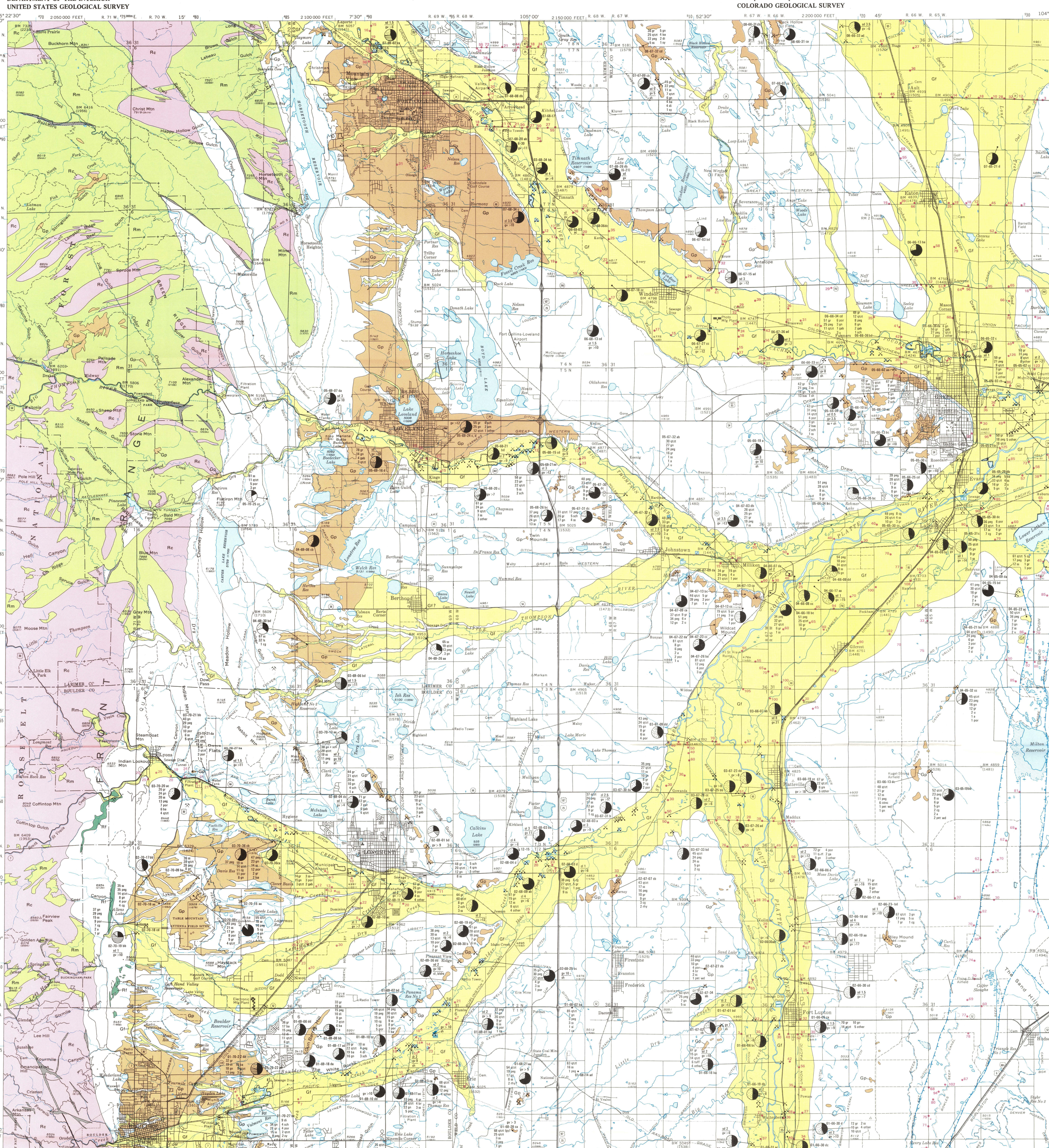
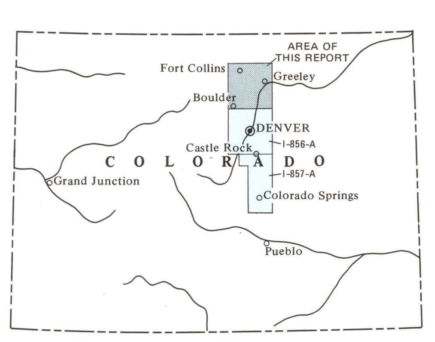
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

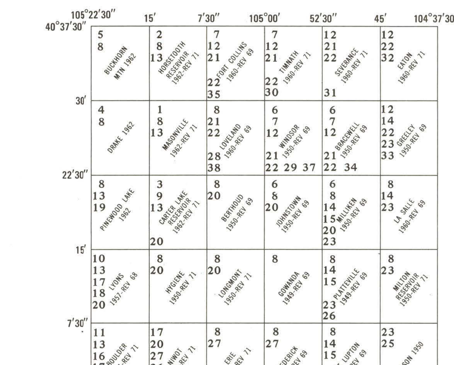
Prepared in cooperation with the
COLORADO GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
BOULDER-FORT COLLINS-GREELEY AREA, COLO
MAP I-855-D





MAP SHOWING AREA OF FRONT RANGE URBAN CORRIDOR GRAVEL STUDIES



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MAP SHOWING POTENTIAL SOURCES OF GRAVEL AND CRUSHED-ROCK AGGREGATE IN THE BOULDER-FORT COLLINS-GREELEY AREA, FRONT RANGE URBAN CORRIDOR, COLORADO

By
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1974

INTRODUCTION

Gravel or crushed rock are essential constituents of all concrete structures, including building foundations, roads, curbs and gutters, sidewalks, and other urban facilities. Urban growth has reduced the availability of these commodities in the Front Range Urban Corridor by depletion, by building on the deposits, and by local zoning laws that prohibit extraction. The remaining resources must be conserved by land-use planning based on knowledge of their distribution, quality, and quantity.

Deposits of high-quality gravel in the Boulder–Fort Collins–Greeley area are mostly under flood plains and terraces of major streams. Generally lower quality, somewhat-weathered older gravel underlies higher terraces, benches, and mesas; the quality of the gravel extracted from these deposits can be improved by washing, crushing, and screening. Rock suitable for use as crushed-rock aggregate is abundant in igneous and metamorphic rocks of the mountains. These gravel and rock resources have been grouped into five map units; two are sources of gravel and three are sources of rock suitable for crushing. The map units are based not on quality judgments but on differences in physical characteristics which do determine quality which, in turn, determines suitability for different uses.

Gravel deposits, as here defined and mapped, are inferred to contain at least 20-percent granule- and pebble-size stones: smaller than 2.5 inches (6.5 cm) but retained on a No. 10 (2 mm) U.S. Standard sieve. The minimum figure of 20 percent is estimated to be the lower limit at which gravel can be economically extracted from a deposit. Lower quality deposits have been worked in areas where haulage distances are short and a market for sand exists.

