# DATA FOR GROUND-WATER TEST HOLE NEAR ZAMORA,

# CENTRAL VALLEY AQUIFER PROJECT,

# CALIFORNIA

By James J. French, R. W. Page, and G. L. Bertoldi

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## CONVERSION FACTORS

In this report some measurements are given in inch-pound units; however, some laboratory data are reported in metric units. To convert from metric units to inch-pound units, multiply by the reciprocal of the conversion shown. Conversion factors from unit to unit are listed below.

| Multiply | By | To obtain |
|---|---|---|
| acres | 0.4047 | $hm^2$ (square hectometers) |
| ft (feet) | .3048 | m (meters) |
| ft/d (feet per day) | .00243 | mD (millidarcies) |
| $ft^2$ (square feet) | .0929 | $m^2$ (square meters) |
| $ft^2/yr$ (square feet per year) | .0929 | $m^2/yr$ (square meters per year) |
| gal/min (gallons per minute) | .06309 | L/s (liters per second) |
| inches | 25.4 | mm (millimeters) |
| $lb/in^2$ (pounds per square inch) | 703.1 | $kg/m^2$ (kilograms per square meter) |
| $lb/ft^2$ (pounds per square foot) | 4.881 | $kg/m^2$ (kilograms per square meter) |
| $lb/ft^3$ (pounds per cubic foot) | 16.02 | $kg/m^3$ (kilograms per cubic meter) |
| mi (miles) | 1.609 | km (kilometers) |
| ton/d (tons per day) | .9072 | Mg/d (megagrams per day) |
| ton/acre-ft (tons per acre foot) | 735.7 | $Mg/hm^3$ (megagrams per cubic hectometer) |

Temperature is reported in degrees Celsius (°C). Degrees Celsius are converted to degrees Fahrenheit (°F) by using the formula:

$$\text{Temp °F} = 1.8 \text{ temp °C} + 32$$

## ABBREVIATIONS AND DEFINITIONS

cm (centimeters)
°C/km (degrees Celsius per kilometer)
μg/L or μG/L (micrograms per liter)
MEQ/L (milliequivalents per liter)
mg/L or MG/L (milligrams per liter)
pCi/L (picocuries per liter)
W/(mK) (Watt per meter Kelvin)

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 mean sea level.

The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

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## ABSTRACT

This report provides preliminary data for the first of seven test holes drilled as a part of the Central Valley Aquifer Project, which is part of the National Regional Aquifer Systems Analysis Program. The test hole was drilled in the SW¼SE¼ sec. 34, T. 12 N., R. 1 E., Yolo County, Calif., about 3 miles northeast of the town of Zamora. Drilled to a depth of 2,500 feet below land surface, the hole is cased to a depth of 190 feet with 16-inch diameter casing and equipped with three piezometer tubes to depths of 947 feet, 1,401 feet, and 2,125 feet. A 5-foot well screen is set in sand at the bottom of each piezometer. Each screened interval has a cement plug above and below it to isolate it from other parts of the aquifer, and the well bore is filled between the plugs with sediment.

Eighteen cores and 68 sidewall cores were recovered. Laboratory tests were made for mineralogy, hydraulic conductivity, porosity, consolidation, grain-size distribution, Atterberg limits, X-ray diffraction, diatom identification, thermal conductivity, and chemical quality of water. Geophysical and thermal gradient logs were made.

The hole is sampled periodically for chemical analysis and measured for water level in the three tapped zones.

This report presents methods used to obtain field samples, laboratory procedures, and the data obtained.

## INTRODUCTION

The ground-water test hole near Zamora (12N/1E-34Q) (fig. 1) is the first of a series of test holes drilled as a part of the Central Valley Aquifer Project (CVAP). CVAP, as a part of the National Regional Aquifer Systems Analysis program, will evaluate the entire Central Valley (fig. 2) for its optimum ground-water potential. In the Sacramento Valley, the northern part of the Central Valley, there is a scarcity of geologic and hydrologic data below a depth of a few hundred feet. Most water wells in the Sacramento Valley are less than 300 ft deep (Olmsted and Davis, 1961, p. 137), but the potentially usable aquifer may extend to a depth of 2,500 ft (Bertoldi, 1979, p. 13).

The test hole was drilled and piezometer tubes were installed to provide data on confining beds, hydraulic conductivity, hydraulic connection between permeable units, chemical quality of the water, thermal gradient, mineral composition, and head differentials. The data are given in this report and include a description of rock cuttings coming out of the borehole, drill cores, sidewall cores, and geophysical logs. Also included are laboratory reports on mineralogy, hydraulic conductivity, porosity, consolidation, grain-size distribution, Atterberg limits, X-ray diffraction, age dating of an ash layer, diatom identification, thermal conductivity, thermal gradient, and chemical quality of water. In a few instances, the reporting laboratory's measuring units or definitions have been changed to conform to U.S. Geological Survey usage.

The site near Zamora was selected because it overlies one of the thicker sections of continental deposits near the structural axis of the Sacramento Valley (Page, 1974, figs. 2 and 3). Further, the site overlies a section where erosion would be less than that along the sides of the valley and therefore a more complete record of deposition is likely to be found.

## WELL-NUMBERING SYSTEM

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well 12N/1E-34Q, the first two segments designate the township (T. 12 N.) and the range (R. 1 E.); the third number gives the section (sec. 34); and the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram. A final digit is a serial number for wells in each 40-acre subdivision (12N/1E-34Q1).

| | | | |
|---|---|---|---|
| D | C | B | A |
| E | F | G | H |
| M | L | K | J |
| N | P | Q | R |

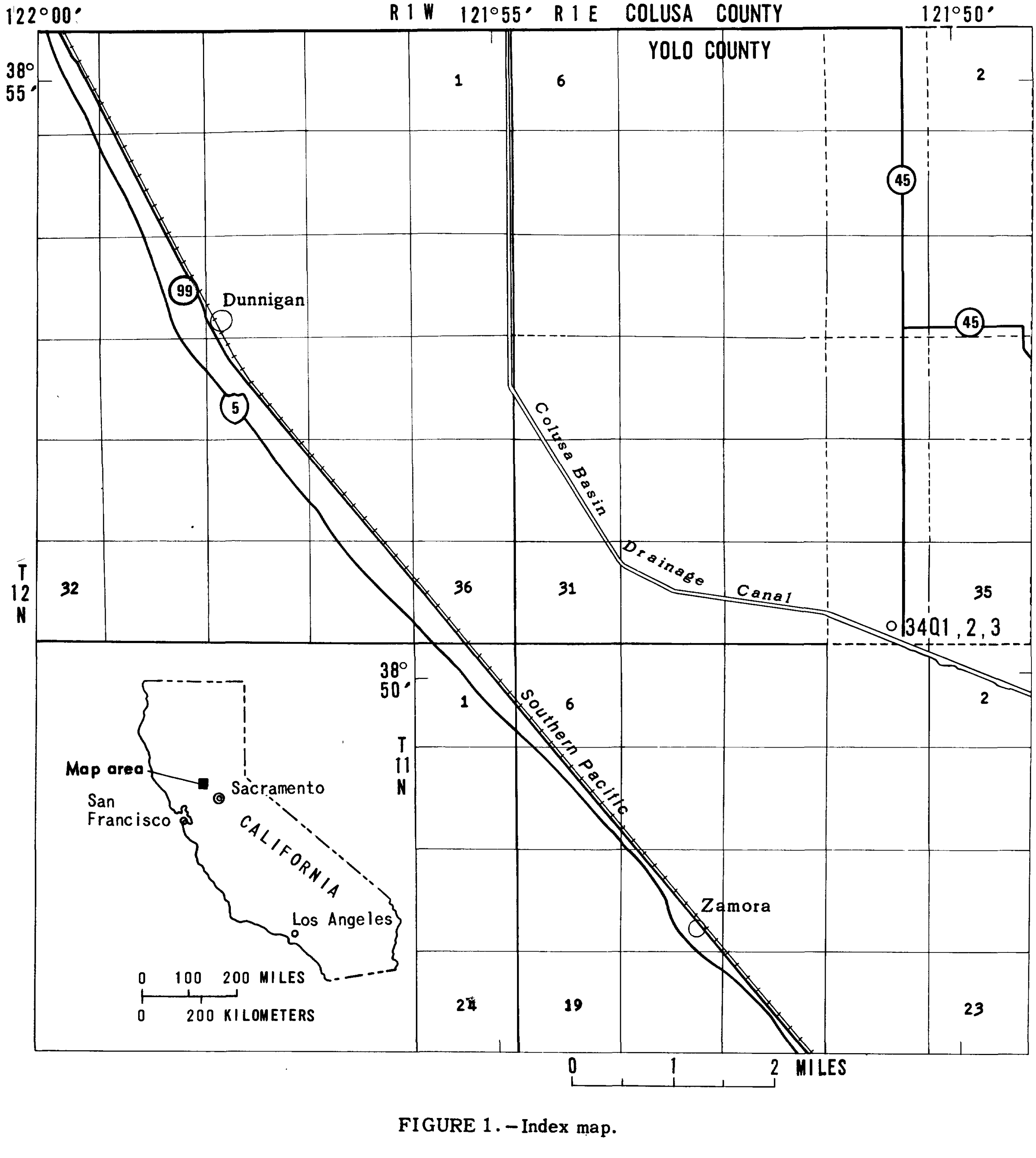



FIGURE 1.—Index map.

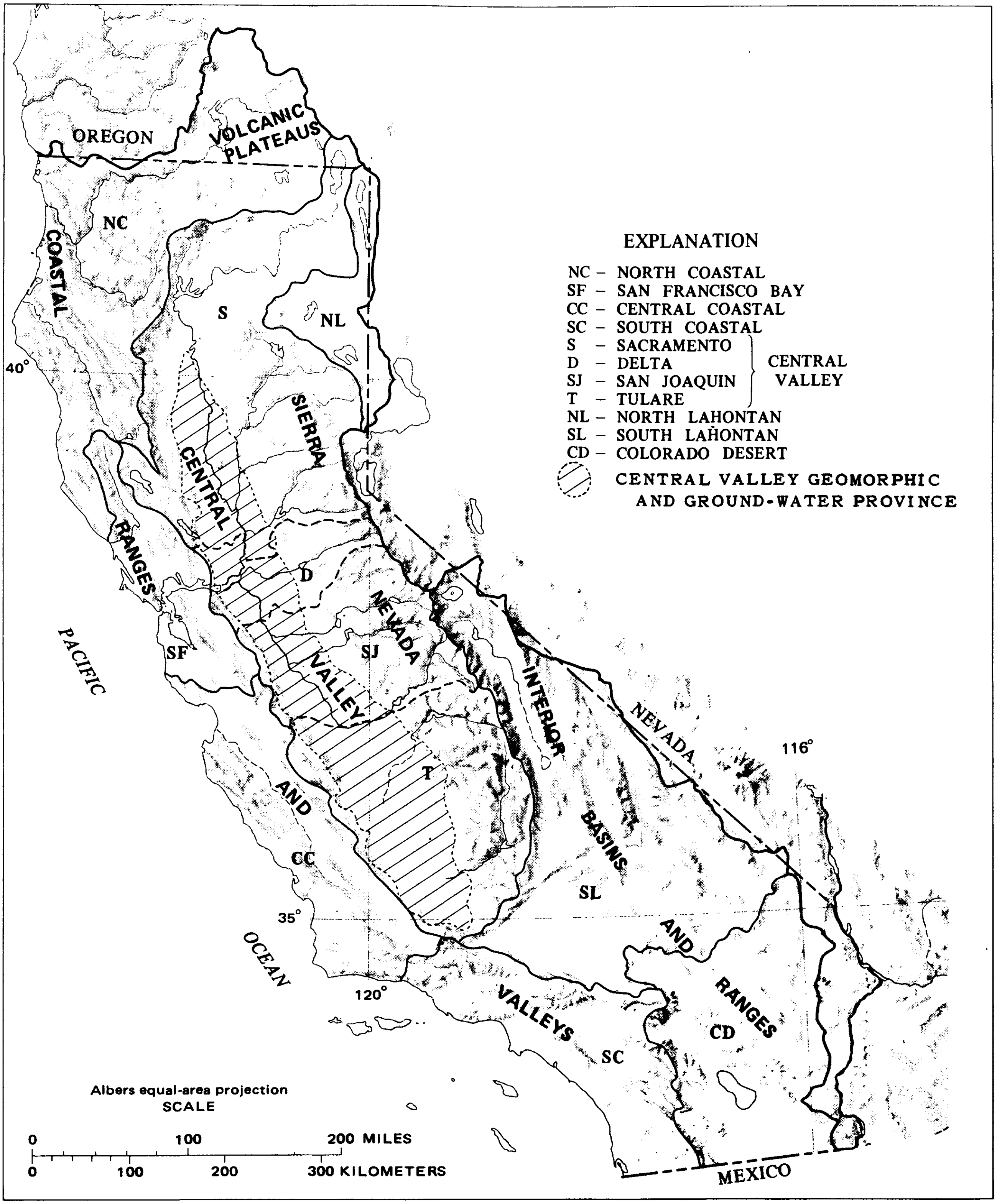



FIGURE 2.—Subregions and landforms of the California Region. (Modified from Thomas and Phoenix, 1976, p. E3).

## PHYSICAL DESCRIPTION OF THE TEST HOLE

The test hole was started in alluvium February 15, 1979, and bottomed at 2,501 ft in blue-green siltstone April 6, 1979. It was drilled by a mud-rotary rig using roller cone bits. Bit sizes used were 20 inches to a depth of 190 ft, 13-3/8 inches to 900 ft, 12¼ inches to 1,750 ft, and 9-7/8 inches to 2,501 ft. Deviation surveys by a Totco instrument were made every 250 ft to assure that deviation from the vertical did not exceed 5°. Monitoring of deviation by a Geolograph instrument was also used. The test hole is cased with 16-inch-diameter cemented steel casing from land surface to 190-foot depth (fig. 3).

Three 4-inch diameter steel piezometers were installed at depths of 947 ft (34Q3), 1,401 ft (34Q2), and 2,125 ft (34Q1). The bottom 5 ft of each piezometer is screened to provide access to the aquifer. Each screened interval has a cement plug above and below it to isolate it from other parts of the aquifer. The cement plugs were implaced at depth intervals as follows: 844-859 ft; 978-993 ft; 1,346-1,361 ft; 1,505-1,520 ft; 2,085-2,100 ft; 2,250-2,451 ft.

The selection of the plugged intervals was made through a study of the geophysical logs and the log of cuttings and core descriptions. The objective was to emplace fast-setting cement opposite clay intervals. The plugs were placed in the annular space between casings and the borehole wall, with a grout pipe, so as to assure a vertical seal of the borehole. The bottom 200 ft of the hole was plugged with cement to seal off water of poor quality.

After the plugs were set, the drilling mud was washed from the casings and each casing was developed by airlift until recovery after drawdown was adequate to demonstrate free entry of formation water into the casings.

The test hole was finished with a 7-foot square concrete slab surrounding the hole and a 6-foot square sheet metal house built over it (fig. 4).

During the drilling of the test hole, rock cuttings coming out of the borehole were continuously monitored and collected at frequent intervals. In addition, 18 drill cores were taken and 68 sidewall cores were recovered. Core bits used were 4 × 5½ HW, split barrel. Cores recovered were put into a PVC tube and padded, if necessary, to prevent movement inside the tube. The tube was marked for orientation as to depth and top of core and wrapped in cheesecloth tied with twine. The entire tube was then coated with melted paraffin. The cores are to be stored in the California Well Sample Repository in Bakersfield, Calif.

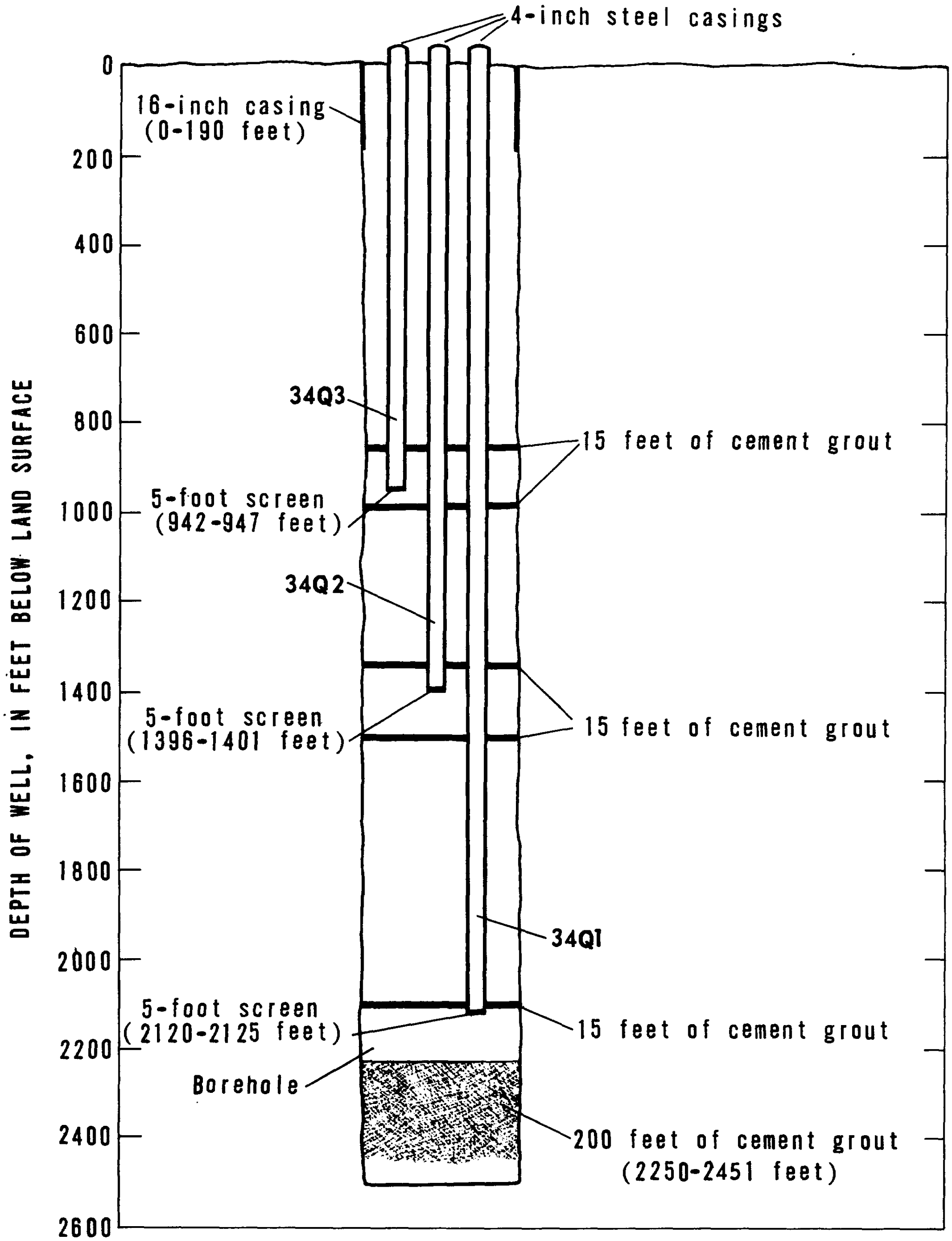



FIGURE 3.— Diagrammatic construction of test hole near Zamora.

FIGURE 4.— Photograph of surface structure.

## CUTTINGS AND CORE DESCRIPTIONS

The descriptions given in table 1 are for the depth interval indicated, from top to bottom, unless only a single depth is given. The single depths indicate that the description is for that depth only, not an interval. The log was constructed from all available data, including cuttings, cores, and geophysical logs. All depths are from land-surface altitude which is 24.27 feet above National Geodetic Vertical Datum of 1929.

The order of listing the elements of a sample description is rock type and texture, color, sorting, rounding, and cementation. Any or all these elements were used by the geologist at the drill site to describe each interval.

The color descriptions follow the Rock Color Chart of the Geological Society of America. This color chart has color chips for comparison with the cuttings and each chip is designated with a code. The code consists of a color name and an alphanumeric system which describes hue, value, and chroma. An example of this code is: light-olive-gray 5Y5/2, where the color name is defined by hue (5Y), value (5), and chroma (2).

The texture descriptions follow the National Research Council (1947) classification of grain size (table 2).

