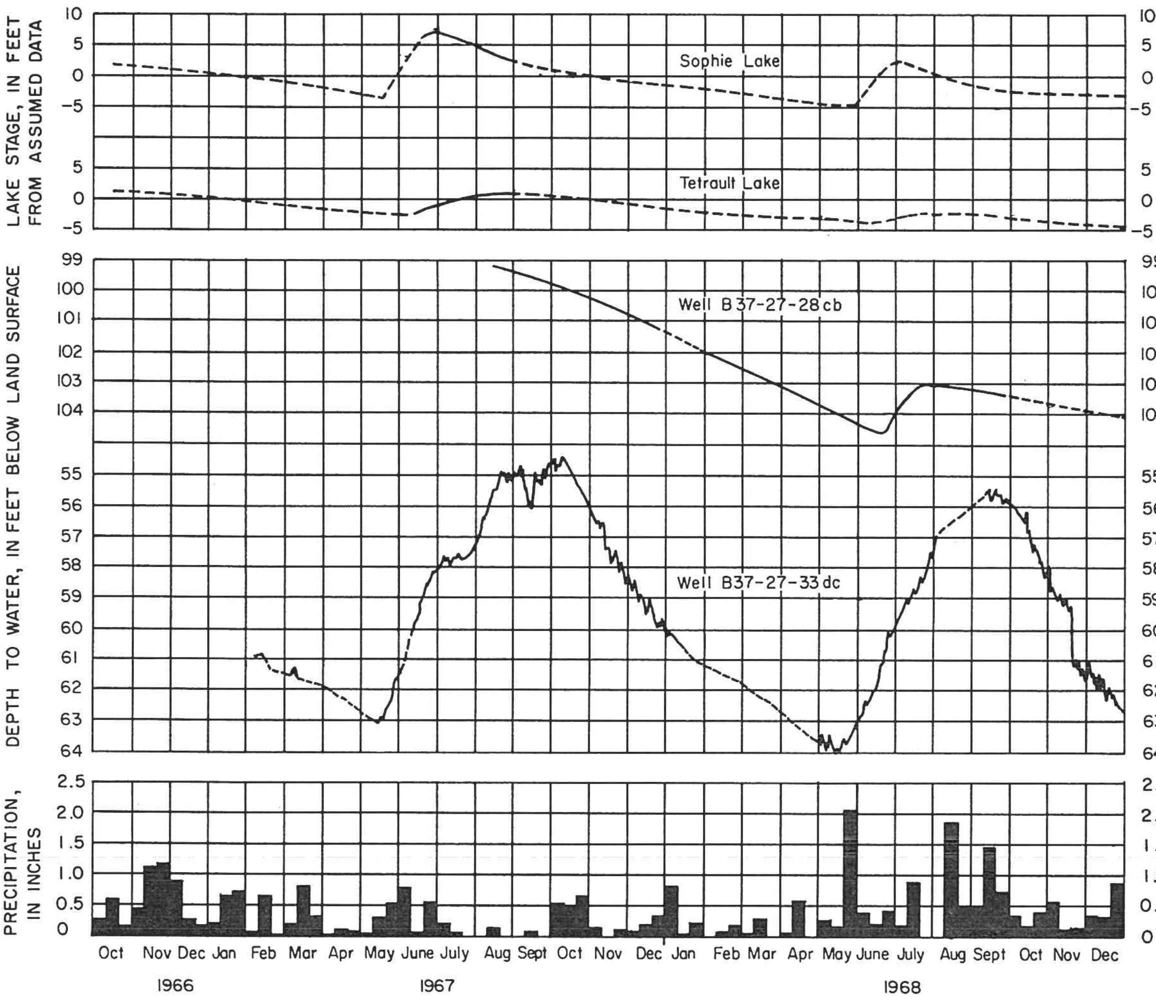


Figure 10.–Hydrographs of Sophie and Tetrault Lakes, wells B37-27-28cb and B37-27-33dc, and precipitation at Eureka, October 1966 through December 1968. Solid lines denote continuous record, dashed lines denote weekly or monthly measurements.

Kootenai River valley at Warland about 30 miles southwest of Sophie Lake. About 13 inches of water evaporated from that pan during June, July, and August of 1967. Evaporation at Sophie Lake would probably be slightly greater than indicated by the pan because there is more opportunity for air movement on the Tobacco Plains than in the Kootenai valley. No conclusive data are available, but it is thought that during a normal year, precipitation would almost balance evaporation.

Ground-water Movement

The direction of ground-water movement beneath the Tobacco Plains is influenced by the shape and size of the bodies of till or Precambrian rocks and by the shape and size of the streams and lakes. As can be seen from Plate 1, these boundaries are irregular, consequently the ground-water flow system is complicated. Field data are not sufficient to define the flow system, so a simple steady-state analog model was constructed to help determine the effects of the boundaries on the direction of ground-water flow. The model is based on the fact that electricity and ground water both flow in response to a potential gradient and if the gradients are proportional, the flow of electricity and ground water are analogous. The model was made from teledeltos paper, which conducts electricity and represents the permeable alluvium, outwash, and deltaic and lake-bottom deposits. Areas representing poorly permeable till or Precambrian rocks were removed from the paper and areas representing lakes were coated with highly conductive silver paint. Streams were represented by lines of carbon paint, which is a poorer conducter than silver paint but better than the teledeltos paper. The conductivity of the carbon paint can be increased by using thicker coats of paint, thus producing a line of varying electric resistance that corresponds to the stream grade. The alluvium along the

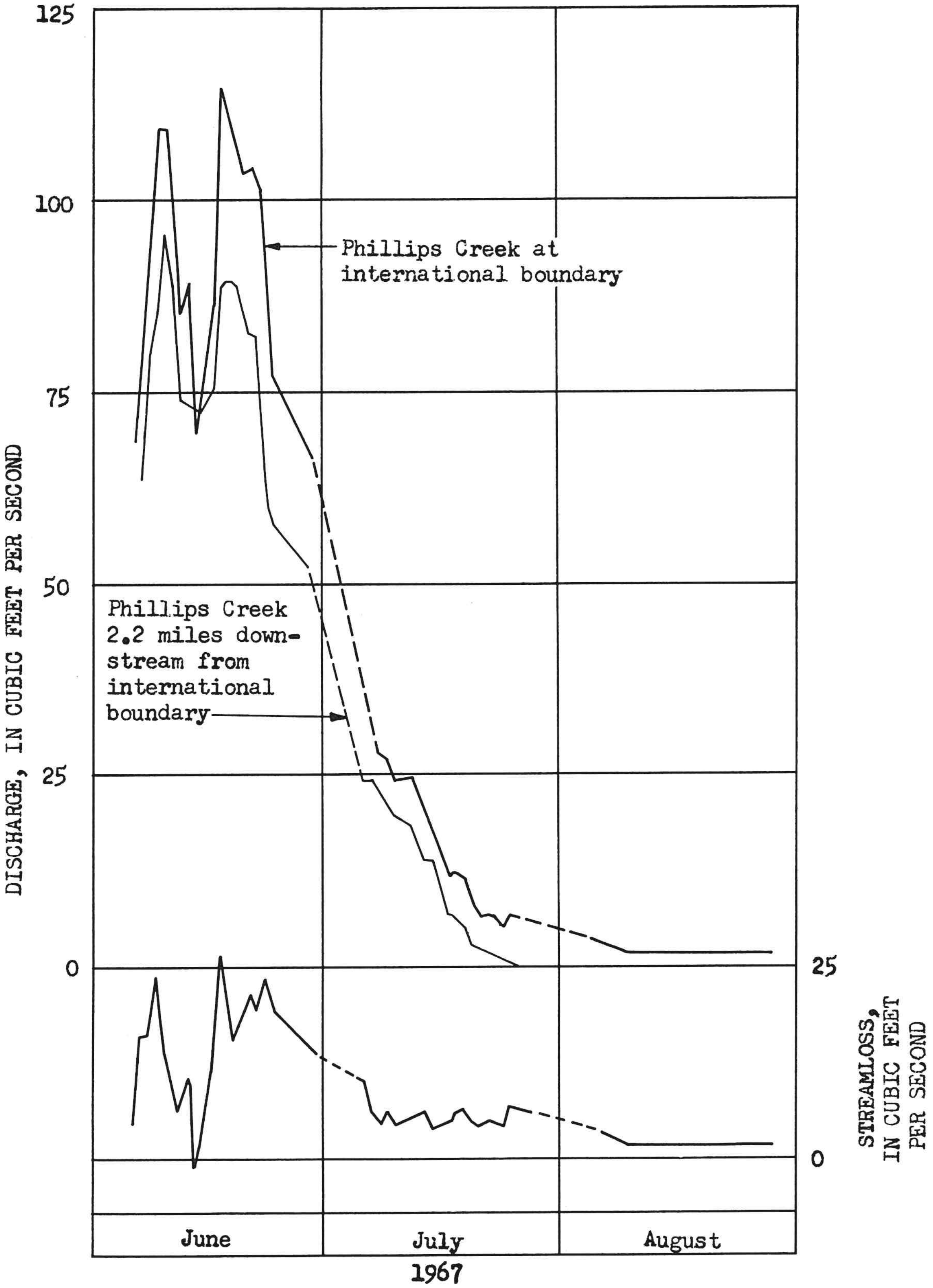


Figure 11.–Discharge at two locations on Phillips Creek, May to September 1967, and streamloss between the two locations for the same period.

Kootenai River is believed to be much more permeable than the outwash, lake bottom, or deltaic deposits, so the corresponding area on the model was coated with carbon paint.

Voltage was applied to each area representing a lake or stream and adjusted to correspond to the altitude of the water surface. For example, the lowest water-surface altitude on the model is at the junction of the Kootenai and Tobacco Rivers (2,270 feet) and one of the highest is where Phillips Creek crosses the international boundary (2,670 feet). Thus, if water could flow from Phillips Creek to the Kootenai River, it would lose 400 feet of head (potential). The potential of these two points on the model was held at 4 volts; each volt represents 100 feet of head.

A vacuum-tube voltmeter was used to measure the potential at various places on the teledeltos paper, and lines of equal potential were drawn. The lines correspond to water-table contours if the boundaries are correctly modeled and if the flow system operates under steady-state conditions. The resulting map (Fig. 12) shows a potential distribution that would result from a geometric arrangement of boundaries of flow or no flow as shown on Plate 1 and from a constant permeability distribution on the Tobacco Plains and a constant but higher permeability distribution in the alluvium along the Kootenai River. Data are not available to check the potentiometric map, but the water-level data from the wells fit the map except in the area of Indian and Kasanka Creeks. In this area, water levels in wells were lower than predicted by the model. The discrepency could result from incomplete hydraulic connection between the streams and aquifer. In construction of the model, complete hydraulic connection was assumed; therefore, the predicted water levels near the stream would be higher than water levels near a stream with imperfect hydraulic connection.