SOURCES OF GRAVEL

Gravel deposits have been and are being deposited by the South Platte River and its tributaries, Boulder Creek, Lefthand Creek, St. Vrain Creek, Little and Big Thompson Rivers, and the Cache La Poudre River. These deposits can be divided into two groups that differ in physical characteristics and in the manner of occurrence. The best gravel for concrete aggregate and most other uses is under flood plains and terraces of the major streams. These deposits are generally less than 50 feet (15 m) above stream level and are younger and, therefore, less altered than the gravel in the other older group of deposits. Water tables are generally near the surface of the flood plains.

The gravel deposits composing the other group underlie high broad surfaces (pediments) generally more than 50 feet (15 m) above local stream levels. Scattered remnants of very old gravel deposits in the mountains are hundreds of feet (hundreds of meters) above nearby stream levels. All these deposits mark the sites or remnants of former stream channels. All have been weathered and partly cemented by thick accumulations of calcium carbonate or caliche ($CaCO_3$), which diminishes their quality. Water tables are generally low under these deposits.

GRAVEL DEPOSITS UNDERLYING FLOOD PLAINS AND TERRACES

Boulder Creek. – The gravel deposits of Boulder Creek have been the major source of gravel for the Boulder area for many years. Boulder Creek and its tributaries drain mountain areas largely underlain by Boulder Creek Granodiorite, biotite gneiss, some schist, and a small area of Silver Plume Granite. Pebble counts (100 pebbles per count) from deposits near Boulder indicate that 50 percent of the stones are granite, granodiorite, or quartz monzonite, 20 percent are gneiss, and 15 percent are pegmatite. The percentage of granite, granodiorite, quartz monzonite, and pegmatite decreases downstream to 25 percent at the confluence with St. Vrain Creek. Stones of gneiss appear to be more durable, and the percentage increases from 20 percent near the mountain front to 40 percent 12 miles (19 km) downstream. The percentage of quartzite stones increases from 20 percent near the mountain front to 30 percent downstream.

The average size of stones in the gravel deposits of Boulder Creek decreases downstream from the foothills. Mechanical analyses of samples from the Niwot quadrangle show an average size of 1.25 inches (31.8 mm), whereas samples from the Gowanda quadrangle average 0.625 inch (15.8 mm) in diameter.

The thickness of the gravel deposits along Boulder Creek is variable. Generally, the deposits are somewhat thicker near the mountains and somewhat thinner away from the mountains. The deposits are generally thickest under the center of the flood plain and taper to a featheredge near the edge of the flood plain or terrace. Measured thicknesses of the gravel are 15–25 feet (4.5–7.6 m) near Boulder, 10 feet (3 m) one-half mile (0.8 km) northwest of Liggett, and 8–12 feet (2.4–37 m) 2 miles (3.2 km) northwest of Erie.

Lefthand Creek. – Extensive deposits just east of the foot of the Front Range near Altona have been used by the Boulder County Road Department and others for many years, mostly for highway surfacing. Sixty percent of the area drained by Lefthand Creek and its tributaries is underlain by Boulder Creek Granodiorite and Silver Plume Granite. Pebble counts from gravel deposits on Table Mountain indicate that 30–50 percent of the stones are granitic (including pegmatite), 15–35 percent sandstone, 10–55 percent quartzite, 5–40 percent gneiss or schist, and 5–10 percent rhyodacite porphyry (fine-grained igneous rock).

The gravel in the deposits of Lefthand Creek near the mountains at Altona is very coarse and consists largely of boulder and cobble gravel. The average size of stones decreases eastward to the confluence of Lefthand and St. Vrain Creeks. Analyses of gravel from that locality indicate that the average diameter of stones in that area is 1 inch (2.54 cm). The thickness of the deposits, according to sparse data, is as much as 15 feet (4.5 m) at the west edge of the deposit and about 10 feet near the east end of the deposit. The deposits are generally thickest under the center of the flood plains and taper to a featheredge at the edge of the flood plain.

St. Vrain Creek. – The gravel deposits of St. Vrain Creek have been the source of gravel for the Longmont and Lyons areas. St. Vrain Creek and its tributaries drain mountain areas largely underlain by Silver Plume Granite. Pebble counts (100 pebbles each) from deposits between Lyons and Longmont indicate that the stones are composed of 50–75 percent granitic rocks, 20–40 percent gneiss, 5–15 percent porphyry, 5–20 percent sandstone, and as much as 15 percent quartzite. Downstream, the percentage of granitic rocks decreases, and that of quartzite increases.

The average size of stones decreases downstream from the Lyons area to the confluence of St. Vrain Creek with Lefthand and Boulder Creeks. Near Lyons, the diameter of more than 50 percent of the stones is more than 1 inch (2.54 cm), but in pits 5 miles (8 km) east of Longmont, the average diameter is 0.37 inch (9.5 mm).

The thickness of the gravel deposits is known at scattered points along St. Vrain Creek. For example, test pits a few miles east of Lyons indicate that the gravel is as much as 20 feet (6 m) thick, and pits in the Longmont area indicate that the gravel is generally 10 feet (3 m) thick but may be as much as 15 feet (4.5 m) thick locally.

Cache La Poudre River. – The gravel deposits of the Cache La Poudre River have been the major source of gravel for Fort Collins, Windsor, and Greeley since the area was first settled. The river and its tributaries drain mountain areas largely underlain by mica schist and granite. Pebble counts from deposits west of Greeley indicate the following rock types and percentages: Granitic rocks, 76–84 percent; quartzite, 2–11 percent; rhyodacite, 2–7 percent; gneiss, 3–4 percent. The distance along the river from which samples were taken was only 4 miles (6.4 km); thus, changes in composition were not evident.

The average diameter of the stones is about 1 inch (2.54 cm) north of Fort Collins, whereas it is less than 0.25 inch (6.35 mm) northwest of Greeley.

Thickness of the gravel under the flood plain and terraces of the Cache La Poudre River ranges from 20 feet (6 m) northwest of Fort Collins to 50 feet (15 m) northwest of Greeley. The average thickness of gravel under the flood plain of the river and adjacent terraces is about 20 feet (6 m). Drill records of various reliability indicate greater thicknesses locally over buried channels. For more information, the reader should consult the theses of Ching (1972) and Shelton (1972).

South Platte River. – The South Platte River flows northward through the eastern part of the area toward Greeley. The river and its tributaries south of the area such as Bear Creek, Clear Creek, and Cherry Creek drain mountain areas underlain by various igneous, metamorphic, and sedimentary rocks. Pebble counts made of samples from the Fort Lupton, Platteville, and La Salle areas show that 67–72 percent of the stones are granitic, 6–10 percent are gneiss, 9–22 percent are quartzite, and that only a few percent are sandstone, tuff, basalt, and gabbro. No significant change in composition of the stones was found between Brighton and Greeley.