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q

[Test hole 12N/1E-34Q. Altitude of land surface 24.27 ft. Drilled by Rodgers Water Well Drilling Co. in 1979. Screens at 942-947 ft (Q3); 1,396-1,401 ft (Q2); and 2,120-2,125 ft (Q1)]

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 3 | Sand (fill). |
| 3 | 12 | Clay, gray, yellowish-green between 5Y4/1 and 5GY4/1, very slick. |
| 12 | 40 | Clay, silty, and clay, color as above. |
| 40 | 185 | Clay, silty, and clay, as above, with about 10 percent black specks of clay and some yellowish-brown clay 5Y5/2 to 5Y5/6. |
| 185 | 190 | Sand, overall light-olive-gray 5Y5/2, fine, silty. |
| 190 | 200 | Clay. |
| 200 | 215 | Clay, gray, light-olive-gray 5Y5/2, and yellowish-gray 5Y7/2, hard. |
| SIDEWALL CORE NO. 90 | | 208 ft. |
| | 208 | Clay, yellowish-gray 5Y7/2, hard. |
| CORE NO. 1 | | 215-221 ft. Recovered 1.5 ft. |
| 215 | 216.5 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, <10 percent of 1/8-inch specks of moderate-yellowish-brown 10YR5/4 to moderate-brown 5YR4/4 bits of hard clay mixed with soft clay. |
| END CORE NO. 1 | | |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| CORE NO. 2 | | 221-227 ft. Recovered 2.8 ft. |
| 221 | 223.8 | Clay, as above. |
| END CORE NO. 2 | | |
| 227 | 230 | Clay, as above. Dusky-yellow 5Y6/4 matrix with olive-gray 5Y4/1; 0.08-0.16-inch platey angular fragments which break with fingernail. |
| 230 | 244 | Clay and silt. |
| SIDEWALL CORE NO. 89 | | 244 ft. |
| | 244 | Clay and silt, moderate-yellowish-brown 10YR5/4 to dark-yellowish-brown 10YR4/2. Nodule of very fine gravel. |
| 244 | 250 | Clay, as above; may be more silty. |
| 250 | 271 | Rock fragments, dark-gray N3, and clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. Rock fragments subangular to subrounded; about 70 percent rock fragments, very-fine-gravel size, and sand, gray-black N2 to medium-light-gray N6, medium to fine. |
| 271 | 285 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2; rock fragments 7 to 10 percent, very-fine to fine-gravel size, dark-gray N3. Some interbedded sand. |
| SIDEWALL CORE NO. 86 | | 276 ft. |
| | 276 | Sand, moderate-yellowish-brown 10YR5/4, fine; rusty iron streaks. |
| 285 | 292 | Sand, coarse to very coarse, and clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2; some clay, pale-yellowish-brown 10YR6/2 to moderate-yellowish-brown 10YR5/4. |
| SIDEWALL CORE NO. 85 | | 288 ft. |
| | 288 | Clay, pale-yellowish-brown 10YR6/2 to moderate-yellowish-brown 10YR5/4. |
| 292 | 308 | Clay, light-olive-gray 5Y5/2, olive-gray 5Y3/2, and grayish-yellow 5Y8/4, with rock fragments, dark-gray 98 percent and white 2 percent, some sand, fine to very coarse, and gravel, very fine, angular to subangular, elongate to equidimensional. |
| SIDEWALL CORE NO. 84 | | 302 ft. |
| | 302 | Sand, clayey, and gravel, fine, yellowish-gray 5Y7/2, sand, fine to very coarse, dark and light grains, subrounded; gravel to ¼-inch, subrounded, mostly black; clay, grayish-yellow 5Y8/4. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| 308 | 328 | Sand, very fine to coarse, and clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, some dark-yellowish-brown 10YR4/2; sand is more than 50 percent dark grains. |
| SIDEWALL CORE NO. 82 | | 323 ft. |
| | 323 | Sand, dark-yellowish-brown 10YR4/2, very fine, some very coarse; black particles, rounded to subangular, fine grains mostly quartz with many red and black grains, loose, not cemented. |
| 328 | 372 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, and some gravel, very fine, dark, well sorted, subangular to subrounded. Some clay, dark-yellowish-orange 10YR6/6. Some interbedded sand. |
| SIDEWALL CORE NO. 81 | | 330 ft. |
| | 330 | Sand, dusky-yellow 5Y6/4, fine to very coarse, well rounded, frosted. |
| 372 | 382 | Sand, coarse to very coarse, fair sorting, subangular to subrounded; clay particles, very-light-gray N8, olive-gray 5Y4/1, and pinkish-gray 5YR8/1. |
| 382 | 390 | Clay, olive-gray 5Y5/2 to dark-greenish-gray 5GY4/1; near 390 ft, moderate-yellowish-brown 10YR5/4 to dark-yellowish-brown 10YR4/2. |
| 390 | 392 | Clay, grayish-olive 10YR4/2; gravel, dusky-yellow 5Y6/4, very fine, subrounded, some white minerals. |
| 392 | 405 | Sand, coarse to very coarse, 70 percent dark grains, mostly dark-gray, N3, and 30 percent light grains, mostly yellowish-gray 5Y8/1, subangular to angular, quartz, rock fragments, feldspar. |
| 405 | 417 | Sand, medium to very coarse, mostly medium-gray N5 to black N1, some light-olive-gray 5Y5/2; some white grains, fair sorting, rounded to angular. |
| SIDEWALL CORE NO. 75 | | 408 ft. |
| | 408 | Sand, light-olive-gray 5Y5/2, medium to very coarse, rounded, frosted; 1 pebble 3/4-inch, black, smooth, well rounded. |
| 417 | 435 | No record, hole caving in. |
| 435 | 445 | Sand, fine to very coarse, mostly medium-gray N5 to black N1, some white grains; clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, and silt, moderate-yellowish-brown 10YR5/4. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
| --- | --- | --- |
| SIDEWALL CORE NO. 74 | | 437 ft. |
| | 437 | Silt, sand, and clay, moderate-yellowish-brown 10YR5/4. Sand, fine. |
| 445 | 447 | Sand, very coarse, grayish-black N2 and grayish-yellow 5Y8/4, fair sorting, subrounded to subangular; gravel, grayish-black N2 and grayish-yellow 5Y8/4, very fine, fair sorting, subrounded to subangular; and clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. |
| 447 | 453 | Sand, very coarse, good sorting, subangular to angular, predominantly gray and white grains; clay, hard, moderate-yellowish-brown 10YR5/4; and gravel, very fine to fine, fair sorting, subangular to rounded. Note: Pumice in this sample. |
| 453 | 463 | Gravel, very fine; and sand, very coarse, fair sorting, subangular to subrounded, some angular dark fragments, dark-gray N3 to grayish-black N2; some fine-grained white material may be ash; some clay. |
| 463 | 467 | Sand, fine, light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4; some clay and silt. |
| SIDEWALL CORE NO. 71 | | 467 ft. |
| | 467 | Sand, fine, light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4; some clay and silt. |
| 467 | 520 | Clay, silt, and sand. |
| SIDEWALL CORE NO. 68 | | 506 ft. |
| | 506 | Silt and sand, olive-gray 5Y4/1; sand, very fine, cohesive. |
| 520 | 528 | Clay, olive-gray 5Y3/2, and sand, coarse, mixed mineralogy, rounded quartz grains and angular rock fragments, very poor sorting, lots of charcoal-like material. |
| 528 | 534 | Silt and clay. |
| CORE NO. 3 | | 534-544 ft. Recovered 10 ft. |
| 534 | 544 | Clay, silty, ranging in color from light-olive-gray 5Y5/2 to dusky-yellow-green 5GY5/2, some bluish-gray 5B5/1 and grayish-black N2, some very fine gravel near 544 ft; diatomaceous. |
| END CORE NO. 3 | | |
| 544 | 552 | Clay, medium-bluish-gray 5B5/1. |
| 552 | 566 | Sand, coarse to very coarse, 75 percent dark-gray N3 to black N1; some light grains; subangular to angular, fair sorting. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| 566 | 592 | Clay, moderate-brown 5YR3/4 to grayish-brown 5YR3/2, some medium-bluish-gray 5B5/1. |
| 592 | 596 | Gravel, very fine, fair sorting, subangular to angular; clay, silt, and sand, organic material, dark. Clay moderate-brown 5YR3/4 to grayish-brown 5YR3/2; some light-olive-gray 5Y6/1. Some mica. |
| SIDEWALL CORE NO. 65 | 594 | 594 ft. Sand, silt, and clay, light-olive-gray 5Y6/1. Sand, very fine. |
| 596 | 630 | Clay, medium-bluish-gray 5B5/1, and gravel, very fine, fair sorting, subangular to angular, some clay, moderate-brown 5YR3/4 to grayish-brown 5YR3/2, hard. |
| 630 | 635 | Gravel, very fine, 90 percent dark-gray N3 to black N1, 10 percent white N9; fair sorting, subangular to angular; sand, medium to very coarse, fair sorting, subangular to subrounded; and clay, light-olive-gray 5Y5/2 to medium-bluish-gray 5B5/1, some moderate-yellowish-brown 10YR5/4. |
| SIDEWALL CORE NO. 63 | 633 | 633 ft. Sand, light-olive-gray 5Y5/2, mostly medium grained, some very coarse, rounded, abundant mica. |
| 635 | 648 | Clay, carbonaceous, greenish-gray 5GY6/1; near bottom same but more sand, about 5 percent, very coarse, some quartz and dark minerals, gravel, very fine, mostly dark-gray N3 to black N1, some white N9, subrounded to angular. |
| 648 | 655 | Sand, as above. |
| 655 | 680 | Clay, carbonaceous, greenish-gray 5GY6/1, some sand, as above. |
| 680 | 690 | Sand, very fine to fine, some gravel, and silty clay, light-olive-gray 5Y5/2. |
| SIDEWALL CORE NO. 60 | 685 | 685 ft. Sand, some gravel and silty clay, light-olive-gray 5Y5/2. Sand, very fine to fine. |
| 690 | 778 | Clay, olive-gray 5Y4/1, grayish-black N2, light-olive-gray 5Y5/2, and olive-gray 5Y3/2; silt, dark-yellowish-orange 10YR6/6, and sand, very coarse, to gravel, very fine, angular to subrounded, about 30-40 percent dark grains. |
| SIDEWALL CORE NO. 59 | 727 | 727 ft. Clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 58 | | 741 ft. |
| | 741 | Clay, light-olive-gray 5Y5/2; some fine gravel. |
| SIDEWALL CORE NO. 57 | | 769 ft. |
| | 769 | Silt, dark-yellowish-orange 10YR6/6; some black mica flakes, cohesive, clayey. |
| 778 | 792 | Sand, medium to very coarse, and gravel, fine. |
| SIDEWALL CORE NO. 56 | | 788 ft. |
| | 788 | Sand, pale-yellowish-brown 10YR6/2, medium to very coarse grained; some very fine gravel, angular to subrounded; gravel and coarse sand particles are black and white; medium sand is yellowish-brown. |
| 792 | 800 | Clay, light-olive-gray 5Y5/2. |
| 800 | 805 | Sand, very coarse, some black grains. |
| 805 | 811 | Clay (75 percent), light-olive-gray 5Y5/2, medium-bluish-gray 5B5/1, some hard, some soft, and sand, very coarse, to gravel, fine (25 percent). |
| 811 | 812 | Swelling clay. |
| 812 | 814 | Clay, as above, and sand, medium, to gravel, very fine, subrounded to subangular; quartz and black particles. |
| CORE NO. 4 | | 814-824 ft. Recovered 10 ft. |
| 814 | 824 | Clay, mostly dark-greenish-gray 5GY4/1, some olive-gray 5Y4/1. Silty clay in bottom foot. |
| END CORE NO. 4 | | |
| 824 | 827 | Clay, as at 814 ft. |
| 827 | 832 | Clay (60 percent), light-olive-gray 5Y5/2, dusky-yellow 5Y6/4, medium-bluish-gray 5B5/1, sand (25 percent), medium to very coarse, subangular, and gravel (15 percent), very fine, subangular. Granular material is about 40 percent quartz and 30 percent black grains. Some vegetal detritus. |
| 832 | 840 | Clay (70 percent), as above; yellow clay is slippery, less sticky than blue clay, sand, very coarse, and gravel, very fine. Some vegetal detritus. |
| 840 | 847 | Clay (50 percent), greenish-gray 5GY6/5, light-olive-gray 5Y5/2, gravel (30 percent), very fine to fine, black N1, angular to rounded, and sand (15 percent), medium. Vegetal detritus (5 percent), some quartz. |
| CORE NO. 5 | | 847-852 ft. Recovered 3.5 ft. |
| 847 | 850.5 | Clay, dark-greenish-gray 5G4/1 to dark-greenish-gray 5GY4/1. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| END CORE NO. 5 | | |
| 852 | 868 | Clay, as at 847 ft. |
| 868 | 875 | Gravel, very fine, 20-30 percent dark particles, medium-dark-gray N4 to black N1; light particles, white N9 to very-light-gray N8, some light-brown 5YR5/6, angular to subrounded, most subangular to subrounded, good to fair sorting, and sand, very coarse. Dark particles non-magnetic. Some silt. |
| SIDEWALL CORE NO. 54 | | 869 ft. |
| | 869 | Silt, light-olive-gray 5Y6/1, with yellow streaks, cohesive, may have clay binding. |
| 875 | 887 | Clay, moderate-yellowish-brown 10YR5/4 to medium-light-gray N6. |
| CORE NO. 6 | | 882-887 ft. Recovered 4.4 ft. |
| 882 | 886.4 | Clay, moderate-yellowish-brown 10YR5/4 to medium-light-gray N6. |
| END CORE NO. 6 | | |
| 887 | 900 | Sand (75 percent), very fine to very coarse, 75 percent dark grains; clay (20 percent), as at 882 ft, and gravel (5 percent), very fine, grayish-olive 10Y4/2 to moderate-brown 5YR3/4. |
| SIDEWALL CORE NO. 53 | | 897 ft. |
| | 897 | Sand, medium-dark-gray N4, fine to medium, rounded to well rounded, uniform size, very well sorted, frosted grains. |
| CORE NO. 7 | | 898-903 ft. Recovered 0.4 ft. |
| 898 | 898.4 | Sand, very fine to coarse, mostly very fine, subangular, 40 percent black N1. |
| END CORE NO. 7 | | |
| 900 | 922 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y4/1. |
| SIDEWALL CORE NO. 52 | | 910 ft. |
| | 910 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y4/1. |
| 922 | 962 | Gravel, very fine, well sorted, subangular to angular, white and dark particles, sand, coarse, some very fine, fair sorting, silt and clay, light-olive-gray 5Y5/2, dusky-yellow-green 5GY5/2, moderate-yellowish-brown 10YR5/4, and grayish-orange 10YR7/4. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 51 | | 925 ft. |
| | 925 | Silt, grayish-orange 10YR7/4, some very fine sand, cohesive. |
| SIDEWALL CORE NO. 50 | | 941 ft. |
| | 941 | Gravel, very fine to medium, and sand, coarse, 75 percent grayish-olive 10Y4/2 to black N1; 25 percent white N9 to light-gray N7; subrounded, silt and clay matrix. Matrix, light-olive-gray 5Y5/2 to dusky-yellow-green 5GY5/2. |
| SIDEWALL CORE NO. 49 | | 953 ft. |
| | 953 | Gravel with fine sand, gravel as large as ½ inch, rounded to very well rounded, sand and gravel mostly of metamorphic origin. |
| SIDEWALL CORE NO. 48 | | 962 ft. |
| | 962 | Gravel, very fine, to sand, coarse, mostly dark grains, subangular to subrounded, some silt and clay, light-olive-gray 5Y5/2. |
| 962 | 970 | Gravel, very fine to fine, sand, very coarse, mostly black N1 minerals or rock fragments, angular to subrounded, fair sorting. |
| 970 | 974 | Clay. |
| CORE NO. 8 | | 974-979 ft. Recovered 5 ft. |
| 974 | 976 | Clay, light-bluish-gray 5B7/1, and light-olive-gray 5Y5/2; silt, dark-yellowish-brown 10YR4/2, and some sand, very fine. |
| 976 | 979 | Sand, very fine, silty, and clay, as above, increases from 5 percent near 979 ft to 40 percent near 974 ft. |
| END CORE NO. 8 | | |
| 979 | 996 | Clay. |
| 966 | 1,030 | Siltstone or claystone, medium-light-gray N6. |
| 1,030 | 1,036 | Sand and silt. |
| SIDEWALL CORE NO. 47 | | 1,033 ft. |
| | 1,033 | Sand, very fine, and silt; overall color light-olive-brown 5Y5/6 to light-olive-gray 5Y5/2. |
| 1,036 | 1,048 | Claystone, light-olive-gray 5Y6/1; some gravel, very fine, subangular. |
| 1,048 | 1,076 | Clay, olive-gray 5Y4/1, and light-olive-gray 5Y6/1, and sand, very fine to very coarse, moderately sorted, subangular; noticeable mica fraction. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 46 | 1,058 | 1,058 ft. Sand, dark-yellowish-brown 10YR4/2, very fine, silty, cohesive. |
| SIDEWALL CORE NO. 45 | 1,064 | 1,064 ft. Sand, very-pale-orange 10YR8/2, very fine, silty, cohesive. |
| 1,076 | 1,100 | Clay, some silt, grayish-blue 5PB5/2, light-olive-gray 5Y6/1, olive-gray 5Y3/2, and pale-brown 5YR5/2, and sand, very coarse, mostly dark grains, subangular. |
| SIDEWALL CORE NO. 44 | 1,090 | 1,090 ft. Silt, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. |
| 1,100 | 1,112 | Sand, medium to very coarse, gray N3 to black N1, fair sorting, subangular. |
| 1,112 | 1,140 | Clay, light-olive-gray 5Y5/2, and grayish-olive-green 5GY3/2, some very-pale-orange 10YR8/2. |
| SIDEWALL CORE NO. 42 | 1,118 | 1,118 ft. Clay, very-pale-orange 10YR8/2, scattered small rusty spots. |
| 1,140 | 1,143 | Sand, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, fine to medium; some gravel. |
| SIDEWALL CORE NO. 41 | 1,142 | 1,142 ft. Sand, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, fine to medium, some gravel. |
| 1,143 | 1,162 | Clay, grayish-olive-green 5GY3/2, moderate-brown 5YR4/4. |
| 1,162 | 1,166 | Sand, medium to coarse, mostly medium-dark-gray N3 to black N1, some medium-light-gray N6; well sorted, subangular to subrounded, clay, light-olive-gray 5Y5/2, and grayish-olive-green 5GY3/2, and some gravel, very fine, quartz. |
| SIDEWALL CORE NO. 40 | 1,164 | 1,164 ft. Sand, medium-light-gray N6, fine to medium, occasional coarse grains, rounded, frosted. |
| 1,166 | 1,192 | Sand, medium to fine, olive-gray 5Y3/2; poor sorting, some gravel, very fine to medium, a few grains up to 0.3 inch, mostly dark-gray N4, olive-gray 5Y4/1, and black N1, some moderate-brown 5YR4/4 to dusky-brown 5YR2/2, white N9, and light-gray N7; rounded to subrounded, mixed mineralogy; clay, dusky-yellow 5Y6/4 and light-olive-gray 5Y5/2, and silt, dusky-yellow-brown 10YR2/2, in somewhat cohesive silt pebbles up to 0.4 inch, friable. |
| 1,192 | 1,198 | Sand, light-olive-gray 5Y5/2, fine to medium, some silt, black minerals, and rock fragments. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 39 | | 1,195 ft. |
| | 1,195 | Sand, light-olive-gray 5Y5/2, fine to medium, some silt, black minerals and a rock fragment. |
| 1,198 | 1,238 | Gravel, coarse, to sand, medium-light-gray N8 to dark-gray N3; subangular to subrounded, silt, light-olive-gray 5Y5/2, and clay, light-olive-gray 5Y5/2; quartz. |
| SIDEWALL CORE NO. 38 | | 1,220 ft. |
| | 1,220 | Sand, light-gray N7, medium to fine, silty, rounded. |
| CORE NO. 9 | | 1,200-1,205 ft. Recovered 2 ft. |
| 1,200 | 1,202 | Silt, some clay, light-olive-gray 5Y5/2; some gravel medium-dark-gray N4 to dark-gray N3, very fine to fine, subrounded, elongated. |
| END CORE NO. 9 | | |
| 1,238 | 1,248 | Gravel, very fine, to sand, fine to medium, angular to subrounded, light-olive-gray 5Y5/2 to olive-gray 5Y4/1; less than 10 percent gravel, some rock fragments medium-dark-gray, N4, to dark-gray N3. |
| SIDEWALL CORE NO. 37 | | 1,244 ft. |
| | 1,244 | Sand, light-olive-gray 5Y5/2, fine to medium, some black minerals. |
| 1,248 | 1,272 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1. |
| 1,272 | 1,276 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, and sand, medium to coarse, subangular, 25 percent dark, 70 percent medium, 5 percent light, overall olive-gray 5Y3/2. |
| 1,276 | 1,310 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, some silt. |
| SIDEWALL CORE NO. 36 | | 1,290 ft. |
| | 1,290 | Clay, some silt, light-olive-brown 5Y6/1 and light-olive-gray 5Y5/2. |
| 1,310 | 1,320 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, dark-greenish-gray 5G4/1 and sand, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, some black N1; medium to very coarse, fair sorting, subangular to angular, occasional quartz, some silt. |
| SIDEWALL CORE NO. 35 | | 1,314 ft. |
| | 1,314 | Silt, clayey, moderate-yellowish-brown, 10YR5/4, firm, slightly plastic. |
| 1,320 | 1,330 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| 1,330 | 1,342 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, moderate-yellowish-brown 10YR5/4, and sand, medium to coarse, overall light-olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4, black N1 grains, well sorted, subangular to subrounded, some silt. |
| SIDEWALL CORE NO. 34 | | 1,332 ft. |
| | 1,332 | Silt, clayey, dark-yellowish-brown 10YR4/2. |
| 1,342 | 1,363 | Clay, light-olive-gray 5Y5/2, and dusky-yellow-green 5GY5/2, to greenish-gray 5GY6/1; some siltstone, silt, and fine sand. |
| SIDEWALL CORE NO. 33 | | 1,354 ft. |
| | 1,354 | Clay, some silt and fine sand, greenish-gray 5G6/1 and dark-greenish-gray 5G4/1. |
| 1,363 | 1,475 | Gravel, very fine to medium, and sand, fine to very coarse, very-light-gray N8, dark-gray N3 to grayish-black N2; angular to subrounded, some rounded, mixed with clay, silt, and siltstone; light-olive-gray 5Y5/2 to light-olive-brown 5Y5/6, near bottom, medium-light-gray N5 to medium-gray N4, black minerals and rock fragments. |
| SIDEWALL CORE NO. 32 | | 1,385 ft. |
| | 1,385 | Sand and gravel, overall light-olive-gray 5Y5/2, sand, medium to very coarse, subangular to rounded, gravel, ½-inch diameter, rounded, clay matrix. |
| SIDEWALL CORE NO. 30 | | 1,392 ft. |
| | 1,392 | Gravel, very fine to fine, and sand, coarse, mostly medium-dark-gray N4 to black N1, in a silt and clay matrix, light-olive-gray 5Y5/2 to light-olive-brown 5Y5/6. |
| SIDEWALL CORE NO. 27 | | 1,453 ft. |
| | 1,453 | Sand and gravel, fine sand to very fine gravel, very-light-gray N8, black minerals and rock fragments. |
| 1,475 | 1,498 | Clay, olive-gray 5Y6/1, gravel, very fine to fine, and sand, coarse to very coarse, some fine to medium; 90 percent dark-gray N3 to grayish-black N2, 10 percent white N9 to very-light-gray N8, angular to subrounded. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 26 | | 1,477 ft. |
| | 1,477 | Sand, light-olive-gray 5Y5/2, fine to medium, firm with a silt matrix. |
| 1,498 | 1,502 | Gravel, very fine to fine, sand, coarse to very coarse, dark-gray N3 to grayish-black N2, angular to subrounded. |
| 1,502 | 1,525 | Silt and clay, some claystone and siltstone, olive-gray 5Y4/1, some gravel, very fine to fine, subangular to subrounded. |
| SIDEWALL CORE NO. 25 | | 1,503 ft. |
| | 1,503 | Silt, clay, olive-gray 5Y4/1, and some gravel, very fine, subrounded to subangular, some black minerals. |
| CORE NO. 10 | | 1,519-1,524 ft. Recovered 2 ft. |
| 1,519 | 1,521 | Clay with a small amount of gravel; gravel may have fallen in. |
| END CORE NO. 10 | | |
| 1,525 | 1,535 | Gravel, very fine to fine, and sand, coarse to very coarse, dark-gray N3 to grayish-black N2, angular to subrounded; some hard silty beds. |
| SIDEWALL CORE NO. 24 | | 1,531 ft. |
| | 1,531 | Silt, clayey, yellowish-gray 5Y7/2, hard. |
| 1,535 | 1,550 | Clay. |
| 1,550 | 1,560 | Sand, olive-gray 5Y4/1, very fine to fine, some silt. |
| SIDEWALL CORE NO. 23 | | 1,552 ft. |
| | 1,552 | Sand, olive-gray 5Y4/1, very fine to fine, some silt. |
| 1,560 | 1,640 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1, silt, olive-gray 5Y4/1; some gravel, very fine to fine, and sand, coarse, light-olive-gray 5Y5/2, medium-dark-gray N4 to dark-gray N3, and grayish-black N2; one percent dusky-red 5R3/4, subangular to subrounded, quartz; limestone fragments at about 1,630 ft, moderate-brown 5YR4/4 to grayish-brown 5YR3/2. |
| SIDEWALL CORE NO. 22 | | 1,592 ft. |
| | 1,592 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1. |
| SIDEWALL CORE NO. 21 | | 1,626 ft. |
| | 1,626 | Clay, silty, olive-gray 5Y4/1, hard. |
| 1,640 | 1,645 | Silt, clay, with sandy, silty clay, and sand, very fine; overall color olive-gray 5Y4/1. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 20 | | 1,643 ft. |
| | 1,643 | Silt, clay, and sand, very fine, olive-gray 5Y4/1. |
| 1,645 | 1,680 | Clay, greenish-black 5GY2/1, some olive-gray 5Y4/1; silt, some claystone, some gravel, very fine; sand, very fine to some very coarse, grayish-green 10G4/2 to greenish-black 5G2/1, subangular to subrounded. |
| SIDEWALL CORE NO. 19 | | 1,663 ft. |
| | 1,663 | Clay, olive-gray 5Y4/1, silty, cohesive. |
| SIDEWALL CORE NO. 18 | | 1,680 ft. |
| | 1,680 | Silt, clay, and some very fine gravel, greenish-gray 5GY6/1 and dark-greenish-gray 5GY4/1. |
| 1,680 | 1,686 | Gravel, very fine, greenish-gray 5GY6/1, and dark-greenish-gray 5GY4/1, subangular to subrounded, some rounded, and sand, very fine to coarse, subangular to subrounded. |
| 1,686 | 1,728 | Clay, light-olive-gray 5Y5/2, and dark-greenish-gray 5GY4/1; some sandy or gravelly clay; gravel in clay, very fine to fine; sand, coarse, grayish-green 10GY5/2 to greenish-black 5GY2/1, subangular to subrounded; small limestone fragments at about 1,690 ft, some calcareous cement. |
| 1,728 | 1,792 | Clay, light-olive-gray 5Y5/2, mostly medium-bluish-gray 5B5/1, medium-gray N5, medium-dark-gray N4, and dark-greenish-gray 5GY4/1; some sandy or gravelly clay, gravel, very fine to fine; sand, medium to coarse, dark-greenish-gray 5G4/1 to grayish-black N2, subangular to subrounded; mica, feldspar, quartz, some claystone and siltstone. |
| CORE NO. 11 | | 1,753-1,757 ft. Recovered 4 ft. |
| 1,753 | 1,757 | Clay, medium-gray N5 to medium-dark-gray N4. |
| END CORE NO. 11 | | |
| SIDEWALL CORE NO. 17 | | 1,770 ft. |
| | 1,770 | Gravel and clay, yellowish-gray 5Y7/2, gravel very fine to fine to ¼-inch, black N1, subangular. |
| 1,792 | 1,815 | Sand, fine to coarse, black and white grains, very angular, well sorted; clay and silt, medium-bluish-gray 5B5/1 and greenish-gray 5GY4/1; black grains may be obsidian. |

