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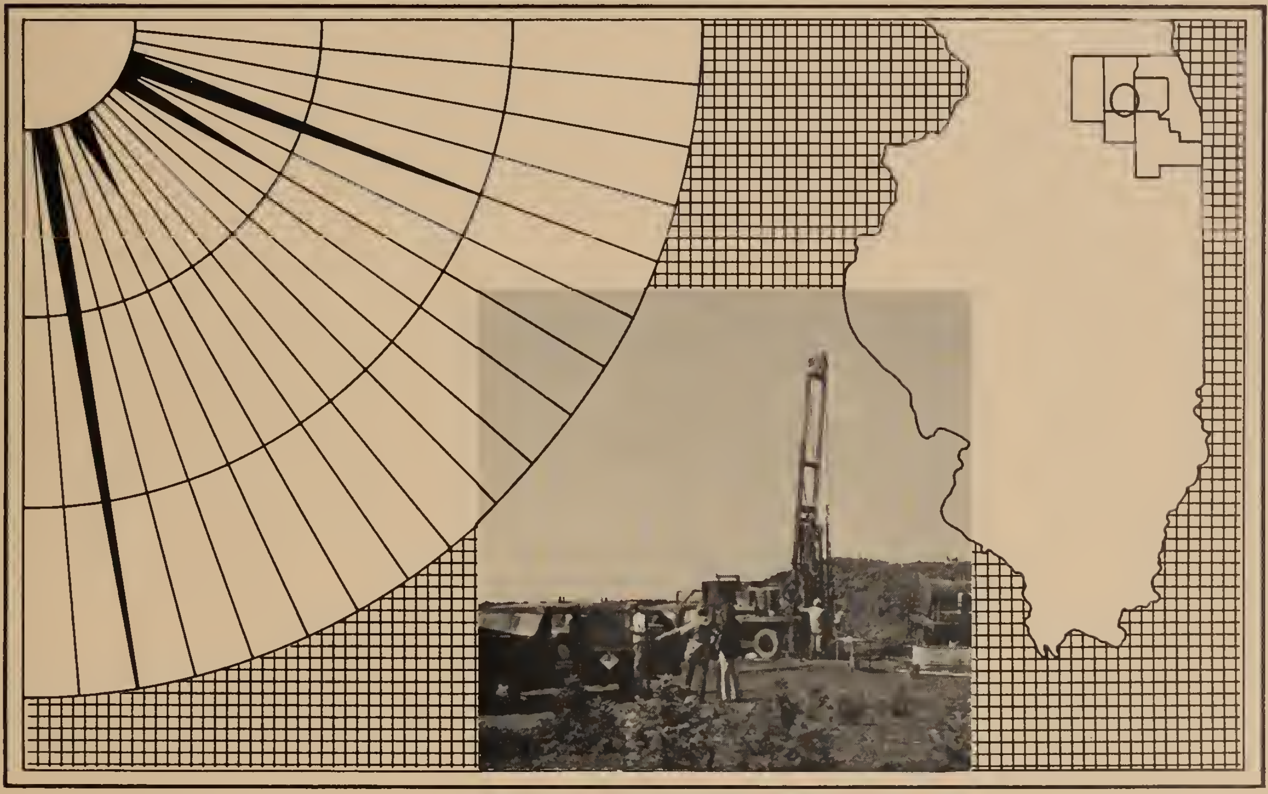
GEOLOGICAL-GEOTECHNICAL STUDIES FOR SITING THE SUPERCONDUCTING SUPER COLLIDER IN ILLINOIS

Results of the Spring 1985 Test Drilling Program

J. P. Kempton, R. A. Bauer, B. B. Curry, W. G. Dixon, Jr.,
A. M. Graese, P. C. Reed, and R. C. Vaiden



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ABSTRACT

As a continuation of a regional drilling program that began in 1984 for siting the Superconducting Super Collider (SSC), a proposed proton accelerator, 2366 feet of NX wireline bedrock core and 200 split-spoon samples representing 1043 feet of glacial drift were recovered from eight test holes drilled in Kane, Du Page, Kendall and De Kalb counties of northeastern Illinois. On-site observations established the lithology, drilling rate, fracture frequency, rock quality designation, joint and fracture character of the bedrock, and blow counts and approximate unconfined compressive strength for the drift. Post-drilling operations included borehole testing for in-situ geophysical characteristics and permeability. Detailed laboratory descriptions of the core added detail to field logs. Laboratory tests on bedrock included tensile strength, triaxial strength, and unconfined compressive strength; and on the drift, particle-size distribution and moisture content. Data are presented and summarized for each of the eight test holes.

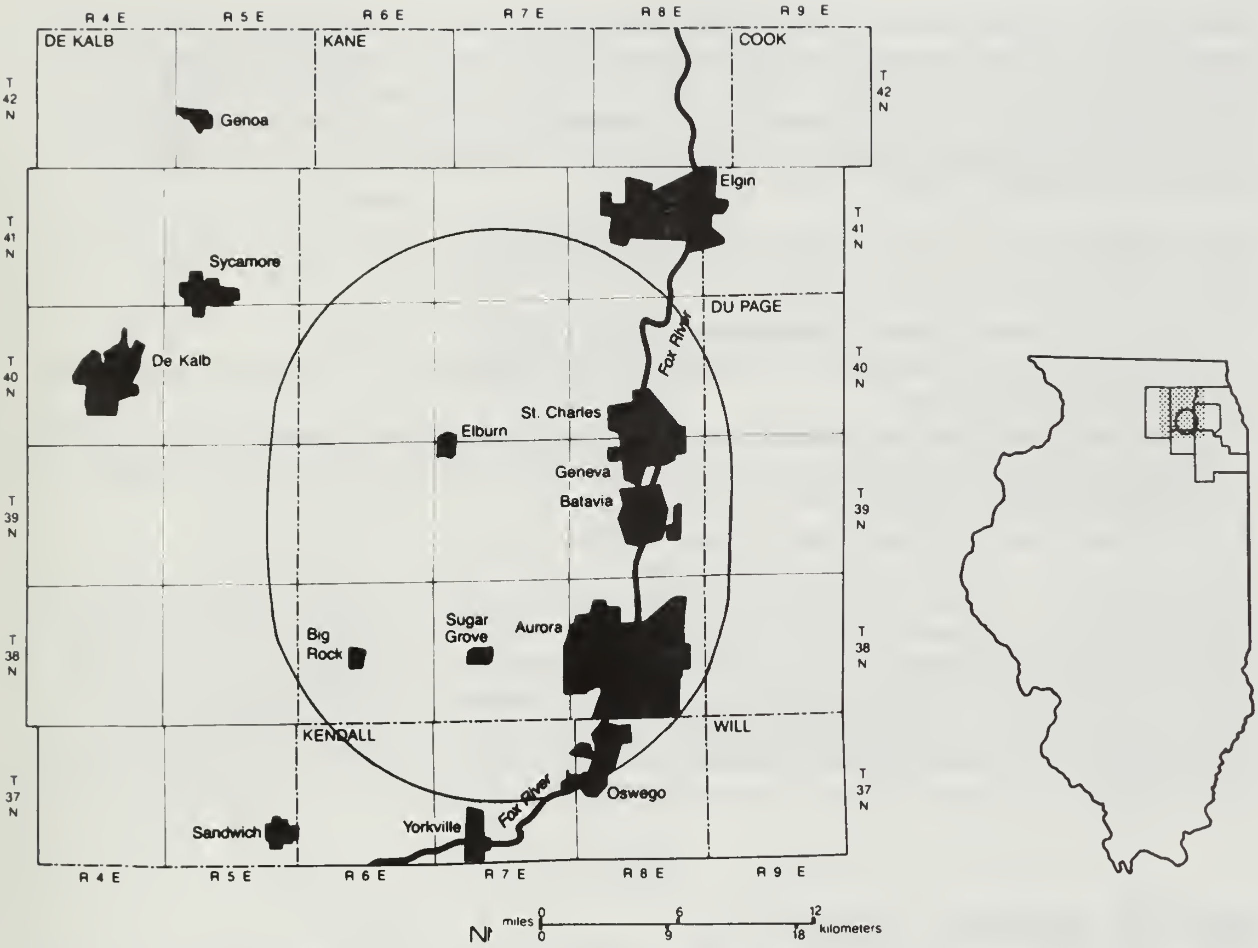


Figure 1 Study area in northeastern Illinois showing one possible ring configuration for the SSC.

INTRODUCTION

The purpose of this report is to summarize logs collected and laboratory results from NXwireline bedrock core and split spoon samples of drift from eight test holes, Illinois State Geological Survey (ISGS) F-10 through F-17. These test holes were drilled to confirm existing information and establish baseline data on the stratigraphic, hydrogeologic, and geotechnical characteristics of the glacial materials and bedrock of the region as part of an extensive program to determine the geological and environmental suitability of northeastern Illinois for siting the proposed Superconducting Super Collider (SSC). Data for the first nine test holes (ISGS F-1 through ISGS F-9) are presented in Kempton and others (1987); reports on the subsequent thirteen test holes and other test drilling are in preparation.

The first seventeen test holes (ISGS F-1–F-17) have been sited in an area of 36 townships (approximately 1,300 square miles) including Kane County and parts of De Kalb, Cook, Du Page, Kendall, and Will Counties (fig. 1). The study was completed prior to selection of a tentative ring and tunnel circumference. The study area extends mainly west of the Fox River about 30 miles west of downtown Chicago. One of the area's major facilities is Fermilab, which is an internationally recognized center for research in high-energy physics. The Tevatron, Fermilab's particle accelerator, could be the injector for the SSC.

Background for these studies has been presented in earlier reports. *Siting the Superconducting Super Collider in Illinois* was published by the Illinois Department of Energy and Natural Resources (DENR) in February 1985 (Etchison, 1985). Later in the year, the Illinois State Geological Survey published the results of the first phase of its investigation: *Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois: Preliminary Geological Feasibility Report* (Kempton and others, 1985).

Site suitability is being evaluated both from an environmental and a geological perspective. The siting studies consist of four phases:

1. preliminary feasibility study (Kempton and others, 1985);
2. investigation of a selected region, including the Fermilab facilities, to locate the most suitable corridor for the SSC ring;
3. verification of predicted surface and subsurface conditions within the corridor and surrounding area by drilling test holes (Kempton and others, 1987), and presentation of the results in geological feasibility reports;
4. consultation services during the site selection process.

This report, part of phase 3, presents the preliminary results of the spring 1985 test drilling program. It provides a description of the procedures used for data collection, a summary of the results, and preliminary interpretations of the samples and other data collected from Test Holes ISGS F-10 through F-17. The detailed field logs and descriptions for all holes are on open file at the Illinois State Geological Survey. Laboratory test data also are on open file at ISGS. Data not yet available will be summarized in subsequent reports. The 1986 test drilling program (Test Holes ISGS S-18 through S-30) will also be presented in another report.

GEOLOGIC SETTING

The geology of the proposed SSC site in northeastern Illinois is characterized by glacially deposited material lying above Paleozoic bedrock, including carbonates, shales, siltstones and some sandstones (fig. 2). Glacial drift thickness ranges from 0 to more than 500 feet. In De Kalb and Kane Counties, the bedrock surface is dissected and filled with glacial materials. The deepest of these valleys is the Troy Bedrock Valley in western De Kalb County where the lowermost elevation of the bedrock surface is less than 450 feet above mean sea level (m.s.l.). Bedrock units dip approximately 0.2° to the southeast. The Ordovician Galena and Platteville Dolomite Groups are exposed at the bedrock surface in De Kalb County (fig. 3). In western Kane County, these dolomite units are overlain by interbedded shale and dolomite of the Ordovician Maquoketa Shale Group, which are in turn overlain by dolomite formations of the Silurian System in eastern Kane and Du Page Counties. In the southwestern part of the study area lies a narrow zone (0.5 to 2 miles wide) of nearly vertical faults—the Sandwich Fault Zone (Kolata and others, 1978). The fault zone juxtaposes the Ordovician Galena and Platteville Dolomite Groups on the northeast side of the fault with Cambrian- and Lower Ordovician-aged rocks of Prairie du Chien Group and Eminence, Potosi, and Franconia Formations on the southwest side.

Additional information on the geologic setting of the study area is discussed in the *Preliminary Geologic Feasibility Study* (Kempton and others, 1985) as well as the *Handbook of Illinois Stratigraphy* (Willman and others, 1975).

Bedrock Stratigraphy

Of primary interest for the SSC siting are the rocks of the Kankakee, Elwood and Wilhelmi Formations (Silurian System), and the Maquoketa, Galena and Platteville Groups (Ordovician System) (fig.2).

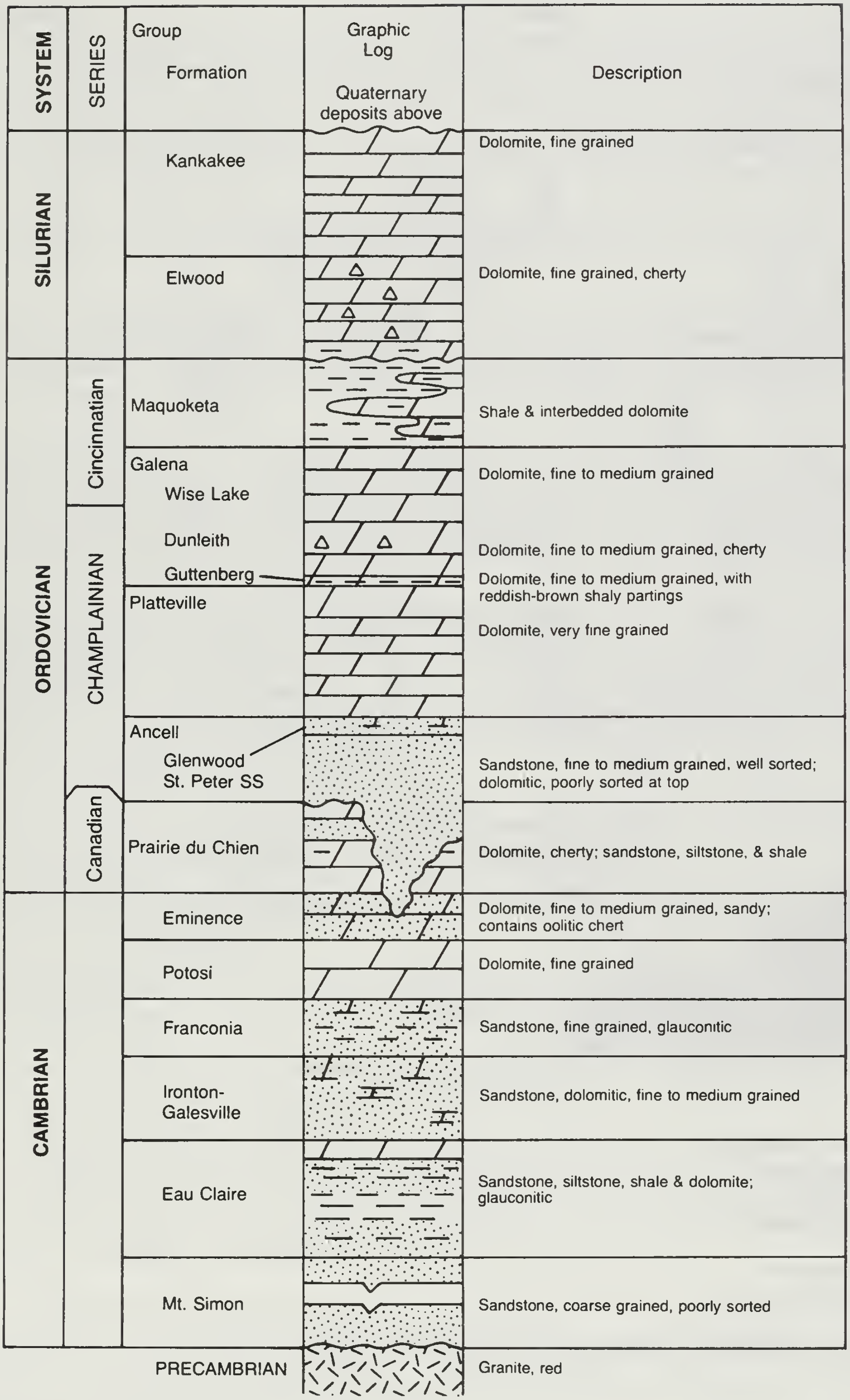


Figure 2 Stratigraphy of bedrock units in study area (modified from Kempton and others, 1985).

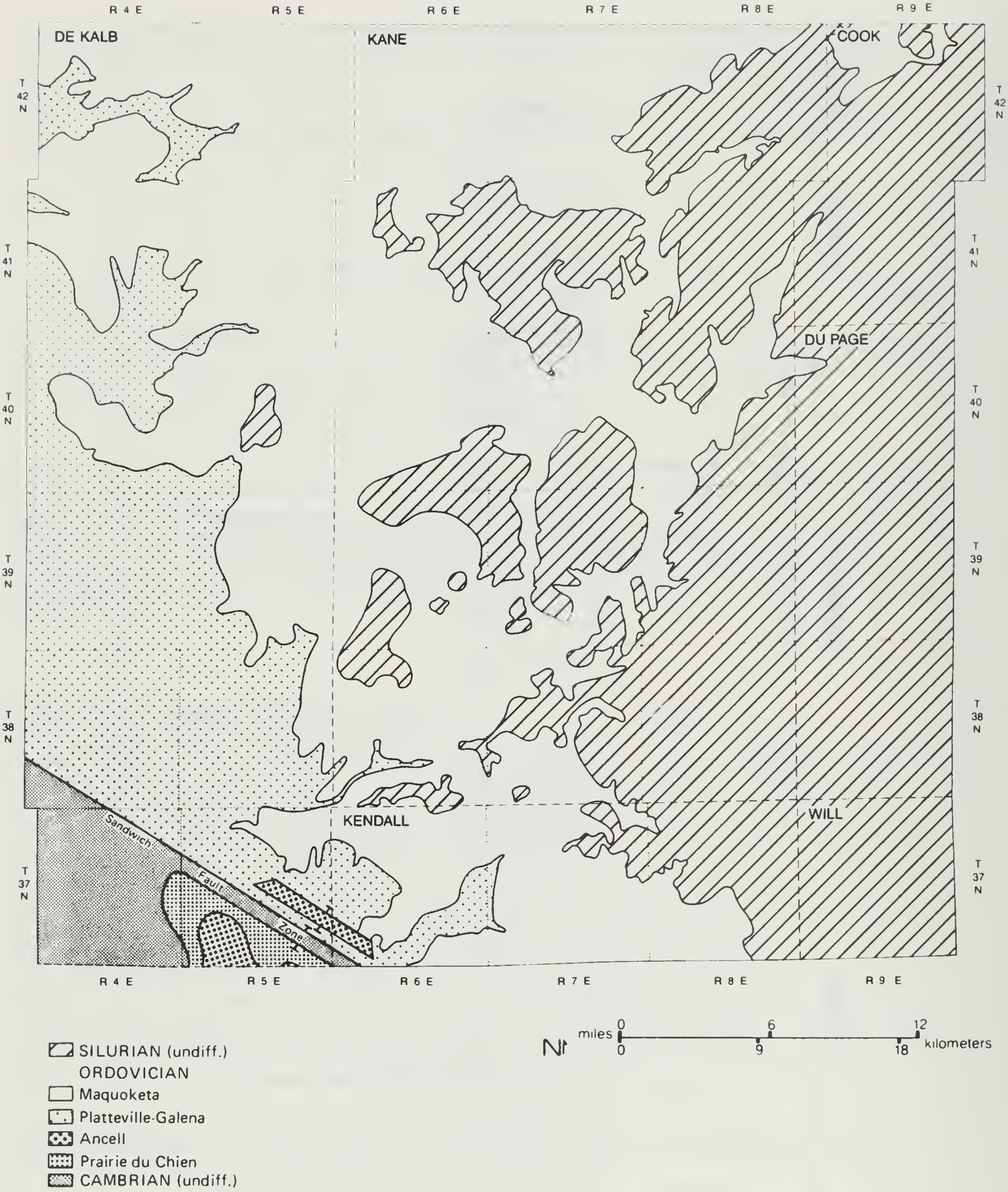


Figure 3 Generalized geologic map of the bedrock surface.

Silurian System

The formations within the Silurian System in the study area consist primarily of light gray, fine-grained, thin- to medium-bedded dolomite with thin, green shaly partings. In some places, the Silurian has been completely eroded; thus, it ranges from 0 to more than 100 feet thick.

Kankakee Dolomite Formation light greenish and pinkish gray, pure, fine-grained dolomite that occurs in thin beds separated by wavy, green shaly partings. The lower contact is gradational.

Elwood Dolomite Formation light brownish gray, cherty, and slightly more argillaceous than the dolomite above.

Wilhelmi Formation gray, argillaceous dolomite and dolomitic shale that fills channels cut into the underlying Maquoketa rocks. This erosional surface is irregular; thus, thickness estimates of the underlying Maquoketa Group and Silurian strata are imprecise. The Wilhelmi has not been identified in any cores recovered in the study area and is not delineated in figure 2.

Ordovician System

The Prairie du Chien (Canadian; oldest), Ancell, Platteville, Galena (Champlainian) and Maquoketa Groups (Cincinnatian; youngest) are included within the Ordovician System. The Platteville, Galena, and Maquoketa Groups will be discussed in detail because of their relevance to the SSC siting. Buschbach (1964) contains discussions of the Prairie du Chien and Ancell Groups.

Maquoketa Shale Group green, gray, and red shale with fossiliferous carbonate. The Maquoketa Group ranges from 130 to 210 feet thick where overlain by Silurian formations within the study area. Regionally, the Maquoketa is divided into the Neda, Brainard, Fort Atkinson, and Scales Formations from top (youngest) to bottom (oldest). However, in certain areas of the state, particularly in the SSC study area, these units are not easily distinguishable because the thickness and lithology vary considerably. Additional discussion of the Maquoketa Group is presented in Kolata and Graese (1983).

Neda Formation red, silty, hematitic shale containing flattened, concentrically layered spheroids. Within the study area, the Neda is absent due to pre-Silurian erosion.

Brainard Shale predominantly greenish gray, silty, fossiliferous, dolomitic shale interbedded with dolomite and limestone.

Fort Atkinson Dolomite olive-gray, pure to argillaceous, coarse-grained dolomite and limestone. The Fort Atkinson grades downward into the Scales Shale.

Scales Shale olive-gray, silty, dolomitic shale. There is generally a greenish gray shale zone at the base of the Scales, and the contact with the underlying Galena Group is abrupt.

Galena and Platteville Dolomite Groups primarily gray to brown, fine- to medium-grained dolomite. The Galena Group is typically fine- to medium-grained, medium- to thick-bedded, and vuggy and vesicular in contrast to the underlying Platteville Group, which is fine-grained, thinner bedded, and less vuggy and porous. The Galena Group in the area is approximately 200 feet thick (where not eroded); the Platteville Group is 140 to 150 feet thick.

The Galena typically has many clay partings that are composed of mostly illite with some chlorite. One fairly persistent clay bed generally less than 2 in thick occurs about 90 feet below the top of the Galena. The clay bed is composed of mixed-layer illite and smectite (80 and 20 percent, respectively), carbonate and potassium feldspar, and is probably the Dygerts Bentonite Bed (Willman and Kolata, 1978). To avoid confusion with swelling bentonite, the clay bed is referred to as the Dygerts Bed.

The Galena Group is divided into three formations in this area. The uppermost Wise Lake Dolomite is composed of relatively pure carbonates; the underlying Dunleith Dolomite is cherty and more vuggy. The basal formation of the Galena is the Guttenberg Dolomite, which is characterized by reddish brown shale partings. The Platteville Dolomite Group, which is divided into several formations and members, is not discussed here. A detailed discussion of the Galena and Platteville Groups can be found in Willman and Kolata (1978).

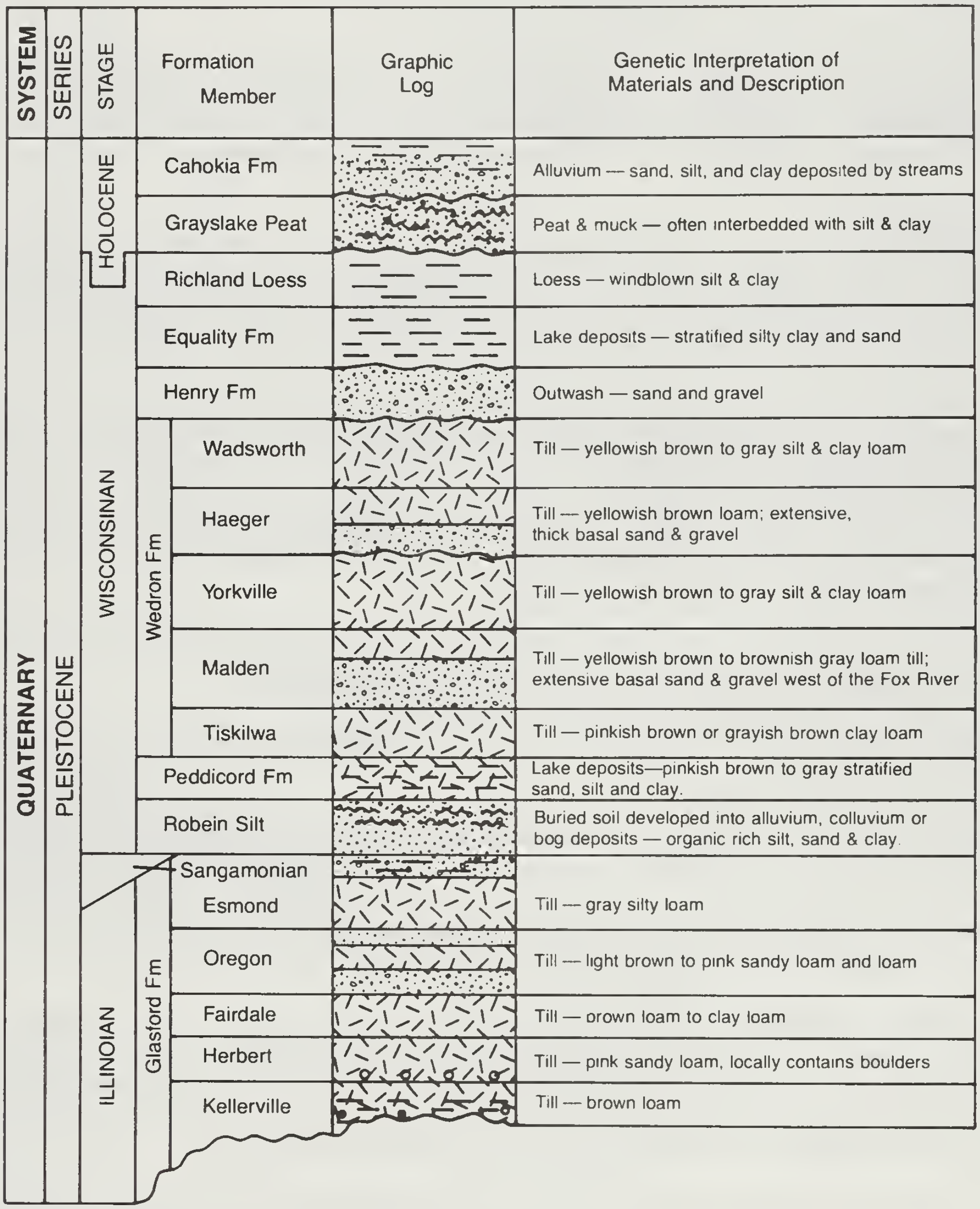


Figure 4 Stratigraphy of Quaternary deposits (chiefly glacial drift) in northern Illinois (modified from Kempton and others, 1985).

Glacial Drift Stratigraphy

Glacially derived sediments (drift) of Quaternary age overlie an erosional topography on Paleozoic dolomite and shale. Figure 4 shows the stratigraphic succession. A discussion of glacial deposits of the region can be found in Kempton and others (1985) and Wickham and others (in press). Berg and others (1985) describe the Glasford Formation to the north of the study area. Preliminary work suggests many of these deposits can be traced into the study area, and this report uses their informal stratigraphy.

Drift samples were taken at 5-foot intervals where possible. Stratigraphic correlations are based in part on sample color, particle-size distribution, and data from clay mineral analyses.

SUMMARY OF RESULTS: TEST-HOLE DESCRIPTIONS, DATA, AND INTERPRETATIONS

The location of each test hole (fig. 5, table 1) was selected to provide

- stratigraphic data (table 2) for areas where well-data control was limited or lacking
- geotechnical and hydrologic data on the geologic units lying between the surface and a potential tunnel elevation of about 400 feet above m.s.l.
- information for design and cost estimates.

