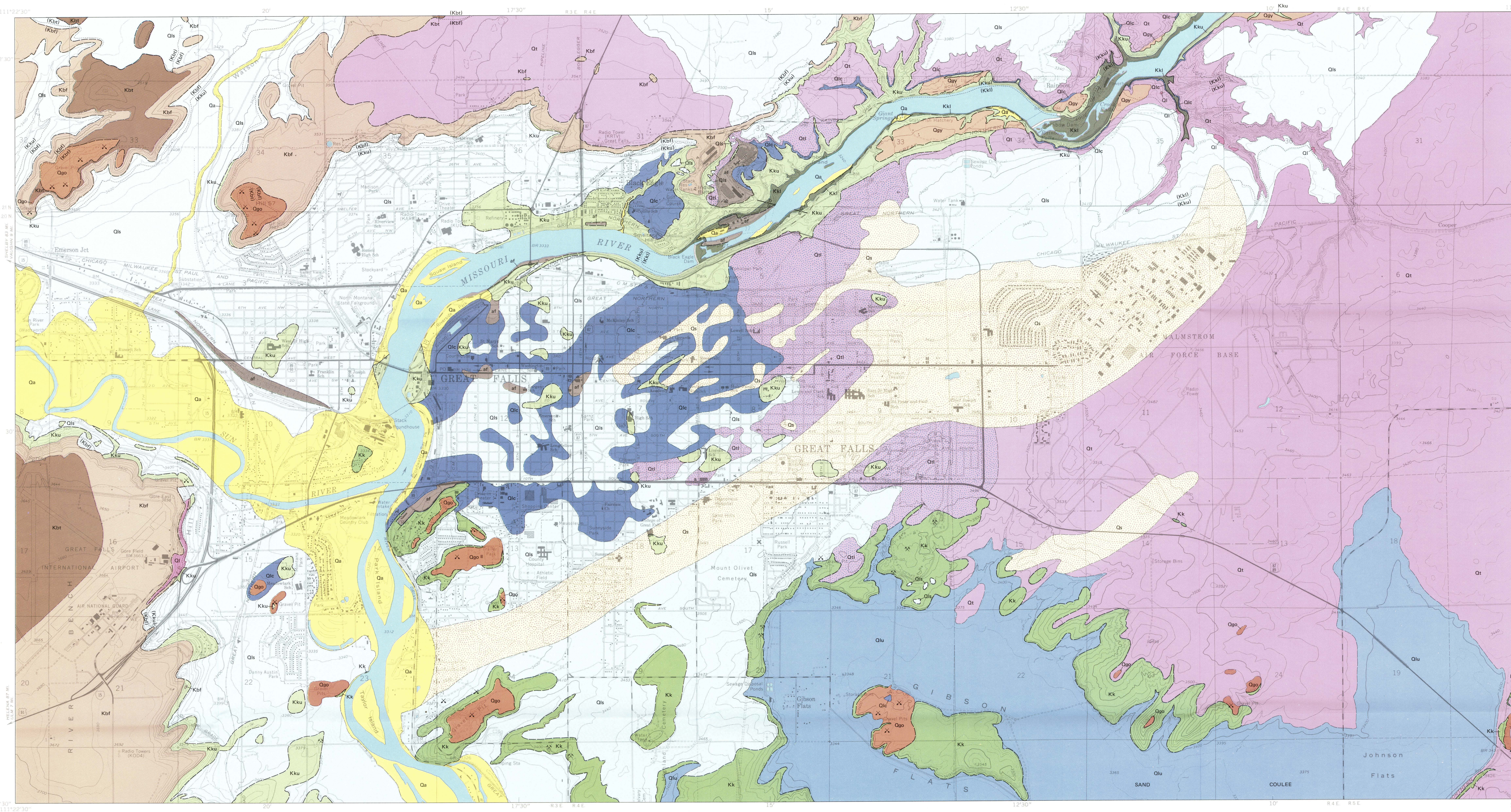
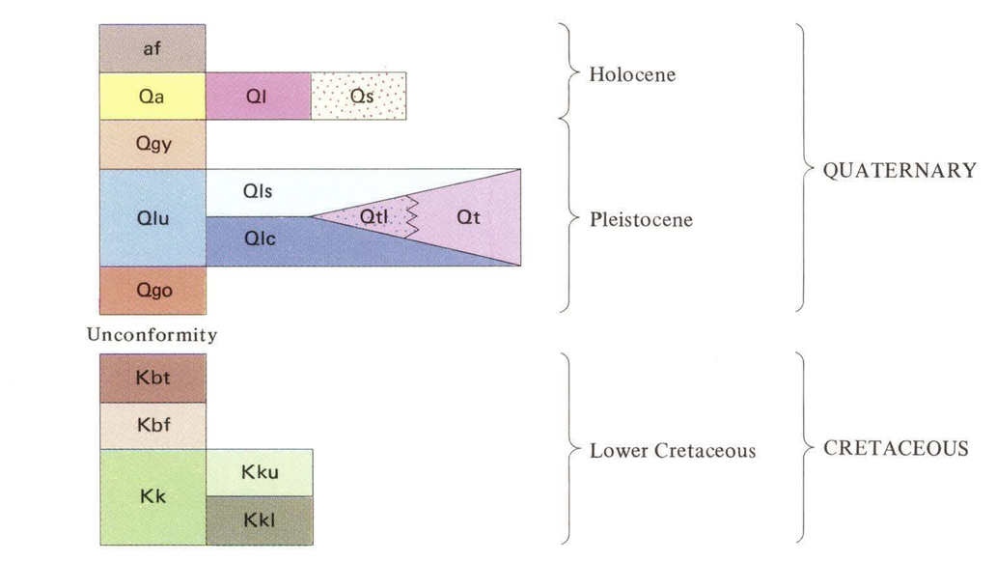