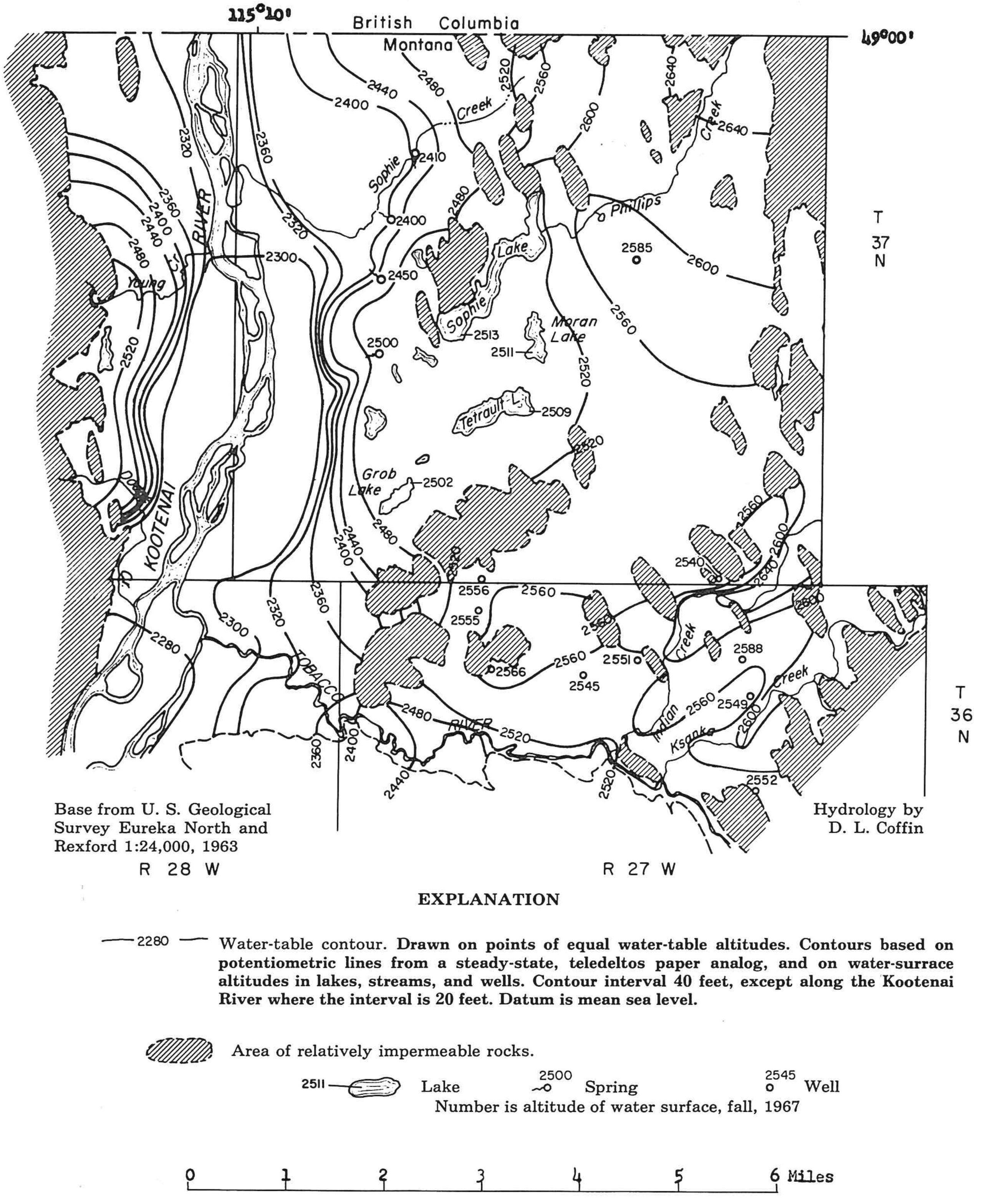
The direction of ground-water flow on the Tobacco Plains is qualitatively shown on Figure 13, which was made by constructing flow lines normal to the potentiometric lines of Figure 12. Phillips, Indian, Kasanka, Dodge, and Young Creeks recharge the aquifer, which in turn discharges into the Kootenai and Tobacco Rivers and to springs along the east edge of the Kootenai River valley. Although not shown by the model, some discharge is by evapotranspiration and some recharge is from direct percolation of precipitation into the unconsolidated deposits. Ground-water discharge by evapotranspiration is probably small because the depth to water is greater than 20 feet except in small areas around the edges of the lakes and along the Kootenai River.

Ground-water Discharge

Discharge from the springs on the west edge of the Tobacco Plains is listed in Table 3. Yearly discharge was estimated from the discharge measurements and from monthly staff-gage readings. Ground-water discharge to

Table 3.—Discharge measurements and estimated yearly flow from springs on west edge of the Tobacco Plains

				Estimated yearly discharge	
Name	Location of measurement	Date	Discharge (cfs)	Water year 1967 (acre-feet)	Water year 1968 (acre-feet)
Sophie Creek	B37-27-17cba	10-28-66	3.58		
		4- 7-67	3.20		
		7- 6-67	4.10		
		10-15-68	3.30		
				2,500	2,000
Campbell Spring	B37-27-17cdd	10-28-66	.97		
		3- 7-67	.74		
		7- 6-67	.98		
		10-15-68	.90		
				600	450
Murray Creek	B37-27-29bbb	10-28-66	17.4		
		3- 7-67	11.6		
		7- 6-67	12.5		
		7-24-68	11.5		
		8-29-68	11.5		
		10- 4-68	10.3		
		11- 4-68	10.4		
		12- 2-68	9.08		
		1- 6-69	9.04		
		2- 6-69	8.29		
				9,900	7,400
		Total yearly discharge		13,000	9,850



Base from U. S. Geological Survey Eureka North and Rexford 1:24,000, 1963

Hydrology by D. L. Coffin

EXPLANATION

—— 2280 —— Water-table contour. **Drawn on points of equal water-table altitudes. Contours based on potentiometric lines from a steady-state, teledeltos paper analog, and on water-surrace altitudes in lakes, streams, and wells. Contour interval 40 feet, except along the Kootenai River where the interval is 20 feet. Datum is mean sea level.**

▨ Area of relatively impermeable rocks.

2511 Lake 2500 Spring 2545 ○ Well

Number is altitude of water surface, fall, 1967

Figure 12.–Potentiometric map of the Tobacco Plains area, northwestern Montana.

the Kootenai River can be estimated from the gaging station summary in Table 4. During the low-flow period, from September 1967 through April 1968, the Kootenai River gained an average of 200 cfs between the international boundary and Rexford. Of the 200 cfs about 20 cfs was unmeasured tributary inflow and about 14 cfs was measured discharge from the springs. The remaining 166 cfs can be attributed to unmeasured ground-water discharge into the river. If this ground-water inflow were constant, then about 120,000 acre-feet would be discharged directly into the Kootenai River during the year. Ground-water inflow as computed from gaging station records is subject to the errors of stream gaging. The records show a streamflow gain, which can be attributed to ground-water inflow, but the magnitude of the gain remains uncertain.

Assuming that the Kootenai River gained about 120,000 acre-feet and springs discharged about 10,000 acre-feet, then ground-water discharge from the Tobacco Plains during water year 1968 was about 130,000 acre-feet. About 7,000 acre-feet came from Phillips Creek and Sophie Lake, which leaves about 123,000 acre-feet unaccounted for. The additional discharge could be attributed to:

1. Underflow from Canada to the Tobacco Plains and to the alluvium along the Kootenai River.
2. Precipitation absorbed and transmitted by deposits underlying the Tobacco Plains.
3. Unmeasured runoff from the mountains absorbed on the Tobacco Plains and on the west side of the Kootenai River.
4. Errors in computing flow of the Kootenai and Tobacco Rivers.
5. Errors in estimating unmeasured tributary inflow.

Water Use

Ground water is used for domestic and stock purposes by about thirty families that live widely scattered on the Tobacco Plains. Total annual pumpage is probably less than 20 acre-feet and probably has little effect on the ground-water reservoir. Ground-water discharge is diverted for irrigation from Murray Creek, Sophie Creek, and Campbell Spring. The total diversion from these sources is probably less than 1,000 acre-feet per year. Water from Phillips Creek is diverted to irrigate hay fields in the summer, and the creek is used to water stock during the winter. The area at the south end of the Tobacco Plains is irrigated by water diverted from Grave and Therriault Creeks and from Indian Creek.

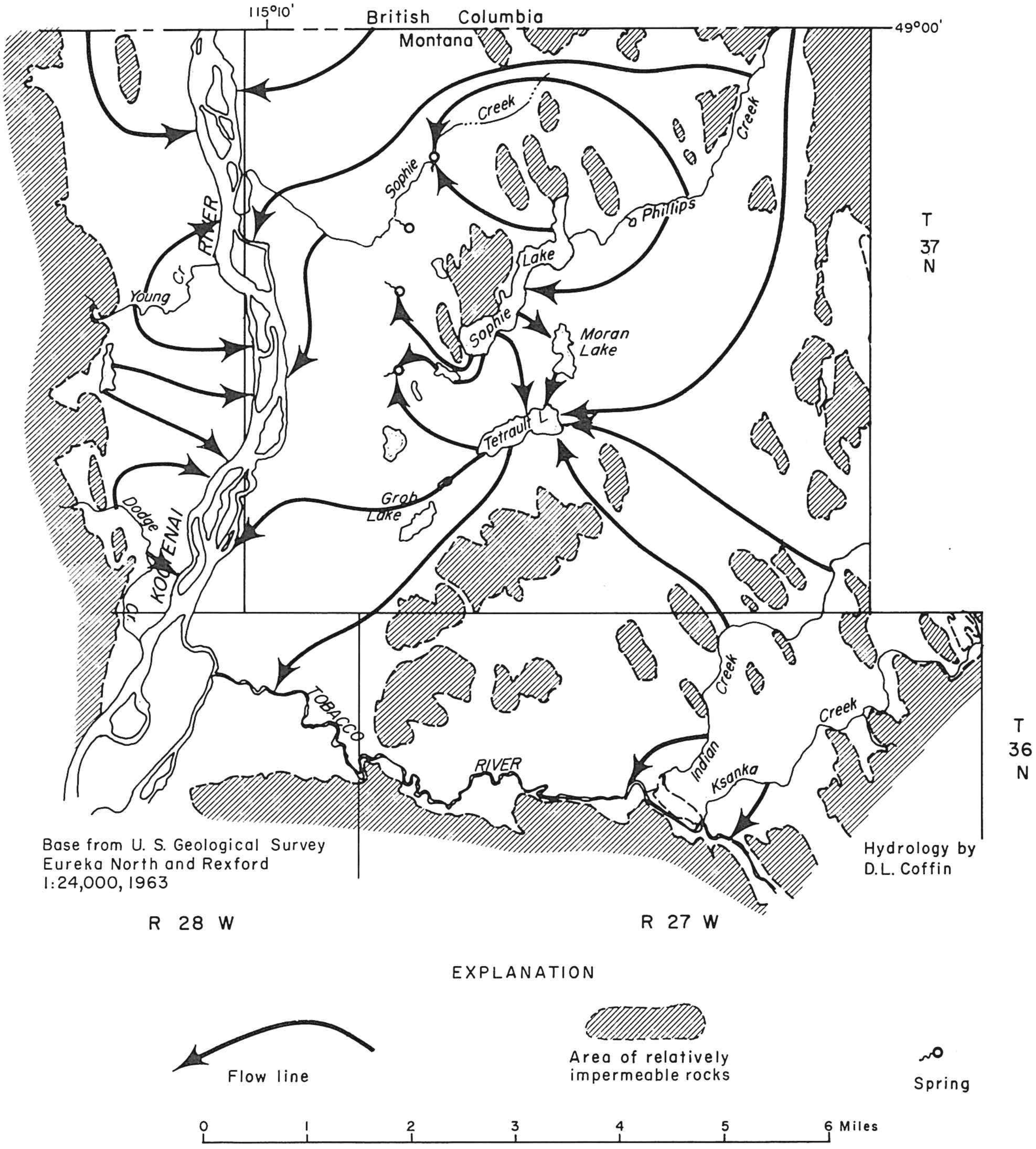
WATER QUALITY

Most of the water in the study area is of good chemical quality and is suitable for irrigation, domestic, and most industrial uses. Dissolved solids in 44 samples taken during the study ranged from 80 to 5,540 mg/l (milligrams per liter), but 42 samples contained between 80 and 336 mg/l (Table 9, appendix). Water in the area is moderately hard to very hard. Total hardness ranges between 65 and 360 mg/l; 24 of the 44 samples contained between 121 and 180 mg/l and are classified as hard. The principal cations are calcium, magnesium, and sodium. The principal anion is bicarbonate. These ions presumably were derived from limestone and dolomite in the Precambrian metasediments and in the unconsolidated deposits eroded from the Precambrian rocks.

Generally, water from rivers or streams contains fewer dissolved solids and is softer than ground water. Between June and September of 1967, dissolved solids in the Kootenai River varied from 123 mg/l on June 29 to 219 mg/l on September 8; total hardness was 133 and 240 mg/l in the same period (U. S. Geological Survey, 1967). Dissolved solids decrease during the runoff period because of dilution by water from snowmelt. The change in conductivity of water in the Stillwater River between

Table 4.—Monthly discharge, Kootenai and Tobacco Rivers, water year October 1967 to September 1968

		Average discharge (cfs)											
Name	Location	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Kootenai River at Newgate, British Columbia	Lat 49°00′52″ N. Long 115°10′27″ W.	4,279	3,667	2,697	2,509	2,681	3,270	3,365	21,500	40,170	21,960	9,454	7,074
Tobacco River near Eureka	B36-27-9ddb	94	88	77	77	92	146	167	650	632	240	122	185
	Total	4,373	3,755	2,774	2,586	2,773	3,416	3,532	22,150	40,802	22,200	9,576	7,259
Kootenai River near Rexford	B36-28-21ba	4,507	4,021	2,910	2,788	3,063	3,565	3,726	22,710	42,090	22,230	9,877	7,489
	Net gain	134	266	136	202	290	149	194	560	1,288	30	301	230



Base from U. S. Geological Survey
Eureka North and Rexford
1:24,000, 1963

Hydrology by
D.L. Coffin

Figure 13.–Sketch map indicating direction of ground-water flow in the Tobacco Plains area, northwestern Montana.

time of high runoff (June) and low runoff (October) is shown in Figure 14. Conductivity of water as shown in Figure 14 can be converted to dissolved-solids concentration by multiplying by a factor of 0.6. The downstream increase in dissolved solids is produced by additional contributions to streamflow from ground water.