TABLE 1. -Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 16 | | 1,805 ft. |
| | 1,805 | Silt, sandy, moderate-olive-brown 5Y4/4, cohesive, hard but friable. |
| SIDEWALL CORE NO. 15 | | 1,812 ft. |
| | 1,812 | Silt and fine sand, greenish-gray 5GY6/1 to dark-greenish-gray 5GY4/1. |
| 1,815 | 1,821 | Clay, light-olive-gray 5Y5/2 to grayish-olive 20Y4/2. |
| 1,821 | 1,830 | Sand, very fine to coarse, some gravel, fine; medium-dark-gray N4, brownish-gray 5GY4/1, and dark-greenish-gray 5G4/1 to black N1, subangular to subrounded, silt, and clay, medium-bluish-gray 5B5/1 and dark-greenish-gray 5G4/1. |
| SIDEWALL CORE NO. 14 | | 1,824 ft. |
| | 1,824 | Silt, clay, and very fine sand, dark-greenish-gray 5G4/1. |
| 1,830 | 1,869 | Sand, fine to coarse, gravel, fine, mostly dark-greenish-gray 5GY4/1 and 5G4/1 to black N1, some very-light-gray N8 to yellowish-gray 5Y8/1; subangular to subrounded, poorly sorted. Minor amounts of clay and silt, medium-bluish-gray 5B5/1; rock fragments of coarse-sand size, very angular, some fine sand cemented to coarse sand. |
| SIDEWALL CORE NO. 13 | | 1,845 ft. |
| | 1,845 | Sand and some gravel, sand, medium to coarse, some very coarse, overall olive-gray 5Y3/2 to dark-greenish-gray 5G4/1; gravel, fine, mostly greenish-black 5GY2/1 and grayish-black N2, some very-light-gray N8 and yellowish-gray 5Y8/1 to light-olive-gray 5Y6/1, some silt. |
| SIDEWALL CORE NO. 12 | | 1,869 ft. |
| | 1,869 | Sand, dark-greenish-gray 5GY4/1 to dark-greenish-gray 5G4/1, very fine to fine. |
| 1,869 | 1,880 | Clay and silt, greenish-black 5GY2/1, some pale-yellowish-brown 10YR6/7. |
| 1,880 | 1,903 | Clay, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, and sand, coarse, to gravel, fine, mostly dark-greenish-gray 5GY4/1 and 5G4/1 to black N1, some very-light-gray N8 to yellowish-gray 5Y8/1, angular to rounded. |
| CORE NO. 12 | | 1,880-1,885 ft. Recovered 5 ft. |
| 1,880 | 1,880.3 | Sand, very coarse, to gravel, fine. |
| 1,880.3 | 1,882.8 | Clay, medium-bluish-gray 5G5/1 to dark-greenish-gray 5G4/1, with occasional gravel to 0.23 inch, subangular to subrounded. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| 1,882.8 | 1,883.5 | Sand, fine to medium. |
| 1,883.5 | 1,885 | Clay, as above. |
| END CORE NO. 12 | | |
| 1,903 | 1,940 | Clay, pale-olive 10Y6/2, grayish-olive 10Y4/2, and dark-greenish-gray 5G4/1, some silt, and some gravelly and sandy clay, quartz, pyrite, and dark-green to black chert. |
| SIDEWALL CORE NO. 11 | | 1,929 ft. |
| | 1,929 | Clay, dark-greenish-gray 5GY4/1, some silt and very-fine gravel. |
| 1,940 | 1,958 | Sand, medium to coarse, and gravel, very fine, mostly dark-greenish-gray 5GY4/1 and 5G4/1, greenish-black 5GY2/1, and black N1, some light-gray N8 to yellowish-gray 5Y8/1, subangular to subrounded, some silt. |
| SIDEWALL CORE NO. 10 | | 1,953 ft. |
| | 1,953 | Silt, clayey, pale-olive 10Y6/2, flakey. |
| 1,958 | 1,972 | Clay, dark-greenish-gray 5G4/1 and greenish-gray 5G6/1. |
| 1,972 | 1,980 | Sand, fine to medium, and gravel to cobbles, large, mostly dark-gray N3 and greenish-black 5GY2/1 to black N1, some light-olive-gray 5Y6/2; subangular to subrounded, some sandy clay. |
| SIDEWALL CORE NO. 9 | | 1,974 ft. |
| | 1,974 | Sand, silty, light-olive-gray 5Y5/2, fine to medium, subangular to subrounded, black, white, and olive grains with some iron staining, fair sorting. |
| 1,980 | 2,015 | Clay, dark-greenish-gray 5G4/1, medium-gray N5, and medium-bluish-gray, claystone and siltstone, medium-gray N5 and medium-dark-gray N4, some sandy and gravelly clay, some sand, coarse, and gravel, very fine, mostly dark-gray N3 and dark-greenish-gray 5GY4/1 to black N1, some yellowish-gray 5Y8/1 to white N9; angular to rounded. |
| CORE NO. 13 | | 1,980-1,985 ft. Recovered 5 ft. |
| 1,980 | 1,980.5 | Gravel and sandy clay. |
| 1,980.5 | 1,985 | Clay, claystone, siltstone, medium-gray N5 and medium-dark-gray N4. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| END CORE NO. 13 | | |
| 2,015 | 2,103 | Clay, dark-olive-gray 5G4/1, dark-greenish-gray 5G4/1; clay, silty, dark-greenish-gray 5G4/1; silt; sandy and gravelly clay beds, gravel, fine, black N1, few reddish-brown 10R5/4 to 10R3/4; subangular to subrounded, sand, very fine, and rock fragments; black N1 at about 2,080 ft; some gravel about 50 percent quartz and 50 percent dark minerals. |
| CORE NO. 14 | | 2,024-2,029 ft. Recovered 5 ft. |
| 2,024 | 2,029 | Clay, silty, dark-greenish-gray 5G4/1. Some very fine sand and silt, angular to subangular, clear quartz, black biotite, and hematite, moderate-red 5R4/6. |
| END CORE NO. 14 | | |
| SIDEWALL CORE NO. 8 | | 2,094 ft. |
| | 2,094 | Silt, moderate-olive-brown 5Y4/4, grayish-olive 10Y4/2, and dark-greenish-gray 5GY4/1; some sand, very fine to fine, moderate-olive-brown 5Y4/4 to grayish-olive 10Y4/2, and some gravel, very fine, dark-greenish-gray to grayish-black N2, subangular to subrounded. |
| 2,103 | 2,135 | Sand, dark-greenish-gray 5G4/1 to greenish-black 5GY2/1; fine to very coarse, and gravel, very fine to fine. |
| SIDEWALL CORE NO. 7 | | 2,111 ft. |
| | 2,111 | Sand, medium-dark-gray N4, medium to coarse, some fine gravel, subangular to rounded. |
| SIDEWALL CORE NO. 6 | | 2,121 ft. |
| | 2,121 | Sand, fine to coarse, overall grayish-olive 10Y4/2, to olive-gray 5Y3/2, and gravel, very fine to fine, about 75 percent dark-greenish-gray 5GY4/1 to black N1 and 25 percent very-light-gray N8 to light-olive-gray 5Y6/1, subangular to subrounded. |
| SIDEWALL CORE NO. 5 | | 2,131 ft. |
| | 2,131 | Sand, dark-greenish-gray 5GY4/1 to greenish-black 5GY2/1, fine to very coarse. |
| 2,135 | 2,200 | Clay and silt, greenish-gray 5GY6/1 to dark-greenish-gray 5GY4/1; probably some claystone and siltstone, some gravelly clay, gravel very fine to fine, clear and white quartz about 30 to 40 percent, black rock fragments about 60 to 70 percent; many rock fragments contain glassy- green minerals, less than one percent dark-reddish-brown 10R3/4. |

TABLE 1. - Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| SIDEWALL CORE NO. 4 | | 2,141 ft. |
| | 2,141 | Silt and very fine gravel, greenish-gray 5GY6/1 to dark-greenish-gray 5GY4/1; some silty clay and claystone, pale-olive 10Y6/2 to grayish-olive 10Y4/2. |
| 2,200 | 2,220 | Clay, grayish-blue-green 5BG5/2, dark-greenish-gray 5G4/1, and light-olive-gray 5Y3/2, some claystone and siltstone, medium-gray N5 and medium-dark-gray N4. |
| CORE NO. 15 | | 2,200-2,205 ft. Recovered 5 ft. |
| 2,200 | 2,205 | Siltstone, gray and bluish-gray, darker gray and more consolidated in upper part; some clay. |
| END CORE NO. 15 | | |
| 2,220 | 2,240 | Claystone, silty, dark-greenish-gray 5G4/1, brownish-gray 5YR4/1, and dusky-yellow 5Y6/4, mostly dard-greenish-gray, some sandy clay, sand, coarse; and gravel, very fine. |
| 2,240 | 2,260 | Clay, dark-greenish-gray 5G4/1, and silty claystone as at 2,220-2,240 ft; some gravelly clay, gravel, very fine to fine, grayish-black N2 rock fragments, quartz, angular to subangular. |
| 2,260 | 2,276 | Silt and very fine sand, dark-greenish-gray 5GY4/1. |
| SIDEWALL CORE NO. 3 | | 2,266 ft. |
| | 2,266 | Silt and sand, very fine, dark-greenish-gray 5GY4/1. |
| 2,276 | 2,310 | Claystone, medium-bluish-gray 5B5/1, to dark-greenish-gray 5G4/1; clay, grayish-blue-green 5BG5/2; clay, silty, dark-greenish-gray 5G4/1; some sandy and gravelly clay, sand, coarse; gravel, very fine to fine, rock fragments, subangular. |
| CORE NO. 16 | | 2,300-2,305 ft. Recovered 5 ft. |
| 2,300 | 2,305 | Claystone and clay, claystone, hard, medium-bluish-gray 5B5/1 to dark-greenish-gray 5G4/1, effervescent; clay, soft, grayish-blue-green 5BG5/2, and very little sand, medium to very coarse, and gravel, very fine to fine, dark-gray N3 and dark-greenish-gray 5GY4/1 to black N1, some yellowish-gray 5Y8/1 to white N9; subangular to subrounded. |
| END CORE NO. 16 | | |
| 2,310 | 2,348 | Clay and claystone, some sand. Clay, silty, dark-greenish-gray 5G4/1. Sand (10 percent), coarse, subrounded to subangular, quartz and black fragments. |

TABLE 1. -Log of test hole near Zamora, 12N/1E-34Q--Continued

| Depth (ft) From | To | Description |
|---|---|---|
| 2,348 | 2,368 | Sand, olive-gray 5Y4/1, very fine to coarse, subangular to subrounded, some gravel, very fine to fine, mostly very fine, subangular to subrounded. |
| SIDEWALL CORE NO. 2 | | 2,355 ft. |
| | 2,355 | Sand, olive-gray 5Y4/1 to dark-greenish-gray 5GY4/1, very fine to fine. |
| 2,368 | 2,393 | Claystone. |
| 2,393 | 2,398 | Clay, pale-olive 10Y6/2 to grayish-olive 10Y4/2, gravelly and sandy, some sand, medium to very coarse, some gravel, very fine to fine, dark-greenish-gray 5GY4/1 to black N1 and some greenish-gray 5GY6/1 to white N9. |
| 2,398 | 2,422 | Claystone and clay, dusky-blue-green 5BG3/2. |
| CORE NO. 17 | | 2,400-2,405 ft. Recovered 1.7 ft. |
| 2,400 | 2,401.7 | Claystone, dusky-blue-green 5BG3/2. |
| END CORE NO. 17 | | |
| 2,422 | 2,440 | Clay, and gravelly and sandy clay, dark-greenish-gray 5G4/1. |
| 2,440 | 2,455 | Claystone and clay, dark-greenish-gray 5G4/1, some sand, coarse; gravel, very fine to fine, grayish-red 10R4/2, medium-dark-gray N4 to dark-gray N8, and very-light-gray N8; rock fragments; mica, quartz. |
| 2,455 | 2,470 | Silt, gravelly, olive-gray 5Y4/1 to dark-greenish-gray 5G4/1, some clay. |
| SIDEWALL CORE NO. 1 | | 2,466 ft. |
| | 2,466 | Silt, olive-gray 5Y4/1 to dark-greenish-gray 5GY4/1, some siltstone, moderate-olive-brown 5Y4/4; some fine gravel. |
| 2,470 | 2,501 | Clay, claystone, siltstone, dark-greenish-gray 5G4/1, and dusky-blue-green 5G4/1, some sand and silt, sand, medium. |
| CORE NO. 18 | | 2,495-2,501 ft. Recovered 5 ft. |
| 2,495 | 2,497 | Siltstone, dusky-blue-green 5BG3/2. |
| 2,497 | 2,498.5 | Silt and sand, medium. |
| 2,498.5 | 2,501 | Siltstone, dusky-blue-green 5BG3/2. |
| END CORE NO. 18 | | |
| Total depth 2,501 ft (log) | | |

TABLE 2. - Grain-size classification

| Name | Grade limits (diameter in inches) | |
|---|---|---|
| Large cobbles | 10 | 5 |
| Small cobbles | 5 | 2.5 |
| Very coarse gravel | 2.5- | 1.3 |
| Coarse gravel | 1.3- | .6 |
| Medium gravel | .6- | .3 |
| Fine gravel | .3- | .16 |
| Very fine gravel | .16- | .08 |
| Very coarse sand | .08- | .04 |
| Coarse | .04- | .02 |
| Medium sand | .02- | .01 |
| Fine sand | .01- | .005 |
| Very fine sand | .005- | .0025 |
| Silt | .0025- | .0002 |
| Clay | <.0002 | |

## GEOPHYSICAL LOGS

Geophysical logs (pl. 1) made in the test hole include Schlumberger dual induction-spherically focused electric, compensated neutron, formation density, caliper, gamma, porosity index (percentage sandstone matrix), bulk density, spontaneous potential, resistivity, and conductivity. A spectral gamma (KUT) log was made by Century Geophysical Corp.

Induction-electric logging devices induce a current into the rocks at the borehole and record the resistivity (reciprocal of conductivity). Because the contrast between borehole mud and formation water in a freshwater system is commonly large, this device is focused to minimize the influence of the borehole mud and also of the lithology above and below the focused interval.

The dual-induction log (pl. 1, log A) of the test hole included a deep induction log, in ohms per square meter per meter; a spherically focused log, in ohms per square meter per meter; a conductivity log, in millimhos per meter; and a spontaneous potential log, in millivolts.

Neutron logging devices continuously emit neutrons into the rocks of the borehole. The neutrons collide with the nuclei of the formation material, losing some of their energy with each collision. The greatest energy loss occurs when the neutron strikes a hydrogen nucleus; thus neutron logging is primarily a function of the hydrogen content of the rocks at the borehole. The compensated neutron log minimizes the influence of the borehole.

The compensated neutron-formation density log (pl. 1, log B) of the test hole included a caliper, in inches; a gamma log, in API units[1]; compensated neutron porosity, in percent; and bulk density, in grams per cubic centimeter.

[1]API units are standard units for nuclear logs established by the American Petroleum Institute (1959) based on the use of a permanent calibration facility.

The formation density log is obtained by emitting medium-energy gamma rays into the formation. These rays act as high-velocity particles which collide with electrons in the formation. The ray loses some energy at each collision. The scattered gamma rays reach the detector and are counted as an indication of formation density. The greater the density of the formation the fewer counts in the detector so that what is actually measured is the number of electrons per cubic centimeter.

The description of the KUT probe is from a preliminary report by Century Geophysical Corp. (written commun., 1980). The KUT probe (pl. 1, log C) is sensitive to natural gamma radiation. It is classed as a spectral gamma-ray probe, because it categorizes gamma rays according to their energy levels. Other natural gamma logs do not distinguish between energy levels, but are sensitive to all gamma rays above a fixed energy.

Gamma rays are categorized by the KUT probe as coming from potassium (K), uranium (U), or thorium (T). These three sources comprise 98 percent of the naturally occurring radioactive sources. It is the ability to distinguish a potassium or thorium deposit from uranium, particularly in low grade deposits, that makes KUT logging valuable.

## MINERAL ANALYSES

Mineral analyses were made on 38 samples by N. C. Janke, consulting geologist of Sacramento, Calif. (table 3). Identification of minerals was done using methods and classification from Deer, Howie, and Zussman (1966) and Winchell (1951). Janke found 53 minerals or mineral series (table 4). Volcanic rock fragments could be detected in most of the samples. In samples from below a depth of 953 ft, some metamorphic and sedimentary fragments were obvious (N. C. Janke, written commun., Feb. 8, 1980).

Janke also submitted a table of categories for microscopic combinations of minerals, glasses, mineraloids or other detrital aggregates that were difficult to identify as to lithic or mineral type (table 5).

## EXPLANATION OF TABLE 3

Sample depth: Depth or depth interval, in feet, of sample. "Ditch" indicates sample was taken from cuttings coming up the borehole; "sidewall" indicates sample was taken from a device that cores the side of the borehole.

Sample texture and intervals analyzed: Sample texture is indicated by the percentages of weights retained on five sieve intervals c/m/f/vf/p: coarse (+35) mesh, medium (-35, +60) mesh, fine (-60, +120) mesh, very fine (-120, +230) mesh, pan (-230) mesh. The coarse, c (+35) mesh material is overstated in most instances as it is, at least in part, composed of cuttings, not loose grains; and the pan material, p (-230) mesh, is composed, in large part, of drilling mud.

The size intervals chosen for analysis--medium sand, m (-35, +60) mesh, and fine sand, f (-60, +120) mesh--are common to most rocks and sediments, and contain mineral sizes most easily identified under the microscope, with the result that error in identification is minimized. Heavy mineral suites characteristic of sediment types also tend to fall within these ranges.

Particle types as percentage of interval analyzed: The first listing of particle types is based on whole-field counts ($150 \leq N$) of the monomineralic grains and composite particles, polycrystalline grains or rock fragments (L), or both, found in the light fraction--specific gravity (s.g.) $\leq 2.9$. An approximation to equal-sized grains was made by weighting the counts. The percentage of heavy minerals, again with $150 \leq N$, is listed next (s.g. $>2.9$) with the percentage of heavy opaques given below this as a percentage of the heavy minerals only. Below these, the non-opaque heavy minerals are listed in a semiquantitative mode.

K - Feldspar: Potassium or potash feldspar.
P: Plagioclase with anorthite less than 34 percent (An $<$ 34 pct.) and with anorthite greater than 34 percent (An $>$ 34 pct.).
Quartz - monocrystalline and polycrystalline: Quartz, chalcedony, and chert.
Lithic fragments: Rock fragments not identified as to rock type; many include interstitial plagioclase.
Light opaques: Usually composed of a mass, often semiporous, of hematite and goethite. They are alteration products of hornblende and pyroxene monocrystals or polycrystals.
Volcanic glass: Glass identified as being of volcanic origin.
Calcite: A common mineral, but found only in traces in sampled intervals.

Mean ratio Q:F:L: Ratio of quartz (Q) to total feldspar (F) - potash and plagioclase, to lithic fragments (L).

Percentage of heavy minerals, specific gravity $>2.9$: Percentage of heavy minerals in sample. Opaques, as a percentage of the heavy minerals--magnetic and non-magnetic: Opaque, heavy minerals classified as magnetic or non-magnetic; they are indicated as a percentage of the heavy-mineral fraction only.

Detail of other non-opaque heavy minerals: Non-opaque heavy minerals as a percentage of the heavy-mineral fraction only. Includes orthopyroxene (opx) and clinopyroxene (cpx). Composite I contains mostly sausserite-zoisite, actinolite, chlorite, and some feldspar. Composite II commonly contains uralite with some chlorite and minor goethite.

BH and GH are used to classify very fine-grained masses with mixed indices of refraction. BH includes the classes CIIB + CIII + sideromelane + possible small amounts of classes CIA or CIB, and CIIA; dark green, greenish-brown, brown, red-brown, or orange-brown refractions. And GH includes CIA, CIB + CIIA + possible sideromelane, or palagonite, or both; slightly brownish-green, green, yellowish-green, pale green, white, colorless, or very pale brown refractions, as indicated below, by N. C. Janke, consulting geologist.

EXPLANATION OF TABLE 3--Continued

Found in the heavy mineral fraction (specific gravity $> 2.9$)

| Common colors in oblique reflected light | Fine designation[1] and approximate index of refraction, N | Usual constituents, others are possible |
| --- | --- | --- |
| White, yellowish, pale-gray, brownish | CIA<br>N, high | Leucoxene, other titanium minerals, clay, and often goethite (see CIII below). |
| Smooth, often waxy, white, colorless, green, pale-green, yellow, yellowish-green, often mottled | CIB<br>$1.63 \leq N$ to a maximum of 1.8 | Sausserite containing variable amounts of albite, clinozoisite, epidote, zoisite, and occasionally pyrophyllite and paragonite. |
| Blue-green | CIIA<br>$N < 1.68$ usual, may be to 1.76 | Uralite (fibrous amphibole such as actinolite) talc, epidote, or zoisite, and possibly quartz. |
| Dark-green, brownish-green | CIIB<br>$1.6 < N < 1.7+$ | Amphiboles, calcite, chlorite, plagioclase, pumpellyite. |
| Colorless to brownish | Sideromelane<br>$N \leq 1.6$ | Basic glass, often microlitic, sometimes partially altered to palagonite, commonly with calcite, chlorite, and zeolites. |
| Green, greenish-brown, brown to red-brown or orange-brown | CIII<br>$1.7 \leq N$ | Bowlingite (green to greenish-brown) and iddingsite (brown and red mixtures). Minerals include variable amounts of: goethite, hematite, chlorites, and other phyllosilicates, and may include leucoxene. |
| Brick-red | Hematite<br>2.9- $\leq$ N | Particles identified as hematite may only be coated, and this is even more likely for goethite. The indices of both of these minerals are very difficult to obtain in rapid counting of detrital aggregates; thus classification is based on color. |
| Yellowish-brown | Goethite<br>2.3- $\leq$ N | |

[1]Particles are not monomineralic or mostly glass.