Geology mapped in 1950–53 and 1974–75

GEOLOGIC MAP

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

af — ARTIFICIAL FILL (HOLOCENE) – Chiefly clay, silt, sand, and sandstone rubble derived largely from building excavations; also includes bricks, cinders, concrete, and other manmade refuse. Generally loose fills emplaced in low areas that were poorly drained or semicompacted fills used as pads surrounding buildings or for other facilities. Generally less than 10 feet (3 m) thick. Does not include highway and other road fills or small areas of railroad fills

Qa — ALLUVIUM (HOLOCENE) – Mostly silt and fine sand, minor clay and gravel. Deposited chiefly on the flood plains of the Sun and Missouri Rivers; water table in most places is within 10 feet (3 m) of the surface. Generally loose, fairly permeable, and subject to slumping along steep undercut river banks. As indicated from auger holes, thicknesses are believed to commonly range from 10–40 feet (3–12 m), but in most places it is difficult to distinguish the alluvium from underlying Qls deposits

Ql — LANDSLIDE DEPOSITS (HOLOCENE) – Mostly slumps but also includes small debris slides and mudflows. Along steep east face of Gore Hill the slide material consists chiefly of Qls deposits and minor bedrock rubble; sliding is accelerated where natural slopes have been steepened by man. Sliding in northeast part of map area is on steep natural slopes and involves Qls and Qt deposits

Qs — DUNE SAND (HOLOCENE) – Mostly windblown fine sand, in places forming semiactive dunes 3–5 feet (1–2 m) high. Very loose, highly permeable, and highly subject to wind and water erosion. Generally less than 10 feet (3 m) thick; not mapped in most places where less than 2–3 feet (0.5–1 m) thick. Indefinite contact with Qls deposits in eastern part of map area

Qgy — YOUNGER GRAVEL (PLEISTOCENE) – Very poorly sorted gravel, sand, cobbles, and boulders consisting of quartzites, argillites, locally derived sandstones, and a few granitic rock types. Forms terrace remnants in Missouri River trench in northern part of mapped area; highly permeable and well drained. As much as 40 feet (12 m) thick but more commonly 15–25 feet (5–8 m) thick. Locally underlain by Qlc or Qt deposits but in most places the unit lies directly on bedrock (Kku)

