Data from Core Analyses, Aquifer Testing, and Geophysical Logging of Denver Basin Bedrock Aquifers at Castle Pines, Colorado

by S.G. Robson and E.R. Banta

U.S. GEOLOGICAL SURVEY

Open-File Report 93-442

Prepared in cooperation with the
COLORADO DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER; the
CASTLE PINES METROPOLITAN DISTRICT; and the
CASTLE PINES NORTH METROPOLITAN DISTRICT

Denver, Colorado
1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Robert M. Hirsch, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
Box 25046, MS 415
Denver Federal Center
Denver, CO 80225

Copies of this report can be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	2.54	centimeter (cm)
	25.40	millimeter (mm)
mile (mi)	1.609	kilometer

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5(°C)+32.$$

Degree Fahrenheit (°F) may be converted to degree Celsius (°C) by using the following equation:

$$°C = 5/9(°F-32).$$

The following abbreviation also is used in this report: gram per cubic centimeter (g/cm^3)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Data from Core Analyses, Aquifer Testing, and Geophysical Logging of Denver Basin Bedrock Aquifers at Castle Pines, Colorado

By S.G. Robson *and* E.R. Banta

Abstract

In 1987, the U.S. Geological Survey began an investigation to obtain detailed geologic and hydrologic data pertaining to the bedrock aquifers in the Denver basin and to evaluate techniques for estimating aquifer characteristics by use of core analyses, aquifer tests, and geophysical logs. This report contains data collected during this investigation at a test site at Castle Pines, Colorado. Data consist of lithologic descriptions of about 2,400 feet of drill core and laboratory determinations of mineralogy, grain size, bulk and grain density, porosity, specific yield, and specific retention for selected core samples. Water-level data, atmospheric-pressure measurements, aquifer-compression measurements, and borehole geophysical logs also are included.

INTRODUCTION

The Castle Pines Metropolitan District and the Castle Pines North Metropolitan District provide water from bedrock aquifers to residential communities and golf courses in an area about 5 mi north of Castle Rock (fig. 1). To better define the hydraulic characteristics of the bedrock aquifers in the area, the two Metropolitan Districts undertook a core-drilling project in February 1987 that was designed to obtain continuous drill core from land surface to a depth of 3,100 ft. The hydrologic consultant from the Districts (Jehn and Wood, Inc.) supervised the core drilling, collected, cataloged, and stored the core, prepared a detailed lithologic description of the core, and provided core samples for laboratory analyses. Geophysical logs of the two core holes (C1 and C1A) and a nearby irrigation well (A3) (fig. 1) also were obtained by Jehn and Wood, Inc.

In October 1987, additional work at the site was begun by the U.S. Geological Survey, in cooperation with the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer; the Castle Pines Metropolitan District; and the Castle Pines North Metropolitan District. An additional well (designated USGS) was drilled near the core holes to enable more extensive geophysical logging and onsite testing. The purpose of the investigation by the U.S. Geological Survey was to obtain detailed geologic and hydrologic data pertaining to the bedrock aquifers in the Denver basin and to evaluate several techniques for estimating aquifer characteristics by use of core analyses, aquifer tests, and geophysical logs.

Purpose and Scope

This report presents data from core analyses, aquifer testing, and geophysical logging of the bedrock aquifers at the test site. The data were collected during 1987 and 1988. About 600 samples of drill core were analyzed at the Engineering Research Laboratories of the Colorado State University at Fort Collins, Colorado. Analyses consisted of specific-retention determinations on all samples, selected determinations of hydraulic conductivity, and selected thin-section descriptions. Geophysical logs and aquifer-test data were collected following completion of drilling of a test well.

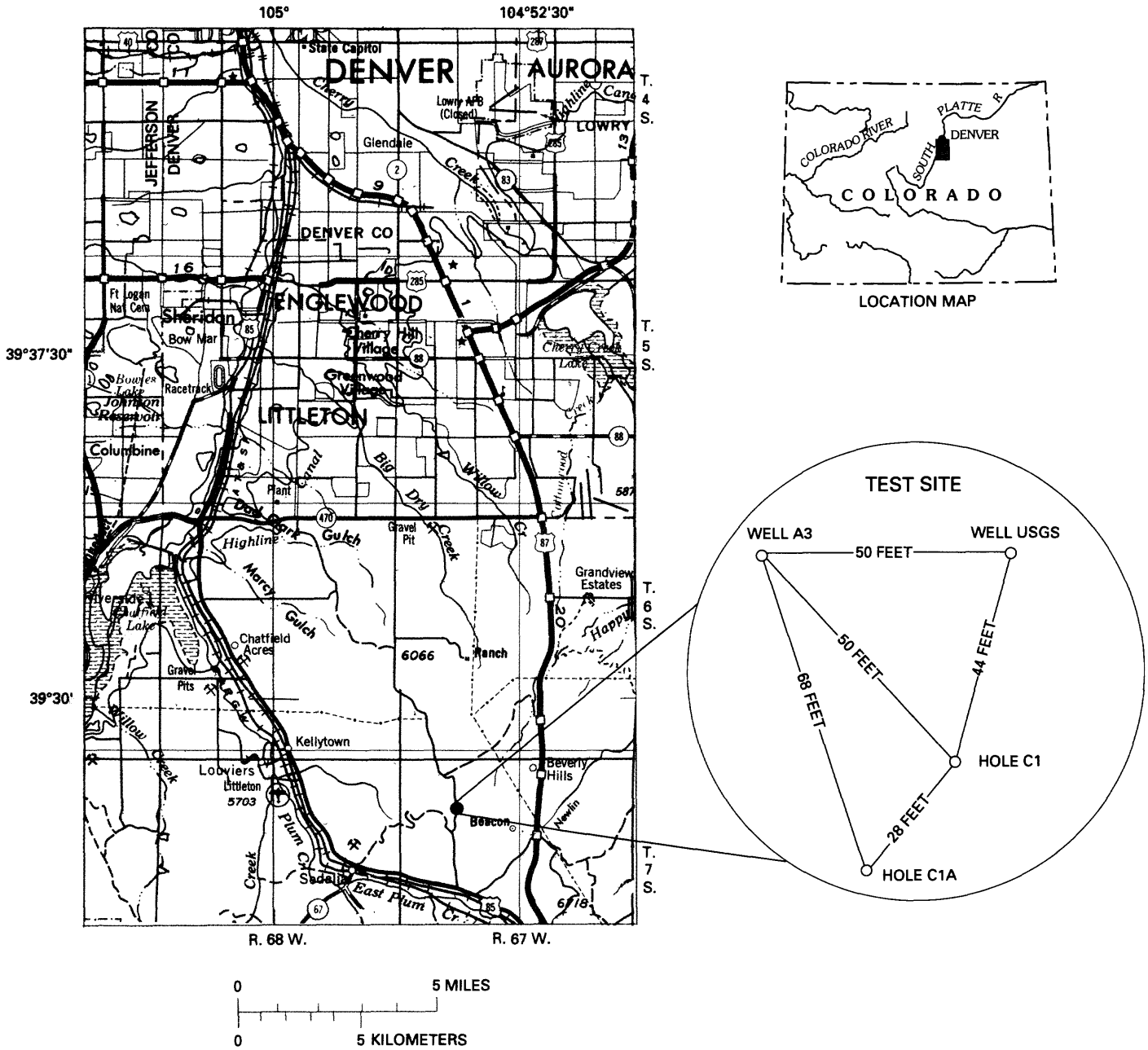

Figure 1. Location of test site.

Acknowledgments

Data contained in this report were obtained as a joint undertaking of hydrologists and geologists from Federal, State, and local agencies and from private industry. David B. McWhorter and Anthony Garcia of the Colorado State University Engineering Research Laboratories performed extensive laboratory analyses for specific retention that were critical to this study. George D. Van Slyke of the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer, provided valuable insight and advice pertaining to the selection of core samples. James L. Jehn, Robert L. Raforth, Ann Moench, and Phillip Martin of Jehn and Wood, Inc., were instrumental in collection, description, sampling, and storage of the large volume of core collected at the test site. The cooperation of the Castle Pines Metropolitan District and the Castle Pines North Metropolitan District was crucial to the undertaking and completion of this study. The dedicated assistance and cooperation of all these individuals and agencies was essential to this study and is gratefully acknowledged.

DESCRIPTION OF TEST SITE

Location and Facilities

The test site is located in the northeast quarter of the southwest quarter of section 9, Township 7 south, Range 67 west, about 20 mi south of Denver (fig. 1). The site is at an altitude of 6,610 ft on the hilly western margin of the Denver basin. A 12-3/4-in-diameter irrigation well (A3) was completed in the Arapahoe aquifer at a total depth of 2,398 ft in July 1985. The well is equipped with a submersible pump capable of yielding 348 gal/min from a pumping water level about 1,330 ft below land surface. The static water level in the well was about 1,300 ft below land surface in April 1988.

In February 1987, a core hole (C1) was drilled 58 ft southeast of well A3 (fig. 1). Core was recovered to a depth of about 1,957 ft, at which point the core barrel was lost, forcing the abandonment of the hole after the upper 1,955 ft of hole was logged (Raforth and Jehn, 1990). A second hole (C1A) was drilled to about 1,895 ft at a point 68 ft south-southeast of well A3 (fig. 1), and coring continued from about 1,895 to 3,110 ft followed by geophysical logging. After completion of coring and logging of C1 and C1A, the holes were filled by injection of cement grout and abandoned.

Well USGS, drilled for the U.S. Geological Survey, was constructed in October 1987, 50 ft east of well A3 and 44 ft northeast of hole C1. Well USGS was drilled and logged to a depth of 2,400 ft in order to fully penetrate the Arapahoe aquifer. After geophysical logging was completed in well USGS, 2,400 ft of blank casing was set and pressure grouted into the well bore. When well-bore temperatures stabilized, temperature logs were run in the casing to determine the equilibrium-temperature profile of the formations. An extensometer then was installed in the casing and was used to measure the changes in thickness of the aquifer caused by fluid-pressure changes produced by pumping the nearby irrigation well A3. After extensometer testing was completed, the 4-in diameter steel casing in well USGS was gun perforated to provide hydraulic connection to specific sandstone and mudstone intervals. Aquifer tests then were conducted by pumping well A3 and monitoring pressure changes in each perforated interval of well USGS by use of pressure transducers isolated between inflatable packers. Well USGS was capped at the completion of the study.

Geohydrology

The Denver ground-water basin (fig. 2), as defined in this report, includes the four principal bedrock aquifers above the Pierre Shale (table 1). The principal aquifers are contained in the Dawson Arkose, the Denver, Arapahoe, and Laramie Formations, and the Fox Hills Sandstone. The ground-water basin is approximately elliptical in shape with the long axis trending north-south. Three generalized geologic sections are shown in figure 3. The basin is of structural origin and is flanked on the west by the Rocky Mountains and on the east by the High Plains. Along the northern, eastern, and southern boundaries of the basin, beds dip gently toward the center of the basin. Near the western margin of the basin, beds may dip steeply toward the center of the basin or may be truncated by the offset of faults.

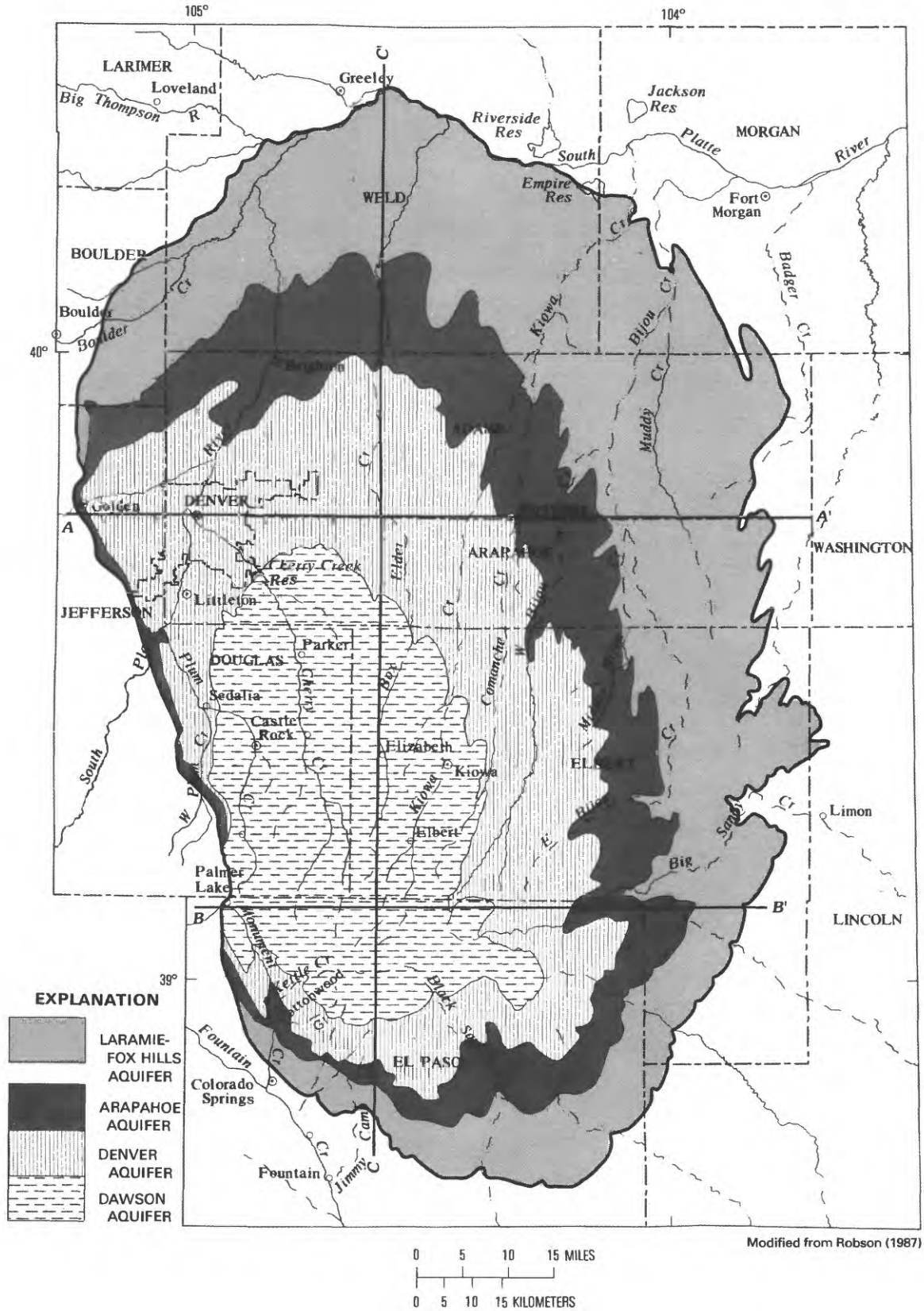

Figure 2. Principal aquifers of the Denver basin.

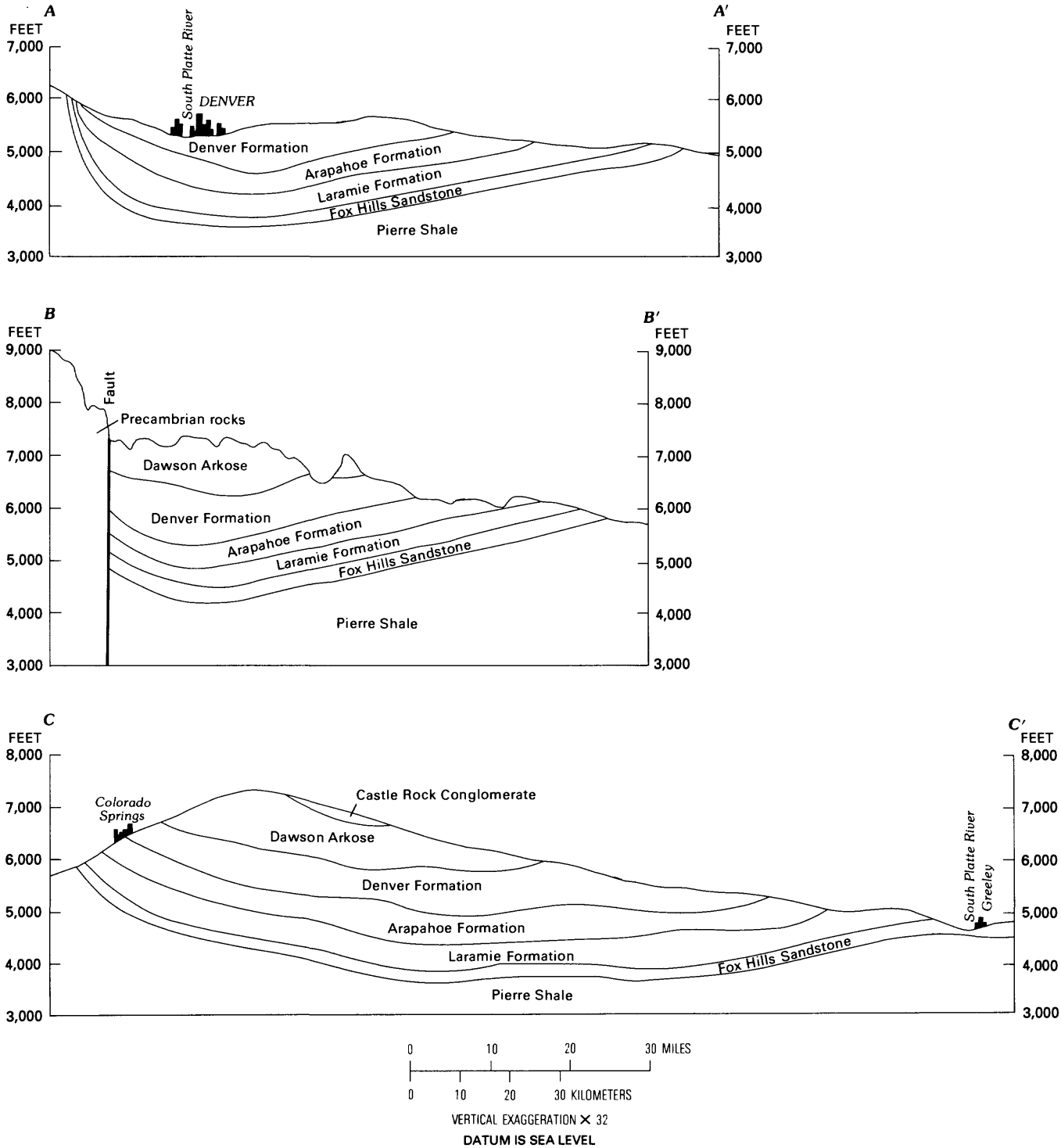

Figure 3. Generalized geologic sections through the Denver basin (trace of sections shown in fig. 2; modified from Robson, 1987).

Sediments penetrated by drilling at the test site consist of conglomerate, sandstone, mudstone, and shale of Tertiary and Cretaceous age that contain the four bedrock aquifers. The deepest formation encountered at the test site was the Pierre Shale, a Cretaceous shale that probably is about 5,000 ft thick in the test-site area and generally does not yield water to wells. The Cretaceous Fox Hills Sandstone overlies the Pierre Shale at a depth ranging from 3,000 to 3,090 ft at the test site. The Laramie Formation overlies the Fox Hills Sandstone at a depth ranging from 2,355 to 3,000 ft. The lower part of the Laramie Formation is sandier and more permeable than the upper part of the formation. The lower part of the Laramie Formation and the Fox Hills Sandstone constitute the Laramie-Fox Hills aquifer, a regionally extensive aquifer that is the deepest of the four principal bedrock aquifers in the Denver basin. The upper part of the Laramie Formation at the test site extends in depth from 2,355 to 2,800 ft and forms a confining layer between overlying and underlying aquifers.

The Arapahoe Formation extends in depth from 1,824 to 2,355 ft at the test site and consists of poorly to well-consolidated fine- to coarse-grained sandstone interlayered with siltstone and a few beds of shale. The Arapahoe aquifer is within the formation and is a permeable and extensively used aquifer in the Denver basin.

The Denver Formation of Tertiary and Cretaceous age overlies the Arapahoe Formation and extends in depth from 962 to 1,824 ft at the test site. The Denver Formation consists of moderately to well-consolidated fine- to medium-grained sandstone interlayered with siltstone, mudstone, and shale. The Denver aquifer is within this formation.

The Tertiary Dawson Arkose overlies the Denver Formation and extends from land surface to a depth of 962 ft at the test site. The Dawson Arkose consists of generally light-colored fine- to coarse-grained arkosic sandstone and conglomerate ranging from poorly to well consolidated. Beds of mudstone are less prevalent in the Dawson Arkose than in the underlying Denver Formation. The Dawson aquifer extends from the water table in the Dawson Arkose (at a depth of about 110 ft at the test site) to the base of the formation.

Table 1. Geohydrologic description of selected aquifers in the Denver basin

[Modified from Major and others (1983); gal/min, gallons per minute]

Era	System	Series	Stratigraphic unit		Physical characteristics	Hydrologic unit			Hydrologic characteristics
			Formation	Thickness (feet)	Lithology and environmental deposition	Name	Confining unit	Thickness (feet)	
Cenozoic	Tertiary	Pliocene Oligocene	Castle Rock Conglomerate	0-50	Arkosic conglomerate and sandstone, firmly cemented, cliff-forming, fine- to coarse-grained, pale pink to yellowish brown. Lower part contains boulders.	Castle Rock Conglomerate			Generally drained; may yield 1 to 2 gal/min from zones of fracture permeability.
		Eocene	Undivided intrusive and extrusive rock	20-200	Dikes, sills, irregular intrusive and extrusive igneous bodies, which intrude or cap older sedimentary rocks. Rock types include mafic monzonite, latite, rhyolite, and welded tuff.	Volcanic rocks			Generally drained; may yield 5 to 10 gal/min from zones of fracture permeability.
			Dawson Arkose	800-1,400	Sandstone and conglomeratic sandstone with interbedded siltstone and shale. Light gray, grayish-yellow, and pink. Much of the sandstone is very coarse grained, quartzose, and distinctly arkosic. Zones composed predominantly of sandstone are generally less than 200 feet thick and lenticular. Consolidation ranges from poor to thorough. Some sandstones are cemented with silicaeous and ferruginous material and are highly resistant to erosion. Alluvial and lacustrine origin.	Dawson aquifer	Shale	0-1,170 (490-1,170 where overlain by volcanic rock)	Yields as much as 300 gal/min.
Mesozoic	Cretaceous	Paleocene Upper Cretaceous	Denver Formation	600-1,100	Shale, silty claystone, and andesitic sandstone. Light brown, yellowish-brown, dusky yellow, green, and greenish-gray silty claystone and shale with interbeds of tan to light brown and olive-brown tuffaceous and andesitic sandstone. Beds of carbonaceous siltstone, shale, and lignite are common. The sandstone beds are weakly crossbedded and lenticular. West of Denver, the formation is interbedded with basalt flows. Alluvial and lacustrine origin.	Denver aquifer	Shale and silty shale	0-100	Not known to yield water to wells.
								0-530 (530-1,080 where overlain by Dawson Arkose)	Yields from 5 to 20 gal/min. Yields increase to as much as 50 gal/min along the western edge of the basin where the sandstone layers are closely spaced. Water of poor quality may be in the andesitic and lignitic beds.
			Arapahoe Formation	400-700	Sandstone, conglomeratic sandstone, shale, and siltstone. Light gray to pale orange and grayish-yellow, fine- to coarse-grained quartzose sandstone and conglomeratic sandstone with interbeds of light gray, light brown, and yellowish-gray shale and siltstone. Reddish-brown iron staining is common. Sandstones and conglomerates are lenticular, but are closely spaced and cover large areas; the horizons frequently exceed 250 feet in thickness. The unit can be divided into an upper and a lower part--the upper consisting of 100 to 400 feet of shale with interbedded sandstone and the lower consisting of 200 to 500 feet of sandstone with interbedded shale. Distinctly quartzose sandstones distinguish this unit from the predominantly andesitic nature of the overlying unit. Alluvial and lacustrine origin.	Arapahoe aquifer	Shale and silty shale	0-100	Not known to yield water to wells.
								0-610 (410-610 where overlain by Denver Formation)	Yields as much as 500 gal/min are not uncommon in the central part of the basin where the sandstone thickness exceeds 250 feet. Yields decline as sandstone thickness thins toward the outcrop areas. Uraniferous and ferruginous zones are noted within the aquifer.

Table 1. Geohydrologic description of selected aquifers in the Denver basin--Continued

Era	System	Series	Stratigraphic unit		Physical characteristics	Hydrologic unit				Hydrologic characteristics
			Formation	Thickness (feet)	Lithology and environmental deposition	Name		Confining unit	Thickness (feet)	
Mesozoic	Cretaceous	Upper Cretaceous	Laramie Formation	90-700	Shale, interbedded siltstone, and sandstone. The upper 40 to 175 feet is yellowish-gray, silty, carbonaceous shale with interbedded siltstone and fine-grained sandstone. Carbonized plant remains are common. The lower 300 feet are light greenish-gray shale with interbedded silty shale and lenticular cross-bedded, very fine-grained sandstone; contains seams of subbituminous coal. Upper part brackish water or swamp origin. Lower part alternating marine and freshwater origin.	Upper Laramie shale		Shale	0-470 (where overlain by Arapahoe Formation)	Yields 5 to 10 gal/min to stock and domestic wells. Water quality is usually poor. Hydrogen sulfide and methane occurrences are associated with the carbonaceous rocks.
					Sandstone, white to yellowish-brown, fine- to medium-grained, ripple marked. Recognized locally only in the Marshall area. Deltaic origin.	Laramie-Fox Hills aquifer	C sandstone	Shale lenses	0-350 (250-350 where overlain by upper Laramie shale)	Yields from 5 to 250 gal/min to stock and domestic wells. Carbonaceous, uraniferous, and ferruginous zones are dispersed through the aquifer.
					Sandstone and shale with coal beds. Light olive-gray to brownish-gray, friable, carbonaceous, pyritic, medium to thick crossbedded, fine- to very fine-grained sandstone with interbedded carbonaceous shale and thin coal beds. Particles of black chert impart a "salt-and-pepper" appearance. Deltaic and estuarine origin.		B sandstone			
					Sandstone and shale with coal beds. Light olive-gray to yellowish-gray, carbonaceous, pyritic, medium to thick crossbedded, fine to very fine-grained sandstone, with interbedded shale and thin coal beds. Particles of black chert impart a "salt-and-pepper" appearance. Deltaic to estuarine origin.		A sandstone			
			Fox Hills Sandstone	60-120	Sandstone, olive-gray, medium to thick, crossbedded, very fine to fine-grained, with calcareous and ferruginous concretions. Estuarine to near-shore marine origin.		Milliken sandstone			
				900±	Sandstone, shale, and siltstone, light olive-gray, medium- to thin-bedded, very fine to fine-grained, clayey sandstone, with interbedded, bioturbated shaley siltstone. Marine origin.		Lower Fox Hills transition zone			Yields some quantities of poor quality water.
			Pierre Shale	8,000±	Shale, silty, medium gray to dark gray, dense, calcareous, bioturbated, fossiliferous, with thin laminae of carbonized plant remains. Marine origin.	Pierre Shale		Shale	50-220	Generally yields no water. Small quantities of water can be obtained near the outcrop areas from the fractured or weathered zones or from sandstone lenses. Water is generally of poor quality.

ANALYSES OF CORE SAMPLES

Lithology

A total of 3,110 ft of core drilling was undertaken in holes C1 and C1A under the supervision of Jehn and Wood, Inc. (Raforth and Jehn, 1990). A lithologic description of the core was prepared at the drill site prior to placing the core in plastic cylinders for transportation and storage. The core description of the upper 2,355 ft of hole listed in table 2 was prepared by physical and binocular microscopic examination of the core by Robert Raforth, Jan Earle, and Ann Moench of Jehn and Wood, Inc. The core descriptions presented in table 2 do not conform to U.S. Geological Survey format because they are considered to be field notes that represent the geologists' first impressions of the core as it was removed from the ground.

The correlation between core-sample depths in holes C1 and C1A and the geophysical-log depths in those holes and well USGS are listed in table 3. A generalized description of the core-sample lithology also is shown.

Table 2. Lithologic description of core from holes C1 and C1A

[", inch; ', foot; ft, feet. Data from Jehn and Wood, Inc., written commun., 1988]

Depth (feet)	Description
	Core Hole C1
0-42.6	No core, cemented interval for surface casing
42.6-55.1	Sandstone, pale grey-green, very arkosic, micaceous, white and grey-green clay matrix, non-calcareous, fine-coarse grading to coarse pebbles in part, very well indurated, porous
55.1-56.6	Sandstone, grey-green, very fine-medium, slightly arkosic, very micaceous, non-calcareous, very well indurated, porous, some white clay matrix (decomposed feldspar)
56.6-65.8	Sandstone, pale grey-green with pink hue, fine-coarse grading to fine-pebbly at 58.5; arkosic, micaceous, white and grey-green clay matrix, non-calcareous, porous, moderate-well indurated
65.8-66.5	Core lost
66.5-70.2	Sandstone, as above, becoming very argillaceous, very well indurated at 66.5-68.2, rest moderately well indurated
70.2-70.5	Core lost
70.5-71.0	Sandstone, as above
71.0-73.5	Sandstone, yellow-green - grey-green, fine-very fine with some medium-very coarse grains floating in fine matrix, arkosic, micaceous, yellow-brown, pale grey and grey-green silt and clay matrix, very argillaceous, moderately indurated spotty/ pods of rusty stain in part
73.5-74.0	Sandstone, as above, very heavy rusty yellow brown iron oxide stain, mostly in matrix
74.0-76.0	Sandstone, yellow green - grey green, fine-very fine with some medium-very coarse grains floating in matrix, arkosic, slightly micaceous, quartzose, yellow-brown, pale grey and grey-green silt and clay matrix, very argillaceous, non-calcareous, moderate to poor induration
76.0-79.3	Sandstone, pale grey-green, fine-very coarse with streaks of medium to very coarse, grading to very fine-medium with some coarse-very coarse at 78.0, very argillaceous, arkosic, micaceous, abundant white clay matrix, non-calcareous, porous, poorly-moderately indurated in part, quartzose
79.3-80.8	Siltstone, pale grey-green, sandy with very fine-very coarse interbed at 80.1, spotty rusty stain in part, porous
80.8-82.7	Sandstone, pale grey-green, very fine-very coarse mostly very fine-medium, quartzose, arkosic, non-calcareous, white clay matrix due to decomposed feldspar, some grey-green clay matrix, argillaceous, very micaceous, moderately indurated, mostly porous
82.7-89.3	Sandstone, pale grey-green, fine-very coarse, pebbly in part, very arkosic, argillaceous, micaceous, mostly well indurated with some moderate induration, porous, white decomposed feldspar matrix, non-calcareous, few streaks of rusty iron oxide stain, quartzose
89.3-89.5	Sandstone, as above, very argillaceous (core severely washed)
89.5-89.6	Core lost
89.6-90.0	Sandstone, as above, very argillaceous with grains floating in siltstone/clay matrix
90.0-93.5	Sandstone, tan, fine-very coarse, some pebbly, arkosic, micaceous, porous, noncalcareous, slightly argillaceous-very argillaceous in part, quartzose, moderately-poor induration
93.5-94.1	Core lost
94.1-98.8	Sandstone, pale grey-green, fine-very coarse, some pebbly, arkosic, quartzose, micaceous, non-calcareous, porous, slightly-moderately argillaceous, grades to fine-pebbly with heavy rusty iron oxide stain at 96.7 and 99.1, poor- moderate induration
98.8-99.1	Core lost
99.1-100.4	Sandstone, as above, iron oxide stain common