This section describes data available for each test hole, such as bedrock and drift stratigraphy, geophysical logging, pressure testing, and fracture spacing and orientation.

Bedrock Stratigraphy

Overall distribution and thickness of the rock units were generally as predicted on the basis of preliminary work by Kempton and others (1985) and earlier investigations (Buschbach, 1964; Willman, 1973; Willman and Kolata, 1978; and Kolata and Graese, 1983). Most of the Silurian formations and dolomite of the Galena and Platteville Groups generally have uniform lithology; the Maquoketa Group is quite variable in lithology and thickness. The rock types encountered in the Maquoketa Group in this study area do not correspond directly to those in Cook County where a typical lower shale (Scales Shale), middle carbonate (Fort Atkinson Dolomite) and an upper shale unit (Brainard Shale) are found. Rather, there appear to be at least two shale-carbonate successions, and the thicknesses of these units are variable (Graese and Kolata, 1985).

Table 1. Location and elevation for test holes ISGS F-10 – F-17

Hole no.	7.5-minute quadrangle	Location	Land surface elevation above m.s.l. (±1 ft)
F-10	Aurora North	NW SW NW NE 25, T38N-R8E	706
F-11	Hinckley	NE SE NE SW 14, T38N-R5E	731
F-12	Maple Park	NW NE SE SW 10, T40N-R6E	872
F-13	Maple Park	NW NE SE SW 10, T40N-R6E	872
F-14	De Kalb	SE SE NE NE 16, T40N-R4E	871
F-15	Pingree Grove	NW SW NW SW 30, T41N-R8E	848
F-16	Yorkville	SE SW SE SW 3, T37N-R7E	659
F-17	Somonauk	NE NE NE NW 27, T38N-R5E	743

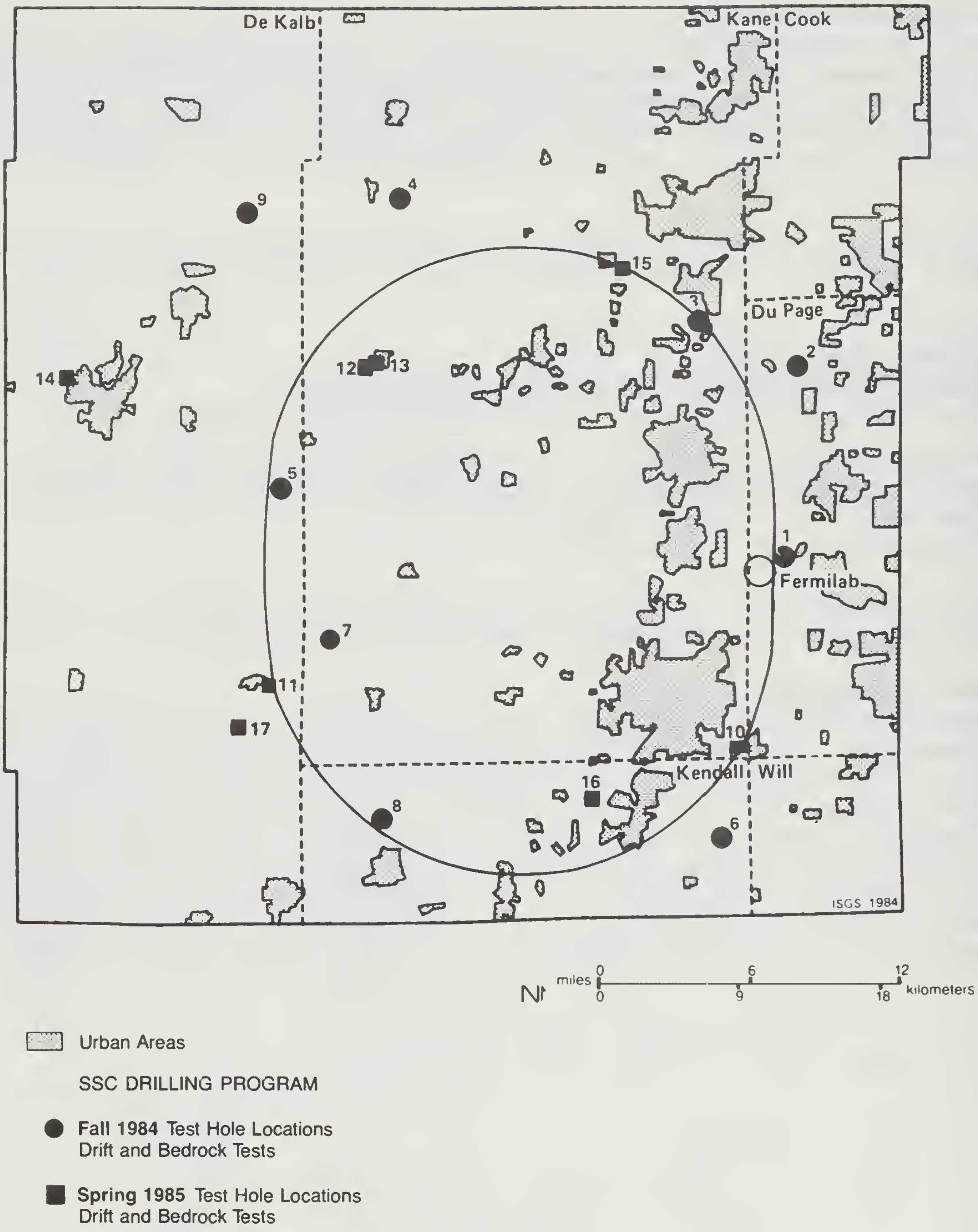


Figure 5 Test hole locations of fall 1984 (circles) and spring 1985 (squares) drilling programs.

Table 2. Test-hole summary, Spring 1985 drilling, thickness of units (ft)

Hole no.	T.D.	Drift	Silurian	Maquoketa	Galena	Platteville	St. Peter
F-10	402.9	77.5	28.6**	161.5	135.3*	NC	NC
F-11	441.9	117.0	NP	NP	166.8**	151.9	6.4*
F-12	482.3	125.0	NP	135.7**	197.6	24.0*	NC
F-13	159.5	121.6	NP	37.9**	NC	NC	NC
F-14	480.1	172.0	NP	14.5**	207.6	86.0*	NC
F-15	462.0	195.0	NP	138.2**	128.8*	NC	NC
F-16	312.1	62.0	NP	126.7**	123.4*	NC	NC
F-17	668.1	165.0	NP	NP	144.4**	143.5	215.2*

Notes: NP = Not present
NC = Not cored, but present below T.D.
* = Entire unit not cored, but present below T.D.
** = Entire unit not cored, upper contact eroded by Quaternary glaciers and streams

Table 3. Temperature logs of water in boreholes

Hole no.	Time after completion of boring (hrs)	Temperature range (°F) Low	High	Remarks
F-10	16	52.0	53.7	highest in bottom of hole
F-11	17	55.0	56.0	highest in bottom of hole
F-12	15	56.5	58.0	
F-14	16	55.0	56.5	highest in bottom of hole
F-15	1	55.0	58.0	highest in bottom of hole
F-16	16	53.0	56.5	highest in bottom of hole
F-17	48	53.0	55.0	highest in bottom of hole

Glacial Drift Stratigraphy

The thickness and distribution of most stratigraphic units encountered during drilling were as indicated by Wickham (1979), Kemmis (1978), and Kempton and others (1985). In particular, the character and thickness of the Tiskilwa Till Member of the Wedron Formation are well documented (Wickham and others, in press). Additional work is needed, however, to determine the stratigraphic position of thick, widespread sand and gravel bodies, especially in the southern half of the study area. Moreover, the stratigraphic and geomorphic relationships among deposits of the Wadsworth, Haegar, Yorkville, and Malden Till Members east of the Fox River and in the southern portion of the study area need further examination as suggested by Johnson and others (1985).

The Peddicord Formation is composed of stratified silt, clay and subordinate sand, overlies the Robein Silt and underlies the Tiskilwa Till Member of the Wedron Formation. The sediments are interpreted to have been deposited in proglacial lakes associated with an advancing ice front that deposited the Tiskilwa Till Member (Johnson and others, 1985).

Table 4. Caliper log summary of boreholes

Hole no.	Diameter	Remarks
F-10	3 in. (5 – 403.6 ft)	lower 4 feet affected by cuttings; slight constrictions at 131, 232, 244 and 267 ft
F-11	3 in. (7 – 442.9 ft)	bottom 20 ft filled with cuttings
F-12	3 in. (6 – 471.5 ft)	bottom 3 ft filled with cuttings; slight narrowing at 377 – 400 ft
F-14	3 in. (6 – 480.9 ft)	
F-15	3 in. (5 – 463.2 ft)	bottom 7 ft of test hole affected by cuttings
F-16	3 in. (4 – 313.2 ft)	bottom foot affected by cuttings; slight constriction at 263 and 287 ft
F-17	3 in. (0 – 392 ft)	opening present at 285 – 392 ft which caused temporary loss of circulation

One radiocarbon date of 37,100 ± 2000 yrs. B.P. (ISGS-1398; Barry Fisher, personal communication) was obtained from several wood fragments recovered from laminated sand just above the bedrock surface at ISGS F-10. This radiocarbon age is consistent with other dates obtained from the Robein Silt in this area (Curry and Kempton, 1985).

Geophysical Logging

Significant characteristics of the geophysical logs are presented in the order of completion in the field. Test-hole summaries (fig. 14, for example) show only gamma-ray and neutron logs; all other log configurations are on open file at the Illinois State Geological Survey, Champaign.

■ Temperature Log

Borehole fluid temperatures ranged from 47.5° to 58.9°F (table 3), but the values are not considered to be in equilibrium with the in-situ water in bedrock. Because of time constraints, all logs were run a few hours after completion of drilling, but equilibrium is approached after several hours or several months, depending on test-hole conditions (Stevens and others, 1975). Cooler temperatures were generally encountered in the Silurian dolomites rather than in the rocks in lower stratigraphic position. The shallow water in bedrock is probably mixed with relatively cool water in the drift (Booth and Vagt, 1986), but there was also likely leakage of drift water around the base of casing into the bedrock portion of the test hole.

■ Caliper Log

The caliper logs demonstrate that the boreholes maintained a 3-inch diameter through most of the rock coring. Deviations from this norm are shown in table 4.

■ Self-Potential Single-Point Resistivity and Natural Gamma Log—Configurations

Galena and Platteville Groups are characterized by high resistivity and generally low gamma radiation. Slight deflections towards higher gamma readings and lower resistivity indicate argillaceous dolomite. Very sharp peaks in this trend indicate thin, mixed-layer clay beds, which are characteristic of the Galena Group (Kolata and others, 1984). On most logs, the Dygerts Bed (Willman and Kolata, 1978) was consistently found between 84 and 90 feet below the Galena/Maquoketa contact. A sharp peak on both self-potential and resistivity logs at the top of the Galena may be attributed to disseminated pyrite.

In the Maquoketa Shale Group, the Scales Shale has a reading characteristic of many shales: low resistance and high gamma radiation. The lower contact between the Scales and Galena separates lithologies with nearly opposite electric- and gamma-log signatures. The upper contact of the Scales is often gradational with the overlying lithologies.

Fort Atkinson Dolomite consists of a pure to argillaceous, fossiliferous dolomite, but is not clearly represented as a distinct layer in all of the logs. Rather, the logs and corresponding cores show that above the Scales, the abundance of dolomite beds generally increases upwards, which is characteristic of the Maquoketa Shale in this area. The interbedded dolomitic shales and dolomite register an irregular, intermediate intensity signature with an occasional high resistance peak indicating relatively pure dolomite.

The Elwood and Kankakee Formations (Silurian) cannot be consistently differentiated with these logs.

Glacial drift character may be distinguished on the gamma logs as well, but sample control is often necessary. In general, the high clay content of till registers higher gamma emissions than do sand and gravel bodies. Especially useful in conjuction with these logs are interpretations of the neutron log.

■ Neutron Log

The configuration of this log generally corresponds to rock porosity below the water table. The highest bedrock porosities shown by these logs were generally in the thin to medium-thick beds of pure fossiliferous dolomite in the Maquoketa Group. Sand and gravel deposits in the drift also have pronounced signatures indicating high porosities.

■ Density (Gamma-Gamma) Logs

These logs generally are a smooth curve suggesting similar rock density from glacial drift to bedrock. The Galena always has the lowest radiation, and therefore the greatest density. As the rock becomes more shaly and less dense, the incoming radiation increases because less dense materials absorb less radiation.

Hydrogeologic Data

■ Packer Tests

A total of 379 packer tests were conducted in 76 test intervals during the spring 1985 drilling program. For the tests that detected water flow into the rock, the calculated hydraulic conductivity was between 5.0×10^{-7} to 5.4×10^{-2} cm/sec.; however, the equipment is most accurate from 1.0×10^{-6} to 5.0×10^{-4} cm/sec. The highest permeabilities are consistently within the top 100 feet of bedrock, usually ranging in order-of-magnitude from 10^{-2} to 10^{-4} cm/sec.

The hydraulic conductivities, as calculated from packer-test data, are presented in tables for each test-hole description, and also plotted graphically on the summary diagrams; the range of the five tests per interval is shown. The tabulated data should be compared with the graphs. A sequence of tests in which the values become successively lower suggests that fine-grained material may have progressively blocked waterflow. Conversely, a sequence of tests in which the permeability successively increases suggests that fine-grained material was washed out. Water leakage around packer bladders was strongly suspected when flow only occurred at the highest pressure test. Permeability of the glacial drift was not measured in this study.

■ Piezometers

One-inch outside diameter (OD) piezometers were installed in most test holes. The lower 20 feet of pipe was slotted (see fig. 6). Table 5 indicates the depth to the bottom of each slotted section, and the stratigraphic unit and lithology of the tested section.

Table 6 lists periodic water-level readings. Water levels have not been attained in piezometers in ISGS F-10 and ISGS F-14 after 15 months of monitoring; the remaining piezometers appear to have more-or-less static water levels. Piezometers in ISGS F-15 and ISGS F-17 were plugged and abandoned by 8-15-86, in addition to ISGS F-3, ISGS F-5 and ISGS F-9 (Kempton and others, 1987).

Piezometers installed in adjacent test holes, ISGS F-12 and ISGS F-13, indicate that the head difference between the shallow bedrock aquifer (Visocky and others, 1985) and the Galena Group is about 260 ft.

Geotechnical Data

Joint characteristics and amount of dip of the joint planes were recorded from cores. Joint planes in the Silurian formations, Maquoketa Group and Galena and Platteville Groups are generally wavy, rough, nonweathered, tight and contain no clay filling. They also are high angle joints (near vertical).

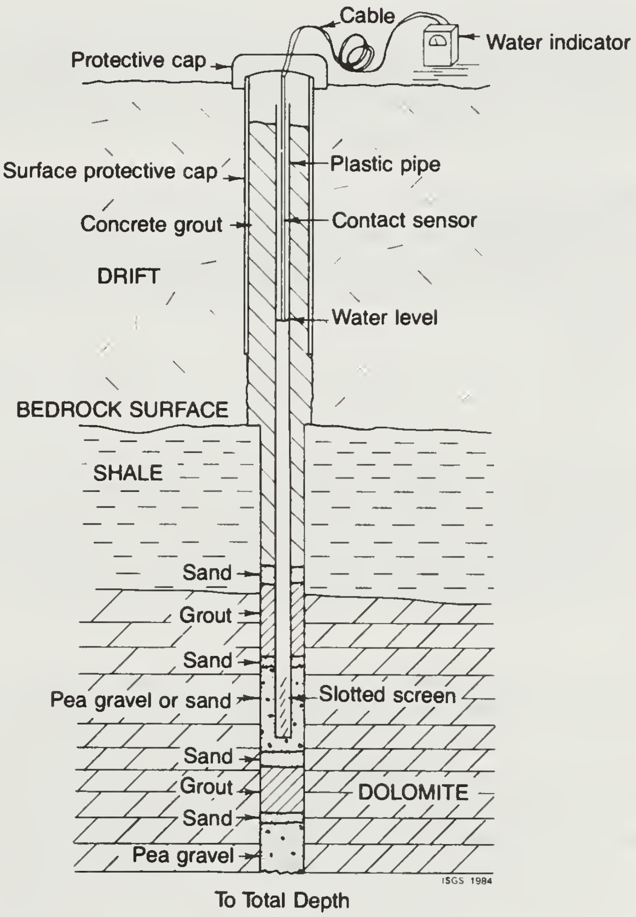


Figure 6 Standing water level piezometer design.

Table 5. Characteristics of 1.0-inch diameter (OD) piezometers installed in each borehole

Hole no.	Depth from ground surface to bottom of slotted section (ft)	Elevation of bottom of slotted section (ft)	Stratigraphic unit; lithology
F-10	337.7	368.7	Galena; limestone
F-11	350.0	381.3	Platteville; dolomite
F-12	466.0	405.0	Platteville; dolomite
F-13	157.0	713.0	Maquoketa; dolomite
F-14	478.0	392.8	Platteville; dolomite
F-15	455.0	393.0	Galena; dolomite
F-16	264.5	395.0	Galena; limestone
F-17	349.0	394.3	Platteville; dolomite

Note: Length of slotted pipe is 20.0 feet.

Laboratory strength testing of the cores from test holes ISGS F-10 through F-17 included unconfined and confined compression, indirect tension, axial and diametral point-load, moisture content, specific gravity, compressive-wave velocity, and shore hardness. Table 7 shows average strength and other physical property values for the individual formations per borehole. The complete test results are on open file at the Illinois State Geological Survey.

GENERAL PROCEDURES

The drilling program included a plan for test hole locations and necessary drilling specifications. The following statements briefly summarize the procedures followed for drilling and sampling each test hole:

1) Survey personnel located the drilling site, obtained permission from land owner to drill, checked the location of utilities, and located supply of water for drilling.
2) The driller provided a rotary drilling rig.
3) The driller took split-spoon samples in drift (usually at 5-foot intervals). Survey geologists recorded blow counts (N values for standard penetration test), described materials and sampled cores for laboratory analysis.
4) The driller set casing to bedrock and cored the bedrock using a wireline drilling method with a 10-foot core barrel to take 1.87-inch-diameter continuous core.
5) Water levels in the test hole were recorded before drilling resumed each day. Survey geologists described each length of core and noted the number and nature of fractures. Loss of circulation of drilling fluid was also recorded during drilling. Selected samples were placed in plastic bags for future laboratory testing for strength, density, moisture content, etc. Two Survey geologists were normally present for this work.
6) Survey geologists recorded geophysical logs of each hole.
7) Survey geologists supervised pressure tests of hole at regular and/or selected intervals, to check zones where drilling records indicated a loss of circulation occurred, where significant natural fractures were noted, and at elevation 400 feet above m.s.l. (one of the proposed elevations selected for the SSC tunnel).

Table 6. Water level depths measured in piezometers (ft)

Hole no.	F-10	F-11	F-12	F-13	F-14	F-15	F-16	F-17
Total depth	337.7	350.0	466.0	157.0	478.0	455.0	264.5	349.0
Land surface elev.	706.4	731.3	872.0	872.0	870.8	848.0	659.5	743.3
1985								
5-10	—	36.2	—	—	—	—	—	—
5-24	285.8	33.4	—	—	—	—	—	—
5-29	—	—	—	—	—	—	—	—
6-21	—	—	278.5	18.8	98.7	—	—	—
6-28	294.1	25.1	278.7	16.8	98.9	385.5	—	—
7-16	—	—	276.4	16.6	100.2	—	—	—
7-18	302.0	24.1	—	—	—	385.4	191.9	—
8-19	307.6	—	—	—	—	—	192.7	—
8-21	—	39.1	276.9	17.4	102.3	400+	—	—
9-17	312.3	25.2	265.7	17.9	101.6	386.6	193.4	23.1
10-17	317.0	32.6	275.0	17.9	102.6	385.6	191.9	23.4
11-19	319.3	22.8	278.4	13.8	103.1	385.3	192.1	17.6
12-12	320.6	21.3	278.2	13.4	103.4	384.9	192.1	16.3
1986								
1-14	321.7	22.1	278.0	14.8	102.9	384.8	192.3	18.8
2-20	332.7	27.0	277.9	15.4	102.0	384.5	192.0	19.6
3-12	—	25.8	278.1	15.3	101.3	384.7	192.1	19.8
4-17	326.1	22.6	278.2	15.6	99.7	384.9	192.2	19.9
5-15	327.5	22.1	278.0	16.1	98.1	384.4	192.2	20.4
6-18	329.3	21.8	278.4	14.9	96.7	385.2	191.9	19.3
7-17	328.3	22.2	277.7	15.0	95.3	384.8	192.1	18.6
8-15	331.7	22.6	278.3	151.8	94.7	*	192.2	*

*Piezometer plugged and abandoned
— Indicates no reading for that date.

8) The driller installed a 1-inch-outer-diameter plastic pipe from the ground surface to depth determined by the geologist. The lower 20 feet of the pipe was slotted and placed in position. Pea-size gravel was poured into the hole to fill around and 20 feet above the slotted portion; and finally, grout seals were poured above the pea gravel to isolate and seal the zone of observation (fig. 6).
9) The driller pulled the surface casing pipe and replaced it with a short section of pipe with a locking cap to protect the plastic pipe.
10) The driller grouted the space around the 1-inch plastic pipe to ground surface and restored the site to pre-drilling conditions.

Geophysical Borehole Logging
Sensing devices are lowered into a well or other borehole to produce continuous records (graphs) of various rock properties of the borehole wall and the fluids that fill the borehole. The logs are used for correlation and characterization of various rock attributes. The Illinois State Geological Survey uses several combined types of geophysical logs run sequentially in the test holes: Temperature-Conductivity, Caliper, Spontaneous Potential, Single-Point Resistivity, Density, and Natural Gamma-Neutron.

The Illinois State Geological Survey is currently using a Log-Master 554-E carryall-mounted borehole logger, built by Log-Master International, Enid, Oklahoma. Logs are made using a sonde about 2 inches in diameter and of various lengths depending on the property to be measured. The sonde is lowered into the borehole attached to the end of the cable containing four electrical conductors. The cable is raised and lowered using a winch which has a depth measuring device to indicate the depth of the sonde. The electrical conductors are connected to an electrical control panel and chart recorder that records signals being returned from the logging tool. The log records are available on open file at the ISGS.

- **Temperature and Fluid Conductivity Log**

The ISGS temperature and fluid conductivity probe is capable of detecting borehole temperatures to 1/50 of one degree from 15° to 212°F and conductivities equivalent to NaCl concentrations from less than 200 to over 50,000 mg/l.

Temperature logs are interpreted relative to the expectation of a "normal" geothermal gradient of about 1°F increase in temperature per 100 feet of increased depth below the level of seasonal variations. Groundwater temperatures below the level of seasonal variations are approximately equal to the mean annual temperature in the area. In this part of northern Illinois the mean annual temperature is about 50°F (Stevens and others, 1975).

- **Caliper Log**

The caliper log, which measures borehole diameter, is the simplest of logs to run, record, and interpret. The caliper probe has a set of arms that are extended radially by a spring-loaded mechanism so they contact the borehole walls. The probe may show fractures, cavities or narrowing of the borehole. This log is used primarily to evaluate the condition of the borehole and to determine the advisability of running logs that require nuclear sources such as density and neutron logs. This probe is not affected by fluid in the borehole.

- **Electric Log**

The probe senses both potential differences and the single-point resistivity which are referred to simply as an electric log. In both cases a grounding electrode is placed in either the mud-pit or a small water-filled hole at the surface. The potential log is a measure of the potential difference among the rock materials. The single-point resistivity log shows the relative relationships of the electrical resistivity of the rock formations. These logs are primarily used for geologic correlation,

Table 7. Mean rock strength values of rock core per formation and group

Hole No ISGS	Rock type	Qu (psi)	Modulus psix10^6	Indirect tensile strength (psi)	Axial point-load index (psi)	Moisture content (dry wt%)	Specific gravity	Shore hardness	Diameter point load index (psi)	Index of anisotropy
Silurian										
F-10	limestone	13,859	6.61	1,002	1,488	2.06	2.68	50	530	2.8
Maquoketa										
F-10	shale	3,480	0.49	428	417	6.40	2.36	15	86	5.2
F-15	dol-shale	6,737	1.02	727	727	3.22	2.47	32	170	5.7
F-16	lim-shale	4,199	0.57	585	765	4.10	2.51	28	245	4.1
Average		5,252	0.77	612	642	4.35	2.45	26	160	5.2
F-12	limestone	21,061	4.30	1,245	1,853	0.67	2.72	67	889	2.3
F-15	limestone	19,417	3.94	1,518	1,322	0.11	2.71	56	648	2.0
F-16	limestone	9,344	1.39	798	1,292	2.23	2.59	38	335	4.0
Average		15,805	3.00	1,092	1,537	1.26	2.66	53	617	3.0
Galena (Wise Lake)										
F-11	dolomite	6,800	4.73	852	1,364	2.36	2.62	55	384	3.7
F-12	dolomite	7,136	3.37	614	917	3.63	s.54	41	397	2.5
F-14	dolomite	9,963	4.07	700	1,100	2.61	2.56	50	483	2.4
F-15	dolomite	11,763	5.86	830	1,306	1.35	2.70	62	634	2.1
F-16	dolomite	12,237	6.08	1,023	1,807	1.05	2.66	58	628	3.0
F-17	dolomite	10,179	7.65	847	1,666	0.70	2.65	59	657	2.7
Average		9,874	5.38	823	1,388	1.86	2.63	55	544	2.7
F-10	limestone	16,148	11.72	1,089	1,974	0.79	2.66	49	609	3.4
Galena (Dunleith)										
F-11	dolomite	1,666	1.56	207	663	7.62	2.43	36	155	2.5
F-12	dolomite	6,688	4.69	530	718	4.67	2.47	46	281	2.5
F-14	dolomite	6,406	2.72	527	863	2.34	2.56	46	337	2.6
F-16	dolomite	7,326	3.30	1,111	1,146	2.42	2.62	68		
F-17	dolomite	11,267	8.08	1,125	1,524	0.65	2.70	60	574	3.4
Average		6,178	3.86	596	855	3.97	2.53	48	319	2.6
Platteville										
F-11	dolomite	10,874	8.02	1,025	1,625	1.40	2.68	64	786	2.2
F-12	dolomite	10,045	3.76	843	1,338	2.95	2.51	40	488	2.7
F-14	dolomite	14,506	4.52	1,205	1,520	1.76	2.66	54	687	1.9
F-17	dolomite	14,798	8.49	1,171	2,003	0.15	2.73	67	986	2.1
Average		12,506	6.56	1,070	1,638	1.46	2.66	58	801	2.2
F-11	limestone	22,775	6.30	1,411	2,460	0.24	2.69	58	715	3.4
St. Peter										
F-17	sandstone	1,795	0.69	120	260	6.62	2.23	12	58	4.5

to measure bed thickness, and for interpreting porosity of the rock in the wall of the borehole. In general, shale will cause deflections toward the middle on both these logs, because it has strongly positive potential and low resistivity due to the high degree of ionization of the clay particles in the shale. In this study, the basal shale of the Maquoketa Group has this characteristic. Dolomite of the Galena Group, by contrast, causes deflections toward the margins of the chart. Dolomite has low potential and high resistance to electrical current flow; sandstone is generally intermediate. Electric logging requires an uncased hole filled with fluid of low salinity.

■ Gamma-Ray Log

Natural-gamma logs are graphs of the amount of natural gamma radiation emitted by earth materials. Significant background solar radiation is eliminated by the blanket of earth, allowing the measurement of very low levels of radiation from potassium-40, uranium, and thorium-232. These elements are most abundant in the clay minerals and less concentrated in clean quartz sand, gravel, and pure carbonate rock. Both fluid filling and steel casing tend to dampen the levels of radiation, but relative levels are easily recognized.

The chief use of the gamma log is for stratigraphic correlation and identification of lithology. The sensitivity of the gamma probe is limited by the borehole diameter, the presence and type of fluid, the size and material of casing, and rock density. Most secondary gamma-ray photons are believed to originate from within 12 inches of the borehole wall. The scale settings and departure depicted on the gamma log can be calibrated in either American Petroleum Institute units or counts per second.