Qlu — GLACIAL LAKE GREAT FALLS DEPOSITS, UNDIVIDED (PLEISTOCENE) – Probably consists of a relatively thin upper Qls unit and a thick lower Qlc unit. On the basis of water-well data outside the mapped area, the deposits likely exceed 300 feet (91 m) in thickness in the preglacial channel of the Missouri River. In Gibson Flats the unit probably is underlain in places by Qgo deposits and elsewhere lies directly on bedrock. In Johnson Flats the unit is thought to be directly underlain by Qt deposits

Qls — Sandy and silty subunit – Predominantly fine sand and silt; minor amounts of clay-size fraction. Generally loose, easily erodible, and nonplastic. Subject to some slumping on steep slopes. Units generally 5–30 feet (2–9 m) thick in the business district of the city but locally may be much thinner; more than 50 feet (15 m) thick in places in the valleys of the Missouri and Sun Rivers. Fairly well drained in upland areas and along valley walls. Water table commonly at a depth of 10–20 feet (3–6 m) in the broad valleys of the Missouri and Sun Rivers. Commonly underlain by subunit Qlc in central and western parts of map area and by unit Qt in the eastern part of the map area. Fossil snails locally present

Qlc — Clayey subunit – Predominantly a montmorillonite-rich clay; lesser amounts of silt and fine sand. Indistinct to well-developed light and dark laminae (varves?). The high plasticity, high shrink-and-swell capacity, and low strength of the unit (see table for physical characteristics in selected areas) may cause severe construction and maintenance problems unless these characteristics are given proper design considerations. Commonly 5–20 feet (2–6 m) thick in the business district of the city but probably exceeds 100 feet (30 m) in the valleys of the Missouri and Sun Rivers. Underlain by bedrock in most places but locally underlain by unit Qgo in the valleys of the Missouri and Sun Rivers

Qtl — TILL AND INTERCALATED GLACIAL LAKE DEPOSITS (PLEISTOCENE) – Intercalated layers of unsorted and unstratified clay, silt, and sand, resembling unit Qt in composition, and layers of glacial lake deposits of Lake Great Falls, resembling subunit Qlc. Commonly, individual layers are less than ¼ to 1 inch (0.6–2.5 cm) thick, but till layers may be considerably thinner or thicker. Plasticity, shrink-and-swell capacity, and strength generally lie between those of units Qlc and Qt (see table). Thicknesses generally range from less than 10 feet (3 m) along western margins of the unit to more than 50 feet (15 m) along eastern margins where the unit grades imperceptibly into Qt. The unit probably was formed along the terminal margin of the glacier ice front and represents ablation till, flow till, and ice-marginal lake deposits

Qt — TILL (PLEISTOCENE) – Unsorted and unstratified mixture of clay, silt, and sand containing a few pebbles, cobbles, and boulders. Compact and highly impermeable. Generally characterized by low to negligible moisture content except near the surface. Fairly plastic where sufficient moisture is present. Generally stable in natural slopes up to near vertical and as much as 70 feet (21 m) high, except locally where overlain by units Qls or underlain by unit Qlc. May be fairly difficult to excavate at depth where dry and very compact. Thicknesses range from less than 50 feet (15 m) in the western part of the mapped area to more than 200 feet (60 m) in the eastern part. Approximately 60 feet (18 m) of upper part of unit is generally oxidized and gray to tan in color; below 70 feet (21 m) the unit is generally unoxidized and very dark gray to bluish gray in color. Locally underlain by units Qlc and Qgo; in other places underlain by bedrock

Qgo — OLDER GRAVEL (PLEISTOCENE) – Poorly sorted deposit consisting of abundant, well-rounded gravel, cobbles, and boulder-size rocks of quartzite and argillite, and lesser chert, limestone, and sandstone in a silty sand matrix. High to moderate permeability and well drained. Rocks are coated with caliche, especially in upper part of the deposit, and locally are cemented. Unit lies on bedrock and in most places predates the glacial deposits. Generally between 5 feet (1.5 m) and 20 feet (6 m) thick

BLACKLEAF FORMATION (LOWER CRETACEOUS)