GRAVIMETRIC SURVEY

A gravity survey in the north half of the project area covered a strip 5 to 7 miles wide that extends northwest from Trego to the international boundary. The purpose of the survey was to estimate the approximate thickness of valley fill and the bedrock configuration. Gravity methods are usually fairly good for estimating the shape and depth of a basin in dense bedrock if the basin is filled with less dense material.

FIELD METHODS

Gravity measurements were made at 252 sites by Worden gravimeter that has a scale constant of about 0.4 milligal per dial division. The measurements were referred to the Kalispell airport station that was established by Woollard (1958, p. 533) as having a value of 980.5819 gals. Most sites were at bench marks, road intersections, section corners, or other places where altitudes had been determined by instrumental leveling by the U. S. Geological Survey. The altitudes at a few sites were determined by instrumental leveling during the study. Maximum error in altitude is probably less than 10 feet, and most points are probably located within 4 feet vertically. Position control was obtained from USGS 1:24,000 topographic maps and is believed to be accurate within about 0.1 minute. To determine the gravimeter drift, readings were made at a selected base station at the beginning and end of each day's work and at a previously occupied point at intervals of about 3 hours. To mini-

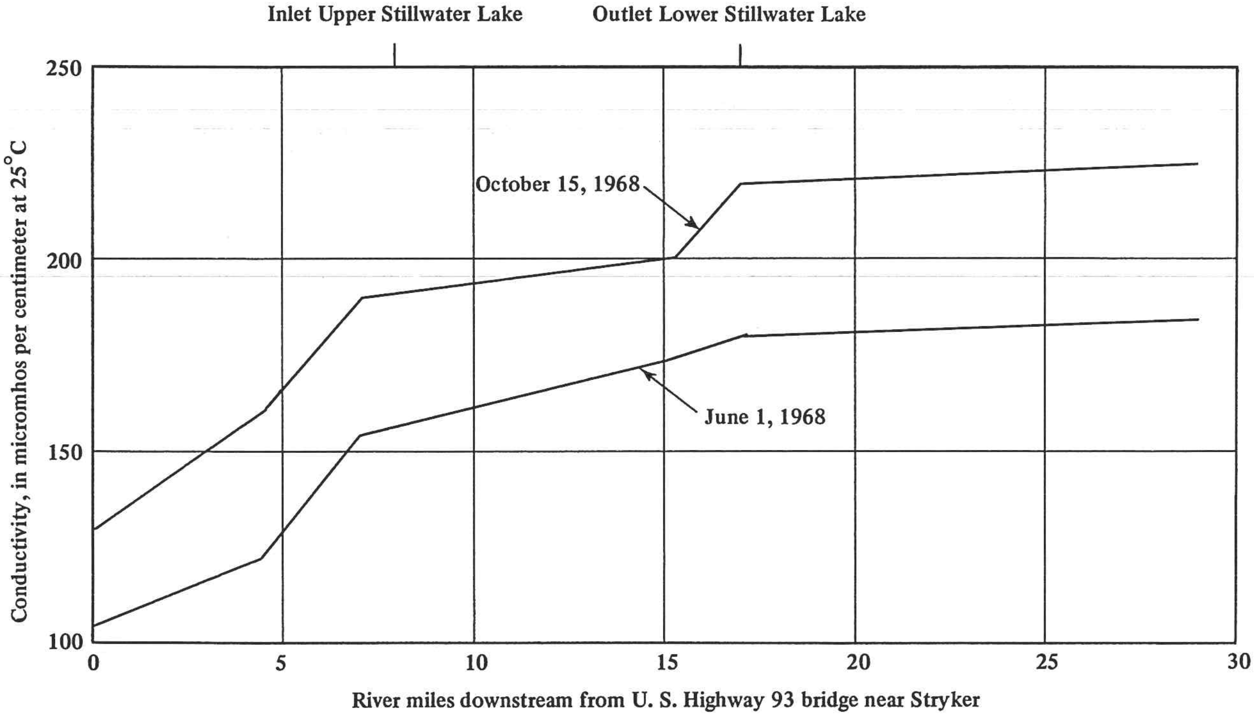


Figure 14.–Downstream increase in conductivity of water in the Stillwater River on June 1, 1968 and Oct. 15, 1968.

mize errors in reading the meter, at least two readings were taken and averaged at each site.

REDUCTION OF DATA

The gravity data were adjusted for meter drift and corrected for elevation, latitude, and terrain effects. Corrections were calculated on a computer by the U. S. Geological Survey. Bouguer values were obtained for densities of 2.67 and 2.10 g/cm^3 (grams per cubic centimeter). Peripheral terrain corrections from 2.6 to 166.7 km (kilometers), based on a density of 2.67 g/cm^3, were calculated by computer. The inner zone terrain corrections from the gravity site out to 2.6 km were calculated by hand with the aid of the Hammer Chart.

GRAVITY FEATURES

The gravity map (Pl. 3) shows Bouguer anomalies computed for density of 2.67 g/cm^3. Basic data from which computations were made and Bouguer values computed for a density of 2.10 g/cm^3 are on file at the U. S. Geological Survey office in Helena, Montana.

The main gravity features shown on the Bouguer gravity map are within the Rocky Mountain Trench. An elongate gravity low, which coincides with the trench, is marked by a series of depressions. The trench is significantly offset in the southeast part of the area.

Relatively high gravity occurs in areas of exposed bedrock and is reduced in proportion to the thicknesses of overlying low-density material. The elongate gravity low associated with the trench indicates a structural depression filled with low-density rocks. Gravel, sand, and silt of Pleistocene age overlie a thick section of deposits probably of Tertiary age.

A series of deep basins within the trench in Canada between Ft. Steele and the international boundary may be downfaulted blocks between longitudinal and transverse faults within the trench (Garland and others, 1961, p. 2504). The series of depressions in the study area may also represent downfaulted blocks. Leech (1959, p. 15) stated that the trench lacks important strike-slip displacements in Canada south of lat 49°30′ N.; Garland and others (1961, p. 2504) reached the same conclusion. This seems to be true for the longitudinal faults in the area of this study, but strike-slip movement along transverse faults is suggested by the fact that the depression east of Fortine is offset more than 10,000 feet southwest.

Another gravity feature, not well-documented but strongly suggestive, is a gravity low along the Kootenai River in the vicinity of and northeast from Rexford. This gravity low suggests thicker sediments in this area but the sediments are not as thick as those in the Rocky Mountain Trench. The low is probably associated with faulting. Johns (1961, Pl. 1) mapped two probable faults east of Rexford and inferred one along the Kootenai River valley west of Rexford. An additional indication of a fault along the Kootenai valley is that the U. S. Corps of Engineers (oral commun., 1968) found "greater than expected" depths to bedrock at the site of a new bridge across the Kootenai River, 7 miles southwest of Rexford.

GRAVITY PROFILES

Gravity profiles C-C′ and D-D′ and the diagramatic geologic sections (Fig. 15) were determined from the gravity data by M. Dean Kleinkopf of the U. S. Geological Survey. Calculations were made from a two-dimensional computer program. An east-dipping regional gradient, assumed as the difference between bedrock gravity readings at each end of the profiles divided by the length of the profile, was removed. In C-C′ the gradient was about 1.2 milligals per mile and in D-D′ it was about 1.8 milligals per mile. The density contrast between the Cenozoic deposits and the more dense pre-Cenozoic deposits was assumed as 0.5 g/cm^3 and is believed to be accurate within ±0.1 g/cm^3. The depth of valley fill calculated is proportional to the density contrast; a lower density contrast would require a thicker section of valley fill. It was also assumed that the residual anomalies are produced entirely by the density contrast associated with bedrock relief and that the anomalies and the inferred geologic features have an infinite extent normal to the profiles.

The profiles indicate that the depressions north of Sophie Lake and east of Fortine contain about 3,000 feet of valley-fill deposits. At Glen Lake and northeast of Eureka there is slightly less than 3,000 feet of fill, but near Stryker, Precambrian rocks are exposed across almost the entire width of the Trench.

SUMMARY

The Tobacco and Stillwater Rivers in northwestern Montana drain part of the Rocky Mountain Trench. They are tributary to the Kootenai and Flathead Rivers, respectively. The trench is a relatively narrow depression between mountain ranges extending more than 1,000 miles from Montana to the Yukon Territory. South of the international boundary the trench can be attributed to downfaulting between major longitudinal faults. Structural basins within the trench are caused by downfaulting between transverse faults. In the study area the basins have been filled by as much as 3,000 feet of low-density material. The walls of the trench are metasediments of the Belt Supergroup (Precambrian).

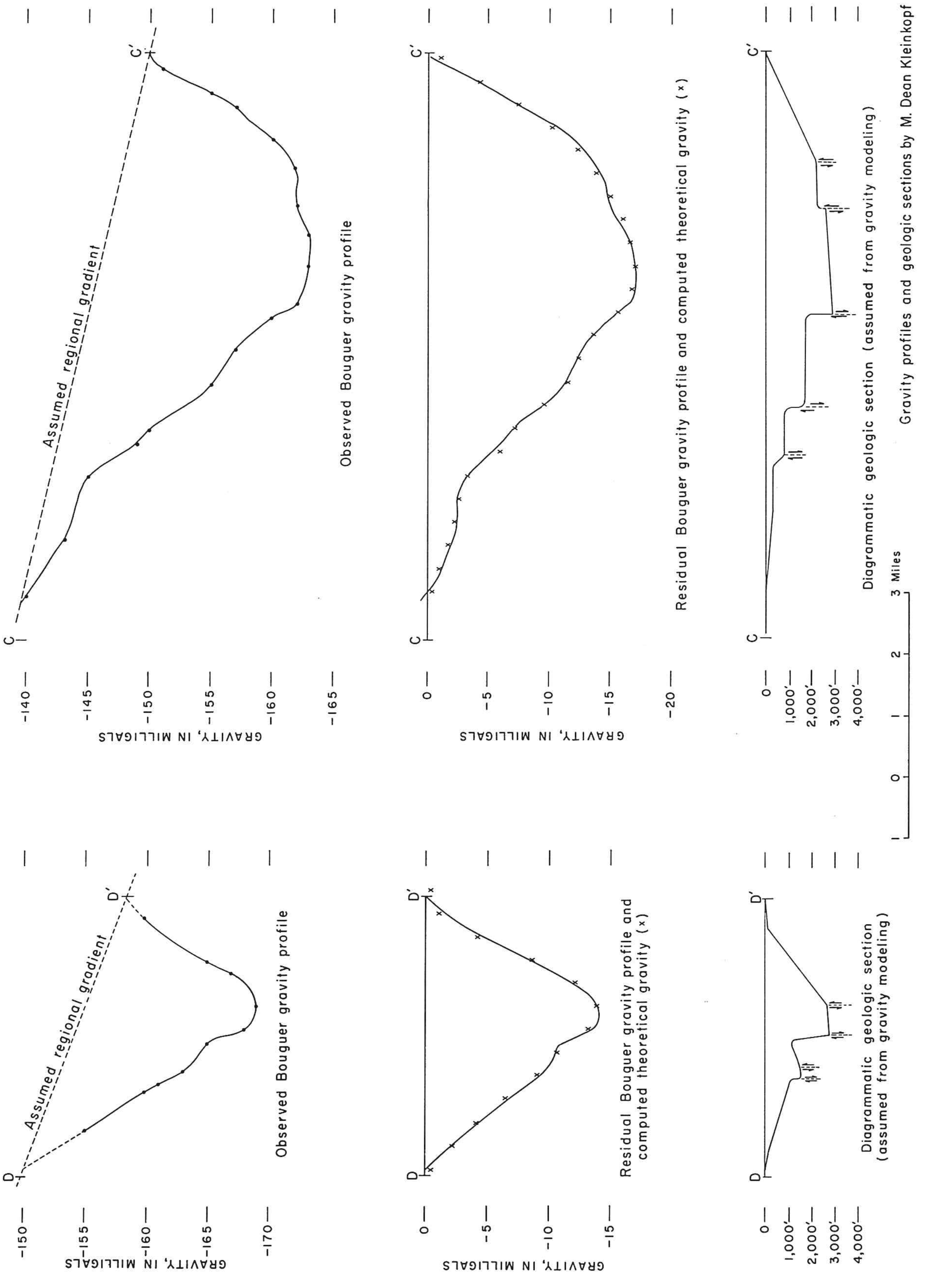
The last advance of the Cordilleran ice sheet filled the trench with as much as 5,000 feet of ice. The ice greatly modified the floor of the trench, and melting of the ice caused the deposition of outwash and the deposition of sediments in glacial lakes. Some outwash and near-shore lake deposits are coarse grained, well sorted, and capable of storing and transmitting large amounts of water.