The gravel deposits underlying the South Platte River flood plain and adjacent terraces are composed of about 50 percent sand and 50 percent granules and small pebbles. The size distribution changes little between Brighton and Greeley. Well records indicate that coarser material may be present locally in the lower part of the deposit. Overburden consists of silty sandy flood-plain deposits 2–4 feet (0.6–1.2 m) thick. Windblown sand deposits on the terraces are as much as 15 feet (4.5 m) thick locally but are generally only a few feet thick.

The thickness of the deposits ranges from 50 feet (15 m) near Fort Lupton to 110 feet (33 m) near La Salle and Greeley.

Beebe Draw. – Along the east edge of the area is an ancient abandoned buried channel of the South Platte River which contains sand and gravel. The buried channel is slightly more than 1 mile (1.609 km) wide. Well records and some test drilling by the U.S. Geological Survey (Smith, Schneider, and Petri, 1964) indicate that the deposits may be as much as 50 feet (15 m) thick. A blanket of windblown sand and silt as much as 30 feet (9 m) thick under some dune crests covers the stream deposits of Beebe Draw. The water table under Beebe Draw is near the surface.

Samples of the alluvium under Beebe Draw could be obtained only from the fine-grained upper part and consequently the coarseness of the gravel is unknown. Detailed drilling and sampling would be necessary before development of such deposits. The types of stones are known from terrace remnants a mile or two south of the Lower Latham Reservoir. Pebble counts indicate that 59–61 percent of the stones are granitic, 19–30 percent are quartzite, 4–7 percent are gneiss, and a few percent are sandstone, conglomerate, and porphyry.

UPLAND GRAVEL DEPOSITS UNDERLYING PEDIMENTS AND HIGH LEVEL TERTIARY SURFACES

Most of the gently sloping benches just east of the front of the mountains and many of the drainage divides in the eastern three-fourths of the map area are underlain by gravel deposits. Thick soil profiles have developed in these deposits, and much clay and caliche (calcium carbonate) cement are present locally. Many stones have partly or completely disintegrated because of the long weathering, but the quality of the gravel removed from these deposits can be improved by washing, crushing, and screening. Generally, only small amounts of these deposits have been used locally and those mostly for highway or road construction. An exception is the deposit on Table Mountain, 6 miles (9.7 km) west of Longmont. The Boulder County Road Department has used large volumes of this coarse deposit, which is as much as 16 feet (5 m) thick. A pebble count (100 pebbles) indicates that 45 percent of the stones are granitic, 21 percent are red sandstone, 17 percent are gneiss, 8 percent are rhyolitic porphyry, and 4 percent are quartzite. Owing to the coarseness of the gravel, no samples were analyzed; however, it is estimated that 50 percent of the deposit is composed of stones whose diameter is 2 inches (5 cm) or more.

Many of the upland gravels are remnants of long narrow stream deposits. An example is a discontinuous line of small deposits, including Riley Mound, on the drainage divide between the South Platte River and Beebe Draw. The remnants are deeply weathered and partly cemented by caliche. Five pebble counts suggest that the prolonged weathering altered many stones to clay and sand. The gravel consists of 50–65 percent quartzite, 25–35 percent granitic rocks, about 5 percent gneiss, 5–12 percent sandstone, and the remainder, other types such as conglomerate and dark fine-grained igneous or metamorphic rocks.

The deposits on the divide are as much as 15 feet (4.5 m) thick, but most of the remnants are only 5 feet (1.5 m) thick.

Other linear discontinuous gravel deposits trend southeastward from the foothills toward Longmont and represent ancient channels of the Little Thompson River.

SOURCES OF ROCK SUITABLE FOR USE AS CONCRETE AGGREGATE

The crystalline igneous and metamorphic rocks that underlie the mountainous western part of the area have been and are being quarried to provide crushed rock for use as aggregate in concrete. About 25 percent of the mountain area, mostly the southwestern part, is underlain by granite, granodiorite, quartz diorite, and pegmatite, most of which are suitable for use as aggregate. For the most part, the granitic rocks are not deeply weathered except along shear zones. Less than 5 percent of the area is underlain by rhyodacite and dikes of shoshonite.

Seventy-five percent of the area of crystalline rocks is underlain by mica schist and gneiss, including three small areas of amphibolite. Gneiss and schist have strong to weak foliation (splitting planes), depending on the amount of mica present. Strong foliation tends to downgrade the quality of the rock for uses as crushed aggregate, and these metamorphic rocks vary from suitable to unsuitable. Drilling and blasting will be necessary for quarrying.

EXPLANATION OF MAP UNITS

Gf — GRAVEL DEPOSITS UNDERLYING TERRACES AND FLOOD PLAINS – Pebbles generally well rounded, unweathered; deposits contain little deleterious "lime" ($CaCO_3$). Lithologic composition reflects bedrock in source areas along Boulder Creek, St. Vrain Creek, Lefthand Creek, the Little and Big Thompson Rivers, and the Cache La Poudre River; clasts are composed chiefly of quartzite, granite, gneiss, and pegmatite. Few or no reactive constituents. Source of best quality gravel for concrete aggregate and road metal

Gp — UPLAND GRAVEL DEPOSITS UNDERLYING PEDIMENTS AND HIGH-LEVEL TERTIARY SURFACES – Poorly stratified and poorly sorted cobble and boulder gravels near mountains. Average size of stones decreases away from mountains. Thick well-developed old soil profiles contain much clayey material and thick deleterious caliche ($CaCO_3$) zones as cement and rinds on stones. Low-quality source of concrete aggregate; source of road metal

Rf — FINE-GRAINED IGNEOUS ROCKS – Crop out adjacent to the mountains as dikes and sills. The Valmont dike of shoshonite (alkalic basalt) has been quarried in the past. A sill of rhyodacite 3 miles (4.8 km) southwest of Lyons is quarried for crushed rock

Rc — COARSE-GRAINED IGNEOUS ROCKS – The Boulder Creek Granodiorite and the Silver Plume Granite, quartz monzonite, and quartz diorite (tonalite) occur along the west edge of the area, most of these rocks are south of Pinewood Lake. Tonalite or quartz diorite occurs as scattered long narrow bodies north of Pinewood Lake. Many small bodies of pegmatite are along the northwest edge of the area. Most of these rocks are potential sources of high-quality crushed-rock aggregate, although pegmatite may be unsuitable

Rm — METAMORPHIC ROCKS – Much of the area of crystalline rocks north of Pinewood Lake is underlain by micaceous metamorphic rocks. Quartz mica schist, various kinds of gneiss, and amphibolite are the common rocks. Foliated rocks are inferior to nonfoliated granitic rocks, but many gneisses have been used for aggregate elsewhere

SHEAR ZONE – Crushed, broken, or sheared rock along a major fault; much altered locally. Undesirable as a source of crushed rock for concrete aggregate, but might be used locally for road metal or fill