Kbt — Taft Hill Member – Consists chiefly of dark-gray soft bentonitic shale, fairly numerous beds of bentonite commonly 2–3 inches (5–8 cm) thick, and a few beds of glauconitic sandstone and siltstone. Most of the bentonitic shale and bentonite beds are highly plastic when wet but form a loose spongy surface when dry; they weather to poorly exposed gentle slopes that are susceptible to landsliding if over-steepened by excavation. Probably all of the unit can be excavated without blasting except for possibly the glauconitic sandstone. A maximum of 100 feet (30 m) of the lower part of the 240-foot (73-m)-thick member is present in the mapped area north of the Sun River, where a 20–30-foot (6–9-m) -thick bed of friable glauconitic sandstone forms the top of the mapped unit; south of the Sun River the maximum thickness is about 25 feet (8 m)

Kbf — Flood Member – Consists of an upper sandstone approximately 65 feet (20 m) thick, a middle dark shale unit 50 feet (15 m) thick, and a basal thin-bedded flaggy sandstone and minor interbedded shale approximately 20 feet (6 m) thick. Upper unit, which is fairly massive, forms near-vertical cliffs and is generally stable except for local rockfalls; in excavating, may require substantial blasting. Small springs locally issue from the base of the upper sandstone unit south of the Sun River. Middle shale unit forms moderate natural slopes that may be subject to sliding if over steepened by excavation; the shale is fissile and fairly hard where unweathered, but becomes soft and plastic where weathered and wet; entire middle unit probably can be excavated with conventional power tools without blasting. In most places the lower unit forms an indistinct, moderately stable ledge; probably can be excavated in most places by heavy power equipment. Total thickness of member is 138 feet (42 m) at type section immediately west of the mapped area

Kk — KOOTENAI FORMATION, UNDIVIDED (LOWER CRETACEOUS) – Consists predominantly of mudstone, shale, sandstone, siltstone, and minor limestone beds. Shown in those areas where exposures are poor and where the distinctive limestone bed at the top of the lower member is absent

Kku — Upper member – Predominantly mudstone and shale in red, maroon, purple, green, yellow, or gray beds commonly 2–10 feet (0.5–3 m) thick; lesser amounts of sandstone and siltstone in thicker beds. In northeast part of area, beds weather to rounded hills separated by deeply incised stream courses. Weathered material is moderately plastic but generally is stable on natural slopes. One basal generally fine grained and platy sandstone bed, 15–30 feet (5–9 m) thick, outcrops in numerous places in southern part of the mapped area and underlies most of the city of Great Falls. The basal sandstone is fairly resistant to weathering, stands in near-vertical natural slopes or in excavated cuts, and may require blasting for removal. Excavation would be facilitated by presence of major northwest-trending joints 1–6 feet (0.3–2 m) apart and by the general platy nature of the beds; material from this unit in a large quarry south of Tenth Avenue South is crushed and used as aggregate. Member is approximately 195 feet (59 m) thick in vicinity of Black Eagle Dam and about 230 feet (70 m) thick in the northeastern corner of the mapped area

Kkl — Lower member – Chiefly fine-grained sandstone, shale, and siltstone in beds commonly 1–10 feet (1–3 m) thick; minor limestone beds in upper part of the member. Sandstones and siltstones generally are well indurated, thickly bedded, and form prominant near-vertical cliffs along the Missouri River downstream from Rainbow Falls. May require blasting for removal but excavation would be facilitated by presence of major northwest-trending joints 1–6 feet (0.3–2 m) apart and of a secondary joint pattern normal to the major joints giving a blocky characteristic appearance to the sandstone. A small normal fault, parallel to the normal joint pattern is present downstream from Black Eagle Dam. Shales are generally soft and moderately fissile with most being dark red. Some shales are maroon, purple, green, yellow, or gray; weathered material is moderately plastic but slopes generally are stable. Locally, intramember channel sandstones intersect the otherwise uniform bedding; channel sandstones are thick bedded to massive, well indurated, and as much as 50 feet (15 m) thick. A distinctive dark-gray fossiliferous limestone bed, which weathers bright orange, forms the top of the member; it has a maximum thickness of approximately 2 feet (0.6 m) in the mapped area below Rainbow Falls but is absent west of Rainbow Falls. Member has a total thickness of approximately 175 feet (60 m). Approximately the upper 125 feet (38 m) are exposed below Black Eagle Dam