TABLE 3. - Mineral analyses

[Test hole 12N/1E-34Q. Mineral analyses by N. C. Janke, Consulting Geologist]

| Sample depth (ft) | 187 (ditch) | | 285 (ditch) | | 323 ft (sidewall) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 4.7/28.1/31.1/13.9/22.2 | | 15.8/6.4/6.4/9/0/62.4 | | 7/2/41/34/17 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 5.0 | 3.4 | 7.9 | 3.0 | 10.2 | 10.3 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 40.8 | 36.6 | 11.9 | 33.3 | 29.6 | 47.7 |
| Plagioclase An > 34 pct. (± 4 pct.) | 8.9 | 14.5 | 5.8 | 9.4 | 25.5 | 9.3 |
| Quartz - monocrystalline and polycrystalline | 9.5 | 8.5 | 8.1 | 9.8 | 20.4 | 22.7 |
| Lithic fragments | 32.2 | 30.5 | 64.0 | 41.0 | 10.2 | 9.3 |
| Light opaques | 0.2 | 1.7 | 0.5 | 1.7 | 1 | 0 |
| Volcanic glass | - | - | - | - | - | - |
| Calcite | trace | trace | trace | trace | - | - |
| Mean ratio Q:F:L | (9:58:33) | | (9:36:55) | | 21:68:11 | 23:68:9 |
| Pct. heavy minerals s.g. > 2.9 | 3.4 | 4.8 | 1.9 | 1.8 | 3.1 | 0.9 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 49.7 | 43.3 | 26.6 | 19.6 | 13.5 | 18.3 |
| Non-magnetic | 0.3 | 0.2 | 4.0 | 5.1 | 0.5 | 0.5 |

| Detail of other non-opaque heavy minerals | 187 (ditch) | 285 (ditch) | 323 ft (sidewall) |
|---|---|---|---|
| Very abundant 24-50 pct. | Composite II (uralite, etc.)<br>cpx (augite, diopside) | Composite II (uralite, etc.)<br>cpx (augite, diopside) | GH |
| Abundant 10-24 pct. | opx (hypersthene) | hornblende (green or colorless)<br>opx (hypersthene) | L, opx† |
| Common 4-10 pct. | Hornblende (green or colorless) | | Cordierite, hematite, coated or replaced unidentifiable fossil parts, ferro-actinolite |
| Sparse 1- 4 pct. | Composite I (sausserite, etc.)<br>biotite (brown) | biotite<br>Composite I (sausserite, etc.) | Cpx, BH, green hornblende, chloritoid, xanthophyllite-clintonite, sideromelane, chlorite, anthophyllite-gedrite |
| Rare or doubtful < 1 pct. | chlorite | chlorite | Clinozoisite, zircon, fluorite, non-magnetic opaques (some with analcite), glauconite, oxy-hornblende* |
| Comments or special characteristics | Cockscomb solution ends on hypersthene not uncommon. | Cockscomb solution ends common on small hypersthene grains. | †Bronzite to ferro hypersthene varities, some with uralitized rims<br>*Calcite traces in the fine fraction only. |

# TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 355 (ditch) | | 438 (ditch) | | 447 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 63.2/11.5/9.2/12.1/4.0 | | 80.2/2.0/2.5/2.9/12.4 | | 81.0/1.9/1.9/4.0/11.2 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 9.7 | 13.4 | 0.8 | 0.2 | 3.5 | 3.1 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 22.0 | 18.5 | 14.6 | 16.1 | 20.7 | 17.0 |
| Plagioclase An > 34 pct. (± 4 pct.) | 4.0 | 5.1 | 6.8 | 25.4 | 9.9 | 17.8 |
| Quartz - monocrystalline and polycrystalline | 26.6 | 13.1 | 1.4 | 0 | 0 | 1.4 |
| Lithic fragments | 35.2 | 48.3 | 71.4 | 51.4 | 53.5 | 51.1 |
| Light opaques | 0.4 | 0.7 | 0.2 | 0.2 | 1.2 | 0.9 |
| Volcanic glass | - | - | - | - | 3.0 | 0.4 |
| Calcite | trace | trace | - | - | - | - |
| Mean ratio Q:F:L | (20:34:46) | | (1:35:64) | | (1:40:59) | |
| Pct. heavy minerals s.g. > 2.9 | 2.2 | 0.9 | 4.8 | 6.8 | 8.2 | 8.8 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 24.5 | 11.4 | 14.3 | 14.4 | 20.4 | 14.7 |
| Non-magnetic | 1.0 | 0.8 | 0.4 | 0.1 | 0.3 | 0 |
| Detail of other non-opaque heavy minerals | | | | | | |
| Very abundant 24-50 pct. | Composite II (uralite, etc,)<br>cpx (augite, diopside) | | opx (hypersthene) | | Green hornblende, opx (hypersthene) | |
| Abundant 10-24 pct. | Hematite (psuedomorphic after hornblende, and as coatings); chlorite<br>opx (enstatite, hypersthene | | Green hornblende,<br>cpx (augite) | | Composite II (uralite, etc.)<br>cpx (augite, diopside) | |
| Common 4-10 pct. | Hornblende (tremolitic?)<br>oxyhornblende | | Chlorite<br>brown hornblende<br>olivine | | Composite I (sausserite, etc.) | |
| Sparse 1- 4 pct. | Biotite (brown and green varities)<br>aegirine?<br>spinel | | Composites I and II (uralite, etc.; sausserite, etc.)<br>oxyhornblende<br>biotite | | Chlorite<br>brown hornblende<br>biotite<br>oxyhornblende | |
| Rare or doubtful < 1 pct. | Cummingtonite?<br>periclase | | Apatite (rare) | | Fluor apatite (rare) | |
| Comments or special characteristics | One-half percent plant remains in the c-fraction. Volcanic provenance probable due to hypersthene, the sizes of subhedral crystals, oxyhornblende, and zoning in the pyroxenes. No exsolution lamellae were observed in the augite. Occasional glomoporphyritic aggregates. | | Most hypersthene has cockscomb (solution) terminations. Less than one-half percent plant remains. Subhedral sizes, pyroxene zoning, hypersthene, and oxyhornblende. | | Most hypersthene has cockscomb (solution) terminations. The above sample also shows very common solution pits on pyroxene prism faces. Subhedral sizes, pyroxene zoning, hypersthene, and oxyhornblende. | |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 453 (ditch) | | 463 (ditch) | | 467 (sidewall) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 97.2/0.0/0.1-/0.2/2.5 | | 70.1/1.4/4.0/11.7/12.8 | | 2/2/8/43/45 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 5.1 | 6.2 | 4.2 | 7.3 | 5 | 14 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 23.9 | 14.3 | 14.3 | 12.3 | 36 | 29 |
| Plagioclase An > 34 pct. (± 4 pct.) | 20.3 | 23.5 | 18.3 | 26.5 | 21 | 12 |
| Quartz - monocrystalline and polycrystalline | 0 | 0 | 1.0 | 9.2 | 18 | 24 |
| Lithic fragments | 38.1 | 49.1 | 55.1 | 36.7 | 6 | 5 |
| Light opaques | 0.5 | 0.4 | 0.6 | 0 | 1 | 1 |
| Volcanic glass | 1.2 | 4.5 | - | 2.2 | 0 | 0 |
| Calcite | trace | trace | - | - | - | - |
| Mean ratio Q:F:L | (0:5:49) | | (6:45:49) | | 21:73:6 | 29:66:6 |
| Pct. heavy minerals s.g. > 2.9 | 10.9 | 2.0 | 6.5 | 2.8 | 2.7 | 2.7 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 18.9 | 11.0 | 22.2 | 12.0 | 16.5 | 14.0 |
| Non-magnetic | 0.5 | 0.2 | 0.6 | 0.2 | 0 | 0 |
| Detail of other non-opaque heavy minerals | | | | | | |
| Very abundant 24-50 pct. | Composite II (uralite, etc.) | | Composite II (uralite, etc.) | | GH | |
| Abundant 10-24 pct. | Composite I (sausserite, etc.) green hornblende, cpx (augite) | | Cpx (diopside, augite) green hornblende | | Enstatite, hyperstnene ( a few glomoporphyritic), tremolite, actinolite, ferroactinolite | |
| Common 4-10 pct. | Brown hornblende | | Composite I (sausserite, etc., opx (hypersthene chlorite | | Green hornblende, chlorite, anthophyllite-gedrite, cordierite | |
| Sparse 1- 4 pct. | Chlorite, oxyhornblende, brown biotite | | Oxyhornblende, brown biotite | | Dumortierite, clinozoisite, L, cummingtonite, augite, diopside-hedenbergite | |
| Rare or doubtful < 1 pct. | | | Zeolites, pigeonite?, periclase | | Sphene, hercynite | |
| Comments or special characteristics | Medium and fine fractions poorly represented. Total 'grab' sample was used here to obtain a few hundred grains. Possibly volcanic. | | Sparse cockscomb ends and solution pits on pyroxene. Volcanic provenance probably due to hypersthene and zoning on augite. | | | |

TABLE 3. - Mineral analyses--Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample depth (ft) | 520 (ditch) | | 544 (ditch) | | 571 (ditch) | |
| Sample texture c/m/f/vf/p | 33.0/0.9/4.3/20.0/41.7 | | 49.1/2.3/4.3/11.4/32.9 | | 47.7/1.1/3.4/6.7/41.1 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 5.9 | 7.0 | 2.0 | 3.4 | 2.3 | 4.1 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 11.5 | 10.8 | 5.1 | 9.9 | 5.3 | 8.0 |
| Plagioclase An > 34 pct. (± 4 pct.) | 6.4 | 17.7 | 3.4 | 9.2 | 1.5 | 4.8 |
| Quartz - monocrystalline and polycrystalline | 4.9 | 5.9 | 3.5 | 0.4 | 4.1 | 5.8 |
| Lithic fragments | 65.2 | 54.1 | 81.8 | 73.9 | 81.8 | 75.3 |
| Light opaques | 1.9 | 1.0 | 8.8 | 1.7 | 2.0 | 0.6 |
| Volcanic glass | 1.4 | 1.6 | - | - | 1.0 | 0.1 |
| Calcite | trace | trace | trace | trace | trace | trace |
| Mean ratio Q:F:L | (6:32:62) | | (2:17:81) | | (5:4:81) | |
| Pct. heavy minerals s.g. > 2.9 | 3.5 | 1.9 | 2.1 | 2.5 | 3.1 | 1.3 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 42.0 | 35.0 | 38.4 | 34.9 | 55.1 | 48.0 |
| Non-magnetic | 0.4 | 0.1 | 0.5 | 0.1 | 0.7 | 0.4 |
| Detail of other non-opaque heavy minerals--Dominant | Composite II (uralite, etc. | | | | | |
| Very abundant 24-50 pct. | | | Composite II (uralite, etc.), cpx (diopside, augite | | Cpx (augite), composite II (uralite, etc.) | |
| Abundant 10-24 pct. | Green hornblende | | Opx (hypersthene), green hornblende | | Green hornblende, opx (hypersthene) | |
| Common 4-10 pct. | Opx (hypersthene, cpx (augite, diopside) chlorite | | Chlorite | | | |
| Sparse 1- 4 pct. | Hornblende (and other amphiboles), oxyhornblende, anthophyllite, brown biotite | | Oxyhornblende, composite I (sausserite, etc.) anthophyllite, tremolite, serpentine, brown biotite | | Biotite, chlorite | |
| Rare or doubtful < 1 pct. | Arfvedsonite? | | Sphene | | Sphene (rare), pigeonite | |
| Comments or special characteristics | Very rare cockscomb ends and solution pits on pyroxene. Volcanic provenance probable due to hypersthene and zoning on augite. | | | | Very few types present. Rare cockscomb solution ends on pyroxene. N = 150. FH slide has exceptionally few grains. Volcanic provenance probable due to hypersthene and zoning on augite. | |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 593 (ditch) | | 602 (ditch) | | 629 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 49.4/5.1/4.0/2.6/38.9 | | 14.2/1.3/5.5/4.9/74.1 | | 31.7/3.3/3.9/6.2/54.9 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 6.6 | 5.2 | 10.7 | 6.8 | 5.8 | 5.6 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 16.9 | 24.5 | 13.0 | 29.3 | 18.9 | 33.6 |
| Plagioclase An > 34 pct. (± 4 pct.) | 11.7 | 21.9 | 13.6 | 18.2 | 6.4 | 22.0 |
| Quartz - monocrystalline and polycrystalline | 12.2 | 6.2 | 5.3 | 3.4 | 6.2 | 1.2 |
| Lithic fragments | 48.6 | 34.4 | 48.2 | 39.8 | 58.2 | 35.6 |
| Light opaques | 0.4 | 0.2 | 0.5 | 0.2 | 0.3 | 0.1 |
| Volcanic glass | 0.5 | - | 3.1 | 0.6 | 1.8 | - |
| Calcite | trace | trace | trace | trace | - | - |
| Mean ratio Q:F:L | (10:48:42) | | (5:48:47) | | (4:48:48) | |
| Pct. heavy minerals s.g. > 2.9 | 2.7 | 2.4 | 5.6 | 2.9 | 2.4 | 2.0 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 26.2 | 23.3 | 21.5 | 25.7 | 25.9 | 26.8 |
| Non-magnetic | 0.6 | 0.4 | 0.7 | 0.4 | 2.4 | 1.9 |
| Detail of other non-opaque heavy minerals | | | | | | |
| Very abundant 24-50 pct. | Composite II (uralite, etc.), cpx (augite, diopside) | | Composite II (uralite, etc.), cpx (augite, diopside) | | Composite II (uralite, etc.) cpx (augite, diopside) | |
| Abundant 10-24 pct. | Opx (hypersthene), green hornblende | | Hornblende (green and colorless types), opx (hypersthene) | | Opx (hypersthene), hornblende (green plus colorless types) | |
| Common 4-10 pct. | Composite I (sausserite, etc.) | | Composite I (sausserite, etc.) | | Composite I (sausserite, etc.) | |
| Sparse 1- 4 pct. | Green biotite, brown biotite, brown hornblende, chlorite | | Brown biotite, chlorite | | Green biotite, chlorite | |
| Rare or doubtful < 1 pct. | Spinel (rare) serpentine? | | | | Vermiculite (rare) | |
| Comments or special characteristics | Cockscomb ends on hypersthene common. | | Augite occasionally zoned. Cockscomb ends on hypersthene common. | | | |
| | Volcanic provenance probable due to hypersthene and zoning on augite. | | | | | |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 654 (ditch) | | 685 (sidewall) | | 710 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 41.4/3.4/3.8/6.2/45.1 | | 3/5/19/38/36 | | 61.8/2.4/1.9/3.1/30.8 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 12.6 | 5.0 | 25 | 12 | 5.9 | 3.7 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 16.6 | 31.0 | 20 | 29 | 30.4 | 43.9 |
| Plagioclase An > 34 pct. (± 4 pct.) | 6.3 | 20.3 | 23 | 15 | 5.6 | 14.3 |
| Quartz - monocrystalline and polycrystalline | 8.3 | 5.0 | 19 | 24 | 8.8 | 5.8 |
| Lithic fragments | 49.0 | 29.4 | 4 | 9 | 41.2 | 15.1 |
| Light opaques | - | - | 3 | 0 | - | - |
| Volcanic glass | 2.0 | 1.3 | 0 | 0 | 0.6 | 0.4 |
| Calcite | trace | trace | | | trace | trace |
| Mean ratio Q:F:L | (7:50:43) | | 21:75:4 | 27:63:10 | (8:60:32) | |
| Pct. heavy minerals s.g. > 2.9 | 4.2 | 8.0 | 2.0 | 2.1 | 7.5 | 16.8 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 31.9 | 14.2 | 10.2 | 7.5 | 9.4 | 5.1 |
| Non-magnetic | 1.3 | 0.9 | 0 | 0 | 1.2 | 0.9 |

| Detail of other non-opaque heavy minerals | | | |
|---|---|---|---|
| Very abundant 24-50 pct. | Composite II (uralite, etc.) | GH | Composite II (uralite, etc.) |
| Abundant 10-24 pct. | Hornblende (green plus colorless types), opx hypersthene), cpx (augite, diopside) | Green hornblende, cpx (augite-ferroaugite) diopside-hedenbergite (some very uralitized.) | Cpx (augite, diopside), hornblende (green plus colorless types) opx (hypersthene) |
| Common 4-10 pct. | Composite I (sausserite, etc.) | Opx (enstatite-hypersthene), chlorite | Vermiculite |
| Sparse 1- 4 pct. | | Zoisite, anthophyllite-gedrite, oxyhornblende, L, basic glass | Composite I (sausserite, etc. |
| Rare or doubtful < 1 pct. | Oxyhornblende (rare) chlorite | Graphite, apatite, picotite, biotite, axinite | Brown biotite (rare, chlorite |
| Comments or special characteristics | Uncommon to rare cockscomb solution ends on hypersthene. Augite occasionally zoned. | Most lithic fragments larger than 35 mesh | Occasional minute to prominent cockscomb solution ends on hypersthene. Volcanic provenance probable due to hypershtene and zoning on augite. |

TABLE 3. - Mineral analyses--Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample depth (ft) | 771 (ditch) | | 788 (sidewall) | | 814 (ditch) | |
| Sample texture c/m/f/vf/p | 32.3/6.8/4.9/6.8/49.2 | | 60/22/20/3/5 | | 29.8/4.5/4.0/4.9/56.8 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 5.2 | 3.2 | 14 | 14 | 3.3 | 3.8 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 31.0 | 31.1 | 19 | 36 | 41.7 | 34.2 |
| Plagioclase An > 34 pct. (± 4 pct.) | 9.0 | 14.1 | 21 | 12 | 6.2 | 18.9 |
| Quartz - monocrystalline and polycrystalline | 7.4 | 7.2 | 19 | 18 | 10.5 | 13.2 |
| Lithic fragments | 42.8 | 38.7 | 13 | 13 | 33.6 | 26.2 |
| Light opaques | 0.7 | 0.5 | 4 | 0 | 0.9 | 0.1 |
| Volcanic glass | - | - | 0 | 1 | - | - |
| Calcite | trace | trace | | - | - | - |
| Mean ratio Q:F:L | (8:49:43) | | 22:64:14 | 19:67:13 | (12:56:32) | |
| Pct. heavy minerals s.g. > 2.9 | 4.0 | 5.1 | 5.3 | 5.9 | 3.8 | 3.6 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 16.9 | 14.7 | 10.4 | 8.8 | 27.8 | 21.3 |
| Non-magnetic | 1.2 | 1.9 | 0 | 0 | 0.4 | 3.0 |

| Detail of other non-opaque heavy minerals | | | |
|---|---|---|---|
| Very abundant 24-50 pct. | Cpx (augite, diopside) composite II (uralite, etc.) | GH | Composite II (uralite, etc.) |
| Abundant 10-24 pct. | Green biotite, hornblende (green or colorless) opx (hypersthene) | L, opx (enstatite-hypersthene) | Cpx (augite, diopside), hornblende (green or colorless) |
| Common 4-10 pct. | | Cpx (augite, diopside, hedengergite, diallage, some very uralitized), hornblende, CAM*, epidote | Opx (hypersthene), green biotite, composite I (sausserite, etc.) |
| Sparse 1- 4 pct. | Composite I (sausserite, etc.) | Chlorite, picotite, clinozoisite, oxychlorite | Oxyhornblende |
| Rare or doubtful < 1 pct. | Brown biotite, chlorite | Glauconite, lawsonite | Brown biotite, chlorite |
| Comments or special characteristics | Occasional cockscomb solution ends on hypersthene. Volcanic provenance probable due to hypersthene and exsolution lamellae in some of the augite. | Many coarse grains and pebbles larger than 35 mesh. *Actinolite, ferro-actinolite, aegerine, cummintonite, richterite. | Occasional cockscomb ends on hypersthene. Volcanic provenance probable due to hypersthene and exsolution lamellae in some of the augite. |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 827 (ditch) | | 847 (ditch) | | 874 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 44.4/4.3/4.9/6.3/40.1 | | 28.1/1.8/2.6/3.4/64.1 | | 87.1/1.4/0.7/1.2/9.6 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 6.0 | 5.8 | 4.9 | 1.3 | 1.7 | 1.6 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 29.1 | 41.3 | 24.9 | 43.2 | 37.6 | 26.6 |
| Plagioclase An > 34 pct. (± 4 pct.) | 12.3 | 15.0 | 7.7 | 14.3 | 8.4 | 21.4 |
| Quartz - monocrystalline and polycrystalline | 14.4 | 7.8 | 8.9 | 5.8 | 5.7 | 2.8 |
| Lithic fragments | 34.9 | 25.1 | 43.3 | 32.0 | 35.6 | 35.1 |
| Light opaques | - | 0.1 | 6.6 | 0.1 | 1.4 | - |
| Volcanic glass | - | 0.4 | - | 0.2 | - | - |
| Calcite | - | - | - | - | - | - |
| Mean ratio Q:F:L | (12:57:31) | | (6:54:30) | | (4:56:40) | |
| Pct. heavy minerals s.g. > 2.9 | 4.4 | 4.3 | 3.7 | 3.1 | 9.6 | 12.5 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 19.8 | 15.0 | 16.9 | 12.3 | 19.8 | 12.9 |
| Non-magnetic | 1.2 | 1.2 | 1.9 | 1.1 | 0.9 | 4.7 |

| Detail of other non-opaque heavy minerals | 827 (ditch) | 847 (ditch) | 874 (ditch) |
|---|---|---|---|
| Very abundant 24-50 pct. | Composite II (uralite, etc.), cpx (augite, diopside) | Composite II (uralite, etc.), hornblende (green or colorless) | Composite II (uralite, etc.) cpx (augite, diopside) |
| Abundant 10-24 pct. | Hornblende (green or colorless), opx (hyperstnene) | Cpx (augite, diopside) opx (hypersthene) | Hornblende (green, colorless or brown), opx (hypersthene) |
| Common 4-10 pct. | Biotite (mostly green) | Green biotite | |
| Sparse 1- 4 pct. | | Chlorite | Biotite, Composite I (sausserite, etc.) |
| Rare or doubtful < 1 pct. | Brown hornblende (not oxyhornblende) chlorite | Oxyhornblende, brown hornblende | Spinel, chlorite, zircon |
| Comments or special characteristics | Cockscomb solution ends very rare. Volcanic provenance probable due to hypersthene and exsolution lamellae in some of the augite. | Cockscomb solution ends on hypersthene not uncommon. | Occasional to common cockscomb solution ends on hypersthene, rarely on augite. |
| | | Volcanic provenance indicated by hypersthene, the sizes of subhedral crystals, and zoning in the pyroxenes. | |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 892 (sidewall) | | 898 (ditch) | | 927 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 8/52/28/4/8 | | 72.5/2.1/2.7/4.8/17.9 | | 61.5/3.8/2.4/3.4/28.9 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 14 | 12 | 2.8 | 3.0 | 5.7 | 9.1 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 27 | 39 | 49.8 | 46.5 | 30.4 | 36.0 |
| Plagioclase An > 34 pct. (± 4 pct.) | 22 | 14 | 4.1 | 10.9 | 3.1 | 11.2 |
| Quartz - monocrystalline and polycrystalline | 7 | 13 | 5.8 | 9.4 | 13.5 | 9.3 |
| Lithic fragments | 20 | 12 | 29.9 | 26.4 | 38.6 | 27.8 |
| Light opaques | 1 | 1 | 0.1 | 0.3 | 2.4 | 1.0 |
| Volcanic glass | 0 | 0 | - | - | - | 0.7 |
| Calcite | | | trace | trace | trace | trace |
| Mean ratio Q:F:L | 8:72:20 | 15:73:13 | (8:62:30) | | (13:50:37) | |
| Pct. heavy minerals s.g. > 2.9 | 6.4 | 13.4 | 7.7 | 3.5 | 6.2 | 4.9 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 11.6 | 7.4 | 22.9 | 17.2 | 19.7 | 14.1 |
| Non-magnetic | 0 | 0 | 0.4 | 0.1 | 0 | 0 |