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
100.4-104.6	Sandstone, pale grey-green, very fine-medium, some coarse-very coarse, argillaceous, very micaceous, iron oxide stain common, arkosic, poorly-moderately indurated, white and grey clay and silts common, poorly sorted, porous, quartzose
104.6-106.9	Sandstone, tan, fine-pebbly, very arkosic, micaceous, poorly sorted, quartzose, white clay matrix, porous, poorly-moderately indurated
106.9-107.7	Core lost
107.7-109.0	Sandstone, as above
109.0-113.7	Sandstone, grey-green, very fine-medium with some coarse-pebbly, moderately-poorly sorted, arkosic, micaceous, argillaceous, poor-moderately indurated, porous, some white clay matrix, non-calcareous, quartzose
113.7-115.7	Sandstone, grey-green, very fine-fine, some medium, arkosic, micaceous, moderately argillaceous, very poorly-moderately indurated, porous, quartzose
115.7-119.9	Sandstone, grey-green, fine-pebbly, very arkosic, non-calcareous, quartzose
119.9-120.6	Sandstone, grey-green, fine-very fine, very silty, micaceous, very argillaceous, slightly arkosic, non-calcareous, quartzose
120.6-120.9	Sandstone, grey-green, fine-very coarse, arkosic, micaceous, poorly sorted, poorly-moderately indurated, non-calcareous, silty, quartzose
120.9-124.8	Sandstone, grey-green, fine-very fine, silty, micaceous, argillaceous, quartzose, slightly arkosic, non-calcareous, poorly indurated - moderate in part, scattered medium grains with rare coarse grains, mostly well sorted
124.8-128.0	Siltstone, grey-green, interbedded with some very fine sand with rare medium-coarse, poorly sorted, poorly-moderately indurated, argillaceous-very argillaceous in part, variable porosity, non-calcareous, grey silts, grades downward to:
128.0-135.5	Sandstone, grey-green, very fine-fine with occasional medium-coarse, arkosic, micaceous, poorly sorted, poorly-moderately indurated, non-calcareous, porous, very silty as above, very argillaceous, quartzose, occasional rusty yellow orange stain
135.5-147.0	Sandstone, as above, becoming somewhat coarser grained with occasional pebbles, still very argillaceous and silty, quartzose, heavy rusty red brown stain at 137.6-137.9, 138.1-139.0, mostly fine-coarse with some very coarse from 140.5-143.0, heavy rusty red brown stain at 142.9 and 143.9-144.4
147.0-159.8	Sandstone, tan-pinkish tan, fine-very coarse, occasionally pebbly in part, very arkosic, quartzose, micaceous, some white clay matrix, moderately indurated to very friable in part, poorly sorted interbed of grey-green sandstone, as above, at 157.9-158.2, porous, slightly-moderately argillaceous
159.8-163.5	Sandstone, grey-green, very fine-silty, slightly arkosic, micaceous, brown and grey-green silt matrix, well sorted in upper 2 ft, grades downward to very fine-fine with some occasional medium-coarse, porous, quartzose, poorly-moderately indurated, basal contact gradational
163.5-169.0	Sandstone, tan with some pinkish or green hue, fine-coarse, occasional coarse-pebbly, very arkosic, micaceous, poorly sorted, slightly argillaceous, interbedded with sandstone, very fine-medium, grey-green, arkosic, very micaceous, silty at 165.3-166.4, 169.3-169.7, 170.4-170.6, 171.1-172.2, moderately-poorly indurated, quartzose, porous
169.0-169.3	Core lost
169.3-172.2	Sandstone, as above
172.2-184.7	Sandstone, as above, generally coarser grained with abundant pebbles, very arkosic, poorly indurated-friable
184.7-184.9	Sandstone, grey-green, fine-silty, very micaceous, slightly arkosic, argillaceous, poorly-moderately indurated, porous, non-calcareous, quartzose, well sorted, lost core interval is probably mostly this lithology with gradational lower contact
184.9-187.5	Core lost
187.5-200.2	Sandstone, tan with pink cast, fine-medium grading to fine-pebbly, micaceous, very arkosic, slightly-moderately argillaceous, friable to moderately indurated in part, quartzose, non-calcareous, porous, poorly sorted, white clay matrix common; clasts up to 1" thick noted

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
200.2-202.0	Sandstone, grey-green, fine-medium with some coarse, slightly arkosic, very micaceous, silty, porous, quartzose, poorly sorted, moderately indurated, gradational lower contact
202.0-216.4	Sandstone, pale grey-green, fine-coarse, grades to fine-pebbly, non-calcareous, increasingly arkosic, micaceous, increasing white clay content, moderately indurated-poorly indurated in part, poorly sorted, porous, moderate-very argillaceous in part, abundant grey-green silt/clay matrix
216.4-218.6	Core lost
218.6-220.1	Sandstone, as above
220.1-220.3	Core lost
220.3-222.2	Sandstone, tan, fine-pebbly, very arkosic, micaceous, argillaceous, quartzose, porous, poorly sorted, moderate induration, non-calcareous
222.2-223.3	Sandstone, grey-green, very fine-fine occasional medium to coarse, silty, micaceous, very argillaceous, arkosic, quartzose, non-calcareous, moderate induration, gradational lower contact
223.3-226.3	Sandstone, pale grey-green, fine-coarse, occasional very coarse-pebbly, poorly sorted, arkosic, micaceous, argillaceous, mostly porous, poorly-moderately indurated, non-calcareous, quartzose
226.3-226.5	Core lost
226.5-229.5	Sandstone, as above, becoming very argillaceous with heavy clay matrix at 228-229.5
229.5-234.1	Sandstone, tan-pale grey-green, fine-pebbly, very arkosic, quartzose, slightly argillaceous, poorly indurated-friable poorly sorted, porous, non-calcareous, micaceous
234.1-236.4	Sandstone, grey-green, fine-medium, some coarse-very coarse, arkosic, micaceous, argillaceous, poorly sorted, poorly indurated-friable in part, non-calcareous, porous, grades to coarser average grain size at 230 with coarse-very coarse more common but still mostly fine-medium, rusty orange stain at 236.4
236.4-236.9	Siltstone, dark grey-green, abundant fine-very fine sandstone grains, few medium grains, moderately well indurated, very sharp, undulatory contact with above sandstone, iron oxide stain occurs at this contact
236.9-237.5	Core lost
237.5-238.9	Siltstone, as above, lower contact also undulatory with rusty orange iron oxide stain
238.9-242.3	Sandstone, pale grey-green, fine-very coarse, occasional pebbles, very arkosic, micaceous-porous, non-calcareous, moderately-poorly indurated, some dark grey-green matrix, rusty yellow orange stain at 240.7
242.3-248.8	Sandstone, grey-green, fine-very coarse with occasional medium-very coarse, poorly sorted, micaceous, non-calcareous, porous, moderately-poorly indurated, silty-very silty in part, moderate-very argillaceous in part, arkosic, quartzose, non-calcareous; some pebbles from 244.5-247.1; rusty red brown stain 247.5-248.4; and rusty yellow brown stain 248.7
248.8-253.1	Sandstone, very light tan-bleached white, fine-very fine, very silty, very argillaceous grades downward to fine-very coarse at 249.2 (series of fining upward sequences with light tan to light grey-green, fine-very fine sands at top and medium-very coarse, occasional pebbly in bottom of sequence, arkosic, micaceous, argillaceous-very argillaceous, red brown and yellow brown stain common)
253.1-260.1	Sandstone, pale grey-green/yellow green, fine-pebbly quartzose (cobble at 256.5), arkosic, micaceous, poorly sorted, very argillaceous at top grading to moderately argillaceous, poorly indurated to friable, non-calcareous
260.1-261.2	Core lost
261.2-263.4	Sandstone, as above
263.4-266.1	Sandstone, grey-green, very fine-medium with occasional coarse-very coarse, arkosic, micaceous, poorly sorted, very silty, very argillaceous, moderately indurated, non-calcareous, quartzose
266.1-266.6	Core lost
266.6-269.7	Sandstone, as above

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
269.7-281.9	Sandstone, pale grey-green to tan, fine-coarse, some very coarse-pebbly, arkosic, micaceous, poorly sorted, very argillaceous at top, mostly moderately argillaceous, poorly indurated-friable, quartzose
281.9-284.3	Sandstone, tan and grey-green with occasional yellow brown, fine-coarse, some very coarse, arkosic, poorly sorted, micaceous, abundant white clay matrix, with grey siltstone common
284.3-285.3	Core lost
285.3-293.8	Siltstone, grey and grey-green, sandy with fine-very fine, non-calcareous, quartzose, arkosic, sandstone, rare rusty red brown stain (patchy) occasional interbed of very coarse-pebbly, arkosic, sandstone which is very silty, poorly sorted, moderately indurated
293.8-297.8	Siltstone, as above, heavy rusty red brown stain 296-297
297.8-301.1	Sandstone, grey-green, fine-coarse grading to fine-pebbly at 301, arkosic-very arkosic, micaceous, poorly sorted, non-calcareous, slightly argillaceous, porous, slightly indurated to mostly friable, silty in part
301.1-301.4	Core lost
301.4-309.8	Sandstone, as above
309.8-317.4	Sandstone, dark grey-green, very fine-fine grading to very fine-medium with some coarse-very coarse, very silty with grey and white matrix, arkosic, micaceous, quartzose, poorly sorted, variable porosity, very argillaceous, occasional patchy red brown iron oxide stain
317.4-323.1	Sandstone, grey-green to tan, fine-pebbly, pebbles common at base, slightly argillaceous, non-calcareous, poorly sorted, arkosic, quartzose, porous, moderately indurated to friable
323.1-330.0	Sandstone, dark grey-green, fine-very fine, rare medium- coarse, very micaceous, arkosic, quartzose, non-calcareous, moderately-well sorted, poor-moderate induration, porous, moderately argillaceous, interbedded with very friable, fine-very coarse-pebbly sandstone at 326.4-327.3
330.0-363.0	Siltstone, dark grey-green, micaceous, sandy with abundant fine-very fine sandstone with some medium-very coarse and occasional pebbles, arkosic, moderately indurated, poorly sorted, non-calcareous, very argillaceous, patchy rusty red brown stain common, interbedded with fine-coarse arkosic sandstone (very argillaceous) quartzose at 351.9-352.2 at 350.0 - Changes to very dark green-grey cast; at 351.0 - Sandstone interbed, as above; at 354.0 - Becomes sandier; and at 360.0 - Less green color with more dark grey - Grades into:
363.0-369.7	Sandstone, dark grey/dark grey-green, very fine-pebbly, very silty, arkosic, very micaceous, very silty, moderately indurated to friable, non-calcareous, quartzose, very argillaceous
369.7-370.4	Core lost
370.4-377.6	Siltstone, dark grey, occasional red-brown, patchy stain, rare sand grains at 375.0 - Coarse sand grains common
377.6-379.0	Sandstone, dark grey-green, fine-very coarse, few pebbles, arkosic, micaceous, quartzose, very silty, non-calcareous, moderately indurated, some rusty yellow brown stain, poorly sorted
379.0-379.8	Siltstone, as above, grades downward
379.8-384.1	Sandstone, tan-light brown, fine-coarse, occasional very coarse, arkosic, micaceous, poorly sorted, non-calcareous, moderately argillaceous, poorly indurated, porous
384.1-390.0	Siltstone, dark grey-green, sandy (as above) in upper 1-1/2', rest rare sand grains, argillaceous-very argillaceous
390.0-392.3	Mudstone, grey-green, very argillaceous, silty
392.3-404.7	Siltstone, as above
404.7-413.0	Sandstone, light brown with pink and white cast, fine-very coarse, occasional pebbles, very arkosic, slightly argillaceous, micaceous, non-calcareous, poorly indurated - friable in part, some white clay (decomposed feldspar), poorly sorted, few pebbles > 1".
413.0-417.0	Sandstone, as above, with some grey-green silt matrix, somewhat finer grained

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
417.0-424.0	Sandstone, as above
424.0-425.5	Siltstone, dark grey-green, very sandy with abundant very fine of sandstone, very micaceous
425.5-430.5	Sandstone, pale grey-green, very fine-medium, micaceous, silty, occasional rusty yellow orange stain, some heavily tarnished pyrite (?)
430.5-432.0	Sandstone, medium grey, very fine-medium, very micaceous, very carbonaceous in laminations top 1 1/2 ft, cross bedding, grades downward
432.0-440.3	Sandstone, medium grey, fine-cobbles (≤4" dia.), micaceous, slightly arkosic, some yellow-brown silt, few clay galls, poorly indurated, argillaceous, silty, carbonaceous porous (overall grain size is mostly in the very fine-medium range)
440.3-445.0	Siltstone, dark grey-green, sandy with very fine sandstone, micaceous
445.0-448.7	Siltstone, as above, with common rusty red brown stain
448.7-453.2	Sandstone, dark grey-green with red brown cast, fine-very fine, micaceous, slightly arkosic, very silty with red brown common, moderate induration, grades downward with increasing grain size
453.2-457.8	Sandstone, as above, with medium-very coarse common and occasional pebbles
457.8-458.2	Core lost
458.2-461.5	Mudstone, variegated/mottled red, red-brown, grey-green, yellow-brown, micaceous, argillaceous, occasional sandstone interbed
461.5-462.3	Sandstone, brown, fine-very fine, very silty, micaceous
462.3-470.3	Mudstone, variegated/mottled red, red-brown, grey-green, yellow-brown, micaceous, argillaceous, occasional sandstone interbed; 469+ - Slightly carbonaceous
470.3-472.0	Sandstone, fine-very fine, very silty, micaceous
472.0-485.6	Mudstone, dark grey, brown and grey-green, carbonaceous-very carbonaceous in part, argillaceous, micaceous, silty
485.6-488.7	Sandstone, dark grey-green, fine-very fine, very silty, micaceous, non-calcareous
488.7-491.0	Siltstone, grey-green, sandy, grades downward
491.0-505.0	Siltstone, dark grey, carbonaceous-very carbonaceous, sandy, micaceous with some mudstone interbeds
505.0-521.3	Siltstone, as above, with grey-green common, non-calcareous, argillaceous, leaf imprints on bedding surfaces (carbonized) cross bedding & slump features common at 520.0 - Very sandy
521.3-525.4	Core lost
525.4-532.5	Siltstone and mudstone interbedded, as above, carbonaceous-very carbonaceous in part, slightly calcareous, very argillaceous
532.5-534.5	Sandstone, light-medium grey, very fine-medium, occasional coarse, micaceous, slightly argillaceous, some interbedded siltstone, as above
534.5-543.2	Siltstone, as above, sandy, carbonaceous
543.2-546.5	Sandstone, mostly pale yellow-brown with some light grey near top, fine-coarse grading to fine-pebbly, porous, slightly argillaceous, slightly carbonaceous in upper 2'+, arkosic, micaceous, poorly sorted, poorly indurated-friable
546.5-550.0	Core lost 546.5-547.8, some dark grey mudstone just above and below lost interval
550.0-551.4	Sandstone, as above
551.4-555.9	Core lost
555.9-559.8	Sandstone, as above, with some interbedded dark grey-green, fine-very fine lenses (.1-.2 thick)
559.8-561.5	Sandstone, dark grey-green, very fine-medium with some coarse-very coarse, quartzose, very silty, slightly carbonaceous, arkosic, micaceous, moderately indurated, non-calcareous, very argillaceous, poorly sorted

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
561.5-564.8	Sandstone, medium grey, very fine-medium with some coarse-very coarse, quartzose, very silty, slightly carbonaceous, arkosic, micaceous, moderately indurated, non-calcareous, very argillaceous, massive carbon in upper 0.3' with heavy iron oxide stain for next 1.0'
564.8-575.0	Sandstone, pale yellow brown and tan, fine-coarse, pebbly in part, iron oxide stain common, arkosic, mostly argillaceous, poorly indurated, porous, non-calcareous, poorly sorted, grades downward
575.0-581.8	Sandstone, as above, mostly medium-pebbly, slightly argillaceous, friable
581.8-582.9	Core lost
582.9-584.9	Sandstone, as above
584.9-595.0	Siltstone, dark grey, carbonaceous-very carbonaceous with plant debris common (leaves, stems, etc.) thinly laminated with mudstone
595.0-619.3	Sandstone, brown and tan with pink cast, medium-very coarse, very arkosic, micaceous, quartzose, friable-unconsolidated, poorly sorted, some patchy yellow brown iron oxide stain especially in top 0.4'. Upper contact sharp. This sand is a series of fining upward sequences stacked together, with the finer sand interval very fine-medium with occasional coarse-very coarse with pebbles common, usually poorly indurated to unconsolidated
619.3-619.5	Core lost
619.5-620.3	Sandstone, as above
620.3-620.6	Core lost
620.6-621.7	Sandstone, as above
621.7-625.4	Core lost
625.4-634.7	Sandstone, as above, mostly medium-pebbly, increased pink color, friable, clean and porous, sharp lower contact, with 0.1' heavy rusty yellow orange stain, fine sandstone at basal contact with mudstone
634.7-634.8	Mudstone, grey-green slightly carbonaceous, argillaceous, micaceous
634.8-636.1	Core lost
636.1-641.4	Siltstone, dark grey-green with some grey-green, very carbonaceous with plant debris, increasing sand content (very fine), micaceous
641.4-644.0	Sandstone, grey brown, very fine-fine at top grading to fine-very coarse, carbonaceous-very carbonaceous, arkosic, micaceous, well sorted at top to poorly sorted, moderately indurated to friable, heavy yellow stain at upper contact, some patchy stain in rest of sand, argillaceous
644.0-644.7	Core lost
644.7-645.4	Sandstone, tan-brown, very fine-medium, very argillaceous, micaceous, moderate induration, slightly arkosic, silty, lower 0.2' mainly siltstone
645.4-648.2	Sandstone, tan with pink cast, medium-pebbly, very arkosic, micaceous, porous, friable-poorly consolidated, poorly sorted, very sharp upper and lower contacts
648.2-651.2	Sandstone, light brown-pale yellow brown, fine-very fine, moderately argillaceous, uniform to patchy yellow brown and rusty yellow stain
651.2-652.0	Mudstone, pale grey green, slightly micaceous, non-calcareous, very argillaceous
652.0-662.5	Sandstone, tan with pink cast, fine-pebbly, very arkosic, micaceous, poorly sorted, non-calcareous, patchy yellow stain, stain more common toward base, upper contact appears to be sharp with rusty stain on sandstone, slightly-moderately argillaceous, friable
662.5-663.5	Core lost
663.5-668.0	Sandstone, grey-green with yellow cast, fine-very fine, very micaceous, slightly arkosic, argillaceous, rusty yellow-brown stain common grades to fine-pebbly, heavy uniform rusty yellow stain at base, lower contact sharp

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
668.0-672.2	Siltstone, dark grey-green, upper 1.0' sandy, micaceous, argillaceous, carbonaceous
672.2-675.1	Sandstone, grey, with common rusty yellow-brown stain, fine-very fine with occasional medium-coarse, argillaceous, very micaceous, mostly well sorted
675.1-685.7	Siltstone, dark grey and grey-green, sandy in part, micaceous, carbonaceous, very sandy 680.5-681.8 and 684.8-685.3
685.7-693.5	Mudstone, dark grey, micaceous, silty, carbonaceous
693.5-700.1	Sandstone, light brown with yellow cast, heavy rusty yellow-brown stain in upper 2 1/2'; fine-coarse, poorly sorted, argillaceous, silty, slightly arkosic, very micaceous, poorly indurated, porous, non-calcareous, some interbedded fine grey-green sand from 697-699
700.1-705.1	Sandstone, grey-brown, occasional yellow-brown solution banding, mostly fine-very fine with occasional medium-coarse
705.1-724.0	Sandstone, light brown to tan, fine-coarse, pebbly in part, some rusty yellow-brown stain intervals, some grey-green interbedded fine-very fine sand in upper 2', arkosic, micaceous, poorly sorted, non-calcareous, poorly-moderately indurated, quartzose, slightly-moderately argillaceous, porous
724.0-725.2	Core lost
725.2-729.2	Mudstone, medium-dark grey, micaceous, argillaceous silty
729.2-734.8	Siltstone, medium grey, argillaceous, slightly carbonaceous, slightly calcareous in part, grades to dark grey, very carbonaceous at 734.8
734.8-737.5	Siltstone, grading to very fine sandstone, dark grey, carbonaceous-very carbonaceous with plant debris, micaceous, argillaceous
737.5-746.2	Sandstone, grey-brown, fine-very coarse, pebbly in part, slightly arkosic, micaceous, quartzose, poorly sorted, porous, moderately argillaceous, poorly indurated-friable, non-calcareous
746.2-747.1	Sandstone, dark grey-brown, fine-very fine, argillaceous, micaceous, slightly carbonaceous, moderate induration, non-calcareous
747.1-747.6	Core lost
747.6-748.1	Sandstone, as above
748.1-751.6	Sandstone, grey-brown, fine-pebbly, arkosic, micaceous, porous, non-calcareous, poorly indurated-friable, carbonaceous, argillaceous, quartzose, some interbedded sandstone, as above
751.6-754.0	Siltstone, grey-green, argillaceous, very muddy
754.0-758.2	Sandstone, grey-brown with green cast, fine-very fine, quartzose, trace mica, well sorted, argillaceous, silty, carbonaceous, cross bedded
758.2-760.8	Mudstone, grey-green, argillaceous, carbonaceous, trace mica, silty in part
760.8-761.5	Mudstone, dark grey, very carbonaceous, argillaceous, trace mica, grades to sandstone below with increasing siltstone content
761.5-763.3	Sandstone, medium grey, very fine, very argillaceous, micaceous
763.3-764.0	Sandstone, as above, silty
764.0-766.2	Mudstone, medium-dark grey, carbonaceous-very carbonaceous, micaceous, argillaceous, silty
766.2-768.8	Core lost
768.8-771.0	Siltstone, medium grey, carbonaceous, sandy grading to sandstone
771.0-775.2	Sandstone, medium grey, very fine, carbonaceous-very carbonaceous, very silty, argillaceous-very argillaceous, micaceous, non-calcareous, moderately porous, quartzose, rusty yellow-orange stain common
775.2-782.0	Sandstone, light brown, fine-very coarse, occasionally pebbly, arkosic, micaceous, non-calcareous, slightly-moderately argillaceous, poorly indurated-friable, porous

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
782.0-784.0	Sandstone, fine-medium, some coarse, as above
784.0-792.5	Sandstone, as above
792.5-793.0	Core lost
793.0-797.9	Mudstone, medium-dark grey, very argillaceous, carbonaceous, sharp, ferruginous contact with above sandstone, grades into lower sandstone with increasing siltstone content
797.9-800.0	Sandstone, medium grey, fine-very fine, micaceous, slightly-moderately carbonaceous, argillaceous, quartzose, non-calcareous, grades downward with increase in medium with some coarse grains, cross bedded in part
800.0-809.0	Sandstone, light grey-brown, very fine-medium, some coarse, rare very coarse, quartzose, non-calcareous, slightly arkosic, poorly indurated-friable, occasional patchy rusty yellow-orange stain, porous interbedding with sandstone, as above, cross bedded
809.0-813.5	Sandstone, light grey-brown, fine-coarse, occasionally pebbly, arkosic, micaceous, non-calcareous, porous, poorly sorted, poorly indurated, some rusty yellow-brown stain at 812±, slightly-moderately argillaceous, occasional fine-very fine sandstone interbed
813.5-814.3	Core lost
814.3-818.3	Sandstone, as above
818.3-821.4	Sandstone, fine-pebbly, well indurated, as above, few black chert pebbles
821.4-821.8	Sandstone, medium grey-brown, very fine-medium, moderately argillaceous, slightly arkosic, quartzose, micaceous, poorly indurated
821.8-822.6	Core lost
822.6-825.0	Mudstone, dark grey, scour base of sandstone preserved at top
825.0-835.1	Sandstone, grey-brown with yellow cast, very fine-medium, heavy rusty yellow-brown stain at top 0.5 ft, occasional pale yellow-brown stain, very argillaceous at top, mostly slightly-moderately argillaceous, micaceous, poorly indurated, slightly carbonaceous, porous, non-calcareous, quartzose
835.1-842.0	Sandstone, light brown with pink cast, fine-pebbly, micaceous, slightly arkosic, non-calcareous, poorly sorted, poorly indurated-friable, silty, slightly-moderately argillaceous, porous, quartzose
842.0-842.9	Core lost
842.9-845.3	Sandstone, as above
845.3-851.3	Sandstone, light-medium grey, very fine-medium, rare coarse, micaceous, slightly arkosic, quartzose, porous, poorly indurated-friable, non-calcareous, slightly argillaceous, grades downward with increasing grain size
851.3-853.1	Sandstone, grey-brown, fine-coarse, arkosic, micaceous, porous, quartzose, poorly indurated-friable, non-calcareous, slightly-moderately argillaceous
853.1-853.8	Core lost
853.8-856.7	Sandstone, as above, grades to fine-pebbly, brown with pink cast
856.7-861.2	Mudstone, dark grey, argillaceous, slightly calcareous, micaceous, slightly carbonaceous, increasingly silty toward base
861.2-867.6	Sandstone, brown-grey, fine-very fine occasionally fine-coarse, argillaceous-very argillaceous, patchy rusty red-brown and yellow-brown stain, micaceous, quartzose, poorly indurated, coarser interbeds are arkosic, heavy rusty red-brown stain at 867±
867.6-873.2	Sandstone, grey-brown with pink cast, fine-very coarse, pebbly in part, arkosic-very arkosic, micaceous, quartzose, poorly indurated, friable, non-calcareous, occasional patchy yellow-brown stain, slightly argillaceous, porous
873.2-873.5	Core lost
873.5-875.4	Sandstone, as above
875.4-884.0	Sandstone, as above, becoming increasingly coarser in grain size
884.0-886.0	Core lost

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
886.0-886.6	Sandstone, dark grey, fine-pebbly, very silty, poorly sorted, arkosic, micaceous, quartzose, very argillaceous, grades downward with increasing silt content
886.6-890.1	Siltstone, medium grey, very sandy, some yellow-brown stain at 888.6, increasing carbonaceous content, non-calcareous
890.1-892.8	Sandstone, light brown with yellow cast, fine-very fine, occasional medium; micaceous, slightly arkosic, quartzose, common spotty yellow-brown stain, argillaceous
892.8-893.4	Core lost
893.4-897.7	Siltstone, medium-dark grey, very sandy, argillaceous, micaceous, non-calcareous, carbonaceous-very carbonaceous in part, (896-896.6 not sandy, slightly calcareous, as above), rusty yellow-brown stain at 897.2, increasing very fine sand content toward base
897.7-898.0	Sandstone, medium grey, fine-very fine, argillaceous, non-calcareous, moderately indurated, micaceous, grades downward
898.0-902.0	Sandstone, grey-brown with yellow-brown stain common, fine-pebbly, porous, arkosic, micaceous, poorly sorted, poorly indurated
902.0-904.0	Sandstone, medium grey, fine-very fine, some yellow-brown stain, micaceous, very argillaceous, silty
904.0-908.0	Sandstone, light brown-tan, fine-coarse, occasionally very coarse-pebbly, quartzose, arkosic, micaceous, porous, non-calcareous, poorly sorted, poorly indurated, patchy-spotty pale to rusty yellow-brown/yellow-orange stain, gradational lower contact
908.0-909.0	Sandstone, medium grey with common rusty yellow-brown stain, fine-medium, argillaceous, very carbonaceous, grades downward
909.0-910.5	Mudstone, dark grey, very carbonaceous, silty, slightly calcareous, micaceous
910.5-911.9	Sandstone, medium grey with common yellow-brown & rusty red-brown stain, very fine-medium, slightly arkosic, micaceous, quartzose, poorly indurated, moderate sorting, mostly moderately argillaceous with some slightly argillaceous intervals
911.9-913.4	Core lost
913.4-913.9	Sandstone, as above
913.9-922.0	Sandstone, light brown with yellow cast, fine-medium with some coarse, slightly arkosic, micaceous, quartzose, porous, non-calcareous, poorly indurated common yellow-brown stain and solution banding, slightly argillaceous, moderate sorting
922.0-930.3	Sandstone, as above, becoming fine-coarse, occasionally very coarse-pebbly
930.3-931.1	Sandstone, as above, very carbonaceous
931.1-939.7	Sandstone, medium grey, with yellow cast, as above, abundant grey clay as matrix or as drapes (highlight cross bedding) or galls, most sands are stained moderately to very heavy with rusty yellow-brown
939.7-943.3	Sandstone, as above, less massive clay, moderately-well indurated, mostly fine-very coarse-pebbly, ferruginous lower contact
943.3-946.0	Mudstone, grey-green, argillaceous, grades to silty and then sandy
946.0-951.9	Sandstone, medium-dark grey, very fine-silty, cross bedded, very carbonaceous (looks like plant debris), porous
951.9-957.0	Sandstone, yellow-green, very fine-medium, occasionally coarse, poorly sorted, quartzose, micaceous, porous, moderately indurated, moderately argillaceous, silty, grades downward
957.0-961.8	Sandstone, as above, fine-pebbly, very arkosic
961.8-975.7	Mudstone, grey-green, argillaceous, silty, slightly calcareous in part
975.7-977.5	Sandstone, grey-brown, fine-very fine, some medium, argillaceous, moderately well indurated, micaceous, grades downward

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
977.5-981.7	Sandstone, as above, fine-coarse at 979.0 - Medium-dark grey, carbonaceous, fine-medium at 980.5 - Medium grey, fine-coarse
981.7-988.2	Sandstone, dark grey, fine-pebbly, very carbonaceous, moderately argillaceous, arkosic, micaceous, quartzose, moderately indurated, poorly sorted, non-calcareous
988.2-992.0	Mudstone, grey-green, argillaceous, slightly carbonaceous
992.0-994.2	Siltstone, grey-green, slightly carbonaceous, argillaceous
994.2-996.8	Mudstone, dark grey, fissile, very carbonaceous
996.8-999.2	Sandstone, dark grey, fine-very fine, carbonaceous-very carbonaceous, very argillaceous, micaceous
999.2-1000.2	Mudstone, dark grey, fissile, very carbonaceous
1000.2-1002.7	Sandstone, medium grey, fine-very coarse, occasionally pebbly, slightly arkosic, slightly micaceous, carbonaceous in part, quartzose, poorly sorted, medium-poor induration, moderately argillaceous
1002.7-1003.3	Core lost
1003.3-1005.5	Sandstone, as above, sharp lower contact
1005.5-1016.5	Siltstone, grey green, sandy (very fine), micaceous, occasional coarse imbedded grain, slightly carbonaceous, interbedded with mudstone, grey-green, green, gradational contacts
1016.5-1018.2	Sandstone, grey-brown, fine-coarse, argillaceous, quartzose, moderately well indurated, slightly arkosic, micaceous, silty, poorly sorted, poor porosity
1018.2-1022.8	Sandstone, medium grey, fine-coarse, some very coarse-pebbly, micaceous, slightly arkosic, slightly carbonaceous, quartzose, slightly-moderately indurated, slightly-moderately argillaceous
1022.8-1023.5	Core lost
1023.5-1025.0	Sandstone, as above
1025.0-1027.0	Mudstone, grey-green, argillaceous
1027.0-1028.6	Core lost
1028.6-1037.5	Sandstone, dark brown-grey, very fine-silty, micaceous, argillaceous, porous, quartzose, moderately-poorly indurated, slightly carbonaceous, very carbonaceous 1,036-1,037.5
1037.5-1038.7	Core lost
1038.7-1041.4	Sandstone, as above, very carbonaceous in part, becoming fine-medium with some coarse, lower contact gradational
1041.4-1048.1	Sandstone, dark brown-grey, fine-pebbly, arkosic, carbonaceous, micaceous, quartzose, porous, poorly sorted, poorly indurated, slightly argillaceous
1048.1-1048.3	Probable 0.2' core loss at contact
1048.3-1049.6	Siltstone, grey-green, very sandy, carbonaceous
1049.6-1050.4	Sandstone, dark grey-green, fine-very coarse, arkosic, quartzose, micaceous, carbonaceous, mud plugged, moderately well indurated, poorly sorted, poor porosity
1050.4-1050.9	Core lost
1050.9-1052.5	Mudstone, grey-green, silty, argillaceous, non-calcareous
1052.5-1053.5	Siltstone, grey-green, sandy, non-calcareous, micaceous
1053.5-1056.2	Sandstone, pale grey-green, very fine-medium, occasional coarse, micaceous, quartzose, porous, moderate sorting, poorly indurated, non-calcareous
1056.2-1056.7	Mudstone, dark grey, carbonaceous, silty, sandy

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
1056.7-1061.7	Mudstone, grey-green, argillaceous, carbonaceous, silty, sandy in part, grades to siltstone at 1061
1061.7-1068.1	Sandstone, grey-green, very fine-medium, micaceous, quartzose, very argillaceous, carbonaceous, moderate-poor induration, arkosic, poor porosity, grades to very-fine-very coarse at 1066.7 (porous)
1068.1-1068.4	Core lost
1068.4-1069.3	Sandstone, dark grey, fine-pebbly, very carbonaceous, very argillaceous, poorly sorted, moderately indurated, moderate porosity
1069.3-1070.5	Mudstone, dark grey, carbonaceous-very carbonaceous (stems, etc.), micaceous, silty
1070.5-1075.2	Sandstone, mostly dark-grey, fine-very coarse, pebbly in part, arkosic, micaceous, carbonaceous-very carbonaceous with some massive carbonaceous laths, poorly sorted, moderately argillaceous, poorly indurated-friable
1075.2-1077.0	Sandstone, medium-brown, fine-very fine, carbonaceous-very carbonaceous, very argillaceous, micaceous, silty, quartzose, moderate induration, moderate sorting, non-calcareous
1077.0-1078.4	Siltstone, grey-green, sandy, carbonaceous, argillaceous
1078.4-1080.0	Sandstone, grey, fine-medium, some coarse, carbonaceous, micaceous, quartzose, moderate induration, very argillaceous, poor porosity, non-calcareous
1080.0-1082.3	Core lost
1082.3-1085.7	Mudstone, grey-green, micaceous, argillaceous, carbonaceous, silty and sandy
1085.7-1085.8	Sandstone, grey-green, very fine, very argillaceous, micaceous
1085.8-1089.1	Mudstone, dark grey, carbonaceous, silty, argillaceous at 1086.5 - Sandstone, grey-green, very fine, very argillaceous, micaceous (0.1')
1089.1-1098.0	Mudstone, grey-green, argillaceous, micaceous, silty beginning at 1091.6'; at 1095-1096.2 - Very fine sandstone, very argillaceous, micaceous
1098.0-1120.2	Mudstone, dark grey and grey-green interbedded, carbonaceous, micaceous; at 1,099.1-1,099.4 - Sandstone, dark grey, very fine, some medium, micaceous, carbonaceous, very muddy; at 1,106.9-1,107.2 - Sandstone, very fine-very coarse, micaceous, very muddy - From 1111.3 to 1117.6 core is thoroughly mangled. Pieces that are present show grey green mudstone and siltstone, carbonaceous, micaceous. There is undoubtedly some lost core in this interval (should be 2.9'). This lost core is arbitrarily assigned to the interval from 1111.6-1114.5, but could be anywhere from 1111.3-1117.6.
1120.2-1121.4	Sandstone, dark brown, very fine, some fine-medium, micaceous, carbonaceous, argillaceous, porous, moderately well indurated
1121.4-1121.5	Mudstone, grey green
1121.5-1122.0	Core lost
1122.0-1127.0	Mudstone, grey-green with red-brown mottle, silty
1127.0-1130.5	Mudstone, grey-green and dark grey, micaceous, silty, carbonaceous
1130.5-1131.1	Sandstone, pale grey-green, very fine-very coarse, argillaceous, micaceous
1131.1-1133.7	Mudstone, dark grey and grey-green, micaceous, silty, grades to siltstone at 1133.3
1133.7-1136.8	Sandstone, brown with some grey, very fine-medium, occasional coarse-very coarse, carbonaceous, micaceous, quartzose, porous, poorly-moderately indurated, moderate sorting, moderately argillaceous
1136.8-1141.6	Sandstone, light brown with pink cast, fine-coarse, micaceous, quartzose, arkosic, poorly indurated to friable, poorly sorted, slightly argillaceous to very clean and porous, becomes more argillaceous and silty beginning 1139.3
1141.6-1143.0	Core lost
1143.0-1143.7	Sandstone, green and grey-green, fine-very fine, some medium and coarse, argillaceous, carbonaceous, moderately-well indurated, micaceous, quartzose