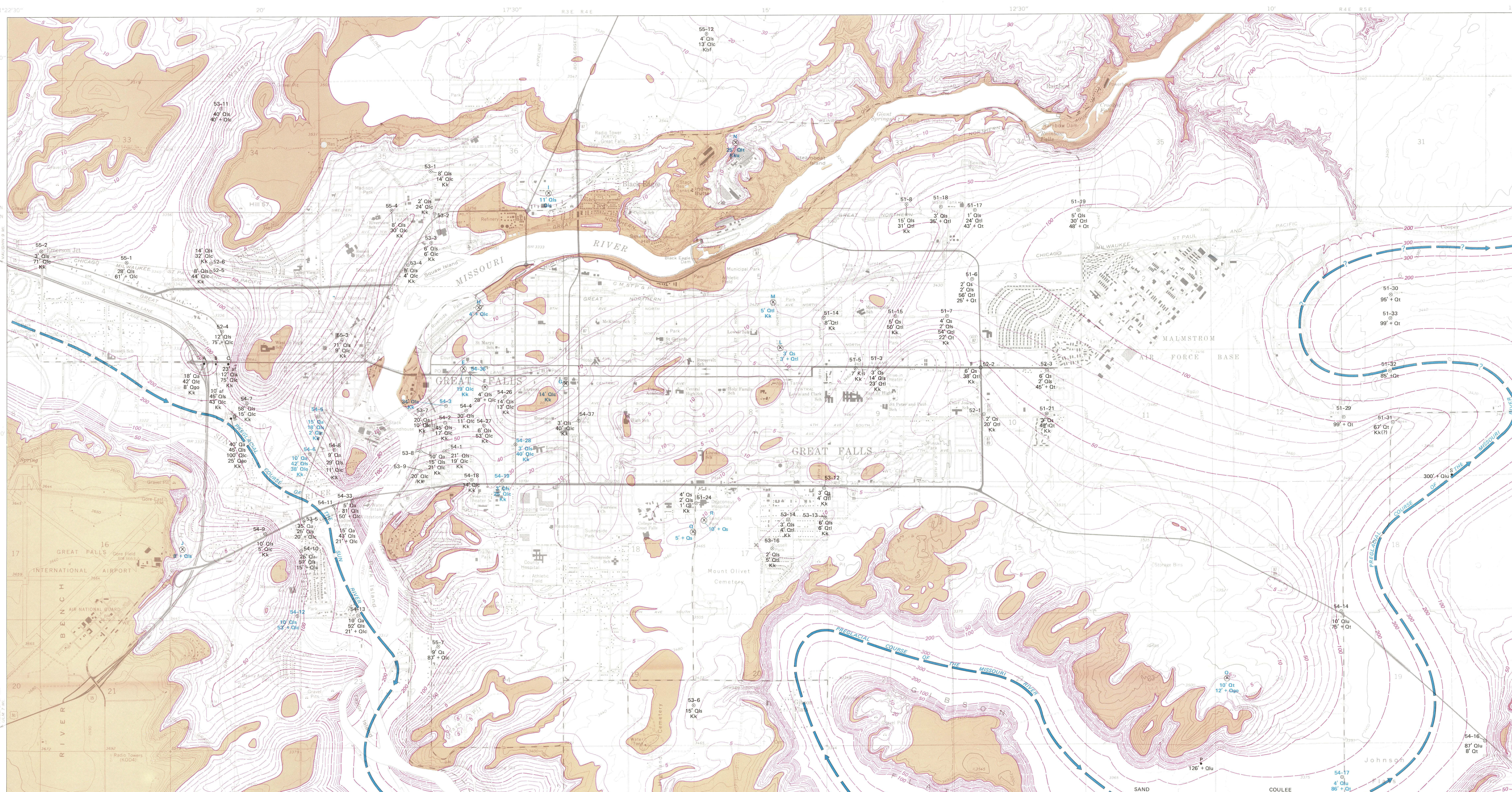
CONTACT – Long dash where approximate, inferred, or gradational