Phillips Creek flows onto the Tobacco Plains from Canada and empties into Sophie Lake. Seepage from Sophie Lake and Phillips Creek is an important source of recharge to the ground-water reservoir beneath the Tobacco Plains. Between May 21, 1967, and September 1, 1967, about 1,900 acre-feet of water recharged the ground-water reservoir a 2.2-mile reach of Phillips Creek. Between May 21, 1967, and March 15, 1968, recharge from the lower reaches of Phillips Creek and from Sophie Lake amounted to about 4,900 acre-feet. Infiltration from Sophie Lake causes water levels in nearby lakes to rise and causes the discharge of springs on the west edge of the Tobacco Plains to increase. Ground water beneath the Tobacco Plains moves west and southwest to be discharged by the springs and to the Kootenai River. Gaging-station records indicate that in water year 1968 the Kootenai River gained about 110,000 acre-feet from ground-water inflow between the international boundary and Rexford.

Ground water is not pumped in large quantities from wells in the study area. Most of the towns and many rural homes depend on streams for the water supply. Irrigation is almost entirely from surface water.

The quality of ground and surface water is good, and except for a few locations, the water is suitable for irrigation and most domestic and industrial uses.

Permeable sand and gravel deposits adjacent to the proposed site for Libby Reservoir will become saturated and provide additional storage for Libby Reservoir, which is scheduled to begin filling in 1972. Because subsurface geologic data are insufficient to predict accurately the amount of usable bank storage, plans cannot be made to use this water for generating power. An electric analog of the area was constructed, and although the model is too crude to permit final estimates of bank storage, the results show that the distribution of active bank storage along the reservoir will be mainly a function of reservoir stage and the slope of the floor of the reservoir. The magnitude of active bank storage is controlled by the transmissivity and storage coefficient of the deposits adjacent to the reservoir. The model study indicates that additional geologic data for evaluating bank storage accurately are needed only from about one-fourth the length of the reservoir and within about 2 miles from its edge. The study allowed the estimated cost of the data-collection plan to be reduced by about half (Coffin, 1970).



Gravity profiles and geologic sections by M. Dean Kleinkopf

Figure 15.–Gravity profiles showing inferred depth to basement rock.

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Table 5.–Hydraulic characteristics assumed for the geologic units

Geologic unit	Lithology	Transmissivity T (ft^2 / day)	Coefficient of storage (S) Run 1	Run 2	Run 3
Alluvium	Gravel	67,000	0.20	0.10	0.40
Lake-bottom deposits	Silt, clay, sand	T_L = 1,300	S_L = .05	.025	.10
Deltaic deposits	Sand, gravel	T_D = 13,000	S_D = .15	.075	.30
Outwash	Sand, gravel, clay	T_O = 9,300	S_O = .10	.05	.20
Till	Clay, sand, boulders	0	-----	-----	-----
Precambrian strata	Dolomite, argillite, quartzite	0	----	----	-----

Table 6.–Record of selected wells and springs.

Well number: See text for description of well-numbering system.
Type of well: Dn, driven; Dr, drilled; Du, dug; Sp, spring.
Type of casing: C, concrete; G, galvanized iron; P, steel pipe; W, wood.
Method of lift: B, bucket; C, centrifugal; Cy, cylinder; J, jet; N, none; P, pitcher pump; S, submersible; T, turbine.
Type of power: E, electric; G, gasoline; H, hand operated; N, none.
Use of water: D, domestic; Gi, garden irrigation; I, irrigation; In, industrial; N, not being used; O, observation of water-level fluctuations; P, public; S, stock.
Altitude of land surface: Expressed in feet above sea level and obtained from topographic maps.
Depth to water: Water levels expressed in feet and tenths are measured; those in whole feet are reported.
Remarks: Ca, water sample collected for chemical analysis; Y, yield in gallons per minute; D, drawdown in feet produced by pumping at yield shown; F, natural flow in gallons per minute; Ff, flowed when first drilled; In, inadequate supply; L, log of well given in table 12; T, temperature in degrees Fahrenheit; Tw, test well.

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift	Type of power	Use of water	Altitude of land surface	Depth to water below land surface (feet)	Date of measurement	Remarks
B30-23- 1ab	Larry Kelch	----	Dr	116	7	P	S	E	D	3,100	43.5	6-15-67	Ca; L; Y 5
1db	Paul Horn	----	Dn	26	1 1/4	P	C	E	D	-----	----	--------	In
B31-23- 3db1	William Lawrence	1966	Dr	348	7	P	S	E	D	3,042	23.5	6-20-67	L; Y 3; D 262
3db2	-----do-----	----	Du	9	48x64	W	C	E	N	3,018	6.2	6-20-67	
4aa	Leo Boe	----	Du	8	33x41	W	C	G	Gi	3,004	2.9	6-15-67	Ca
13cc	Kenneth Graham	----	Dr	77	7	P	S	E	D	3,040	40	--------	L
14ca	William Donsbach	----	Dr	90	6	P	S	E	S	3,020	19.2	6-15-67	
25ab	Albert Evans	1960	Dr	76	7	P	J	E	D	3,052	50	--------	Ca; Y 9
36bb	Clifford Hanley	1959	Dr	87	7	P	J	E	D	3,024	40	--------	L; Y 8
36dc	Wayne Kelch	1966	Dr	175	7	P	S	E	D	3,055	44.3	6-15-67	L; Y 5
B32-23- 7ac	William Mattson	----	Dr	39	7	P	C	E	D	-----	11.5	6-20-67	Ca
8cb	John Isakson	1965	Dr	38	6	P	J	E	D	-----	14.2	6-20-67	
17bb	State of Montana	1955	Dr	39	7	P	---	E	D	-----	24	--------	Ca; L
18aa	-----do-----	----	Sp	4	33x35	W	B	N	D	-----	1.0	6-21-67	
18ab	-----do-----	----	Du	6	18	G	Cy	H	D	-----	3.3	6-21-67	
B33-23-30dd	-----do-----	----	Du	4	18	G	N	N	N	-----	2.0	6-21-67	
32dd	Everett Adams	----	Dr	115	7	P	J	E	D	-----	----	--------	Ca
B33-24- 9dd	Leslie Harris	1962	Dr	53	7	P	S	E	D	-----	22	--------	L; Y 25
B34-24-31bc	Jim Openshaw	----	Dn	21	2	P	J	E	D	-----	----	--------	Ca
B34-26- 5ab	Larry Curtiss	1957	Dr	147	7	P	S	E	D	3,431	100	--------	L; Y 200; D 35

B35-25-19ba	Edrick Vredenburg	1965	Dr	---	6-4	P	S	E	D	3,078	154.6	6-27-67	Ca
19bb	-----do-----	1966	Dr	---	6	P	S	E	D	3,060	136.2	6-27-67	
31ca	Bob Parker	1961	Dr	125	7	P	S	E	D	3,000	42.8	6-27-67	Ca; L
B35-26-11dd	Gehre Bros.	1957	Dr	35	7	P	J	E	D	-----	17	--------	L
12aa	E. F. Ruhl	----	Dr	27	7	P	J	E	D	3,008	12.9	6-28-67	
12ac	Levi Bogena	----	Dr	115	7	P	Cy	H	D	2,955	2.0	6-28-67	Y 2; Ff; bedrock at 80 feet
14bd	Luther Norman	----	Dr	21	7	P	J	E	D	2,887	8.7	6-27-67	Ca
15dd	Howard Dickinson	----	--	7	48x48	W	C	E	D	2,843	4	--------	
24dc	Winton Weydemeyer	----	Du	5	28	C	C	E	D	2,920	2.8	6-27-67	Ca
25ab	-----do-----	1966	Dr	107	5	P	S	E	D	2,919	0.6	9-26-67	Ca; L; Y 15; D 42
25ca	Fortine School	1966	Dr	265	6	P	S	E	D	2,962	----	--------	Ca; L
B36-26-33cc	Dick Eugene	1952	Dn	25	1 1/4	P	P	H	D	-----	----	--------	
33dc	Eureka Grange	----	Sp	---	-----	---	---	---	P	2,740	----	--------	Ca; T 46°
B36-27- 2cb	Ed Suchy	1965	Dr	101	4	P	J	E	D	2,655	67	--------	L; Y 7; D 4
3cc	Art Nutting	1966	Dr	260	6	P	S	E	D	2,650	101.5	7-20-66	L
4dc1	-----do-----	1967	Dr	---	6	P	N	N	N	2,620	75.0	10-17-67	
4dc2	-----do-----	----	Dr	165	6	P	---	E	D	2,600	----	--------	Ca
5ab	Carl Lundean	----	Du	45	6	G	Cy	H	O	2,612	38.1	7-20-66	
5bd	Henry Lenarz	----	Dr	85	6	P	S	E	D	2,602	46.7	7-18-66	Ca
5dc	Bert Roe	----	Dr	168	6	P	S	E	S	2,597	32.3	7-19-66	
8ab	-----do-----	----	Dr	228	-----	P	---	E	---	2,582	----	--------	Ca
9ba	David Butts	----	Dr	160	6	P	J	E	D	2,600	----	--------	
11ba	Fred King	----	Dr	---	6	P	S	E	In	2,664	----	--------	
11bb	Loyd West	1959	Dr	204	7	P	S	E	D	2,670	121	--------	L; Y 150; D 10
11cb	Eureka Ranger Station	1958	Dr	106	8	P	T	E	D	2,618	70	--------	L; Y 65; D 29
14ba	Harles Bergette	1966	Dr	120	6	P	S	E	In	2,591	39.4	7-19-66	Ca
14bb	-----do-----	1966	--	102	6	P	---	---	D	-----	50	--------	L
B36-28-15ab	L. B. Martin	1955	Dr	130	6	P	J	E	D	2,305	70	--------	
29ad	U.S. Government	----	Dn	24	1 1/2	P	P	H	N	2,275	19.0	10-18-67	
B37-27- 6cb	Leo Collar	----	Dr	90	4	P	J	E	D	2,360	52.0	7-20-66	Ca
7bc	Louis Brown	----	Dr	120	6	P	J	E	D	2,375	75	--------	
7cc	U.S. Geol. Survey	1967	Dr	140	6	P	N	N	O	2,357	50.0	7- 8-67	Y 9; D 0; Tw
8da	I. M. Brown	----	Sp	---	-----	---	---	---	S,I	2,405	----	3- 7-67	F 1,350
14cb	Robert William	----	Dr	299	5	P	J	E	D,S	2,670	85.2	10-17-67	Ca
17cd	H. D. Smiley	----	Sp	---	-----	---	---	---	D,S	2,440	----	3- 7-67	Ca; F 315; Campbell Spring
20cc	-----do-----	----	Sp	---	-----	---	---	---	D,I	2,410	----	3- 7-67	F 5,400
28cb	U.S. Geol. Survey	1967	Dr	340	6	P	N	N	O	2,600	111.1	7-12-67	L; Y 9; D 1; Tw
33cd	Don Benedict	----	Dr	162	6	P	S	E	D	2,619	58.8	10-17-67	
33dc	Iowa Flats School	1966	Dr	237	6	P	N	N	O	2,611	52.2	10-18-66	
34cd	John Mocko	----	Dn	36	1 1/2	P	J	E	D	-----	----	--------	
35dd	Dick Brinton	----	Dr	---	7	P	S	E	D,S	2,673	132.8	7-19-66	Ca

Table 7.–Drillers' logs of wells and test holes. (Test-hole locations without section subdivisions are uncertain and are not shown on Plate 2.)