| Detail of other non-opaque heavy minerals | 892 (sidewall) | 898 (ditch) | 927 (ditch) |
|---|---|---|---|
| Very abundant 24-50 pct. | Opx (at least three types of bronzite-hypersthene present) | Composite II (uralite, etc.) | Composite II (uralite, etc. |
| Abundant 10-24 pct. | GH, L, green hornblende | Hornblende (green, colorless or brown), opx (hypersthene), cpx (augite, diopside) | Cpx (augite, diopside) hornblende (green and colorless) opx (hypersthene) |
| Common 4-10 pct. | Epidote | Biotite | Biotite |
| Sparse 1- 4 pct. | Chlorite, anthophyllite-gedrite, brown biotite, zoisite, clinozoisite, augite-ferroaugite, brown hornblende, oxyhornblende | | |
| Rare or doubtful < 1 pct. | Sphene, staurolite | Chlorite | Chlorite, cummingtonite? |
| Comments or special characteristics | | Occasional to common cockscomb solution ends on hypersthene, rarely on augite.<br>Volcanic provenance indicated by hypersthene, the sizes of subhedral crystals, and zoning in the pyroxenes. | |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 941 (sidewall) | | 953 (sidewall) | | 957 (ditch) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 68/13/6/3/11 | | 66/15/8/5/7 | | 60.7/5.2/2.4/3.2/28.5 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 16 | 13 | 9 | 13 | 5.1 | 4.9 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 33 | 31 | 40 | 41 | 30.7 | 31.5 |
| Plagioclase An > 34 pct. (± 4 pct.) | 13 | 15 | 11 | 15 | 9.5 | 5.9 |
| Quartz - monocrystalline and polycrystalline | 16 | 23 | 13 | 20 | 15.1 | 13.9 |
| Lithic fragments | 14 | 7 | 16 | 5 | 29.6 | 31.0 |
| Light opaques | 0 | 2 | 0 | 0 | 1.1 | 0.2 |
| Volcanic glass | 0 | 0 | 0 | 0 | - | - |
| Calcite | | | | | trace | trace |
| Mean ratio Q:F:L | 17:68:14 | 26:66:7 | 15:68:16 | 21:73:5 | (16:48:36) | |
| Pct. heavy minerals s.g. > 2.9 | 15.8 | 21.7 | 22.0 | 31.0 | 8.8 | 12.6 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 5.2 | 5.2 | 8.7 | 14.5 | 18.8 | 14.3 |
| Non-magnetic | 1.2 | 1.2 | 5.0 | 5.0 | 0.3 | 0.4 |

| Detail of other non-opaque heavy minerals | 941 | 953 | 957 |
|---|---|---|---|
| Dominant | GH | | |
| Very abundant 24-50 pct. | | | Composite II (uralite, etc.) hornblende (green and colorless) |
| Abundant 10-24 pct. | | GH, epidote,* L | Cpx (augite, diopside) opx (hypersthene) |
| Common 4-10 pct. | Opx (hypersthene) epidote, cpx (aegerine, augite), L, green hornblende | Opx (hypersthene), clinozoisite, opaques, (hematite and chromite) | Biotite |
| Sparse 1- 4 pct. | GH, glaucophane, non-magnetic black opaques | Green hornblende, glaucophane, BH, piedmontite, tremolite, actinolite-ferroactinolite, allenite | Zircon, chlorite |
| Rare or doubtful < 1 pct. | Riebeckite, pigeonite, zoisite, oxyhornblende, specular hematite | Spinel | |
| Comments or special characteristics | | * Some may be clinozoisite. Many have cockscomb solution ends, as does the hypersthene.. | Common cockscomb solution ends on pyroxene. Volcanic provenance indicated by hypersthene, the sizes of subhedral crystals, and zoning in the pyroxenes. |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 1,244 (sidewall) | | 1,392 (sidewall) | | 1,453 (sidewall) | |
|---|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 23/41/23/6/7 | | 66/15/8/5/6 | | 78/9/5/3/6 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 13 | 18 | 14 | 22 | 9 | 16 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 42 | 42 | 26 | 24 | 30 | 41 |
| Plagioclase An > 34 pct. (± 4 pct.) | 7 | 10 | 6 | 8 | 14 | 7 |
| Quartz - monocrystalline and polycrystalline | 19 | 15 | 17 | 13 | 20 | 19 |
| Lithic fragments | 11 | 8 | 30 | 20 | 15 | 6 |
| Light opaques | 1 | 0 | 1 | 1 | 1 | 0 |
| Volcanic glass | 0 | 0 | 1 | 3 | 0 | 0 |
| Calcite | | | | | | |
| Mean ratio Q:F:L | 21:68:11 | 16:76:8 | 19:50:31 | 16:63:22 | 23:61:16 | 21:72:6 |
| Pct. heavy minerals s.g. > 2.9 | 12.4 | 26.0 | 9.0 | 12.8 | 14.1 | 13.5 |
| Opaques (as a pct. of the heavy minerals) Magnetic | 3.1 | 3.0 | 10.9 | 11.8 | 7.4 | 10.8 |
| Non-magnetic | 1.0 | 1.0 | 1.4 | 1.4 | 1.2 | 1.2 |
| Detail of other non-opaque heavy minerals | | | | | | |
| Very abundant 24-50 pct. | | | GH, epidote | | GH | |
| Abundant 10-24 pct. | GH, epidote (includes some clinozoisite), green hornblende | | L | | Hypersthene, epidote, L | |
| Common 4-10 pct. | Chlorite, anthophyllite-gedrite, chlorite + chamoisite, chloritoid, opx (enstatite-hypersthene | | Actinolite-tremolite + tremolite-ferro-actinolite, green hornblende, clino-zoisite | | Clinozoisite | |
| Sparse 1- 4 pct. | Brown hornblende, actinolite-tremolite + tremolite-ferroactinolite, thulite | | Pumpellysite, β-zoisite, barkevikite(?) Δ | | Chlorite, thulite, diopside-hedenbergite, piedmontite, actinolite-tremolite, green hornblende, anthophyllite-gedrite, pumpellyite, opaques* | |
| Rare or doubtful < 1 pct. | Allanite, hematite, oxyhornblende | | Pyrite, hematite, spinel | | Barkevikite, sphene, garnte, allenite | |
| Comments or special characteristics | | | Δ Grains absorb too much light to be sure. | | * The opaque material is black and resinous with some cleavage. It is not sphalerite or galena. | |

TABLE 3. - Mineral analyses--Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample depth (ft) | 1,552 (sidewall) | | 1,643 (sidewall) | | 1,845 (sidewall) | |
| Sample texture c/m/f/vf/p | 6/8/33/29/25 | | 12/18/20/18/33 | | 59/18/6/4/12 | |
| Intervals analyzed | m | f | m | f | m | f |
| Particle types as percent of interval analyzed | | | | | | |
| K - Feldspar | 18 | 22 | 8 | 19 | 11 | 13 |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 34 | 23 | 46 | 30 | 21 | 27 |
| Plagioclase An > 34 pct. (± 4 pct.) | 9 | 14 | 10 | 9 | 3 | 14 |
| Quartz - monocrystalline and polycrystalline | 24 | 16 | 19 | 24 | 34 | 20 |
| Lithic fragments | 8 | 10 | 9 | 5 | 23 | 12 |
| Light opaques | 0 | 2 | 1 | 1 | 0 | 1 |
| Volcanic glass | 0 | 0 | 0 | 0 | 0 | 0 |
| Calcite | | | | | | |
| Mean ratio Q:F:L | 26:66:8 | 19:70:11 | 21:70:9 | 27:67:5 | 37:39:24 | 23:63:13 |
| Pct. heavy minerals s.g. > 2.9 | 20.5 | 17.6 | 3.5 | 7.2 | 16.4 | 25.7 |
| Opaques (as a pct. of the heavy minerals) | | | | | | |
| Magnetic | 21.3 | 10.1 | 5.3 | 3.5 | 5.4 | 5.5 |
| Non-magnetic | 15.1 | 15.1 | 0.3 | 0.3 | 1.8 | 1.8 |

| Detail of other non-opaque heavy minerals | | | |
|---|---|---|---|
| Very abundant 24-50 pct. | | Green hornblende | L |
| Abundant 10-24 pct. | GH, epidote, pyrite, green hornblende | HG, L, oxyhornblende | Epidote, GH, hypersthene* green hornblende |
| Common 4-10 pct. | Brown hornblende† hypersthene, oxy-hornblende, chlorite, clintonite, L | Colorless or brown hornblende, chlorite, epidote, hypersthene, CAMΔ | |
| Sparse 1- 4 pct. | Glaucophane-crossite, cpx (diopside-hedenbergite + augite-ferro-actinolite), clinozoisite, hematite, anthophyllite-gedrite | Anthophyllite-gedrite, actinolite, serpentine (?) | Clino-amphiboles other than green hornblende, anthophyllite-gedrite, augite, hematite, oxyhornblende |
| Rare or doubtful < 1 pct. | | Hematite | |
| Comments or special characteristics | † May include barkevikite. | ΔColorless hornblende and other amphiboles undifferentiated. | *Several glomo-porphyritic aggregates. |

TABLE 3. - Mineral analyses--Continued

| Sample depth (ft) | 2,111 (sidewall) | | 2,355 (sidewall) | | |
|---|---|---|---|---|---|
| Sample texture c/m/f/vf/p | 62/22/6/4/6 | | 4/13/34/25/23 | | |
| Intervals analyzed | m | f | m | f | |
| Particle types as percent of interval analyzed | | | | | |
| K - Feldspar | 14 | 19 | 5 | 8 | |
| P: Plagioclase An < 34 pct. (± 4 pct.) | 24 | 29 | 33 | 42 | |
| Plagioclase An > 34 pct. (± 4 pct.) | 3 | 8 | 6 | 7 | |
| Quartz - monocrystalline and polycrystalline | 20 | 17 | 14 | 10 | |
| Lithic fragments | 33 | 15 | 18 | 22 | |
| Light opaques | 0 | 1 | 3 | 1 | |
| Volcanic glass | 0 | 0 | 0 | 0 | |
| Calcite | | | | | |
| Mean ratio Q:F:L | 21:45:34 | 19:65:16 | 18:58:23 | 11:65:24 | |
| Pct. heavy minerals s.g. > 2.9 | 14.3 | 16.5 | 9.6 | 9.5 | |
| Opaques (as a pct. of the heavy minerals) Magnetic | 3.7 | 6.4 | 14.4 | 10.1 | |
| Non-magnetic | 2.6 | 2.6 | 2.0 | 2.0 | |

| Detail of other non-opaque heavy minerals | | | |
|---|---|---|---|
| Very abundant 24-50 pct. | Hypersthene | GH, L | |
| Abundant 10-24 pct. | GH, epidote, L | | |
| Common 4-10 pct. | Green hornblende, CAM† | Green hornblende, CAM,† epidote, hypersthene, anthophyllite-gedrite | |
| Sparse 1- 4 pct. | Anthophyllite-gedrite oxyhornblende + brown hornblende‡, hematite | Cordierite, augite-ferroaugite, brown hornblende, chlorite, hematite, biotite | |
| Rare or doubtful < 1 pct. | Chlorite, chromite, marcasite, red garnet, serpentine(?) | Chrysotile | |
| Comments or special characteristics | ‡ May include barkevikite<br>† Several clino-amphibole types, including actinolite-tremolite, tremolite, ferro-actinolite, and ferro-hastingsite. | | |

TABLE 4. - Summary alphabetical list of minerals identified in samples

[The word "series" in parentheses after mineral name indicates that several varieties within the series were found]

Actinolite-Ferroactinolite (series)
Actinolite-Tremolite (series)
Allanite
Amphiboles (Clino-, undifferentiated)
Analcite
Anthophyllite-Gedrite (series)
Apatite
Augite-Ferroaugite (series)
Axinite

Basic glass (not Sideromelane)
Biotite
Bronzite-Ferrohypersthene (series)

Chlorite (including oxy-chlorite and undifferentiated varieties)
Chloritoid
Chromite
Chrysotile
Clinozoisite
Cordierite
Cummingtonite

Diallage
Diopside-Hedenbergite (series)
Dumortierite

Enstatite-Bronzite (series)
Epidote

Fluorite

Garnet (red)
Glauconite
Glaucophane
Graphite

Hematite (some specular)
Hercynite
Hornblende (green, brown, and oxy-varieties)
Hypersthene

Lawsonite

Marcasite

Piedmontite
Picotite
Pigeonite
Plagioclase (series)
Potash Feldspar (undifferentiated)
Pumpellyite

Richterite (part of series)
Riebeckite

Serpentine(?)
Sideromelane
Sphene (Titanite)
Spinel
Staurolite

Thulite

Xanthophyllite-Clintonite (series)

Zircon

$\alpha$-Zoisite
$\beta$-Zoisite

## X-RAY DIFFRACTION

X-ray diffraction is the phenomenon of the apparent bending of X-rays passing near opaque objects. The diffraction depends on the crystal structure of the object. A single crystal substance produces a diffraction pattern of spots called a Laue pattern, and a powdered substance produces a pattern of rings called an X-ray powder pattern. From the X-ray diffraction pattern of a substance the crystal structure and the unit cell dimension can be determined.

Eight samples of fine-grained material were submitted to Technology of Materials, Santa Barbara, Calif. Of special interest was the identification and quantification of various clay minerals in the samples. Thirteen X-ray diffraction charts and 19 electron micrographs of clay materials are included in their report, part of which is paraphrased here.

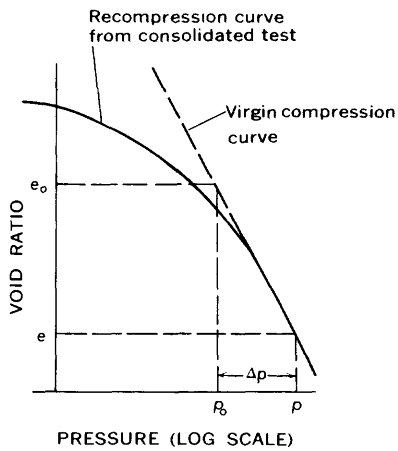
> The X-ray diffraction data show a considerable difference in the amount of crystalline material for various samples. The poor pattern for the 535-foot depth indicates the presence of a considerable amount of amorphous material. It was initially felt that this could be an allophane, which is a completely amorphous clay. An electron microscopic study, however, showed that this amorphous phase is due to a high concentration of diatomite, showing fragments of diatom skeletons. Optical microscopy of the samples above and below this level showed no indications of diatom skeletons. The clay content of the samples consists mostly of kaolinite. The electron micrographs of the deepest sample at 2,305 ft show a relatively high concentration of halloysite. No montmorillonite was found in any of the samples to a measurable extent.

The X-ray diffraction charts and micrographs are on file in the Sacramento office of the Geological Survey. Table 5 is a summary of the X-ray diffraction data.

TABLE 5.- Summary of X-ray diffraction data

| Sample 34Q series | α-Quartz (pct.) | Feld-spar (pct.) | Kaolin-ite (pct.) | Illite | Amorphous, by difference (pct.) | Other crystalline phases |
|---|---|---|---|---|---|---|
| 220 ft | 15 | 17 | 26 | Minor | 30-40 | Mica (trace?), fine fraction only |
| 535 ft | 8 | 6 | 10 | None | 60-75 (High diatomite) | Gypsum (trace) |
| 820 ft | 16 | 20 | 17 | Minor | 20-30 | Chlorite (trace) |
| 975 ft | 18 | 17 | 24 | Minor | | Mica (minor) |
| 1,200 ft | 17 | 13 | 11 | Trace? | 50-60 | None |
| 1,755 ft | 16 | 32 | 13 | Minor | 15-25 | Mica (minor +) |
| 2,025 ft | 18 | 31 | 32 | None | 15-30 | None |
| 2,305 ft | 15 | 30 | [1]21 | Trace | 20-30 | Halloysite (by TEM). Minor unknown phase mica (trace) |

[1]Kaolinite and halloysite.




The virgin compression curve or the field consolidation curve, for clayey soils, appears on a semilogarithmic diagram as a straight line as shown at left. This line can be represented by the equation

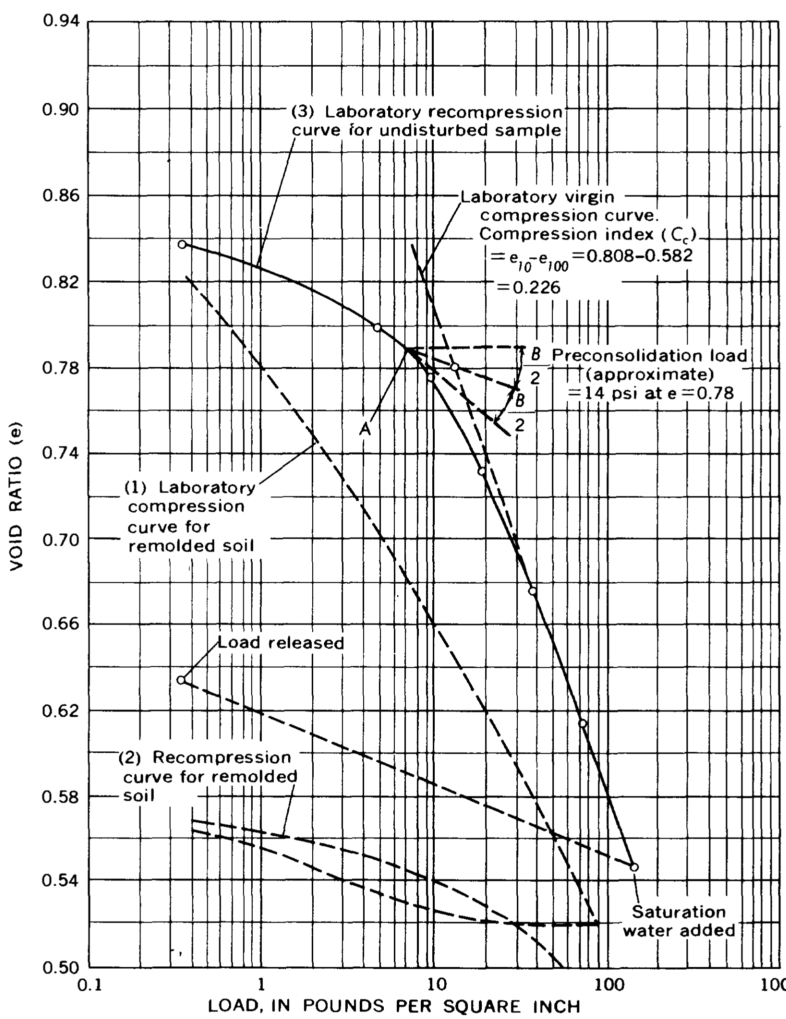
$$e = e_o - C_c \log_{10} \frac{P_o + \Delta p}{P_o}$$

in which $C_c$ (dimensionless) is the compression index

The virgin compression curve is established by extending the straight-line part of the recompression curve. By selecting two points $(e_o, p_o)$ and $(e, p)$ and substituting in the above equation, $C_c$ can be determined

$$C_c = \frac{e_o - e}{\log_{10} \frac{P_o + \Delta p}{P_o}}$$

*A*. METHOD OF DETERMINING THE COMPRESSION INDEX ($C_c$)




Graphical determination of preconsolidation load:
Draw tangent and horizontal line to point of maximum curvature (*A*)
The point of intersection between virgin compression curve and line bisecting angle *B*, is preconsolidation load and void ratio

*B*. VOID RATIO-LOAD CURVES AND PRECONSOLIDATION LOAD

FIGURE 5.--Void ratio-load curve, compression index, and preconsolidation load. (After Johnson, Moston, and Morris, 1968.)

## CONSOLIDATION TESTS

Consolidation tests were made on 15 samples by J. H. Kleinfelder and Associates, geotechnical consultants, Sacramento, Calif. Results from these tests show values for dry unit weight, moisture content, Atterberg limits, specific gravity, initial void ratio, porosity, coefficient of consolidation, estimated applied stress, vertical hydraulic conductivity, compression index, and recompression index. Table 6 summarizes these data derived from laboratory tests. Definition of the elements in table 6 as well as a description of the laboratory methods are found in Johnson, Moston, and Morris (1968, p. 10-18).

Compression is the volume change of the sample by loading. Consolidation is the volume change of the sample by loading through a period of time. If

TABLE 6. - Data from

| Sample depth (feet) | Dry weight ($lb/ft^3$) | Moisture content (percent of dry weight) | Atterberg limits | | Specific gravity | Initial void ratio ($e_o$) | Porosity (percent) |
|---|---|---|---|---|---|---|---|
| | | | Liquid | Plastic | | | |
| 215 | 100.0 | 25.8 | 52 | 28 | 2.59 | 0.577 | 37 |
| 535 | 55.0 | 66.6 | 103 | 52 | 2.29 | 1.443 | 69 |
| 818 | 87.6 | 33.1 | 43 | 15 | 2.70 | .926 | 48 |
| 847 | 112.9 | 19.0 | -- | -- | 2.68 | .485 | 33 |
| 882 | 107.9 | 17.0 | 36 | 16 | 2.51 | .451 | 31 |
| 976 | 91.5 | 27.0 | 38 | 13 | 2.67 | .823 | -- |
| 1,200 | 104.7 | 22.8 | 35 | 12 | 2.68 | .599 | 37 |
| 1,521 | 124.8 | 22.2 | -- | -- | -- | -- | -- |
| 1,753 | 92.7 | 28.8 | 53 | 26 | 2.64 | .778 | 44 |
| 1,883 | 96.8 | 30.4 | 58 | 29 | 2.56 | .648 | 39 |
| 1,981 | 83.2 | 16.9 | 33 | 5 | 2.56 | .644 | 39 |
| 2,024 | 92.1 | 20.1 | 28 | 11 | 2.67 | .509 | 34 |
| 2,301 | 101.1 | 24.7 | 56 | 27 | 2.51 | .55 | -- |
| 2,401 | 95.4 | 29.6 | 40 | 6 | 2.54 | .66 | -- |
| 2,496 | 93.5 | 28.5 | Non-plastic | | 2.57 | .72 | -- |

[1]Data insufficient for calculation.

the void spaces are filled with air, compression takes place; but, if the voids are filled with water, little or no compression will take place and only as water drains from the sample will consolidation take place.