BOUNDARY OF DEPOSIT OR LINE OF CONTACT BETWEEN DEPOSITS

BURIED OR ABANDONED STREAM CHANNEL UNDER BEEBE DRAW UNDERLAIN BY GRAVEL

LARGE GRAVEL PIT

GRAVEL PIT

ABANDONED GRAVEL PIT

QUARRY

02-68-03 a (Sand; Granules and pebbles; Clay and silt; Cobbles and boulders) — DISTRIBUTION OF GRAIN SIZES IN GRAVEL DEPOSIT, IN PERCENT BY WEIGHT – Diagram indicates analysis of a sample that contained 15-percent clay and silt, 35-percent sand, 30-percent granules and pebbles, and 20-percent cobbles and boulders. Number adjacent to diagram is land-net location: first number is township, second is range, third is section, and letters are sectional subdivisions. Numerical data are found in accompanying table

37 qtzt, 24 peg, 17 ss, 12 gn, 9 gr, 1 cg — PERCENTAGE OF STONE TYPES IN DEPOSIT – Based on one count of 100 pebbles

a	Aphanite (any dark-colored very fine grained rock)	peg	Pegmatite
		pet wd	Petrified wood
ba	Basalt (includes gabbro, dolerite)	por	Porphyry
		qtz	Quartz
br	Breccia (siliceous)	qtzt	Quartzite
ca	Caliche	rhy	Rhyolite
cg	Conglomerate	sch	Schist
conc	Concretion (mostly siderite)	sh	Shale
di	Diorite	si	Siderite
gn	Gneiss	ss	Sandstone
gr	Granite	sy	Syenite
ls	Limestone	u	Unknown

sd 2 / gv >6 — ABBREVIATED LOG OF DEPOSIT – From well records and other drilling or test data of U.S. Geological Survey and Colorado Division of Highways. Thicknesses shown are in feet

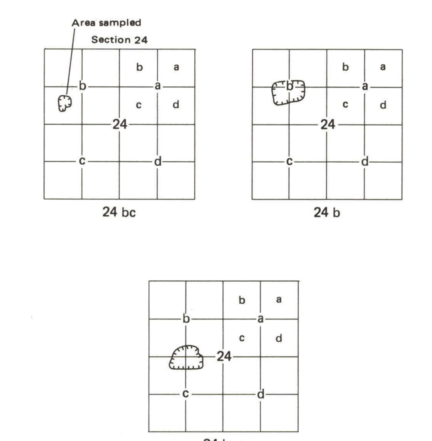
cl	Clay	sd	Sand	ss	Sandstone
gv	Gravel	sh	Shale	st	Silt

30 — THICKNESS OF GRAVEL DEPOSIT – In feet

EXPLANATION OF TABLE

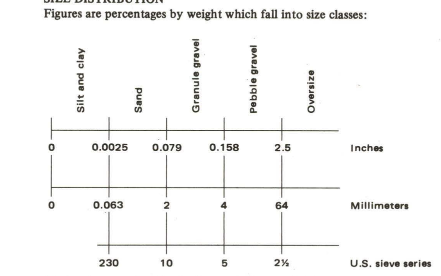
SAMPLE LOCALITY

Sample localities are listed by the section in which they lie, under the heading of township and range. Within the section, localities are listed by quarter section and quarter-quarter section. Quarter sections are lettered a, b, c, d, counterclockwise, beginning with the northeast quarter. Within quarter section, the quarter-quarter sections are lettered in the same manner (as 24 bc). Where only one letter is listed (as 24 b), the area sampled lies within more than one quarter-quarter section. Where two letters are listed, separated by a comma (as 24 b, c), the area sampled lies in both quarter sections.



SIZE DISTRIBUTION

Figures are percentages by weight which fall into size classes:



Blank where no size-distribution analysis is available

DEPTH OF SAMPLE
- Gravel sample, depth not stated in field report
ob Overburden sample, depth not stated in field report

DEPTH TO WATER TABLE
- Not stated in field report
? Stated in field report as unknown

SOURCES OF INFORMATION

CDH	Colorado Division of Highways. Numbers refer to their indexing system of county and pit number.
Ching	Ching, P. W., 1972, Economic gravel deposits of the lower Cache la Poudre River: Colorado State Univ. M.S. thesis.
Flatiron	Flatiron Sand and Gravel Company, Boulder, Colo.
USGS	U.S. Geological Survey, sampling for the purpose of this project. Numbers refer to indexing system of quadrangle and sample number.
*	Sample has been combined with samples from nearby localities for representation on the map as a composite sample.