	Thickness (feet)	Depth (feet)
B30-23-1ab		
Sand	20	20
Bedrock	96	116
B31-23-3db1		
Clay, silty	33	33
Clay; and cobbles	46	79
Clay	53	132
Clay; and gravel	8	140
Clay; and grit	106	246
Clay, sand, and gravel; bluish-gray	16	262
Clay; and gravel; dark-yellowish-orange (seepage water)	56	318
Clay, gravel, and rock; dark-yellowish-orange (water)	30	348
B31-23-13cc		
Clay	75	75
Sand and gravel	2	77
B31-23-36bb		
Clay	80	80
Bedrock	7	87
B31-23-36dc		
Topsoil	1	1
Clay	43	44
Bedrock	131	175
B32-23-17bb		
Gravel	24	24
Hardpan	12	36
Gravel	3	39

Table 7—Continued

	Thickness (feet)	Depth (feet)
B33-24-9dd		
Topsoil	1	1
Gravel and boulders	43	44
Sand and gravel (water)	9	53
B34-25-17		
Topsoil	3	3
Hardpan and large boulders	35	38
Gravel, cemented	51	89
Sand (water)	12	101
Sand, coarse, and gravel	4	105
B34-25-17		
Topsoil	1	1
Clay, silty	41	42
Sand, silty (seepage water)	60	102
Sand, fine	61	163
Sand	18	181
Quicksand	6	187
Sand, coarse, and gravel (water)	2	189
B34-25-20		
Clay, gravel, and boulders	35	35
Gravel and rock	3	38
Clay, brown, soft	18	56
Clay and boulders	45	101
Gravel, clay, and sandy clay; in layers	7	108
Clay, soft, muddy	2	110
Gravel, rough and hard (water)	4	114
B34-25-19		
Overburden	11	11
Clay and silt; contains layers of gravel and boulders	90	101
Gravel, cemented	6	107
Clay; contains hard layers, and boulders	66	173
Gravel, and boulders	17	190

Table 7—Continued

	Thickness (feet)	Depth (feet)
B34-25-19		
Silt and gravel	30	30
Silt, brown; contains layers and pockets of sand and gravel	95	125
Clay, gray and brown in layers	102	227
Clay, gray	8	235
Gravel (water)	10	245
B34-26-5ab		
Gravel, cemented, and clay	140	140
Gravel, water-bearing, and heavy sand	7	147
B35-25-31ca		
Silt	120	120
Gravel, blue	5	125
B35-26-11dd		
Gravel, non-water-bearing	17	17
Gravel and sand, water-bearing	18	35
B35-26-25ab		
Overburden	12	12
Gravel and gray clay	14	26
Clay, gray, and layers of sand and gravel	54	80
Clay, brown, and layers of sand, gravel, and clay	18	98
Gravel and boulders (water)	9	107

Table 7—Continued

	Thickness (feet)	Depth (feet)
B35-26-25		
Overburden	14	14
Gravel, coarse, and rocks	34	48
Gravel, hard, cemented	23	71
Hard formation	11	82
Clay, gray, hard, and boulders	40	122
Clay, gray, soft	60	182
Gravel	1	183
Clay, gray, soft	73	256
Boulders and rocks (water)	11	265
B35-26-25ca		
Clay	23	23
Clay, sandy	6	29
Hardpan, brown	33	62
Hardpan, dark-brown	58	120
Sand, coarse, water-bearing	4	124
B36-27-2cb		
Gravel, coarse, loose	45	45
Gravel, sand, and clay	40	85
Sand (water)	5	90
Conglomerate	11	101
B36-27-2		
Overburden	6	6
Clay, sandy	11	17
Gravel and boulders	18	35
Boulders and layers of clay	65	100
Gravel layers	50	150
Clay, gray, soft	100	250
Clay, brown, soft	31	281
Gravel and rock (water)	12	293
Sand	2	295
Clay, silty	2	297
Gravel (water)	8	305

Table 7—Continued

	Thickness (feet)	Depth (feet)
B36-27-3cc		
Gravel, loose	100	100
Sand and gravel	20	120
Gravel, sand, and clay	40	160
Clay	20	180
Clay, sandy	40	220
Sand and gravel	40	260
B36-27-10		
Gravel and silt	32	32
Clay	16	48
Clay, muddy, hard	27	75
Clay, muddy, hard; contains thin gravel beds	18	93
Sand and boulders	8	101
Clay	4	105
Clay, gravel, and boulders	22	127
B36-27-11bb		
Gravel, very coarse	35	35
Boulders	48	83
Gravel, very coarse, and boulders	39	122
Sand, coarse, and gravel	27	149
Sand, fine, brown	37	186
Clay, dark	15	201
Clay, light	3	204
Gravel, water-bearing	>1	204
B36-27-11		
Clay, gravel, and sand	25	25
Gravel, cemented	20	45
Gravel, water-bearing	9	54

Table 7—Continued

	Thickness (feet)	Depth (feet)
B36-27-11		
Clay and boulders	24	24
Gravel, and layers of clay	43	67
Clay and boulders	21	88
Gravel and broken rocks	6	94
Clay, hard	10	104
Clay and gravel	6	110
Sand	41	151
Silt and boulders	39	190
Gravel and boulders (water)	15	205
B36-27-11		
Overburden	5	5
Gravel, coarse, and clay	27	32
Rocks and boulders	3	35
Clay, sandy	4	39
Rocks and boulders	19	58
Clay, hard	13	71
Clay, gray, soft	49	120
Sand, fine, brown	11	131
Boulders and layers of rock	12	143
Sand, soft	1	144
Rocks, hard	6	150
Gravel and layers of soft clay	11	161
Clay, gray, hard	50	211
Gravel and broken shale	18	229
B36-27-11cb		
Clay and coarse gravel	36	36
Clay and sand	13	49
Gravel, cemented, and hardpan	12	61
Hardpan, light-brown	17	78
Gravel and sand	7	85
Sand, coarse (water)	11	96
Gravel and coarse heavy sand (good water supply)	8	104
Clay and coarse gravel (water shut off)	2	106

Table 7—Continued

	Thickness (feet)	Depth (feet)
B36-27-11		
Topsoil	2	2
Gravel and cobbles	49	51
Sand	71	122
Rock (water)	78	200
B36-27-11		
Clay, sandy	10	10
Clay, brown, soft	6	16
Clay, hard, and boulders	5	21
Sand, coarse	10	31
Gravel, clay, and rocks; in layers	11	42
Clay, sandy	13	55
Clay, hard, and rocks	11	66
Boulders	3	69
Sand	12	81
Rocks and boulders	6	87
Clay, hard, and boulders	24	111
Boulders and gravel (water)	8	119
Clay	18	137
Rocks and gravel (water)	4	141
B36-27-14		
Overburden	4	4
Sand, fine	8	12
Gravel, cemented	25	37
Clay, brown, and boulders	20	57
Clay, gray, soft	34	91
Sand, layers are soft to hard	22	113
Shale, very hard	2	115
Gravel and boulders (water)	12	127
B36-27-14		
Clay, sand, and gravel	42	42
Gravel, water-bearing, and clay	8	50

Table 7—Continued

	Thickness (feet)	Depth (feet)
B36-27-14bb		
Overburden	45	45
Clay	3	48
Silt and gravel	7	55
Clay and layers of gravel	13	68
Silt, sand, and gravel	5	73
Clay and layers of gravel	10	83
Gravel, coarse (water)	19	102
B36-27-14		
Sand, clay, and gravel	50	50
Cemented gravel, and sand; very tight (water).	105	155
Gravel, water-bearing	76	231
B36-27-15		
Silt, sandy	36	36
Silt and gravel	8	44
Gravel, water-bearing	2	46
B36-27-15		
Subsoil	16	16
Sand and gravel	24	40
Clay and sand	36	76
Rock	3	79
B37-27-33		
Overburden	2	2
Clay, hard, sandy	3	5
Clay, sandy, and fine gravel	18	23
Gravel, coarse, and boulders; contains some clay layers	22	45
Clay in layers, or sandstone	7	52
Boulders and rock (water level, 60 feet)	25	77
Gravel, cemented, and hard shale layers	33	110
Boulders, rough gravel, and hard clay (water level, 118 feet)	15	125

Table 7–Continued

	Thickness (feet)	Depth (feet)
B37-27-33--continued		
Clay, hard	5	130
Clay and boulders	25	155
Drills very rough	1.5	156.5
Sand, hard, or sandy clay	1	157.5
Drills very rough	0.5	158
Sand, hard, or sandy clay	2	160
Boulders and clay; contains water	2	162
Clay and boulders	14	176
Boulders and rock	3	179
Clay, soft, or sandy clay	13	192
Clay, soft; contains occasional hard layer or boulder	31	223
Clay, hard, and rock	6	229
Boulders (water level, 230 feet)	3	232
Sand, soft, or clay	1	233
Boulders	1	234
Boulders and clay	13	247
Clay, soft	4	251
Clay in layers	54	305

Table 8.–Measurements of depth to water in wells and stage measurements of lakes, springs, and streams.

Date	Water level	Date	Water level	Date	Water level
		B36-27-5ab			
1966		1967		1968	
July 20	38.06	May 4	38.97	Jan. 23	43.28
Oct. 18	35.04	June 7	39.13	Mar. 5	44.10
Nov. 9	38.14	July 8	39.46	Apr. 8	44.56
Dec. 7	40.89	Aug. 5	37.18	May 2	44.76
1967		Aug. 28	37.11	May 28	39.20
Jan. 10	42.56	Sept. 26	36.28	July 2	40.53
Feb. 7	43.29	Nov. 6	39.39	discontinued	
Mar. 6	43.84	Nov. 28	41.17		
Apr. 4	44.20				
		B36-27-5dc			
1966		1967		1967	
July 19	32.25	Apr. 4	36.43	Nov. 6	31.36
Oct. 18	28.88	May 4	43.47	Nov. 28	32.67
Nov. 9	29.62	June 7	35.70	1968	
Dec. 7	31.60	July 8	52.34	Jan. 23	35.00
1967		Aug. 5	33.02	Mar. 5	36.17
Feb. 7	34.97	Aug. 28	32.04	May 2	50.89
Mar. 6	36.87	Sept. 26	31.44	May 28	36.38
				discontinued	
		B37-27-7cc			
1967		1967		1968	
July 8	50.00	Oct. 26	56.12	Apr. 8	56.62
Aug. 17	54.28	Nov. 2	56.07	May 2	55.19
Aug. 24	54.62	Nov. 6	56.07	May 28	51.04
Aug. 31	55.03	Nov. 28	56.89	July 2	51.50
Sept. 7	55.25	Dec. 6	56.75	Sept. 9	55.45
Sept. 14	55.51	1968		Oct. 14	55.60
Sept. 21	55.76	Jan. 23	56.62	Nov. 20	56.24
Sept. 28	55.91	Jan. 30	56.91	1969	
Oct. 5	55.98	Feb. 10	56.84	Mar. 18	56.90
Oct. 12	56.07	Mar. 5	56.65	Apr. 22	52.48
Oct. 19	56.07				