As beds of sediment are deposited layer on layer through geologic time, each layer is compressed by the layers above it. The layers attain a state of consolidation in equilibrium with the superimposed load. The layer is then called normally consolidated. In a normally consolidated layer, density will increase with depth of overburden and the void ratio will decrease. The relation between density increase and void ratio decrease is approximately an extended straight line (virgin compression curve) on a semilogarithm graph (fig. 5). Figure 5 also shows the method for determining the compression index and the graphical explanation of the void ratio curves (Johnson and others, 1968).

consolidation tests

| Coefficient of consolidation ($ft^2/yr$) | Estimated applied stress overburden ($lb/in^2$) | Vertical hydraulic conductivity | | Compression index | Recompression index |
|---|---|---|---|---|---|
| | | calculated (ft/d) | test (ft/d) | | |
| 4.58 | $1.05 \times 10^2$ | $1.3 \times 10^{-6}$ | | 0.237 | 0.050 |
| 4.89 | $2.50 \times 10^2$ | $3 \times 10^{-6}$ | $1.1 \times 10^{-4}$ | 1.22 | .067 |
| 71.2 | $3.75 \times 10^2$ | $2.2 \times 10^{-5}$ | | .422 | .028 |
| 5.41 | $8.47 \times 10^2$ | $8.2 \times 10^{-7}$ | $6.8 \times 10^{-5}$ | .197 | .033 |
| 7.82 | $4.05 \times 10^2$ | $8.2 \times 10^{-7}$ | | .216 | 2.70 |
| (1) | -- | (1) | | .648 | .028 |
| 21.3 | $5.50 \times 10^2$ | $2.2 \times 10^{-6}$ | | .191 | .031 |
| -- | -- | -- | | -- | -- |
| 46.2 | $8.00 \times 10^2$ | $5.5 \times 10^{-6}$ | | .579 | .034 |
| 15.1 | $8.55 \times 10^2$ | $2 \times 10^{-6}$ | | .870 | .035 |
| 13.9 | $9.00 \times 10^2$ | $1.7 \times 10^{-6}$ | | .454 | .018 |
| (1) | -- | (1) | | .412 | .023 |
| [2]101 | $1.04 \times 10^2$ | $7.7 \times 10^{-6}$ | | .44 | .05 |
| -- | -- | -- | | .71 | .05 |
| -- | -- | -- | | .48 | .04 |

[2]Inadequate compression curve.

## ATTERBERG LIMITS

The water content in a clay is important to the consistency of the clay. As water content increases the clay changes consistency from a solid state through a plastic state to a liquid state. The limits of these three states are arbitrarily fixed by a standardized testing procedure and are called Atterberg limits (Atterberg, 1911). The water content, in percentage of dry weight, at the transition between the liquid and plastic states is called the liquid limit, at the transition between the plastic and semisolid states is called the plastic limit, and at the transition between the semisolid and solid states is called the shrinkage limit. A decrease in volume of the clay takes place as the water content decreases. Atterberg limits for 12 core samples are given in table 6.

## HYDRAULIC CONDUCTIVITY AND POROSITY ANALYSES

Core analyses were made on 36 sidewall cores by Core Laboratories, Inc. Sidewall cores are obtained by shooting a 2-inch long, 5/8-inch diameter cylinder horizontally into the side of the borehole. In the laboratory the cores are oriented in the testing apparatus so that the results indicate horizontal, not vertical, hydraulic conductivity. An explanation follows which gives test procedures and tabulations of the results.

Five-eighths-inch diameter sidewall core samples recovered from the test hole were submitted to the New Orleans Laboratory of Core Labs, Inc. for special core analyses. Samples at depths 1,244, 1,845, and 2,131 ft could not be tested because they were unconsolidated and of poor sample quality. Sidewall cores are identified and lithologically described in table 7.

After drying in a humidity-controlled oven at 145°F and 45 percent relative humidity, porosities were determined at room conditions with a Boyle's law helium porosimeter. Upon completion of porosity determinations, the samples were evacuated and resaturated with formation water obtained from the well and specific water permeabilities were determined. Porosity and water permeability test results are presented in table 8.

Fifteen samples were selected by the U.S. Geological Survey for single-point mercury-injection capillary pressure tests. After drying under controlled humidity and temperature, porosities were again determined with a Boyle's law helium porosimeter. They were then placed in a mercury pump chamber and evacuated prior to the introduction of mercury at a maximum pressure of 1,500 lb/in$^2$. Because of the presence of small fractures in some of the samples tested, the water saturations may be slightly higher than the results indicate. As requested by the U.S. Geological Survey, test results of the fractured samples were reported along with the other results in table 9. In the table, fractured samples are noted.

TABLE 7. - Identification and description of sidewall cores submitted for analyses

| Depth (feet) | Lithologic description |
|---|---|
| 244 | Clay and silt, moderate-yellowish-brown 10YR5/4 to dark-yellowish-brown 10YR4/2. Nodule of very fine gravel. |
| 288 | Clay, pale-yellowish-brown 10YR6/2 to moderate-yellowish-brown 10YR5/4. |
| 323 | Sand, dark-yellowish-brown 10YR4/2, very fine, some very coarse; black particles, rounded to subangular, fine grains mostly quartz with many red and black grains, loose, not cemented. |
| 437 | Silt, sand, and clay, moderate-yellowish-brown 10YR5/4. Sand, fine. |
| 467 | Sand, fine, light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4; some clay and silt. |
| 594 | Sand, silt, and clay, light-olive-gray 5Y6/1. Sand, very fine. |
| 685 | Sand, some gravel and silty clay, light-olive-gray 5Y5/2. Sand, very fine to fine. |
| 727 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. |
| 741 | Clay, light-olive-gray 5Y5/2; some fine gravel. |
| 910 | Clay, light-olive-gray 5Y5/2 to olive-gray 5Y4/1. |
| 941 | Gravel, very fine to medium, and sand, coarse, 75 percent grayish-olive 10Y4/2 to black N1; 25 percent white N9 to light-gray N7; subrounded, silt and clay matrix. Matrix, light-olive-gray 5Y5/2 to dusky-yellow-green 5GY5/2. |
| 962 | Gravel, very fine, to sand, coarse, mostly dark grains, subangular to subrounded, some silt and clay, light-olive-gray 5Y5/2. |
| 1,033 | Sand, very fine, and silt; overall color light-olive-brown 5Y5/6 to light-olive-gray 5Y5/2. |
| 1,090 | Silt, light-olive-gray 5Y5/2 to olive-gray 5Y3/2. |
| 1,142 | Sand, light-olive-gray 5Y5/2 to olive-gray 5Y3/2, fine to medium, some gravel. |
| 1,195 | Sand, light-olive-gray 5Y5/2, fine to medium, some silt, black minerals and a rock fragment. |
| 1,290 | Clay, some silt, light-olive-brown 5Y6/1 and light-olive-gray 5Y5/2. |

TABLE 7. - Identification and description of sidewall cores submitted for analyses--Continued

| Depth (feet) | Lithologic description |
|---|---|
| 1,354 | Clay, some silt and fine sand, greenish-gray 5G6/1 and dark-greenish-gray 5G4/1. |
| 1,392 | Gravel, very fine to fine, and sand, coarse, mostly medium-dark-gray N4 to black N1, in a silt and clay matrix, light-olive-gray 5Y5/2 to light-olive-brown 5Y5/6. |
| 1,453 | Sand, and gravel, fine sand to very fine gravel, very-light-gray N8, black minerals and rock fragments. |
| 1,503 | Silt, clay, olive-gray 5Y4/1, and some gravel, very fine, subrounded to subangular, some black minerals. |
| 1,552 | Sand, olive-gray 5Y4/1, very fine to fine, some silt. |
| 1,592 | Clay, light-olive-gray 5Y6/1 to olive-gray 5Y4/1. |
| 1,643 | Silt, clay and sand, very fine, olive-gray 5Y4/1. |
| 1,680 | Silt, clay, and some very fine gravel, greenish-gray 5GY6/1 and dark greenish-gray 5GY4/1. |
| 1,812 | Silt and fine sand, greenish-gray 5GY6/1 to dark-greenish-gray 5GY4/1. |
| 1,824 | Silt, clay, and very fine sand, dark-greenish-gray 5G4/1. |
| 1,845[1] | Sand, and some gravel, sand, medium to coarse, some very coarse, overall olive-gray 5Y3/2 to dark-greenish-gray 5G4/1; gravel, fine, mostly greenish-black 5GY2/1 and grayish-black N2, some very-light-gray N8 and yellowish-gray 5Y8/1 to light-olive-gray 5Y6/1, some silt. |
| 1,869 | Sand, dark-greenish-gray 5GY4/1 to dark-greenish-gray 5G4/1, very fine to fine. |
| 1,929 | Clay, dark-greenish-gray 5GY4/1, some silt and very-fine gravel. |
| 1,953 | Silt, clayey, pale-olive 10Y6/2, flakey. |
| 2,094 | Silt, moderate-olive-brown 5Y4/4, grayish-olive 10Y4/2, and dark-greenish-gray 5GY4/1; some sand, very fine to fine, moderate-olive-brown 5Y4/4 to grayish-olive 10Y4/2, and some gravel, very fine, dark-greenish-gray to grayish-black N2, subangular to subrounded. |
| 2,121 | Sand, fine to coarse, overall grayish-olive 10Y4/2, to olive-5Y3/2, and gravel, very fine to fine, about 75 percent dark-greenish-gray 5GY4/1 to black N1 and 25 percent very-light-gray N8 to light-olive-gray 5Y6/1, subangular to subrounded. |

TABLE 7. - Identification and description of sidewall cores submitted for analyses--Continued

| Depth (feet) | Lithologic description |
|---|---|
| 2,131[1] | Sand, dark-greenish-gray 5GY4/1 to greenish-black 5GY2/1, fine to very coarse. |
| 2,141 | Silt and very fine gravel, greenish-gray 5GY6/1 to dark-greenish-gray 5GY4/1; some silty clay and claystone, pale-olive 10Y6/2 to grayish-olive 10Y4/2. |
| 2,266 | Silt and sand, very fine, dark-greenish-gray 5GY4/1. |
| 2,355 | Sand, olive-gray 5Y4/1 to dark-greenish-gray 5GY4/1, very fine to fine. |
| 2,466 | Silt, olive-gray 5Y4/1 to dark-greenish-gray 5GY4/1, some siltstone, moderate-olive-brown 5Y4/4; some fine gravel. |

[1]Insufficient sample for analysis.

TABLE 8. - Hydraulic conductivity and porosity of samples

| Depth (ft) | Hydraulic conductivity (ft/d) | Porosity (percent) | Depth (ft) | Hydraulic conductivity (ft/d) | Porosity (percent) |
|---|---|---|---|---|---|
| 244 | <0.00002 | 24.4 | 1,392 | 0.00005 | 28.2 |
| 288 | <.00002 | 16.8 | 1,453 | .17 | 19.7 |
| 323 | .00781 | 32.5 | 1,503 | .00436 | 37.6 |
| 437 | .0010 | 45.5 | 1,552 | .0108 | 34.2 |
| 467 | .00027 | 33.7 | 1,592 | <.00002 | 35.7 |
| 594 | <.00002 | 38.4 | 1,643 | .000020 | 33.7 |
| 685 | <.00002 | 25.7 | 1,680 | <.00002 | 27.0 |
| 727 | <.00002 | | 1,812 | .0199 | 37.8 |
| 741 | <.00002 | 36.4 | 1,824 | <.00002 | 28.9 |
| 910 | <.00002 | 17.7 | 1,869 | .0023 | 31.5 |
| 941 | .23 | 19.0 | 1,929 | .00002 | 28.5 |
| 962 | .00380 | 18.2 | 1,953 | .00024 | 30.5 |
| 1,033 | .0011 | 37.1 | 2,094 | .0018 | 30.7 |
| 1,090 | <.00002 | 26.9 | 2,121 | .15 | 27.1 |
| 1,142 | <.00002 | 29.6 | 2,141 | <.00002 | 24.2 |
| 1,195 | <.00002 | 27.6 | 2,266 | <.00002 | 24.2 |
| 1,290 | <.00002 | 30.6 | 2,355 | .0234 | |
| 1,354 | <.00002 | 19.7 | 2,466 | .00027 | 36.3 |

TABLE 9. - Mercury-injection capillary pressure data, single point

| Depth (feet) | Hydraulic conductivity (ft/d) | Porosity (percent) | Wetting phase saturation[1] (percent pore space) |
|---|---|---|---|
| 288[2] | <0.00002 | 16.8 | 37.7 |
| 323 | .0078 | 32.2 | 9.6 |
| 437[2] | .001 | 41.0 | 8.5 |
| 467 | .00027 | 26.3 | 16.4 |
| 685 | <.00002 | 23.3 | 20.1 |
| 941 | .2311 | 19.8 | 24.4 |
| 962 | .00380 | 14.9 | 22.0 |
| 1,392 | .00005 | 25.6 | 15.3 |
| 1,503 | .00436 | 33.5 | 13.9 |
| 1,643 | .0002 | 28.9 | 12.7 |
| 1,680[2] | <.00002 | 26.8 | 13.2 |
| 1,869 | .0023 | 28.1 | 12.0 |
| 1,953 | .0002 | 26.5 | 23.7 |
| 2,121 | .1508 | 27.6 | 3.7 |
| 2,355 | .023 | 30.9 | 15.7 |

[1]Injection pressure of 1,500 lb/in$^2$ atmospheric.
[2]Small fractures in sample; wetting phase saturation may be higher than indicated.

## GRAIN-SIZE DISTRIBUTION

Mechanical analyses of grain-size distribution were made on 14 samples by J. H. Kleinfelder and Associates, geotechnical consultants, Sacramento, Calif. (fig. 6). The procedure used was American Society for Testing and Materials designation D 422 (American Society for Testing and Materials, 1980).

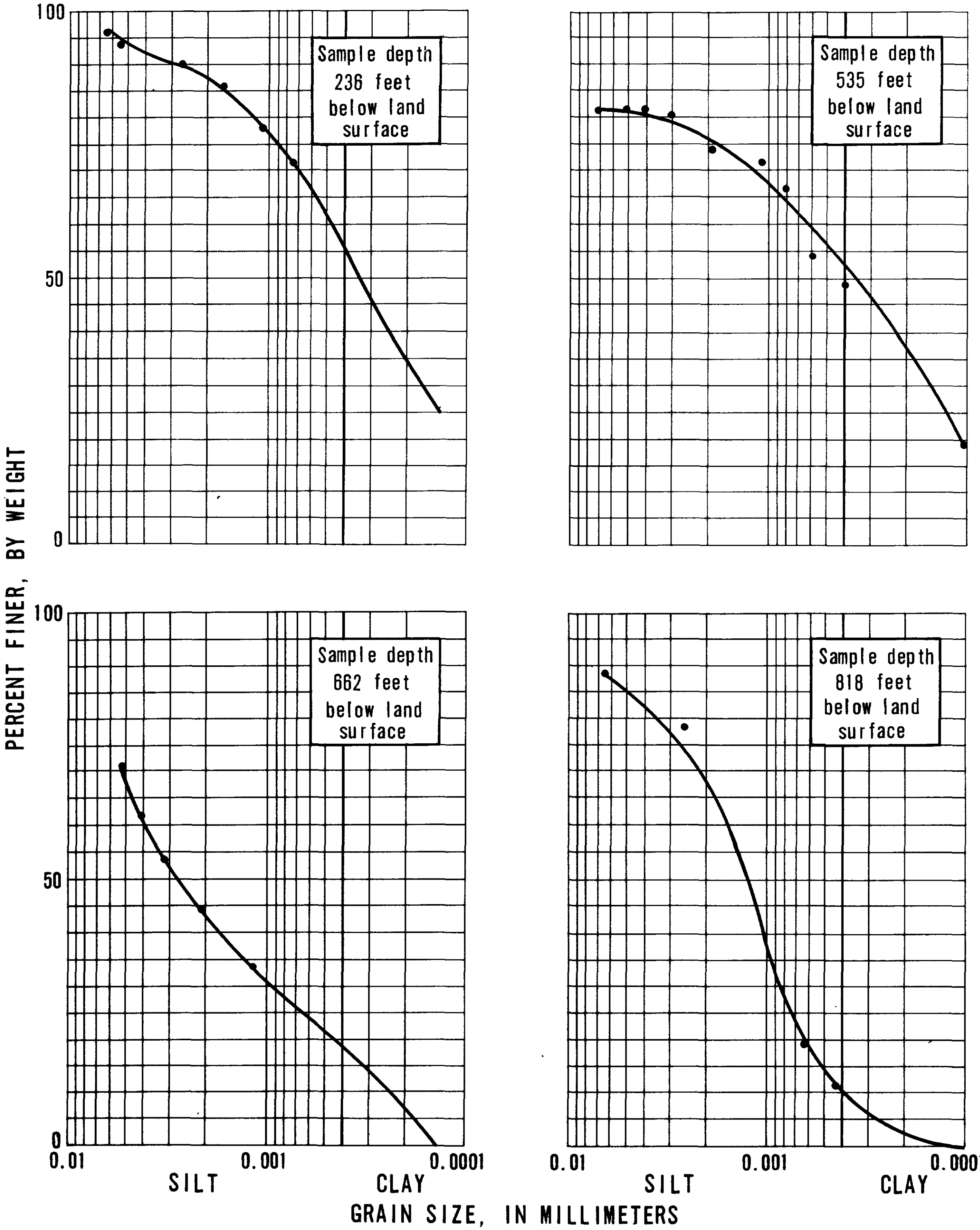



FIGURE 6.— Grain–size distribution.

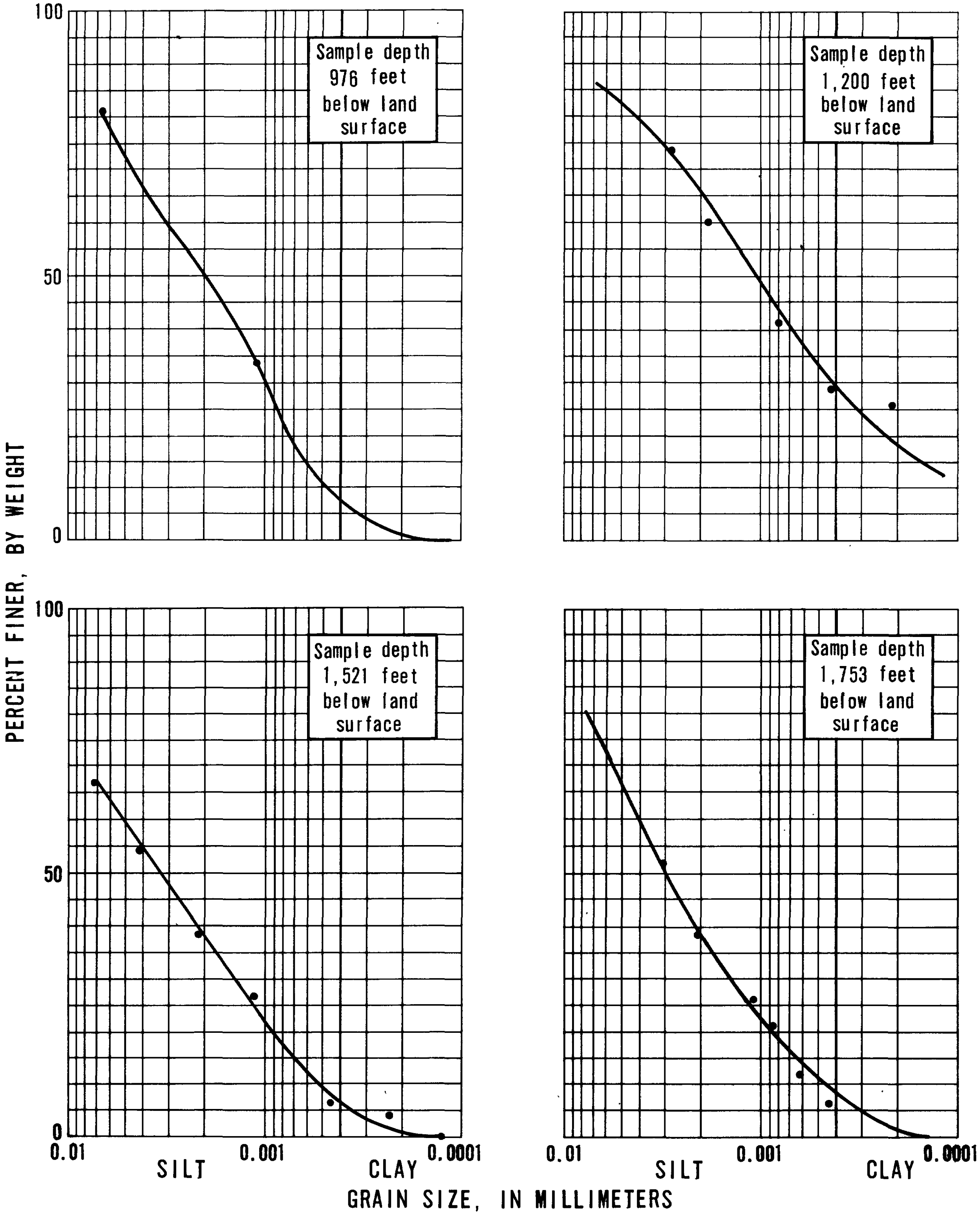



FIGURE 6.– Continued.

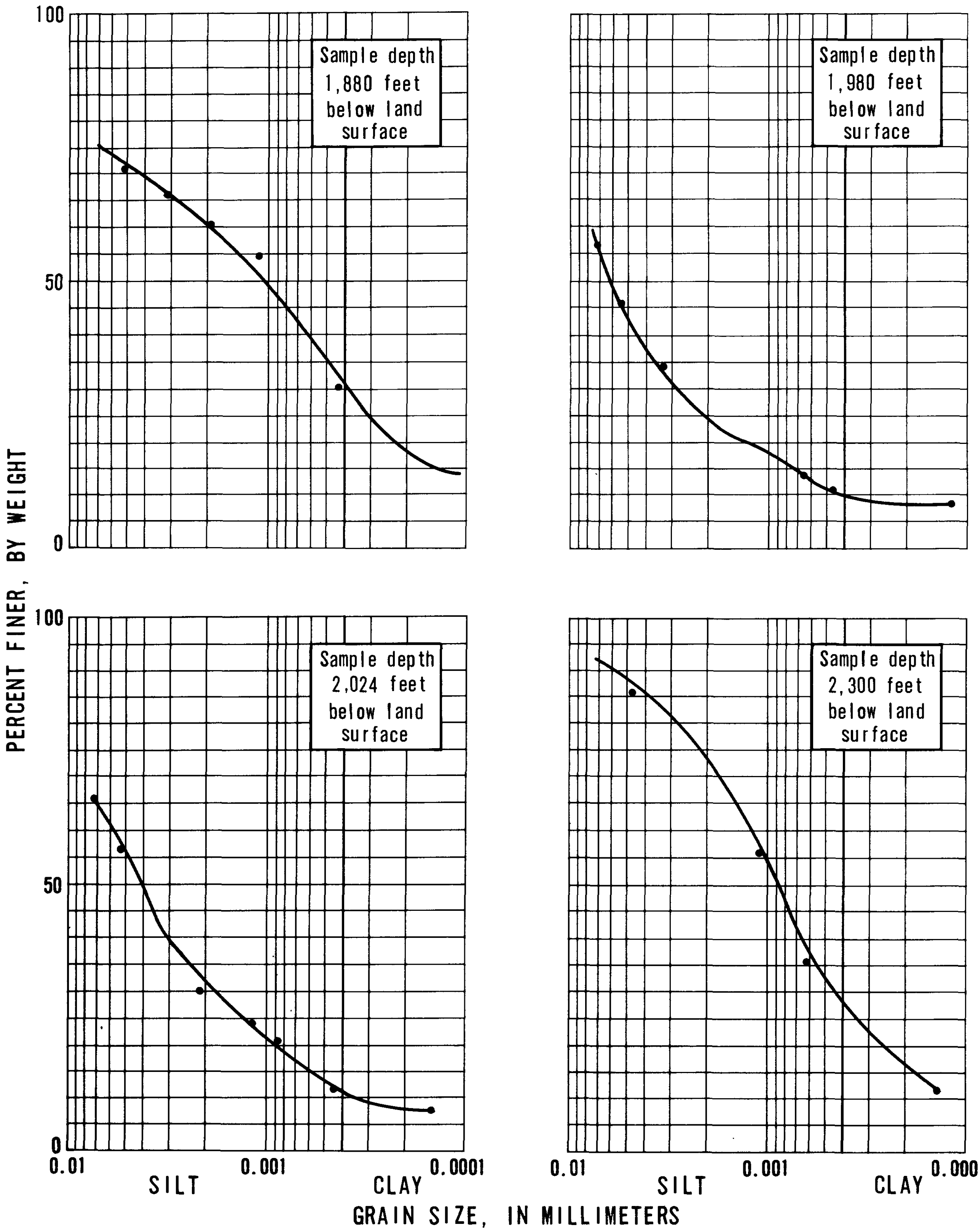



FIGURE 6.— Continued.