TABLE OF SAMPLE DATA

Sample locality (Section 1/4-sec. 1/4-1/4-sec.)	Silt and clay	Sand	Granule gravel	Pebble gravel	Oversize	Depth of sample, feet	Depth of sample, meters	Depth to water table, feet	Depth to water table, meters	Source of information
TOWNSHIP 1 NORTH, RANGE 66 WEST										
6 bc	1	51	13	35	0	0.5- 9	0.2-2.7	4.5	1.4	CDH 3-79
	1	34	14	51	0	0.5- 9	0.2-2.7			
ca	65	32	2	1	0	0 - 1.5	0 -0.5	5	1.5	CDH 3-54
	1	48	15	36	0	1.5- 5	0.5-1.5			
	3	33	18	46	0	5 - 9	1.5-2.7			
	1	36	16	47	0	5 - 10	1.5-3.0			
18 ba	1	50	20	29	0	1 - 12	0.3-3.7	6	1.8	CDH 3-111
	3	52	22	23	0	- -	- -			CDH 3-113
19 db	2	56	12	30	0	2 - 8	0.6-2.4	-	-	CDH 3-91
	48	40	5	7	0	0 - 2	0 -0.6			
30 d	26	55	11	8	0	0 - 2	0 -0.6	17	5.2	CDH 3-16
	1	40	17	42	0	2 - 7	0.6-2.1			
	0	56	25	19	0	7 - 15	2.1-4.6			
	0	51	20	29	0	- -	- -			
	32	59	3	6	0	ob	ob			
	5	95	0	0	0	- -	- -			
	9	45	15	31	0	- -	- -			
dc	4	55	18	23	0	2 - 12	0.6-3.7	15	4.6	CDH 3-105
	6	49	19	26	0	2.5- 12	0.8-3.7			
31 ac	44	38	8	10	0	0 - 2	0 -0.6	20	6.1	CDH 3-15
	1	51	16	32	0	2 - 15	0.6-4.6			
	1	25	24	50	0	2 - 15	0.6-4.6			
	36	48	8	8	0	0 - 3.5	0 -1.1			
	2	43	20	35	0	3.5- 15	1.1-4.6			
	3	37	18	42	0	2 - 15	0.6-4.6			
	1	57	20	22	0	- -	- -			
	30	68	2	0	0	ob	ob			
TOWNSHIP 1 NORTH, RANGE 67 WEST										
1 bd	37	58	4	1	0	0 - 2	0 -0.6	6	1.8	CDH 3-73
	1	40	19	40	0	2 - 15	0.6-4.6			
	57	34	7	2	0	0 - 1	0 -0.3			
	1	55	18	26	0	1 - 7	0.3-2.1			
	77	20	2	1	0	0 - 6	0 -1.8			
2 cb	29	29	4	31	7	0 - 5	0 -1.5	-	-	CDH 3-34
36 ba	34	41	14	11	0	0 - 1	0 -0.3	8	2.4	CDH 3-1
	2	48	20	30	0	1 - 6	0.3-1.8			
TOWNSHIP 1 NORTH, RANGE 68 WEST										
2 ba						- -	- -	-	-	USGS Fr-3
14 ad						- -	- -	-	-	USGS Fr-4
21 aa	1	33	10	56	0	- -	- -	-	-	USGS Er-11
28 ca						- -	- -	-	-	USGS Er-12
TOWNSHIP 1 NORTH, RANGE 69 WEST										
1 ba	30	67	1	2	0	0 - 2.5	0 -0.8	4	1.2	CDH 7-22
	1	26	5	44	24	2.5- 12	0.8-3.7			
	44	56	0	0	0	0 - 2.5	0 -0.8			
	0	28	4	57	11	0 - 11	0 -3.4			
	2	27	3	50	18	2.5- 12	0.8-3.7			
2 bd	3	46	13	38	0	- -	- -	-	-	USGS Er-4
6 dd	5	36	7	52	0	- -	- -	-	-	USGS Ni-1
8 bb	1	29	10	60	0	- -	- -	-	-	USGS Ni-2
10 cc	3	35	9	49	4	- -	- -	-	-	USGS Er-7
dd	60	37	2	1	0	0.5- 2.5	0.2-0.8	3	0.9	CDH 7-6
	1	24	6	48	21	0 - 10	0 -3.0			
	1	21	5	55	18	0 - 10	0 -3.0			
	0	68	12	20	0	0 - 4	0 -1.2			
11 ac	2	30	7	39	22	1 - 8	0.3-2.4	6	1.8	CDH 7-21
	57	42	1	0	0	0 - 3	0 -0.9			
	2	21	3	56	18	3 - 8	0.9-2.4			
	3	29	6	50	12	2 - 9	0.6-2.7			
	62	38	0	0	0	0 - 3.5	0 -1.1			
13 ca	4	47	12	37	0	- -	- -	-	-	USGS Er-10
17 ad	1	39	9	51	0	- -	- -	-	-	USGS Ni-4
18 da	3	28	7	50	12	3 - 8	0.9-2.4	-	-	Flatiron
34 ad						- -	- -	-	-	USGS Er-13
TOWNSHIP 1 NORTH, RANGE 70 WEST										
22 ad	45	52	2	1	0	0 - 3	0 -0.9	5	1.5	CDH 7-12
	51	45	3	1	0	0 - 2	0 -0.6			
	6	21	5	30	38	2 - 6	0.6-1.8			
	2	22	6	52	18	6 - 11	1.8-3.4			
da						- -	- -	-	-	USGS Ni-6
27 bc						- -	- -	-	-	USGS Ni-7
TOWNSHIP 2 NORTH, RANGE 66 WEST										
6 d	31	56	6	7	0	0 - 2.5	0 -0.8	14	4.3	CDH 3-45
	3	55	17	25	0	2.5- 14	0.8-4.3			
	2	48	23	27	0	2 - 14	0.6-4.3			
	1	48	19	32	0	2 - 14	0.6-4.3			
17 cb	35	55	5	5	0	0 - 1.5	0 -0.5	18	5.5	CDH 3-44
	2	44	24	30	0	1.5- 18	0.5-5.5			
	2	58	19	21	0	0 - 10	0 -3.0			
	2	50	16	32	0	2 - 18	0.6-5.5			
18 dd	21	59	10	10	0	0 - 5	0 -1.5	18	5.5	CDH 3-47
	2	48	20	30	0	5 - 18	1.5-5.5			
19 aa	2	56	18	24	0	1 - 18	0.3-5.5	18	5.5	CDH 3-46
	2	43	22	33	0	1 - 18	0.3-5.5			
23 bd	6	34	17	37	6	- -	- -	-	-	USGS MR-3
30 ab	2	51	18	29	0	0 - 5	0 -1.5	5	1.5	CDH 3-48
	2	46	19	33	0	0 - 6	0 -1.8			
cd	1	55	16	28	0	1 - 7	0.3-2.1	4.5	1.4	CDH 3-17
	30	67	1	2	0	0 - 1.5	0 -0.5			
	1	49	15	35	0	1.5- 7	0.5-2.1			
	1	58	16	25	0	2 - 7	0.6-2.1			
TOWNSHIP 2 NORTH, RANGE 67 WEST										
7 cb						- -	- -	-	-	USGS Go-10
27 db						- -	- -	-	-	USGS Fr-2
34 ab	2	28	8	62	0	- -	- -	-	-	USGS Fr-1