■ Neutron Log

The neutron log indicates the concentration of hydrogen in the area surrounding the logging probe by using a 3-curie americium-241/beryllium source having a flux of 6.6×10^6 neutrons per second. These are high-energy neutrons (greater than 10^5 ev or 0.1 Mev) that pass through the walls of the source, fluid column, casing and rock and are slowed down to energies below 0.025 Mev by collisions with atomic nuclei. Hydrogen is the most effective element in reflecting neutrons because its nucleus has nearly the same mass as a neutron. The flux of the thermal neutrons is proportional to the amount of hydrogen in the vicinity of the neutron source. The configuration of the neutron log may be used to interpret rock porosity.

The principal limitation of the neutron log is that it cannot discriminate between hydrogen in pore water and hydrogen in the form of hydroxyl ions (OH^-) principally found in clay minerals. As a result, shale and other formations containing minerals with hydroxyl hydrogen show high porosity on neutron logs. The neutron logs of sandstone, limestone, and dolomite with very low clay mineral content, are good indicators of relative porosity.

The neutron log is normally run with a natural-gamma log to aid the interpreter in recognizing shaly formations. A caliper log is also essential in interpreting the neutron log, because changes in the volume of water surrounding the probe will produce changes in the level of thermal neutron flux.

■ Density Log (Gamma-Gamma Log)

The density log is a record of the approximate rock density determined by bombarding the rock with intense gamma radiation from a 0.125-curie cesium-137 source and measuring the amount of secondary emission from the rock. For this measurement, the flux is inversely proportional to the bulk density. Dense rock materials absorb much of the radiation emitted from the source, whereas less dense materials tend to generate higher levels of secondary emission received by the detector. Natural background gamma emissions are generally insignificant and do not affect the log. Since changes in borehole diameter may affect the log, a caliper log is a necessary supplement.

Hydrogeology
The most suitable elevation to construct a tunnel in 1985 appeared to be within the uniform Galena Group, and special emphasis was given to characterize the hydraulic conductivity and piezometric head levels of the Galena Group and rocks and materials directly above and below. Data on hydraulic conductivity were determined by pressure (packer) tests while piezometers were set to permit measurement of piezometric heads at a proposed tunnel elevation. Overall evaluations of the hydrogeologic setting based on these and other data will be presented in subsequent reports including Kempton and others (in preparation). Data on fluid losses during drillling were recorded as were water levels in open boreholes prior to the resumption of drilling each morning.

■ **Pressure Testing**
Downhole pressure testing provides information on the in situ hydraulic conductivity of the rock units within the project area. A pair of pneumatically operated rubber packers or bladders separated by 21.0 feet of perforated pipe are lowered into a borehole to a predetermined depth. The packers are inflated to seal against the rock sidewalls; water is pumped into the rock interval between the packers at a steady pressure, and finally, the rate of water flow is measured. The equipment used for these particular tests is sensitive to hydraulic conductivities between 1.0×10^{-6} to 5.0×10^{-4} cm/sec. The data recorded during the tests are used to calculate an approximate permeability value. These data will be used in the engineering cost study to calculate pumping and construction costs for the proposed tunnel. A graphic comparison of four commonly used units of hydraulic conductivity is shown in figure 7. This figure also indicates relative terms associated with different ranges of values and also lists representative earth materials and rock types below their commonly measured ranges of values.

Hydraulic conductivity is a rock property only (Freeze and Cherry, 1979) and should not be affected by pore-water pressure or pressure gradients. However, this is not always observed in the field. Some of the factors which can affect the results of pressure tests are: the type of flow, laminar or turbulent; erosion of fines and plugging of the rock unit; erosion and washout of fines to increase permeability; hydrostatic uplift and increase of permeability; friction loss in the pipes; leakage around a packer; and rupture of a packer. Accordingly, a five-step up and down increase and decrease sequence of pressures for each test interval is used in this study.

A standardized procedure was adopted for this program so that the data from the holes could be more easily compared. Below a depth of 150 feet the tests were run in succession at a given test interval at pressures of 35 psi, 70 psi, 100 psi, 70 psi and 35 psi. Above a depth of 150 feet the pressures used were 10 psi, 30 psi, 50 psi, 30 psi, and 10 psi. These pressures will not cause hydrostatic uplift.

Prior to pressure testing, the equipment was calibrated to determine the amount of pressure loss in the pipe system due to the frictional drag between the wall of the pipe and the water. Packers were set 21 feet apart; thus measurements were made in selected 21-foot intervals of rock in each test hole.

The pneumatic pressure (gage, at ground surface) applied to the packers is based on the depth of the bottom packer and is the sum of four pressures: Gage (the maximum water pressure to be applied to a test interval) plus Column (the depth of the water table times 0.433) plus Hydrostatic (the distance from the water table to the lower packer times 0.433) plus Set (an arbitrary number, 40, selected from experience to seal the packer firmly against the rock wall without rupturing the rock or packer bladder). Figure 8 is an example of the water pressure test form used in the field.

Installation of Piezometers

A standing-water-level Casagrande (head) type piezometer (see fig. 6) was installed in most holes to make long-term observations of the water pressure at one proposed tunnel elevation, 400 feet above mean sea level. The installation consisted of placing and sealing a slotted 1.0-inch outer diameter plastic pipe within permeable backfill material opposite the zone to be tested. Above the test section (and below when the piezometer was not placed at the bottom of the hole), space between the borehole walls and the pipe was sealed with grout. To insure integrity of the seal, the grout was pumped into the hole through a tremie pipe kept below the surface of the grout. The water level in the pipe equilibrates with the pore-water pressure of the test section and is measured using an electric drop line. The top of the plastic pipe is protected by a short section of surface casing cemented in place and locked with a protective cap.

Geotechnical Testing Program

Bedrock: Field Procedures

Geotechnical information is recorded in the field on two forms (figs. 9, 10). The first form (fig. 9) is used to record general information about both glacial drift and bedrock as well as to record standard drilling information and to describe specific features and core characteristics such as joints, fractures, standard penetration test (SPT [N or blow counts]), core recovery, RQD (Rock Quality Designation), fracture frequency, and bed spacing. The second form (fig. 10) is used to show other physical attributes of the core such as the depths and spacing of rock discontinuities and features of these discontinuities in detail.

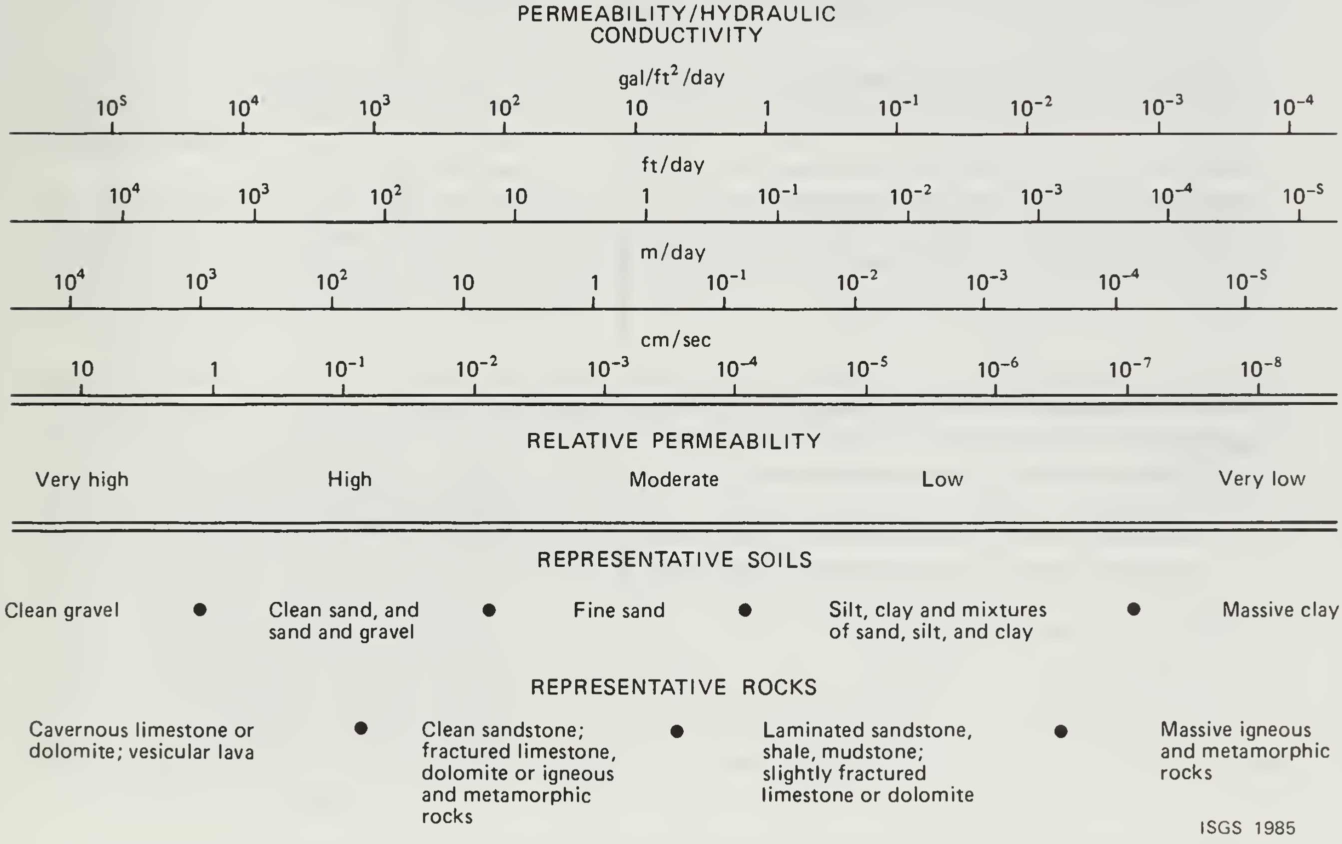


Figure 7 Permeability/hydraulic conductivity chart (modified from the U.S. Dept. of Interior Groundwater Manual, 1981).

WATER PRESSURE TEST

HOLE NO. ________

PROJECT ________________________________ Sheet ____ of ____

LOCATION SKETCH

Hole Location ________________

Angle (From Horizontal) __________

Bearing ____________________

Hole Size ____________________

Total Depth of Hole ____________

Tested by ___________________

Date Tested __________________

Coordinates: N ________________

E ________________

Ground Elevation ______________

Depth to Bedrock (down–hole) ________

Water Depth Before Testing

Inclined ______ Vert. ______

Height of Gauge Above Ground ________

Test Number	INTERVAL TESTED (–ft.) (–m.)			TAKE (–cu. ft.) (–gal.) (–liters) / min.					PRESSURE (–psi) (–Kg/cm^2)				PERMEABILITY
	From	To	Length	Meter		Water Loss	Elapsed Time (min)	Take	Gauge (+)	Column (+)	Friction Loss (–)	Net	(Units)
				Start	End								

REMARKS:

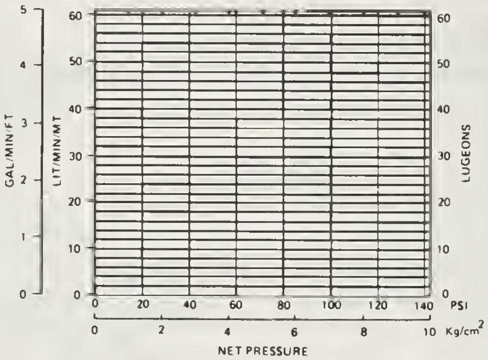


Figure 8 Water pressure testing form (from Harza Engineering Company).

Drilling rate During drilling, the average time taken to core through each foot of rock is recorded in minutes (table 8). The drilling rate is a function of rock type. For example, drilling through massive shaly units (such as the base of the Maquoketa Group), or cherty horizons is slower than drilling through massive carbonate rock.

Core recovery Each run of the core barrel is advanced a measured distance (usually about 10 ft) by the driller; core recovery is calculated as the total length of core collected in the core barrel divided by the length of the run (table 9). Less than 100 percent core recovery may be caused by voids, or by fractured rock that is pulverized during coring and lost through circulation during drilling.

RQD (Rock Quality Designation) This value (given as a percent) is the quotient of the sum of the length of all core segments greater than 4 inches long (between natural fractures) to the length of the core run (table 10). Disk fractures that develop as a result of shrinkage caused by loss of moisture, drilling, or stress fracturing from drilling or handling are not counted.

Fracture frequency The fracture frequency is determined by counting the number of *natural fractures* per 10 feet (this does not include induced breaks along bedding). Experience shows that there is generally good correlation between RQD and fracture frequency.

Distance between horizontal separations is a record of the length of core segments as they are removed from the core barrel. This includes mechanically and handling-induced separations along bedding as well as natural fractures. Note that if the distance between horizontal separations is less than 0.2 feet, the accompanying RQD and fracture frequency may *not* reflect severely broken core because the separations occur along bedding planes during or after drilling.

Fractures The positions of fractures are recorded as a simple sketch of core fractures (fig. 11), and may be compared with hydraulic conductivity calculated from the packer test data (for example, table 11).

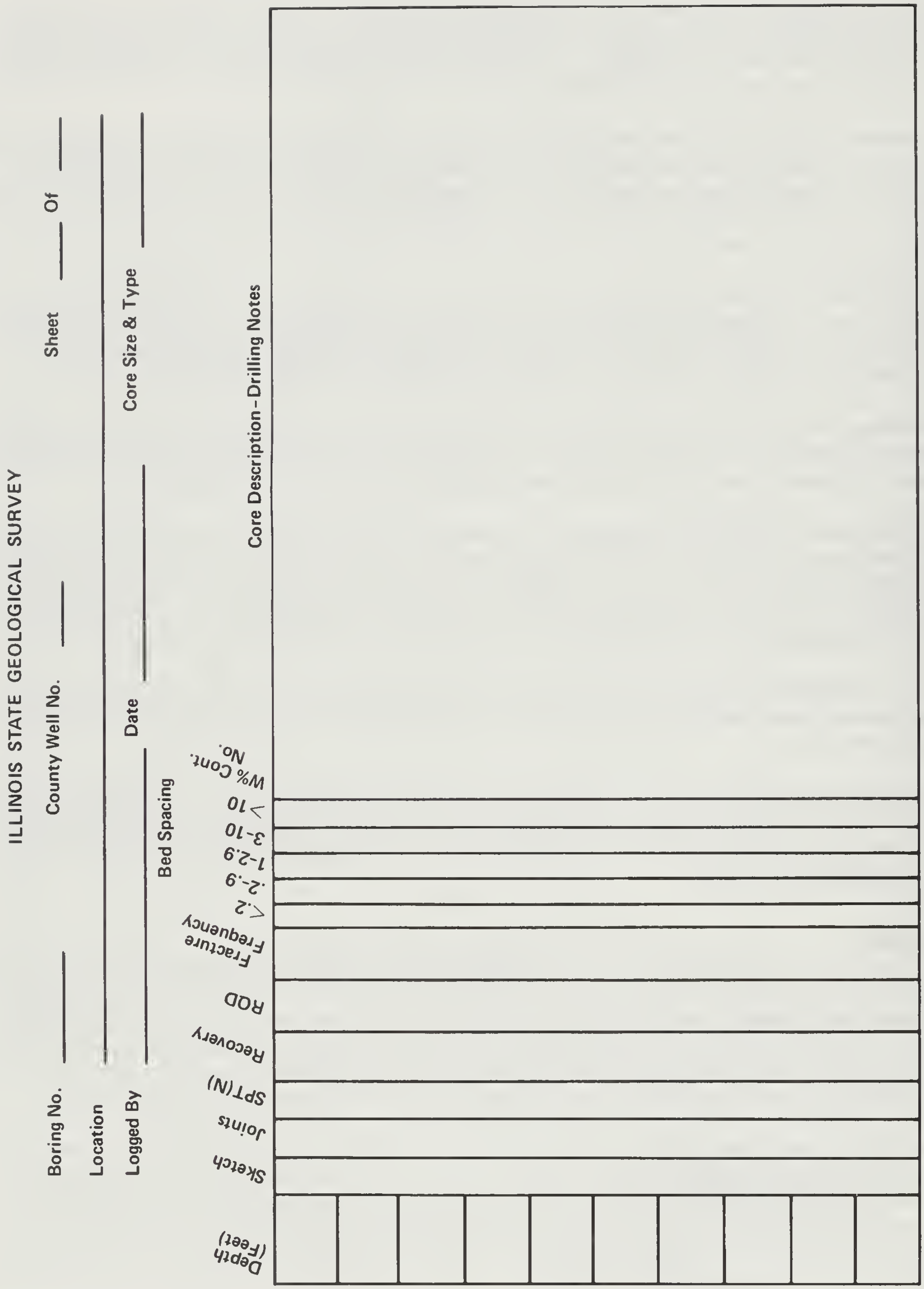
To provide general evaluation of the data, two summary sheets per test hole diagramatically show the recorded observations from the data forms. Figure 11 shows the drilling rates and rock discontinuity information for each test hole. Figure 12 depicts the dip of mapped joints within a specific unit of core.

Glacial Drift

Tables that summarize engineering and particle-size distribution data for drift samples are provided for each test hole. Samples, typically about 1.5 feet long, were collected every 5 feet. These data include blow counts (N; number of blows per foot), unconfined compressive strength (Qp; tons/ft^2) by pocket penetrometer, and moisture content (W; percent). Selected samples were tested for dry and moist density. Also included for each sample are laboratory particle-size determinations by wet sieving for gravel and sand, and by hydrometer for silt and clay.

Standard Penetration Test (SPT or blow counts) is the number of blows needed to drive a split-spoon sampler (outside diameter = 2.0 in.) 12 in. by a 140-pound hammer dropped 30 in. Blow counts usually do not exceed 100. If after 100 blows, the sampler has not been driven at least 1 foot, it is referred to as a Refusal (R). In those cases reported here where the blow count is greater than 100, the split spoon sample was driven at least 1 foot. The recovered samples have an outside diameter of about 1.4 in.

Unconfined compressive strength measurements were made with a Soiltest Model CL-700 pocket penetrometer. Measurements were taken on the ends and centers of sample cores. The recorded value is an average of at least two of these tests.



ILLINOIS STATE GEOLOGICAL SURVEY

Boring No. ____ County Well No. ____ Sheet ____ Of ____

Location ____

Logged By ____ Date ____ Core Size & Type ____

Depth (Feet)	Sketch	Joints	SPT(N)	Recovery	RQD	Fracture Frequency	Bed Spacing <.2	.2-.9	1-2.9	3-10	>10	W% Cont. No.	Core Description–Drilling Notes

Figure 9 Example of field drilling-log form.

County Well No. ______

ROCK DISCONTINUITY LOG

Boring No. F-1	Logged by: RAB	Date: 8-30-84	Depth 71.6 to 212.9	Sheet 1 of 4

GENERAL					FILLING																					ROCK PLANES										REMARKS
Depth (ft)	Discont. Type		Dip (°) from Horizontal	Width (ft)	AMT.			COLOR							TYPE						CONSIST.					COND.				ROUGHNESS						
	Bedding	Joint			None	Partial	Complete	Black	Gray	Green	Brown	Red	Yellow	Other	Shale	Clay	Mineralized	Healed	Mineral Type	Other	Soft	Hard	Crumbly	Fissile	Slickensided	Sound	Altered	Very Altered	Staining	Planar	Wavy	Uneven	Rough	Smooth	Slickensided	

Figure 10 Example of rock discontinuity log.

Table 8. Mean drilling rates per hole and stratigraphic unit (min/ft)

ISGS test hole no.	No. of core runs	Silurian	No. of core runs	Maquoketa	No. of core runs	Galena Wise Lake	No. of core runs	Galena Dunleith	No. of core runs	Platteville	No. of core runs	St. Peter
F-10	3	1.69	15	2.26	13	2.13						
F-11					13	1.69	4	1.58	16	1.87		
F-12			14	2.42	14	1.75	5	2.08	2	1.95		
F-13			5	2.10								
F-14			1	2.22	16	1.41	5	1.69	9	1.88		
F-15			16	2.60	12	2.07						
F-16			12	2.40	12	2.06						
F-17					9	1.98	5	2.12	16	2.45	21	1.93
Mean Drill Rates		1.69		2.40		1.84		1.88		2.09		1.93

Table 9. Mean core recovery per hole and stratigraphic unit (%)

ISGS test hole no.	No. of core runs	Silurian	No. of core runs	Maquoketa	No. of core runs	Galena Wise Lake	No. of core runs	Galena Dunleith	No. of core runs	Platteville	No. of core runs	St. Peter
F-10	3	100.00	16	99.50	13	99.64						
F-11					13	100.00	4	96.87	16	100.00		
F-12			16	97.39	15	100.00	5	100.00	2	100.00		
F-13			7	83.71								
F-14			1	100.00	16	99.84	5	100.00	9	100.00		
F-15			16	99.50	12	100.00						
F-16			12	99.58	12	99.83						
F-17					10	99.60	5	100.00	18	81.27	22	94.54
Mean recovery per strati-graphic unit		100.00		97.40		99.85		99.34		92.51		94.54

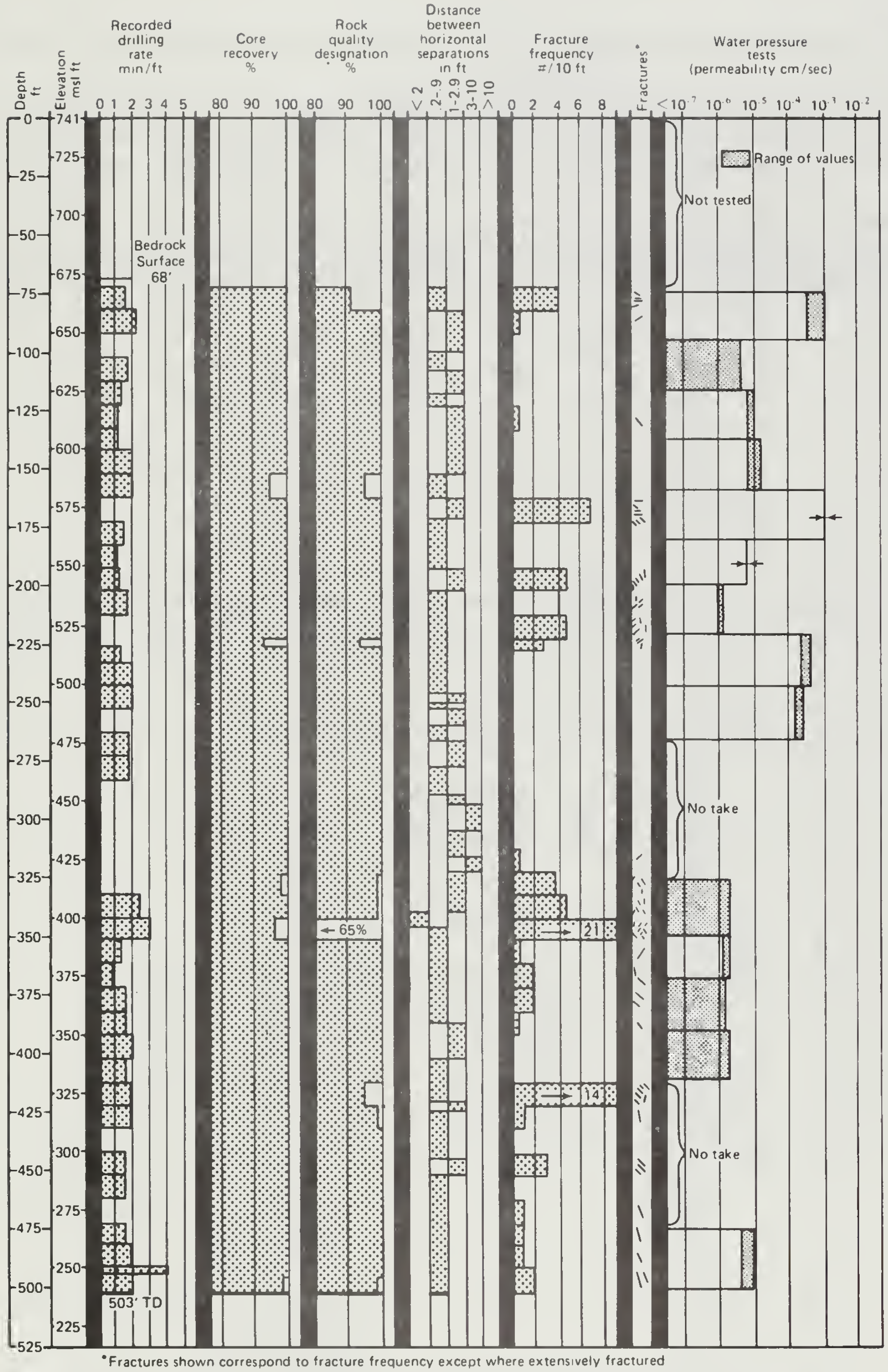


Figure 11 Summary diagram of drilling, core, and borehole characteristics.

Table 10. Mean rock quality designation (RQD) per hole and stratigraphic unit (%)

ISGS test hole no.	No. of core runs	Silurian	No. of core runs	Maquoketa	No. of core runs	Galena Wise Lake	No. of core runs	Galena Dunleith	No. of core runs	Platteville	No. of core runs	St. Peter
F-10	3	100.00	16	98.84	13	99.64						
F-11					13	96.57	4	93.55	16	98.56		
F-12			14	97.39	15	99.53	5	99.20	2	100.00		
F-13			7	70.14								
F-14			1	100.00	16	99.34	5	98.20	9	98.44		
F-15			16	99.50	12	98.58						
F-16			12	99.58	12	99.83						
F-17					10	96.70	5	100.00	19	73.36	22	94.54
Mean RQD per stratigraphic unit		100.00		95.80		98.69		97.96		88.19		94.54

Moisture content is the ratio of the weight of water in the sample to the weight of the dry solids.

Both moist and dry density were determined sporadically depending on sample recovery and cohesiveness. Drift samples between 4.0 and 5.5 in. long were measured for length and diameter and stored in glass jars. The samples were weighed, dried, and then reweighed and remeasured.

Particle-size determinations for gravel and sand were made by wet sieving techniques; for silt and clay by hydrometer analysis (ASTM 0-4-22, 1982). We define particle size classes as follows: *clay*, <0.0039 mm; *silt*, between 0.0625 and 0.0039 mm; *sand*, between 2.0 and 0.0625 mm; and *gravel*, >2.0 mm.

Table 11. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-10

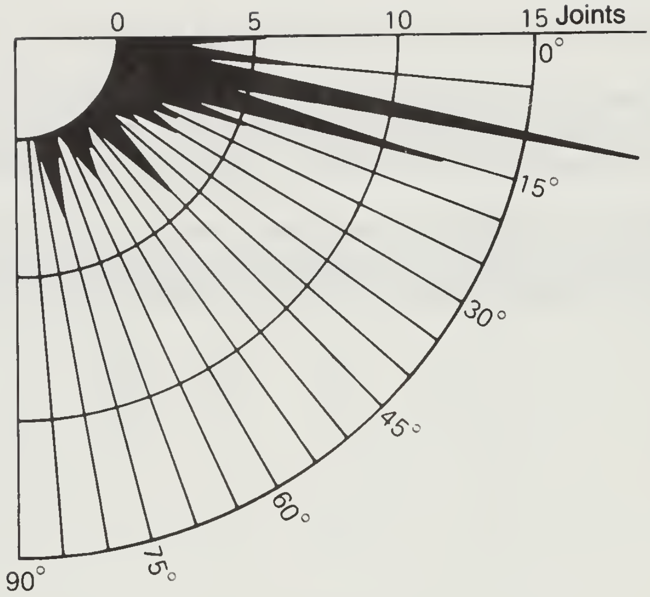
Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
355-344	--	--	--	--	--
335-314	--	--	--	--	--
315-294	--	--	--	--	--
295-274	--	--	--	--	--
275-254	--	--	--	--	--
255-234	--	--	--	--	--
185-164	1.7×10^{-4}	1.2×10^{-4}	1.3×10^{-4}	1.3×10^{-4}	1.7×10^{-4}
165-144	3.4×10^{-3}	1.4×10^{-3}	1.1×10^{-3}	1.4×10^{-3}	1.7×10^{-3}
145-124	1.3×10^{-3}	9.3×10^{-3}	9.9×10^{-3}	1.3×10^{-3}	3.3×10^{-3}
125-104	2.5×10^{-4}	2.1×10^{-4}	1.9×10^{-4}	2.0×10^{-4}	2.4×10^{-4}
115-94	3.9×10^{-3}	4.2×10^{-3}	1.7×10^{-3}	5.4×10^{-2}	5.4×10^{-2}

Notes:

Below a depth of 165 feet, P_1 = 35 psi
P_2 = 70 psi
P_3 = 100 psi

Above a depth of 165 feet, P_1 = 10 psi
P_2 = 30 psi
P_3 = 50 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.