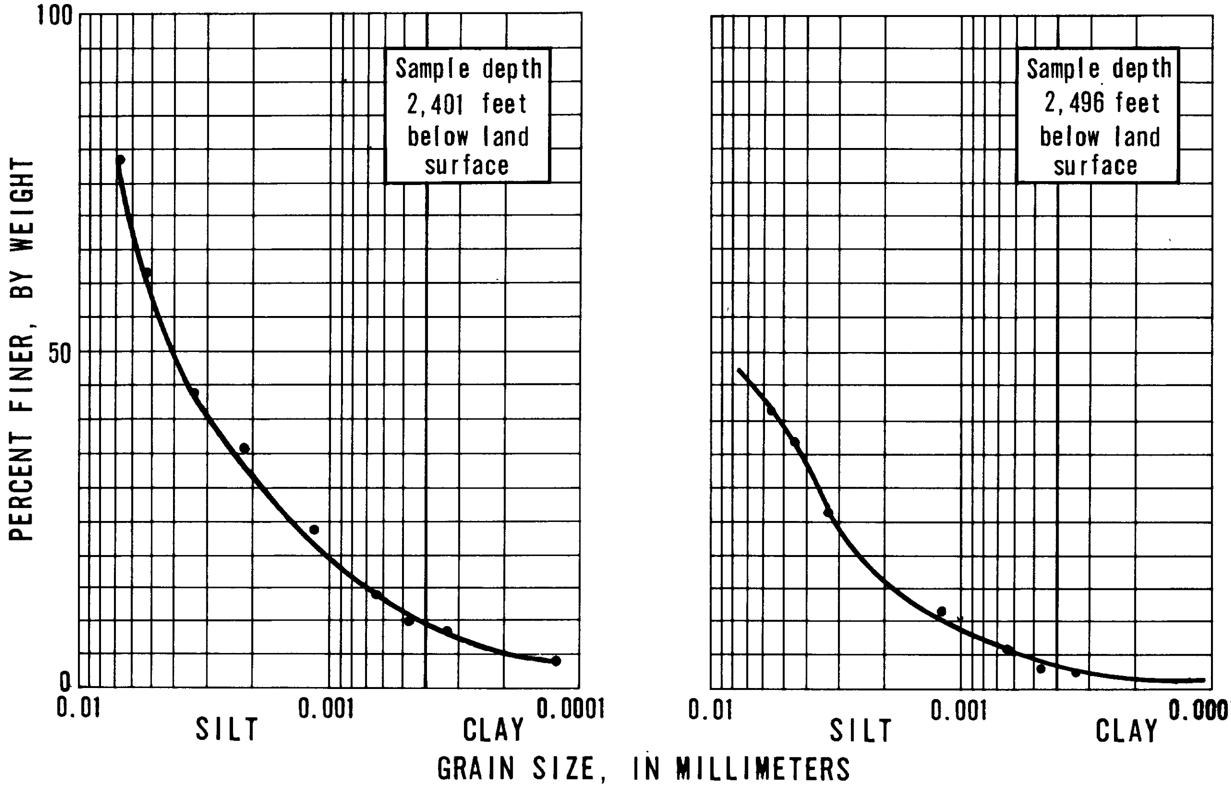



FIGURE 6.— Continued.

## ASH

A pumiceous ash found in samples from a depth of 453 ft was at first thought to be equivalent to the Maidu ash (informal usage) because of the nearly identical major chemical elements (table 10). Trace elements are different, however, indicating that the pumiceous ash is not the Maidu ash (E. J. Helley, U.S. Geological Survey, oral commun., 1980). C. E. Meyer and A. M. Sarna-Wojcicki of the U.S. Geological Survey now consider the ash as probably being younger than the Maidu (E. J. Helley, oral commun., 1980). The Maidu ash is 450,000 ± 80,000 years old (E. J. Helley, oral commun., 1980, and R. W. Page and G. L. Bertoldi, U.S. Geological Survey, written commun., 1981).

TABLE 10. - Major chemical elements in three pumice samples from depth of 453 feet

[Analyses by C. E. Meyer, U.S. Geological Survey, written commun., 1980]

| Element | White Pumice Lab No. T 21-1 | White Pumice Lab. No. T 21-2 | Tan Pumice Lab. No. T 21-3 | Maidu ash (mean)[1] |
|---|---|---|---|---|
| | Atomic weight (percent of sample) | | | |
| Silica (Si) | 33.432 | 32.795 | 34.091 | 34.17±0.32 |
| Aluminum (Al) | 6.283 | 6.320 | 6.459 | 6.28± .15 |
| Iron (Fe) | .566 | .599 | .519 | .56± .02 |
| Magnesium (Mg) | .095 | .096 | .101 | .10± .01 |
| Manganese (Mn) | .023 | .027 | .013 | .12± .01 |
| Calcium (Ca) | .575 | .583 | .591 | .59± .02 |
| Barium (Ba) | .088 | .078 | .097 | .08± .01 |
| Titanium (Ti) | .095 | .090 | .091 | .09± .01 |
| Sodium (Na) | 2.371 | .730 | 2.443 | 2.64± .10 |
| Potassium (K) | 2.866 | 2.809 | 3.018 | 2.81± .11 |
| Chlorine (Cl) | .115 | .099 | .100 | .10± .01 |
| Oxygen (O) | 53.491 | 53.813 | 52.475 | -- |

[1]E. J. Helley (U.S. Geological Survey, written commun., 1980).

## DIATOMS

A silty-clay interval was cored (core no. 3, 534-544 ft), and an interval of diatomaceous clay was recovered. A sample of this clay from a depth of 535 ft was submitted to J. Platt Bradbury of the Paleontology and Stratigraphy Branch of the U.S. Geological Survey in Denver, Colo. His comments and analyses are used throughout this section.

According to Bradbury (written commun., 1979) the sample contained the following diatoms:

*Epithemia adnata
*E. turgida
Eunotia pectinalis
*E. monodon v. major
E. quaternaria
E. flexuosa
Synedra ulna
S. capitata
*Fragilaria brevistriata
*F. construens v. venter
Cyclotella meneghiniana
*Melosira italica?
Melosira distans
*Melosira sp. cf. m. interrupta
*Amphicampa eruca
Cocconeis placentula
Amphora ovalis
Rhopalodia gibba
R. gibba v. ventricosa
Cymbella minuta
C. aspera
Gomphonema sp. cf. g. turris
G. accuminatum v. clavus

Species marked by an asterisk (*) are the more common elements of the flora. The diatom flora is quite diverse, and ecologically somewhat inconsistent. For example, the most common species, E. adnata, generally prefers comparatively alkaline water where it lives in shallow environments attached to the stems of submerged aquatic plants. Most of the Eunotia species, however, live in neutral or acidic water in similar habitats. This probably represents seasonal changes in water chemistry with the resulting mixture of diatom species.

The diatom flora certainly resembles that from several of the units of the Corcoran Clay Member of the Tulare Formation of Pliocene and Pleistocene age which K. E. Lohman of the U.S. Geological Survey reported in 1954 (written commun.), and a general correlation with this deposit would seem to be a good possibility. On the other hand, there are no species of Stephanodiscus in the Zamora sample, and they occur in considerable abundance in most of the samples of the Corcoran Clay member samples from the San Joaquin Valley studied by Lohman. This suggests that an exact correspondence between the samples is not likely although it is possible that environmental differences over such a distance could account for the lack of Stephanodiscus species in the Zamora sample.

These comments also apply to the relation between the Zamora sample and the diatomaceous clay from the Montezuma Hills area in the southern Sacramento Valley on which Lohman of the U.S. Geological Survey reported (Olmsted and Davis, 1961, p. 74). The Montezuma Hills are approximately 20 mi due south of the test hole.

## THERMAL CONDUCTIVITY

In 10 of the cores thermal conductivity was measured by needle probe by the Office of Earthquake Studies, Branch of Tectonophysics of the U.S. Geological Survey in Menlo Park, Calif. In this method a hypodermic needle (fig. 7), which contains a heating wire and a temperature-sensing thermistor, is inserted into a part of the core. A constant electric current is applied to the heating wire and the rise in temperature is recorded. After an initial high rate of temperature increase, the rate of temperature increase versus logarithm of time stabilizes. The stabilized rate of temperature increase is the thermal conductivity, which depends largely on the water content and very little on the mineralogical composition of the core (Von Herzen and Maxwell, 1959). Thermal conductivities and pertinent data for 10 cores from test hole 12N/1E-34Q are given in table 11.

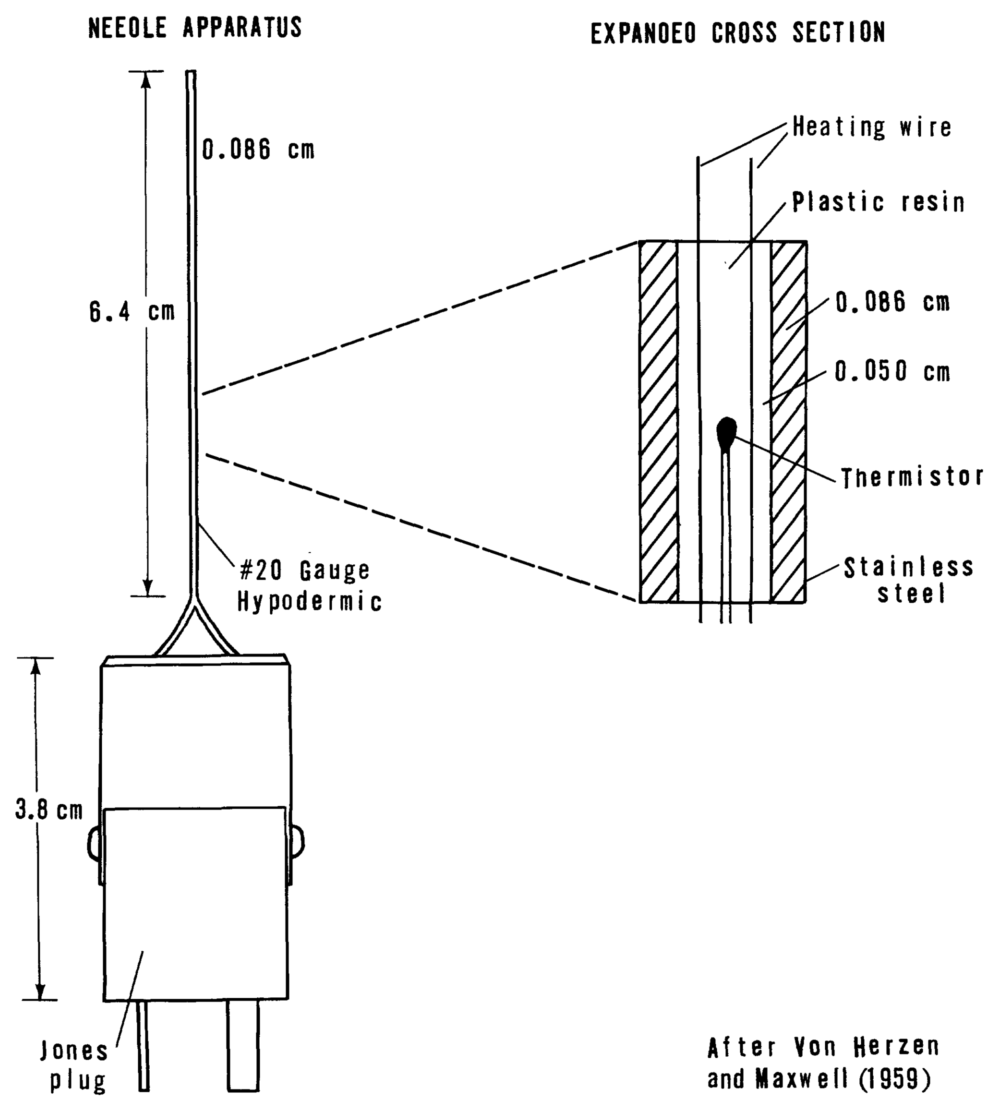



FIGURE 7.--Needle-probe apparatus for measuring thermal conductivity.

TABLE 11. - Thermal conductivity data

[Test angle: A, axial, R, radial; Probe: T, top of core; B, bottom of core; Condition: N, natural; M, moist]

| Core | Depth (feet) | Test angle | Probe | Conductivity (Watt per meter Kelvin) | Condition | Comment |
|---|---|---|---|---|---|---|
| 2 | 223 | A | T | 1.44 | N | Fairly firm. |
| | 223.8 | A | B | 1.49 | N | Fairly firm. |
| 3 | 539 | A | T | 1.36 | M | Cap on one end not sealed. Moisture and firmness appear to be consistent throughout core. |
| | 541.5 | R | | 1.31 | M | |
| | 544 | A | B | 1.27 | M | |
| 4 | 814 | A | T | 1.25 | N | Fairly hard. Use short probe. |
| | 816 | R | | 1.45 | N | Fairly hard. Use long probe. |
| | 817 | A | B | 1.31 | N | Fairly hard. Use short probe. |
| | 818 | A | T | 1.39 | N | All tending to be on dry side. |
| | 819.5 | R | | 1.21 | N | Bottom part of sample appears to be sand. |
| | 824 | A | B | .95 | N | |
| 5 | 848 | A | T | 1.91 | N | Pretty firm. |
| | 849.5 | R | | 1.48 | N | Pretty firm. |
| | 851 | A | B | 1.52 | N | Pretty firm. |
| 8 | 974 | A | T | 1.40 | N | Firm. |
| | 975 | R | | 1.29 | N | Firm. |
| | 976 | A | B | 1.37 | N | Firm. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | 977 | A | T | 1.18 | N | Top is on dryish side. |
| | 979 | A | B | .81 | N | |
| 9 | 1,201 | A | T | 1.68 | N | Firm. |
| | 1,202 | A | B | 1.87 | N | Firm. |
| 10 | 1,519 | A | T | 1.43 | N | Small core, 2-inch diameter. |
| | 1,520 | R | | 1.42 | N | |
| 11 | 1,754 | A | T | 1.31 | N | Fairly hard--shade dry. |
| | 1,755.5 | R | | 1.38 | N | Fairly hard--shade dry. |
| | 1,757 | A | B | 1.42 | N | Fairly hard--shade dry. |
| 12 | 1,882.5 | R | | .79 | N | Hard. |
| | 1,885 | A | B | 1.04 | N | Hard. |
| 14 | 2,025 | A | T | 1.34 | N | Very firm. |
| | 2,027 | R | | 1.48 | N | Very firm. |
| | 2,029 | A | B | 1.50 | N | Very firm. |

| | | Number | Standard error |
|---|---|---|---|
| Average of all tests | 1.34 | 30 | 0.11 |
| Average of axial tests | 1.37 | 21 | .12 |
| Average of radial tests | 1.27 | 9 | .24 |
| Average of top | 1.40 | 11 | .13 |
| Average of bottom | 1.33 | 10 | .20 |

Note: Averages do not include dubious test on core 8 at 979-foot depth.

## THERMAL GRADIENT LOG

A graphic log of the thermal gradient was made by the U.S. Geological Survey's Office of Earthquake Studies, Branch of Tectonophysics (fig. 8). The thermal gradient was 20.25°C/km and the bottom-hole temperature was 29.5°C. Projected from the thermal gradient through the zero depth axis the top-hole temperature was estimated to be 16.8°C.

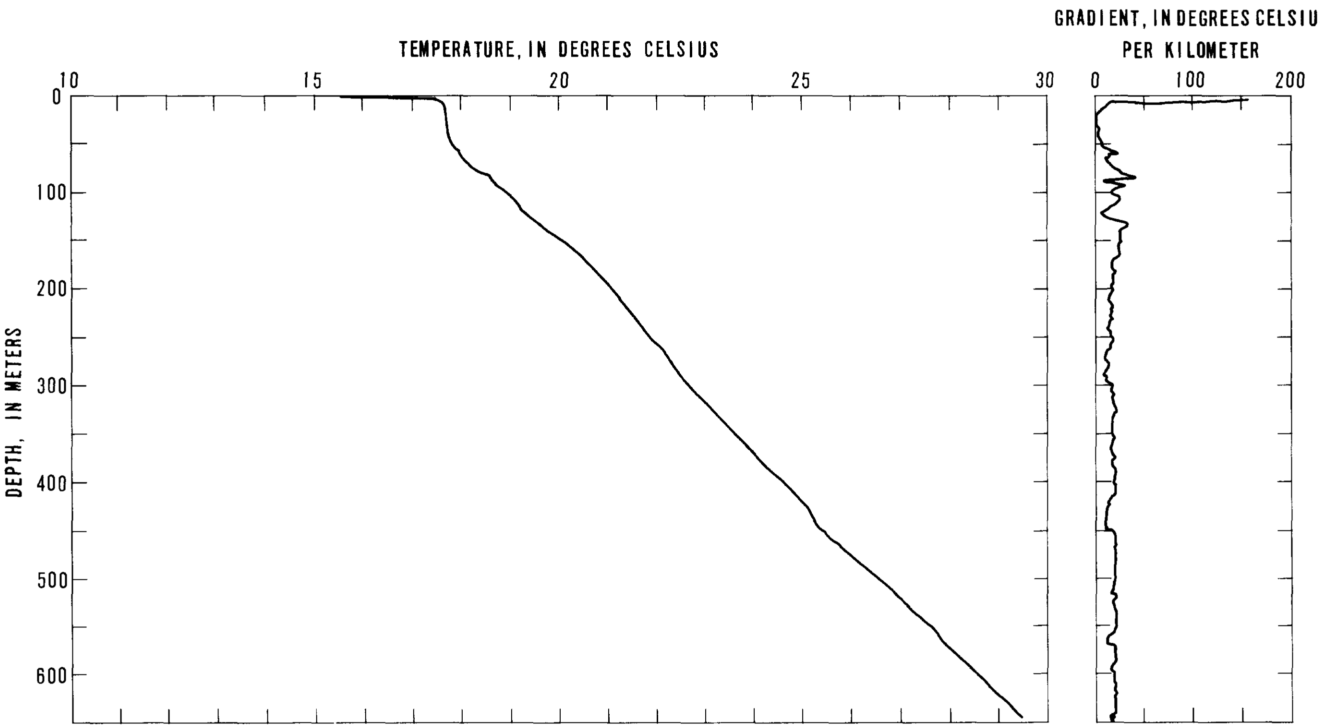



FIGURE 8.– Thermal gradient log.

## CHEMICAL ANALYSES OF WATER

The chemical characteristics of the water in the three depth zones opposite the screened intervals were obtained from water samples collected by submersible pump. In each instance a quantity of water equal to the volume of the casing was pumped out at least once before a sample was collected. For example, the deep zone was pumped at the rate of 10 gal/min for 6 hours, the middle zone for 4 hours, and the shallow zone for 2 hours. During these times the values for specific conductance and temperature stabilized.

Specific conductance, pH, temperature, and alkalinity were recorded at the field site. After completing field determinations, the remaining part of the sample was split. Samples that required filtering were filtered using a 0.1-micrometer filter membrane. Samples to be analyzed for nutrients were chilled immediately after filtering by packing in ice. All samples were refrigerated until packed for shipping to the U.S. Geological Survey Central Laboratory in Denver, Colo.

The analyses are shown in table 12. Figures 9 and 10 show the chemical differences in the water samples. Figure 9 shows plots of the ionic analyses of five samples and is a water-type classification as described by Piper (1944). Figure 10 is a classification of irrigation water based on sodium and salinity hazards according to the U.S. Salinity Laboratory Staff (1954). The water from the deep zone near 2,120-2,125 ft (34Q1) is a sodium chloride type with a dissolved-solids concentration of more than 1,200 mg/L. The sodium hazard (fig. 10) is very high and the salinity hazard is high. The water from near the 1,396-1,401 ft (34Q2) zone is a sodium bicarbonate type ranging in dissolved-solids concentration from 482 mg/L in 1979 to 428 mg/L in 1980. The sodium hazard ranged from medium in 1979 to very high in 1980; the salinity hazard is medium. The water from near the 942-947-foot zone (34Q3) is a sodium bicarbonate type with a dissolved-solids concentration of 426 mg/L. The sodium hazard is low and the salinity hazard is medium.