TOWNSHIP 2 NORTH, RANGE 68 WEST										
3 a	45	53	2	0	0	0 - 1	0 -0.3	4	1.2	CDH 3-41
	2	30	6	62	0	1 - 14	0.3-4.3			
	45	54	1	0	0	0 - 2.5	0 -0.8			
	1	30	6	63	0	2.5- 11	0.8-3.4			
	73	27	0	0	0	0 - 5	0 -1.5			
	61	37	0	2	0	0 - 2	0 -0.6			
	1	29	10	60	0	2 - 12	0.6-3.7			
	16	84	0	0	0	6.5- 9	2.0-2.7			
	61	38	1	0	0	0 - 2.5	0 -0.8			
	1	94	3	2	0	2.5- 6	0.8-1.8			
	65	35	0	0	0	0 - 3	0 -0.9			
	2	30	4	64	0	4 - 14	1.2-4.3			
	67	32	1	0	0	1	0.3			USGS Go-8
bc	45	55	0	0	0	0 - 1	0 -0.3	4	1.2	CDH 3-75
	1	41	7	46	5	3 - 11	0.9-3.4			
	0	49	18	33	0	4 - 11	1.2-3.4			
	40	60	0	0	0	0 - 3	0 -0.9			
	0	28	8	64	0	7 - 12	2.1-3.7			
	1	24	8	62	5	1 - 6	0.3-1.8			
d	1	27	9	63	0	1 - 9	0.3-2.7	6	1.8	CDH 3-12
	1	24	7	68	0	1 - 7	0.3-2.1			
	57	38	1	4	0	0.5- 1.5	0.2-0.5			
	1	24	6	69	0	1.5- 9	0.5-2.7			
4 d	3	30	8	57	2	4.5- 10	1.4-3.0	4.5	1.4	CDH 3-114
9 ab	2	33	10	55	0	4.5- 10	1.4-3.0	4.5	1.4	CDH 3-110
19 dd	1	36	6	57	0	- -	- -	-	-	USGS Er-2
29 bc	1	32	10	57	0	- -	- -	-	-	USGS Er-3
30 b	3	33	9	55	0	- -	- -	-	-	USGS Er-1
TOWNSHIP 2 NORTH, RANGE 69 WEST										
1 bd	25	31	14	25	5	0.5- 9	0.2-2.7	?	?	CDH 7-7
	42	49	3	5	1	0.5- 7	0.2-2.1			
	32	22	8	20	18	0.5- 5	0.2-1.5			
4 dc	43	50	3	4	0	0 - 1	0 -0.3	4.5	1.4	CDH 7-11
	4	27	6	36	27	1 - 4	0.3-1.2			
	4	27	6	57	6	1 - 4	0.3-1.2			
	5	17	8	68	2	0.5- 4	0.2-1.2			
10 ac	72	28	0	0	0	0 - 1	0 -0.3	-	-	CDH 7-10
	2	34	7	48	9	1 - 7	0.3-2.1			
11 bc	25	70	4	1	0	0 - 1.5	0 -0.5	3	0.9	CDH 7-20
	2	20	6	57	15	1.5- 6	0.5-1.8			
	1	25	6	58	10	2 - 7	0.6-2.1			
36 dd	35	65	0	0	0	0 - 3	0 -0.9	6	1.8	CDH 7-15
	1	29	6	54	10	3 - 11	0.9-3.4			
	1	93	5	1	0	1 - 3	0.3-0.9			
TOWNSHIP 2 NORTH, RANGE 70 WEST										
9 ba						- -	- -	-	-	USGS Hy-9
c						- -	- -	-	-	USGS Hy-10
15 aa	9	4	37	50	0	- -	- -	-	-	USGS Hy-11
17 bb	3	53	11	33	0	- -	- -	-	-	USGS Ly-2
18 aa						- -	- -	-	-	USGS Ly-3
cd						- -	- -	-	-	USGS Ly-4
19 bb	21	77	1	1	0	0 - 1.5	0 -0.5	9	2.7	CDH 7-5
	1	15	2	10	72	1.5- 10	0.5-3.0			
	2	20	4	20	54	5 - 10	1.5-3.0			
	1	19	5	15	60	1.5- 9	0.5-2.7			
TOWNSHIP 3 NORTH, RANGE 65 WEST										
19 bb	2	33	16	49	0	- -	- -	-	-	USGS MR-2
TOWNSHIP 3 NORTH, RANGE 66 WEST										
7 ab	8	87	4	1	0	0 - 16	0 -4.9	19	5.8	CDH 3-35
	0	55	15	30	0	16 - 20	4.9-6.1			
	6	48	8	38	0	20 - 23	6.1-7.0			
	23	73	2	2	0	0 - 7	0 -2.1			
	1	51	19	29	0	7 - 15	2.1-4.6			
	9	81	6	4	0	15 - 21	4.6-6.4			
	0	99	1	0	0	0 - 8	0 -2.4			
	0	58	17	25	0	8 - 21	2.4-6.4			
	1	34	13	52	0	21 - 24	6.4-7.3			
13 dc						- -	- -	-	-	USGS MR-1
19 cc	2	65	11	22	0	0 - 18	0 -5.5	24	7.3	CDH 3-66
TOWNSHIP 3 NORTH, RANGE 67 WEST										
9 dd	3	54	19	24	0	- -	- -	-	-	USGS Go-1
23 dd	1	53	12	34	0	0 - 7.5	0 -2.3	4	1.2	CDH 3-49
25 bb	0	50	22	28	0	0 - 8	0 -2.4	8	2.4	CDH 3-50
26 ad	0	60	20	20	0	0 - 6	0 -1.8	6	1.8	CDH 3-51
	0	61	18	21	0	0 - 6	0 -1.8			
28 cc	1	70	6	23	0	1 - 8	0.3-2.4	8	2.4	CDH 3-8
	0	43	7	50	0	0 - 7	0 -2.1			
	24	76	0	0	0	0 - 6	0 -1.8			
	1	45	10	44	0	1 - 8	0.3-2.4			
30 da	1	34	6	59	0	- -	- -	-	-	USGS Go-3
31 b	2	40	11	47	0	- -	- -	-	-	USGS Go-5
	2	26	12	55	5	3 - 12	0.9-3.7	5	1.5	CDH 3-78
	1	56	7	36	0	2 - 12	0.6-3.7			
33 bd	3	44	9	44	0	- -	- -	-	-	USGS Go-6
TOWNSHIP 3 NORTH, RANGE 69 WEST										
6 bd	0	27	6	49	18	1 - 12	0.3-3.7	?	?	CDH 7-8
	4	23	5	40	28	1.5- 12	0.5-3.7			
	34	55	5	6	0	0.3- 3	0.1-0.9			
	3	20	6	36	35	3 - 12	0.9-3.7			
TOWNSHIP 3 NORTH, RANGE 70 WEST										
13 aa	69	23	3	5	0	0 - 2	0 -0.6	?	?	CDH 7-13
	4	25	5	24	42	2 - 12	0.6-3.7			
20 ac	0	33	11	56	0	- -	- -	-	-	USGS Hy-2
21 bb						- -	- -	-	-	USGS Hy-3
da						- -	- -	-	-	USGS Hy-4
27 ba	36	52	3	9	0	0 - 1.5	0 -0.5	7	2.1	CDH 7-23
	4	24	2	48	22	1.5- 12	0.5-3.7			
36 ca	1	44	10	45	0	- -	- -	-	-	USGS Hy-8
cb	0	38	7	55	0	- -	- -	-	-	USGS Hy-7
TOWNSHIP 4 NORTH, RANGE 65 WEST										
6 bc	25	68	3	4	0	ob	ob	-	-	CDH 3-90
	1	54	17	28	0	- -	- -			