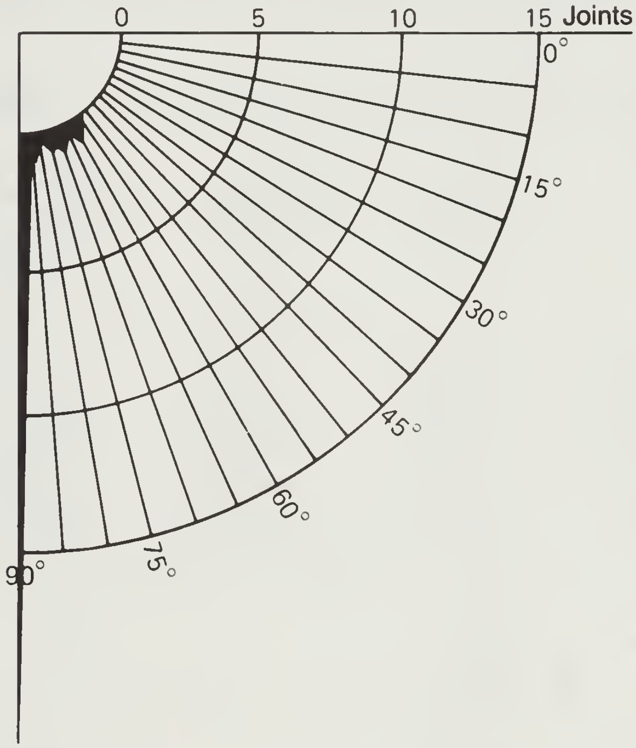


Figure 12 Examples of method used to show number and angle of dip of joints.

INTRODUCTION TO RESULTS OF DRILLING AND TESTING PROGRAMS

The remainder of the report provides for each test boring:

A) location, property owner, surface elevation and total depth of test-hole,

B) a stratigraphic column,

C) summary diagram of data including: drilling rate, core recovery, rock quality designation, distance between horizontal separations, fracture frequency, schematic sketch of fracture orientation and depth, water pressure tests, piezometric data, gamma-ray and neutron logs, indirect tensile and unconfined compression strength data, and finally, tangent modulus data,

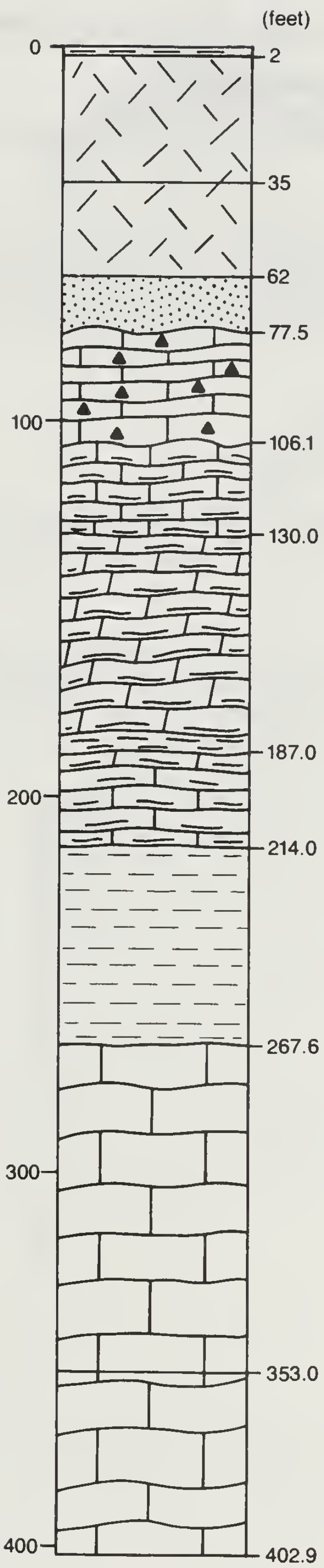
D) pressure test data (table),

E) dip diagram(s) of joints observed in core, and

F) engineering properties and particle-size analyses of drift.

The ground surface elevation given for each test hole was surveyed using benchmarks where expedient; otherwise the elevations given at road intersections on 7.5-minute USGS quadrangle maps were used as control.

Test Hole ISGS F-13 was drilled adjacent to ISGS F-12 for the purpose of installing piezometers at different levels. The piezometer in ISGS F-13 is within bedrock (Maquoketa Shale Group) just below the drift/bedrock contact, whereas the piezometer at ISGS F-12 is within the Galena Group.



QUATERNARY SYSTEM
RICHLAND LOESS
Silty clay loam, brown (0-2 ft)

WEDRON FORMATION
YORKVILLE TILL MEMBER
Till; gray silty clam loam, silty clay and loam, poorly stratified to massive (2-35 ft)

MALDEN TILL MEMBER
Till; gray clay and silty clay (35-62 ft)
Sand; gray, laminated, contains wood fragments (62-77.5 ft)

SILURIAN SYSTEM
ELWOOD DOLOMITE
Limestone, yellow-gray to light greenish gray, some yellow-orange staining, dolomitic, very fine-grained, slightly argillaceous, very cherty; beds 0.2-0.3 ft thick separated by thin greenish gray shaly partings (77.5-106.1 ft)

ORDOVICIAN SYSTEM
MAQUOKETA SHALE GROUP
Limestone, yellow-gray to medium gray, medium- to coarse-grained, argillaceous; separated by thin, greenish gray and purple shaly partings (106.1-130.0 ft)

Dolomite, minor limestone, greenish gray to light blue-gray, silty, very argillaceous, beds separated by thin, greenish gray shaly partings (130.0-187.0 ft)

Limestone, light gray to olive-gray, fine-to coarse- grained, argillaceous, fossiliferous (187.0-214.0 ft)

Shale, olive-gray, calcareous, slightly fossiliferous; some minor dolomite beds (214.0-267.6 ft)

GALENA DOLOMITE GROUP
WISE LAKE DOLOMITE
Limestone, very pale orange to pale yellow-brown, fine- to medium-grained; oil shows in upper 8.0 ft, fossiliferous (267.6-402.9 ft)

Mixed-layer clay bed, 0.03 ft thick, greenish gray (353.0 ft)

Figure 13
Stratigraphic column for Test Hole F-10.

TEST HOLE ISGS F-10

Location: NW 1/4 SW 1/4 NW 1/4 NE 1/4 Sec. 25, T38N, R8E
Farm: Oakhurst Forest Preserve, Forest Preserve District of Du Page County
Surface elevation: 706 feet above m.s.l.
Total depth: 402.9 feet

Stratigraphy

Bedrock
The stratigraphic column (fig. 13) shows the lithologies and depths of the drift and rock units encountered in ISGS F-10. The hole penetrated (from top to bottom) 28.6 feet of Silurian cherty limestone (Elwood Formation); 161.5 feet of interbedded shale, dolomite, and limestone of the Maquoketa Group; and 135.3 feet of Galena Group (Wise Lake Formation) limestone to a total depth of 402.9 feet. The Galena, except for the upper 8 feet, was relatively nonporous, and is unusual in that it is limestone rather than dolomite. A 0.03-foot thick mixed-layer clay bed (the Dygerts Bed) was encountered at 353.0 feet in the Galena Group.

Glacial Drift
Test hole ISGS F-10 penetrates about 2 feet of Richland Loess and 75.5 feet of the Wedron Formation. The upper 2 feet are composed of brown silty clay loam (Richland Loess) that is underlain by 60 feet of dark gray loam and clay till with one 0.5-foot thick sand bed noted at a depth of 28 feet. From 62 to 77.5 feet is poorly sorted sand with abundant wood fragments near the top. Wood fragments tested yielded a radiocarbon date of 37,100 ± 2000 yrs B.P. (ISGS-1398, Barry Fisher, personal communication).

On the basis of engineering properties, particle-size determinations, and clay mineralogy, the materials at ISGS F-10 are correlated to the informal stratigraphy at the Fermilab National Accelerator Laboratory Site (Landon and Kempton, 1971). The till from a depth of about 2 to 35 feet correlates with Landon and Kempton's till 2 of unit B (basal Yorkville Member; Kemmis, 1978); and, from 35 to 62 feet, unit D (Malden Till Member). The wood fragments were probably eroded from a local deposit of the Robein Silt (Curry and Kempton, 1985).

Geophysical Logging
A complete suite of logs was recorded on this hole. The log deflections between 353 to 354 feet on the gamma and neutron logs correspond to a thin, mixed-layer clay bed, the Dygerts Bed, (fig. 14).

Hydrogeologic Data

■ Pressure Testing
The results of the individual pressure test intervals for this boring are listed in Table 11; the hydraulic conductivity values estimated for test intervals are shown graphically in Figure 14, and range from 5.4×10^{-2} cm/sec to less than 1.0×10^{-6} cm/sec. Values greater than 5.0×10^{-4} cm/sec are inaccurate according to our friction-test data, and are probably somewhat greater than the calculated values. The value of 5.4×10^{-2} cm/sec is the greatest calculated value from all packer tests from ISGS F-1 through ISGS F-17.

■ Piezometer
The test interval for the piezometer in ISGS F-10 is between the depths of 337.7 and 316.7 feet. It is in massive limestone of the Wise Lake Formation (Galena Group). The water level in the piezometer has steadily declined from its initial depth of 285.8 feet on 5-24-85 to 331.7 feet on 8-15-86 (table 6). At this rate of decline, the water level may drop below the tested section by the beginning of 1988. On this basis, the head is probably related to the deeper sandstone aquifer and possibly to the cone of depression created by municipal wells along the Fox River (Visocky and others, 1985).

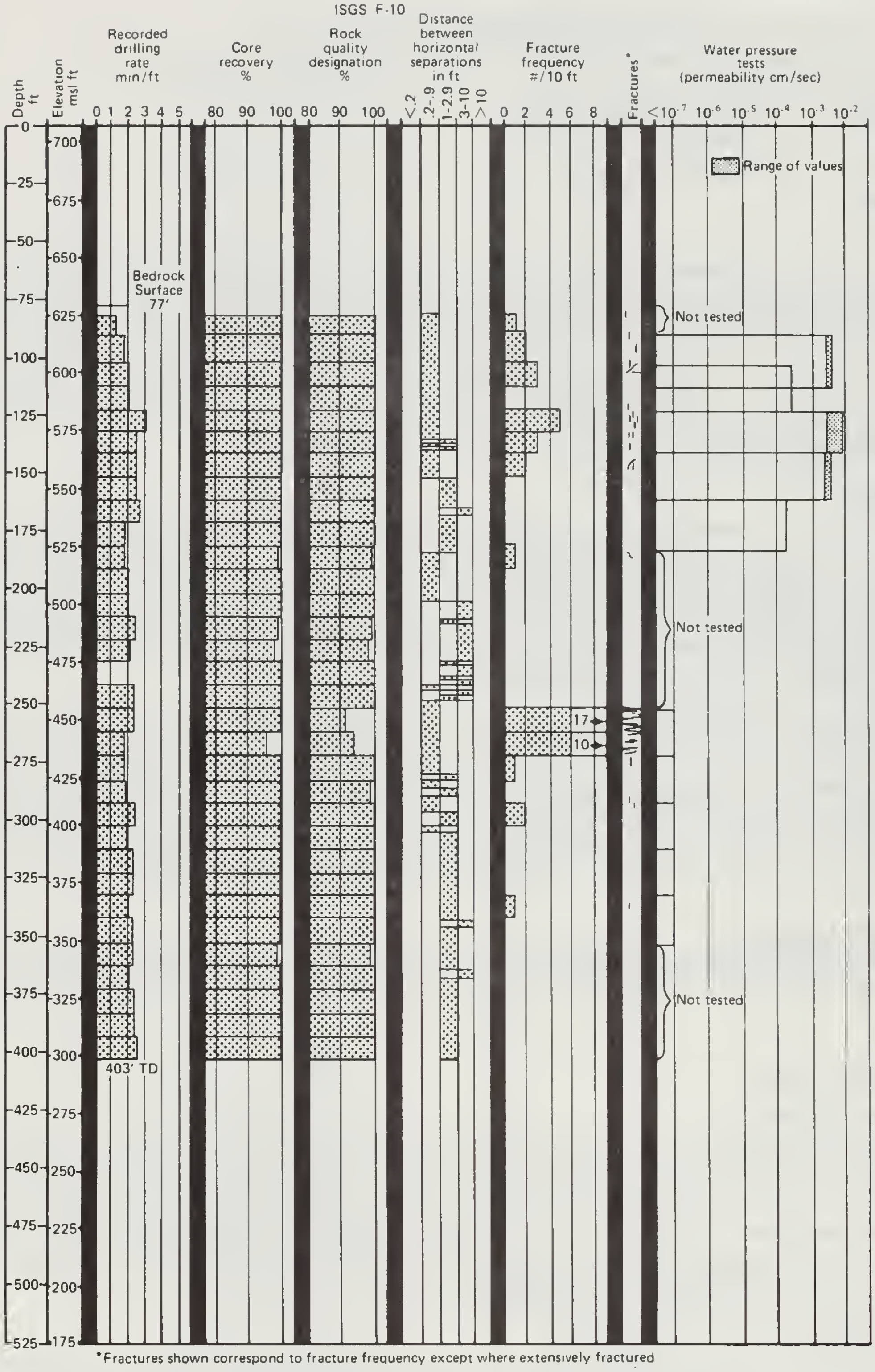


Figure 14 Summary diagram for Test Hole F-10.

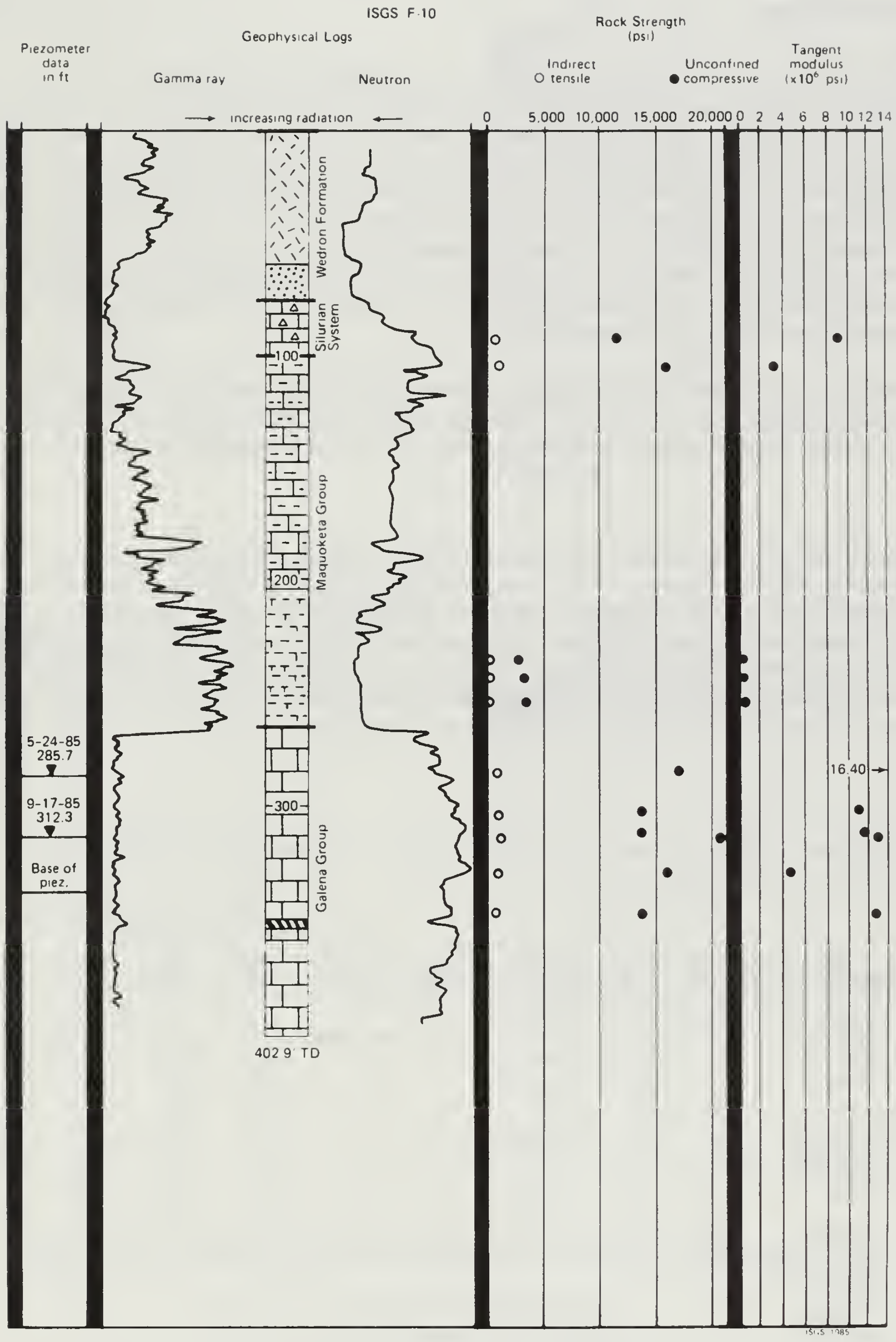


Figure 14 *continued*

Geotechnical Data

Bedrock

Borehole ISGS F-10 is very similar to ISGS F-1 and ISGS F-2 (Kempton and others, 1987) with an initial loss of circulation in the jointed Silurian and also a concentration of fractures in the lower section of the Maquoketa right above the contact with the Galena (fig. 14). This zone, with 24 fractures in 14 feet of core, is interpreted to be a zone of soft sediment deformation features with slips oriented in multiple directions (fig. 17). Outside the soft sediment deformation zone, only 19 joints were encountered in this hole (fig. 16). Figures 15 and 18 show the numbers and dips for the rest of the formations. Seventy-nine percent of the joints are wavy; 21 percent are planar, but all asperities are rough. Core recovery and Rock Quality Designation (RQD) values are excellent (Deere and others, 1966) throughout the entire hole with average values at or above 98 percent (tables 9 and 10, respectively).

After initially having no circulation in bedrock, circulation was regained in the Silurian by advancing the casing. Circulation was lost in the Maquoketa at a depth of 139 feet, but measurements each morning before drilling indicated that the water level was at about 42 feet below the ground surface.

Drift

The upper 30 feet of the till contain more sand and silt than below. This till has variable unconfined compressive strengths, ranging from medium to very high, but relatively consistent N values and moisture content. The underlying clayey till encountered between about 35 to 62 feet has medium bearing strength, with relatively high moisture content ranging from 22.7 to 26.2 percent (table 12). These latter two properties stem from the unit's high clay content (up to 62.3 percent). The lowermost 15 feet of material are composed of sand, which may have high bearing capacity with a normal load, but may run if cut to a vertical face.

Table 12. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-10

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Sand (%)	Silt (%)	Clay (%)	Unified soil classification
8.5-10.0	gray silty	18	4.5	15.5	--	--	3.5	9.4	51.7	39.0	CL
13.5-15.0	clay loam,	18	<-----	-----	-----	POOR SAMPLE	-----	-----	-----	----->	CL
20.0-21.0	and	17	1.3	16.0	--	--	5.3	11.7	43.8	44.6	CL
23.5-25.0	loam till	17	<0.5	11.1	--	--	12.5	30.1	46.4	23.5	CL
28.5-30.0		15	2.3	11.0	--	--	17.4	27.4	42.7	29.9	CL
33.5-35.0		22	>4.5	16.1	--	--	4.5	7.9	44.6	47.5	CL
38.5-40.0	olive-gray	14	1.8	26.2	--	--	0.5	3.6	34.1	62.3	CL
43.5-45.0	clay and	13	1.9	22.8	--	--	1.4	4.6	40.7	54.8	CL
48.5-50.0	silty clay	13	1.0	24.3	--	--	5.6	4.9	33.0	62.1	CL
53.5-55.0	till	--	--	22.7	--	--	2.2	5.3	40.0	54.6	CL
58.5-60.0		22	1.8	14.5	--	--	9.9	30.6	46.4	23.0	CL
63.5-65.0	boulder	30	<-----	-----	-----	NO SAMPLE	-----	-----	-----	----->	GP
68.5-70.0	brown, medium	37	--	--	--	--	--	--	--	--	SP
73.5-75.0	to fine sand	35	--	--	--	--	--	--	--	--	SP
78.5-80.0	with wood fragments	63	--	--	--	--	--	--	--	--	SP
	bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction

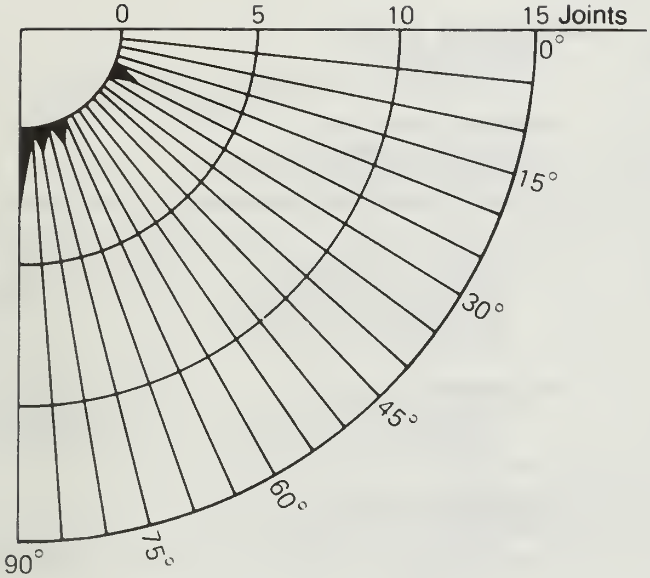


Figure 15

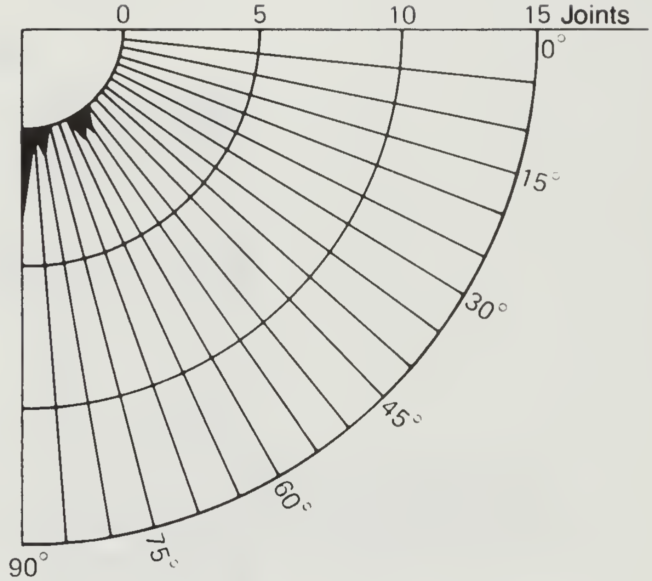


Figure 16

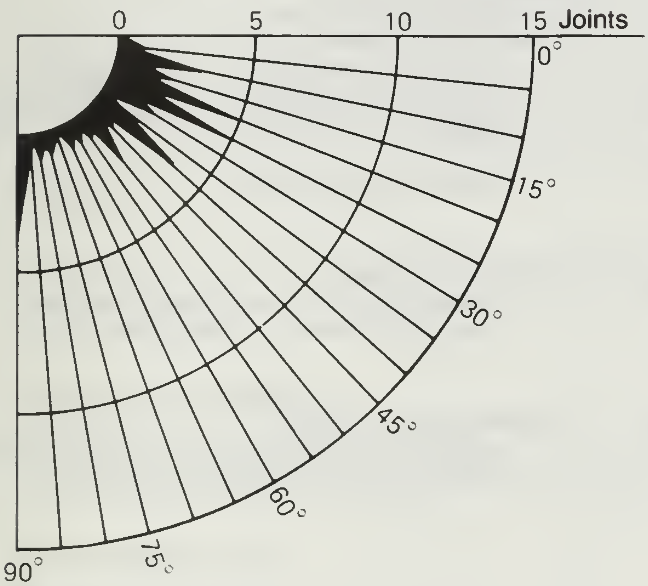


Figure 17

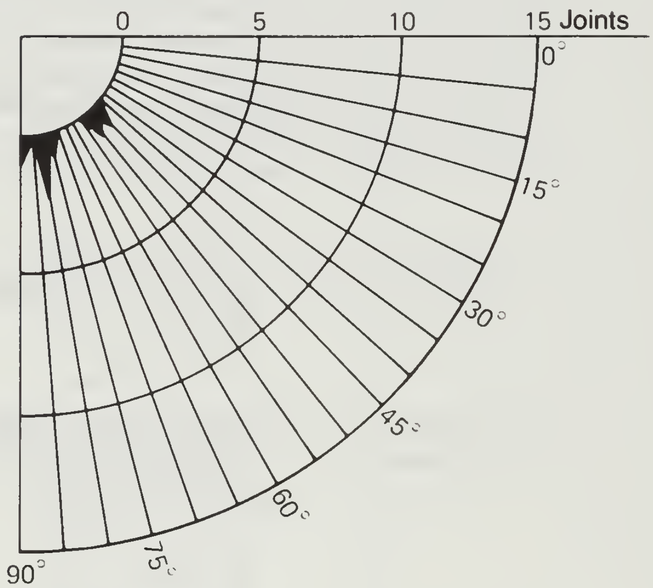
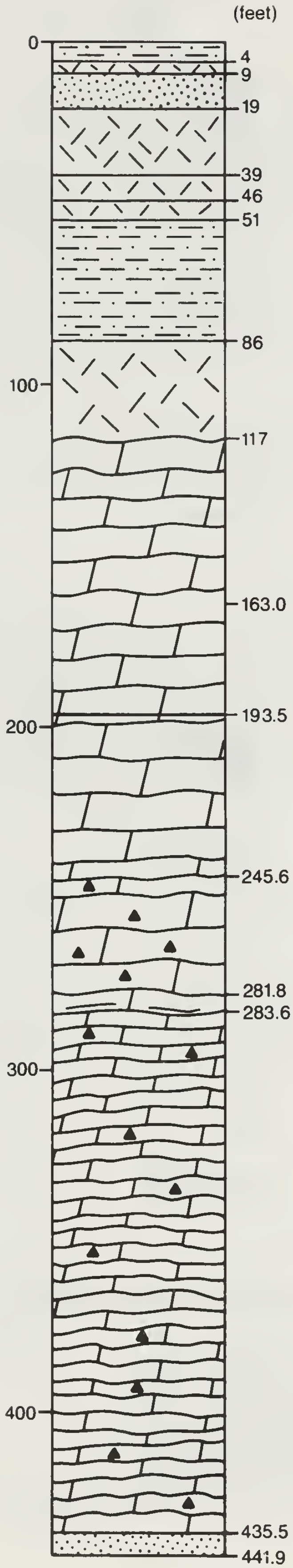


Figure 18

Number and angle of dip of joints in core from Test Hole ISGS F-10

15 28.6 feet of Silurian System strata.
16 161.5 feet of Maquoketa Group strata (soft sediment features excluded).
17 161.5 feet of Maquoketa Group strata (soft sediment features included).
18 135.3 feet of Galena (Wise Lake) Group strata.



QUATERNARY SYSTEM

RICHLAND LOESS

Silty clay loam; grayish brown, massive, gleyed (0-4 ft)

WEDRON FORMATION

MALDEN TILL MEMBER

Till; brownish gray loam (4-9 ft)

Sand; pinkish brown, medium-grained, stratified (9-19 ft)

TISKILWA TILL MEMBER

Till; pinkish brown pebbly clay loam and loam (19-39 ft)

Till; gray pebbly loam (39-46 ft)

Till; pinkish brown pebbly loam massive (46-51 ft)

PEDDICORD FORMATION

Interlaminated loam, clay loam and fine sand, pinkish brown, coarsens downward (51-86 ft)

GLASFORD FORMATION

HERBERT TILL MEMBER (?)