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1143.7-1144.9	Mudstone, dark grey and grey-green, silty and sandy, carbonaceous, rusty red-brown siltstone at 1144.4-1144.6
1144.9-1145.7	Sandstone, grey-green, fine-coarse, some very coarse, quartzose, micaceous, silty, very argillaceous, poorly sorted
1145.7-1148.9	Core lost
1148.9-1154.4	Mudstone, grey-green and grey, some red-brown mottle
1154.4-1154.7	Sandstone, brown, fine-medium, some coarse-very coarse, well indurated, moderately porous, quartzose, micaceous
1154.7-1156.5	Core lost
1156.5-1160.1	Mudstone, grey-green and dark grey, carbonaceous, micaceous, mottled red-brown
1160.1-1160.6	Siltstone, grey-green with rusty yellow-brown stain, sandy
1160.6-1178.0	Mudstone, as above, grades to sandy siltstone at 1176.5
1178.0-1185.7	Sandstone, grey-brown with pink cast, fine-coarse, some very coarse-pebbly, arkosic, micaceous, quartzose, poorly indurated, friable, poorly sorted, carbonaceous-very carbonaceous in part, pyritized wood at 1181.8', slightly-moderately argillaceous
1185.7-1186.9	Mudstone, grey-green with red-brown mottle, micaceous, carbonaceous
1186.9-1188.4	Sandstone, medium grey, very fine-fine, some medium-coarse, very argillaceous, micaceous, carbonaceous-very carbonaceous at 1188
1188.4-1190.0	Mudstone, grey-green with red brown mottle, micaceous, carbonaceous, grades to siltstone at 1190
1190.0-1192.0	Siltstone, grey-green with some sand grains (up to very coarse imbedded), grades to sandstone
1192.0-1195.4	Sandstone, grey-brown, fine-coarse, very coarse common, micaceous, arkosic, quartzose, poorly sorted, poorly indurated, porous, moderately argillaceous
1195.4-1197.8	Mudstone, grey and grey-green with red-brown mottle, argillaceous, increasingly silty toward base, non-calcareous
1197.8-1198.5	Sandstone, grey-green, fine-coarse, micaceous, silty, quartzose, poorly sorted, well indurated, slightly porous
1198.5-1204.7	Mudstone, grey-green, argillaceous, carbonaceous, slightly micaceous, non-calcareous
1204.7-1205.8	Sandstone, medium brown, fine-very fine, occasional medium, micaceous, slightly arkosic, quartzose, well sorted, poorly indurated, porous, carbonaceous
1205.8-1208.4	Siltstone, grey, very sandy, very carbonaceous, micaceous, argillaceous
1208.4-1209.5	Sandstone, grey-brown, fine-coarse, occasional very coarse, micaceous, quartzose, very carbonaceous, pyritic, arkosic, poorly indurated, poorly sorted, porous
1209.5-1213.4	Core lost
1213.4-1215.0	Mudstone, grey-green with red-brown mottle, argillaceous, grades to siltstone
1215.0-1219.8	Siltstone, grey-green, micaceous, argillaceous
1219.8-1222.8	Core lost
1222.8-1231.0	Mudstone, grey-green with red mottle, argillaceous, micaceous, increasing carbonaceous toward base, very silty in part, some imbedded sand grains (up to coarse) beginning at 1230
1231.0-1238.9	Sandstone, grey-green at top, rest grey brown, fine-coarse, occasional coarse-very coarse, arkosic, micaceous, quartzose, poorly indurated, poorly sorted, porous, moderately argillaceous, carbonaceous-very carbonaceous
1238.9-1242.0	Mudstone, grey-green, carbonaceous, red-brown mottle
1242.0-1244.2	Core lost
1244.2-1247.9	Mudstone, grey-green with red brown mottle, argillaceous, silty, carbonaceous, includes silt and very fine sandstone toward base

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1247.9-1255.0	Sandstone, grey-green at top, rest light brown, very argillaceous and silty to 1252, fine-coarse, occasionally very coarse and pebbly, carbonaceous, arkosic, micaceous, mostly poorly indurated, poorly sorted, mostly porous, moderately argillaceous, very argillaceous and silty at base
1255.0-1257.1	Core lost
1257.1-1258.0	Sandstone, as above
1258.0-1258.7	Mudstone, grey-green, silty, micaceous
1258.7-1270.8	Sandstone, dark grey, very fine-medium, occasional coarse-very coarse, quartzose, micaceous, very carbonaceous, moderately-poorly indurated, arkosic, argillaceous, fair porosity becoming good at 1263
1270.8-1277.7	Sandstone, as above, becoming more coarse-grained with occasional pebbles toward base
1277.7-1281.5	Sandstone, dark grey, fine-very fine, occasional medium-coarse, carbonaceous, micaceous, silty, arkosic, well indurated, well sorted, grades downward to conglomeratic at 1279.1
1281.5-1294.5	Mudstone, grey and grey-green with red-brown mottle, argillaceous, slightly carbonaceous, silty from 1283-1285.5
1294.5-1296.4	Sandstone, grey-brown, fine-very fine, some medium-very coarse, micaceous, carbonaceous, quartzose, arkosic, moderately-poorly indurated, silty, fair sorting, moderately argillaceous
1296.4-1301.1	Mudstone, grey, some carbonaceous, argillaceous, micaceous; at 1297-1297.3 - Sandstone, as above at 1299.5-1301.1 - Very silty
1301.1-1305.4	Mudstone, as above, slightly silty
1305.4-1307.6	Siltstone, grey and grey-green, carbonaceous, micaceous, grades downward
1307.6-1317.6	Sandstone, medium grey, fine-very fine, occasional medium, quartzose, micaceous, very carbonaceous, slightly arkosic, silty, well indurated, well sorted, mostly porous, grades to fine-coarse, cross bedded at 1315
1317.6-1321.0	Mudstone, dark grey and grey-green, carbonaceous-very carbonaceous; very silty from 1319.5-1321.0
1321.0-1323.2	Mudstone, as above, with red-brown mottle
1323.2-1324.0	Siltstone, grey-green, grades to sandstone
1324.0-1326.1	Sandstone, dark grey-brown, very fine, occasionally fine-medium, quartzose, very carbonaceous, micaceous, argillaceous, moderately-poorly indurated, well sorted, cross bedded
1326.1-1327.2	Siltstone, grey-green, sandy
1327.2-1328.3	Mudstone, grey-green with red-brown mottle, argillaceous
1328.3-1330.1	Siltstone, grey and grey-green, argillaceous
1330.1-1334.4	Mudstone, grey-green and grey, argillaceous, carbonaceous
1334.4-1334.8	Siltstone, grey, carbonaceous, micaceous, grades downward
1334.8-1335.9	Sandstone, grey, very fine grading to fine, argillaceous, carbonaceous, micaceous, quartzose, well sorted, mostly porous, poorly indurated
1335.9-1337.0	Siltstone, grey, sandy, micaceous
1337.0-1338.1	Core lost
1338.1-1338.7	Siltstone, as above
1338.7-1342.8	Siltstone, grey and grey-green, interlaminated with grey-green and red-brown mudstone, carbonaceous, very sandy
1342.8-1348.0	Sandstone, grey-brown, fine-medium grading to fine-coarse, some very coarse at 1345.5, carbonaceous-very carbonaceous with interbedded carbonaceous lathes, mostly porous, slightly-moderately argillaceous, micaceous, quartzose, arkosic
1348.0-1349.0	Siltstone, grey and grey-green
1349.0-1352.0	Mudstone, dark grey and grey-green, argillaceous

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1352.0-1352.5	Siltstone, grey, argillaceous, micaceous, grades downward
1352.5-1358.1	Sandstone, pale grey-green and grey, fine-pebbly, micaceous, quartzose, arkosic, poorly sorted, poorly indurated, argillaceous, carbonaceous-very carbonaceous in part, porous
1358.1-1358.8	Core lost
1358.8-1363.8	Sandstone, as above
1363.8-1365.5	Mudstone, grey and grey-green, very fine, silty, micaceous, argillaceous
1365.5-1367.0	Siltstone, grey and grey-green, sandy, grades downward
1367.0-1369.0	Sandstone, grey and grey-green, silty, carbonaceous, micaceous, argillaceous
1369.0-1369.9	Mudstone, grey and grey-green, silty and sandy
1369.9-1373.1	Core lost
1373.1-1379.4	Sandstone, grey and pale grey-green, mostly fine-very fine, some medium-coarse, very carbonaceous, micaceous, argillaceous, moderately indurated, well sorted, moderately porous
1379.4-1381.2	Siltstone, grey-green and dark grey, very carbonaceous, silty and sandy, micaceous
1381.2-1382.6	Sandstone, grey-brown, fine-very fine, occasional medium, quartzose, micaceous, silty, very carbonaceous, moderately well indurated, well sorted, moderately porous
1382.6-1384.0	Mudstone, red-brown and dark grey, silty and sandy
1384.0-1386.0	Sandstone, grey-brown, very fine-medium, some coarse, very carbonaceous, micaceous, argillaceous, moderate-poor sorting, moderately-well indurated, moderately porous
1386.0-1393.5	Mudstone, grey-green, very silty and sandy becomes less silty and sandy toward base
1393.5-1399.5	Sandstone, grey, brown, fine-very fine, very carbonaceous, very micaceous, very argillaceous, poorly indurated, well sorted, porous
1399.5-1415.2	Sandstone, light brown, fine-coarse, some very coarse-pebbly, carbonaceous-very carbonaceous, quartzose, micaceous, arkosic, slightly-moderately argillaceous, poorly indurated-friable-unconsolidated, poorly sorted; at 1412 - Very carbonaceous
1415.2-1417.1	Core lost
1417.1-1428.9	Sandstone, as above - Lower 0.5' includes mudstone rip up clasts
1428.9-1430.5	Mudstone, dark grey-green, micaceous, very carbonaceous, increasingly silty toward base
1430.5-1444.2	Sandstone, light brown, with pink cast, fine with occasional medium, quartzose, very micaceous, very carbonaceous, cross bedded in part, arkosic, friable, porous, slightly argillaceous-moderately argillaceous in part; at 1439-1442 - Heavy rusty red stain; at 1442-1443.4 - Sandstone, as above, fine-very coarse; at 1443.4-1444.2 - Sandstone, dark grey and grey-green, fine, very micaceous, carbonaceous-very carbonaceous
1444.2-1446.4	Mudstone, grey-green and dark grey, argillaceous, micaceous, carbonaceous
1446.4-1449.0	Mudstone, grey-green and dark grey, slightly argillaceous, micaceous, carbonaceous, silty
1449.0-1454.8	Sandstone, grey-green at top 1', rest dark grey, very fine, argillaceous, micaceous, very carbonaceous, with interbedded siltstone
1454.8-1455.6	Core lost
1455.6-1456.7	Mudstone, dark grey and grey-green, argillaceous, micaceous, carbonaceous
1456.7-1460.0	Sandstone, grey-green, very fine, very silty, micaceous, well sorted, moderately-well indurated, moderate porosity
1460.0-1461.5	Core lost

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1461.5-1465.0	Mudstone, dark grey, slightly argillaceous
1465.0-1467.8	Siltstone, grey brown, slightly argillaceous, very sandy
1467.8-1476.0	Mudstone, dark grey and grey-green, argillaceous, silty in part, carbonaceous, some occasional red-brown mottle, very silty at base
1476.0-1478.4	Sandstone, grey-brown, fine-very fine quartzose, micaceous, carbonaceous-very carbonaceous, argillaceous-very argillaceous, silty, moderately indurated, well sorted, moderate porosity
1478.4-1479.4	Mudstone, dark grey, carbonaceous
1479.4-1480.7	Siltstone, grey, carbonaceous, muddy
1480.7-1483.5	Sandstone, grey-brown, fine-very fine, quartzose, very micaceous, carbonaceous, moderately argillaceous, poorly indurated, well sorted, moderately porous
1483.5-1484.5	Core lost
1484.5-1492.0	Sandstone, as above, becoming coarser grained (up to very coarse-pebbly) and arkosic
1492.0-1494.5	Mudstone, dark grey, argillaceous, silty
1494.5-1498.6	Siltstone, grey, carbonaceous, argillaceous in part
1498.6-1500.0	Sandstone, grey-brown, very fine, very micaceous, carbonaceous, argillaceous, quartzose, moderately-poorly indurated, fair porosity, well sorted
1500.0-1502.1	Mudstone, dark grey and grey-green, carbonaceous, argillaceous
1502.1-1510.3	Mudstone, as above, mostly silty
1510.3-1511.4	Siltstone, dark grey and grey-green, micaceous, sandy, carbonaceous
1511.4-1512.0	Sandstone, grey-brown, very fine, quartzose, very micaceous, carbonaceous, silty, argillaceous, moderately indurated, well sorted, fairly porous
1512.0-1513.0	Siltstone, dark grey, carbonaceous, micaceous, with some interbedded sandstone, as above at 1512.9
1513.0-1516.7	Mudstone, dark grey
1516.7-1521.0	Sandstone, grey-brown, very fine-fine, very carbonaceous, quartzose, well sorted, moderate induration, moderately porous
1521.0-1522.4	Sandstone, as above, fine-medium, cross bedded
1522.4-1532.5	Sandstone, grey and grey-brown, fine-medium, some coarse-very coarse, micaceous, interbedded with carbonaceous laminae and lathes with fine sandstone, moderately-very argillaceous in part, slightly arkosic, fair sorting, poorly indurated, friable in part, sharp scour base
1532.5-1533.3	Core lost
1533.3-1534.1	Sandstone, as above
1534.1-1537.7	Mudstone, grey-green and dark grey, argillaceous
1537.7-1538.5	Siltstone, grey, micaceous, carbonaceous, grades downward
1538.5-1543.0	Sandstone, grey and grey-brown, fine-very fine, occasional medium, very micaceous, quartzose, very carbonaceous, cross bedded, moderately argillaceous, moderately porous
1543.0-1543.5	Core lost
1543.5-1545.1	Sandstone, as above
1545.1-1550.4	Sandstone, medium brown, fine-medium, some coarse, micaceous, quartzose, carbonaceous-very carbonaceous in part, friable, slightly argillaceous in part
1550.4-1558.0	Mudstone, grey-green and grey, argillaceous, micaceous, becomes increasingly silty

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1558.0-1559.3	Siltstone, grey and grey-green, argillaceous, micaceous
1559.3-1577.0	Sandstone, dark grey, very fine grading to fine-coarse at 1560.6, carbonaceous-very carbonaceous, quartzose, micaceous, arkosic, moderately argillaceous, poorly sorted, poorly indurated-friable-unconsolidated, porous. Upper ±15' of this sandstone is a series of very fine grading to fine-coarse intervals, dominant grain size is about medium
1577.0-1596.7	Sandstone, light brown to tan, fine-coarse, some very coarse, slightly-moderately argillaceous, micaceous, arkosic, quartzose, carbonaceous, poorly sorted, poorly indurated-unconsolidated, porous
1596.7-1603.0	Mudstone, dark grey-green, micaceous, argillaceous, silty-very silty in part
1603.0-1607.0	Siltstone, dark grey and grey-green, micaceous, argillaceous
1607.0-1608.0	Mudstone, dark grey, micaceous, silty, non-calcareous
1608.0-1610.7	Siltstone, dark grey and grey-green, micaceous, sandy and with sandstone lenses; at 1608.5-1609.1 and 1610.2-1610.7 - Very fine-fine, occasionally very fine-medium, micaceous, argillaceous, carbonaceous
1610.7-1612.3	Mudstone, dark grey, carbonaceous, micaceous, argillaceous
1612.3-1619.6	Siltstone, dark grey and grey-green, carbonaceous-very carbonaceous, micaceous with thin lenses of very fine sandstone at 1613.9-1614.1 and 1615.1-1615.2, micaceous, argillaceous, very argillaceous toward base
1619.6-1624.7	Mudstone, dark grey and grey-green, argillaceous, carbonaceous, micaceous, silty
1624.7-1629.4	Siltstone, dark grey and grey-green, argillaceous, micaceous, carbonaceous, sandy; at 1626.9-1627.2 - Sandstone, very fine, brown, argillaceous, micaceous
1629.4-1630.2	Sandstone, medium brown, fine-very fine, argillaceous-very argillaceous, quartzose, micaceous, very carbonaceous, slightly porous, poorly indurated, well sorted
1630.2-1631.0	Siltstone, dark grey, carbonaceous, argillaceous, micaceous
1631.0-1637.0	Mudstone, dark grey and grey-green, argillaceous, micaceous, carbonaceous, mostly very poorly indurated
1637.0-1639.0	Siltstone, grey-green with abundant very fine brown sandstone, micaceous, very argillaceous
1639.0-1642.8	Mudstone, dark grey, argillaceous, carbonaceous, micaceous
1642.8-1647.0	Siltstone, grey-green and dark grey, carbonaceous, micaceous, sandy, occasional laminae of very fine sandstone, grades downward
1647.0-1648.9	Siltstone, very dark grey, with abundant fine-very fine sandstone, very carbonaceous, very micaceous
1648.9-1649.2	Sandstone, light grey, fine-very fine, quartzose, very micaceous, very carbonaceous, slightly arkosic, poorly indurated, well sorted, porous
1649.2-1649.9	Core lost
1649.9-1653.3	Sandstone, as above
1653.3-1657.5	Sandstone, as above, becoming coarser grained, grades to very fine-medium to fine-very coarse at base
1657.5-1657.7	Core lost
1657.7-1659.1	Siltstone, dark grey, very carbonaceous with carbonaceous interbeds
1659.1-1660.0	Siltstone, yellow-brown, sandy
1660.0-1666.5	Sandstone, medium grey and grey-brown, very fine-medium grades to very coarse, carbonaceous-very carbonaceous, micaceous, porous, poorly sorted, poorly indurated-friable, cross bedded in part
1666.5-1670.0	Mudstone, dark grey and grey-green, silty, argillaceous, carbonaceous, slightly calcareous
1670.0-1671.8	Siltstone, grey-green, argillaceous, with abundant very fine sandstone throughout, slightly porous, micaceous
1671.8-1672.9	Mudstone, dark grey, silty, argillaceous, micaceous, carbonaceous

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1672.9-1674.5	Siltstone, grey-green, with very fine sandstone throughout, slightly porous, argillaceous, micaceous
1674.5-1676.6	Mudstone, dark grey, silty, micaceous, carbonaceous
1676.6-1678.9	Siltstone, grey-green, argillaceous, micaceous, sandy
1678.9-1680.2	Mudstone, dark grey, carbonaceous, micaceous, argillaceous, silty
1680.2-1684.2	Sandstone, grey-brown, very fine, micaceous, carbonaceous-very carbonaceous, quartzose, argillaceous, slightly porous, moderate induration, well sorted, some interlaminations of dark grey siltstone
1684.2-1685.3	Sandstone, grey-brown, fine-very fine, quartzose, very micaceous, carbonaceous, argillaceous, well indurated, well sorted, slightly porous
1685.3-1690.2	Sandstone, medium grey, fine-very fine, quartzose, very micaceous, carbonaceous, slightly-moderately argillaceous, friable, well sorted, non-calcareous, moderately porous, cross bedded
1690.2-1693.5	Sandstone, light grey, fine-coarse, some very coarse, quartzose, arkosic, micaceous, poorly sorted, poorly indurated-friable, carbonaceous, slightly-moderately argillaceous, moderately porous, some white clay matrix
1693.5-1701.9	Mudstone, dark grey, argillaceous, micaceous, silty, increasing silt content toward base - gradational contact
1701.9-1703.0	Core lost
1703.0-1707.7	Siltstone, grey-green, micaceous, sandy, carbonaceous, increasing sandstone content - gradational contact
1707.7-1708.9	Sandstone, grey-green, fine-medium, some coarse-very coarse, micaceous, quartzose, arkosic, moderately argillaceous, poorly sorted, moderately indurated, moderately porous
1708.9-1710.4	Sandstone, as above, very well indurated with rusty yellow-brown stain
1710.4-1712.2	Sandstone, medium grey and grey-green, fine-medium, occasional coarse-very coarse, micaceous, quartzose, moderately argillaceous, poorly sorted, poorly indurated, carbonaceous-very carbonaceous, moderately porous
1712.2-1728.7	Sandstone, grey-brown, fine-coarse, common very coarse in part, occasional pebbles, quartzose, arkosic, micaceous, poorly indurated, poorly sorted, slightly-moderately argillaceous with some dark grey siltstone interbeds, porous
1728.7-1731.0	Sandstone, grey-green and dark grey, fine-very fine, some medium-coarse, argillaceous, well indurated, moderately well sorted, carbonaceous, micaceous
1731.0-1735.4	Sandstone, as above, with some interbedded fine-coarse arkosic sandstone that looks like 1712.2-1728.7 interval, very carbonaceous in fine intervals, coarse intervals are porous
1735.4-1736.0	Siltstone, dark grey, very carbonaceous, micaceous, with abundant very fine sandstone
1736.0-1737.9	Sandstone, medium-dark grey, fine-very fine, argillaceous, quartzose, micaceous, very carbonaceous, well sorted, poorly indurated, moderately porous
1737.9-1740.0	Core lost
1740.0-1746.5	Mudstone, medium grey and grey-green, silty with increasing silt toward base, argillaceous, micaceous, gradational lower contact
1746.5-1749.0	Siltstone, grey-green and dark grey, sandy, micaceous
1749.0-1750.5	Mudstone, grey-green and medium grey, argillaceous, micaceous, silty
1750.5-1752.1	Siltstone, grey-green and dark grey, very argillaceous, micaceous, very muddy with some very fine sandstone and some dark grey mudstone
1752.1-1753.9	Siltstone, as above, with occasional coarse grain imbedded
1753.9-1754.7	Siltstone, grey-green, sandy, micaceous, carbonaceous
1754.7-1761.0	Sandstone, yellow green and medium grey, very fine-medium grading to fine-coarse, moderately argillaceous, quartzose, micaceous, carbonaceous, poorly indurated-friable, porous, poorly sorted, very coarse-pebbly at base

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1--Continued
1761.0-1768.7	Sandstone, tan with pink cast, fine-pebbly, quartzose, arkosic, argillaceous, micaceous, poorly sorted, moderately indurated-friable, moderately porous, carbonaceous
1768.7-1774.1	Mudstone, dark grey and grey-green, silty-very silty, non-calcareous
1774.1-1776.5	Siltstone, medium grey, sandy, carbonaceous-very carbonaceous, argillaceous in part, micaceous, some coarse sand imbedded beginning 1776, sandstone content increasing throughout
1776.5-1778.5	Sandstone, dark grey, fine-medium, some coarse-very coarse, slightly arkosic, quartzose, micaceous, very argillaceous, very silty, moderately indurated, slightly-moderately porous
1778.5-1780.5	Sandstone, grey-brown, fine-coarse, some very coarse, quartzose, arkosic, micaceous, moderately argillaceous, poorly indurated, carbonaceous-very carbonaceous, poorly sorted, moderately porous
1780.5-1783.3	Mudstone, dark grey and grey-green, argillaceous, silty, micaceous, non-calcareous
1783.3-1785.7	Siltstone, grey-green and grey, argillaceous, micaceous, carbonaceous
1785.7-1786.6	Sandstone, pale grey-green, fine-very fine, quartzose, micaceous, slightly-moderately argillaceous, porous, well sorted, poorly indurated
1786.6-1787.0	Sandstone, dark grey, fine-pebbly, very muddy-silty, carbonaceous, well indurated, poorly sorted, micaceous
1787.0-1789.0	Sandstone, medium grey, fine-medium grading to fine-coarse, strong fetid odor, carbonaceous, micaceous, quartzose, slightly arkosic, poorly sorted, poorly indurated; at 1788-1788.8 - Sandstone, as above, well indurated with yellow-brown stain (pyrite cement?)
1789.0-1792.3	Sandstone, medium grey and pale yellow-green, fine-pebbly, arkosic, quartzose, micaceous, carbonaceous, slightly-moderately argillaceous, moderately porous, poorly sorted, moderately indurated-friable
1792.3-1793.4	Core lost
1793.4-1798.0	Mudstone, grey-green, argillaceous, silty
1798.0-1799.0	Siltstone, grey-green, micaceous, argillaceous, sandy, grades to sandstone
1799.0-1803.5	Sandstone, grey-green, mostly fine-very fine, some medium-coarse, very micaceous, very carbonaceous, quartzose, moderately indurated, moderately well sorted, argillaceous
1803.5-1803.8	Core lost
1803.8-1807.0	Mudstone, pale grey-green, argillaceous, micaceous, silty, occasional imbedded sand grain into very coarse size
1807.0-1815.2	Sandstone, medium grey, mostly yellow-brown to yellow-green, fine-very coarse, occasional pebbly, arkosic, slightly micaceous, slightly carbonaceous to carbonaceous in part, slightly-moderately argillaceous, porous, fair-poorly indurated
1815.2-1823.7	Mudstone, medium-dark grey, argillaceous, carbonaceous, occasional very coarse sand grain near base
1823.7-1827.6	Sandstone, pale grey-green, fine-silty with some medium-very coarse, slightly micaceous, slightly carbonaceous, very argillaceous, slightly porous, well indurated
1827.6-1831.7	Sandstone, grey-brown, fine-very coarse, occasional pebbly, micaceous, slightly arkosic, quartzose, slightly-very carbonaceous in part, fair-poor induration, porous, moderately argillaceous
1831.7-1832.7	Core lost
1832.7-1836.3	Sandstone, as above
1836.3-1837.0	Mudstone, dark grey, argillaceous, very carbonaceous with woody fragments
1837.0-1843.6	Mudstone, medium grey, argillaceous, silty, carbonaceous, increasingly silty toward base
1843.6-1850.7	Sandstone, grey-brown, very fine-medium, micaceous, carbonaceous, moderately argillaceous, fair induration, porous, quartzose, pyritic at 1848.4; at 1850-1850.7 - Very argillaceous and silty with sandstone, as above

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
1850.7-1855.5	Sandstone, fine-coarse, some very coarse, arkosic, fair-poor induration, micaceous, slightly carbonaceous, slightly-moderately argillaceous, porous, quartzose
1855.5-1859.7	Sandstone, fine-pebbly, some coarse carbonaceous fragments, poorly consolidated, arkosic, quartzose
1859.7-1861.1	Sandstone, as above, medium-very coarse, few pebbles
1861.1-1862.3	Siltstone, dark grey, carbonaceous, micaceous
1862.3-1872.1	Sandstone, grey-brown and grey, fine-very coarse, pebbly in part, arkosic, quartzose, slightly carbonaceous, micaceous, slightly-moderately argillaceous, fair induration, porous, very carbonaceous, generally coarser grained and poorly consolidated below 1869.3
1872.1-1872.4	Core lost
1872.4-1875.0	Siltstone, grey-green, argillaceous, carbonaceous, micaceous with some interlaminated sand (very fine-fine), in slump features
1875.0-1875.6	Sandstone, pale grey-green, fine-very coarse, silty, argiilaceous, micaceous, moderately porous, moderately indurated
1875.6-1884.6	Mudstone, dark grey, carbonaceous, argillaceous, silty beginning 1878 with some interlaminated sand at that depth
1884.6-1886.4	Mudstone, grey-green, slightly carbonaceous, silty and increasing sand with up to very coarse inbedded grains, micaceous
1886.4-1895.5	Sandstone, grey-green, very fine at top grading to very fine-medium, micaceous, carbonaceous to very carbonaceous in part, moderately well sorted, slightly arkosic, moderately argillaceous, quartzose, moderately porous, some cross bedding apparent
1895.5-1895.8	Core lost
1895.8-1901.3	Sandstone, as above, grades to fine-pebbly at 1899
1901.3-1901.4	Core lost
1901.4-1902.3	Mudstone, dark grey, carbonaceous, silty, micaceous, argillaceous
1902.3-1903.5	Siltstone, medium-dark grey, sandy, micaceous, carbonaceous, argillaceous
1903.5-1911.7	Sandstone, grey and grey-brown, fine-medium, grades to fine-very coarse, quartzose, carbonaceous, micaceous, arkosic, very porous, slightly argillaceous, poorly sorted, poorly indurated, occasional pebbles below 1905; at 1908.3 - Mudstone, interbed (0.5' thick); at 1911.2 - Mudstone, interbed (0.5' thick)
1911.7-1925.2	Sandstone, grey-brown, fine-very coarse, occasional pebbles, quartzose, arkosic, micaceous, carbonaceous, argillaceous, fair-poor porosity, well indurated, occasional thin (<1") mudstone interbeds
1925.2-1928.8	Core lost
1928.8-1934.4	Sandstone, grey and grey-green, fine-pebbly, quartzose, micaceous, arkosic, slightly carbonaceous to carbonaceous in part, slightly argillaceous, porous, poorly indurated, poorly sorted
1934.4-1935.2	Sandstone, medium grey, very fine-medium, argillaceous, carbonaceous, quartzose, micaceous, well indurated, silty interbeds
1935.2-1938.7	Sandstone, grey-brown, fine-pebbly, slightly argillaceous, quartzose, arkosic, micaceous, slightly carbonaceous, porous, poorly indurated
1938.7-1939.2	Sandstone, dark grey, very fine-very coarse, very argillaceous, quartzose, micaceous, very carbonaceous, well indurated, poorly sorted, slightly porous
1939.2-1939.8	Mudstone, dark grey, carbonaceous, micaceous, argillaceous, few imbedded coarse quartz grains
1939.8-1941.0	Core lost
1941.0-1943.7	Mudstone, grey-green, carbonaceous, silty, argillaceous
1943.7-1944.9	Mudstone, as above, very argillaceous in part

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1—Continued
1944.9-1946.3	Core lost
1946.3-1947.5	Mudstone, medium-dark grey, carbonaceous, micaceous, imbedded coarse quartz common, very silty, argillaceous
1947.5-1954.2	Sandstone, medium grey, fine-very coarse, occasional pebbles, quartzose, arkosic, micaceous, slightly carbonaceous, slightly argillaceous, porous, poorly indurated
1954.2-1957.3	Core lost
	Core Hole C1A
	Casing set to 1895.2 depth (Driller) (Approximately 90' below the top of the Arapahoe aquifer).
1895.2-1899.1	Sandstone, grey, fine-very coarse, occasional pebble, quartzose, arkosic, micaceous, slightly carbonaceous, porous, fair-poorly indurated, poorly sorted
1899.1-1905.9	Core lost
1905.9-1907.0	Siltstone, medium-dark grey, micaceous, argillaceous, carbonaceous, slightly porous
1907.0-1909.2	Siltstone, as above, with some fine sand interbedded
1909.2-1911.6	Sandstone, dark grey, fine-medium, some coarse, carbonaceous, micaceous, quartzose, poorly indurated, porous, very argillaceous and very carbonaceous in part moderate sorting
1911.6-1913.2	Core lost
1913.2-1915.2	Mudstone, dark grey, silty, argillaceous, occasional imbedded quartz grains
1915.2-1920.9	Sandstone, dark grey grading to grey brown, very fine-very coarse, occasional pebbly, micaceous, slightly to moderately carbonaceous, slightly argillaceous, quartzose, top 2'± very argillaceous, rest moderately argillaceous, mostly porous, moderately-fairly indurated
1920.9-1921.9	Core lost
1921.9-1922.5	Sandstone, as above
1922.5-1923.2	Core lost
1923.2-1925.3	Sandstone, medium-grey, very fine-very coarse, slightly carbonaceous, slightly arkosic, micaceous, very argillaceous, quartzose, trace pyrite (tarnished cementing grains), moderately indurated
1925.3-1939.1	Sandstone, grey-brown, fine-very coarse, occasional pebbly, micaceous, quartzose, slightly arkosic, slightly-moderately argillaceous, slightly carbonaceous, mostly porous, fair-poor induration; occasional very-fine sand interbedded; subangular-subrounded, clay matrix is mostly white-light tan from decomposed feldspar; Very silty at 1930.4-1930.8; Very argillaceous 1931.8-1932.1
1939.1-1939.7	Core lost
1939.7-1940.7	Sandstone, dark grey, very fine-very coarse, very silty and argillaceous, carbonaceous, quartzose, micaceous, moderate induration
1940.7-1941.9	Siltstone, dark-grey green, micaceous, argillaceous, sandy, slightly porous
1941.9-1944.1	Mudstone, dark-grey green, silty, micaceous, non-calcareous, trace carbon, argillaceous
1944.1-1950.4	Sandstone, grey-brown to dark grey, fine-very coarse-grained, silty, quartzose, micaceous, slightly carbonaceous, fair to moderate induration, moderately to very porous, subrounded-subangular, slightly arkosic
1950.4-1951.8	Core lost
1951.8-1952.7	Sandstone, as above
1952.7-1953.4	Core lost
1953.4-1959.0	Sandstone, dark-grey-brown, fine pebbly, micaceous, quartzose, arkosic, slightly carbonaceous in part, subrounded-subangular, very porous, friable, white clay matrix from decomposed feldspar