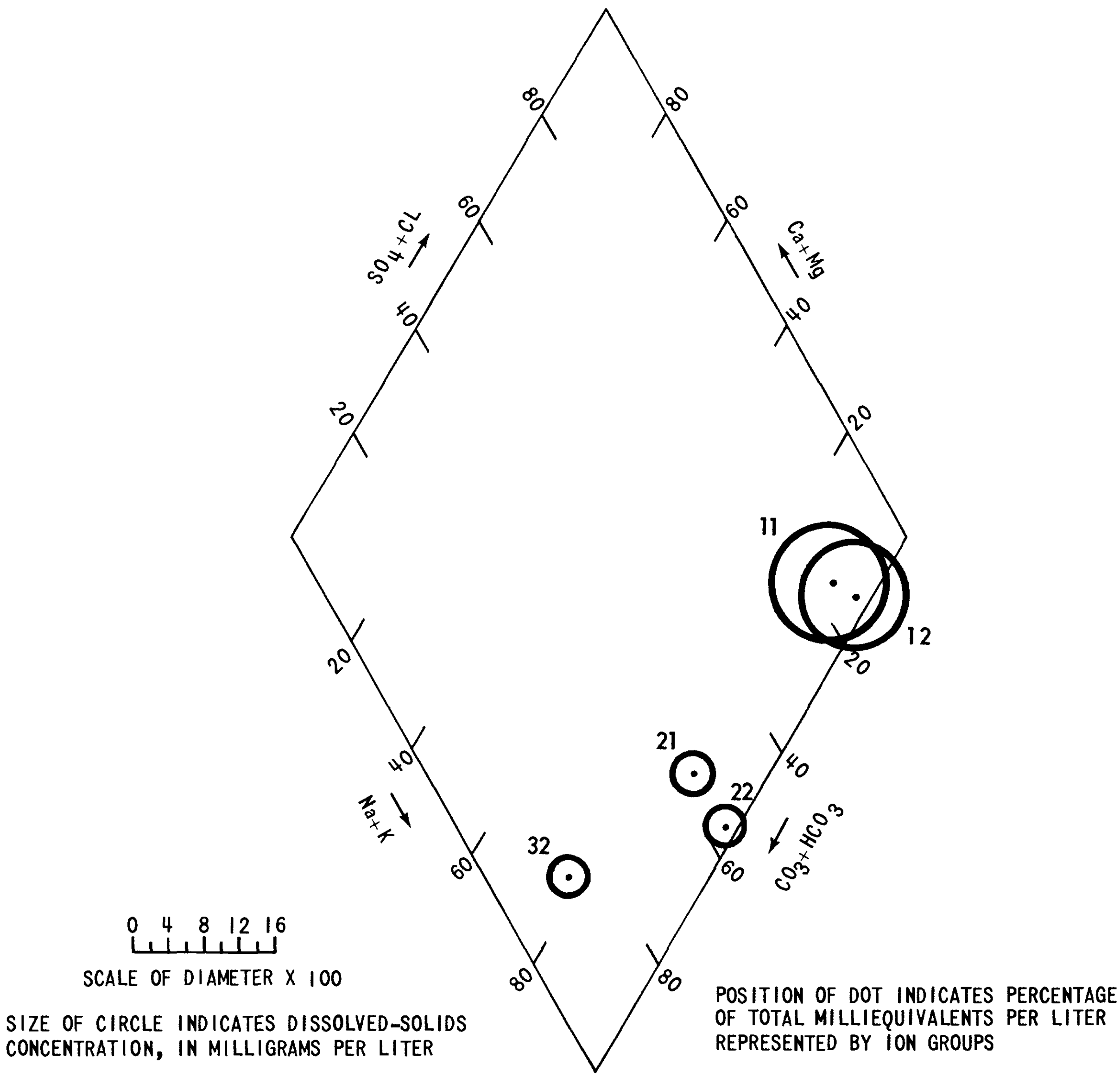
TABLE 12. - Water-quality analysis

| LOCAL IDENT- I- FIER | STATION NUMBER | DATE OF SAMPLE | DEPTH OF WELL, TOTAL (FEET) | SPE- CIFIC CON- DUCT- ANCE (UMHOS) | PH (UNITS) | TEMPER- ATURE (DEG C) | HARD- NESS (MG/L AS CACO3) | HARD- NESS, NONCAR- BONATE (MG/L CACO3) | CALCIUM DIS- SOLVED (MG/L AS CA) |
|---|---|---|---|---|---|---|---|---|---|
| 012N001E34Q01M | 385020121503601 | 79-05-04 | 2125 | 2210 | 8.4 | 21.0 | 90 | 0 | 27 |
| | | 80-04-16 | 2125 | 2546 | -- | 21.0 | 45 | 0 | 12 |
| 012N001E34Q02M | 385020121503602 | 79-05-04 | 1401 | 730 | 8.6 | 21.5 | 49 | 0 | 14 |
| | | 80-04-16 | 1401 | 756 | -- | 20.0 | 9 | 0 | 2.5 |
| 012N001E34Q03M | 385020121503603 | 80-04-16 | 947 | 620 | 7.9 | 19.5 | 79 | 0 | 22 |

| DATE OF SAMPLE | MAGNE- SIUM, DIS- SOLVED (MG/L AS MG) | SODIUM, DIS- SOLVED (MG/L AS NA) | PERCENT SODIUM | SODIUM AD- SORP- TION RATIO | POTAS- SIUM, DIS- SOLVED (MG/L AS K) | ALKA- LINITY FIELD (MG/L AS CACO3) | SULFATE DIS- SOLVED (MG/L AS SO4) | CHLO- RIDE, DIS- SOLVED (MG/L AS CL) | FLUO- RIDE, DIS- SOLVED (MG/L AS F) |
|---|---|---|---|---|---|---|---|---|---|
| 79-05-04 | 5.5 | 470 | 92 | 22 | 3.1 | 180 | 10 | 660 | .2 |
| 80-04-16 | 3.6 | 460 | 95 | 30 | 3.1 | 140 | 2.0 | 630 | .4 |
| 79-05-04 | 3.5 | 160 | 87 | 9.9 | 3.1 | 221 | 35 | 95 | .2 |
| 80-04-16 | .6 | 160 | 96 | 24 | 3.4 | 200 | .2 | 110 | .7 |
| 80-04-16 | 5.8 | 120 | 75 | 5.9 | 4.9 | 290 | 22 | 16 | .1 |

| DATE OF SAMPLE | SILICA, DIS- SOLVED (MG/L AS SIO2) | SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L) | SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L) | NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N) | ALUM- INUM, DIS- SOLVED (UG/L AS AL) | ARSENIC DIS- SOLVED (UG/L AS AS) | BARIUM, DIS- SOLVED (UG/L AS BA) | BORON, DIS- SOLVED (UG/L AS B) | CADMIUM DIS- SOLVED (UG/L AS CD) |
|---|---|---|---|---|---|---|---|---|---|
| 79-05-04 | 17 | -- | 1310 | -- | -- | -- | -- | 12000 | -- |
| 80-04-16 | 1.8 | 1250 | 1210 | .02 | 30 | 1 | 400 | 11000 | 0 |
| 79-05-04 | 38 | -- | 483 | -- | -- | -- | -- | 1100 | -- |
| 80-04-16 | 1.0 | 428 | 400 | .03 | -- | -- | -- | 1100 | -- |
| 80-04-16 | 43 | 426 | 409 | .02 | -- | -- | -- | 810 | -- |

| DATE OF SAMPLE | CHRO- MIUM, DIS- SOLVED (UG/L AS CR) | COPPER, DIS- SOLVED (UG/L AS CU) | IRON, DIS- SOLVED (UG/L AS FE) | LEAD, DIS- SOLVED (UG/L AS PB) | MERCURY DIS- SOLVED (UG/L AS HG) | MOLYB- DENUM, DIS- SOLVED (UG/L AS MO) | SELE- NIUM, DIS- SOLVED (UG/L AS SE) | SILVER, DIS- SOLVED (UG/L AS AG) | ZINC, DIS- SOLVED (UG/L AS ZN) |
|---|---|---|---|---|---|---|---|---|---|
| 79-05-04 | -- | -- | 40 | -- | -- | -- | -- | -- | -- |
| 80-04-16 | 0 | 0 | 30 | 0 | .0 | 55 | 0 | 0 | 890 |
| 79-05-04 | -- | -- | 40 | -- | -- | -- | -- | -- | -- |
| 80-04-16 | -- | -- | <10 | -- | -- | -- | -- | -- | -- |
| 80-04-16 | -- | -- | <10 | -- | -- | -- | -- | -- | -- |




**PERCENTAGE REACTING VALUES**

| SAMPLE NO | TUBE NO | DATE | DISSOLVED SOLIDS (mg/L) | DEPTH (feet) |
|---|---|---|---|---|
| 11 | 34Q1 | 5-4-79 | 1310 | 2125 |
| 21 | 34Q2 | 5-4-79 | 482 | 1401 |
| 12 | 34Q1 | 4-16-80 | 1250 | 2125 |
| 22 | 34Q2 | 4-16-80 | 428 | 1401 |
| 32 | 34Q3 | 4-16-80 | 426 | 947 |

**FIGURE 9.--Water-analysis diagram.**

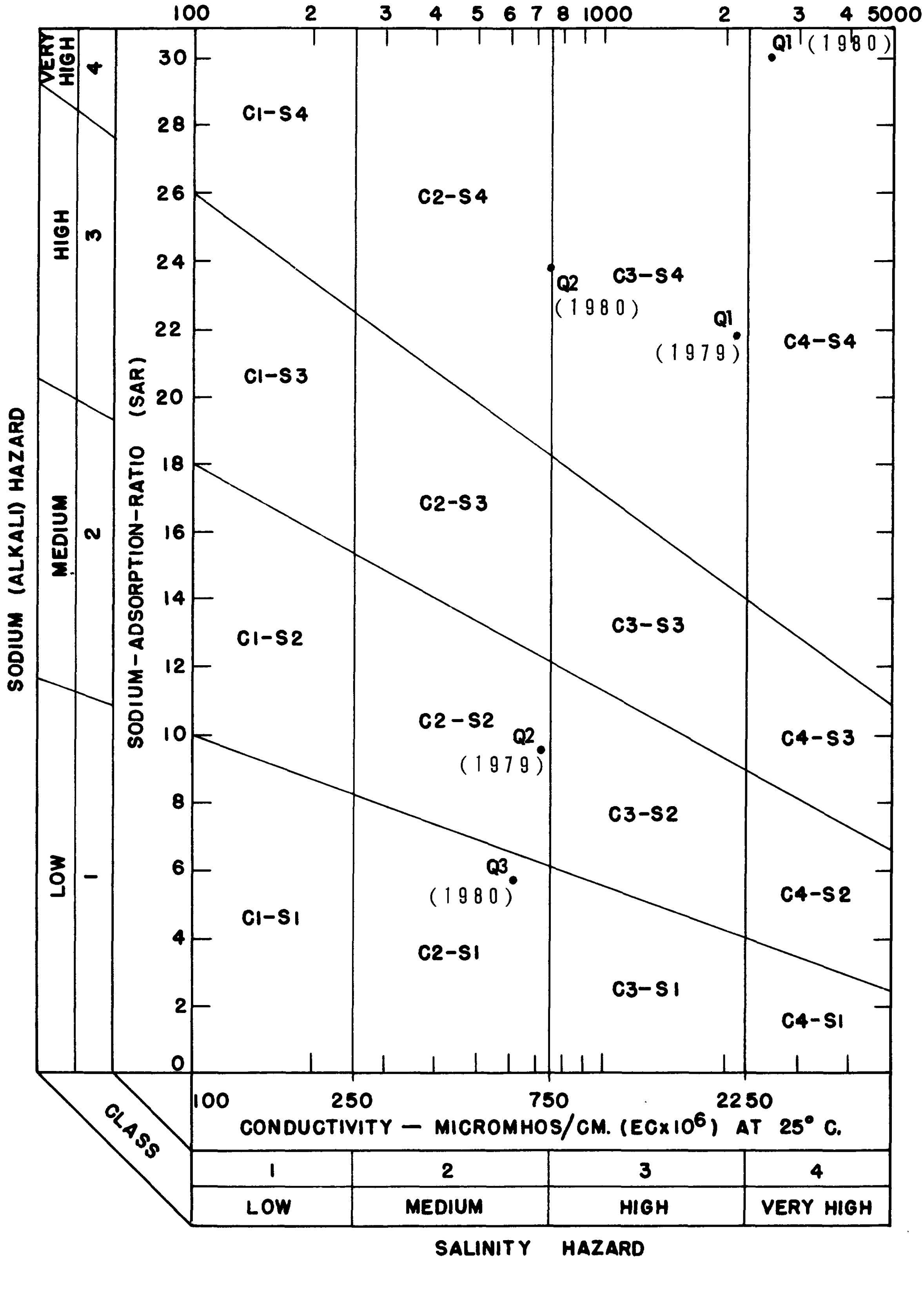



FIGURE 10.--Diagram for the classification of irrigation waters. (From U. S. Salinity Laboratory Staff, 1954, p. 80).

## HYDROGRAPHS

Water levels in three piezometers were measured periodically (table 13) and monitored continuously by recorders. Hydrographs (figs. 11-13) show the fluctuation of water levels in each zone.

TABLE 13. - Records of water level

[Altitude of land surface is 24.27 ft above National Geodetic Vertical Datum of 1929. Measuring point is top of casing]

| Date | Depth to water in feet above (+) or below (-) land surface | | |
|---|---|---|---|
| | Q1 depth 2,125 ft | Q2 depth 1,401 ft | Q3 depth 947 ft |
| Aug. 2, 1979 | +0.45 | -14.46 | -3.88 |
| Aug. 30 | +.53 | -17.11 | -4.10 |
| Oct. 5 | +.17 | -19.27 | -4.81 |
| Nov. 7 | +.06 | -19.23 | -5.12 |
| Dec. 6 | -.06 | -18.23 | -5.44 |
| Dec. 28 | -.02 | -16.91 | -5.39 |
| Jan. 29, 1980 | +.27 | -14.96 | -5.08 |
| Feb. 28 | +1.84 | -11.76 | -4.03 |
| Mar. 20 | +.85 | -12.05 | -4.75 |
| Apr. 16 | +.20 | -10.39 | -4.29 |
| May 14 | +.22 | -9.67 | -3.56 |
| June 18 | +.33 | -11.23 | -3.27 |
| July 9 | +.43 | -12.55 | -3.22 |
| July 30 | +.50 | -13.95 | -3.10 |
| Aug. 21 | +.52 | -15.40 | -3.15 |

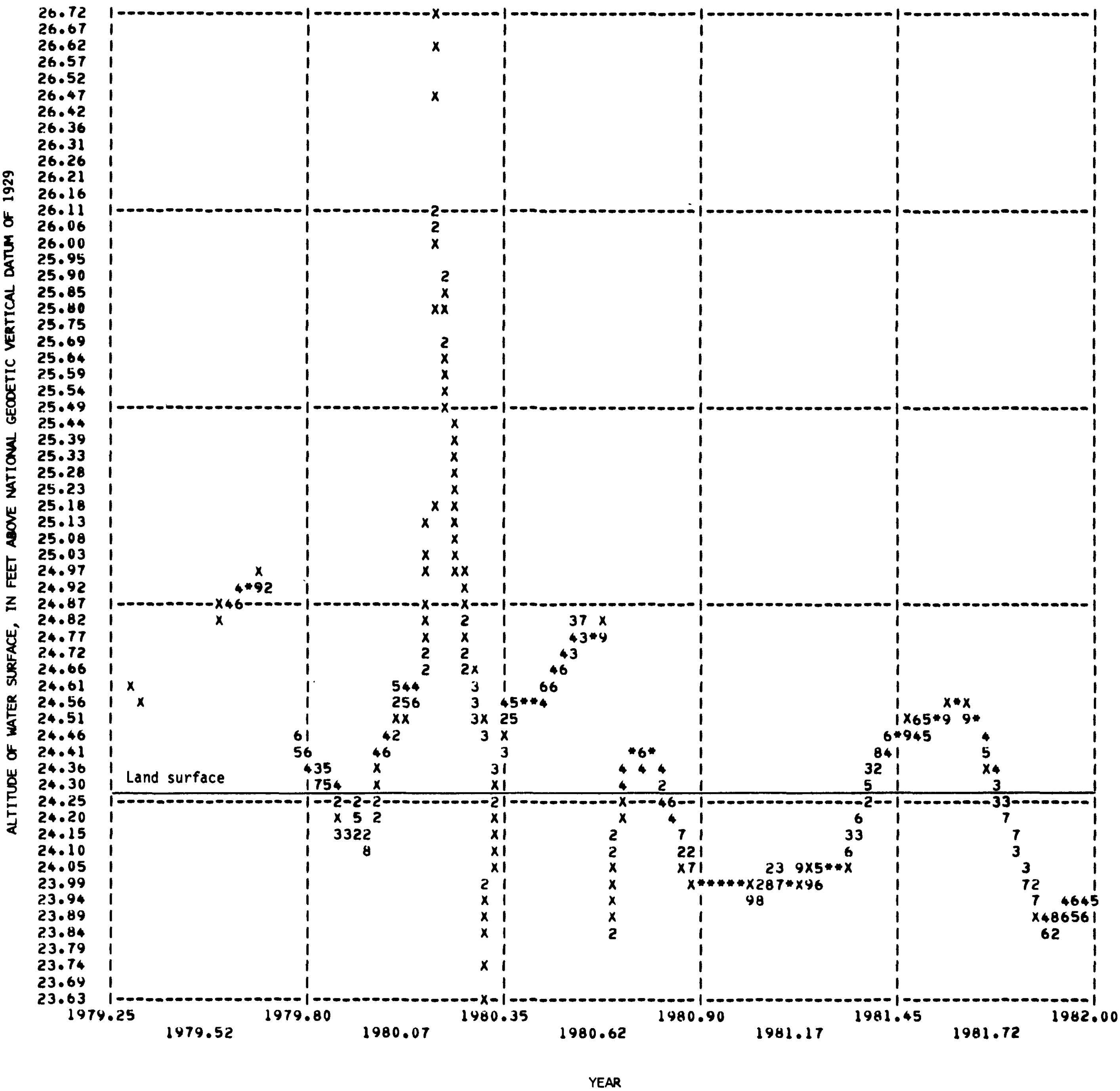



FIGURE 11.--Hydrograph of well 12N/1E-34Q1 near Zamora, Calif. [Explanation of plot: Symbol for a single Y-X plot point = X; numbers 2 to 9 are used for overprinted Y-X plot values and * for more than 9 values.]

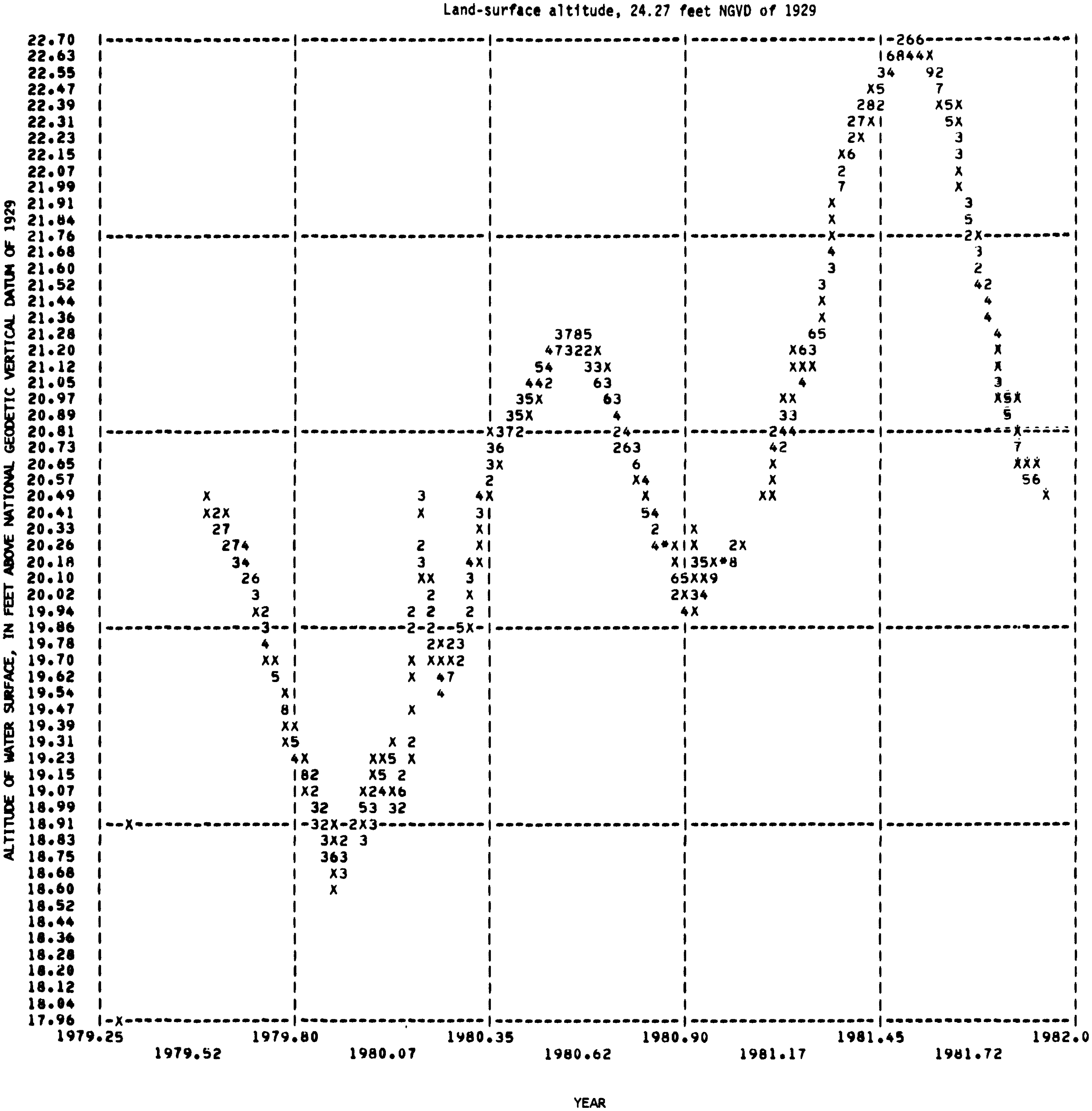



FIGURE 12.--Hydrograph of well 12N/1E-34Q2 near Zamora, Calif. [Explanation of plot: Symbol for a single Y-X plot point = X; numbers 2 to 9 are used for overprinted Y-X plot values and * for more than 9 values.]

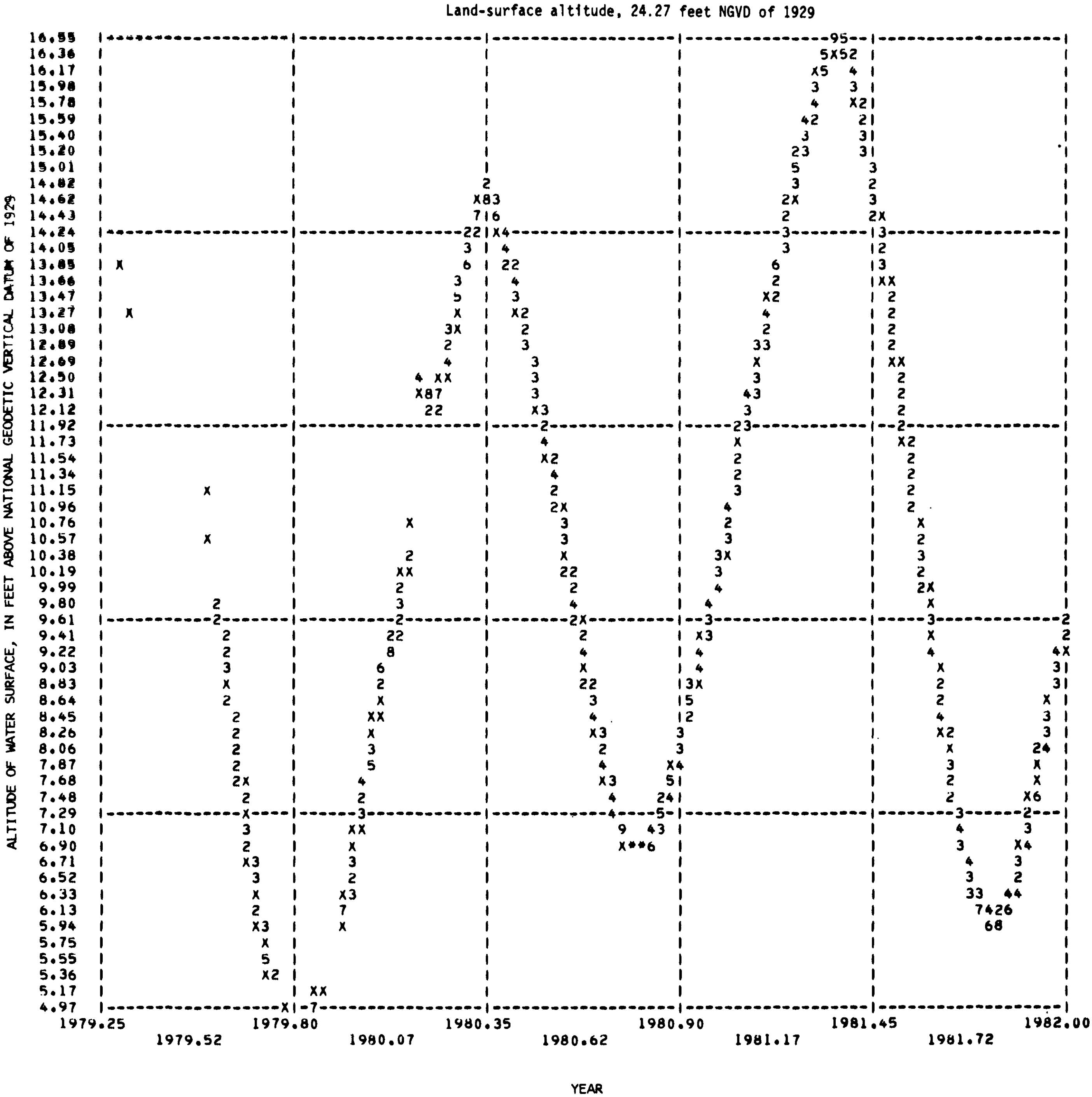



FIGURE 13.--Hydrograph of well 12N/1E-34Q3 near Zamora, Calif. [Explanation of plot: Symbol for a single Y-X plot point = X; numbers 2 to 9 are used for overprinted Y-X plot values and * for more than 9 values.]

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