Till; pinkish brown loam, massive; boulder between 86-87 ft (86-117 ft)

ORDOVICIAN SYSTEM

GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE

Dolomite, light olive-gray, fine- to medium-grained, calcareous, beds are 0.2 to 0.4 ft thick, separated by thin, greenish gray to olive-black shaly partings, very vuggy, fossiliferous (117.0-245.6 ft)

Mixed-layer clay bed (193.5 ft)

DUNLEITH DOLOMITE

Dolomite, as above, but cherty (white nodules and lenses 0.1-0.2 ft thick), very vuggy (245.6-281.8 ft)

GUTTENBERG DOLOMITE

Dolomite, pale yellow-brown, fine- to medium-grained with reddish-brown shaly partings (281.8-283.6 ft)

PLATTEVILLE DOLOMITE

Dolomite, pale yellow-brown, slightly mottled and burrowed, light gray, fine-grained, slightly vuggy, some chert nodules (283.6-435.5 ft)

ANCELL GROUP

ST. PETER SANDSTONE

Sandstone, light gray, fine- to medium-grained, very friable, some dark gray mottling in the upper foot (435.5-441.9 ft)

Figure 19

Stratigraphic column for Test Hole F-11.

TEST HOLE ISGS F-11

Location: NE 1/4, SE 1/4, NE 1/4, SW 1/4, Sec. 14, T38N, R5E
Property: City of Hinckley Water Treatment Plant
Surface Elevation: 731 feet above m.s.l.
Total Depth: 441.9 feet

Stratigraphy

Bedrock

The stratigraphic column (fig. 19) shows the lithologies and depths of the drift and rock units encountered in ISGS F-11. The hole penetrated (from top to bottom) 166.8 feet of Galena Group dolomite, 151.9 feet of Platteville Group dolomite, and 6.4 feet of St. Peter Sandstone (Ancell Group). A 0.05-foot thick mixed-layer clay bed (the Dygerts Bed) was encountered at a depth of 193.5 feet in the Galena Group.

Glacial Drift

The drift at ISGS F-11 is 117 feet thick, composed of 4 feet of Richland Loess, 47 feet of Wedron Formation, 35 feet of Peddicord Formation, and 31 feet of Glasford Formation. The upper 4 feet are composed of gleyed silty clay loam (Richland Loess), which is underlain by about 5 feet of brownish gray clay loam till (Malden Till Member). From 9 to 19 feet is a succession that coarsens downward of poorly sorted, stratified sand (Malden Till Member), underlain by 32 feet of pinkish brown to gray loam and clay loam till (Tiskilwa Till Member). From 51 feet to 86 feet is laminated, poorly sorted clay loam and fine sand with a few intercalated, thin loam till beds near the top (Peddicord Formation). The lowermost 31 feet of drift are pinkish brown loam till (Herbert Till Member, Glasford Formation).

Stratigraphic assignments were made on the basis of regional correlation, chiefly with ISGS F-17 (this report) and descriptions of the drift at the Wedron quarry in La Salle County (Johnson and others, 1985).

Geophysical Logging

A complete suite of logs was run on this hole. The Gamma Ray-Neutron log is presented in Figure 20. The logs have deflections that correspond to a mixed-layer clay bed (the Dygerts Bed) at 193.0 feet and shaly partings at 194.5, 206.2, and 272.6 feet.

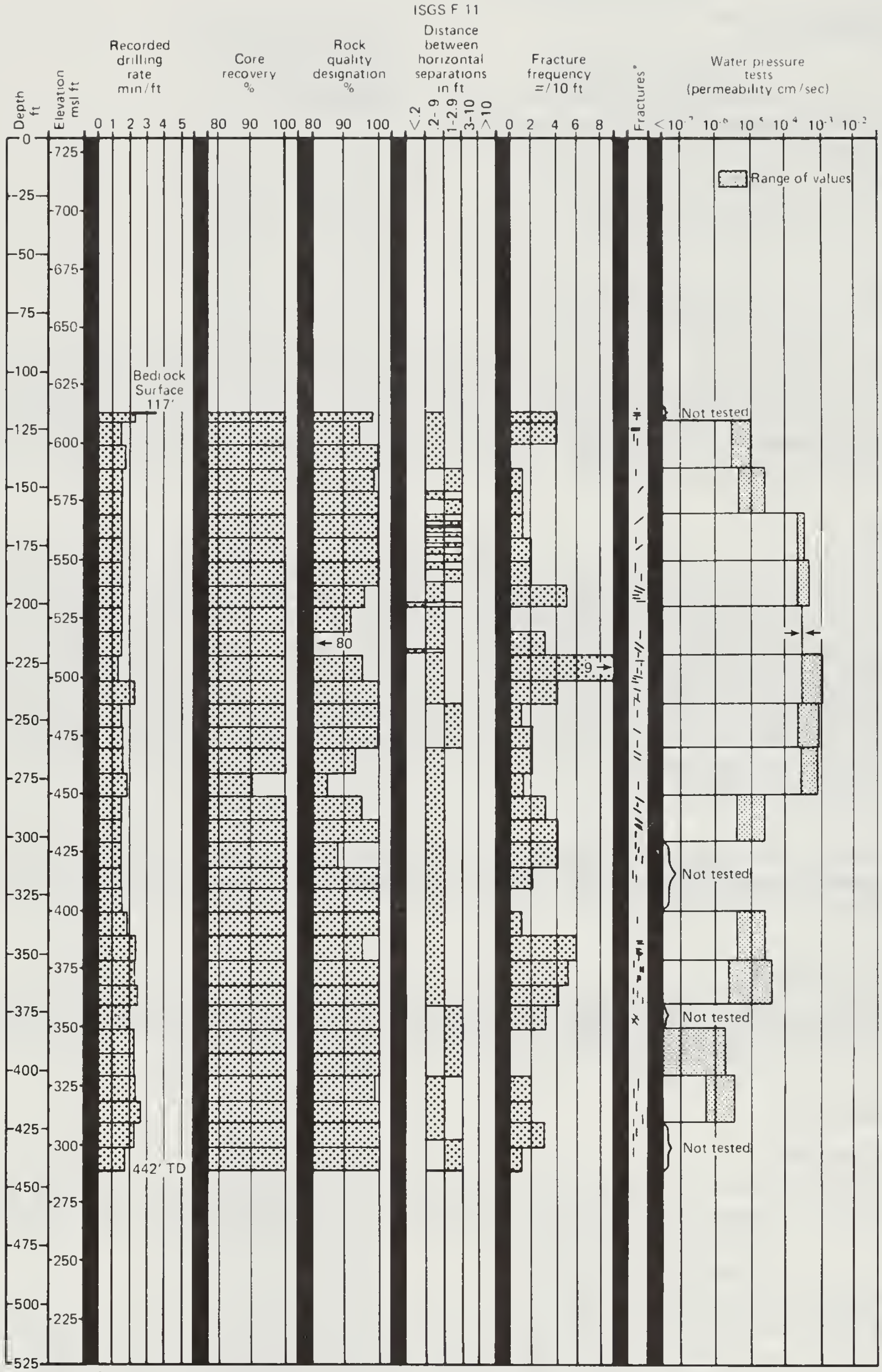
Hydrogeologic Data

■ Pressure Testing

The results of the individual pressure test intervals for this boring are listed in Table 13; the hydraulic conductivity values estimated for test intervals, shown graphically in Figure 20, range from 9.8×10^{-4} to less than 1.0×10^{-6} cm/sec.

■ Piezometer

The test interval for the piezometer in ISGS F-11 is between a depth of 350.0 and 329.0 feet and is in dolomite of the Platteville Group. After an initial level of 36.2 feet on 5-10-85, the water level has fluctuated from 39.0 feet (8-21-85) to 21.8 feet deep (6-18-86; table 6). Since the hydraulic head in the St. Peter Sandstone is at about ground level at this site, the relatively shallow water levels may be related to either the deeper sandstone aquifer or the shallow bedrock aquifer (Visocky and others, 1985).



*Fractures shown correspond to fracture frequency except where extensively fractured

Figure 20 Summary diagram for Test Hole F-11.

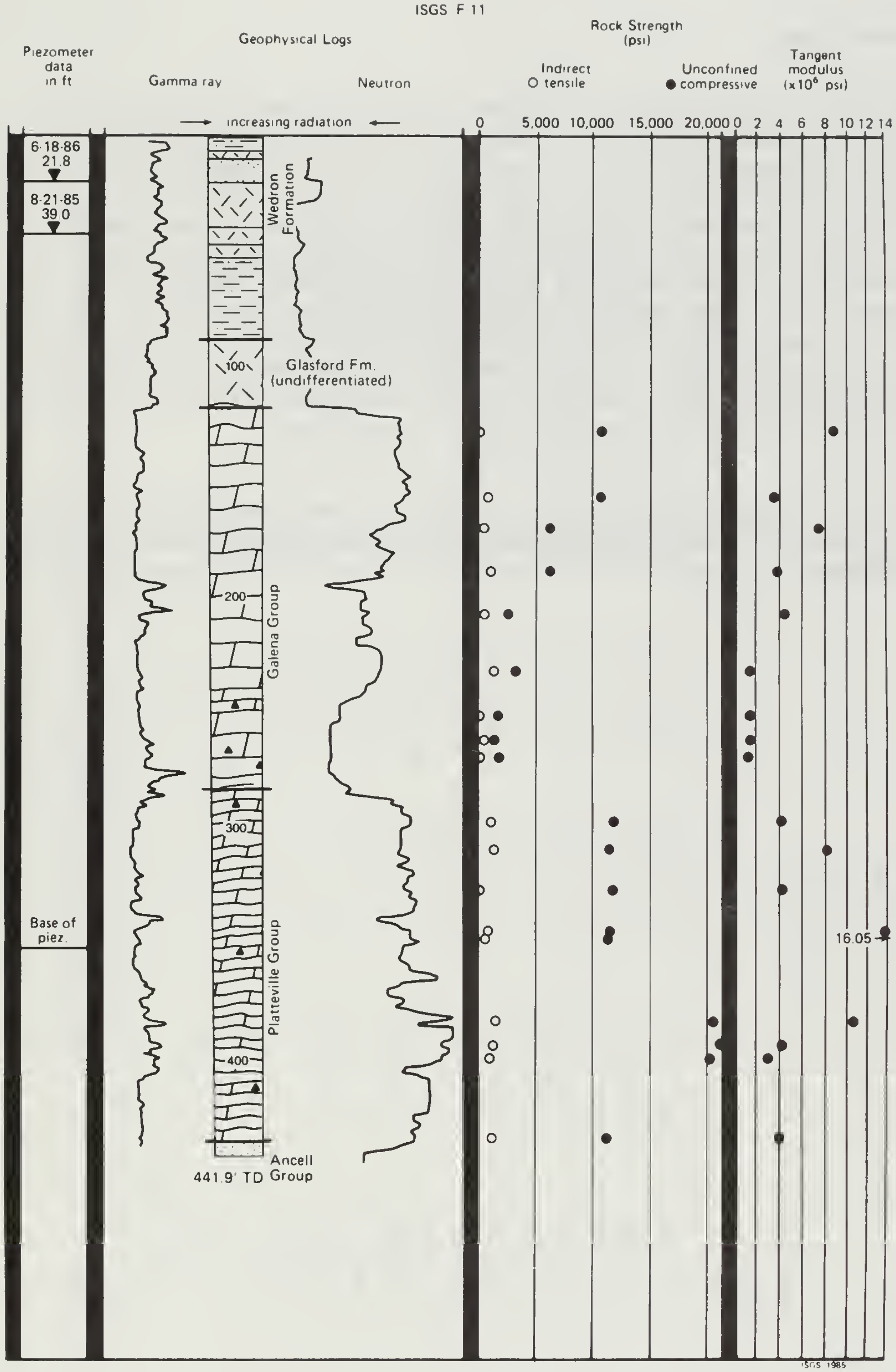


Figure 20 *continued.*

Geotechnical Data

Bedrock

Borehole ISGS F-11 lost circulation at a depth of 232 feet below the ground surface, but the water level in the hole was always about 31 feet below the surface when measured each morning before drilling continued. ISGS F-11 did not encounter any concentrations of joints or fractures; however, it encountered a consistently high number of joints and fractures along the entire borehole (fig. 20). In the Galena, only 13 percent (6 joints) of the joints have partial filling of shale, calcite or pyrite; the rest have no filling. All the joints in the Galena have wavy or uneven surfaces with rough asperities. In the Platteville, 60 percent of the joints have partial filling of calcite or pyrite; 7 percent have partial clay filling. Ninety-two percent have wavy surfaces with 72 percent of the asperities rough. Eighty-three percent (65 joints) of all the joints in this borehole have dips greater than 70 percent (figs. 21, 22, and 23). Average core recovery and RQD values are excellent (tables 9 and 10) throughout the entire hole with values of 93 percent or better. The lowest core recovery and RQD values are 90 and 80 percent, respectively.

Drift

The till units encountered between the depths of 18.8–51.0 feet and 86.0–116.0 feet depth have high bearing capacity. The remaining intervals are composed primarily of sorted sediment, which may have high bearing strength with a normal load, but may run if cut to a vertical face (table 14).

Table 13. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-11

Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
421-401	5.2×10^{-6}	2.3×10^{-5}	1.8×10^{-5}	9.5×10^{-6}	5.2×10^{-6}
401-381	--	--	1.4×10^{-5}	4.2×10^{-6}	--
371-351	5.2×10^{-6}	1.8×10^{-5}	3.9×10^{-5}	4.1×10^{-6}	2.7×10^{-6}
350-330	1.4×10^{-5}	1.4×10^{-5}	2.6×10^{-5}	1.2×10^{-5}	7.8×10^{-6}
300-280	1.5×10^{-5}	1.4×10^{-5}	2.7×10^{-6}	7.1×10^{-6}	5.4×10^{-6}
280-260	7.9×10^{-4}	3.4×10^{-4}	3.3×10^{-4}	3.5×10^{-4}	6.7×10^{-4}
260-240	8.5×10^{-4}	3.2×10^{-4}	2.3×10^{-4}	2.2×10^{-4}	3.5×10^{-4}
240-220	9.8×10^{-4}	3.3×10^{-4}	2.9×10^{-4}	3.7×10^{-4}	4.2×10^{-4}
220-200	2.1×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	1.5×10^{-4}	2.0×10^{-4}
200-180	4.9×10^{-4}	2.7×10^{-4}	2.7×10^{-4}	2.5×10^{-4}	3.6×10^{-4}
180-160	3.3×10^{-4}	1.8×10^{-4}	1.5×10^{-4}	1.7×10^{-4}	2.4×10^{-6}
160-140	2.6×10^{-5}	1.9×10^{-5}	1.4×10^{-5}	5.2×10^{-6}	5.2×10^{-6}
140-120	9.1×10^{-6}	7.7×10^{-6}	5.5×10^{-6}	2.6×10^{-6}	--

Notes:

Below a depth of 160 feet, P_1 = 35 psi
P_2 = 70 psi
P_3 = 100 psi

Above a depth of 160 feet, P_1 = 10 psi
P_2 = 30 psi
P_3 = 50 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

Table 14. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-11

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)	Unified Soil Classification
3.5-5.0	A	12	--	--	--	--	0.1	2.7	63.4	33.9	CL
9.0-9.5	B	40	1.8	12.9	--	--	3.8	27.2	48.2	24.7	CL
9.5-10.5	laminated,	--	--	--	--	--	--	--	--	--	SP
13.0-14.5	pinkish brown	24	--	--	--	--	--	--	--	--	SP
	silt and sand										
18.0-19.5		14	--	18.5	--	--	12.0	50.2	34.8	15.0	CL
23.0-24.5	pinkish brown	13	1.3	13.5	1.96	2.22	7.9	37.3	35.1	27.6	CL
28.0-29.5	to gray clay	45	<0.8	8.9	--	--	17.0	43.8	33.3	22.8	CL
33.0-34.5	loam and loam	45	2.3	10.3	--	--	9.0	43.1	32.1	24.8	CL
38.0-39.5	till	45	2.3	12.0	--	--	7.8	40.6	32.8	26.6	CL
43.0-43.5		71	2.5	12.4	--	--	3.8	31.9	42.7	25.4	CL
47.0-49.5		22	<0.8	--	--	--	19.2	48.6	35.7	15.7	CL
53.0-54.5	laminated,	14	--	--	--	--	--	--	--	--	SP
57.0-58.5	light pinkish	R	--	--	--	--	0.0	21.5	55.3	23.1	CL,SP
63.0-64.5	brown loam,	R	--	--	--	--	0.0	11.5	51.5	37.0	CL,SP
73.0-74.5	clay loam and	R	--	11.4	--	--	--	--	--	--	ML
78.0-79.5	fine sand	R	--	--	--	--	--	--	--	--	SP
83.0-84.5		<-----NO SAMPLE----->									SP
88.0-90.0	pinkish	78	--	--	--	--	19.7	50.0	28.0	22.0	CL
93.0-94.5	brown loam	<-----NO SAMPLE----->									CL
98.5-99.0	till	R	--	--	--	--	7.2	47.4	36.0	16.6	CL
103.0-104.5		<-----NO SAMPLE----->									CL
108.5-110.0	clay loam till	62	--	10.2	--	--	16.3	36.8	35.6	27.3	CL

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot
A gleyed clay loam
B grayish brown loam till

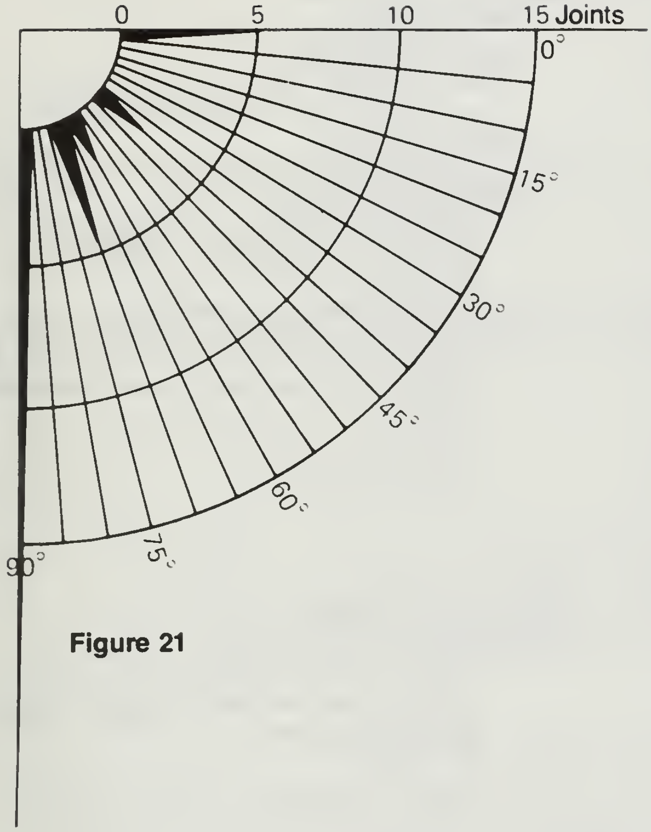


Figure 21

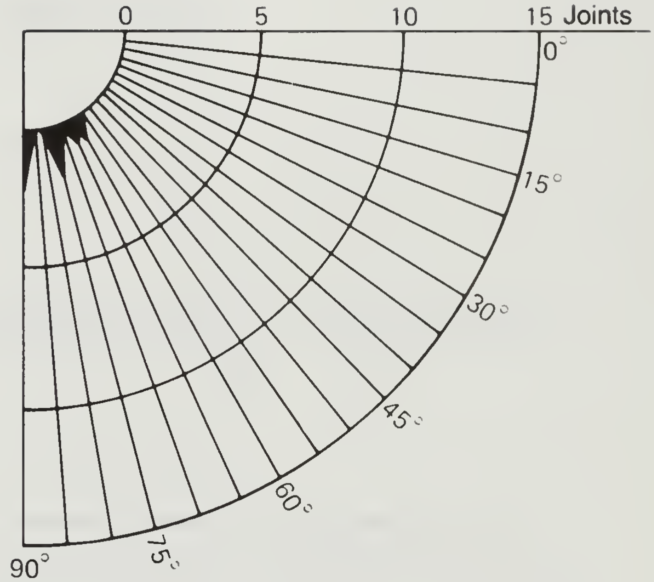


Figure 22

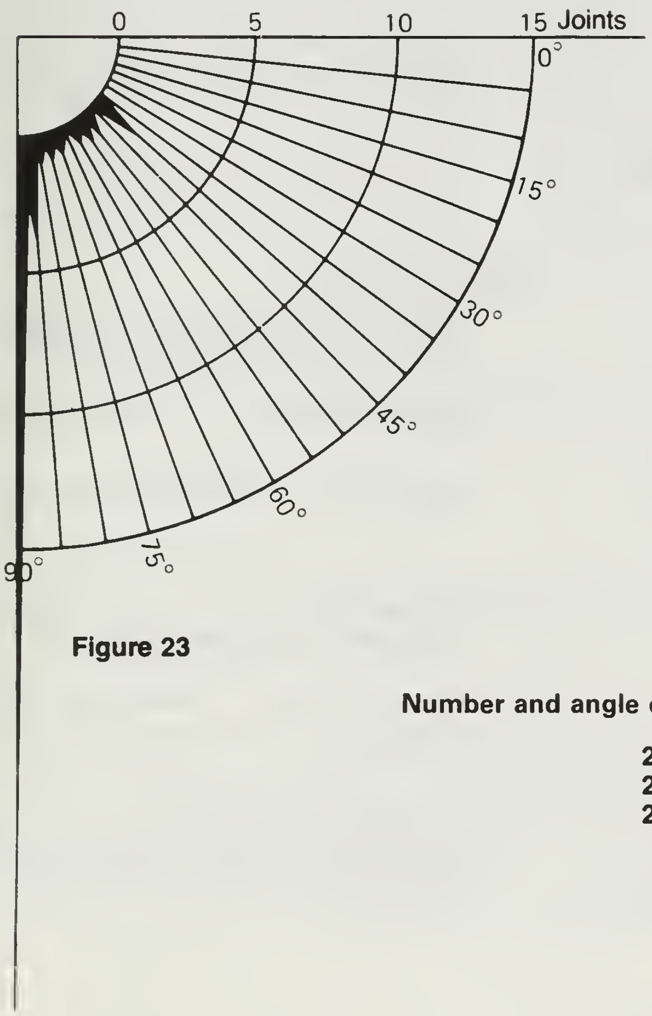
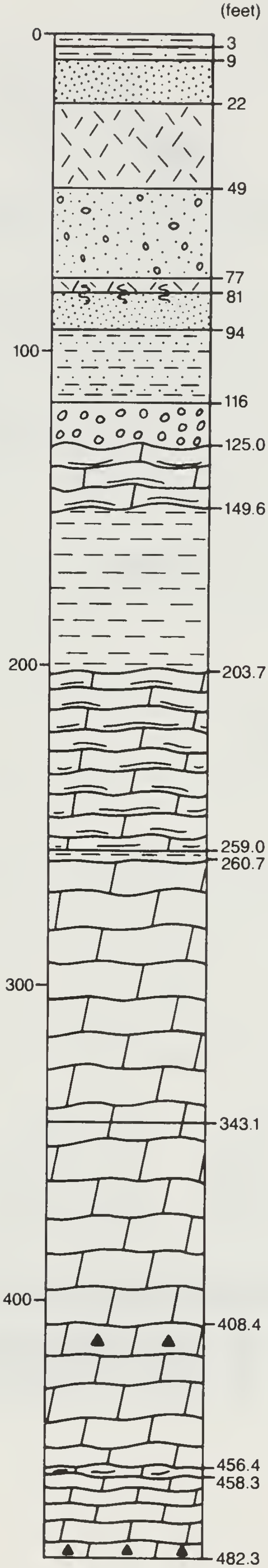


Figure 23

Number and angle of dip of joints in core from Test Hole ISGS F-11

21 128.6 feet of Galena (Wise Lake) Group strata.
22 39.0 feet of Galena (Dunleith) Group strata.
23 151.9 feet of Platteville Group strata.



QUATERNARY SYSTEM

RICHLAND LOESS

Silty clay loam, gleyed (0-3 ft)

EQUALITY FORMATION

CARMI MEMBER

Laminated clay loam; greenish gray, gleyed (3-9 ft)

HENRY FORMATION

Sand and gravel; yellow-brown to gray, laminated (9-22 ft)

WEDRON FORMATION

TISKILWA TILL MEMBER

Till; pinkish brown clay loam and loam (22-49 ft)

Sand and gravel; pinkish brown, stratified, fines downward (49-77 ft)

GLASFORD FORMATION (undifferentiated)

Loam; dark brown, contains 0.45% organic matter and argillans (Sangamon Soil developed into till; 77-81 ft)

Sand; greenish gray, laminated to massive, gravely, gleyed (81-94 ft)

Laminated silt and sand (94-116 ft)

Gravel; dolomitic (116-123 ft)

Rock rubble (123-125 ft)

ORDOVICIAN SYSTEM

MAQUOKETA SHALE GROUP

Dolomite, light olive-gray, dark speckled, fine- to medium-grained, some laminations and cross-beds, argillaceous, beds generally 0.2-0.6 ft thick separated by thin olive-gray shaly partings; grades to shale below (125.0-149.6 ft)

Shale, olive-gray dolomitic; some minor dolomite beds, light olive to olive-gray, argillaceous (149.6-203.7 ft)

Dolomite, light olive-gray to olive-gray, fine- to coarse-grained, argillaceous, fossiliferous, beds 0.1-0.6 ft thick separated by thin, olive-gray shaly partings (203.7-259.0 ft)

Shale, olive-gray, dolomitic (259.0-260.7 ft)

GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE

Dolomite, pale yellow-brown, fine- to medium-grained, vuggy and vesicular, beds up to 0.6 ft thick separated by thin, olive-gray shaly partings (260.7-342.9 ft)

Mixed-layer clay bed, 0.155 ft thick, dark yellowish brown (343.1 ft)

Dolomite, as above, but partings are brownish black (343.1-408.8 ft)

DUNLEITH DOLOMITE

Dolomite, as above, but cherty between 408.4-416.1 ft; not cherty below to 456.4 ft (408.4-456.4 ft)

GUTTENBERG DOLOMITE

Dolomite, as above, but with reddish brown shaly partings (456.4-458.3 ft)

PLATTEVILLE DOLOMITE GROUP

Dolomite, light orange to pale yellow-brown, slightly mottled dark gray, slightly vuggy, beds separated by thin, olive-gray shaly partings, slightly cherty between 472.6-482.3 ft (458.3-482.3 ft)

Figure 24
Stratigraphic column for Test Hole F-12.

TEST HOLE ISGS F-12, F-13*

Location: NW 1/4 NE 1/4 SE 1/4 SW 1/4 Sec. 10, T40N, R6E
Property: Kane County Forest Preserve Bike Trail
Surface Elevation: 872 feet above m.s.l.
Total Depth: 482.3 feet

*Shallow hole drilled adjacent to ISGS F-12 to install piezometer. ISGS F-13 was not geophysically logged, and the stratigraphy is identical to that of ISGS F-12.

Stratigraphy

Bedrock

The stratigraphic column (fig. 24) shows the lithologies and depths of the drift and bedrock units encountered in ISGS F-12. The hole penetrated (from top to bottom) 136 feet of Maquoketa Group dolomite and shale, 198 feet of Galena Group dolomite, and 24 feet of Platteville Group dolomite. A 0.15-foot thick mixed-layer clay bed (the Dygerts Bed) was encountered at 343.10 feet in the Galena Group. Maquoketa in this hole is predominantly dolomite from 204 to 259 feet.

Glacial Drift

The drift at F-12 is 125 feet thick. The upper 22 feet belong to the Richland Loess, the Equality Formation, and the Henry Formation; the underlying 55 feet, to the Wedron Formation; and the lowermost 48 feet, the Glasford Formation. The upper 9 feet are composed of poorly stratified clay loam and silty clay loam (Richland Loess and Equality Formation). These deposits grade downwards to poorly sorted gravelly sand (Henry Formation). Underlying this for 27 feet is pinkish brown clay loam and loam till (Tiskilwa Till Member). From a depth of 49 feet to 77 feet is stratified gravel and sand (Tiskilwa Till Member) that gets generally finer with depth. Between 77 and 81 feet is dark brown loam with evidence of soil formation, such as high organic matter content (0.45%, Richard Cahill, personal communication) and argillans (soil fabric). The buried soil is the Sangamon Soil. The underlying 42 feet are composed of stratified gravel, sand, and laminated silt (Glasford Formation, undifferentiated). The lowermost 2 feet are rubble composed of broken rock fragments.

Geophysical Logging

A complete suite of logs was run on this hole. The Gamma Ray-Neutron logs are shown in Figure 25. A deflection at 343 feet corresponds to a mixed-layer clay bed (the Dygerts Bed). High moisture content is indicated in the Maquoketa Shale between 146-205 feet.