MINOR FAULT – Dashed where approximately located. U, upthrown side; D, downthrown side

(Kbf) / (Kku) CONCEALED BEDROCK CONTACT – Symbols in parentheses denote bedrock units beneath the surficial deposits

ROCK QUARRY – Most of quarried rock is crushed and used as aggregate

GRAVEL PIT – Most pits abandoned because of depletion of gravel deposits



Isopachs mapped in 1950–53 and 1974–75

DEPTH-TO-BEDROCK MAP

PHYSICAL CHARACTERISTICS OF SELECTED GEOLOGIC UNITS

[Analyses by T. C. Nichols, Jr., J. M. Roach, and J. A. Sharps, U.S. Geological Survey]

Sample no.	Map designation	Geologic map unit	General location	Depth of sample[1] (ft)	Depth of sample[1] (m)	Particle size distribution (percent): Clay[2]	Silt[3]	Sand[4]	Atterberg limits: Liquid limit[5]	Plastic limit[6]	Plasticity index[7]	Natural moisture[8]	Shrinkage limit[9]
1	Q	Qs	NE 1/4 sec. 18, T. 20 N., R. 4 E.; S. of 10th Ave. S.	5	1.5	0	3	97			N.P.[10]		
2	R	Qs	NW 1/4 sec. 17, T. 20 N., R. 4 E.; S. of 10th Ave. S.	5	1.5	0	2	98			N.P.		
			Average of Qs unit---			0	2.5	97.5					
3	54-5	Qls	West Great Falls; N. of Sun River	26	7.9	15	7	78			N.P.	37	15
4	I	Qls	Black Eagle; N. of Missouri River	6	1.8	10	64	26			N.P.		
5	J	Qls	Gore Hill; S. of Sun River	4	1.2	0	1	99			N.P.		
			Average of Qls unit--			8.3	24.0	67.7					
6	54-3	Qlc	Second Ave. S. and 3d St.	20	6.1	76	11	13	72	29	43	41	11
7	54-6	Qlc	West Great Falls; N. of Sun River	91	27.7	79	8	13	78	27	51	-	-
8	54-12	Qlc	SW Great Falls; S. of Sun River	20	6.1	74	25	1	64	27	37	35	14
9	54-19	Qlc	10th Ave. S. and 8th St.	20	6.1	87	13	0	88	34	54	40	8
10	54-28	Qlc	Sixth Ave. S. and 9th St.	15	4.5	83	11	6	79	28	51	-	-
11	54-28	Qlc	Sixth Ave. S. and 9th St.	25	7.6	89	9	2	79	31	48	-	-
12	54-36	Qlc	First Ave. N. and 5th St.	10	3.0	76	19	5	75	24	51	35	11
13	E	Qlc	First Ave. N. and 4th St.	14	4.3	76	20	4	86	26	60	38	-
14	G	Qlc[11]	Central Ave. and 14th St.	11	3.4	75 {90[11], 67}	23 {10[11], 29}	2 {0[11], 4}	66 {81[11], 61}	30 {31[11], 28}	36 {50[11], 33}	–	12 {10[11], 13}
15	H	Qlc	8th Ave. N. and Park Dr.	4	1.2	86	14	0	94	34	60	47	16
			Average of Qlc unit--			80.1	15.3	4.6	78.1	29.0	49.1	39.3	12.0
16	L	Qtl[12]	Fourth Ave. N. and 34th St.	6	1.8	86	10	4	63	29	34		12
17	M	Qtl	Eighth Ave. N. and 32d St.	4	1.2	67	19	14	60	24	37		3
18	N	Qtl	Indian Butte; N. of Missouri River	15	4.6	40	32	28	42	20	22		11
			Average of Qtl unit--			64.3	20.3	15.3	55.0	24.3	31		8.7
19	O	Qt	SW 1/4 sec. 24, T. 20 N., R. 4 E.; N. of Sand Coulee	5	1.5	50	35	15	47	22	25		13
20	54-17	Qt	Johnson Flats, Sand Coulee	25	7.6	42	37	21	38	14	24		10
21	54-17	Qt	Johnson Flats, Sand Coulee	50	15.2	41	37	22	39	15	24		12
22	54-17	Qt	Johnson Flats, Sand Coulee	60	18.3	41	36	23	39	15	24		12
			Average of Qt unit---			43.5	36.3	20.2	40.8	16.5	24.3		11.8