Table 8—Continued

Date	Gage height	Date	Gage height	Date	Gage height
		Sophie Creek B37-27-17cb			
1966		1967		1968	
Nov. 9	1.08	Aug. 5	0.98	May 2	.98
Dec. 7	1.07	Aug. 28	0.98	May 28	.98
1967		Sept. 26	1.00	July 2	.70
Jan. 10	1.10	Nov. 6	.98	Sept. 9	.98
Feb. 7	1.04	Nov. 28	1.05	Oct. 14	.98
Mar. 6	1.05	1968		Nov. 20	1.00
Apr. 4	1.02	Jan. 23	1.00	1969	
May 4	1.05	Mar. 5	1.00	Mar. 18	.98
June 7	0.96	Apr. 8	.98	Apr. 22	.70
July 8	0.76				
		Campbell Spring B37-27-17cd			
1966		1967		1968	
Nov. 9	0.82	Aug. 5	.94	May 2	.64
Dec. 7	.81	Aug. 28	.86	May 28	.62
1967		Sept. 26	.80	July 2	.68
Jan. 10	.78	Nov. 6	.78	Sept. 9	.60
Feb. 7	.76	Nov. 28	.74	Oct. 14	.60
Mar. 6	.72	1968		Nov. 20	.59
Apr. 4	.70	Jan. 23	.68	1969	
May 4	.70	Mar. 5	.66	Mar. 18	.53
June 7	.68	Apr. 8	.64	Apr. 22	.50
July 8	1.04				
		Sophie Lake B37-27-21cb			
1966		1967		1968	
Oct. 18	1.84	June 7	3.76	May 2	-4.40
Nov. 9	1.24	Aug. 5	4.36	May 28	-4.40
Dec. 7	0.74	Sept. 26	1.10	July 2	1.88
1967		Nov. 6	- .20	Sept. 9	-2.10
Jan. 10	.35	Nov. 28	- .72	Oct. 14	-2.58
Feb. 2	- .55	1968		Nov. 20	-2.25
Mar. 6	-1.15	Jan. 23	-1.95	1969	
Apr. 4	-2.40	Mar. 5	-3.00	Apr. 22	-5.40
May 4	-3.00	Apr. 8	-4.00		

Table 8—Continued

Tetrault Lake
B37-27-28aa

Date	Water level	Date	Water level	Date	Water level
1966		1967		1968	
Oct. 18	1.32	June 7	-2.54	May 2	-3.34
Nov. 9	1.00	Aug. 5	0.45	May 28	-3.84
Dec. 7	0.60	Sept. 26	0.20	July 2	-3.84
1967		Nov. 6	- .36	Sept. 9	-2.68
Jan. 10	0.28	Nov. 28	- .74	Oct. 14	-2.52
Feb. 2	- .54	1968		Nov. 20	-3.90
Mar. 6	-1.10	Jan. 23	-1.82	1969	
Apr. 4	-1.62	Mar. 5	-2.96	Apr. 22	-5.00
May 4	-2.28	Apr. 8	-3.14		

B37-27-28cb

Date	Water level	Date	Water level	Date	Water level
1967		1967		1968	
July 12	111.06	Nov. 16	100.58	Mar. 20	102.75
Aug. 17	99.14	Nov. 23	100.71	Mar. 31	102.80
Aug. 24	99.27	Nov. 30	100.85	Apr. 8	103.37
Aug. 31	99.35	Dec. 7	100.97	May 2	103.87
Sept. 7	99.43	Dec. 14	101.13	May 28	104.37
Sept. 14	99.53	Dec. 21	101.26	July 2	103.73
Sept. 28	99.77	Dec. 24	101.33	Sept. 9	103.27
Oct. 5	99.87	1968		Oct. 14	103.54
Oct. 12	99.98	Jan. 23	101.90	Nov. 20	103.83
Oct. 19	100.10	Feb. 2	101.93	1969	
Oct. 26	100.21	Feb. 12	101.97	Mar. 18	104.70
Nov. 2	100.32	Feb. 22	102.01	Apr. 22	104.98
Nov. 9	100.45	Mar. 5	102.69		

Murray Creek
B37-27-29bb

Date	Water level	Date	Water level	Date	Water level
1966		1967		1968	
Nov. 9	0.78	Aug. 5	.62	May 2	.32
Dec. 7	.76	Aug. 28	.58	May 28	.50
1967		Sept. 26	.57	July 2	.60
Jan. 10	.75	Nov. 6	.58	Sept. 9	.60
Feb. 7	.74	Nov. 28	.68	Oct. 14	.64
Mar. 6	.74	1968		Nov. 20	.62
Apr. 4	.66	Jan. 23	.68	1969	
May 4	.48	Mar. 5	.38	Mar. 18	.58
June 7	.45	Apr. 8	.42	Apr. 22	.56
July 8	.68				

Table 8–Continued

Date	Water level	Date	Water level	Date	Water level
		B37-27-33dc			
1966		1967		1967	
Oct. 18	52.19	June 23	58.64	Oct. 17	54.80
Nov. 9	54.75	June 30	58.02	Nov. 6	56.51
Dec. 7	57.58	July 7	57.80	Nov. 28	58.45
1967		July 14	57.75	1968	
Jan. 10	59.94	July 21	57.71	Jan. 23	61.01
Feb. 7	60.97	July 28	57.46	Mar. 5	61.87
Feb. 13	60.89	Aug. 5	56.52	Apr. 8	62.91
Feb. 20	61.40	Aug. 12	55.83	May 2	63.71
Mar. 5	61.57	Aug. 19	55.26	May 28	63.36
May 4	62.75	Aug. 26	54.98	July 2	59.85
May 12	62.95	Sept. 2	55.05	Sept. 9	55.79
May 19	63.03	Sept. 9	55.43	Oct. 14	59.29
May 26	62.26	Sept. 16	55.07	Nov. 20	60.90
June 2	61.34	Sept. 23	55.27	1969	
June 9	60.19	Sept. 30	54.68	Mar. 18	63.05
June 16	59.17	Oct. 7	54.73	Apr. 22	62.50
		B37-27-35dd			
1966		1967		1967	
July 19	132.82	Feb. 7	133.48	Nov. 6	132.55
Oct. 18	132.05	Mar. 6	134.00	Nov. 28	132.60
Nov. 9	131.70	Apr. 4	133.86	1968	
Dec. 7	131.90	May 4	134.50	Jan. 28	134.10
1967		Aug. 28	133.08	Mar. 5	133.80
Jan. 10	132.55	Sept. 28	132.83		discontinued

Table 9.–Chemical analyses of water from selected wells, springs, lakes, and streams. (Analyses by Montana State Board of Health. Analytical results in milligrams per liter.)

Location	Date of collection	Name or owner	Aquifer	Iron (Fe)1/	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids2/	Total hardness ($CaCO_3$)
B30-23- 1ab	9-27-67	L. Kelch	Lake-bottom deposits	0	52	22	25	329	0	1	2	0.1	0	270	220
B30-24-22c	10-16-68	Stillwater River	----------	0	34	11	0	146	0	0	1	0	---	126	130
B31-23- 4aa	9-27-67	L. Boe	Alluvium	0	44	9	19	220	0	4	2	0	0	180	145
25ab	9-27-67	A. Evans	Lake-bottom deposits	0	52	29	27	366	0	2	2	0	0	290	250
B32-23- 7ac	9-27-67	W. Mattson	Outwash	0	40	8	16	165	12	6	3	0	0	160	130
17bb	9-27-67	State of Montana	Outwash	0	40	9	20	214	0	0	3	0	0	172	135
B33-23-32dd	9-26-67	E. Adams	Outwash	0	56	20	23	275	24	0	3	.1	0	248	220
B34-24-31bc	9-26-67	J. Openshaw	Alluvium	.07	18	5	13	110	0	0	2	0	0	80	65
B34-25- 9d	10-15-68	Dickey Lake	----------	.0	30	16	2	152	12	0	1	.08	0	144	140
B35-25-19ba	9-26-67	E. Vredenburg	Outwash	.03	42	40	46	427	0	9	7	.01	0	336	270
31ca	9-26-67	B. Parker	Outwash	0	40	20	20	232	15	6	2	0	0	206	180
B35-26-14bd	9-26-67	L. Norman	Alluvium	0	34	13	22	207	9	0	1	0	0	170	140
24dc	9-26-67	W. Wydemeyer	Outwash	.04	40	20	21	244	12	1	3	0	0	210	180
25ab	9-26-67	-----do-----	Outwash	.04	38	16	21	247	0	0	2	0	0	194	160
25ca	9-26-67	Fortine School	Outwash	.06	40	18	27	238	18	4	2	0	0	210	175
B36-26-27a	9-26-67	Glen Lake	----------	.08	24	11	16	159	0	6	2	0	0	128	105
33dc	9-26-67	Eureka Grange	Alluvium	0	38	23	37	308	0	13	3	0	0	226	190
B36-27- 4dc2	10-18-66	A. Nutting	Deltaic deposits	0	9	12	605	1,338	605	3	143	5.2	0	1,500	72
5bd	10-18-66	H. Lenarz	Deltaic deposits	0	40	30	45	265	15	49	11	.2	10.2	310	220
8ab	10-18-66	B. Roe	Lake-bottom deposits	0	11	23	82	195	0	70	47	.6	0	314	121
9d	10-18-66	Tobacco River	----------	0	46	8	30	250	0	0	4	.1	0	180	149
14ba	9-26-67	H. Bergette	Deltaic deposits	0	40	23	51	296	18	16	10	.2	8.1	280	195
26c	10-15-68	Thirsty Lake	----------	0	0	88	2,112	2,020	1,510	91	450	.76	1.6	5,540	360
B37-26-30d	9-26-67	Indian Creek	----------	.08	30	12	14	177	0	5	3	0	0	136	125
B37-27- 1b	9-26-67	Phillips Creek	----------	0	24	11	24	165	0	15	5	0	0	120	105
1b	5-29-68	Phillips Creek	----------	.1	19	20	0	97	0	8	4	.44	0	88 to 110	129
6cb	9-26-67	L. Collar	Alluvium	0	50	15	24	177	0	84	5	.4	.5	250	185
14cb	9-26-67	R. William	Deltaic deposits	0	28	15	20	195	0	9	3	0	0	142	130
17bd	9-26-67	Sophie Creek	Lake-bottom deposits	0	30	13	22	201	0	7	4	0	0	150	130
17bd	5-29-68	-----do-----	Lake-bottom deposits	.05	33	22	0	171	0	4	5	.12	0	148	192
17cd	9-26-67	Campbell Spring	Lake-bottom deposits	.03	26	16	15	183	0	4	5	0	0	136	130
21cb	10-18-66	Sophie Lake	----------	.12	24	9	31	190	0	3	3	.1	0	114	99
21cb	11- 9-67	-----do-----	----------	.03	16	10	18	134	0	7	2	0	0	90	80
21cb	5-29-68	-----do-----	----------	0	46	4	0	127	0	0	5	.28	0	132	134
21cb	10-14-68	-----do-----	----------	0	30	9	0	122	0	1	0	0	0	100	110
28aa	9-26-67	Tetrault Lake	----------	.08	18	16	24	183	0	8	3	0	0	134	110
28aa	5-29-68	-----do-----	----------	.05	37	21	0	181	0	4	4	.2	0	152	178
28aa	10-14-68	-----do-----	----------	0	20	22	0	158	0	2	3	0	0	120	140
29bb	10-18-66	Murray Creek	Lake-bottom deposits	0	31	13	21	177	12	5	4	.1	0	140	132
29bb	9-26-67	-----do-----	Lake-bottom deposits	0	24	13	23	189	0	4	2	0	0	150	115
29bb	12-19-67	-----do-----	Lake-bottom deposits	.01	30	15	4	170	0	4	.2	0	.1	146	136
29bb	5-29-68	-----do-----	Lake-bottom deposits	0	38	22	0	116	0	.4	4	.6	0	110	187
29bb	10-14-68	-----do-----	Lake-bottom deposits	0	30	18	2	183	0	1	1	0	0	136	150
35dd	10-18-66	Dick Brinton	Deltaic deposits	0	42	17	15	220	12	2	3	.1	1.2	194	176

1/ In solution at time of analysis
2/ Calculated

Table 10.—Discharge measurements at miscellaneous sites.