Hydrogeologic Data

■ Pressure Testing

The results of the individual pressure test intervals for ISGS F-12 and ISGS F-13 are listed in Table 15 and 16, respectively. The hydraulic conductivity values estimated for test intervals in F-12, shown graphically in Figure 25, range from 5.2×10^{-3} to less than 1.0×10^{-6} cm/sec.

■ Piezometers

The test interval for the piezometer in ISGS F-12 is between depths of 466.0 and 445.0 feet and is in dolomite of the Platteville Group. The water level has been nearly constant at about 278.0 feet deep (table 6). Another piezometer was installed in ISGS F-13, which was drilled 20 feet from ISGS F-12. The test interval in ISGS F-13 is 157 feet to 136 feet and is in dolomite of the Maquoketa Group. After an initial depth of 18.8 feet on 6-21-85, the water level has fluctuated between 13.4 feet (12-12-85) and 17.9 feet (10-17-85). The levels in ISGS F-13 correspond to the shallow bedrock aquifer; the levels in ISGS F-12 are more closely related to the deeper

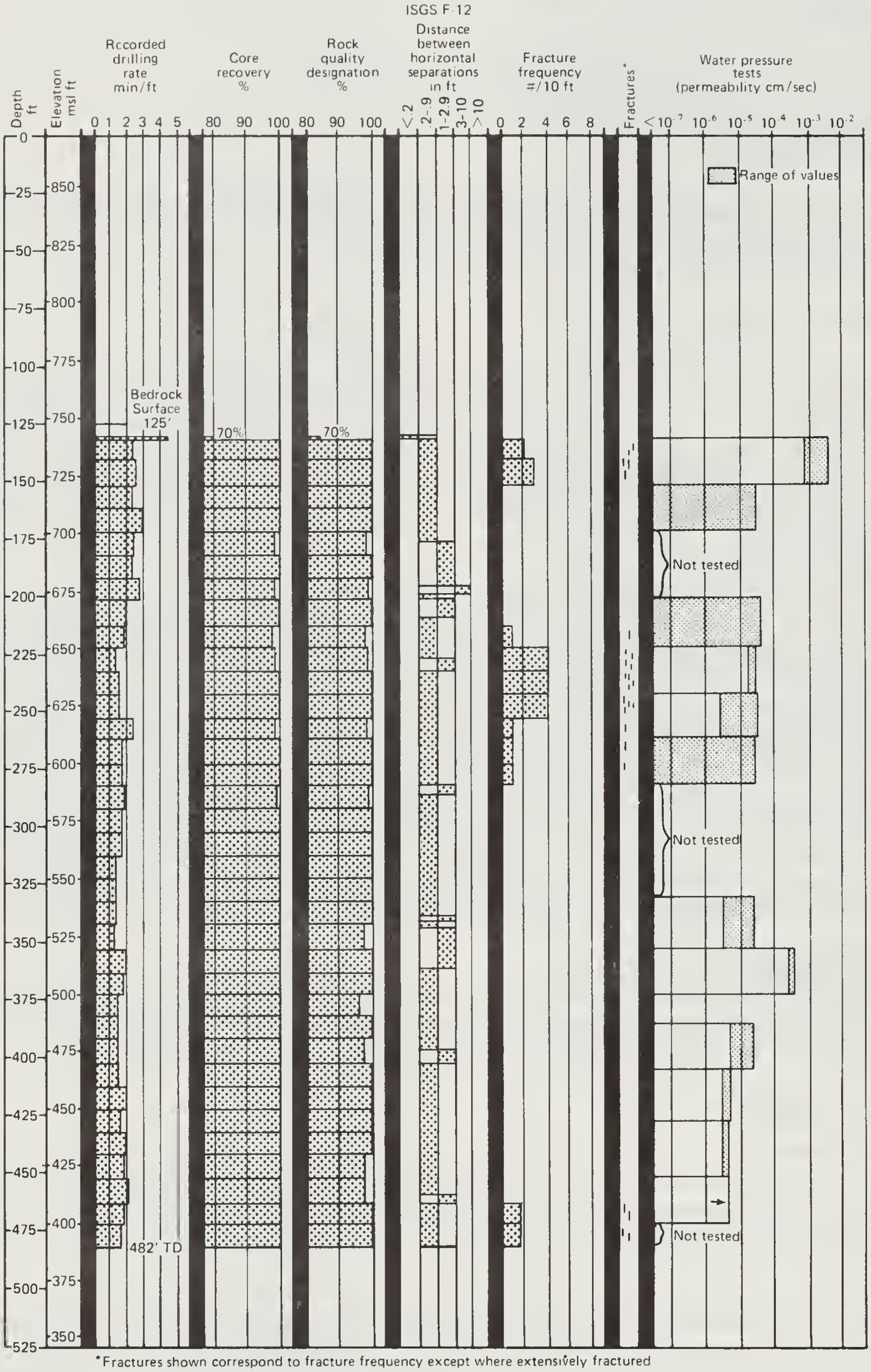


Figure 25 Summary diagram for Test Hole F-12.

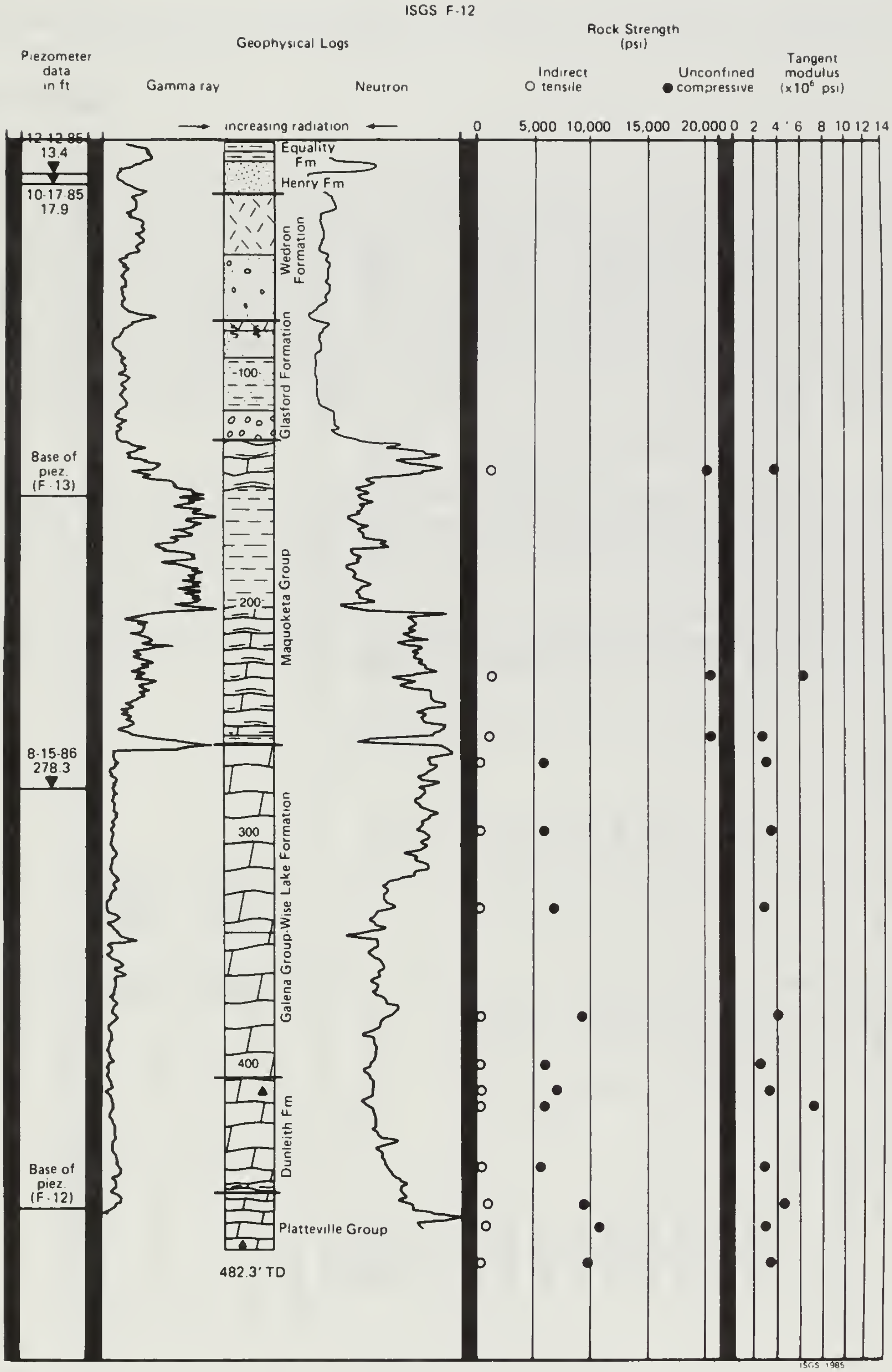


Figure 25 *continued.*

Table 15. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-12

Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
469-448	3.0×10^{-6}	2.9×10^{-6}	3.2×10^{-6}	2.9×10^{-6}	3.0×10^{-6}
447-426	3.0×10^{-6}	3.0×10^{-6}	4.2×10^{-6}	2.9×10^{-6}	3.0×10^{-6}
425-404	6.1×10^{-6}	4.4×10^{-6}	4.2×10^{-6}	4.4×10^{-6}	6.1×10^{-6}
405-384	6.1×10^{-6}	4.4×10^{-6}	1.1×10^{-5}	4.4×10^{-6}	9.1×10^{-6}
370-349	5.3×10^{-4}	3.4×10^{-4}	3.4×10^{-4}	4.3×10^{-4}	4.9×10^{-4}
350-329	5.9×10^{-6}	4.3×10^{-6}	1.2×10^{-5}	4.3×10^{-6}	5.9×10^{-6}
280-259	--	1.4×10^{-6}	1.6×10^{-5}	1.4×10^{-6}	--
260-239	2.9×10^{-6}	1.3×10^{-5}	4.4×10^{-5}	1.2×10^{-5}	1.8×10^{-5}
240-219	1.4×10^{-5}	1.6×10^{-5}	3.5×10^{-5}	1.5×10^{-5}	1.4×10^{-5}
220-199	--	--	2.5×10^{-5}	--	--
172-151	--	4.4×10^{-6}	1.5×10^{-5}	1.4×10^{-6}	--
151-130	5.2×10^{-3}	1.1×10^{-3}	1.0×10^{-3}	8.8×10^{-4}	1.4×10^{-3}

Notes:

Below a depth of 151 feet, P_1 = 35 psi
P_2 = 70 psi
P_3 = 100 psi

Above a depth of 151 feet, P_1 = 10 psi
P_2 = 30 psi
P_3 = 50 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

sandstone aquifer (Visocky and others, 1985). The difference in head between ISGS F-12 and ISGS F-13 was 262.5 feet on 8-15-86 (table 6).

Geotechnical Data

Bedrock

In borehole ISGS F-12, circulation was lost during the entire coring operation, yet water levels in the borehole each morning were about 19 feet below the ground surface. Very few fractures or joints were encountered in this borehole (fig. 25). All joints have dips greater than 70° (figs. 26, 27, and 28). Eighty-four percent of these joints are located in the Maquoketa. Seventy-six percent have partial or complete fillings. Only one is filled with clay; the rest are mineralized with calcite or pyrite. Thirty-eight percent of the joint surfaces are planar, and the rest are wavy, but all have rough asperities. The average core recovery and RQD values are excellent. The values are 97 percent and greater (tables 9 and 10). The lowest value for both indices is 70 percent for one run in the Maquoketa; the rest of the units have values no lower than 97 percent.

Drift

Between 0 and 22 feet, the drift has low to medium bearing capacity, which increases with depth. This upper interval has high moisture content (up to at least 28.4 percent, table 17). The underlying clay loam till from 22 to 49 feet has medium to high bearing capacity and low moisture content. Between 49 to 77 feet is sorted, coarse-grained sand and gravel, which has high bearing capacity. The underlying buried soil (between 77 and 81 feet deep) has high bearing strength, and it contains a minor amount of organic carbon (0.3%, Richard Cahill, personal communication). The underlying stratified and sorted sand and silt between 81 and 120.0 feet has high bearing capacity.

Table 16. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-13

Test interval (ft)	P_1	P_2	P_3	P_2	P_1
145-135	--	1.3×10^{-5}	1.2×10^{-5}	--	--

Notes:

For all test intervals: P_1 = 10 psi, P_2 = 30 psi, P_3 = 50 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

Table 17. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-12

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)	Unified Soil Classification
4.5- 6.0	gleyed, lami-	--	1.8	--	--	--	0.1	2.7	63.4	33.8	MH
8.5-10.0	nated silt	15	0.8	28.4	--	--	0.0	11.6	57.8	30.6	MH
13.0-14.5	loam to gra-	33	--	--	--	--	--	--	--	--	GC
18.0-19.5	velly sand;	30	--	--	--	--	--	--	--	--	GC
23.0-24.5	coarsens	29	1.3	12.7	--	--	9.2	36.2	36.0	27.8	CL
	downward										
28.0-29.5	pinkish brown	33	1.8	11.8	2.62	2.90	4.9	38.2	34.4	27.4	CL
	clay loam			10.8							
32.0-33.5	and	32	1.5	11.9	--	--	2.7	33.2	37.4	29.4	CL
38.0-39.5	loam till	30	2.3	12.1	2.66	2.96	11.9	32.9	35.6	31.5	CL
				11.5							
43.0-44.5		52	--	11.1	--	--	7.0	38.8	36.4	24.9	CL
48.0-49.5		41	2.3	11.1	--	--	7.9	39.2	33.6	27.2	CL
52.0-53.5	pinkish sand	42	2.3	11.1	--	--	--	--	--	--	SP
58.0-59.5	and gravel,	57	--	--	--	--	--	--	--	--	SP
62.0-63.5	coarsens	60	--	--	--	--	--	--	--	--	SP
68.0-69.5	upward	100	--	--	--	--	--	--	--	--	SP
72.0-73.5		77	--	--	--	--	--	--	--	--	SP
79.5-80.0	organic-rich	R	3.8	15.3	--	--	16.4	44.4	38.9	16.8	OL
80.0-81.0	loam (buried	R	--	12.7	3.21	3.59	--	--	--	--	OL
	soil)			11.6							
83.0-84.5	gleyed,	R	--	--	--	--	--	--	--	--	GW
88.0-89.5	greenish gray	67	--	--	--	--	--	--	--	--	SW
93.0-94.5	sand and	115	0.8	18.3	--	--	--	--	--	--	SW
	gravel										
99.0-100.5	laminated,	100	--	--	--	--	0.0	7.1	84.6	8.3	SP
103.0-104.5	gray silt,	118	--	17.4	--	--	0.0	39.7	51.2	9.1	SP
108.0-109.5	silt loam	85	--	--	--	--	--	--	--	--	SP
113.0-114.5	and sand	115	--	--	--	--	--	--	--	--	SP
118.0-119.5	gravel	105	--	--	--	--	--	--	--	--	GW
123.0-124.5	bedrock	90	--	--	--	--	--	--	--	--	GP
	rubble bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot

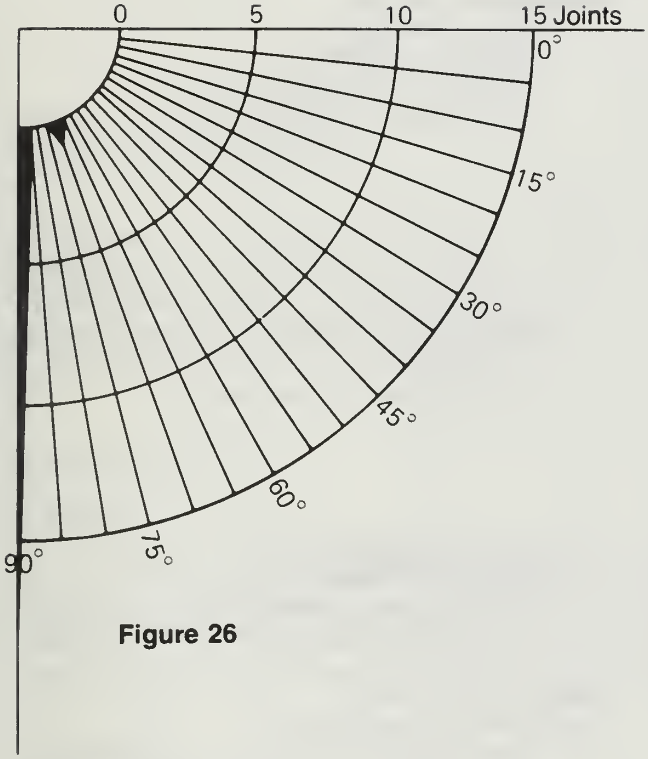


Figure 26

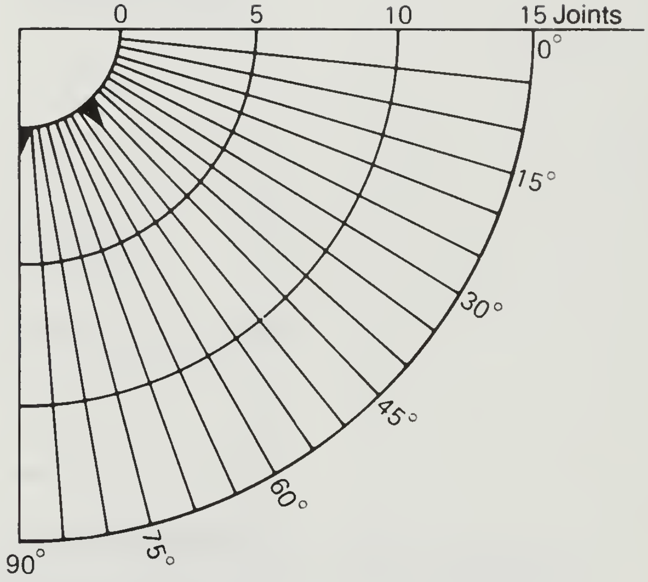


Figure 27

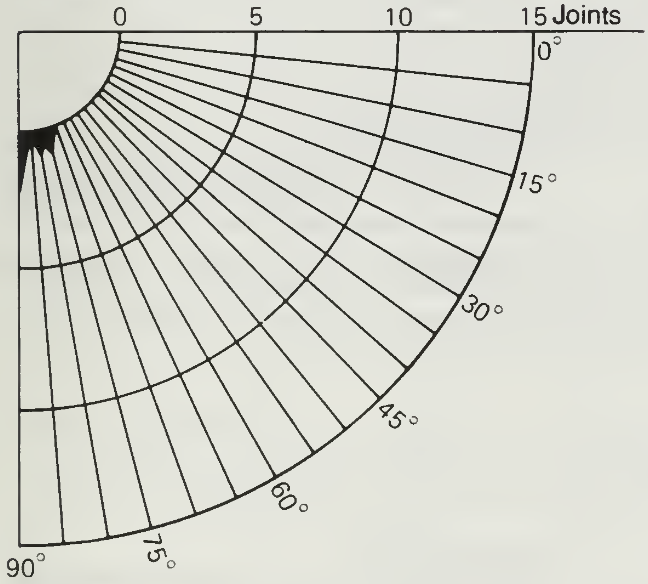
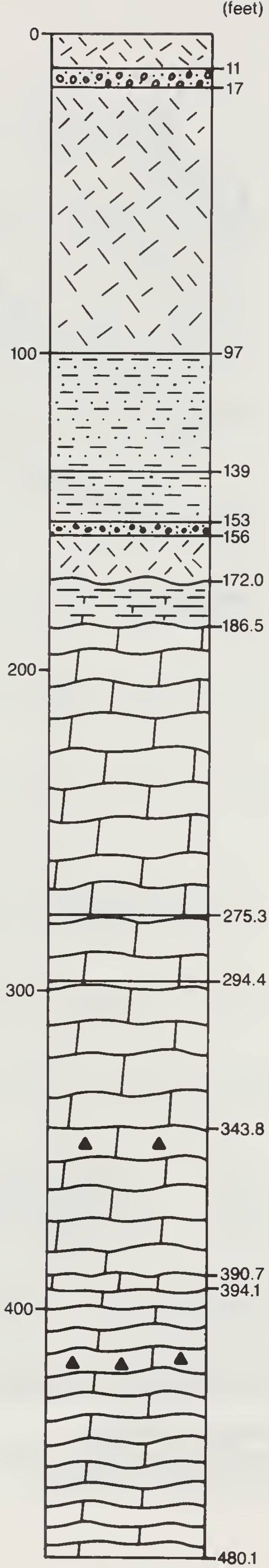


Figure 28

Number and angle of dip of joints in core from Test Hole ISGS F-12

26 130.6 feet of Maquoketa Group strata.
27 147.7 feet of Galena (Wise Lake) Group strata.
28 48.0 feet of Galena (Dunleith) Group strata.



QUATERNARY SYSTEM

WEDRON FORMATION

TISKILWA TILL MEMBER

Till; yellowish brown gravelly loam (0-11 ft)
Gravelly sand; yellowish brown (11-17 ft)
Till; pinkish brown pebbly clay loam, massive (17-97 ft)

PEDDICORD FORMATION

Laminated silt and sand; pinkish brown, wood fragments at top (97-139 ft)
Varved clay; pinkish brown (138-153 ft)

GLASFORD FORMATION

FAIRDALE TILL MEMBER (?)

Sand and gravel; brown (153-156 ft)
Till; grayish brown silty clay loam, massive (156-172.0 ft)

ORDOVICIAN SYSTEM

MAQUOKETA SHALE GROUP

Shale, olive-gray, dolomitic; grades to fine-grained dolomite, light olive-gray to greenish gray, argillaceous 172.0-186.5 ft)

GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE

Dolomite, very pale orange to pale yellow-brown, fine- to medium-grained, very calcareous, slightly vuggy, beds 0.4-1.0 ft thick separated by thin, greenish gray to olive-gray shaly partings (186.5-343.8 ft)

Mixed-layer clay bed, 0.04 ft thick, greenish gray (275.3 ft)

Clay bed, 0.02 ft thick, greenish gray (294.4 ft)

DUNLEITH DOLOMITE

Dolomite, as above, but cherty from 343.8-357.0 ft; not cherty below 390.7 ft (343.8-390.7 ft)

GUTTENBERG DOLOMITE

Dolomite, as above, but with reddish brown shaly partings every 0.1-0.2 ft (390.7-394.1 ft)

PLATTEVILLE DOLOMITE GROUP

Dolomite, very pale orange to pale yellowish brown mottled (burrowed), fine-grained, cherty from 415.2-430.6 ft, mottled dark gray, slightly vuggy, separated by olive-gray partings every 0.1-1.0 ft (394.1-480.1 ft)

Figure 29
Stratigraphic column for Test Hole F-14.

TEST HOLE ISGS F-14

Location: SE 1/4 SE 1/4 NE 1/4 NE 1/4 Sec. 16, T40N, R4E
Property: Northern Illinois University
Surface Elevation: 871 feet above m.s.l.
Total Depth: 480.1 feet

Stratigraphy

Bedrock
The stratigraphic column (fig. 29) shows the lithologies and depths of the drift and bedrock units encountered in ISGS F-14. The hole penetrated (from top to bottom), 14.5 feet of interbedded Maquoketa Group shale and dolomite, 207.6 feet of Galena Group dolomite, and 86.0 feet of Platteville Group dolomite. A 0.04-foot thick mixed-layer clay bed (the Dygerts Bed) was encountered at 275.3 feet in the Galena Group. A 0.02-foot thick clay bed was also encountered at 294.4 feet.

Glacial Drift
The drift at F-14 is 172 feet thick. The upper 97 feet are yellowish brown and pinkish brown clay loam and loam till, with a gravelly sand layer between 11–17 feet of depth (Tiskilwa Till Member). Below this are 56 feet of laminated, poorly to moderately well-sorted loam, sand, silt, or clay (Peddicord Formation). Below a boulder at 153 feet are 3 feet of sand and gravel and 16 feet of grayish brown silty clay loam till (Fairdale Till Member, Glasford Formation).

Geophysical Logging
A complete suite of logs was run on this hole. The gamma ray-neutron logs are presented in Figure 30. A slight decrease in radiation at 382 feet indicates fractures that caused reduction of circulation during drilling. Log deflections present at 294 and 450 feet correspond to a mixed-layer clay bed and shale partings, respectively. The highest moisture content shown on the neutron log in glacial drift represents laminated silt, clay and fine sand from 97-153 feet.

Hydrogeologic Data
The results of the individual pressure test intervals for this boring are listed in Table 18; the hydraulic conductivity values estimated for test intervals, shown graphically in Figure 30, range from 6.5×10^{-5} to less than 1.0×10^{-6} cm/sec.

■ Piezometer
The test interval for the piezometer in ISGS F-14 is between depths of 478.0 and 457.0 feet and is in dolomite of the Platteville Group. After an initial depth of 98.7 feet on 6-21-85, the water level declined to 103.4 feet (12-12-85). It has since steadily risen to 94.7 feet (8-15-86, table 6).

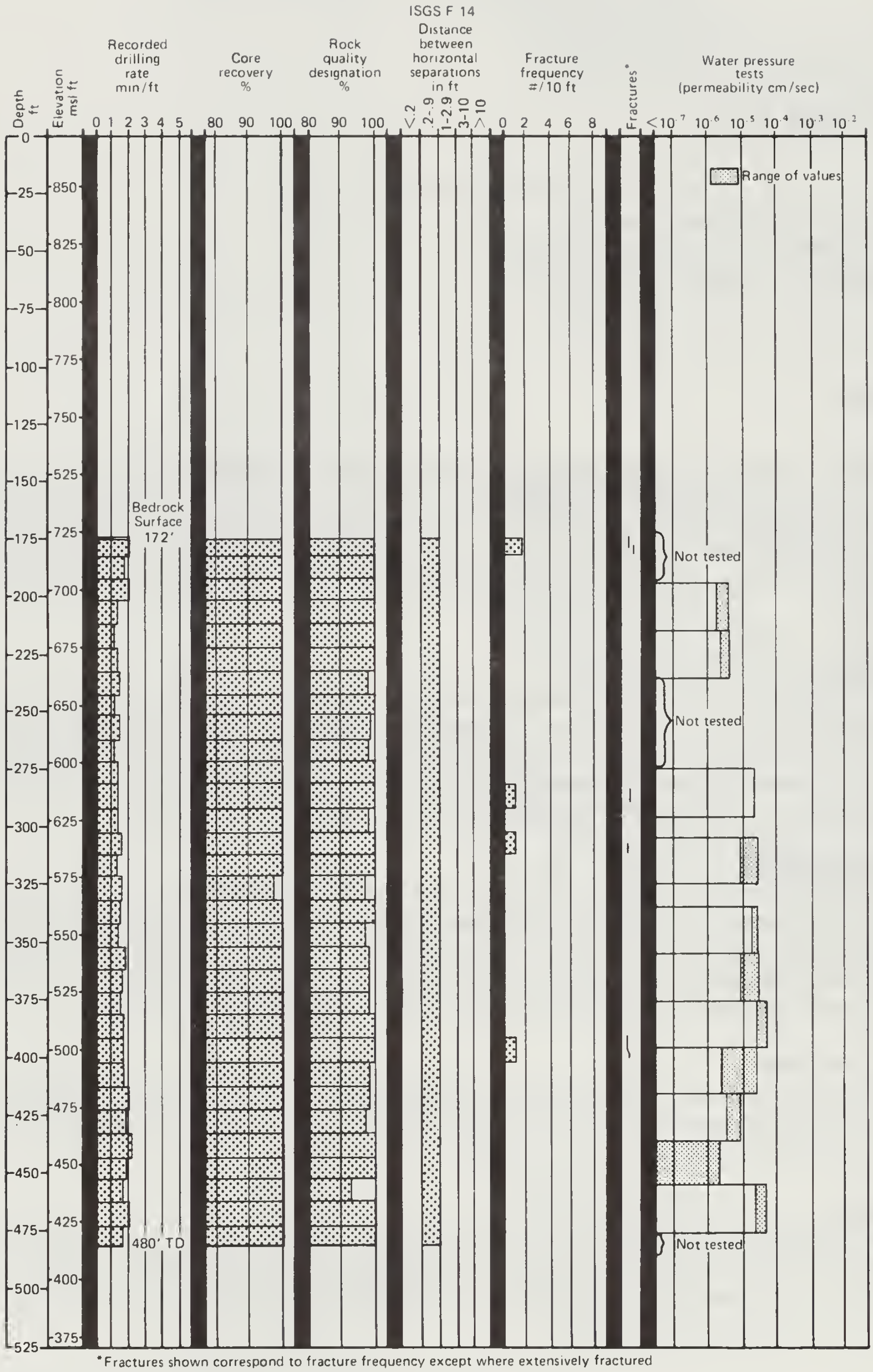


Figure 30 Summary diagram for Test Hole F-14.