	0	54	21	25	0	- -	- -			
9 da						- -	- -	-	-	USGS Ls-10
11 bd	2	44	22	32	0	- -	- -	-	-	USGS Ls-11
15 bd	3	22	75	0	0	- -	- -	-	-	USGS Ls-12
21 ba						- -	- -	-	-	USGS Ls-13
22 ac						- -	- -	-	-	USGS Ls-14
32 cc	16	34	10	40	0	ob	ob	-	-	USGS Ls-15
TOWNSHIP 4 NORTH, RANGE 66 WEST										
7 da	31	51	11	7	0	- -	- -	21	6.4	CDH 3-62
	1	47	16	36	0					
TOWNSHIP 4 NORTH, RANGE 66 WEST – CONTINUED										
	3	41	15	41	0	- -	- -	-	-	USGS Mi-9
8 cc	0	57	27	16	0	- -	- -	-	-	USGS Mi-10
dd	1	74	10	15	0	- -	- -	-	-	USGS Mi-12
17 aa	30	55	15	0	0	0 - 1	0 -0.3	?	?	CDH 3-40
	0	57	21	22	0	1 - 13	0.3-4.0			
	0	75	16	9	0	0 - 15	0 -4.6			
18 bc						- -	- -	-	-	USGS Mi-8
TOWNSHIP 4 NORTH, RANGE 67 WEST										
3 db	57	42	1	0	0	0 - 4	0 -1.2	7	2.1	CDH 3-97
	1	26	7	62	4	3 - 13	0.9-4.0			
	36	61	3	0	0	0 - 3	0 -0.9			
	3	96	1	0	0	4 - 9	1.2-2.7			
	1	28	8	58	5	2 - 12	0.6-3.7			
9 ca	3	31	8	58	0	- -	- -	-	-	USGS Jo-6
da						- -	- -	-	-	USGS Jo-7
13 bc						- -	- -	-	-	USGS Mi-6
ca	2	26	4	68	0	- -	- -	-	-	USGS Mi-7
cc	2	47	10	41	0	- -	- -	-	-	USGS Mi-5
22 da						- -	- -	-	-	USGS Mi-2
23 cc	1	30	4	65	0	- -	- -	-	-	USGS Mi-3
26 ba						- -	- -	-	-	USGS Mi-4
TOWNSHIP 4 NORTH, RANGE 69 WEST										
8 cb	2	43	10	45	0	- -	- -	-	-	USGS CL-2
26 aa	1	73	11	15	0	- -	- -	-	-	USGS Be-1
30 bd	37	27	9	27	0	- -	- -	-	-	USGS CL-3
TOWNSHIP 5 NORTH, RANGE 65 WEST										
2 cc						- -	- -	-	-	USGS Gr-12
3 cb						- -	- -	-	-	USGS Gr-11
15 b	2	56	18	24	0	- -	- -	14	4.3	CDH 3-20
	2	62	16	20	0	- -	- -			
	2	60	20	18	0	- -	- -			
	17	55	10	18	0	ob	ob			
	10	56	14	20	0	ob	ob			
21 bc						- -	- -	-	-	USGS Gr-17
26 ca	26	56	8	10	0	6	1.8	-	-	USGS Ls-9
29 db	21	73	6	0	0	ob	ob	-	-	USGS Ls-5
	0	43	22	35	0	- -	- -			
30 c	24	62	6	8	0	0 - 1.5	0 -0.5	18	5.5	CDH 3-3
	0	55	20	25	0	1.5- 10	0.5-3.0			
cc	0	60	18	22	0	- -	- -	-	-	USGS Ls-4
dc	2	54	16	28	0	- -	- -	-	-	USGS Ls-2
31 c	35	58	5	2	0	0 - 3	0 -0.9	20	6.1	CDH 3-18
	3	51	15	31	0	- -	- -			
	0	51	16	33	0	3 - 14	0.9-4.3			
	0	45	19	36	0	3 - 12	0.9-3.7			
	25	58	17	0	0	0 - 3	0 -0.9			
	1	65	18	16	0	0 - 10	0 -3.0			
TOWNSHIP 5 NORTH, RANGE 66 WEST										
9 aa	25	63	3	9	0	0 - 3	0 -0.9	?	?	CDH 3-14
	2	28	9	49	12	0 - 7	0 -2.1			
	1	30	7	49	13	0 - 4	0 -1.2			
	4	26	10	50	10	0.5- 6	0.2-1.8			
	3	42	11	44	0	- -	- -			
	23	71	3	3	0	ob	ob			
	9	18	6	67	0	- -	- -			USGS Br-5
10 aa						- -	- -	-	-	USGS Br-7
bc	40	55	2	3	0	0 - 3	0 -0.9	?	?	CDH 3-103
	4	39	9	48	0	3 - 9	0.9-2.7			
	1	42	9	43	5	9 - 15	2.7-4.6			
13 bc	5	28	8	59	0	4 - 10	1.2-3.0	?	?	CDH 3-2
	5	24	10	61	0	0.4- 6	0.1-1.8			
	46	51	2	1	0	0 - 0.4	0 -0.1			
	2	25	6	62	5	0.4- 10	0.1-3.0			
19 a	3	31	6	46	14	0.5- 10	0.2-3.0	?	?	CDH 3-108
	7	31	13	47	2	6 - 13	1.8-4.0			
25 cd	69	31	0	0	0	0 - 4	0 -1.2	-	-	USGS Ls-1
	2	48	8	42	0	4	1.2			
34 bc						- -	- -	-	-	USGS Mi-14
35 bc	2	74	11	13	0	- -	- -	-	-	USGS Mi-15
TOWNSHIP 5 NORTH, RANGE 67 WEST										
30 dc	2	19	7	68	4	- -	- -	-	-	USGS Jo-2
31 dc	12	23	14	51	0	- -	- -	-	-	USGS Jo-3
32 a	41	58	1	0	0	0 - 2.5	0 -0.8	4	1.2	CDH 3-37
	1	32	6	58	3	2.5- 6	0.8-1.8			
	2	37	10	51	0	3 - 7	0.9-2.1			
	1	40	10	49	0	3 - 8	0.9-2.4			
	1	27	5	64	3	4 - 10	1.2-3.0			
ab						- -	- -	-	-	USGS Jo-4
TOWNSHIP 5 NORTH, RANGE 68 WEST										
15 cd	56	41	1	2	0	0 - 3	0 -0.9	6	1.8	CDH 6-29
	48	50	1	1	0	0 - 4	0 -1.2			
	3	20	5	43	29	5 - 9	1.5-2.7			
	2	25	4	41	28	1 - 9.5	0.3-2.9			
	2	17	6	41	34	1 - 11	0.3-3.4			
	54	42	3	1	0	0 - 6	0 -1.8			
	2	21	4	51	22	6 - 12	1.8-3.7			
	2	34	6	55	3	1.5- 8	0.5-2.4			
	2	23	6	49	20	3 - 10	0.9-3.0			
20 c	2	35	4	48	11	0 - 7	0 -2.1	4	1.2	CDH 6-5
	3	26	9	56	6	0 - 7	0 -2.1			
	48	51	1	0	0	0 - 3	0 -0.9			
21 aa	65	34	1	0	0	0 - 3	0 -0.9	8	2.4	CDH 6-31
	3	31	6	47	13	3 - 12	0.9-3.7			
	4	30	8	50	8	4 - 12	1.2-3.7			
bd	52	48	0	0	0	0 - 1.5	0 -0.5	6	1.8	CDH 6-17