Date	Discharge (cfs)	Date	Discharge (cfs)
Phillips Creek at international boundary (B37-27-1cbb)			
12- 3-65	3.59	6-20-67	104
5-24-66	40.8	6-22-67	102
7-19-66	17.9	6-23-67	86.8
8-26-66	3.22	6-24-67	77.1
9-29-66	0	6-26-67	73.1
5-29-67	122	6-27-67	71.5
6- 6-67	68.9	6-29-67	66.5
6- 7-67	79.5	7- 6-67	34.2
6- 8-67	96.5	7- 7-67	30.5
6- 9-67	110	7- 9-67	27.7
6-10-67	110	7-10-67	25.4
6-11-67	88.7	7-12-67	24.8
6-12-67	80.4	7-14-67	20.1
6-13-67	84.2	7-18-67	12.5
6-14-67	69.9	7-19-67	11.9
6-16-67	86.7	7-21-67	6.8
6-17-67	115	7-24-67	5.6
6-18-67	110	8- 8-67	2.07
6-19-67	106	9-19-67	3.55
Phillips Creek 2.2 miles south of international boundary (B37-27-15aaa)			
5-24-66	20.9	6-22-67	82.2
7-19-66	15.9	6-23-67	63.1
5-29-67	96.9	6-24-67	57.9
6- 6-67	64.6	6-26-67	55.4
6- 7-67	63.5	6-27-67	54.6
6- 8-67	79.9	6-29-67	52.3
6- 9-67	85.6	7- 6-67	24.2
6-10-67	95.6	7- 7-67	24.4
6-11-67	97.3	7- 9-67	21.5
6-12-67	74.1	7-10-67	20.0
6-13-67	73.9	7-12-67	19.0
6-14-67	72.8	7-14-67	14.0
6-16-67	75.1	7-18-67	6.3
6-17-67	88.5	7-19-67	5.5
6-18-67	89.3	7-21-67	2.3
6-19-67	89.8	7-24-67	1.0
6-20-67	84.9	7-31-67	.38
6-21-67	83.6		

Location	Date	Discharge (cfs)
Fortine Creek		
B33-26-28aac	2- 7-67	10.1
21daa	2- 7-67	31.8
B35-26-15bcc	10-18-66	24.2

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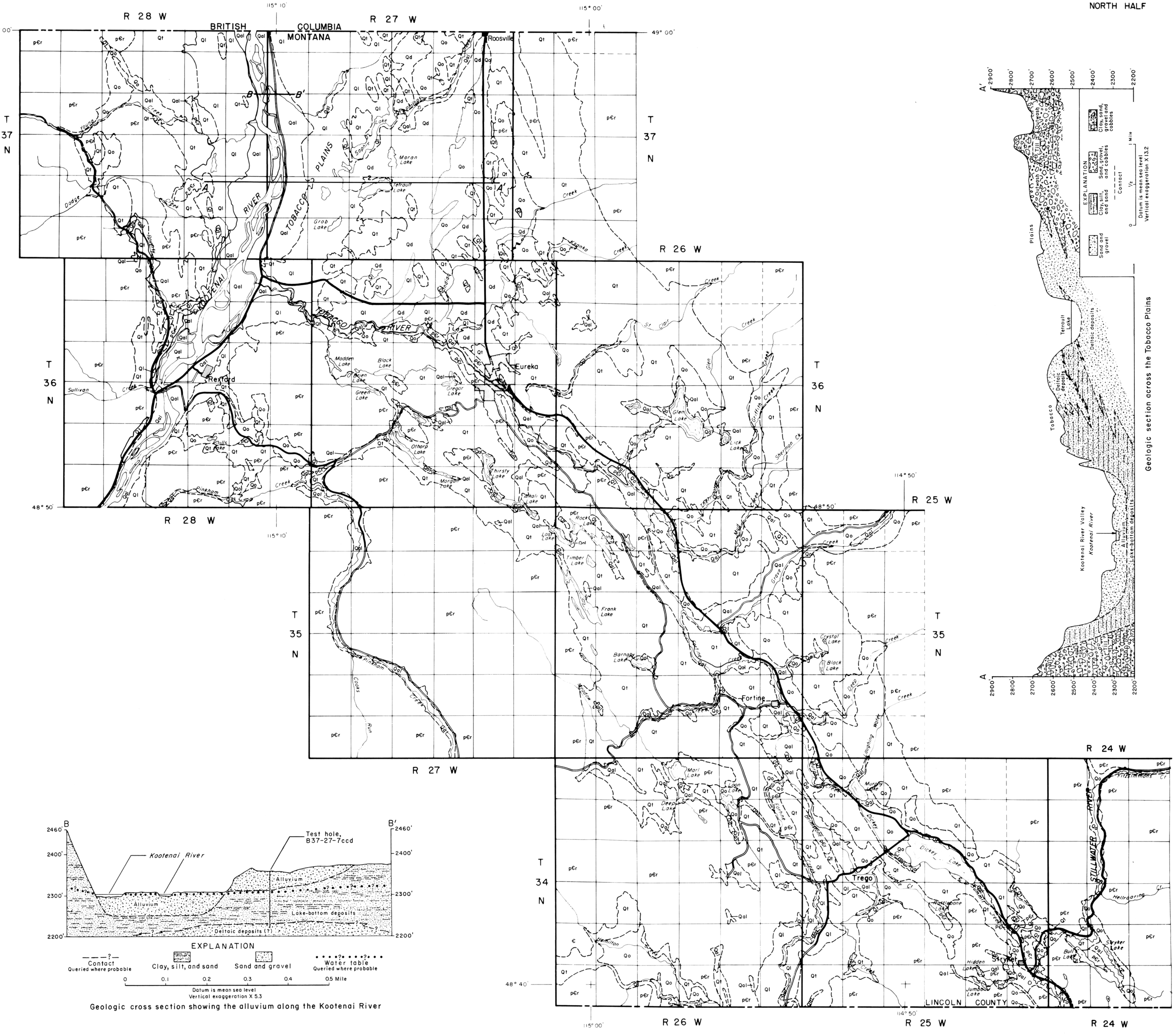

Geologic cross section showing the alluvium along the Kootenai River

Geologic section across the Tobacco Plains

SURFICIAL GEOLOGIC MAP OF THE TOBACCO AND UPPER STILLWATER RIVER VALLEYS, NORTHWESTERN MONTANA

(North Half)

PREPARED IN COOPERATION WITH THE
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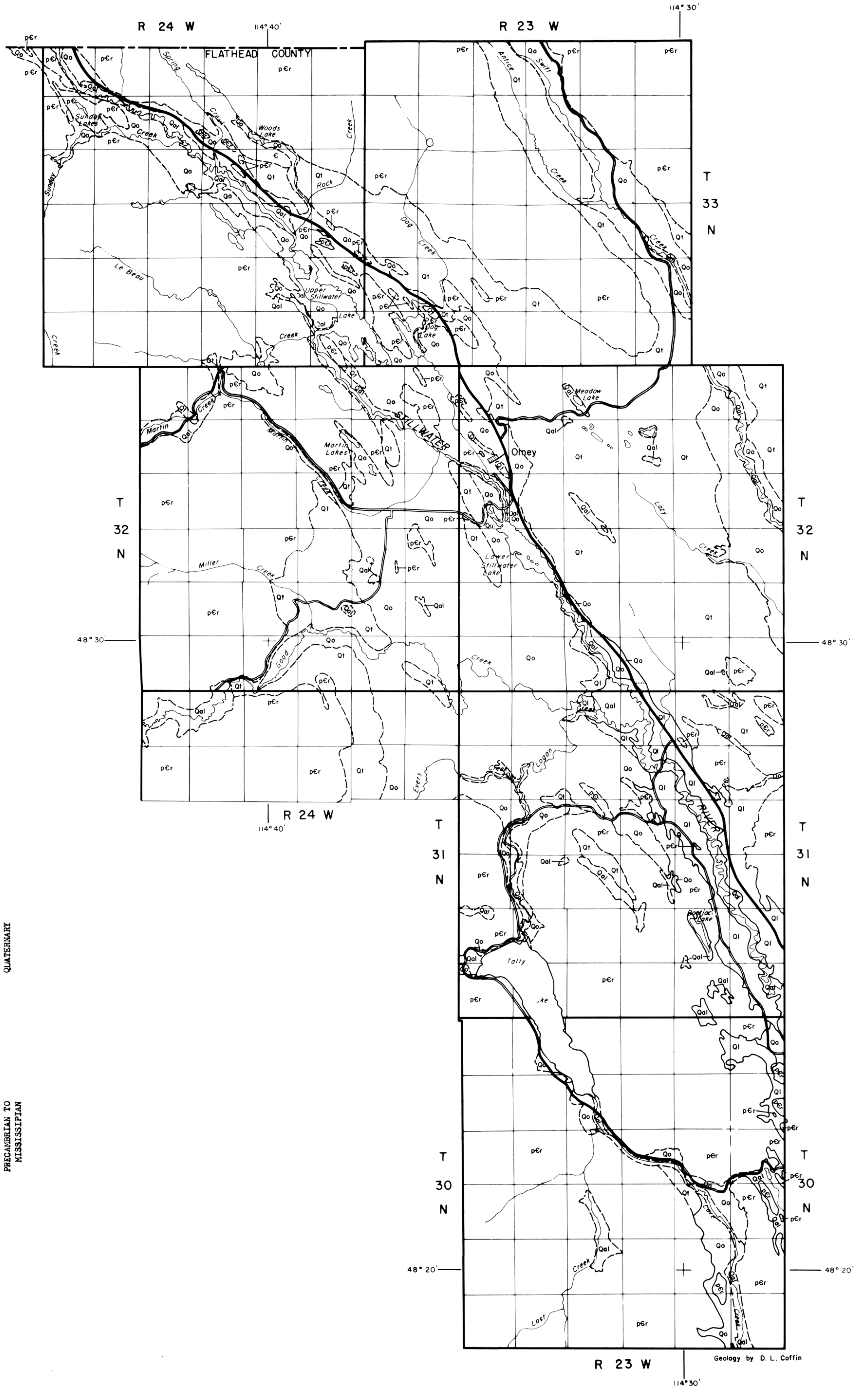
SOUTH HALF



Geology by D. L. Coffin

EXPLANATION

Qal

Alluvium

Sand and gravel along the larger streams; contains a large percentage of clay along the smaller streams and along the Stillwater River south of Olney, small patches of alluvium contain a large percentage of organic material

Ql

Lake-bottom deposits

Silt, clay, and sand deposited in the quiet-water parts of the glacial lakes

Qd

Deltaic deposits

Sand and gravel deposited near the mouths of tributaries to the glacial lakes

Qo

Outwash

Sand, gravel, clay, and silt, poorly sorted in the higher parts of a drainage basin, but better sorted at the lower altitudes

Qt

Till

Unsorted mixture of clay, silt, sand, gravel and boulders, clay and silt predominate, but near bedrock outcrops the percentage of boulders increases

Pleistocene and Holocene

QUATERNARY

pЄr

Precambrian rocks

Argillite, impure limestone, quartzite, and basalt, includes limestone and quartzite of Devonian and Mississippian age east of Roosville

PRECAMBRIAN TO MISSISSIPIAN

——— – – – – ……

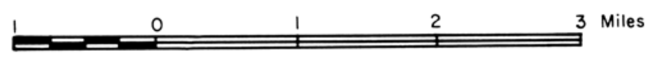
Contact

Dashed where approximately located, dotted where inferred.