[1] Samples 3, 6-12, and 20-22 were obtained as cuttings from auger holes and depth of sample is approximate; the other samples were obtained in excavations made for buildings or for other purposes.
[2] Clay, <0.00015 in. (<0.0039 mm).
[3] Silt, 0.00015-0.0025 in. (0.0039-0.0625 mm).
[4] Sand, 0.0025-0.079 in. (0.0625-2.0 mm).
[5] Water content of the soil in percent of dry soil weight at the boundary between the liquid state and the plastic state.
[6] Water content of the soil in percent of dry soil weight at the boundary between the plastic state and the solid state.
[7] Numerical difference between the liquid limit and the plastic limit. Represents the range of moisture content within which the soil is plastic.
[8] Percent of dry soil weight.
[9] Maximum water content in percent of dry soil weight at which a reduction in water content by evaporation will not cause a decrease in volume of the soil mass.
[10] N.P. denotes that the sample is nonplastic.
[11] Numbers in brackets denote analyses of a dark layer (upper figure) of a varve(?) and of a light layer (lower figure) of a varve(?). The light layer of the sample is approximately 30% thicker than the dark layer and there are approximately five light layers and five dark layers per inch (2.54 cm) of thickness of sample.
[12] Predominantly Qlc unit with only minor Qt unit.

EXPLANATION FOR MAP SHOWING DEPTH TO BEDROCK

BEDROCK OUTCROP OR THINLY COVERED BEDROCK – Surficial cover generally less than 3 feet (1 m)

—100— ISOPACH – Line showing thickness of surficial deposits or depth from surface to bedrock. Solid line is based upon fairly numerous control points and accuracy in most places is believed to be within an isopach interval. Long dashed line is based upon scattered control points; location and interval of line is inferred (inference is greatest along the eastern margin of the mapped area). Control for drawing isopachs, in addition to natural exposures, is based upon examination of approximately 200 building excavations, drilling and logging of 90 power auger holes, examination of records of approximately 700 city blocks of sewerline excavations, and interpretation of selected water wells and test holes. Isopachs shown in 10-foot (3-m) intervals to a depth of 100 feet (30 m) except for addition of the 5-foot (1.5-m) isopach; at depths greater than 100 feet (30 m) only the 100-foot (30 m) intervals are shown. Hachured line indicates area of lesser thickness than surrounding area

5′ Qtl / Kk — 14′ Qls / 32′ Qlc / Kk — SELECTED GENERALIZED LOG – Shows stratigraphic sequence and approximate thickness in feet (1 ft=0.305 m) at sample site. Logs shown in blue are described in table of physical properties

F — Excavation or natural exposure examined by the authors where stratigraphic and thickness control are accurate

52–1 — Power auger hole logged by the authors where interpretation of units and their thicknesses are approximate in places due to difficulty of making interpretations from auger cuttings

D — Water well (approximate location) or test hole with logs interpreted by the authors and where reliability is variable

? INFERRED PREGLACIAL COURSE OF RIVER SHOWING DIRECTION OF FLOW – Queried where the inference is greatest

Base from U.S. Geological Survey
Northwest Great Falls, Northeast Great Falls,
Southwest Great Falls, and Southeast Great Falls, 1965

SCALE 1:24 000
1 ½ 0 1 2 3 MILES
1 .5 0 1 2 3 KILOMETERS
CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

ENGINEERING GEOLOGY OF THE CITY OF GREAT FALLS AND VICINITY, MONTANA

By
Richard W. Lemke and Edwin K. Maughan

1977

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