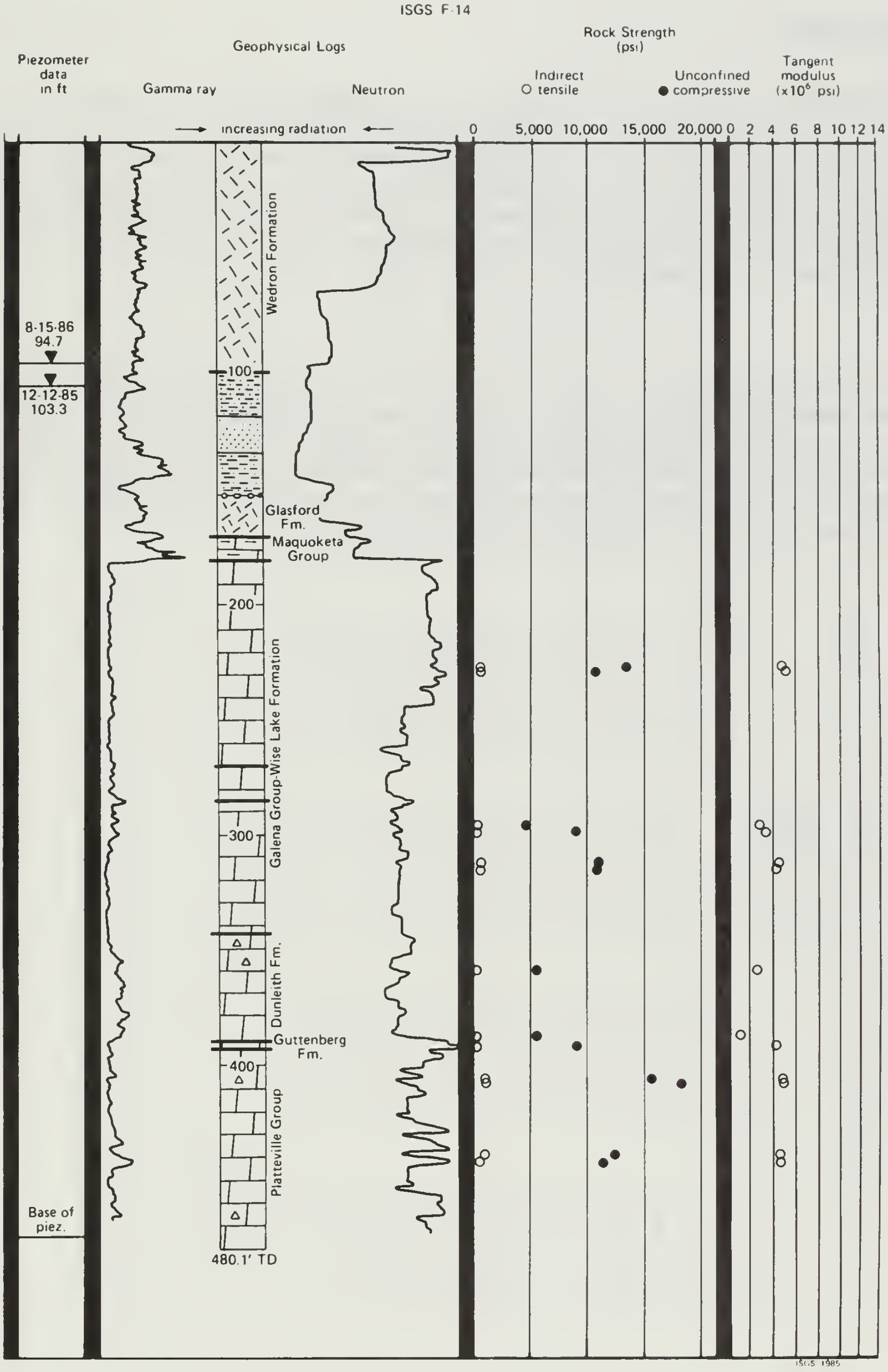


Figure 30 *continued.*

Geotechnical Data

Bedrock

Borehole F-14 maintained circulation throughout the entire depth of the borehole. There was a slight reduction in circulation from about a depth of 350 feet to the bottom of the hole. Measurements of water levels each morning during drilling showed the level to be about 65 feet below the ground surface. Only 5 joints were encountered in the 305 feet of core (fig. 30). The number and angle of dips of joints are shown in figures 31, 32, and 33. Average core recovery and RQD values are excellent (tables 9 and 10) with values of 98 percent and greater. The lowest values are 97 and 93 percent, respectively.

Drift

The upper 97 feet of clay loam till at F-14 has high bearing capacity. The underlying 56 feet of material, composed of stratified sediment, include a basal varved sequence about 10 feet thick with very low bearing strength, high moisture content (up to at least 29.2 percent), and very high clay content (90.4 percent, table 19). The clay mineral constituents are illite (70 percent); kaolinite and chlorite (20 percent); and expandable clay minerals (10 percent). The underlying gravel and silty clay loam till have high bearing capacity.

Table 18. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-14

Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
476.5-454.5	2.9×10^{-5}	4.4×10^{-5}	4.4×10^{-5}	4.8×10^{-5}	5.6×10^{-5}
455.5-434.5	1.7×10^{-6}	2.2×10^{-6}	1.7×10^{-6}	1.1×10^{-6}	--
435.5-414.5	8.5×10^{-6}	9.0×10^{-6}	8.9×10^{-6}	5.6×10^{-6}	3.4×10^{-6}
415.5-394.5	1.0×10^{-5}	9.9×10^{-6}	1.7×10^{-5}	6.8×10^{-6}	3.4×10^{-6}
395.5-374.5	6.5×10^{-5}	4.1×10^{-5}	4.3×10^{-5}	3.4×10^{-5}	2.8×10^{-5}
375.5-354.5	3.1×10^{-5}	2.9×10^{-5}	2.5×10^{-5}	1.6×10^{-5}	8.5×10^{-6}
355.5-334.5	2.7×10^{-5}	2.2×10^{-5}	2.5×10^{-5}	1.7×10^{-5}	1.5×10^{-5}
325.5-304.5	1.5×10^{-5}	1.9×10^{-5}	2.3×10^{-5}	1.3×10^{-5}	8.7×10^{-6}
295.5-274.5	2.4×10^{-5}	2.5×10^{-5}	2.9×10^{-5}	2.3×10^{-5}	1.6×10^{-5}
235.5-214.5	3.2×10^{-6}	2.2×10^{-6}	4.3×10^{-6}	3.3×10^{-6}	3.2×10^{-6}
215.5-194.5	3.1×10^{-6}	4.5×10^{-6}	3.7×10^{-6}	2.4×10^{-6}	1.8×10^{-6}

Notes:

For all test intervals: P_1 = 35 psi
P_2 = 70 psi
P_3 = 100 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

Table 19. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-14

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size Gvl (%)	Particle Size Sand (%)	Particle Size Silt (%)	Particle Size Clay (%)	Unified Soil Classification
8.5-10.0	pinkish	17	--	--	--	--	11.7	33.6	42.9	23.5	CL
13.0-14.5	brown loam	10	--	--	--	--	--	--	--	--	GW
18.0-19.5	and clay	26	--	12.3	2.17	2.44	3.5	38.0	35.2	26.7	CL
	loam till			12.4							
24.5-26.0		25	--	8.6	--	--	6.4	39.0	36.2	24.8	CL
28.0-29.5		34	>4.5	10.1	2.18	2.40	6.1	40.3	33.1	26.6	CL
				10.2							
33.0-34.5		39	>4.5	10.3	--	--	14.2	38.6	34.9	26.5	CL
38.0-39.5		82	>4.5	11.0	--	--	7.4	36.2	35.7	28.1	CL
43.0-44.5		37	4.5	9.8	--	--	4.9	36.2	36.0	27.8	CL
48.0-49.5		100	4.5	8.3	2.37	2.59	2.9	39.7	39.6	20.7	CL
				9.3							
53.0-54.5		37	4.5	--	--	--	--	--	--	--	CL
58.0-59.5		46	--	11.7	--	--	8.7	35.9	36.7	27.4	CL
63.0-64.5		37	--	11.6	2.42	2.70	4.6	35.8	35.5	28.7	CL
				11.4							
68.0-69.5		51	2.5	11.9	--	--	8.9	34.7	36.6	28.8	CL
73.0-74.5		44	2.8	12.2	2.23	2.50	8.0	37.4	36.2	26.4	CL
				11.8							
78.0-79.5		46	3.3	11.4	--	--	7.2	37.2	37.4	25.4	CL
83.0-84.5		48	3.3	11.8	--	--	26.1	37.4	35.9	26.7	CL
88.0-89.5		32	3.5	--	--	--	--	--	--	--	CL
93.0-94.5		43	--	11.2	2.75	3.06	6.3	38.3	35.6	26.2	CL
				11.4							
98.0-99.5	laminated,	76	--	12.1	--	--	6.8	46.6	31.8	21.6	CL,ML
103.0-104.5	pinkish beds	133	2.8	--	--	--	13.0	44.6	35.0	20.4	CL,ML
108.0-109.5	of brown	114	--	--	--	--	--	--	--	--	SP
113.0-114.5	loam, sand,	27	--	--	--	--	0.0	4.1	88.8	7.1	ML
118.0-119.5	silt and	R	--	--	--	--	--	--	--	--	SP
123.0-124.5	clay; wood-	92	--	--	--	--	0.6	91.6	5.7	2.7	SP
128.0-129.5	bearing at top	99	--	--	--	--	0.2	92.1	4.2	3.8	SP
133.0	laminated	101	--	--	--	--	--	--	--	--	SP
138.0	pinkish brown	R	--	--	--	--	0.0	0.3	86.3	13.4	ML
143.0	sand, silt	45	<0.8	26.6	--	--	--	--	--	--	SP
148.0	and clay	42	<0.5	29.2	--	--	0.0	0.3	9.3	90.4	CL
	(cont)		29.6								
153.0	boulder	R	<------------NO SAMPLE------------>								GW
158.0	grayish brown	108	<------------NO SAMPLE------------>								CL
163.0	silty clay	120	>4.5	19.0	2.06	2.45	1.0	13.2	39.0	47.8	CL
168.0	till	R	2.3	16.2	--	--	5.5	24.5	34.5	41.1	CL
			18.5								
	bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot

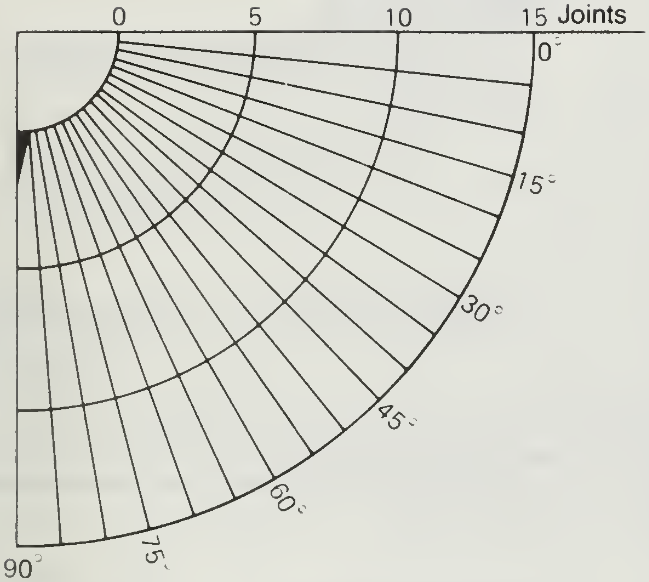


Figure 31

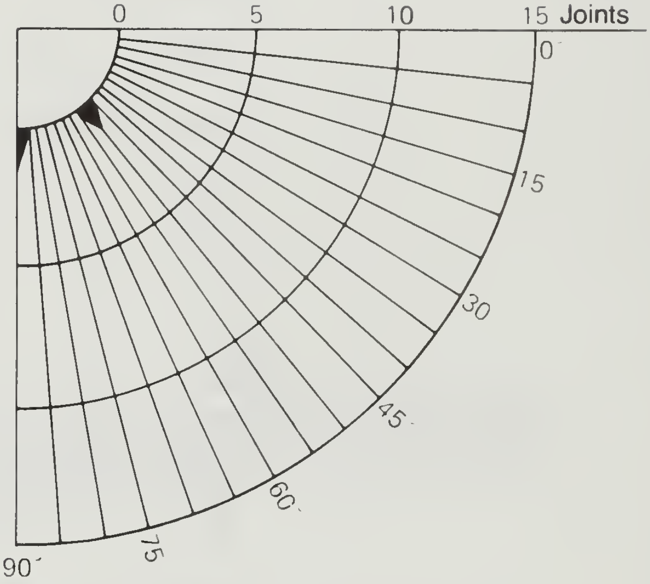


Figure 32

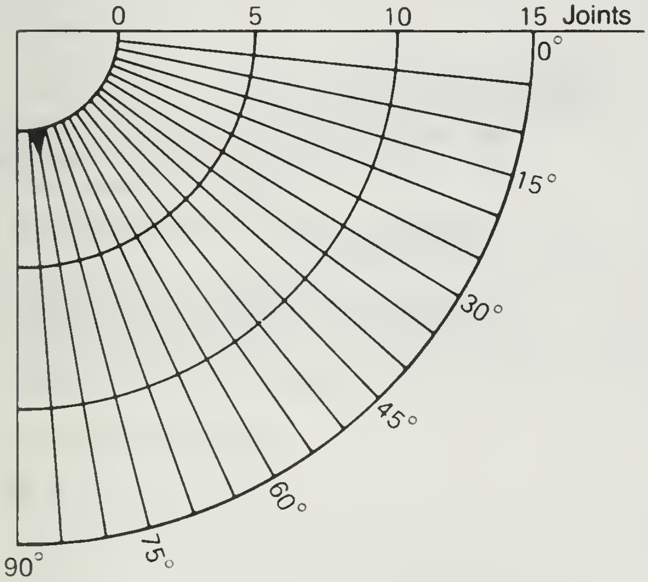
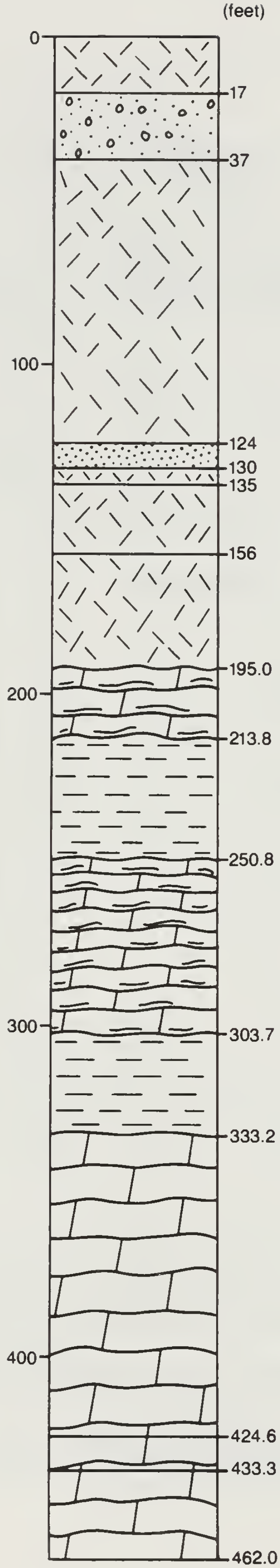


Figure 33

Number and angle of dip of joints in core from Test Hole ISGS F-14

31 14.5 feet of Maquoketa Group strata.
32 207.6 feet of Galena (Wise Lake) Group strata.
33 86.0 feet of Platteville Group strata.



QUARTERNARY SYSTEM

WEDRON FORMATION

MALDEN TILL MEMBER

Till; yellowish brown pebbly loam, massive (0-17 ft)

Sand and gravel; pinkish brown, lower 8 ft is laminated sand (17-37 ft)

TISKILWA TILL MEMBER

Till; pinkish brown pebbly clay loam, massive (37-124 ft)

PEDDICORD FORMATION

Laminated sand; pinkish brown, contains wood fragments (124-130 ft)

GLASFORD FORMATION

UNDIFFERENTIATED

Till; gray loam (130-135 ft)

Till; grayish brown silty clay loam, laminated (135-156 ft)

HERBERT TILL MEMBER

Till; tan to pink cobbly sandy loam to loam (156-195.0 ft)

ORDOVICIAN SYSTEM

MAQUOKETA SHALE GROUP

Dolomite, light olive-gray, dark gray speckled, find- to medium- to coarse-grained, some fine-grained, argillaceous (195.0-213.8 ft)

Shale, olive-gray, dolomitic; some interbedded dolomite, as above (213.8-250.8 ft)

Dolomite, as above, but separated by olive-gray shaly partings, slightly pyritic, slightly vuggy (250.8-303.7ft)

Shale, olive-gray, dolomitic, burrowed (303.7-333.2 ft)

GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE

Dolomite, light orange to pale yellow-brown, fine- to medium-grained, beds 0.2-1.0 ft thick separated by thin, olive-gray shaly partings (333.2-462.0 ft)

Mixed-layer clay bed, 0.02 ft thick, gray (424.6 ft)

Clay bed, 0.04 ft thick, black (433.3 ft)

Figure 34

Stratigraphic column for Test Hole F-15.

TEST HOLE ISGS F-15

Location: NW 1/4 SW 1/4 NW 1/4 SW 1/4 Sec. 30, T41N, R8E
Property: Fox Valley Saddle Club
Surface Elevation: 848 feet above m.s.l.
Total Depth: 462.0 feet

Stratigraphy

Bedrock

The stratigraphic column (fig. 34) shows the lithologies and depths of the glacial drift and bedrock units encountered in ISGS F-15. The hole penetrated (from top to bottom) 139.2 feet of Maquoketa shale and dolomite, and 128.8 feet of Galena Group dolomite. A thin (0.02 ft) mixed-layer clay bed (the Dygerts Bed) was encountered at 424.6 feet in the Galena Group. Another thin clay bed (0.04-ft) was observed at 433.3 feet in the Galena.

Glacial Drift

The drift at F-15 is 195 feet thick. The upper 124 feet are assigned to the Wedron Formation; the underlying 6 feet to the Peddicord Formation; and the lower 65 feet, to the Glasford Formation. From 0 to 17 feet is a yellowish brown pebbly loam till (Malden Till Member), which is underlain by 20 feet of laminated, pinkish brown sand and gravel. From 37 feet to 124 feet is pinkish brown pebbly clay loam till (Tiskilwa Till Member), which is underlain by 6 feet of stratified sand, and loam, including abundant wood fragments (Peddicord Formation). From 130 feet to 135 feet is gray loam till that is underlain by 21 feet of laminated grayish brown loam and clay loam (Glasford Formation, undifferentiated). The lower 39 feet are composed of very compact tan to pink, cobbly loam till (Herbert Till Member, Glasford Formation).

Geophysical Logging

A complete suite of logs was recorded along this hole. The gamma ray-neutron logs are presented in Figure 35. Deflections at 408 and 424 feet correspond to a shaly parting and a mixed-layer clay bed, respectively, in the Galena Group. The highest moisture content suggested by the neutron log in the glacial drift is in sand and loam, which contains wood fragments and occurs from 124 to 130 feet, and till from 130 to 193 feet. High moisture content is indicated in the Maquoketa Shale Group between 235–251 feet and 305–336 feet.

Hydrogeologic Data

■ Pressure Testing

The results of the individual pressure test intervals for this boring are listed in Table 20; the hydraulic conductivity values estimated for test intervals, shown graphically in Figure 35, range from 2.4×10^{-5} to less than 5.0×10^{-7} cm/sec.

■ Piezometer

The test interval for the piezometer in ISGS F-15 was between depths of 455.0 and 434.0 feet and is in dolomite of the Galena Group. The water levels were consistently at depths of about 385.0 feet (table 6). There was one anomalous reading below 400 feet (8-21-85) that appears to be an error. The last water level depth recorded was 384.8 feet (taken on 7-17-86); the piezometer was plugged and abandoned by August 15, 1986.

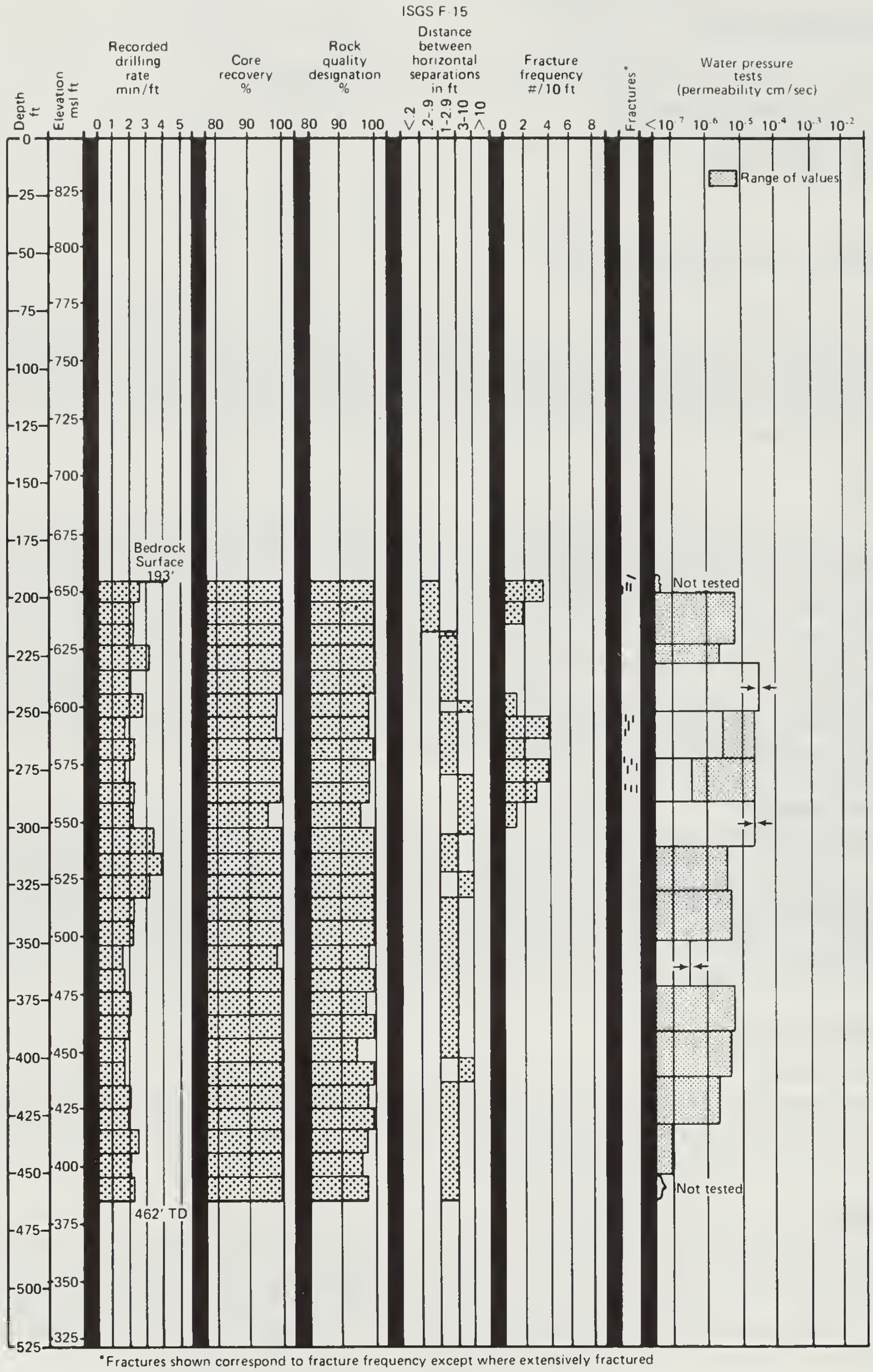


Figure 35 Summary diagram of data for Test Hole F-15.

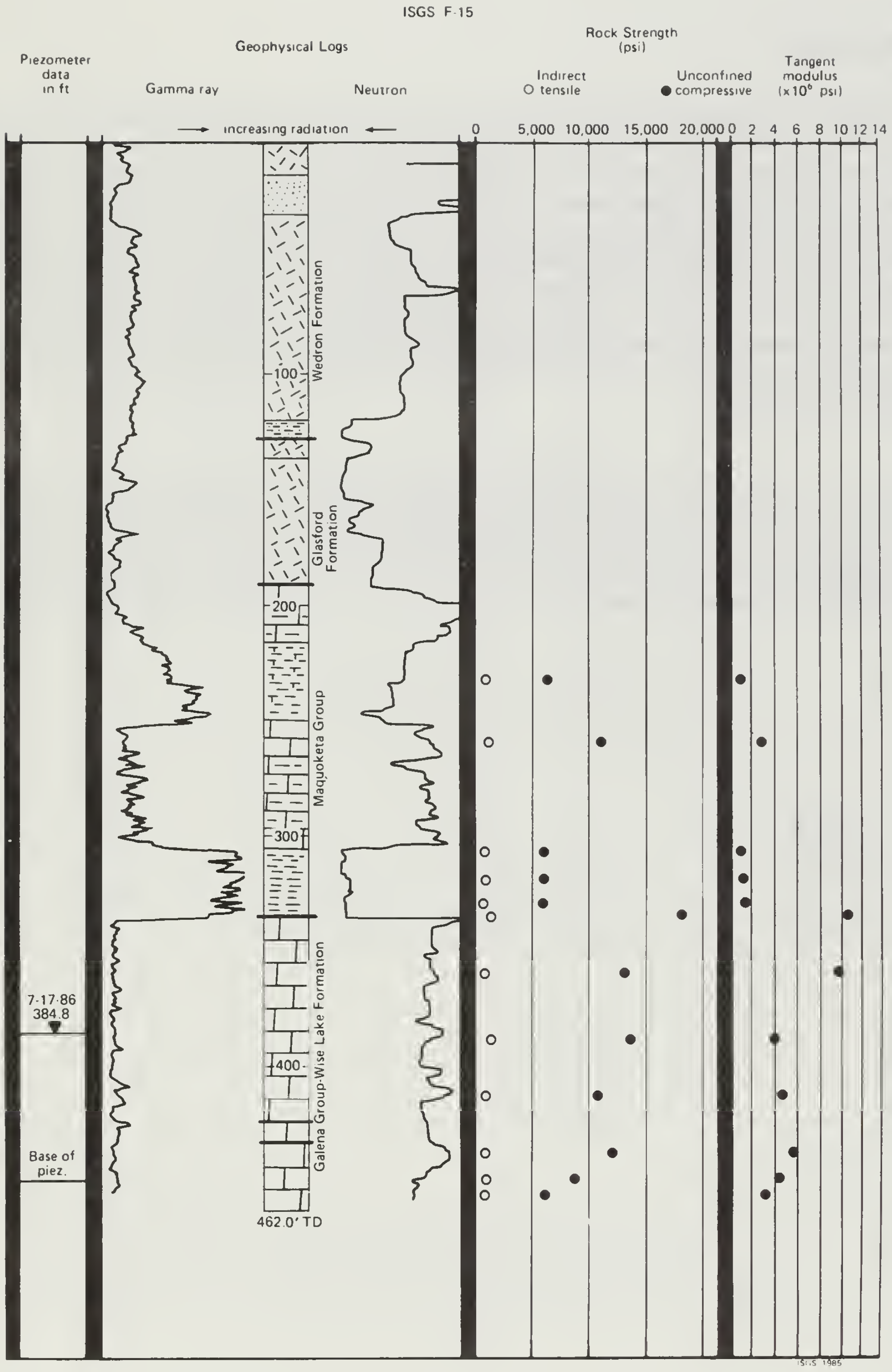


Figure 35 *continued.*

Geotechnical Data

Bedrock

Borehole ISGS F-15 lost approximately 75 percent circulation at 202 feet below the ground surface (within 10 feet of the Maquoketa surface and depth of casing seat) followed by complete loss of circulation at 252 feet. Circulation did not return. Measurement of water levels each morning before resuming drilling indicated water levels decreased progressively as the hole was deepened. The water level at the time of piezometer installation was 58 feet below the ground surface. All (21) of the joints encountered were in the Maquoketa (fig. 34). Ninety percent of the joints had dips greater than 70° (fig. 35, 36). Eight joints had fillings; 8 mineralized with calcite or pyrite. Ninety percent were wavy and uneven with rough asperites. Two joints were planar, and one of these was a smooth surface with no asperities. Average core recovery and RQD values are excellent (tables 9 and 10) with values 95 percent and greater. The lowest value for individual core runs is 94 percent.