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1A--Continued
1959.0-1960.0	Core lost
1960.0-1963.2	Mudstone, grey-green, very argillaceous, carbonaceous
1963.2-1970.3	Sandstone, light grey, fine-very coarse, quartzose, micaceous, arkosic, slightly carbonaceous, friable, very porous, slightly argillaceous, occasionally pebbly
1970.3-1971.2	Core lost
1971.2-1974.1	Sandstone, as above
1974.1-1981.6	Mudstone, dark grey, carbonaceous, argillaceous, becoming silty at 1976±
1981.6-1985.9	Sandstone, medium grey, very fine-medium, quartzose, micaceous, moderate-very carbonaceous in part, moderately argillaceous, silty, slightly porous, subrounded, fair-poor induration
1985.9-1987.3	Sandstone, light-medium grey, fine-very coarse, quartzose, micaceous, slightly carbonaceous, slightly arkosic, porous, poorly indurated-friable, subangular-subrounded
1987.3-1988.3	Mudstone, dark grey, carbonaceous, micaceous, silty
1988.3-2001.5	Sandstone, light grey-grey brown, fine-very coarse, quartzose, micaceous, arkosic, porous, friable, slightly carbonaceous, slightly argillaceous, subrounded-subangular Carbonaceous mudstone interbedded at 1995.4-1995.7
2001.5-2002.2	Core lost
2002.2-2010.7	Sandstone, grey brown, fine-pebbly, quartzose, arkosic, micaceous, carbonaceous, poorly indurated, porous, subrounded-subangular
2010.7-2011.2	Core lost
2011.2-2017.3	Sandstone as above with some silt and interbedded mudstones as follows: at 2011.7-2013.1 - Mudstones are very silty; at 2014.7-2015.0 - Carbonaceous; at 2015.9-2016.3; at 2017.2-2017.3
2017.3-2020.7	Sandstone, light to medium grey, fine to pebbly, quartzose, arkosic, micaceous, subrounded to subangular, slightly argillaceous, porous, friable
2020.7-2021.7	Core lost
2021.7-2022.9	Sandstone, as above
2022.9-2023.8	Sandstone, dark grey, as above with mudstone interbeds
2023.8-2033.2	Sandstone, as above
2033.2-2033.3	Core lost
2033.3-2033.6	Sandstone, as above, very argillaceous, with interbedded mudstone
2033.6-2034.3	Core lost
2034.3-2034.5	Sandstone, as above
2034.5-2036.0	Mudstone, dark grey, carbonaceous, silty, with minor interbedded, coarse, quartzose grains
2036.0-2038.0	Sandstone, medium grey, fine-very coarse, arkosic, quartzose, micaceous, carbonaceous, slightly-moderately argillaceous, moderately indurated, subrounded-subangular, porous
2038.0-2039.0	Mudstone, dark grey, very silty, very carbonaceous
2039.0-2040.7	Sandstone, medium grey, fine-very coarse, arkosic, quartzose, micaceous, carbonaceous-coaly at 2040.3, poorly indurated, porous, subrounded-subangular
2040.7-2041.7	Core lost
2041.7-2044.5	Sandstone, medium-dark grey, fine-very fine, quartzose, micaceous, carbonaceous, moderately argillaceous, slightly-moderately porous, subrounded
2044.5-2044.9	Core lost

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1A--Continued
2044.9-2046.3	Sandstone, as above with some light grey, fine-coarse sand
2046.3-2052.0	Sandstone, light-medium grey, fine-very coarse, occasional pebbles, micaceous, quartzose, arkosic, slightly carbonaceous, subrounded-subangular, porous, slightly argillaceous, poorly indurated to unconsolidated at 2050.4-2051.0 several thin mudstone interbeds
2052.0-2052.5	Core lost
2052.5-2056.8	Sandstone, as above
2056.8-2057.8	Siltstone, dark grey-green, very carbonaceous, micaceous, sandy
2057.8-2058.1	Sandstone, medium grey, fine-very fine, micaceous
2058.1-2058.7	Sandstone, medium grey, fine-very coarse, quartzose, slightly arkosic, micaceous, slightly carbonaceous, porous, fair induration, rare mudstone interbeds, occasionally pebbly
2058.7-2058.9	Core lost
2058.9-2068.5	Sandstone, as above; at 2065.9 Sandstone, as above, coarser grained, pebbles common
2068.5-2070.9	Core lost
2070.9-2081.9	Sandstone, as above
2081.9-2086.7	Sandstone, dark grey, fine-very fine grain, micaceous, carbonaceous, argillaceous, well indurated, laminated with mudstone and siltstone
2086.7-2088.1	Siltstone, dark grey to grey-green, argillaceous, micaceous
2088.1-2089.9	Mudstone, grey-green, argillaceous
2089.9-2090.9	Core lost
2090.9-2091.0	Sandstone, medium-grey, fine-coarse, arkosic, quartzose, micaceous, porous, slightly argillaceous
2091.0-2092.3	Mudstone, dark grey, argillaceous, silty, carbonaceous
2092.3-2094.6	Sandstone, medium grey, fine-medium, some coarse, quartzose, micaceous, porous, well sorted, subrounded
2094.6-2096.5	Mudstone, dark grey, carbonaceous, micaceous
2096.5-2096.7	Core lost
2096.7-2106.3	Sandstone, medium grey, fine-very coarse, some pebbles, quartzose, arkosic, micaceous, massive, slightly carbonaceous in part, poorly indurated to unconsolidated, porous, slightly argillaceous; at 2104.8 - Mudstone interbed 0.2'
2106.3-2107.2	Core lost
2107.2-2114.7	Sandstone, as above
2114.7-2116.7	Sandstone, dark grey, fine-coarse, interbedded with carbonaceous mudstone and siltstone, otherwise as above
2116.7-2117.6	Core lost
2117.6-2117.8	Sandstone, as above
2117.8-2120.4	Core lost
2120.4-2120.8	Sandstone, medium grey, fine-coarse, micaceous, slightly arkosic, quartzose, porous, slightly argillaceous, moderately indurated
2120.8-2121.2	Mudstone, dark grey, carbonaceous, micaceous
2121.2-2121.9	Mudstone, as above, interbedded with very fine sand
2121.9-2126.7	Sandstone, medium grey, fine-very coarse, arkosic, quartzose, micaceous, occasional pebbles, slightly carbonaceous in part, slightly-moderately argillaceous, mostly porous, moderately indurated to unconsolidated; at 2126.0 - Mudstone interbed, 0.7' thick
2126.7-2130.9	Sandstone, as above; at 2130.8 - Mudstone interbed, 0.1' thick
2130.9-2132.3	Sandstone, as above

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1A—Continued
2132.3-2133.1	Core lost
2133.1-2135.4	Sandstone, medium-dark grey, fine-coarse grain, very carbonaceous, micaceous, quartzose, slightly arkosic, well indurated, porous
2135.4-2138.1	Siltstone, dark grey, carbonaceous, sandy, with common coarse-very coarse grain, slightly porous
2138.1-2139.7	Mudstone, dark grey, carbonaceous, argillaceous, sandy, silty
2139.7-2150.6	Sandstone, medium-dark grey, fine-pebbly, arkosic, micaceous, very carbonaceous in part, occasional mud gall, porous, poorly indurated to unconsolidated
2150.6-2151.6	Core lost
2151.6-2158.9	Sandstone, as above
2158.9-2162.2	Core lost
2162.2-2169.6	Sandstone, as above
2169.6-2172.8	Sandstone, as above, interbedded with fine grey sand and mudstone, very carbonaceous
2172.8-2179.3	Sandstone, medium-dark grey, fine grain to pebbly, arkosic, quartzose, micaceous
2179.3-2179.8	Core lost
2179.8-2183.2	Sandstone, as above, interbedded with mudstone, very carbonaceous
2183.2-2189.6	Core lost
2189.6-2190.1	Sandstone, as above, with massive carbon
2190.1-2192.3	Sandstone, medium-dark grey, fine-very fine, micaceous, quartzose, very carbonaceous, with grey mudstone and siltstone laminations, porous
2192.3-2193.3	Core lost
2193.3-2194.1	Sandstone, as above
2194.1-2196.9	Sandstone, medium-grey, fine-medium, with some coarse, rare thin mudstone interbeds, quartzose, micaceous, carbonaceous, moderately indurated
2196.9-2199.8	Sandstone, medium-dark grey, fine-pebbly, arkosic, quartzose, micaceous, porous, slightly argillaceous, some mudstone galls and rare interbeds, slightly carbonaceous-very carbonaceous in part, poorly indurated
2199.8-2201.0	Core lost
2201.0-2202.4	Siltstone, dark grey, carbonaceous, sandy, argillaceous
2202.4-2203.4	Sandstone, medium grey, fine-coarse, with occasional very coarse to pebbly, quartzose, arkosic, micaceous, porous, poorly indurated
2203.4-2203.8	Sandstone, as above, limonite and hematite cement
2203.8-2203.9	Sandstone, as above, very carbonaceous
2203.9-2206.6	Sandstone, medium grey, fine-very coarse, occasional pebbles, quartzose, arkosic, micaceous, carbonaceous, at 2206 interbedded with grey mudstone
2206.6-2207.1	Mudstone, dark grey, carbonaceous, silty
2207.1-2208.9	Sandstone, medium-dark grey, fine-coarse, quartzose, arkosic, micaceous, carbonaceous, porous, poorly consolidated, interbedded with grey mudstone (silty)
2208.9-2211.1	Core lost
2211.1-2212.0	Sandstone, as above
2212.0-2214.0	Mudstone, dark grey, carbonaceous, micaceous

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1A--Continued
2214.0-2216.0	Core lost
2216.0-2218.1	Mudstone, as above
2218.1-2220.1	Core lost
2220.1-2220.4	Mudstone, as above, pyritic? (heavy iron oxide stain)
2220.4-2221.8	Sandstone, rusty yellow-brown, fine-coarse, quartzose, arkosic, micaceous, heavy iron oxide stain with apparent limonite cement 2221-2221.5, porous in part, mostly well indurated
2221.8-2222.1	Core lost
2222.1-2224.7	Sandstone, medium grey, fine-coarse, quartzose, arkosic, micaceous, slightly argillaceous, poorly indurated, porous, slightly carbonaceous; at 2,223.6 - Mudstone interbed 0.1'
2224.7-2224.9	Core lost
2224.9-2225.4	Sandstone, dark grey, very fine-fine, very argillaceous, silty, very carbonaceous
2225.4-2232.1	Sandstone, light-medium grey, fine-very coarse, occasionally pebbly, quartzose, arkosic, micaceous, porous, slightly argillaceous, poorly consolidated
2232.1-2234.1	Core lost
2234.1-2241.6	Sandstone, medium grey, fine-very coarse, occasional pebbly, quartzose, arkosic, micaceous, porous, slightly argillaceous, moderate-fair induration, occasional carbonaceous mudstone interbed (<.1' thick): at 2235.9, 2237.4, and 2241.5
2241.6-2243.6	Core lost
2243.6-2244.0	Sandstone, yellow grey, mostly fine-medium with some coarse-very coarse, moderately heavy iron oxide stain (probably post-core recovery), porous
2244.0-2250.8	Sandstone, medium-dark grey, fine-very coarse, some pebbles, quartzose, arkosic, micaceous, carbonaceous in part, porous, slightly argillaceous, fair-poorly indurated, occasional carbonaceous mudstone interbed (<.1' thick): at 2246.0, 2246.7, and 2250.7
2250.8-2252.3	Core lost
2252.3-2254.8	Sandstone, grey brown-medium grey, fine-very coarse, occasionally pebbly, quartzose, arkosic, micaceous, slightly argillaceous, porous, poorly indurated, carbonaceous
2254.8-2261.0	Sandstone, medium-grey, fine-medium grading to fine-coarse (top 0.7' with heavy iron oxide stain-very well indurated), porous, slightly arkosic, quartzose, micaceous, moderately well sorted
2261.0-2262.8	Core lost
2262.8-2272.8	Sandstone, medium grey, fine-very coarse, occasionally pebbly, quartzose, arkosic, micaceous, porous, slightly argillaceous to moderately argillaceous in part, poorly indurated, occasional interbedded mudstone or mudstone gall with frequent grain size changes from fine-very coarse to fine-medium with mudstone interbeds more common in finer facies: at 2266.4-2270.0 finer facies predominates
2272.8-2273.8	Core lost
2273.8-2277.6	Sandstone, medium-dark grey, fine-very coarse, occasionally pebbly, quartzose, arkosic, micaceous, porous, slightly-moderately argillaceous in part, fair-poor induration, 0.2' mudstone interbed at 2275.1
2277.6-2279.2	Mudstone, dark grey, carbonaceous, argillaceous
2279.2-2280.9	Mudstone, as above, with interbedded siltstone, argillaceous, grades to very fine sand
2280.9-2282.3	Sandstone, dark grey, very fine-medium, quartzose, slightly arkosic, very micaceous, carbonaceous, porous, mostly well sorted with occasional coarse-grain, moderately argillaceous, carbonaceous, fair induration, well cemented from 2282.1-2282.3

Table 2. Lithologic description of core from holes C1 and C1A--Continued

Depth (feet)	Description
	Core Hole C1A--Continued
2282.3-2287.7	Sandstone, as above, interbedded/interlaminated with dark grey siltstone and mudstone, very carbonaceous, grades to coarse sand
2287.7-2292.2	Sandstone, medium grey, fine-very coarse-pebbly, quartzose, arkosic, micaceous, slightly carbonaceous, friable, porous, slightly argillaceous
2292.2-2292.4	Core lost
2292.4-2302.2	Sandstone, as above
2302.2-2304.8	Core lost
2304.8-2310.8	Sandstone, as above, mostly unconsolidated
2310.8-2313.1	Core lost
2313.1-2315.3	Sandstone, as above
2315.3-2316.8	Sandstone, medium-dark grey, very fine-fine, some medium, quartzose, slightly arkosic, micaceous, very carbonaceous, porous, slightly-moderately argillaceous, interbedded with dark grey siltstone, fair induration
2316.8-2321.2	Sandstone, medium grey, fine-pebbly, quartzose, arkosic, micaceous, poorly indurated-unconsolidated, porous, slightly argillaceous
2321.2-2325.1	Core lost
2325.1-2325.2	Mudstone, dark grey, carbonaceous
2325.2-2325.3	Core lost
2325.3-2325.8	Siltstone, medium grey, very sandy, argillaceous
2325.8-2331.0	Sandstone, medium-dark grey, fine-very coarse, pebbles common, common mudstone galls and ripup clasts, carbonaceous-very carbonaceous in part, porous, slightly-moderately argillaceous, quartzose, arkosic, micaceous, fair-moderate induration
2331.0-2332.8	Sandstone, medium-dark grey, fine-medium, quartzose, micaceous, porous, slightly argillaceous, friable-unconsolidated, well sorted
2332.8-2333.8	Core lost
2333.8-2338.2	Sandstone, medium grey, fine-very coarse, occasional pebbles, quartzose, slightly arkosic, micaceous, porous, fair-good induration, moderate-very carbonaceous in part, occasional mudstone gall or ripup clast
2338.2-2340.2	Core lost
2340.2-2340.4	Sandstone, medium-dark grey, fine-medium grading to fine-pebbly, moderate-very carbonaceous in part, quartzose, slightly arkosic, micaceous, porous, well sorted in fine-grained facies
2340.4-2341.0	Core lost
2341.0-2343.5	Sandstone, as above
2343.5-2344.5	Core lost
2344.5-2350.8	Sandstone, medium grey, fine-medium, quartzose, micaceous, well sorted, porous, carbonaceous, friable, slightly argillaceous, upper 0.5' dark grey, silty
2350.8-2354.7	Sandstone, medium grey, fine-medium grading to fine-coarse, quartzose, micaceous, slightly arkosic, porous, slightly argillaceous, bottom 0.2' well indurated
2354.7-2354.8	Mudstone, dark grey, carbonaceous (Top Laramie Formation)
2354.8-2355.2	Siltstone, medium grey, argillaceous
2355.2	Mudstone, dark grey, non-calcareous, carbonaceous (massive, occurs on bedding planes)

Table 3. Core sample number, depths, and lithology

Lithology: ss, sandstone; siltst, siltstone; ms, mudstone; f, fine grained; m, medium grained; c, coarse grained; p, pebbly; arg, argillaceous; v, very; sli, slightly; E-log, geophysical log; N/A, not applicable; NC, no correlation; --, not correlated]

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Dawson Arkose			
51	120.8	N/A	120.5	N/A	NC	ss, f-v f, arg
901	176.5	N/A	176.0	N/A	176.0	ss, f-p, sli arg
902	230.0	N/A	229.0	N/A	229.0	ss, f-p, sli arg
129	258.9	N/A	258.0	N/A	258.0	ss, f-p, arg
903	260.0	N/A	259.0	N/A	259.0	ss, f-p, arg
1	268.0	N/A	268.0	N/A	268.0	siltst, sandy
130	278.0	N/A	278.0	N/A	--	ss, f-c, arg
904	279.7	N/A	279.5	N/A	280.0	ss, f-c, arg
2	293.1	N/A	293.0	N/A	NC	siltst, sandy
3	307.9	N/A	308.0	N/A	305.5	ss, f-p, sli arg
131	320.6	N/A	320.5	N/A	--	ss, f-p, sli arg
4	327.9	N/A	328.0	N/A	328.0	ss, f-v f, arg
113	351.2	N/A	351.5	N/A	351.0	siltst, sandy
5	377.0	N/A	378.0	N/A	377.0	siltst, sandy
132	380.4	N/A	381.5	N/A	383.0	ss, f-c, arg
6	392.3	N/A	393.5	N/A	392.0	siltst
133	397.8	N/A	399.0	N/A	398.0	siltst
7	416.1	N/A	417.0	N/A	416.0	ss, f-v c, sli arg
134	428.0	N/A	429.0	N/A	429.5	ss, v f-m
8	434.9	N/A	436.0	N/A	438.5	ss, v f-m, arg
135	448.7	N/A	449.5	N/A	454.0	ss, f-v f
136	458.7	N/A	458.5	N/A	461.0	ms
114	473.7	N/A	473.5	N/A	475.0	ms, silty
137	485.9	N/A	486.0	N/A	486.0	ss, f-v f
115	492.4	N/A	492.5	N/A	494.0	siltst, sandy
9	507.0	N/A	507.0	N/A	508.0	siltst, sandy
138	534.6	N/A	534.5	N/A	--	siltst, sandy
139	543.3	N/A	544.5	N/A	543.0	ss, f-c, sli arg
140	549.0	N/A	549.0	N/A	--	ss, f-p, sli arg
905	556.1	N/A	556.0	N/A	550.0	ss, f-p, sli arg
906	556.8	N/A	557.0	N/A	551.0	ss, f-p, sli arg
10	568.4	N/A	568.5	N/A	565.0	ss, f-c, arg
141	580.5	N/A	580.5	N/A	--	ss, m-p, sli arg
11	590.0	N/A	589.0	N/A	586.0	siltst
52	596.0	N/A	595.0	N/A	NC	ss, m-v c
142	605.5	N/A	605.5	N/A	--	ss, m-v c

Table 3. Core sample number, depths, and lithology--Continued

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Dawson Arkose--Continued			
12	620.6	N/A	623.5	N/A	625.0	ss, m-v c
143	629.0	N/A	629.0	N/A	--	ss, m-p
907	629.9	N/A	630.0	N/A	633.0	ss, m-p
116	637.4	N/A	637.5	N/A	641.0	siltst, sandy
54	658.0	N/A	658.0	N/A	656.0	ss, f-p, sli arg
13	679.0	N/A	678.5	N/A	678.0	siltst, sandy
117	688.5	N/A	688.0	N/A	--	ms, silty
144	697.8	N/A	697.5	N/A	--	ss, f-c, arg
145	711.6	N/A	711.5	N/A	--	ss, f-c, sli arg
55	712.9	N/A	712.5	N/A	712.0	ss, f-c, sli arg
908	718.0	N/A	717.5	N/A	714.0	ss, f-c, sli arg
146	722.8	N/A	722.5	N/A	717.0	ss, f-c, sli arg
14	733.3	N/A	733.0	N/A	732.0	siltst, sandy
147	747.6	N/A	747.5	N/A	746.0	ss, f-v f, arg
148	755.2	N/A	755.0	N/A	752.0	ss, f-v f, arg
15	762.7	N/A	762.5	N/A	NC	ss, v f, v arg
149	771.4	N/A	771.5	N/A	773.0	ss, v f, arg
150	779.2	N/A	779.0	N/A	--	ss, f-v c, sli arg
16	788.6	N/A	788.5	N/A	789.0	ss, f-v c
17	796.6	N/A	796.0	N/A	795.0	ms, silty
151	804.7	N/A	804.0	N/A	--	ss, v f-m
18	809.0	N/A	808.5	N/A	810.0	ss, f-v f
152	814.3	N/A	813.5	N/A	815.0	ss, f-c, sli arg
19	822.9	N/A	822.0	N/A	824.0	ms
153	826.0	N/A	825.0	N/A	--	ss, v f-m, sli arg
56	838.6	N/A	837.5	N/A	838.0	ss, f-p, sli arg
154	845.5	N/A	845.5	N/A	846.5	ss, v f-m, sli arg
20	857.6	N/A	857.5	N/A	860.0	ms, silty
21	874.6	N/A	874.5	N/A	876.0	ss, f-v c, sli arg
118	887.5	N/A	886.5	N/A	890.0	siltst, sandy
22	919.4	N/A	918.5	N/A	920.0	ss, f-m, arg
155	930.8	N/A	930.0	N/A	NC	ss, f-c, arg
909	933.0	N/A	932.0	N/A	935.0	ss, f-m, arg
23	955.2	N/A	954.5	N/A	958.0	ss, v f-m, arg
			Denver Formation			
24	966.7	N/A	965.5	N/A	968.0	ms, silty
156	980.7	N/A	979.5	N/A	--	ss, f-c

Table 3. Core sample number, depths, and lithology--Continued

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Denver Formation--Continued			
119	992.4	N/A	991.5	N/A	992.0	siltst
157	995.0	N/A	994.0	N/A	--	ms
158	1,004.0	N/A	1,004.0	N/A	1,005.0	ss, f-v c, arg
120	1,011.5	N/A	1,011.5	N/A	1,013.5	siltst, sandy
159	1,021.6	N/A	1,021.5	N/A	1,025.0	ss, f-c, sli arg
57	1,044.0	N/A	1,043.5	N/A	1,045.0	ss, f-p, sli arg
160	1,056.6	N/A	1,056.5	N/A	1,057.0	ms, sandy
161	1,062.2	N/A	1,062.0	N/A	1,062.0	ss, v f-m, v arg
25	1,067.2	N/A	1,067.0	N/A	1,068.0	ss, v f-v, c
163	1,082.6	N/A	1,081.5	N/A	--	ms, sandy
26	1,096.7	N/A	1,095.0	N/A	1,097.5	ms, silty
164	1,120.6	N/A	1,118.5	N/A	1,119.0	ss, v f, arg
121	1,124.0	N/A	1,122.0	N/A	1,122.0	ms, silty
910	1,139.0	N/A	1,137.0	N/A	1,137.0	ss, f-c
181	1,151.1	N/A	1,151.0	N/A	1,152.0	ms
122	1,167.8	N/A	1,166.0	N/A	1,167.5	ms
58	1,180.2	N/A	1,179.0	N/A	1,181.0	ss, f-c, sli arg
911	1,184.4	N/A	1,183.5	N/A	1,185.0	ss, f-c, sli arg
123	1,199.0	N/A	1,198.0	N/A	1,199.0	ms
27	1,219.0	N/A	1,218.0	N/A	1,220.0	siltst
59	1,234.5	N/A	1,234.5	N/A	1,237.0	ss, f-c, arg
124	1,240.5	N/A	1,240.5	N/A	1,245.0	ms
167	1,244.8	N/A	1,245.0	N/A	1,250.0	ms, silty
178	1,252.7	N/A	1,252.5	N/A	--	ss, f-c, arg
28	1,259.3	N/A	1,259.0	N/A	NC	ss, v f-m, arg
29	1,269.7	N/A	1,269.5	N/A	1,269.0	ss, v f-m, arg
168	1,277.6	N/A	1,277.5	N/A	1,276.0	ss, f-v f
30	1,290.1	N/A	1,290.0	N/A	1,290.0	ms
169	1,310.2	N/A	1,310.0	N/A	1,310.0	ss, f-v f
912	1,316.9	N/A	1,317.0	N/A	1,316.0	ss, f-c
170	1,324.1	N/A	1,324.0	N/A	1,325.0	ss, v f, arg
125	1,328.5	N/A	1,328.5	N/A	1,326.5	siltst
162	1,343.7	N/A	1,344.0	N/A	1,347.0	ss, f-m, sli arg
31	1,351.3	N/A	1,351.5	N/A	1,352.5	ms, silty
166	1,375.7	N/A	1,373.5	N/A	1,375.0	ss, f-v f, arg
171	1,391.3	N/A	1,389.0	N/A	--	ms, sandy

Table 3. Core sample number, depths, and lithology--Continued

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Denver Formation—Continued			
172	1,397.6	N/A	1,395.5	N/A	--	ss, f-v f, v arg
179	1,401.6	N/A	1,399.5	N/A	--	ss, f-c, sli arg
913	1,407.5	N/A	1,405.5	N/A	1,405.0	ss, f-c, sli arg
32	1,422.7	N/A	1,420.0	N/A	1,422.0	ss, f-c, sli arg
33	1,437.2	N/A	1,434.5	N/A	1,437.0	ss, f-m, sli arg
34	1,448.3	N/A	1,445.5	N/A	1,448.0	ms, silty
173	1,449.0	N/A	1,446.5	N/A	1,449.0	ss, v f, arg
126	1,468.2	N/A	1,466.0	N/A	1,466.0	ms, silty
914	1,488.7	N/A	1,487.0	N/A	1,492.0	ss, f-p
180	1,489.9	N/A	1,488.5	N/A	--	ss, f-p
35	1,501.3	N/A	1,500.0	N/A	1,502.0	ms
174	1,528.9	N/A	1,527.5	N/A	NC	ss, f-m
36	1,536.9	N/A	1,535.0	N/A	1,538.0	ms
37	1,543.1	N/A	1,541.5	N/A	1,544.0	ss, f-v f, arg
182	1,552.1	N/A	1,550.0	N/A	--	ms
60	1,559.9	N/A	1,557.5	N/A	1,558.0	ss, v f, arg
61	1,577.8	N/A	1,575.5	N/A	1,570.0	ss, f-c, sli arg
38	1,589.4	N/A	1,587.0	N/A	1,588.0	ss, f-c, sli arg
39	1,603.1	N/A	1,601.0	N/A	1,602.0	siltst
175	1,621.8	N/A	1,619.5	N/A	--	ms, silty
127	1,625.2	N/A	1,623.0	N/A	1,625.0	siltst, sandy
62	1,642.9	N/A	1,640.5	N/A	1,644.0	siltst, sandy
40	1,652.4	N/A	1,650.0	N/A	1,655.0	ss, f-v f, sli arg
63	1,654.0	N/A	1,651.5	N/A	1,657.0	ss, v f-m
64	1,664.7	N/A	1,662.0	N/A	1,666.0	ss, v f-m
41	1,673.7	N/A	1,671.0	N/A	1,674.0	siltst, sandy
176	1,682.7	N/A	1,680.0	N/A	1,683.0	ss, v f, arg
42	1,688.9	N/A	1,686.5	N/A	1,690.0	ss, f-v f
65	1,710.5	N/A	1,708.5	N/A	1,710.0	ss, f-m, arg
43	1,721.9	N/A	1,720.0	N/A	1,721.0	ss, f-c
915	1,736.8	N/A	1,735.0	N/A	1,737.0	ss, f-v f
44	1,751.4	N/A	1,749.5	N/A	1,751.0	ms
177	1,761.1	N/A	1,759.0	N/A	1,760.0	ss, f-p, arg
66	1,765.2	N/A	1,763.0	N/A	1,763.0	ss, f-p, arg
128	1,784.2	N/A	1,782.0	N/A	1,780.0	siltst
45	1,800.9	N/A	1,799.0	N/A	1,801.0	ss, f-v f, arg
68	1,810.8	N/A	1,809.0	N/A	1,810.0	ss, f-v c, sli arg

Table 3. Core sample number, depths, and lithology--Continued

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Arapahoe Formation			
69	1,833.7	N/A	1,831.0	N/A	1,833.0	ss, f-v c, arg
46	1,838.8	N/A	1,836.0	N/A	--	ms, silty
47	1,853.9	N/A	1,851.5	N/A	1,852.0	ss, f-c, sli arg
70	1,870.0	N/A	1,867.5	N/A	--	ss, f-v c, sli arg
183	1,872.6	N/A	1,870.5	N/A	--	siltst, sandy
48	1,883.6	N/A	1,881.5	N/A	1,884.0	ms, sandy
184	1,889.3	N/A	1,887.0	N/A	1,890.0	ss, v f-m, arg
71	1,897.7	N/A	1,895.0	N/A	1,897.0	ss, v f-m, arg
49	1,914.9	N/A	1,914.5	N/A	1,914.0	ss, f-v c, arg
185	1,919.0	N/A	1,918.5	N/A	--	ss, f-v c, arg
73	1,930.0	N/A	1,928.0	N/A	1,933.0	ss, f-p, sli arg
916	1,931.9	N/A	1,930.0	N/A	1,935.0	ss, f-p, sli arg
74	1,936.6	N/A	1,934.5	N/A	1,940.0	ss, f-p, sli arg
50	1,942.8	N/A	1,940.0	N/A	1,944.0	ms, silty
75	1,953.2	N/A	1,951.0	N/A	1,955.0	ss, f-v c, sli arg
187	N/A	1,929.2	N/A	1,926.5	--	ss, f-v c, sli arg
111	N/A	1,937.6	N/A	1,935.0	--	ss, f-v c, sli arg
186	N/A	1,953.8	N/A	1,952.0	--	ss, f-p, sli arg
188	N/A	1,961.5	N/A	1,959.5	--	ms
76	N/A	1,968.0	N/A	1,966.0	1,970.0	ss, f-v c, sli arg
77	N/A	1,977.6	N/A	1,975.5	1,978.0	ms, silty
78	N/A	1,983.3	N/A	1,981.5	1,984.0	ss, v f-m, arg
53	N/A	1,994.1	N/A	1,992.0	1,992.0	ss, f-v c, sli arg
79	N/A	1,997.2	N/A	1,995.0	--	ss, f-v c, sli arg
72	N/A	2,003.0	N/A	2,001.5	2,002.0	ss, f-p
80	N/A	2,015.2	N/A	2,014.0	2,017.0	ss, f-p
81	N/A	2,017.5	N/A	2,016.5	--	ss, f-p
917	N/A	2,024.8	N/A	2,022.5	2,026.0	ss, f-p
82	N/A	2,031.7	N/A	2,029.0	--	ss, f-p
83	N/A	2,042.1	N/A	2,042.0	2,042	ss, f-v f, arg
67	N/A	2,053.3	N/A	2,052.0	2,050.0	ss, f-v c, sli arg
84	N/A	2,060.8	N/A	2,060.0	2,059.0	ss, f-p, sli arg
87	N/A	2,067.6	N/A	2,066.5	2,065.0	ss, f-p, sli arg
192	N/A	2,074.5	N/A	2,072.5	--	ss, f-p, sli arg
85	N/A	2,079.8	N/A	2,078.0	2,080.0	ss, f-p, sli arg
86	N/A	2,086.5	N/A	2,084.5	2,086.0	siltst

Table 3. Core sample number, depths, and lithology--Continued

Sample number	Core-sample depth (feet)		E-log depth (feet)			Core lithology
	C1	C1A	C1	C1A	USGS	
			Arapahoe Formation--Continued			
88	N/A	2,098.4	N/A	2,097.0	2,097.5	ss, f-v c, sli arg
89	N/A	2,109.0	N/A	2,108.5	2,110.0	ss, f-v c, sli arg
195	N/A	2,115.0	N/A	2,114.5	2,116.0	ss, f-c, v arg
165	N/A	2,121.0	N/A	2,119.5	--	ms, sandy
90	N/A	2,122.7	N/A	2,121.0	2,125.0	ss, f-v c, sli arg
91	N/A	2,135.6	N/A	2,131.5	2,135.0	siltst, sandy
196	N/A	2,138.4	N/A	2,134.5	--	ms, sandy
918	N/A	2,146.0	N/A	2,143.0	2,145.0	ss, f-p
92	N/A	2,153.8	N/A	2,151.0	2,155.0	ss, f-p
93	N/A	2,163.6	N/A	2,161.5	2,163.0	ss, f-p
197	N/A	2,170.5	N/A	2,168.5	--	ss, f-p, arg
94	N/A	2,180.7	N/A	2,178.5	NC	ss, f-p, v arg
198	N/A	2,194.3	N/A	2,193.5	2,199.0	ss, f-m
95	N/A	2,204.6	N/A	2,203.5	2,208.0	ss, f-v c, sli arg
96	N/A	2,212.3	N/A	2,213.5	2,217.0	ms
199	N/A	2,222.1	N/A	2,219.5	--	ss, f-c
97	N/A	2,230.1	N/A	2,228.5	2,232.0	ss, f-v c, sli arg
98	N/A	2,239.1	N/A	2,236.5	NC	ss, f-v c, sli arg
919	N/A	2,245.4	N/A	2,242.5	2,247.0	ss, f-v c, sli arg
99	N/A	2,247.0	N/A	2,244.0	2,248.0	ss, f-v c, sli arg
200	N/A	2,252.1	N/A	2,250.0	--	ss, f-v c, sli arg
100	N/A	2,275.3	N/A	2,273.5	2,277.0	ss, f-v c, sli arg
101	N/A	2,277.8	N/A	2,276.0	2,279.0	ms
201	N/A	2,283.6	N/A	2,281.5	2,287.0	ss, v f-m, v arg
102	N/A	2,289.8	N/A	2,288.0	2,292.0	ss, f-p, sli arg
920	N/A	2,296.0	N/A	2,295.0	2,296.0	ss, f-p, sli arg
189	N/A	2,296.4	N/A	2,295.5	2,296.5	ss, f-p, sli arg
103	N/A	2,309.8	N/A	2,309.0	2,312.0	ss, f-p, sli arg
104	N/A	2,318.2	N/A	2,318.0	2,321.0	ss, f-p, sli arg
202	N/A	2,330.3	N/A	2,328.0	2,332.0	ss, f-v c, sli arg
921	N/A	2,332.6	N/A	2,330.5	2,334.0	ss, f-m, sli arg
105	N/A	2,336.0	N/A	2,333.5	2,335.0	ss, f-v c
106	N/A	2,353.3	N/A	2,350.0	2,348.0	ss, f-c, sli arg
112	N/A	2,354.7	N/A	2,352.5	2,355.0	siltst, arg
			Laramie Formation			
107	N/A	2,365.4	N/A	2,363.0	NC	ms
108	N/A	2,833.1	N/A	2,830.5	N/A	ss, f
109	N/A	2,875.9	N/A	2,872.5	N/A	ss, f
110	N/A	2,916.2	N/A	2,913.0	N/A	ss, f

Mineralogy

Fifty samples were selected from the core for thin-section analyses to define mineralogy and grain structure (table 4). David B. McWhorter of Colorado State University provided the following description of the analyses. The following descriptions are essentially verbatim.