	1	39	5	48	7	1.5- 9	0.5-2.7			
	1	39	6	48	6	2 - 9	0.6-2.7			
	2	23	10	52	13	3 - 9	0.9-2.7			
	43	57	0	0	0	0 - 8	0 -2.4			
26 bc	14	28	11	47	0	- -	- -	-	-	USGS Jo-1
TOWNSHIP 5 NORTH, RANGE 69 WEST										
7 da	31	63	3	3	0	2 - 4	0.6-1.2	?	?	CDH 6-4
	3	16	5	56	20	6 - 10	1.8-3.0			
16 d	49	51	0	0	0	ob	ob	12	3.7	CDH 6-12
	2	25	5	46	22	- -	- -			
	1	23	5	50	21	- -	- -			
24 c,d	2	28	8	52	10	- -	- -	2	0.6	CDH 6-15
TOWNSHIP 5 NORTH, RANGE 70 WEST										
25 cc	28	57	4	11	0	- -	- -	-	-	USGS CL-1
TOWNSHIP 6 NORTH, RANGE 65 WEST										
32 c	3	37	9	51	0	- -	- -	-	-	CDH 3-96
	8	38	8	46	0	ob	ob			
TOWNSHIP 6 NORTH, RANGE 66 WEST										
2 aa						- -	- -	-	-	USGS Gr-8
13 ba	2	26	12	59	1	- -	- -	-	-	Ching
33 cc	5	27	12	53	3	0.5- 3	0.2-0.9	?	?	CDH 3-23*
	2	27	11	51	9	3 - 8	0.9-2.4			
	4	22	13	57	4	0.5- 6	0.2-1.8			
	2	28	9	47	14	6 - 10	1.8-3.0			
	2	78	11	9	0	0.5- 5.5	0.2-1.7			
	3	54	17	26	0	0.5- 10	0.2-3.0			
	2	39	11	44	4	0.5- 11	0.2-3.4			
	3	32	13	49	3	0.5- 10	0.2-3.0			
	18	61	5	16	0	0.5- 4	0.2-1.2			
	4	77	10	9	0	0.5- 4	0.2-1.2			
	3	23	13	54	7	4 - 9	1.2-2.7			
	1	32	10	40	17					Ching
34 cd						- -	- -	-	-	USGS Br-9
36 bd						- -	- -	-	-	USGS Gr-10
da						- -	- -	-	-	USGS Gr-6
TOWNSHIP 6 NORTH, RANGE 67 WEST										
3 bd	1	28	12	51	8	- -	- -	-	-	Ching
15 ad	13	50	10	27	0	0.5- 4	0.2-1.2	16	4.9	CDH 3-22
	5	24	7	43	21	4 - 12	1.2-3.7			
	5	22	8	48	17	1.5- 12	0.5-3.7			
	7	32	8	38	15	1.5- 12	0.5-3.7			
18 cc	0	39	2	57	2	- -	- -	-	-	Ching
27 cc	2	46	7	45	0	1 - 6	0.3-1.8	?	?	CDH 3-102*
	1	20	4	74	1	6 - 11	1.8-3.4			
	0	28	10	58	4	- -	- -	-	-	Ching*
36 ad	1	39	9	48	3	2.5- 11	0.8-3.4	?	?	CDH 3-104
	1	27	9	63	0	2 - 11	0.6-3.4			
TOWNSHIP 6 NORTH, RANGE 68 WEST										
1 aa	2	21	8	52	17	- -	- -	-	-	Ching*
3 ac	72	25	1	2	0	ob	ob	-	-	CDH 6-27
	72	27	0	1	0	ob	ob			
	2	36	5	52	5	- -	- -			
	43	52	2	3	0	ob	ob			
	5	19	7	39	30	- -	- -			
	39	51	2	8	0	ob	ob			
	3	23	6	49	19	- -	- -			
13 cd	64	35	1	0	0	0 - 2	0 -0.6	4	1.2	CDH 6-13
	1	21	6	49	23	2 - 11	0.6-3.4			
	1	24	8	52	15	0.5- 11	0.2-3.4			
	1	24	7	51	17	0 - 11	0 -3.4			
TOWNSHIP 7 NORTH, RANGE 65 WEST										
21 d	1	41	15	43	0	- -	- -	-	-	USGS Ea-1
TOWNSHIP 7 NORTH, RANGE 66 WEST										
7 cc	26	35	14	25	0	- -	- -	-	-	USGS Se-4
TOWNSHIP 7 NORTH, RANGE 67 WEST										
9 cb	1	39	18	42	0	- -	- -	-	-	USGS Ti-2
TOWNSHIP 7 NORTH, RANGE 68 WEST										
8 db	0	57	30	13	0	- -	- -	-	-	Ching
17 dc	0	33	6	55	6	- -	- -	-	-	Ching
20 ab	1	22	5	50	22	0.2- 11	0.1-3.4	4	1.2	CDH 6-30
	0	20	7	44	29	0.2- 11	0.1-3.4			
	47	52	0	1	0	ob	ob			
26 db	1	16	7	76	0	- -	- -	-	-	Ching*
dd	1	23	12	55	9	- -	- -	-	-	Ching*
34 bb	76	23	1	0	0	0 - 4	0 -1.2	4	1.2	CDH 6-37*
	3	24	6	59	8	2 - 10	0.6-3.0			
	23	21	6	38	12	0 - 10	0 -3.0			
	2	28	12	56	2	- -	- -	-	-	Ching*
bc	2	35	4	55	4	- -	- -	-	-	Ching*
c	66	34	0	0	0	0 - 4	0 -1.2	4	1.2	CDH 6-36
	75	25	0	0	0	0 - 4	0 -1.2			
	2	21	8	45	24	4 - 14	1.2-4.3			
	1	22	5	59	13	2 - 14	0.6-4.3			
36 dc	6	39	22	33	0	- -	- -	?	?	CDH 6-2*
TOWNSHIP 7 NORTH, RANGE 69 WEST										
2 ca	35	61	1	3	0	0 - 0.5	0 -0.2	4	1.2	CDH 6-7
	1	18	4	37	40	0.5- 8	0.2-2.4			
	1	43	11	23	22	0.8- 8	0.2-2.4			
	1	18	6	49	26	1.5- 8	0.5-2.4			
	0	41	12	45	2	- -	- -			
	5	20	7	68	0	- -	- -			
	3	17	5	41	34	- -	- -			
TOWNSHIP 8 NORTH, RANGE 66 WEST										
31 ca	1	34	17	48	0	- -	- -	-	-	USGS Se-2
cb	45	43	4	8	0	ob	ob	?	?	CDH 3-36
	4	47	14	31	4	0.3- 5	0.1-1.5			
	2	41	15	41	1	- -	- -			
33 ad	2	46	16	36	0	5 - 10	1.5-3.0	12	3.7	CDH 3-55
	21	46	9	24	0	0.3- 3	0.1-0.9			
	3	90	6	1	0	ob	ob			
	27	73	0	0	0	ob	ob			
	4	52	16	28	0	- -	- -			
	38	48	6	8	0	ob	ob			
TOWNSHIP 8 NORTH, RANGE 67 WEST										
32 cd						- -	- -	-	-	USGS Ti-1

For sale by U. S. Geological Survey
Denver, Colo. 80225 and Reston, Va. 22092, price $1.00