A————A'

Line of geologic section

Sections shown on figures 6 and 11



Base from U. S. Forest Service, 1968

SURFICIAL GEOLOGIC MAP OF THE TOBACCO AND UPPER STILLWATER RIVER VALLEYS, NORTHWESTERN MONTANA

(South Half)

MONTANA BUREAU OF MINES AND GEOLOGY

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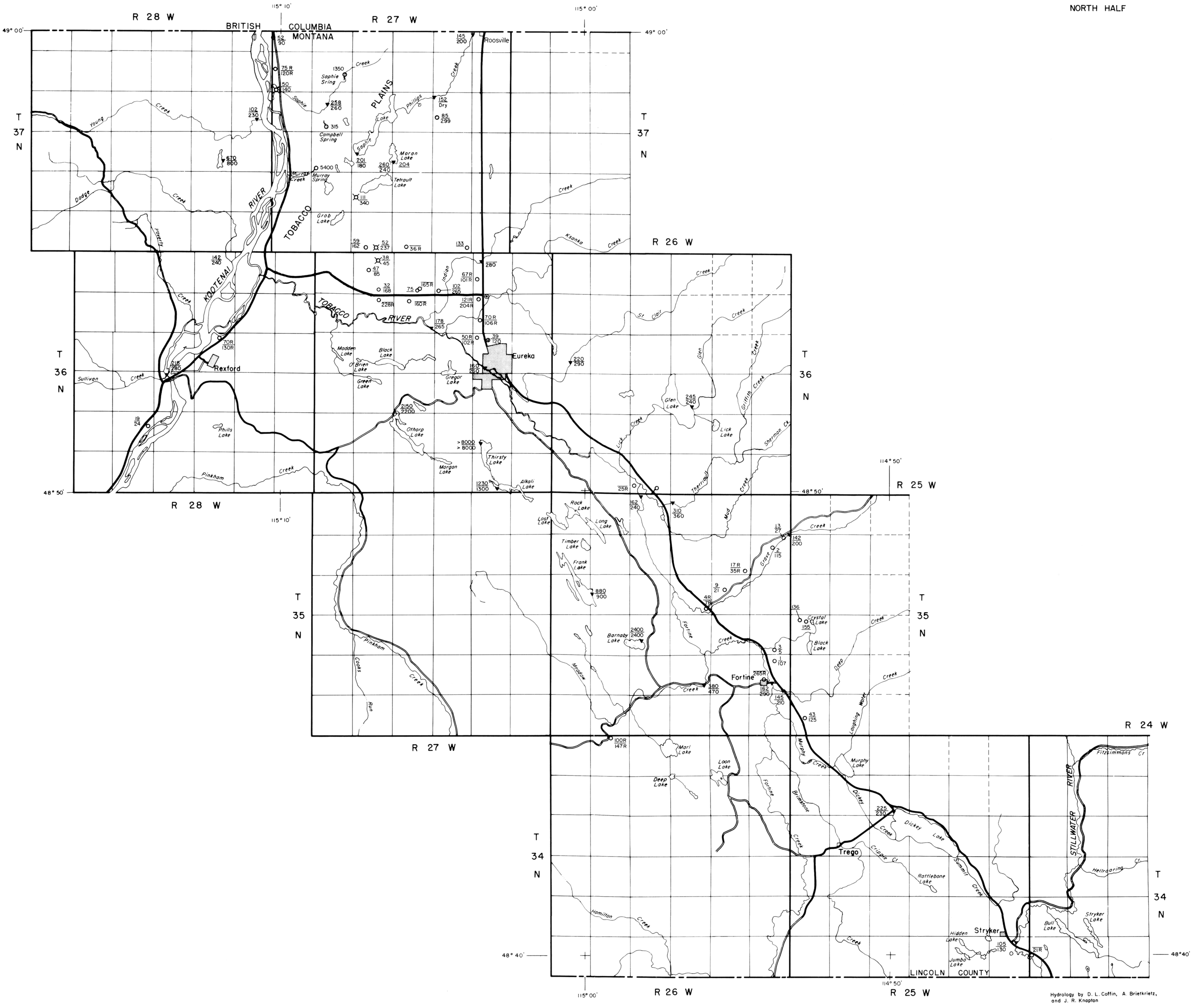
BULLETIN 81 PLATE 2

NORTH HALF



Hydrology by D. L. Coffin, A. Brietkrietz, and J. R. Knapton

MAP SHOWING LOCATION OF WELLS AND SPRINGS, DEPTH TO WATER IN WELLS, DEPTH OF WELLS, AND CONDUCTANCE OF SURFACE WATER AT SELECTED SITES OF THE TOBACCO AND UPPER STILLWATER RIVER VALLEYS, NORTHWESTERN MONTANA

(NORTH HALF)

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BULLETIN 81 PLATE 2

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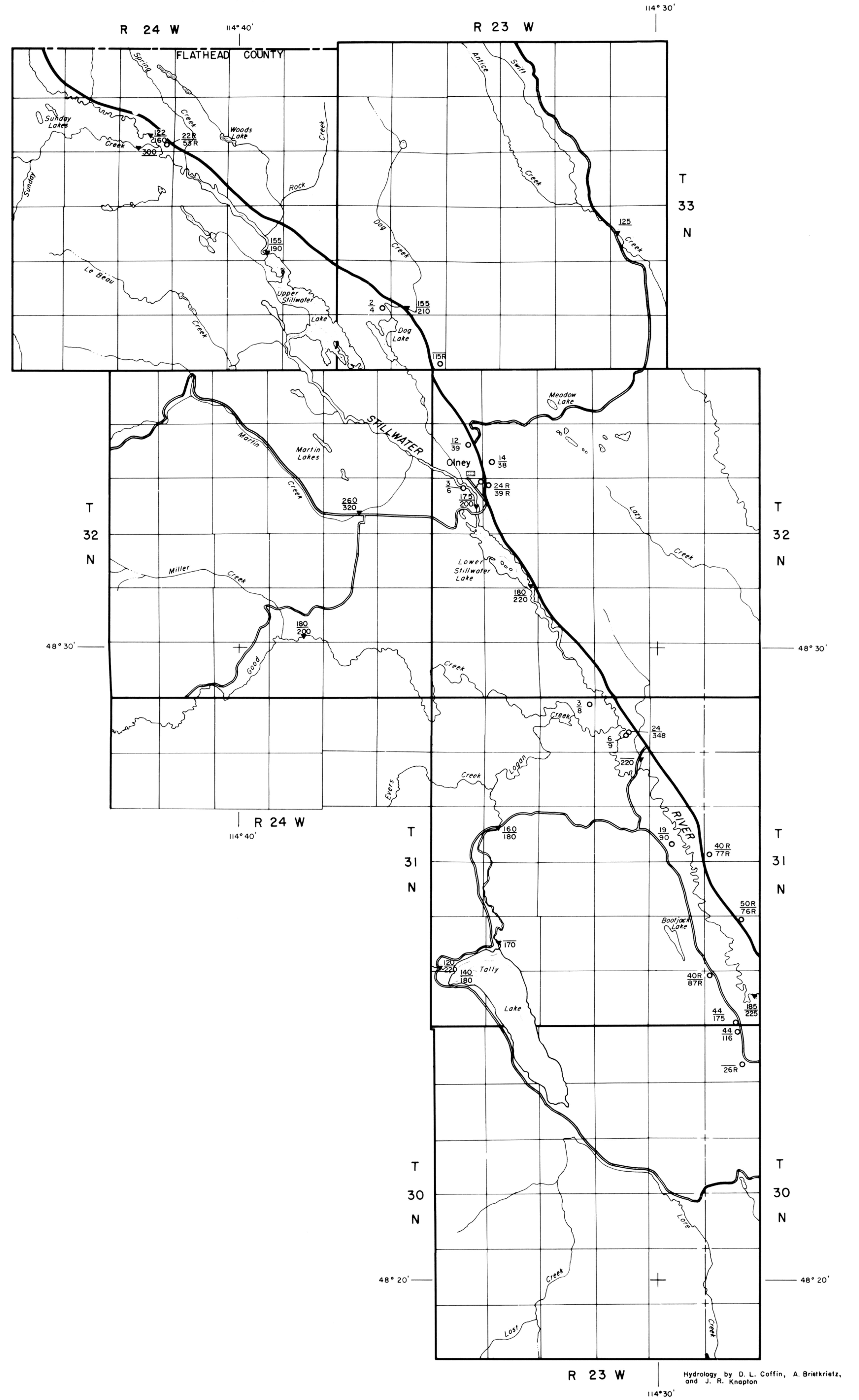

Hydrology by D. L. Coffin, A. Brietkrietz, and J. R. Knapton

EXPLANATION

○ $\frac{40R}{77R}$
Domestic or stock well
Top number is depth to water, in feet; bottom number is depth of well, in feet. R indicates value reported.

$\frac{50}{140}$
Observation well
Top number is depth to water, in feet; bottom number is depth of well, in feet.

⊙ $\frac{39}{120}$
Industrial Well
Top number is depth to water, in feet; bottom number is depth of well, in feet.

315
Spring
Number is flow, in gallons per minute

▼ $\frac{180}{220}$
Location of measurement of electrical conductance of surface water
Top number is the conductance on June 1, 1968; bottom number is the conductance on October 15, 1968. Measurement in micromhos per centimeter at 25° C.

1 0 1 2 3 Miles

Base from U. S. Forest Service, 1968

MAP SHOWING LOCATION OF WELLS AND SPRINGS, DEPTH TO WATER IN WELLS, DEPTH OF WELLS, AND CONDUCTANCE OF SURFACE WATER AT SELECTED SITES OF THE TOBACCO AND UPPER STILLWATER RIVER VALLEYS, NORTHWESTERN MONTANA

(SOUTH HALF)

PREPARED IN COOPERATION WITH THE
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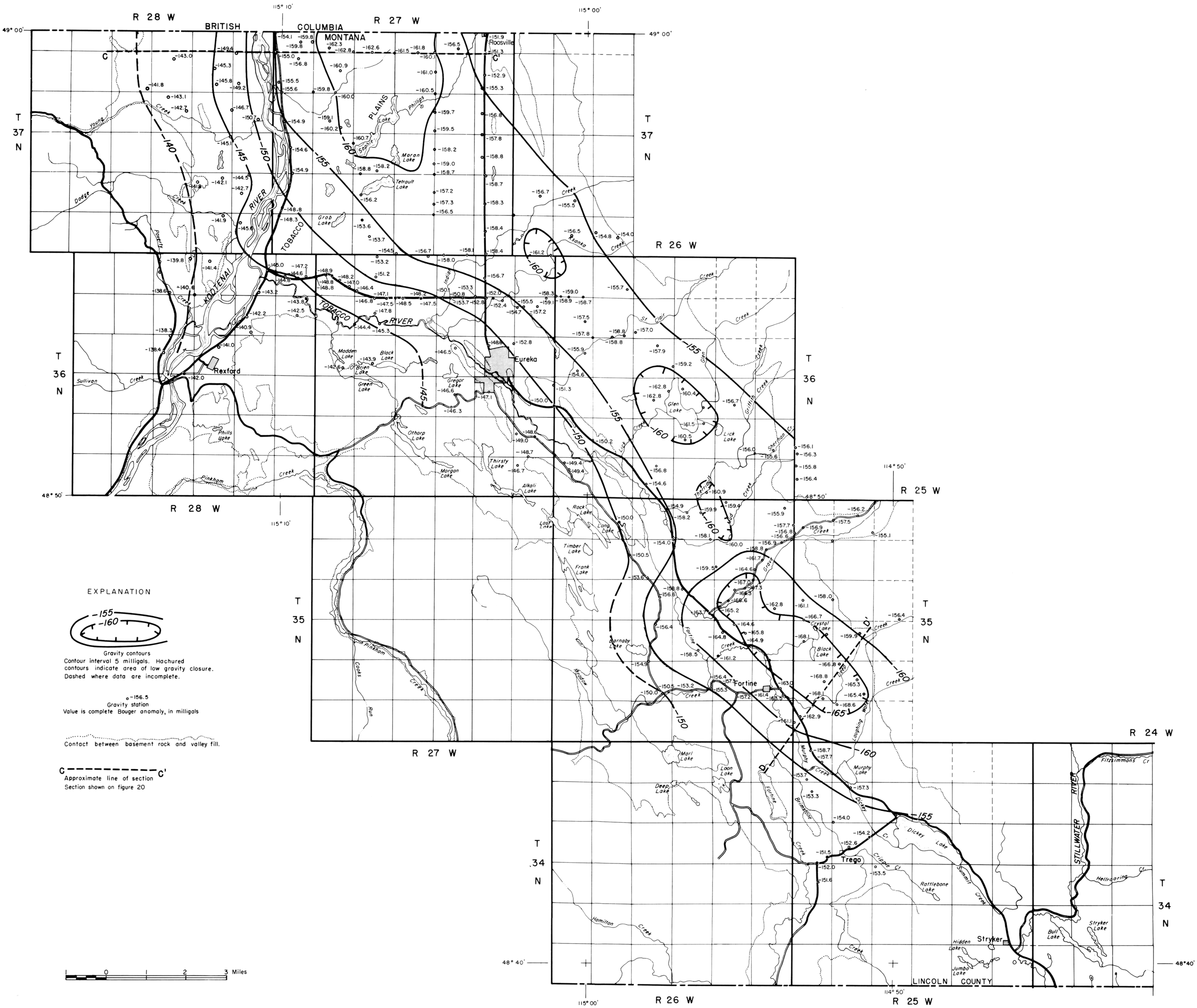

EXPLANATION

-155
-160
Gravity contours
Contour interval 5 milligals. Hachured contours indicate area of low gravity closure. Dashed where data are incomplete.

-156.5
Gravity station
Value is complete Bouger anomaly, in milligals

Contact between basement rock and valley fill.

C — — — C'
Approximate line of section
Section shown on figure 20

Base from U. S. Forest Service, 1968

Gravity by R. G. Mc Murtrey

GRAVITY MAP OF THE TOBACCO PLAINS AND TOBACCO RIVER VALLEY, NORTHWESTERN MONTANA

1968