Each of the 50 samples consisted of a 20- to 25-cm section of 2.5-in-diameter core. From one end of each sample, a 1-in disc was cut for thin-section blanks. Thin sections were cut normal to bedding with the long dimension perpendicular to the axis of the core. The finished size of the thin sections averages about 2 x 3 cm; each slide thus represents about 2 cm of stratigraphic section. Poorly consolidated samples were impregnated with epoxy prior to preparation of thin sections.

Thin sections were examined under petrographic microscopes at Colorado State University and at the U.S. Geological Survey office in Anchorage, Alaska. Mineral identification was achieved using standard petrographic techniques, and percentage estimates were estimated with the aid of comparative charts. These thin sections have been maintained without attached cover slips, so the staining and/or microprobe analysis is yet possible. Thin sections currently (1988) reside with Professor D.B. McWhorter, Department of Agricultural Engineering, Colorado State University.

All of the samples examined consist of clastic material, which ranges from granule-sized (2-3 mm) to clay-sized particles. All samples contain at least 5 percent clay (either detrital or authigenic), and typically display a wide range of grain sizes. As such, these samples do not fall neatly into categories of sand, silt, and clay, but are mixtures of the above. A classification system developed by Pettijohn and others (1987) uses the amount of matrix material as a criterion for distinguishing between "clean" sands, called arenites; "dirty" sands, called graywackes; and mudstones, which contain more than 75 percent clay. This classification system is effective in this work because it distinguishes between materials of similar porosity and clay content; these are properties that strongly affect both hydraulic behavior and log response. For ease of visual estimation, percentages of mineral constituents were estimated based on a unit volume of the media, porosity included. As such, these percentages need to be normalized for use with the Pettijohn classification, which excludes porosity.

Mineral constituents have been divided into categories of (1) framework grains, and (2) matrix (better called cement, for clean sands). Framework grains have been further subdivided into groups displaying similar geophysical properties as follows:

1. Quartz and feldspar: This group contains the dominant silicate minerals making up the bulk of most arenites and graywackes. These minerals are generally nonconductors, have an average density of about 2.65 g/cm^3, and have minimal adsorptive properties. Quartz occurs in mono- and polycrystalline forms, including chert. Several varieties of feldspar are present, including albite, orthoclase, microcline, perthites, and plagioclase feldspars. Alkali feldspars overwhelmingly predominate over the plagioclase group. Feldspars are commonly altered to chlorite, kaolinite, and sericite; mobilization of these alteration products has resulted in "dissolution" of feldspar. These processes have resulted in the creation of considerable secondary porosity in the samples studied, and are a likely source for much of the authigenic cement or matrix in these sediments.

2. Lithics: An abbreviation for lithic fragments, this group consists of rock fragments of variable composition. Lithic fragments observed include sedimentary, volcanic, and granitic rock fragments; geophysical properties are variable but are generally more conductive than the quartz and feldspar group. Lithic fragments are highly susceptible to alteration, and are commonly replaced by chlorite, kaolinite, and sericite. Secondary porosity is commonly developed in lithics. Sedimentary lithics, predominantly mudstone, are most common, followed by volcanic lithics. Volcanic lithics generally display a higher concentration of ferric oxides.

3. Muscovite and biotite: These minerals deserve a classification separate from other "heavy" minerals because of (1) their clay-like electrical properties, and (2) their relative abundance (as much as 5 percent) in some samples. The micas, of which these two are the dominant representatives in this suite, conduct electricity in a fashion similar to clays and have densities of about 2.8 to 2.9 g/cm^3. They are easily recognized by their platy appearance and moderate birefringence (bright interference colors). While musco-vite seems to remain fairly inert, biotite is commonly altered to chlorite.

4. Heavies: Abbreviated for the so-called "heavy" minerals, this group contains accessory minerals, which rarely exceed 1 percent. Heavy minerals are commonly rich in iron and magnesium, resulting in their relatively higher densities (usually between 2.8 and 4 g/cm^3). Heavies observed in this suite include pyroxenes, amphiboles, epidote, garnet, tourmaline, zircon, and rutile.

5. Opaques: This group contains grains, which do not transmit light. In this suite, opaques consist primarily of ferric oxides and organic fragments, although some sulfides may be present as well. Ferric oxides observed include hematite, magnetite, ilmenite, and leucoxene; all of these have high densities and are good conductors of electricity.

Matrix and cements in this suite consist predominantly of clay minerals, although carbonate cements were observed in two samples. The term cement implies that the matrix was formed postdepositionally by diagenetic processes; this term is usually reserved for arenites. Thin section identification of clay minerals is hampered by the exceedingly small grain size of the clay; distinction of different clay minerals in this study was restricted to two groups: chlorite/kaolinite and illite/smectite. These groups do not have any particular properties in common, other than their similar appearance in thin section. In some cases, kaolinite and chlorite can be recognized independently; also the coarser grained smectites, including vermiculite, may be distinguished.

Carbonate cement was observed in the form of calcite spar (sample 27) and siderite (sample 24). Otherwise, this suite displays a surprising paucity of carbonate materials.

The mineralogy of this suite is surprisingly uniform throughout. No significant vertical changes in detrital mineralogy were observed, other than a possible increase of lithic fragments near the base of the section. However, more detailed study may reveal subtler changes in mineralogy.

Table 4. Mineralogy of core samples

[<, less than; ft, feet; approx., approximately. Data from David B. McWhorter, Colorado State University, written commun., 1988]

Sample 1

Formation: Dawson Arkose
Depth: 268 ft
General description: Poorly sorted, medium grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 57-62 percent
- Lithics: <1 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Matrix: approx. 25 percent
- Mostly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 10-15 percent

Sample 2

Formation: Dawson Arkose
Depth: 293 ft
General description: Poorly sorted, coarse grained feldspathic graywacke.
Framework grains:
- Quartz & feldspar: 57 percent
- Lithics: 1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Matrix: approx. 25 percent
- Mostly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 15 percent

Sample 3

Formation: Dawson Arkose
Depth: 308 ft
General description: Moderately sorted, coarse grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 60-65 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Matrix/cements
- Coarse grain%%[PrinterError: out of paper]%%%%[PrinterError: no paper tray]%%ed smectite/vermiculite, with lesser chlorite/kaolinite.

Sample is highly disturbed; estimation of original porosity and cement volumes is not possible.

Table 4. Mineralogy of core samples--Continued

Sample 4

Formation: Dawson Arkose
Depth: 328 ft
General description: Moderately sorted, coarse grained arkosic arenite.
Framework grains:
Quartz and feldspar: 57 percent
Lithics: 1-2 percent
Biotite and muscovite: 1 percent
Heavies: <1 percent
Opaques: <1 percent
Cements: approx. 15 percent
Mostly chlorite/kaolinite; lesser illite/smectite.
Porosity: approx. 25 percent
Depth: 328 ft
General description: Moderately sorted, coarse grained arkosic arenite.
Framework grains:

Sample 5

Formation: Dawson Arkose
Depth: 377 ft
General description: Poorly sorted, medium grained feldspathic graywacke.
Framework grains:
Quartz and feldspar: 57 percent
Lithics: <1 percent
Biotite and muscovite:
Opaques, including organics: <1 percent
Matrix: approx. 20-25 percent
Illite/smectite, with slightly less chlorite/kaolinite.
Porosity: approx. 15-20 percent

Sample 6

Formation: Dawson Arkose
Depth: 392 ft
General description: Poorly sorted, medium to fine grained feldspathic graywacke.
Framework grains:
Quartz and feldspar: 52-47 percent
Lithics: 1 percent
Biotite and muscovite: 1 percent
Heavies: <1 percent
Opaques: <1 percent
Matrix: approx. 40 percent
Predominantly illite/smectite, with lesser chlorite/kaolinite; minor celadonite (an illite).
Porosity: approx. 5-10 percent

Table 4. Mineralogy of core samples--Continued

Sample 7

Formation: Dawson Arkose
Depth: 416 ft
General description: Moderately sorted, coarse grained lithic arenite.
Framework grains:
- Quartz and feldspar: 35-40 percent
- Lithics: 27 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: <1 percent

Cements: approx. 15 percent
- Almost exclusively chlorite/kaolinite; minor illite/smectite.

Porosity is difficult to estimate due to disruption of sample; perhaps 15-20 percent.

Sample 8

Formation: Dawson Arkose
Depth: 435 ft
General description: Moderately sorted, coarse grained lithic arenite.
Framework grains:
- Quartz and feldspar: 33 percent
- Lithics: 28 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: 1-2 percent

Cements: Approx. 15-20 percent
- Coarse grained smectite/vermiculite; lesser chlorite/kaolinite.

Porosity is difficult to estimate due to disruption of sample; perhaps 15-20 percent.

Sample 9

Formation: Dawson Arkose
Depth: 507 ft
General description: Poorly sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 38 percent
- Lithics: 1-2 percent
- Biotite and muscovite: 2-3 percent
- Heavies: <1 percent
- Opaques, including organics: 2 percent

Matrix: approx. 40-45 percent
- Illite/smectite; slightly less chlorite/kaolinite.

Porosity: approx. 10-15 percent

Table 4. Mineralogy of core samples--Continued

Sample 10

Formation: Dawson Arkose
Depth: 568 ft
General description: Moderately well sorted, medium to coarse grained lithic arenite.
Framework grains:
- Quartz and feldspar: 32 percent
- Lithics: 30 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: 1-2 percent

Cements: approx. 10-15 percent
- Illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 20-25 percent

Sample 11

Formation: Dawson Arkose
Depth: 590 ft
General description: Poorly sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 36-41 percent
- Lithics: <1 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including organics: 1-2 percent

Matrix: approx. 50 percent
- Illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 5-10 percent

Sample 12

Formation: Dawson Arkose
Depth: 621 ft
General description: Poorly sorted, coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 38-43 percent
- Lithics: 15 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, including hematite, magnetite: <1 percent

Cements: approx. 15 percent
- Subequal amounts of chlorite/kaolinite and illite/smectite.

Porosity: approx. 25-30 percent

Table 4. Mineralogy of core samples--Continued

Sample 13

Formation: Dawson Arkose
Depth: 679 ft
General description: Poorly sorted, very fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 56 percent
- Lithics: <1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, including organics: 1-2 percent

Matrix: approx. 25 percent
- Illite/smectite; slightly less chlorite/kaolinite.

Porosity: approx. 15 percent

Sample 14

Formation: Dawson Arkose
Depth: 733 ft
General description: Moderately sorted, fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 35-40 percent
- Lithics: 5-10 percent
- Biotite and muscovite: 2-3 percent
- Heavies: 1 percent
- Opaques, including organics, hematite: 1-2 percent

Matrix: approx. 20 percent
- Illite/smectite in poorly sorted laminae; chlorite/kaolinite in cleaner laminae.

Porosity: approx. 25-30 percent

Sample 15

Formation: Dawson Arkose
Depth: 763 ft
General description: Moderately sorted, fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 44-49 percent
- Lithics: 1-2 percent
- Biotite and muscovite: 2-3 percent
- Heavies: <1 percent
- Opaques, including organics: 1-2 percent

Matrix: approx. 20-25 percent
- Subequal amounts of illite/smectite and chlorite/kaolinite.

Porosity: approx. 25 percent

Table 4. Mineralogy of core samples--Continued

Sample 16

Formation: Dawson Arkose
Depth: 789 ft
General description: Moderately sorted, very coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 57-62 percent
- Lithics: 1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Cements: approx. 5-10 percent
- Predominantly chlorite/kaolinite, with lesser illite/smectite.

Porosity: approx. 30 percent

Sample 17

Formation: Dawson Arkose
Depth: 797 ft
General description: Silty mudstone.
Framework grains:
- Quartz and feldspar: 33 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Matrix: approx. 60 percent
- Predominantly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 5 percent

Sample 18

Formation: Dawson Arkose
Depth: 809 ft
General description: Moderately well sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 53-58 percent
- Lithics: 2-3 percent
- Biotite and muscovite: 3-4 percent
- Heavies: <1 percent
- Opaques: <1 percent

Matrix: approx. 15 percent
- Predominantly chlorite/kaolinite, lesser illite/smectite.

Porosity: approx. 20-25 percent

Table 4. Mineralogy of core samples--Continued

Sample 19

Formation: Dawson Arkose
Depth: 823 ft
General description: Silty mudstone
Framework grains:
- Quartz and feldspar: 32 percent
- Lithics: <1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques: <1 percent

Matrix: approx. 60 percent
- Predominantly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 5 percent

Sample 20

Not analyzed

Sample 21

Formation: Dawson Arkose
Depth: 875 ft
General description: Poorly sorted, coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 51-56 percent
- Lithics: 1-2 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques: 1 percent

Cements: approx. 5-10 percent
- Predominantly chlorite/kaolinite; minor illite/smectite.

Porosity: approx. 30 percent

Sample 22

Formation: Dawson Arkose
Depth: 919 ft
General description: Poorly sorted, medium grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 53-58 percent
- Lithics: 1-2 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including magnetite, hematite, organics: 3-4 percent

Cements: approx. 5-10 percent
- Predominantly chlorite/kaolinite with minor illite/smectite some opaque grain coatings (hematite?).

Porosity: approx. 30 percent

Table 4. Mineralogy of core samples--Continued

Sample 23

Formation: Dawson Arkose
Depth: 955 ft
General description: Moderately sorted, coarse grained lithic wacke.
Framework grains:
- Quartz and feldspar: 30-35 percent
- Lithics: 25 percent
- Biotite and muscovite: 2 percent
- Heavies: <1 percent
- Opaques, including magnetite, hematite: 2-3 percent

Matrix: approx. 20 percent
- Predominantly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 15-20 percent

Sample 24

Formation: Denver
Depth: 967 ft
General description: Silty mudstone.
Framework grains:
- Quartz and feldspar: 23-28 percent
- Lithics: none observed
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: <1 percent

Matrix: approx. 65 percent
- Subequal amounts of siderite ($FeCO_3$) and illite/smectite, with lesser chlorite/kaolinite.

Porosity: approx. 5-10 percent

Sample 25

Formation: Denver
Depth: 1,067 ft
General description: Poorly to moderately sorted, coarse grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 61 percent
- Lithics: 1 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including organics, trace magnetite: <1 percent

Matrix: approx. 15 percent
- Predominantly chlorite/kaolinite, with lesser illite/smectite; minor laumontite (a zeolite).

Porosity: approx. 20 percent

Table 4. Mineralogy of core samples--Continued

Sample 26

Formation: Denver
Depth: 1,097 ft
General description: Moderately sorted, medium to fine grained feldspathic graywacke.
Framework grains:
Quartz and feldspar: 58-60 percent
Lithics: <1 percent
Biotite and muscovite: 1-3 percent
Heavies: <1 percent
Opaques, including organics, trace magnetite: 1-2 percent
Matrix: approx. 25 percent
Subequal amounts of illite/smectite and chlorite/kaolinite.
Porosity: approx. 10-13 percent

Sample 27

Formation: Denver
Depth: 1,219 ft
General description: Moderately sorted, medium grained feldspathic graywacke.
Framework grains:
Quartz and feldspar: 56-61 percent
Lithics: <1 percent
Biotite and muscovite: 1-3 percent
Heavies: <1 percent
Opaques: <1 percent
Matrix: approx. 20-25 percent
Subequal amounts of illite/smectite and chlorite/kaolinite; with slightly less calcite spar.
Porosity: approx. 15 percent

Sample 28

Formation: Denver
Depth: 1,259 ft
General description: Well sorted, medium grained feldspathic graywacke.
Framework grains:
Quartz and feldspar: 56 percent
Lithics: <1 percent
Biotite and muscovite: 2-3 percent
Heavies: <1 percent
Opaques, mostly organic: 1 percent
Matrix: approx. 20-25 percent
Chlorite/kaolinite, with lesser illite/smectite.
Porosity: approx. 20-25 percent

Table 4. Mineralogy of core samples--Continued

Sample 29

Formation: Denver

Depth: 1,270 ft

General description: Poorly sorted, very coarse grained arkosic arenite.

Framework grains:

Quartz and feldspar: 60 percent

Lithics: none observed

Biotite and muscovite: <1 percent

Heavies: 1 percent

Opaques, including magnetite, organics: 3-4 percent

Cements: Chlorite/kaolinite, with lesser coarse grained smectite/vermiculite.

Sample is too disrupted to estimate porosity and cement volumes; many framework grains and cemented areas have been plucked.

Sample 30

Formation: Denver

Depth: 1,290 ft

General description: Silty mudstone.

Framework grains:

Quartz and feldspar: 31 percent

Lithics: <1 percent

Biotite and muscovite: <1 percent

Heavies: <1 percent

Opaques, including magnetite, hematite, organics: 1-3 percent

Matrix: approx. 60 percent

Predominantly illite/smectite; lesser chlorite/kaolinite.

Porosity: approx. 5 percent

Sample 31

Formation: Denver

Depth: 1,351 ft

General description: Poorly sorted, medium grained feldspathic graywacke.

Framework grains:

Quartz and feldspar: 56-61 percent

Lithics: <1 percent

Biotite and muscovite: 1-2 percent

Heavies: <1 percent

Opaques, including magnetite, hematite, organics: 1 percent

Matrix: approx. 20 percent

Illite/smectite, with slightly less chlorite/kaolinite.

Porosity: approx. 15-20 percent

Table 4. Mineralogy of core samples--Continued

Sample 32

Formation: Denver
Depth: 1,423 ft
General description: Poorly sorted, coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 63-67 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including magnetite: <1 percent

Cements: approx. 5 percent
- Chlorite/kaolinite, with minor illite/smectite.

Porosity: approx. 25-30 percent
Note: Porosity and cement volumes may not be accurate due to disruption of the sample.

Sample 33A

Formation: Denver
Depth: 1,437 ft
General description: Moderately well sorted, medium grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 61 percent
- Lithics: <1 percent
- Biotite and muscovite: 2 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Cements: approx. 10 percent
- Chlorite/kaolinite, with minor illite/smectite.

Porosity: approx. 25 percent

Sample 34

Formation: Denver
Depth: 1,448 ft
General description: Moderately sorted, medium grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 57 percent
- Lithics: 2-3 percent
- Biotite and muscovite: 3-4 percent
- Heavies: <1 percent
- Opaques, including magnetite, hematite, organics: 1 percent

Matrix: approx. 15-20 percent
- Illite/smectite, with slightly less chlorite/kaolinite.

Porosity: approx. 15-20 percent

Table 4. Mineralogy of core samples--Continued

Sample 35

Formation: Denver
Depth: 1,501 ft
General description: Poorly sorted, medium to coarse grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 60 percent
- Lithics: 1-2 percent
- Biotite and muscovite: 2 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: 1 percent

Matrix: approx. 25-30 percent
- Subequal amounts of chlorite/kaolinite and illite/smectite.

Porosity: approx. 5-10 percent

Sample 36

Formation: Denver
Depth: 1,537 ft
General description: Moderately sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 67-72 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including magnetite, organics: 1 percent

Matrix: approx. 20-25 percent
- Subequal amounts of illite/smectite and chlorite/kaolinite.

Porosity: approx. 5 percent

Sample 37

Formation: Denver
Depth: 1,543 ft
General description: Moderately well sorted, medium to fine grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 50 percent
- Lithics, mostly argillaceous: 5-10 percent
- Biotite and muscovite: 1-3 percent
- Heavies: 1 percent
- Opaques, including magnetite, organics: 2 percent

Cements: approx. 10-15 percent
- Predominantly chlorite/kaolinite; lesser illite/smectite.

Porosity: approx. 25 percent

Table 4. Mineralogy of core samples--Continued

Sample 38

Formation: Denver
Depth: 1,589 ft
General description: Moderately sorted, coarse grained arkosic arenite (?).
Framework grains:
Quartz and feldspar: 55-60 percent
Lithics: 3 percent
Biotite and muscovite: 1 percent
Heavies: 1 percent
Opaques, including organics, minor magnetite: 1 percent
Cements: Chlorite/kaolinite; lesser illite/smectite.
Estimation of porosity and cement volumes not possible due to considerable disruption of the sample.

Sample 39

Formation: Denver
Depth: 1,603 ft
General description: Moderately sorted, medium to fine grained arkosic arenite.
Framework grains:
Quartz and feldspar: 60-65 percent
Lithics: <1 percent
Biotite and muscovite: 3 percent
Heavies: <1 percent
Opaques, including magnetite, organics: <1 percent
Cements: approx. 15 percent
Subequal amounts of chlorite/kaolinite and illite/smectite.
Porosity: approx. 15-20 percent

Sample 40

Formation: Denver
Depth: 1,652 ft
General description: Moderately sorted, coarse grained arkosic arenite.
Framework grains:
Quartz and feldspar: 57 percent
Lithics: 3 percent
Biotite and muscovite: 2 percent
Heavies: <1 percent
Opaques, dominantly organics: 1 percent
Cements: Approx. 10 percent
Predominantly chlorite/kaolinite; minor illite/smectite.
Porosity: approx. 25 percent

Table 4. Mineralogy of core samples--Continued

Sample 41

Formation: Denver
Depth: 1,674 ft
General description: Poorly sorted, medium grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 36-41 percent
- Lithics: <1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, mostly organics: 1-2 percent

Matrix: approx. 50 percent
- Illite/smectite, with slightly less chlorite/kaolinite.

Porosity: approx. 5-10 percent

Sample 42

Formation: Denver
Depth: 1,689 ft
General description: Well sorted, medium grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 54 percent
- Lithics: 7 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Cements: approx. 5-10 percent
- Predominantly chlorite/kaolinite; lesser illite/smectite.

Porosity: approx. 25-30 percent

Sample 43

Formation: Denver
Depth: 1,722 ft
General description: Poorly sorted, coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 60-65 percent
- Lithics: 1-2 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including hematite, magnetite, and lesser organics: 2-3 percent

Cements: approx. 10 percent
- Chlorite/kaolinite, with lesser illite/smectite.

Porosity: approx. 20-25 percent

Table 4. Mineralogy of core samples--Continued

Sample 44

Formation: Denver
Depth: 1,751 ft
General description: Poorly sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 59 percent
- Lithics: 2-3 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques: 1 percent

Matrix: approx. 25 percent
- Mostly illite/smectite; some chlorite/kaolinite.

Porosity: approx. 10 percent

Sample 45

Formation: Denver
Depth: 1,801 ft
General description: Moderately sorted, medium grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 57 percent
- Lithics: 5 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, mostly organic: <1 percent

Matrix: approx. 15-20 percent
- Illite/smectite, including some possible vermiculite; lesser chlorite/kaolinite.

Porosity: approx. 15-20 percent

Sample 46

Formation: Arapahoe
Depth: 1,839 ft
General description: Silty mudstone.
Framework grains:
- Quartz and feldspar: 46-51 percent
- Lithics: <1 percent
- Biotite and muscovite: 1 percent
- Heavies: <1 percent
- Opaques, mostly organic: 1-2 percent

Matrix: approx. 60 percent
- Subequal amounts of illite/smectite and chlorite/kaolinite.

Porosity: approx. 5-10 percent

Table 4. Mineralogy of core samples--Continued

Sample 47

Formation: Arapahoe
Depth: 1,854 ft
General description: Well sorted, medium grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 59 percent
- Lithics: 3-4 percent
- Biotite and muscovite: 1-2 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Cements: approx. 5 percent
- Illite/smectite or vermiculite, with lesser chlorite/kaolinite.

Porosity: approx. 30 percent

Sample 48

Formation: Arapahoe
Depth: 1,884 ft
General description: Poorly sorted, medium to fine grained feldspathic graywacke.
Framework grains:
- Quartz and feldspar: 43 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Matrix: approx. 50 percent
- Illite/smectite, with slightly less chlorite/kaolinite.

Porosity: approx. 5 percent

Sample 49

Formation: Arapahoe
Depth: 1,915 ft
General description: Moderately sorted, coarse grained arkosic arenite.
Framework grains:
- Quartz and feldspar: 68 percent
- Lithics: <1 percent
- Biotite and muscovite: <1 percent
- Heavies: <1 percent
- Opaques, including organics: <1 percent

Cements: approx. 10 percent
- Mostly illite/smectite or vermiculite; some chlorite/kaolinite.

Porosity: approx. 20 percent

Table 4. Mineralogy of core samples--Continued

Sample 50
Formation: Arapahoe
Depth: 1,943 ft
General description: Silty mudstone.
Framework grains:
Quartz and feldspar: 26-31 percent
Lithics: <1 percent
Biotite and muscovite: 1-2 percent
Heavies: <1 percent
Opaques, including organics: 1 percent
Matrix: approx. 60 percent
Illite/smectite, with slightly less chlorite/kaolinite.
Porosity: approx. 5-10 percent.

Density, Porosity, and Specific-Yield Characteristics

Core samples were prepared for laboratory analyses by encasing a 6- to 12-in segment of core in jewelers wax. Three disks, each about 3/4 in thick and oriented so bedding planes were parallel to the flat surfaces at the top and bottom of the disk were cut from each segment. The ring of wax around the circumference of the disk contained and supported the sometimes friable sample.

Laboratory determinations of bulk density, grain density, and volumetric water content were done for each disk. Moisture-retention curves were plotted using volumetric water-content data obtained at gage pressures of 0.0, 0.3, 0.9, 3.0, 9.0, and 13.5 bars in a pressure-plate apparatus. Volumetric water content at 13.5 bars was used in calculating specific retention. Bulk density and grain density were determined at U.S. Geological Survey laboratories; volumetric water content was determined by Anthony Garcia in the laboratories of Colorado State University (McWhorter and Garcia, 1990). Porosity and specific retention were calculated from laboratory data for each disk. Data for bulk density, grain density, porosity, and specific retention listed in table 5 are mean values of the corresponding disk values. Specific-yield data in table 5 were calculated as the difference between the mean porosity and the mean specific retention, which were determined independently. Specific-yield values less than zero have no hydrologic meaning; such values in table 5 indicate that specific yield is approximately zero. Some samples were too friable to withstand testing, and replacement pieces of core were tested or sample means were based on less than three determinations.

Table 5. Bulk- and grain-density, porosity, specific-retention, and specific-yield data for core samples

[g/cm^3, grams per cubic centimeter; asterisk indicates specific yield is approximately zero; dashes indicate no data]

Sample number	Bulk density (g/cm^3)	Grain density (g/cm^3)	Porosity	Specific retention	Specific yield
1	1.98	2.66	0.26	0.26	0.00
2	1.99	2.65	.25	.17	.08
3	1.95	2.61	.25	.15	.10
4	1.78	2.62	.32	.07	.25
5	2.00	2.66	.25	.21	.04
6	1.94	2.74	.29	.33	*
7	1.93	2.64	.27	.07	.20
8	1.93	2.66	.27	.19	.08
9	1.79	2.71	.34	.39	*
10	1.86	2.64	.30	.17	.13
11	1.92	2.67	.28	.35	*
12	1.80	2.62	.31	.08	.23
13	1.96	2.66	.26	.27	*
14	1.84	2.69	.32	.27	.05
15	1.93	2.67	.28	.24	.04
16	1.82	2.63	.31	.08	.23
17	1.93	2.68	.28	.33	*
18	1.79	2.66	.33	.19	.14
19	1.99	2.67	.26	.24	.02
20	1.84	2.66	.31	.27	.04
21	1.86	2.62	.29	.06	.23
22	1.72	2.66	.36	.06	.30
23	1.84	2.66	.31	.19	.12
24	2.08	2.75	.24	.27	*
25	1.80	2.62	.31	.09	.22
26	2.02	2.66	.24	.24	.00
27	2.24	2.79	.20	.17	.03
28	2.01	2.65	.24	.17	.07
29	1.91	2.60	.26	.07	.19
30	2.10	2.66	.21	.23	*
31	1.97	2.65	.26	.20	.06
33	1.67	2.62	.36	.07	.29
34	2.01	2.66	.25	.22	.03
35	2.07	2.66	.22	.23	*
36	2.14	2.65	.19	.19	.00
37	1.88	2.63	.29	.14	.15
38	1.79	2.62	.32	.07	.25

Table 5. Bulk- and grain-density, porosity, specific-retention, and specific-yield data for core samples--Continued

Sample number	Bulk density (g/cm^3)	Grain density (g/cm^3)	Porosity	Specific retention	Specific yield
39	2.09	2.66	0.21	0.19	0.02
40	1.61	2.61	.38	.09	.29
41	1.99	2.67	.25	.27	*
42	1.89	2.65	.29	.18	.11
43	1.91	2.63	.28	.11	.17
44	2.00	2.68	.25	.17	.08
45	2.23	2.78	.20	.13	.07
47	1.71	2.63	.35	.10	.25
48	2.05	2.65	.23	.30	*
49	2.05	2.62	.22	.12	.10
50	2.11	2.66	.21	.23	*
51	1.99	2.59	.23	.16	.07
52	1.74	2.61	.33	.09	.24
53	1.81	2.62	.31	.04	.27
55	1.87	2.62	.29	.06	.23
56	1.77	2.61	.32	.14	.18
57	1.92	2.62	.27	.05	.22
58	1.84	2.61	.30	.11	.19
59	1.77	2.61	.32	.12	.20
60	2.11	2.65	.20	.23	*
61	1.94	2.62	.26	.15	.11
62	2.06	2.66	.22	.17	.05
63	1.70	2.62	.35	.06	.29
64	1.74	2.62	.34	.08	.26
65	1.84	2.64	.31	.18	.13
66	1.95	2.62	.26	.07	.19
67	1.87	2.63	.29	.05	.24
68	1.89	2.65	.29	.11	.18
69	1.92	2.62	.27	.06	.21
71	1.81	2.63	.31	.11	.20
72	1.93	2.63	.27	.04	.23
73	1.90	2.62	.27	--	--
74	1.83	2.62	.30	.09	.21
75	1.79	2.61	.31	--	--
76	1.93	2.62	.26	.07	.19
77	2.15	2.66	.19	--	--
78	2.05	2.63	.22	.16	.06
80	1.94	2.62	.26	.04	.22
83	2.62	2.95	.12	.04	.08
84	2.04	2.71	.25	.05	.20

Table 5. Bulk- and grain-density, porosity, specific-retention, and specific-yield data for core samples--Continued

Sample number	Bulk density (g/cm^3)	Grain density (g/cm^3)	Porosity	Specific retention	Specific yield
85	2.37	2.77	0.14	0.05	0.09
86	2.07	2.65	.22	.16	.06
87	1.90	2.62	.27	.05	.22
88	1.87	2.62	.29	.03	.26
89	1.87	2.61	.28	.03	.25
90	1.91	2.63	.28	.04	.24
91	2.16	2.61	.17	.16	.01
92	1.79	2.63	.32	.04	.28
93	1.86	2.63	.29	.04	.25
94	1.99	2.62	.24	.16	.08
95	1.90	2.61	.27	.07	.20
96	2.06	2.64	.22	.20	.02
97	1.91	2.62	.27	.04	.23
98	1.94	2.62	.26	.04	.22
99	1.85	2.63	.30	--	--
100	1.88	2.62	.28	.05	.23
101	2.20	2.65	.17	--	--
102	1.86	2.62	.29	.04	.25
103	1.88	2.63	.28	--	--
104	1.95	2.64	.26	.03	.23
105	1.88	2.62	.28	.03	.25
106	1.74	2.64	.34	.07	.27
107	2.08	2.65	.21	.19	.02
108	1.76	2.65	.33	.07	.26
109	1.87	2.70	.31	.20	.11
110	1.68	2.68	.37	.08	.29
112	2.15	2.66	.19	.15	.04
113	2.07	2.68	.22	.12	.10
114	1.76	2.67	.34	.39	*
115	1.72	2.69	.36	.36	.00
116	1.94	2.63	.26	.25	.01
118	1.95	2.64	.26	.16	.10
119	1.97	2.71	.27	.23	.04
120	2.03	2.69	.25	.16	.09
121	2.11	2.72	.22	.24	*
122	2.16	2.79	.22	.20	.02
123	1.97	2.67	.26	.27	*
124	2.13	2.71	.21	.19	.02
125	1.95	2.66	.27	.28	*

Table 5. Bulk- and grain-density, porosity, specific-retention, and specific-yield data for core samples--Continued

Sample number	Bulk density (g/cm^3)	Grain density (g/cm^3)	Porosity	Specific retention	Specific yield
126	2.13	2.66	0.20	0.22	*
127	2.02	2.67	.24	.22	.02
128	1.95	2.67	.27	.17	.10
129	2.00	2.61	.23	--	--
132	1.95	2.62	.26	--	--
133	1.94	2.70	.28	.21	.07
134	1.87	2.71	.31	.15	.16
135	1.89	2.74	.31	--	--
136	1.84	2.67	.31	.21	.10
137	1.63	2.67	.39	.35	.04
139	1.76	2.63	.33	.11	.22
146	1.90	2.62	.27	--	--
147	1.82	2.66	.32	.22	.10
148	1.79	2.66	.33	.25	.08
149	1.82	2.63	.31	.14	.17
152	1.93	2.62	.27	.15	.12
154	1.76	2.62	.33	.14	.19
155	1.85	2.64	.30	.13	.17
158	1.73	2.59	.33	.16	.17
159	1.82	2.62	.31	.09	.22
160	2.02	2.66	.24	.23	.01
161	1.92	2.68	.28	--	--
162	1.73	2.64	.35	.10	.25
164	2.17	2.75	.21	.20	.01
166	1.91	2.64	.28	.19	.09
167	2.10	2.70	.22	.21	.01
168	2.01	2.65	.24	.15	.09
169	1.88	2.67	.30	--	--
170	1.84	2.65	.31	.18	.13
173	1.97	2.67	.26	.25	.01
174	2.04	2.69	.24	.23	.01
176	1.95	2.64	.26	.26	.00
177	1.98	2.62	.24	.14	.10
181	2.02	2.69	.25	.24	.01
184	1.77	2.65	.33	.19	.14
189	1.90	2.61	.28	--	--
195	1.85	2.65	.30	.19	.11
198	1.82	2.63	.31	.04	.27
201	2.08	2.65	.21	.13	.08
202	1.95	2.63	.26	.05	.21

Grain-Size Distribution

Grain-size distributions were determined at U.S. Geological Survey laboratories for 142 undisturbed and 21 disturbed samples. Consolidated samples were disaggregated by use of a mortar and a rubber-tipped pestle. The disaggregated sample material was placed in a series of standard 8-in sieves and shaken for 15 minutes on a mechanical shaker. The fraction of sample remaining on each sieve was weighed to determine the percent of sample finer, which is listed in table 6. Grain-size distribution curves were plotted from the data and used to determine the D_{30}, D_{50}, and D_{70} diameters listed in table 6.

Table 6. Grain-size distribution data

[D_{30}, 30th-percentile diameter, in millimeters; D_{50}, 50th-percentile diameter, in millimeters; D_{70}, 70th-percentile diameter, in millimeters; --, no data]

Sample number	Percent of sample finer than the following particle sizes, in millimeters										D_{30}	D_{50}	D_{70}
	0.062	0.125	0.25	0.5	1	2	4	8	16	32			
						UNDISTURBED SAMPLES							
1	37.2	70.4	94.2	99.1	99.8	100.0	100.0	100.0	100.0	100.0	0.053	0.081	0.124
2	27.0	39.3	60.2	80.3	95.4	99.8	99.9	100.0	100.0	100.0	.074	.178	.351
4	8.7	14.3	28.2	53.8	71.6	87.6	98.4	100.0	100.0	100.0	.262	.451	.940
5	35.9	57.6	86.9	91.9	94.7	96.4	98.0	100.0	100.0	100.0	.051	.098	.168
6	59.4	78.2	91.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.044	.092
7	9.2	13.2	22.1	38.7	71.3	95.6	98.4	99.9	100.0	100.0	.348	.636	.973
8	11.9	17.6	23.1	44.3	70.6	90.9	95.4	100.0	100.0	100.0	.313	.581	.984
9	63.3	90.6	96.4	98.7	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.074
10	11.1	14.1	25.3	50.3	84.9	98.4	99.8	100.0	100.0	100.0	.285	.496	.742
11	47.9	78.4	90.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.065	.103
12	6.6	11.6	22.9	39.6	61.7	81.4	93.1	98.3	100.0	100.0	.336	.693	1.339
13	64.7	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.069
14	54.5	98.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.058	.080
15	38.8	94.8	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.056	.071	.092
16	12.3	15.8	23.2	39.3	69.6	95.2	99.7	100.0	100.0	100.0	.335	.639	1.011
17	47.4	71.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.067	.118
18	34.0	72.1	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.058	.083	.120
19	53.5	82.4	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.057	.093
20	60.4	89.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.078
21	11.0	13.6	23.7	44.6	66.1	86.7	98.3	100.0	100.0	100.0	.308	.595	1.140
22	8.2	13.4	35.8	66.8	83.1	94.7	99.2	100.0	100.0	100.0	.209	.343	.573
23	15.2	19.9	29.6	45.5	73.6	96.8	100.0	100.0	100.0	100.0	.254	.559	.915
24	33.3	60.3	88.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.057	.096	.159
25	14.8	20.9	27.2	45.4	77.9	98.5	100.0	100.0	100.0	100.0	.278	.552	.845
26	42.4	90.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.069	.093
27	35.0	79.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.057	.079	.108
28	23.8	90.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.066	.082	.101
29	12.3	15.5	23.8	35.3	53.6	71.9	86.2	95.3	100.0	100.0	.363	.873	1.861
30	37.1	66.8	91.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.052	.084	.137
31	26.1	62.7	93.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.067	.098	.147
32	11.8	15.8	18.5	28.4	45.4	68.9	92.0	100.0	100.0	100.0	.534	1.145	2.067
33	9.7	16.2	48.4	93.4	99.8	100.0	100.0	100.0	100.0	100.0	.168	.256	.349
34	36.2	77.4	97.6	99.9	100.0	100.0	100.0	100.0	100.0	100.0	.056	.078	.110
35	57.0	87.1	98.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.053	.084
36	39.8	82.6	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.053	.073	.102
37	32.1	86.4	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.060	.078	.101
38	9.3	12.7	18.6	36.2	78.3	90.7	96.9	100.0	100.0	100.0	.392	.628	.872
39	40.3	85.8	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.072	.098
40	14.4	19.3	49.2	78.6	93.9	99.0	100.0	100.0	100.0	100.0	.160	.255	.408

Table 6. Grain-size distribution data--Continued

Sample number	Percent of sample finer than the following particle sizes, in millimeters										D_{30}	D_{50}	D_{70}
	0.062	0.125	0.25	0.5	1	2	4	8	16	32			
						UNDISTURBED SAMPLES--Continued							
41	47.7	81.3	98.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	0.065	0.099
42	18.6	42.4	86.6	98.6	100.0	100.0	100.0	100.0	100.0	100.0	.087	.141	.193
43	20.5	31.9	39.3	67.1	92.6	97.7	98.7	100.0	100.0	100.0	.111	.326	.541
44	31.5	60.7	88.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.060	.097	.158
45	13.1	30.9	69.9	98.1	100.0	100.0	100.0	100.0	100.0	100.0	.121	.176	.251
47	5.7	11.4	35.2	81.7	93.2	98.9	99.8	100.0	100.0	100.0	.215	.312	.420
48	30.0	54.8	78.4	92.8	97.1	99.7	100.0	100.0	100.0	100.0	.062	.109	.195
49	6.7	8.4	13.5	29.9	63.5	90.9	99.1	100.0	100.0	100.0	.501	.757	1.179
50	46.4	86.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.066	.094
51	6.5	12.8	21.1	43.8	68.5	89.4	99.7	100.0	100.0	100.0	.328	.595	1.051
52	8.8	13.9	24.6	40.7	62.0	89.4	98.6	100.0	100.0	100.0	.315	.677	1.224
53	3.8	7.4	15.0	35.4	72.6	94.5	99.2	100.0	100.0	100.0	.416	.656	.953
54	9.1	12.1	15.3	26.4	46.3	78.8	95.4	100.0	100.0	100.0	.567	1.082	1.658
55	10.0	15.7	24.4	59.5	79.7	92.4	98.2	100.0	100.0	100.0	.279	.414	.717
56	11.0	17.6	24.1	45.0	69.7	92.8	99.9	100.0	100.0	100.0	.304	.575	1.009
57	7.7	10.1	16.1	26.6	42.1	64.7	90.1	99.0	100.0	100.0	.582	1.274	2.311
58	8.4	13.9	20.7	34.9	56.4	77.1	91.9	100.0	100.0	100.0	.394	.814	1.577
59	9.4	15.9	34.2	68.0	79.3	89.8	96.0	100.0	100.0	100.0	.213	.346	.565
60	31.8	64.2	93.4	98.5	100.0	100.0	100.0	100.0	100.0	100.0	.060	.092	.143
61	3.1	7.1	18.0	28.6	51.5	82.7	97.9	100.0	100.0	100.0	.522	.956	.508
62	40.2	82.9	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.073	.101
63	9.6	17.4	38.6	73.1	93.5	98.7	100.0	100.0	100.0	100.0	.189	.314	.470
64	5.1	9.7	33.8	80.3	95.2	99.0	100.0	100.0	100.0	100.0	.224	.318	.429
65	13.6	21.9	48.3	78.7	95.8	99.4	100.0	100.0	100.0	100.0	.155	.260	.410
66	11.5	15.7	19.6	27.7	43.0	58.9	72.9	85.1	100.0	100.0	.555	1.357	3.465
67	6.8	14.8	24.4	44.4	63.4	83.3	93.8	98.6	100.0	100.0	.304	.613	1.258
68	8.3	14.7	33.8	69.3	91.5	99.2	99.8	100.0	100.0	100.0	.218	.343	.511
69	8.8	20.2	50.0	57.9	68.4	86.6	95.3	97.2	100.0	100.0	.157	.250	1.063
71	11.2	16.8	31.6	65.1	74.8	81.9	89.4	95.6	100.0	100.0	.232	.366	.710
72	4.9	9.3	15.5	23.2	48.9	84.3	96.4	100.0	100.0	100.0	.601	.022	.512
73	13.3	17.5	24.7	37.7	51.0	66.7	80.3	83.9	100.0	100.0	.332	.949	2.366
74	3.3	6.4	12.6	26.7	54.6	82.9	96.8	100.0	100.0	100.0	.543	.892	1.458
76	5.0	8.5	15.1	27.6	50.1	77.1	92.6	100.0	100.0	100.0	.538	.997	1.667
78	28.1	70.9	96.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.064	.089	.123
80	10.9	19.4	27.3	42.1	63.8	80.6	89.5	96.5	100.0	100.0	.284	.644	1.291
84	2.1	7.3	21.4	53.1	73.8	89.4	98.2	100.0	100.0	100.0	.302	.467	.881
85	12.0	16.8	19.5	27.7	37.1	58.2	83.2	100.0	100.0	100.0	.592	1.528	2.774
86	43.5	83.7	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.069	.098
87	11.1	15.6	22.2	36.4	52.5	75.0	93.4	100.0	100.0	100.0	.366	.898	1.714
88	11.5	20.9	27.6	55.5	86.1	97.9	100.0	100.0	100.0	100.0	.265	.436	.694

Table 6. Grain-size distribution data--Continued

Sample number	Percent of sample finer than the following particle sizes, in millimeters										D_{30}	D_{50}	D_{70}
	0.062	0.125	0.25	0.5	1	2	4	8	16	32			
						UNDISTURBED SAMPLES--Continued							
89	3.6	7.8	18.9	38.8	68.1	90.2	98.7	100.0	100.0	100.0	0.368	0.652	1.061
90	16.2	21.3	22.6	31.1	52.4	77.5	95.4	100.0	100.0	100.0	.457	.925	1.626
91	29.9	71.2	85.6	90.7	95.2	98.6	99.9	100.0	100.0	100.0	.062	.087	.122
92	3.6	7.3	13.7	25.0	50.2	80.6	100.0	100.0	100.0	100.0	.574	.995	1.571
93	3.0	7.7	35.5	59.7	76.9	93.9	99.2	100.0	100.0	100.0	.218	.379	.757
94	21.3	43.5	63.9	77.8	87.4	96.1	99.4	100.0	100.0	100.0	.082	.156	.339
95	5.3	11.0	19.9	29.8	51.6	87.9	99.4	100.0	100.0	100.0	.503	.950	1.421
97	4.1	8.6	17.9	36.1	57.7	86.2	97.4	99.0	100.0	100.0	.396	.781	1.349
98	5.6	16.7	32.0	46.5	79.3	96.4	100.0	100.0	100.0	100.0	.228	.538	.822
100	2.8	10.0	24.5	56.1	79.3	97.0	100.0	100.0	100.0	100.0	.282	.437	.757
102	6.8	12.1	22.2	40.8	63.1	90.6	98.9	100.0	100.0	100.0	.334	.666	1.190
104	2.1	4.3	17.1	39.8	55.3	73.3	91.8	100.0	100.0	100.0	.371	.789	1.761
105	4.1	8.5	21.2	48.5	69.6	91.1	100.0	100.0	100.0	100.0	.313	.525	1.013
106	9.5	17.4	29.7	72.2	93.8	99.9	100.0	100.0	100.0	100.0	.251	.348	.482
107	61.0	96.4	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.074
108	5.3	12.0	57.1	99.7	100.0	100.0	100.0	100.0	100.0	100.0	.165	.224	.308
109	20.2	77.1	99.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.070	.090	.115
110	11.9	87.9	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.073	.088	.106
112	74.6	98.9	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.054
113	43.6	64.1	84.9	95.0	98.7	99.8	100.0	100.0	100.0	100.0	--	.077	.152
116	38.6	84.2	97.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.054	.074	.100
118	49.1	87.5	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.063	.091
119	37.9	78.9	94.2	99.0	100.0	100.0	100.0	100.0	100.0	100.0	.054	.076	.107
120	38.4	71.6	90.0	99.4	99.6	99.8	100.0	100.0	100.0	100.0	.052	.079	.121
121	47.9	78.1	97.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.065	.104
123	32.7	56.1	74.3	94.8	99.5	100.0	100.0	100.0	100.0	100.0	.057	.104	.212
124	53.4	82.0	96.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.057	.093
125	42.3	71.9	95.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	--	.074	.119
126	27.6	55.5	97.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.066	.109	.159
127	44.4	84.5	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.068	.097
128	27.5	53.5	84.4	97.2	99.4	100.0	100.0	100.0	100.0	100.0	.066	.114	.181
134	12.4	31.6	74.9	94.3	97.9	98.3	98.7	100.0	100.0	100.0	.118	.168	.231
136	66.3	86.9	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	.070
139	11.4	21.6	53.6	86.6	97.7	99.8	100.0	100.0	100.0	100.0	.150	.231	.353
147	12.4	27.2	63.1	78.5	98.5	99.8	100.0	100.0	100.0	100.0	.132	.194	.341
148	13.1	33.6	80.9	97.6	99.8	100.0	100.0	100.0	100.0	100.0	.111	.159	.213
149	9.5	22.5	46.7	82.5	96.7	99.8	100.0	100.0	100.0	100.0	.155	.266	.393
152	5.0	10.1	21.6	34.4	53.4	81.4	97.8	100.0	100.0	100.0	.394	.883	1.508
154	6.0	13.2	44.4	73.3	91.8	97.9	99.5	100.0	100.0	100.0	.182	.286	.462

Table 6. Grain-size distribution data--Continued

Sample number	Percent of sample finer than the following particle sizes, in millimeters										D_{30}	D_{50}	D_{70}
	0.062	0.125	0.25	0.5	1	2	4	8	16	32			
						UNDISTURBED SAMPLES--Continued							
155	14.5	30.6	63.3	85.0	95.4	98.0	98.1	98.1	100.0	100.0	0.122	0.189	0.310
158	8.7	17.2	44.3	78.1	97.3	99.8	100.0	100.0	100.0	100.0	.173	.281	.423
159	4.7	8.2	17.8	38.8	64.8	88.6	97.9	100.0	100.0	100.0	.374	.674	.164
160	38.1	67.6	94.4	99.6	100.0	100.0	100.0	100.0	100.0	100.0	.051	.082	.133
162	8.2	21.3	66.5	96.0	99.8	100.0	100.0	100.0	100.0	100.0	.143	.194	.271
164	25.2	57.9	94.1	99.9	100.0	100.0	100.0	100.0	100.0	100.0	.069	.106	.158
166	11.2	29.8	53.6	68.6	78.9	90.9	99.2	100.0	100.0	100.0	.126	.225	.549
167	58.0	86.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.051	.084
168	29.6	68.7	96.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.062	.089	.129
170	22.3	62.9	97.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.071	.100	.144
173	38.9	74.3	96.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	.052	.077	.115
174	37.6	82.2	98.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.055	.075	.103
176	45.4	83.6	98.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.067	.097
177	3.4	6.3	14.4	27.9	41.5	57.4	73.2	88.8	100.0	100.0	.556	1.449	3.476
181	54.8	86.2	99.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	.056	.087
184	7.9	23.1	69.3	95.5	97.9	98.5	99.3	100.0	100.0	100.0	.139	.187	.255
198	3.9	12.5	49.9	86.6	97.7	99.8	100.0	100.0	100.0	100.0	.173	.250	.365
201	34.0	72.8	97.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	.058	.083	.119
202	4.5	9.9	23.1	37.7	69.6	93.6	99.3	100.0	100.0	100.0	.347	.653	1.012
						DISTURBED SAMPLES							
901	5.8	11.6	16.9	32.5	51.6	74.5	92.9	99.6	100.0	100.0	.447	.944	1.745
902	6.5	10.8	18.5	34.1	55.2	80.1	97.0	99.3	100.0	100.0	.417	.843	1.510
903	6.6	12.1	15.9	27.2	43.3	58.7	77.0	96.2	100.0	100.0	.564	1.352	3.068
904	8.8	18.3	24.5	36.9	48.1	64.3	81.8	93.7	98.4	100.0	.340	1.085	2.507
905	4.1	6.0	7.3	18.7	62.6	92.5	99.8	100.0	100.0	100.0	.598	.820	1.187
906	5.1	6.9	9.7	15.3	30.9	61.4	91.0	98.7	100.0	100.0	.961	1.544	2.446
907	8.9	16.8	22.8	41.6	70.9	93.1	99.0	100.0	100.0	100.0	.326	.610	.979
908	8.6	13.8	18.5	35.8	49.1	62.2	74.0	92.5	100.0	100.0	.396	1.049	3.162
909	14.9	29.8	48.8	72.2	87.2	96.8	99.2	100.0	100.0	100.0	.126	.259	.468
910	8.2	14.8	24.0	45.0	71.4	92.5	99.2	100.0	100.0	100.0	.305	.570	.964
911	9.0	16.6	22.1	41.1	62.5	83.7	97.6	100.0	100.0	100.0	.334	.667	1.278
912	6.7	14.3	23.1	42.1	70.1	97.0	100.0	100.0	100.0	100.0	.322	.608	.998
913	9.4	18.4	31.8	64.4	95.4	99.9	100.0	100.0	100.0	100.0	.228	.368	.567
914	6.9	14.9	21.5	27.3	43.2	74.1	94.0	100.0	100.0	100.0	.562	1.165	1.824
915	21.1	56.6	89.9	98.4	99.3	99.7	100.0	100.0	100.0	100.0	.074	.110	.165
916	7.2	11.3	16.9	30.2	52.9	84.1	97.7	99.8	100.0	100.0	.495	.915	1.462
917	7.9	14.4	21.4	45.3	64.2	81.6	95.8	100.0	100.0	100.0	.321	.594	1.260
918	6.8	14.7	17.2	35.2	70.9	93.6	99.9	100.0	100.0	100.0	.409	.666	.983
919	5.9	11.1	17.0	27.9	54.3	87.2	98.8	100.0	100.0	100.0	.528	.893	1.392
920	6.3	13.8	23.6	60.8	87.7	98.1	99.9	100.0	100.0	100.0	.282	.409	.634
921	5.4	14.3	61.0	93.0	98.5	99.7	100.0	100.0	100.0	100.0	.158	.212	.304

Gas Permeability

Permeability of selected core samples to gas was determined by Anthony Garcia at the Porous Media Laboratory of Colorado State University. Samples were vertically oriented in the permeameter to enable measurement of gas permeability across bedding planes (table 7).

Table 7. Gas permeability of core samples

[Data from Anthony Garcia, Colorado State University, written commun., 1988]

Sample number	Intrinsic vertical permeability (millidarcies)
2	540
3	3,400
4	1,900
5	150
6	100
7	2,200
8	500
10	1,600
13	850
15	93
17	440
18	1,000
19	430
21	3,700
23	1,900
24	51
25	2,200
27	200
28	580
31	12
34	100
35	150
36	100
37	23
38	7,100
39	85
41	710
42	130
43	1,800
45	34
47	4,100
48	5.9
50	300

ANALYSES ON COMPLETED WELLS

Perforated Intervals in Wells

Well A3 was constructed in 1985 as an irrigation and water-supply well that draws water from the Arapahoe aquifer. The well is cased with 12-3/4-in steel casing set from 18 in above ground surface to a depth of 1,907 ft and in designated intervals between screened sections (Jehn and Wood Inc., 1986). Below 1,907 ft, 335 ft of 12-in continuous slot wire wound screen that has a 0.04-in slot opening was placed in approximately 5-, 10-, 15-, and 20-ft sections, as required, opposite the water yielding sandstone units in the Arapahoe Formation. A 10- to 20-mesh gravel pack was placed in the annular space between the well bore and the screen from total depth (2,398 ft) to 1,872 ft. A mixture of sand and bentonite was placed in the annulus in the 10-ft interval immediately above the gravel pack. The screened intervals for well A3 are listed in table 8.

Table 8. Depth of screened intervals in well A3

Depth of screened intervals in well A3 (feet below top of casing)
1,918.5 - 1,950.5
1,955.5 - 1,966.3
1,974.7 - 2,006.3
2,011.5 - 2,027.3
2,042.5 - 2,063.3
2,067.5 - 2,073.3
2,083.8 - 2,131.3
2,138.7 - 2,180.3
2,187.5 - 2,208.3
2,214.8 - 2,267.3
2,278.7 - 2,320.3
2,323.5 - 2,344.3
2,357.5 - 2,368.3

The casing in well USGS was gun perforated to provide hydraulic connection to selected intervals of water-yielding sandstone or relatively impermeable zones of mudstone in the Arapahoe aquifer. Each perforation consists of a single, approximately 0.38-in-diameter hole extending through the casing, cement grout, and into the formation. Perforations were placed at the depths indicated in table 9.

Table 9. Depth and general lithology at perforations in well USGS

[ss, sandstone; ms, mudstone]

Depth of perforations in well USGS (feet below top of casing)	General lithology
1,836	ss
1,850	ss
1,878	ss
1,897	ss
1,909	ss
1,930	ss
1,940	ss
1,952	ss
1,970	ss
1,976	ms
1,979	ms
1,986	ss
2,001	ss
2,020	ss
2,080	ss
2,084	ms
2,087	ms
2,098	ss
2,110	ss
2,130	ss
2,192	ss
2,206	ss
2,226	ss
2,242	ss
2,254	ss
2,276	ss
2,279	ms
2,282	ms
2,290	ss
2,304	ss
2,324	ss

Water-Level and Atmospheric-Pressure Changes

Water levels in well A3 and atmospheric pressure at the test site were continuously monitored from February 2 to March 1, 1988. Water-level changes were monitored by use of a mercury manometer and a digital recorder. The manometer responded to pressure changes caused by the change in submergence of the end of the airline in well A3. The well was unused during this period and was undergoing a gradual rise in water level (fig. 4). Water-level data were recorded to an accuracy of about 0.01 ft. Atmospheric-pressure changes were monitored by use of a microbarograph that produced a continuous record at a sensitivity of 0.01 in of mercury (0.01 ft of water) (fig. 5).

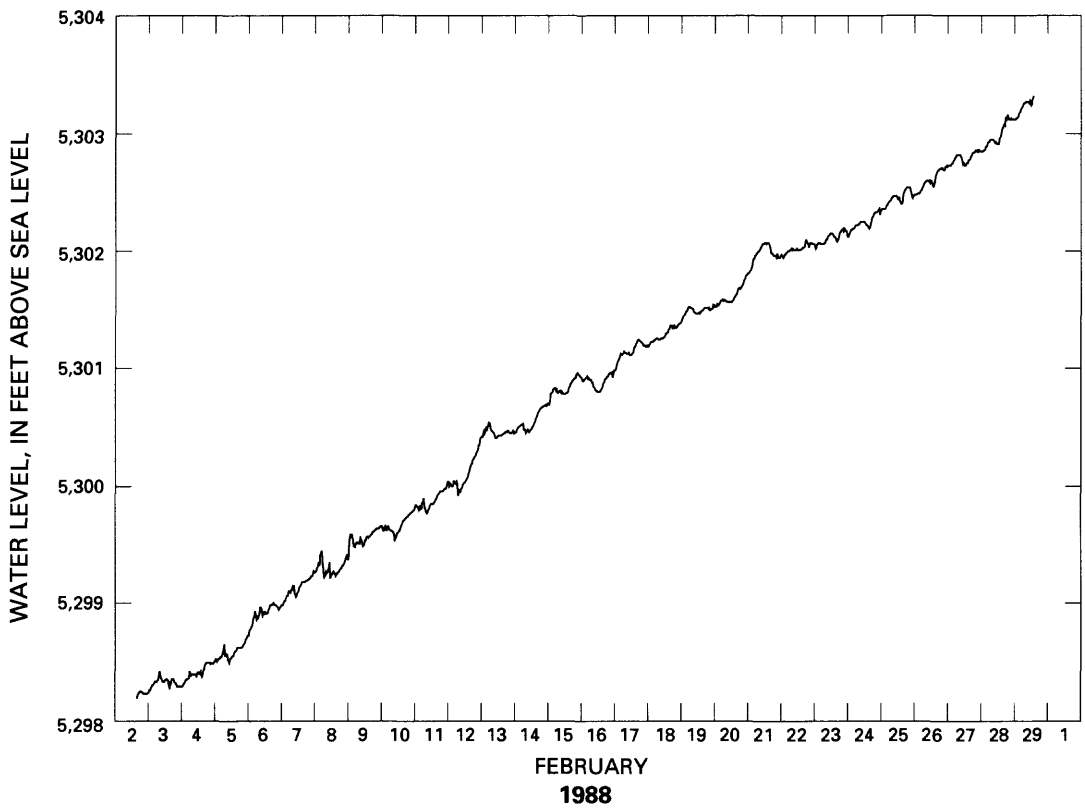

Figure 4. Water levels for well A3.

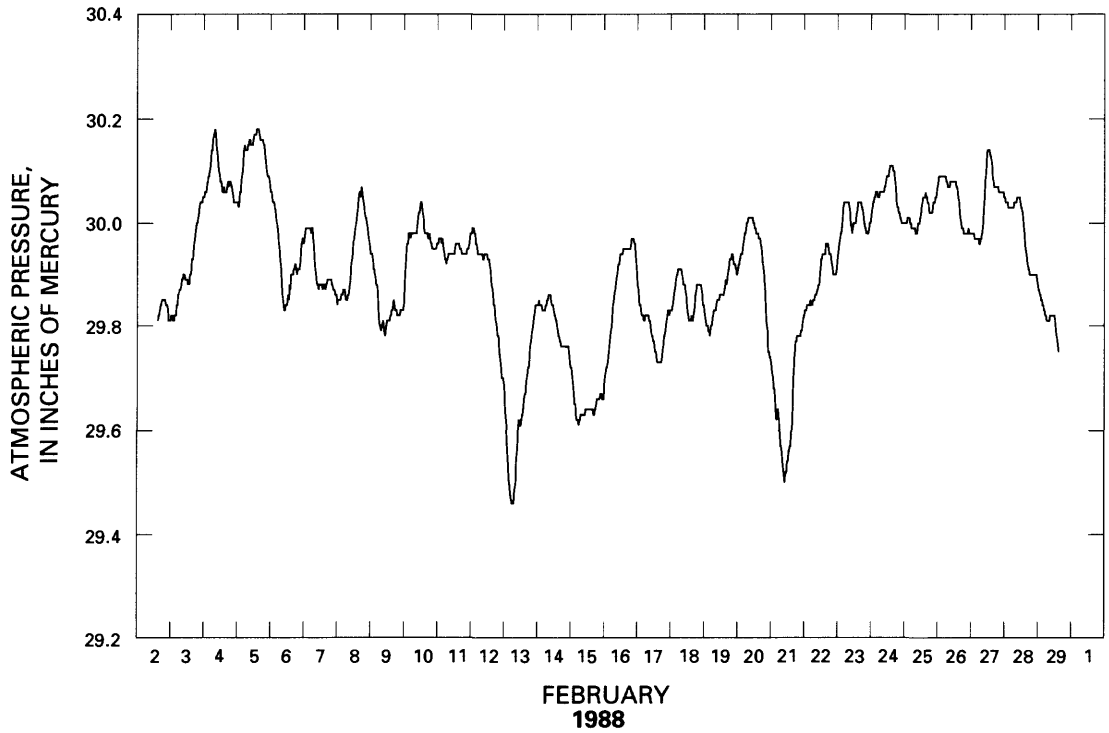

Figure 5. Atmospheric pressure at the test site.

Aquifer-Compression Measurements

A series of aquifer tests were conducted at the test site by pumping well A3 and monitoring formational compression at well USGS. The elastic properties of porous rock cause the thickness of a confined aquifer to decrease slightly when the pore pressure of the water in the formation is decreased, as occurs during pumping of a nearby well. Aquifer compression was measured by use of a well-bore extensometer that consisted of a tensioned wire element that extended from above land surface to an anchor set in the bottom of well USGS. As the thickness of the formation decreased during pumping, the wire element protruded farther above the top of the well casing. This apparent change in element length is a measure of the formation compression. Change in element length was measured with a machinist dial indicator that was accurate to 0.0005 in.

To minimize the effects of friction between the element and the sides of the casing, the element was preloaded and then allowed to contract back to an equilibrium length. Two preload-relaxation cycles were monitored with well A3 idle. Two additional preload-relaxation cycles were monitored with well A3 pumping (table 10). Difference in element length and, hence, the change in aquifer thickness were reported by Robson and Banta (1990) to be about 0.025 in.

Table 10. Aquifer-compression measurements in well USGS

Time after extensometer element preload (minutes)	Change in extensometer element length (inches)
TEST 1, WITH A3 PUMPING	
2.0	0.0490
4.0	.0610
7.0	.0730
10.0	.0782
15.0	.0872
20.0	.0907
25.0	.0928
TEST 2, WITH A3 PUMPING	
1.0	.0250
2.0	.0480
3.0	.0594
4.0	.0670
5.0	.0710
6.0	.0730
8.0	.0825
10.0	.0854
12.0	.0885
14.0	.0903
16.0	.0934
19.0	.0950
22.0	.0954
27.0	.0956
32.0	.0959
38.0	.0959
TEST 3, WITH A3 IDLE	
.57	.0300
.78	.0450
1.5	.0600
3.0	.0770
4.0	.0870

Table 10. Aquifer-compression measurements in well USGS--Continued

Time after extensometer element preload (minutes)	Change in extensometer element length (inches)
TEST 3, WITH A3 IDLE--Continued	
5.0	0.0945
6.0	.1090
7.0	.1150
8.5	.1184
10.0	.1195
12.0	.1207
15.0	.1210
18.0	.1214
20.0	.1217
24.0	.1214
26.0	.1212
TEST 4, WITH A3 IDLE	
.71	.0300
1.0	.0450
1.47	.0600
2.0	.0720
3.0	.0890
4.0	.1000
5.0	.1065
6.0	.1095
8.0	.1140
10.0	.1159
13.0	.1180
14.0	.1185
17.0	.1201
22.0	.1214
30.0	.1228
38.0	.1233

Drawdown During Aquifer Testing

Aquifer tests were conducted on the Arapahoe aquifer by pumping well A3 and monitoring head changes in well USGS. The casing in well USGS was gun perforated at selected points opposite sandstone and mudstone intervals (table 9). Head changes in well USGS were measured by use of pressure transducers that were isolated at the perforation by inflatable packers set above and below each perforation. Well A3 was pumped for 4 hours at a constant rate of about 348 gal/min. After the pumping period, the packers were reset to a new series of perforations and reinflated. The wells were then allowed to recover for about 20 to 70 hours before another 4-hour pumping cycle was begun. The drawdown measured at each perforation is shown in the hydrographs in figure 6.

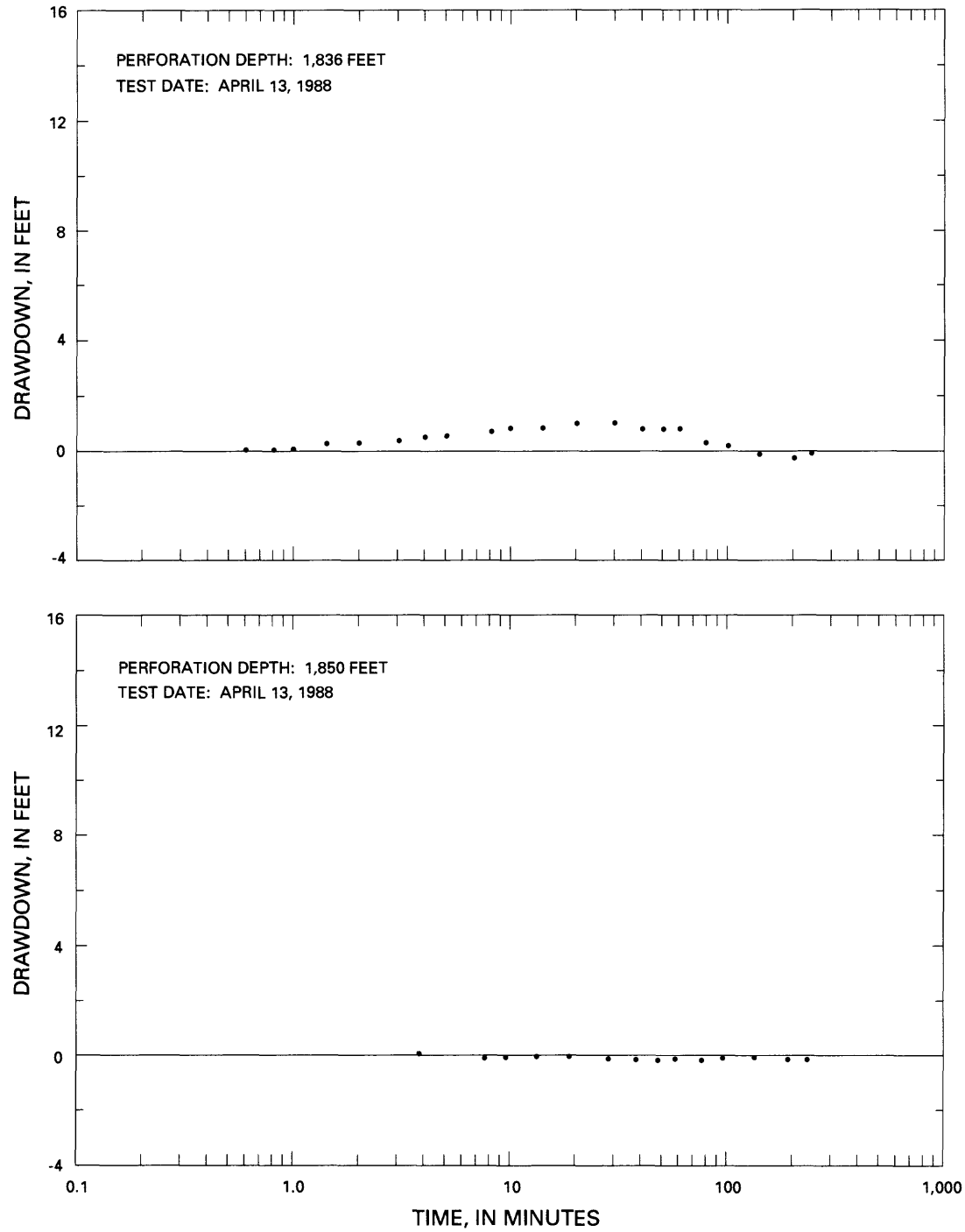

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing.

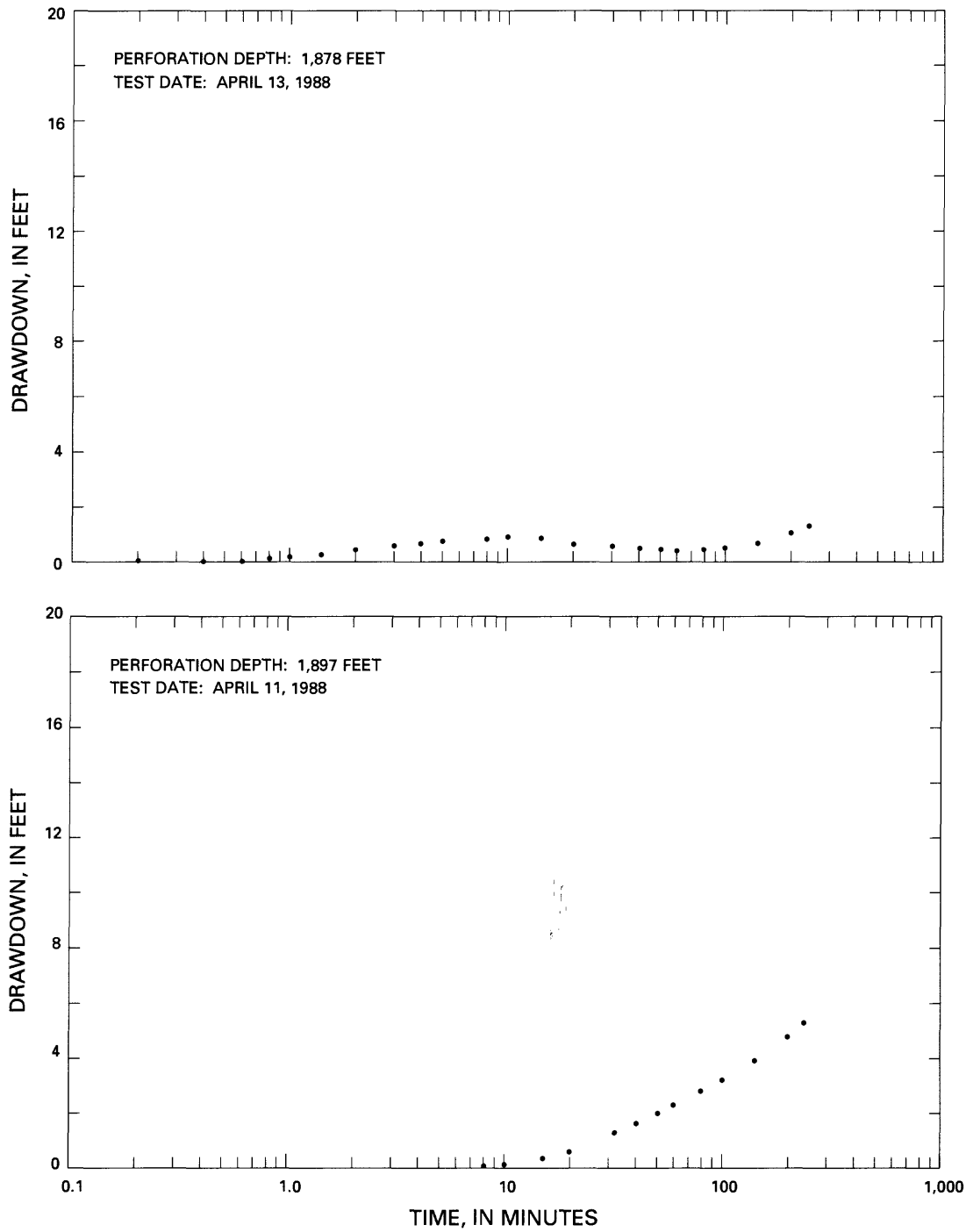

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

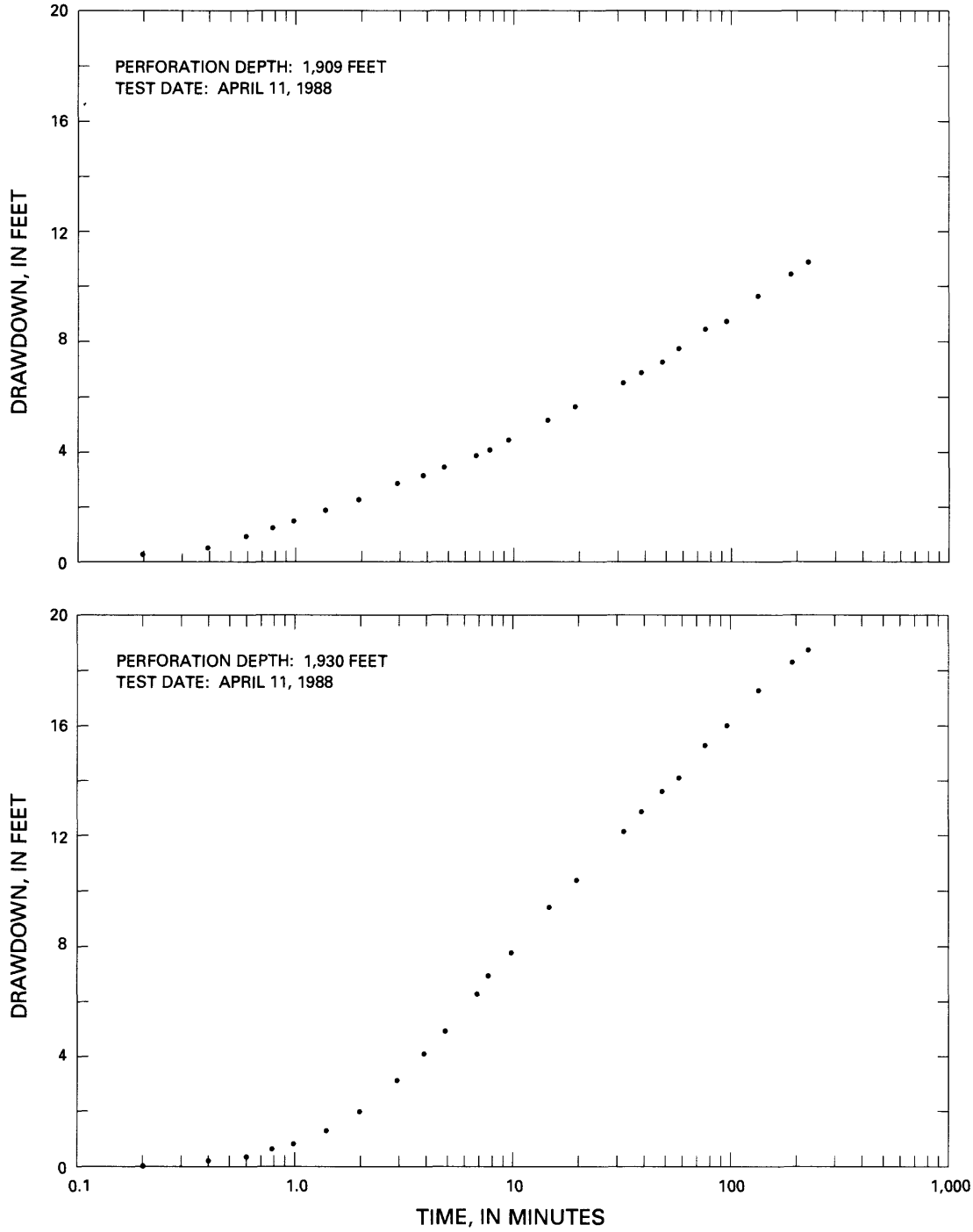

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

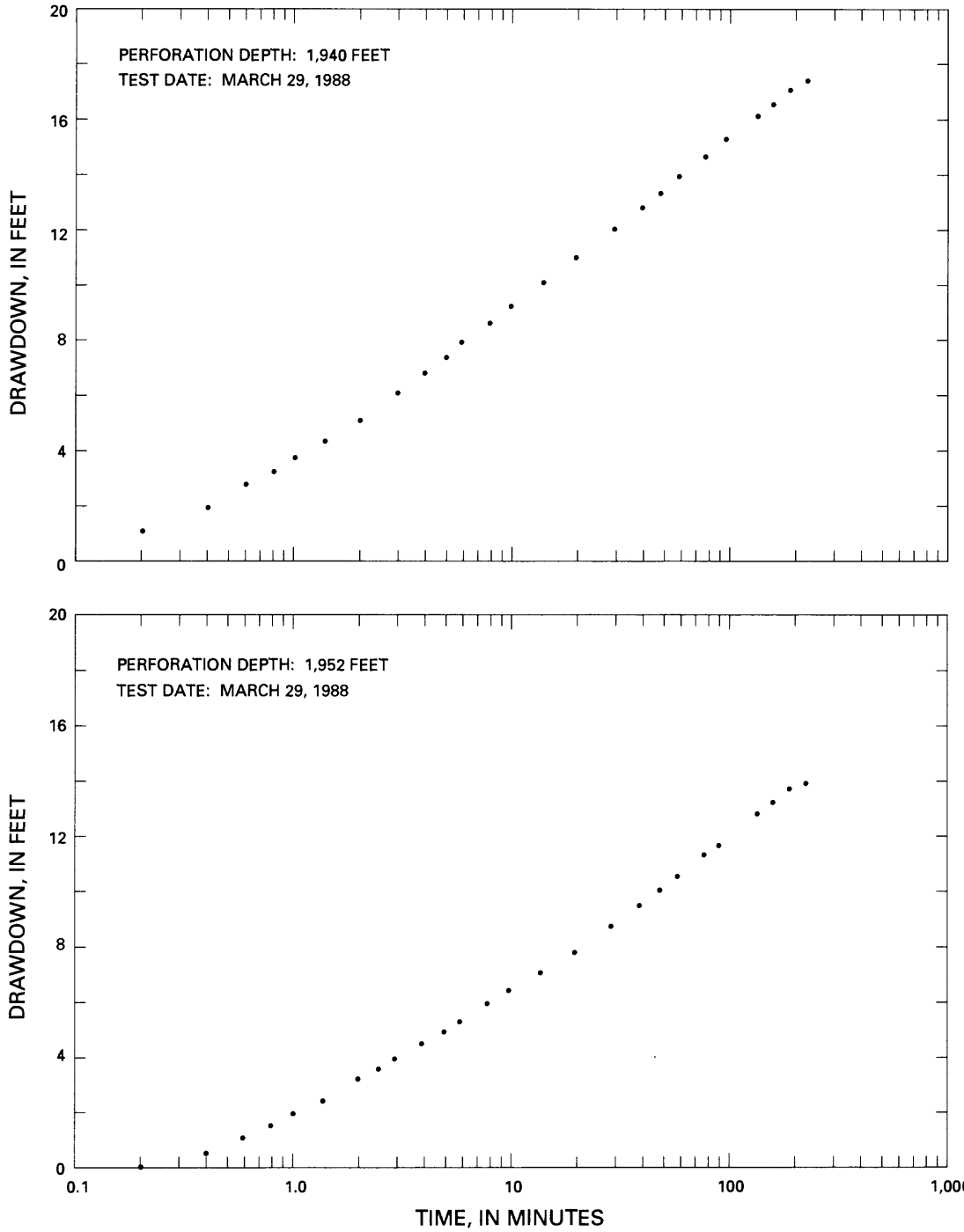

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

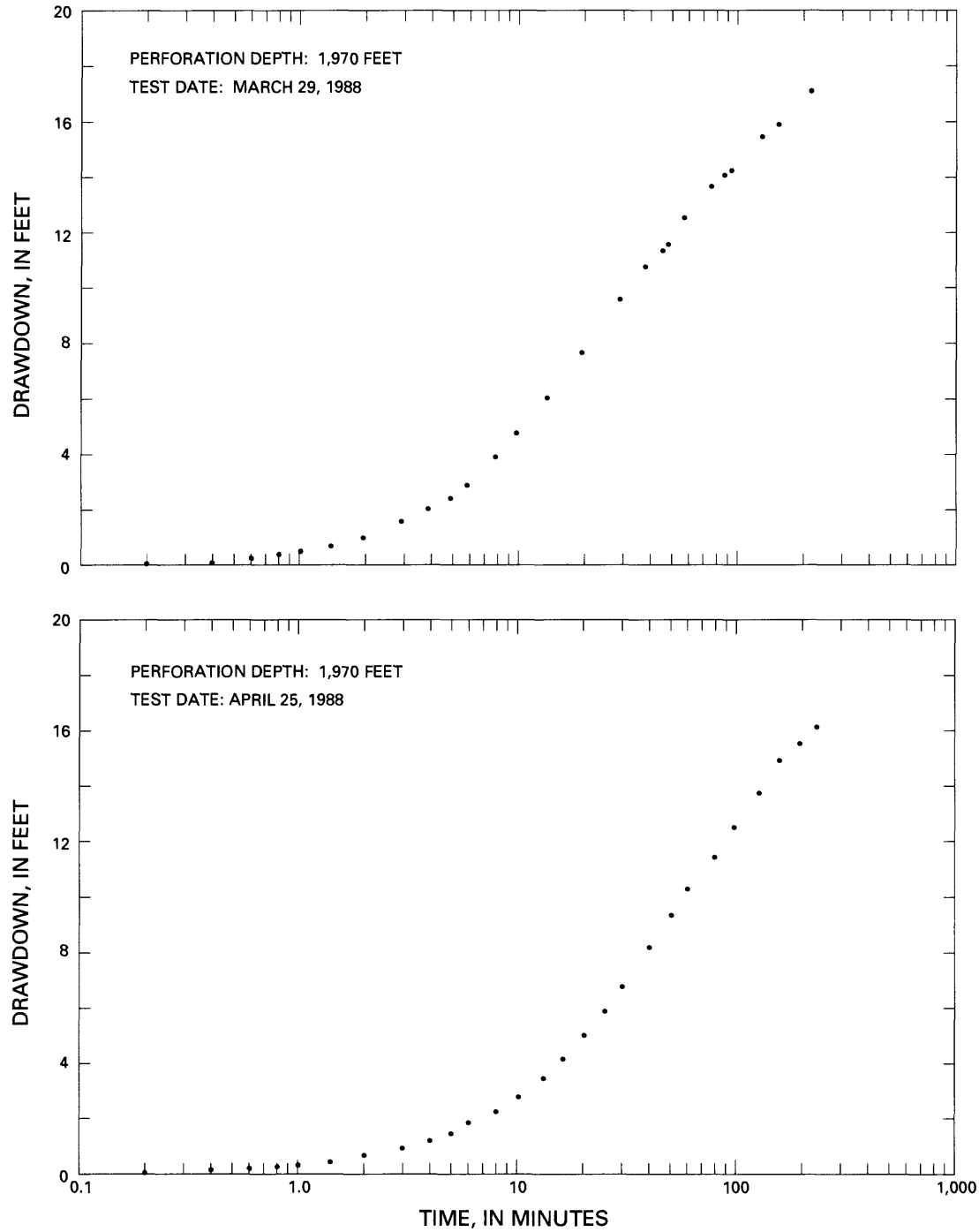

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

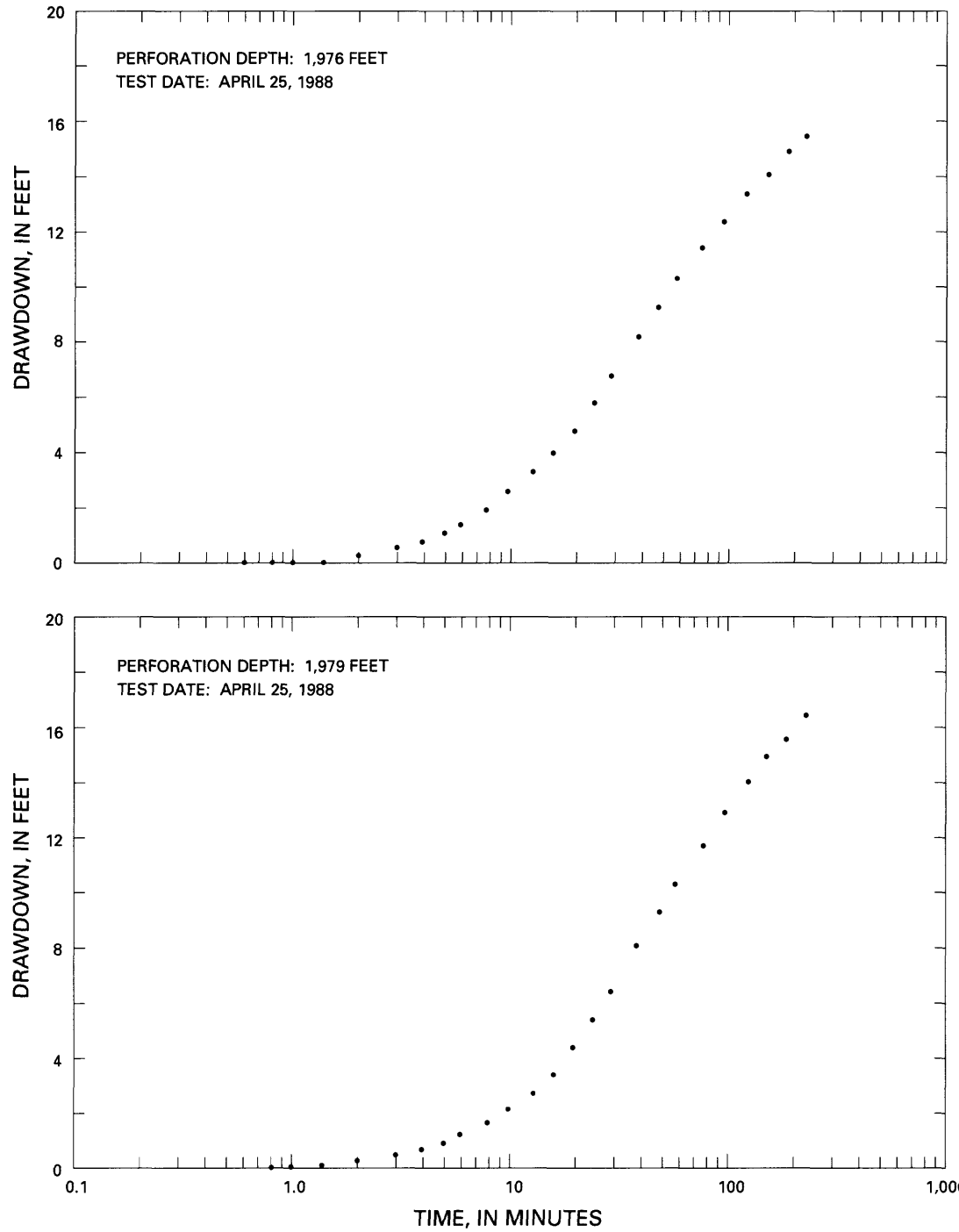

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

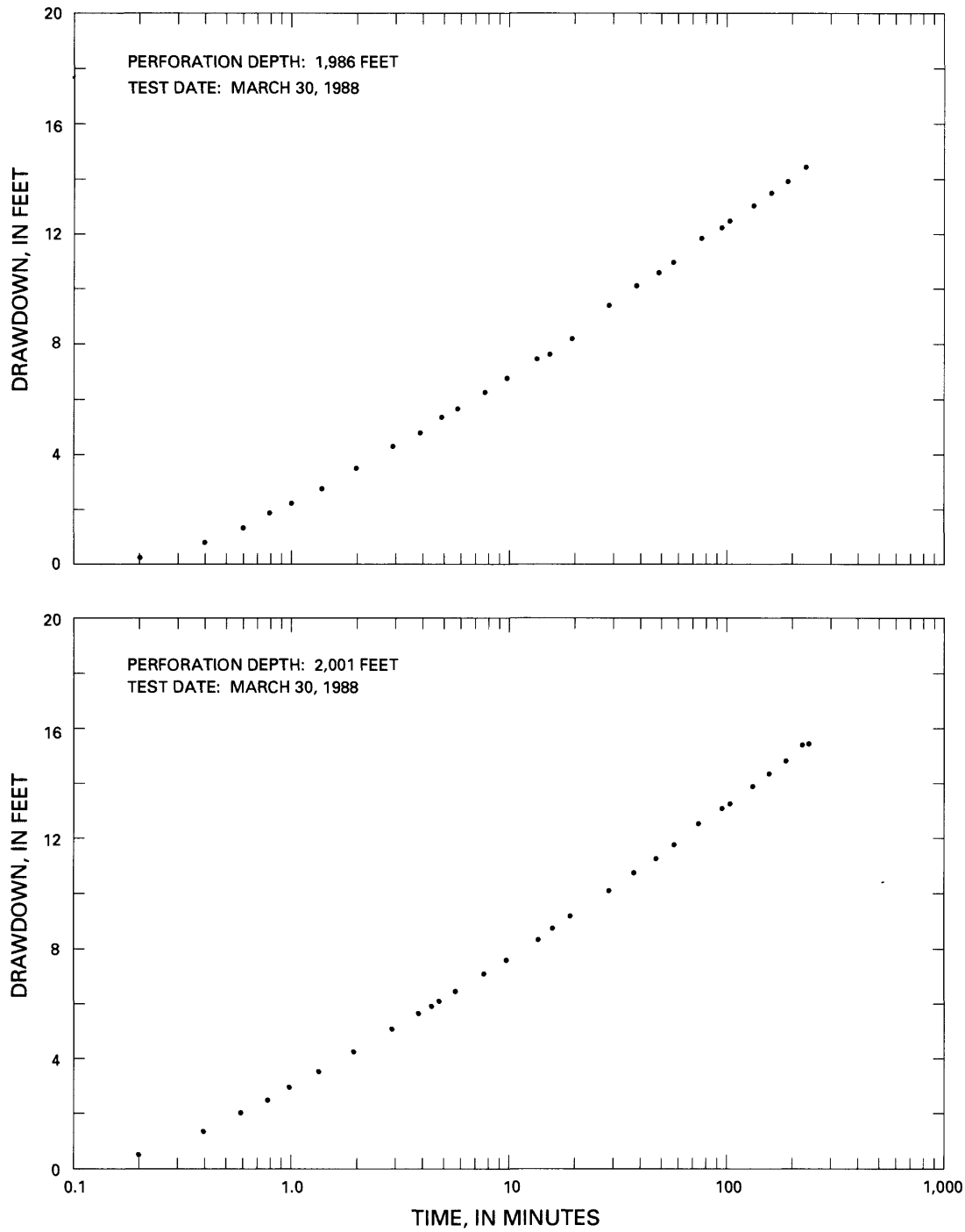

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

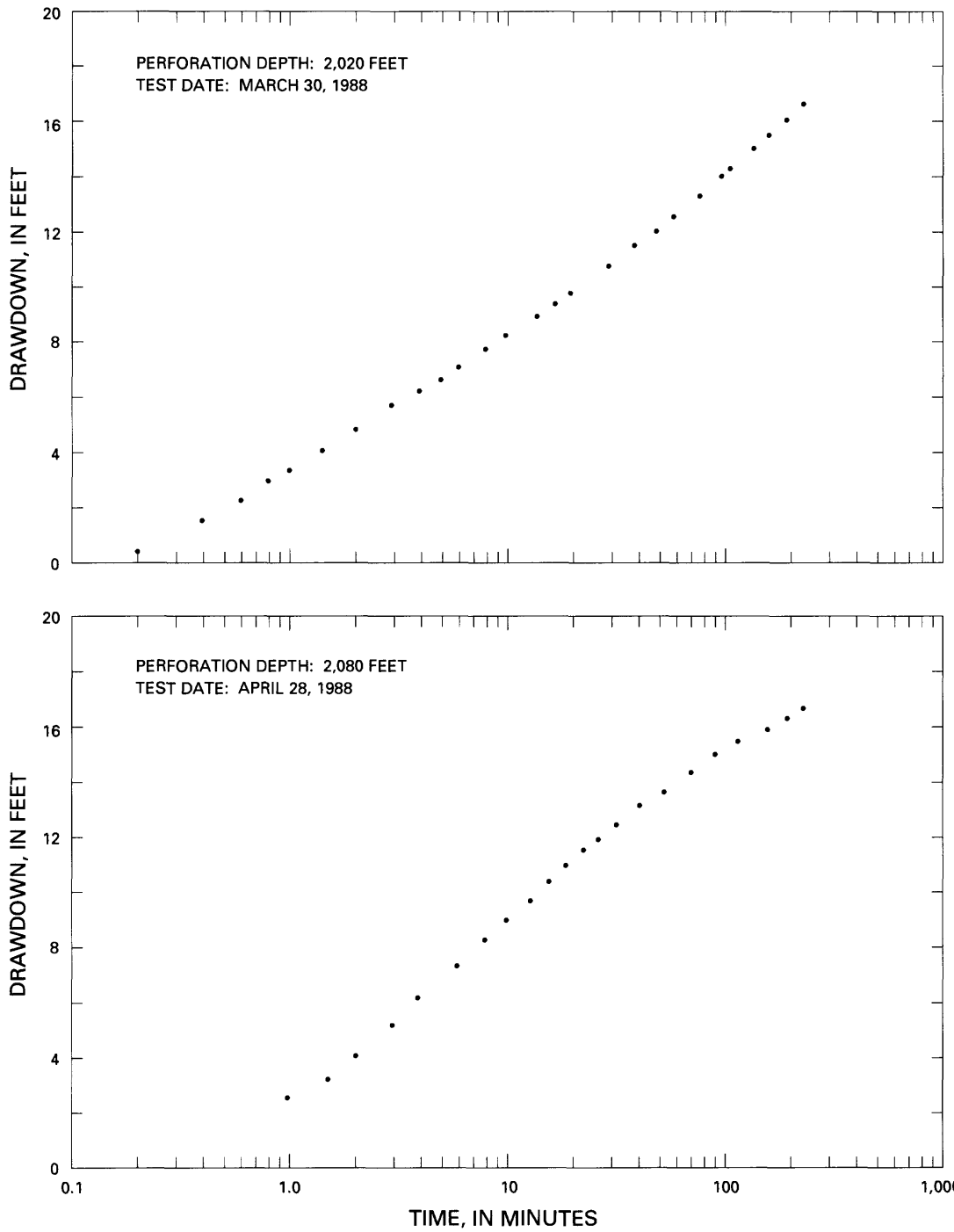

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

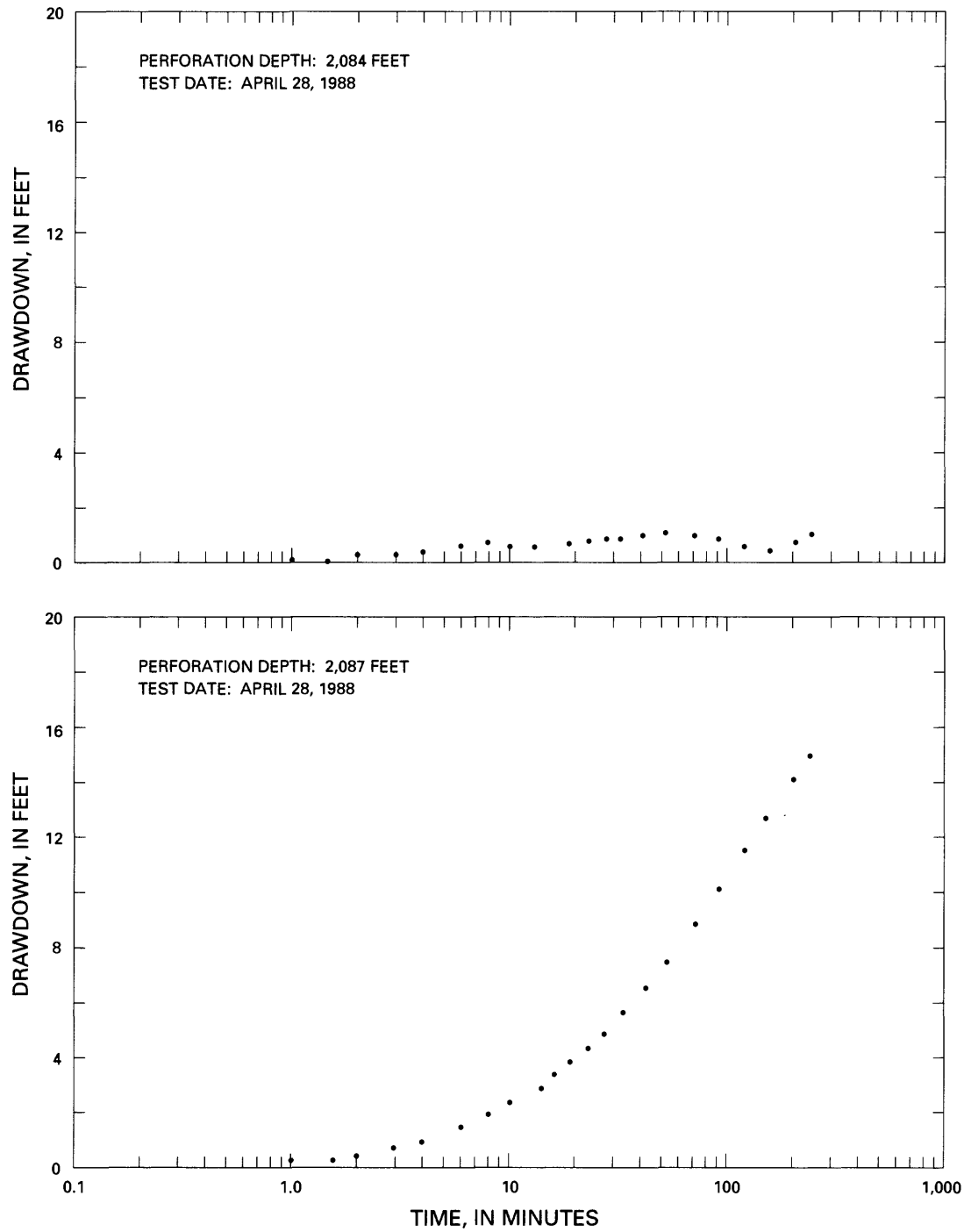

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

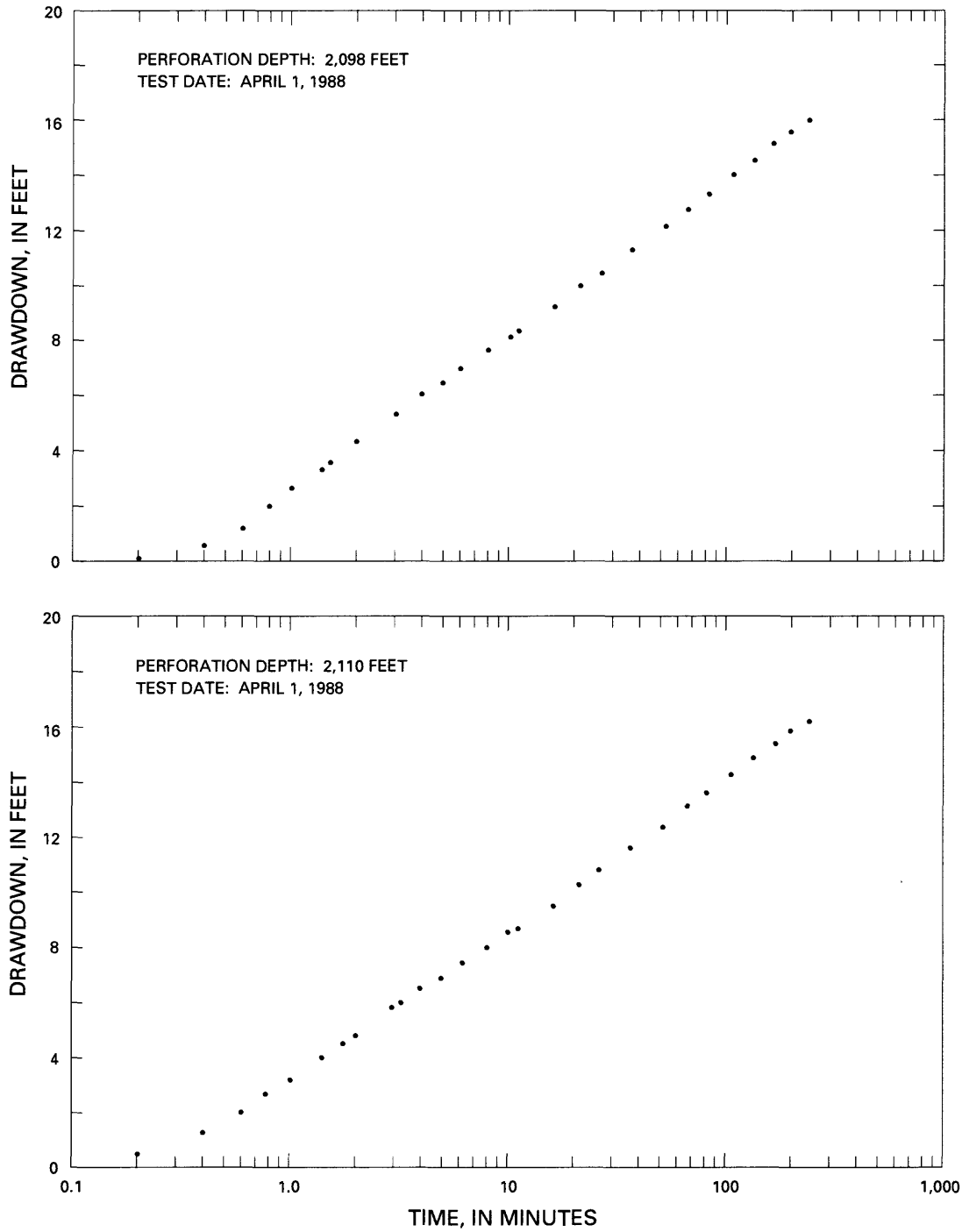

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

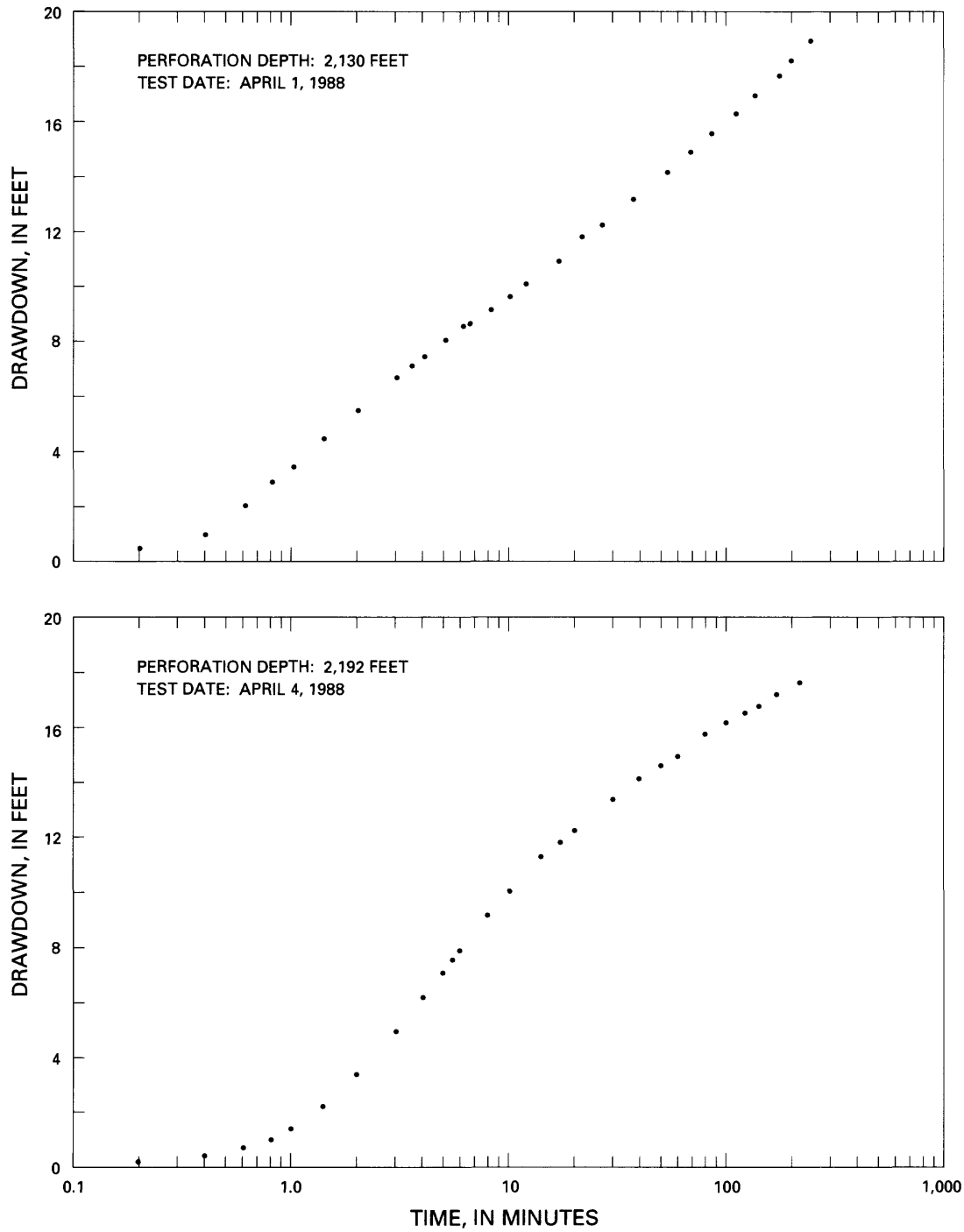

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

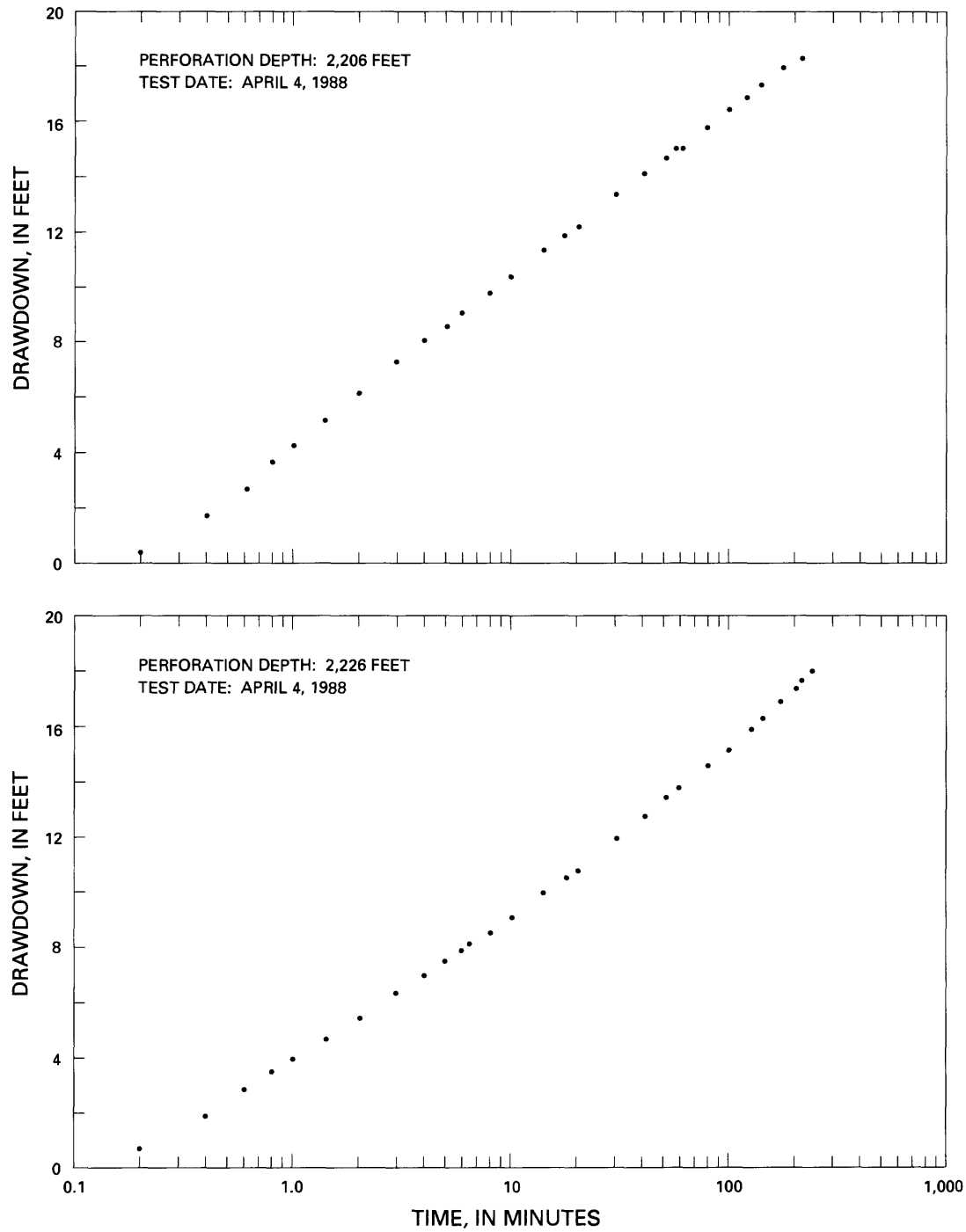

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

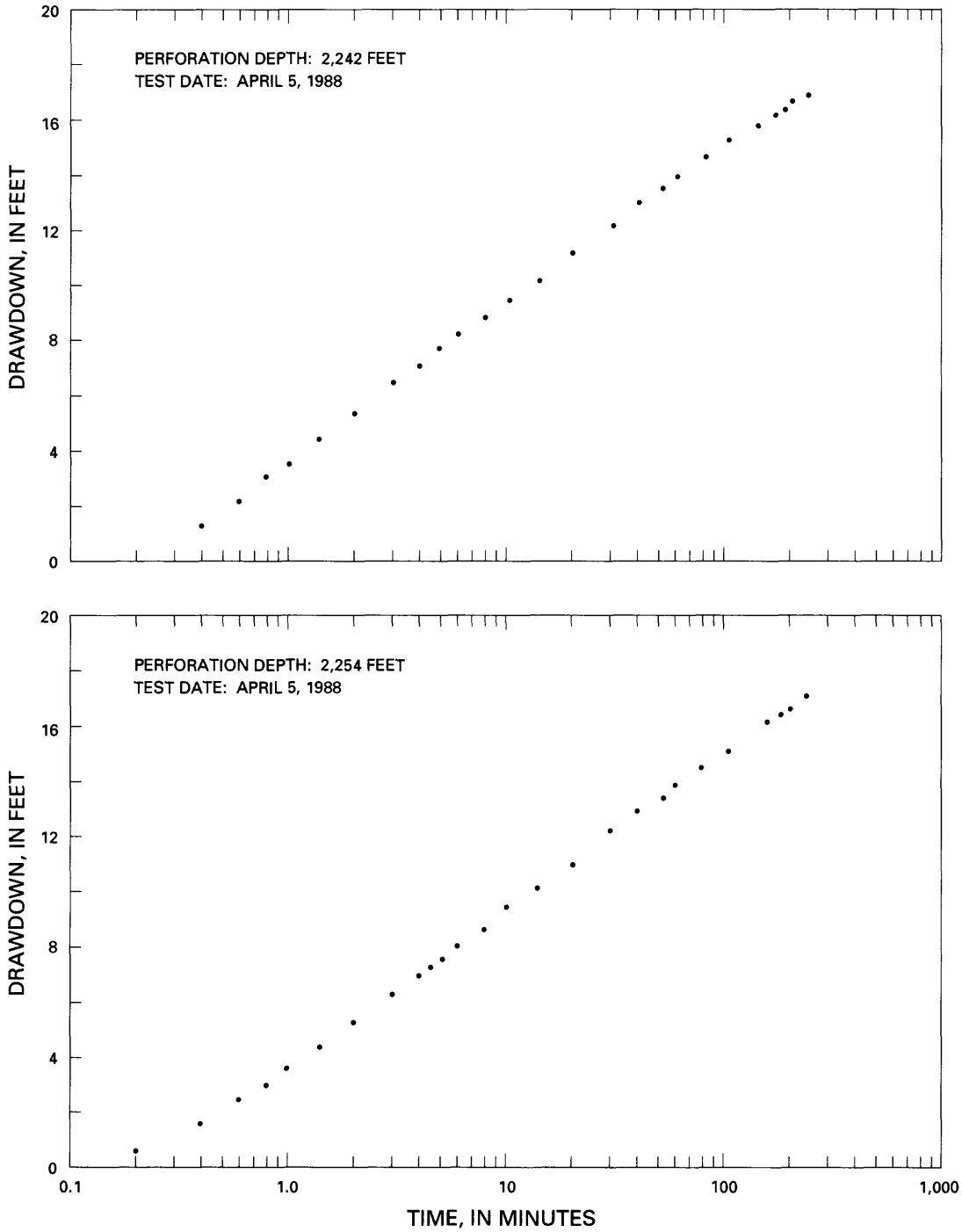

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

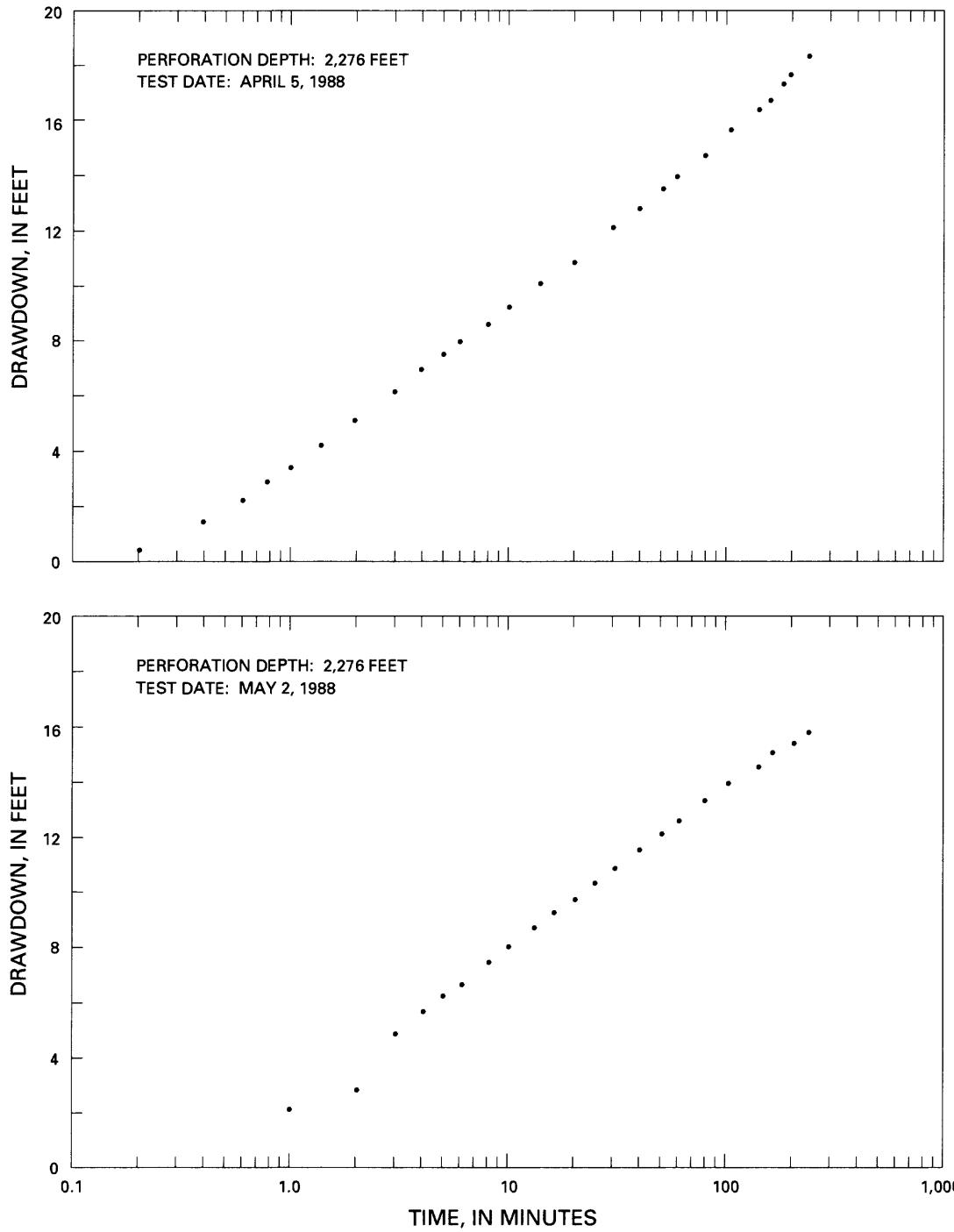

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

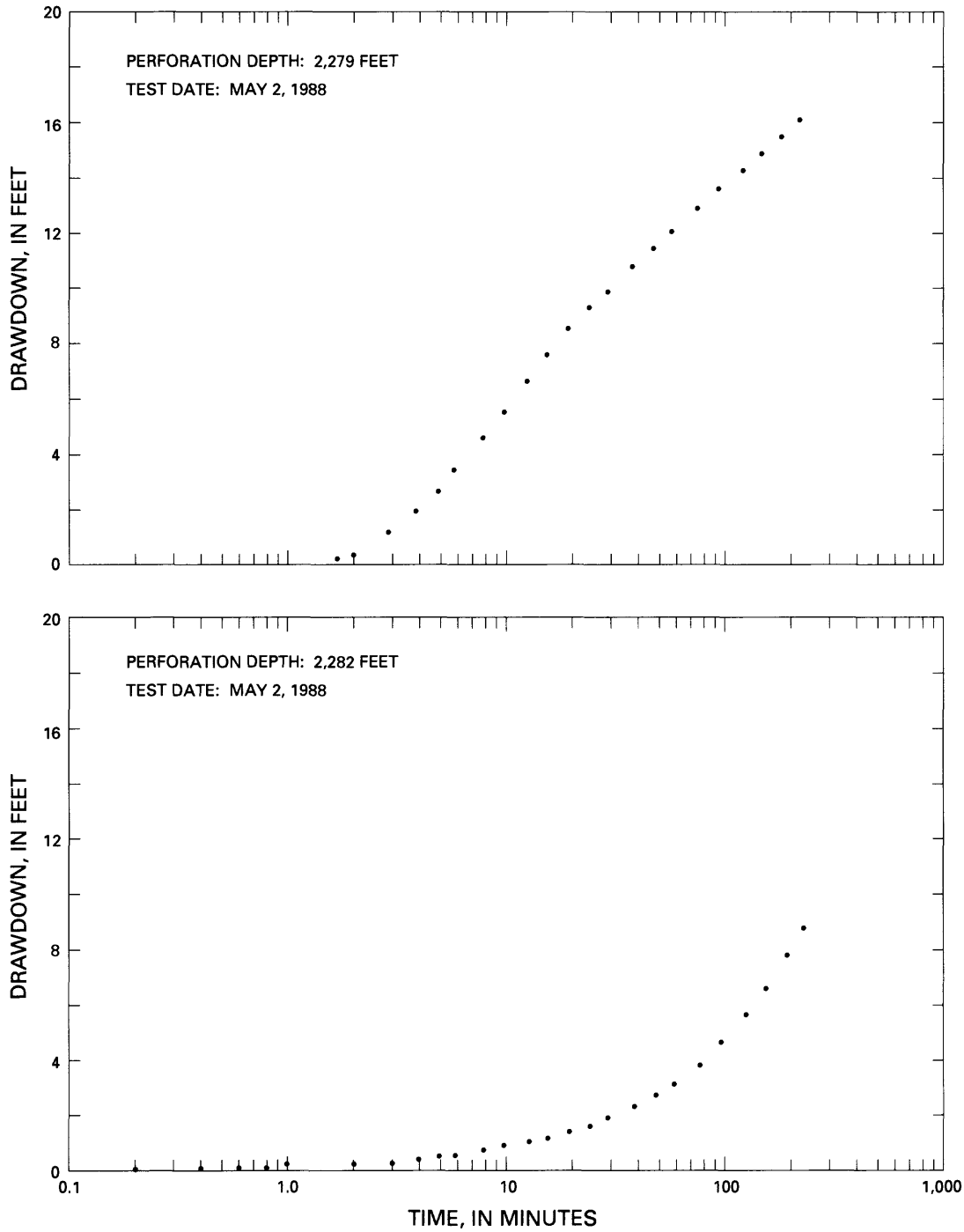

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

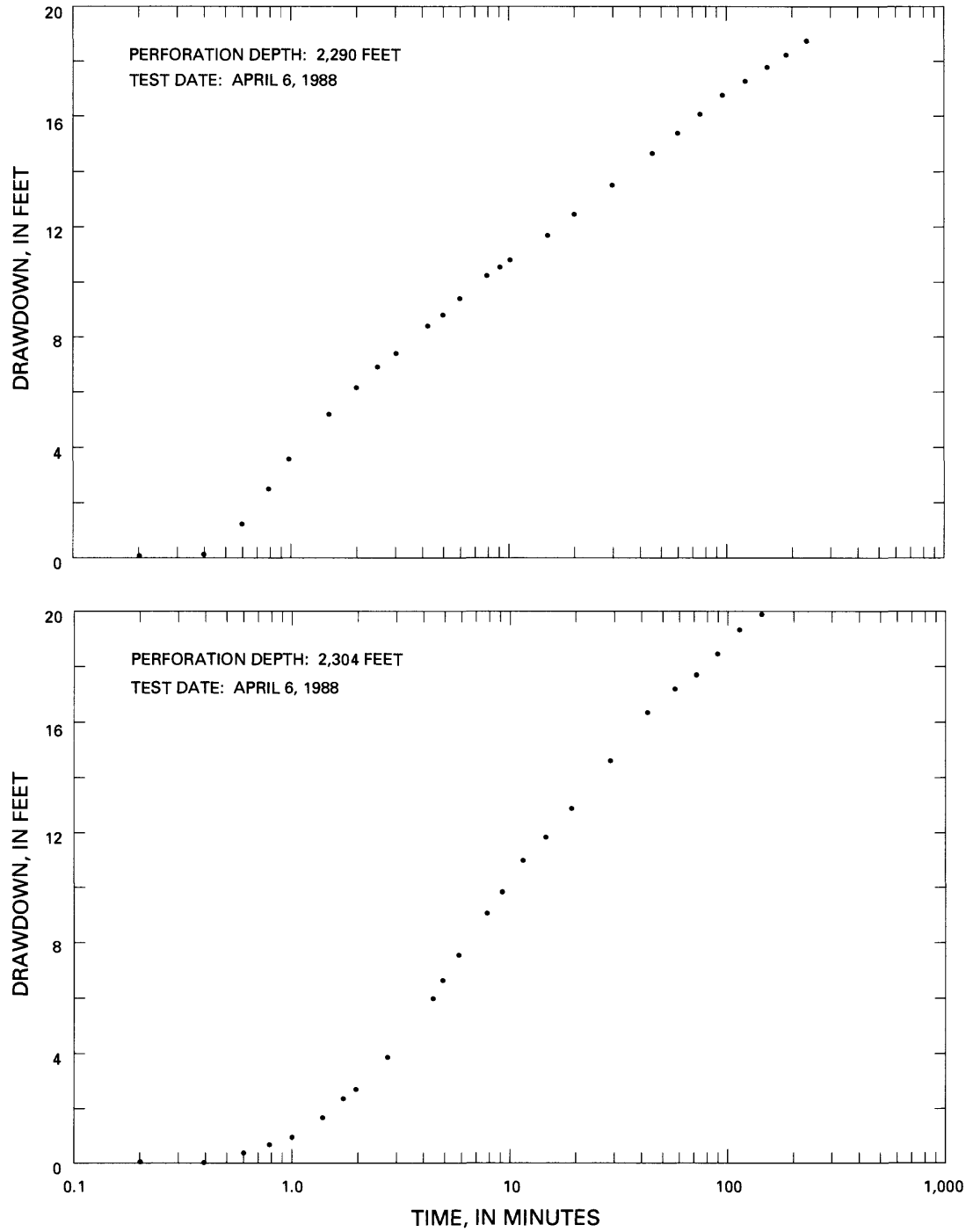

Figure 6. Drawdown measured in observation well USGS at specified depths during aquifer testing. --Continued

GEOPHYSICAL LOGS FOR WELL USGS

A suite of geophysical logs was run on well USGS at the completion of drilling in October, 1987. The following list of log names includes the corresponding abbreviated name shown on the log heading (in parentheses) and a brief description of the nature of the log. Copies of the geophysical logs are included as supplemental information in the pocket at the back of this report. A more complete explanation of these geophysical logs is contained in Schlumberger (1987).

Apparent Fluid Resistivity (RFA): The apparent resistivity of the formation fluid is calculated from other log data and is recorded on this log.

Apparent Porosity (PHIA): The apparent porosity of the formations is calculated from other porosity log data and is recorded on this log. The apparent porosity is more indicative of porosity measured in shale than is either the neutron porosity or density porosity alone.

Bit Size (BS): The outside diameter of the drill bit is recorded on this log.

Bulk Density (RHOB): The bulk density of the formation and the contained fluid as measured by Compton scattering of gamma radiation is recorded on this log.

Bulk Density Compensation (DRHO): The values shown on the bulk density log have been adjusted by the amount shown on the bulk density compensation log to account for mud cake and borehole-wall irregularities.

Bulk Volume of Water (BVW): The bulk volume of water log is a measure of the water-filled effective porosity of the formation. It is less than the effective porosity log where water saturation is less than 1.0.

Caliper (CALI): The diameter of the well bore is recorded on this log.

Conductivity (CILD): The reciprocal of the deep induction resistivity log is recorded on this log.

Density Porosity (DPHI): The porosity of the formation is calculated on the basis of the Compton scattering of gamma radiation emitted from the logging sonde. The degree of scattering is directly related to the density of electrons in the formation. The density and porosity of the formation is determined from the electron density.

Differential Caliper (DCAL): The difference between the bit size and the diameter of the hole is recorded on this log.

Effective Porosity (PHIE): The effective porosity is calculated from other log data and is defined as that porosity associated with the non-clay part of the formation. It is the porosity that would exist if the water bound to the clay minerals were disregarded. The effective porosity log is not necessarily a measure of interconnected porosity; it is a measure of total porosity minus shale porosity.

Formation Grain Density (RHGF): The apparent grain density of the formation is calculated from other log data and is recorded on this log.

Free Fluid Index (FFI): This is a measure of formation porosity based on the nuclear magnetic properties of the fluid in the formation. The FFI porosity measures the volume of fluid in the pore space that is not bound electrically or chemically to the clay minerals, to the surface of the rock matrix, or to other minerals in the formation.

Free Induction Decay Time (T2): This is a measure of the rate of decay in the amplitude of the Larmor frequency during magnetic depolarization of protons in the formation fluid.

Gamma Ray (GR): The total natural gamma radioactivity of the formations is recorded on this log. In sedimentary formations radioactive elements tend to be concentrated in clay and shale, and a gamma ray log can indicate the relative clay or shale content of the formations.

Hole Diameter (HD): The diameter of the well bore is recorded on this log.

Induction Resistivity Log (medium penetration) (ILM): The electrical conductivity of the formation at an intermediate distance beyond the well bore is measured by the logging sonde and recorded as electrical resistivity.

Induction Resistivity Log (deep penetration) (ILD): The electrical conductivity of the formation beyond the zone of mud filtrate invasion in the well bore is measured by the logging sonde and recorded as electrical resistivity.

Interval Transit Time (DT): The time required for a sonic wave to traverse a 1 ft distance through the formation is recorded on this log.

Larmor Frequency (LFRE): The frequency of an electromagnetic signal generated by the change in magnetic polarization of protons in the formation fluid is recorded on this log.

Microinverse (MINV): The resistivity of the formation immediately behind the mud cake is recorded on this log.

Micronormal (MNOR): The resistivity of the mud cake is recorded on this log. The difference between the microinverse and micronormal logs is an indication of the thickness of the mud cake and the relative permeability of the formation. Thicker mud cakes generally develop opposite more permeable formations.

Minimum Shale Index (MSI): This log records an index of the shale content of the formation. The minimum shale content is calculated from the neutron, natural gamma, and spontaneous potential logs.

Neutron Porosity (NPHI): The porosity of the formations is calculated on the basis of the rate of attenuation of high energy neutrons emitted from the logging sonde. The rate of attenuation is directly related to the density of hydrogen nuclei primarily located in the water-filled pore space of the formation.

Permeability-NML (KNML): This log records the permeability of the formation as calculated from the free fluid index and other porosity logs.

Photo Electric Factor (PEF): The photo electric factor is a measure of the general lithology of the formation. The log is based on a comparison of the rates of Compton scattering and photoelectric absorption of gamma rays emitted from the logging sonde.

Signal-to-Noise Ratio (STNR): The signal-to-noise ratio from the nuclear magnetic resonance sonde is recorded on this log.

Sonic Porosity (SPHI): The interval transit time is used as a measure of the formation porosity, which is recorded on this log.

Spherically Focused Log (shallow penetration) (SFL): A focused electric current is used to obtain measurements of formation resistivity near the well bore. The measured values may be shown in an averaged (SFLA) or unaveraged (SFLU) form.

Spontaneous Potential (SP): This log records the changes in electrical potential, as measured at the well bore, produced by electrochemical and electrokinetic processes in the formations.

Temperature: The borehole temperature in degrees Celsius is recorded on this log.

Tension (TENS): The working tension exerted on the logging cable is recorded on this log.

True Resistivity (RT): This log is identical to the deep induction resistivity log.

Water Saturation (SWT): The apparent degree of water saturation in the formation is calculated from other log data and recorded on this log. In an aquifer free of hydrocarbons, the water saturation log should be about 1.0 at all points below the water table.

Wet Resistivity (RO): The apparent resistivity of the fully water-saturated formation is calculated from other log data and recorded on this log. In an aquifer, the wet resistivity log should approximately overlay the true resistivity log.

REFERENCES CITED

Jehn and Wood, Inc., 1986, Castle Pines North Metropolitan District completion report wells A-1, A-2, and A-3: Denver, Jehn and Wood, Inc., 50 p.

Major, T.J., Robson, S.G., Romero, J.C., and Zawistowski, Stanley, 1983, Hydrogeologic data from parts of the Denver basin, Colorado: U.S. Geological Survey Open-File Report 83-274, 425 p.

McWhorter, D.B., and Garcia, A.J., 1990, The concept of specific yield and its evaluation by laboratory measurements: Groundwater Engineering and Management Conference, 1990, Proceedings, p. 235-246.

Pettijohn, F.J., Potter, P.E., and Siever, R., 1987, Sand and sandstone: New York, Springer-Verlag, 553 p.

Raforth, R.L., and Jehn, J.L., 1990, Preliminary results of the coring of the Denver Basin aquifers: Groundwater Engineering and Management Conference, 1990, Proceedings, p. 235-246.

Robson, S.G., 1987, Bedrock aquifers in the Denver basin, Colorado--a quantitative water-resources appraisal: U.S. Geological Survey Professional Paper 1257, 73 p.

Robson, S.G., and Banta, E.R., 1990, Comparison of specific-storage and storage coefficient values measured by aquifer-test, barometric-efficiency and aquifer-compression techniques in deep, closely spaced wells: Groundwater Engineering and Management Conference, Fort Collins, Colo., 1990, Proceedings, p. 223-233.

Schlumberger, 1987, Log interpretation principles/applications: Houston, Schlumberger Educational Services, 198 p.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—774-207 / 80003 REGION NO. 8