Drift

Between 0 to 17 feet is loam till with high bearing capacity; underlying this is sand and gravel (20 ft). Between 37 and 124 feet is clay loam to loam till with very high bearing capacity. The underlying 32 feet are composed of stratified sand and till, chiefly the latter, which has high bearing capacity. The lowermost cobbly loam till unit between depths of 156 and 195 feet depth has very high bearing capacity (greater than 4.5 tsf) and low moisture content (about 6.6 percent; table 21).

Table 20. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-15

Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
452-431	--	--	--	--	--
432-411	--	2.3×10^{-6}	1.7×10^{-6}	2.3×10^{-6}	--
412-391	--	9.0×10^{-7}	4.2×10^{-6}	9.0×10^{-7}	--
392-371	--	9.0×10^{-7}	6.3×10^{-6}	9.0×10^{-7}	6.0×10^{-7}
372-351	6.0×10^{-7}	*	7.0×10^{-7}	5.0×10^{-7}	6.0×10^{-7}
352-331	--	5.0×10^{-7}	7.7×10^{-6}	9.0×10^{-7}	--
332-311	1.8×10^{-6}	5.0×10^{-7}	5.9×10^{-6}	--	--
312-291	1.3×10^{-5}	1.2×10^{-5}	1.3×10^{-5}	1.2×10^{-5}	1.1×10^{-5}
292-271	6.0×10^{-7}	9.0×10^{-7}	1.9×10^{-5}	1.4×10^{-6}	6.0×10^{-7}
272-251	3.3×10^{-6}	6.0×10^{-6}	7.7×10^{-6}	1.1×10^{-5}	9.3×10^{-6}
252-231	2.0×10^{-5}	2.4×10^{-5}	2.4×10^{-5}	2.0×10^{-5}	2.0×10^{-5}
232-211	--	--	1.4×10^{-6}	--	--
222-201	--	--	8.0×10^{-6}	--	--

Notes:

For all intervals: P_1 = 40 psi
P_2 = 70 psi
P_3 = 110 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

*Leak around packer

Table 21. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-15

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Sand (%)	Silt (%)	Clay (%)	Unified Soil Classification
3.5- 5.0	yellowish	8	1.3	12.7	--	--	8.6	33.8	47.2	19.0	CL
8.5-10.0	brown loam	24	2.3	12.0	--	--	9.7	30.3	47.0	22.7	CL
13.0-18.5	till	24	3.5	13.4	--	--	4.9	25.9	49.5	24.6	CL
18.0-19.5		28	--	--	--	--	--	--	--	--	GW
23.0-24.5	pinkish brown	30	--	--	--	--	--	--	--	--	GW
28.0-29.5	sand and	90	--	--	--	--	--	--	--	--	GW
33.0-34.5	gravel	56	--	--	--	--	--	--	--	--	GW
38.0-39.5		24	2.0	12.9	--	--	4.8	32.7	34.0	33.4	CL
43.0-44.5		30	2.3	12.4	--	--	7.4	32.4	33.4	34.3	CL
48.0-49.5		24	3.0	11.8	--	--	17.1	32.9	33.2	33.9	CL
53.0-54.5		28	3.0	12.9	2.76	3.11	5.1	33.6	34.4	32.0	CL
58.0-59.5		30	2.8	12.3	--	--	4.6	34.3	33.0	32.7	CL
63.0-64.5		38	2.8	11.4	--	--	0.3	33.6	34.5	32.0	CL
68.0-69.5	pinkish	80	4.5	10.2	--	--	9.3	36.5	34.6	28.9	CL
73.0-74.5	brown clay	70	>4.5	10.3	--	--	4.2	37.4	33.8	28.8	CL
78.0-79.5	loam till	78	>4.5	10.4	--	--	5.1	36.3	34.2	29.6	CL
83.0-84.5		94	>4.5	10.1	2.41	2.65	24.3	36.9	36.3	26.8	CL
88.0-89.5		R	>4.5	9.4	--	--	5.6	36.3	34.3	29.4	CL
93.0-94.5		R	>4.5	9.6	2.25	2.47	6.5	34.9	35.6	29.5	CL
98.0-99.5		R	>4.5	8.3	--	--	3.4	33.4	43.8	22.8	CL
103.0-104.5		78	3.8	11.2	2.24	2.46	5.7	34.5	38.1	27.3	CL
108.0-109.5		104	3.5	11.7	2.36	2.61	2.9	31.5	41.0	27.5	CL
113.0-114.5		96	4.0	10.7	2.47	2.74	8.6	30.2	38.7	31.0	CL
118.0-119.5		130	3.5	12.4	--	--	3.9	34.0	38.6	27.3	CL
123.0-124.5		66	3.8	11.0	--	--	4.6	31.3	41.8	26.9	CL
128.0-129.5	wood-bearing	R	--	--	--	--	--	--	--	--	SP
133.0-134.5	laminated sand and loam	64	4.0	9.2	2.59	2.86	13.0	34.6	49.6	15.8	CL
138.0-139.5	gray-brown	130	--	--	--	--	38.9	35.0	46.6	18.4	CL
143.0-144.5	laminated	R	--	--	--	--	4.2	23.5	35.8	40.8	CL
148.0-149.5	silty clay	130	4.5	15.1	1.90	2.27	2.7	20.4	46.6	33.0	CL
153.0-154.5	loam	R	--	--	--	--	--	--	--	--	CL
161.0-152.5	pink	R	--	--	--	--	--	--	--	--	CL
164.0-165.5	loam	R	--	--	--	--	--	--	--	--	CL
169.0-170.4	till	R	4.0	7.4	--	--	35.2	57.3	31.7	11.0	CL
171.6	boulders	R	--	--	--	--	--	--	--	--	GP
175.0-176.5	pink	--	>4.5	--	--	--	23.9	50.4	32.5	17.2	CL
179.0-180.5	loam	--	>4.5	6.6	--	--	23.1	50.0	34.0	16.0	CL
184.0-185.5	till, as	--	>4.5	--	--	--	17.8	54.1	32.1	13.8	CL
189.0-190.5	above	--	>4.5	--	--	--	57.3	46.3	36.5	17.2	CL
193.0-194.5		--	>4.5	--	--	--	14.1	42.7	38.7	18.6	CL
	bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot. A five-foot long split barrel was used to core from 175.0-194.5 feet.

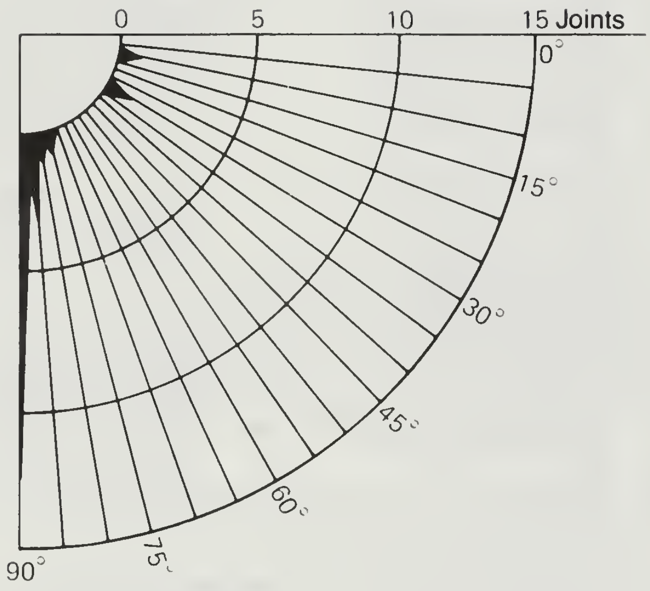
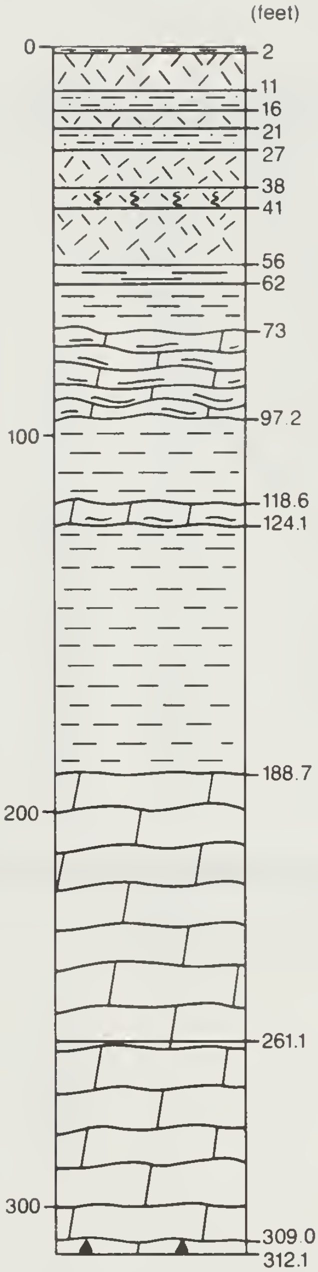


Figure 36

Number and angle of dip of joints in core from Test Hole ISGS F-15

36 138.2 feet of Maquoketa Group strata.



QUATERNARY SYSTEM

RICHLAND LOESS

Silty clay loam, brown (0-2 ft)

WEDRON FORMATION

MALDEN TILL MEMBER

Till; yellowish gray, gravelly clay loam (2-11 ft)
Laminated silt loam; brown (11-16 ft)
Till; brownish gray, gravelly loam, massive (16-21 ft)

TISKILWA TILL MEMBER

Laminated silt loam; pinkish brown (21-27 ft)
Till; pinkish brown loam, massive (27-38 ft)

GLASFORD FORMATION

ESMOND TILL MEMBER (?)

Till; greenish brown loam, massive, gleyed (Sangamon Soil development; 38-41 ft)
Till; gray loam and clay loam, mottled grayish brown, massive (41-56 ft)
Laminated silty clay loam; dark gray (56-62 ft)

ORDOVICIAN SYSTEM

MAQUOKETA SHALE GROUP

Shale, red, purple and green mottled, soft (62-73.0 ft)

Limestone, light olive-gray, dark gray speckled, medium- to coarse-grained, fossiliferous, argillaceous, 0.2-0.6 ft thick beds separated by thin shale beds (73.0-97.2 ft)

Shale, olive-gray, dolomitic (97.2-118,6 ft)

Dolomite, light olive-gray, medium- to coarse-grained, dark gray speckled, slightly argillaceous, beds from 0.2-0.6 ft thick (118.6-124.1 ft)

Shale, olive-gray to greenish gray, dolomitic, fossiliferous (124.1-188.7 ft)

GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE

Dolomite, light orange to pale yellow-brown, fine- to medium-grained, very calcareous, some limestone (188.7-309.0 ft)

Mixed-layer clay bed, 0.10 ft thick, greenish gray (261.1 ft)

DUNLEITH DOLOMITE

Dolomite, as above but cherty (309.0-312.1 ft)

Figure 37
Stratigraphic column for Test Hole F-16.

TEST HOLE ISGS F-16

Location: SE 1/4 SW 1/4 SE 1/4 SW 1/4 Sec. 3, T.37N, R7E
Property: Richard Dickson Farm
Surface Elevation: 659 feet above m.s.l.
Total Depth: 312.1 feet

Stratigraphy

Bedrock

The stratigraphic column (fig. 37) shows the lithologies and depths of the drift and bedrock units encountered in ISGS F-16. The hole penetrated (from top to bottom) 126.7 feet of Maquoketa Group shale and dolomite, and 123.4 feet of Galena Group composed of very calcareous dolomite and some limestone. The upper 11 feet of the bedrock are composed of soft, red, purple and green clay and shale of the Maquoketa Shale Group. A 0.10-foot thick mixed-layer clay bed (the Dygerts Bed) was encountered at 261.1 feet in the Galena Group.

Glacial Drift

The drift at F-16 is about 62 feet thick. Richland Loess occurs in the upper 2 feet; the underlying 36 feet are included within the Wedron Formation; and the lower 24 feet, the Glasford Formation. The upper 2 feet are brown silty clay loam. The underlying 19 feet are composed of interbedded massive loam to clay loam till and laminated rhythmite (Malden Till Member). Underlying this is about 17 feet of laminated silt loam and massive pinkish brown till (Tiskilwa Till Member). From 38 feet to 56 feet are massive brown and grayish brown mottled clay loam to loam till, and the lowermost 6 feet are laminated dark gray silty clay loam (Esmond Till Member, Glasford Formation). The uppermost 3 feet of the Esmond are greenish brown (gleyed), which is evidence for development of the Sangamon Soil.

Geophysical Logging

A complete suite of logs was run on this hole. The gamma ray-neutron log is presented in Figure 38. A deflection at 261 feet corresponds to a mixed-layer clay bed (the Dygerts Bed). The highest moisture content shown on the neutron log is between 38 to 55 feet (glacial drift) and 139 to 189 feet (Maquoketa Shale Group).

Hydrogeologic Data

■ Pressure Testing

The results of the individual pressure test intervals for this boring are listed in Table 22; the hydraulic conductivity values estimated for test intervals (shown graphically in figure 38) range from 6.2×10^{-3} to less than 1.0×10^{-6} cm/sec.

■ Piezometer

The test interval for the piezometer in ISGS F-16 was between depths of 264.5 and 243.5 feet and in limestone of the Galena Group. The water level was consistently at a depth of about 192 feet (table 6). The head measurement is probably influenced somewhat by the cone of depression developed on the piezometric surface of the deeper sandstone aquifer along the Fox River (Visocky and others, 1985).

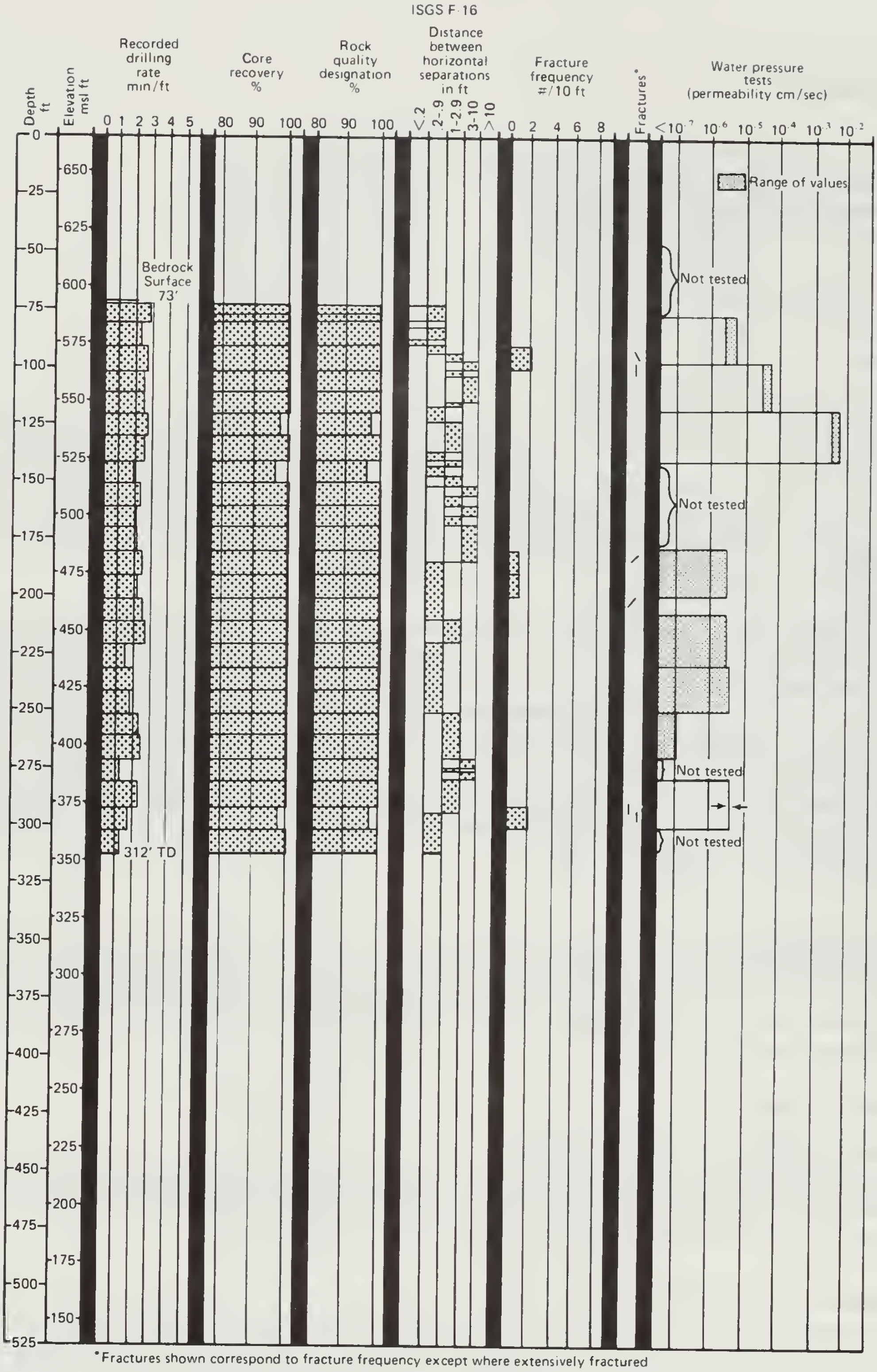


Figure 38 Summary diagram for Test Hole F-16.

Figure 38 *continued.*

Geotechnical Data

Bedrock

Borehole ISGS F-16 lost circulation at 122 feet below the ground surface. Circulation did not return during the drilling of the borehole. Water level readings taken prior to coring each morning showed the level to be approximately 26 feet below the ground surface. Only 6 discontinuities were found in the 312 feet of core (fig. 38). All had dips greater than 70°, (figs. 39 and 40). Two joints in the Maquoketa were completely filled with clay. In the Galena, two were mineralized and two had no filling. All joints were wavy with rough asperities. Average core recovery and RQD are excellent (tables 9 and 10) with values of 97 percent and greater. The lowest core run value is 97 percent.

Drift

The drift between 0 and 27 feet is composed of layers about 5 feet thick of stratified clay loam till of high bearing capacity with material of low bearing capacity. Below this are about 28 feet of loam till with high bearing capacity. The lowermost 6 feet of material are composed of stratified silty clay loam (table 23).

Table 22. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-16

Test intervals (ft)	P_1	P_2	P_3	P_2	P_1
303-282	2.7×10^{-6}	2.7×10^{-6}	3.0×10^{-6}	2.7×10^{-6}	2.7×10^{-6}
269-248	--	--	--	--	--
249-228	--	1.4×10^{-6}	3.0×10^{-6}	--	--
229-208	--	1.4×10^{-6}	2.0×10^{-6}	1.4×10^{-6}	2.7×10^{-6}
199-178	--	1.4×10^{-6}	1.0×10^{-6}	1.4×10^{-6}	1.7×10^{-6}
139-118	2.8×10^{-3}	3.4×10^{-3}	2.4×10^{-3}	3.5×10^{-3}	6.2×10^{-3}
119-98	2.6×10^{-5}	1.6×10^{-5}	3.8×10^{-5}	3.2×10^{-5}	2.0×10^{-5}
99-78	5.1×10^{-6}	2.7×10^{-6}	3.6×10^{-6}	2.7×10^{-6}	5.1×10^{-6}

Notes:

Below 150 ft: P_1 = 30 psi
P_2 = 70 psi
P_3 = 100 psi

Above 150 ft: P_1 = 10 psi
P_2 = 30 psi
P_3 = 50 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

Table 23. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-16

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)	Unified Soil Classification
4.0-5.5	A	22	>4.5	--	--	--	22.9	30.0	36.3	33.7	CL
9.0-10.5		26	4.0	10.0	--	--	13.8	34.2	38.4	27.4	CL
14.0-15.5	B	24	<.8	--	--	--	39.5	38.9	46.5	14.6	CL
19.0-20.5	C	31	2.3	9.8	--	--	16.1	52.4	31.7	15.8	CL
24.0-24.5	D	50	--	--	--	--	1.8	17.8	66.0	16.2	CL
29.0-30.5		90	>4.5	8.8	2.52	2.75	17.8	44.0	34.9	21.1	CL
34.0-35.5	E	75	>4.5	10.5	--	--	7.8	39.4	41.7	18.9	CL
39.0-40.5	gray till;	R	--	--	--	--	14.5	46.7	36.3	17.0	CL
44.0-45.5	gleyed, buried	R	>4.5	9.7	2.34	2.59	15.1	37.3	38.5	24.2	CL
49.0-50.5	soil at top ?	R	>4.5	5.3	--	--	14.7	31.3	37.5	31.2	CL
54.0-55.5		R	--	9.2	--	--	18.7	43.9	34.1	22.1	CL
59.0-60.5	F	93	--	--	--	--	0.0	0.4	65.1	34.5	CL
	bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot.
A yellowish gray gravelly clay loam till
B laminated silty sand rhythmite
C brownish gray loam till
D laminated brown silt loam
E pinkish brown loam till
F laminated dark gray silty clay loam

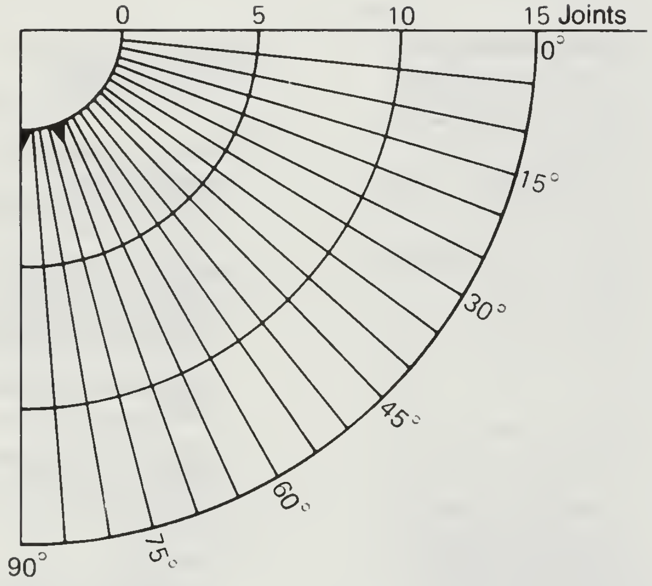


Figure 39

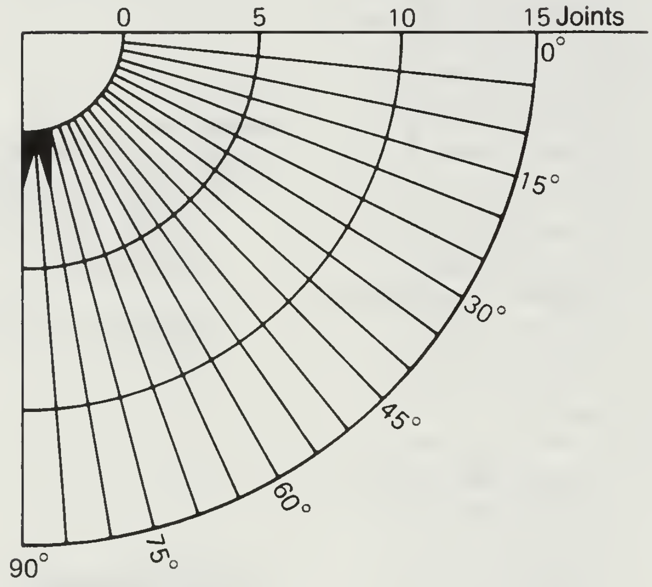


Figure 40

Number and angle of dip of joints in core from Test Hole ISGS F-16

39	157.7 feet of Maquoketa Group strata.
40	123.4 feet of Galena (Wise Lake) Group strata.

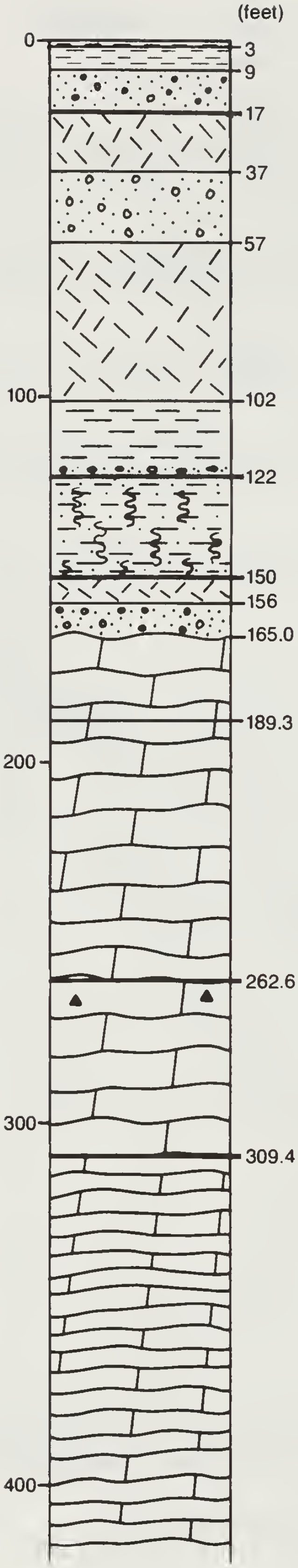


Figure 41
Stratigraphic column for Test Hole F-17.

QUATERNARY SYSTEM

RICHLAND LOESS
Silt loam, gray and orange (0-3 ft)

EQUALITY FORMATION
CARMI MEMBER
Laminated silt loam, sandy loam and stratified gravel; yellowish orange (3-17 ft)

WEDRON FORMATION
MALDEN TILL MEMBER
Till; gray and pinkish brown, pebbly loam, massive (17-37 ft)
Sand and gravel; pinkish brown gravelly sandy loam (37-57 ft)

TISKILWA TILL MEMBER
Till; pinkish brown pebbly loam, massive (57-102 ft)

PEDDICORD FORMATION
Laminated silty clay, sand and loam, gravelly at base (102-122 ft)

ROBEIN SILT
Intercalated thin beds of dark brown loam and gray loam; three thin, brown peat beds (122-150 ft)

GLASFORD FORMATION
KELLERVILLE TILL MEMBER
Till; brown loam, massive (150-156 ft)
Coarse gravel; brown (156-165.0 ft)

ORDOVICIAN SYSTEM

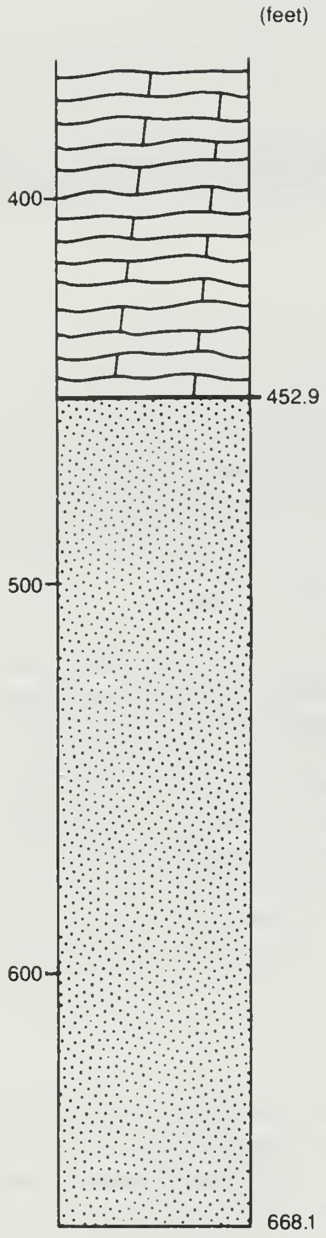
GALENA DOLOMITE GROUP

WISE LAKE DOLOMITE
Dolomite, light orange to pale yellow-brown, fine- to medium-grained, slightly vuggy and vesicular, separated by thin, olive-gray shaly partings (165.0-262.6 ft)

Mixed-layer clay bed, 0.09 ft thick, greenish gray (189.3 ft)

DUNLEITH DOLOMITE
Dolomite, as above, but with chert nodules between 262.6-266.6 ft; below to 309.4 ft is noncherty (262.6-309.4 ft)

PLATTEVILLE DOLOMITE GROUP
Dolomite, light orange to pale yellow-brown, slightly mottled light orange fine- to medium-grained, slightly cherty beds generally 0.1 ft thick, separated by greenish gray to pale blue-green shaly partings (309.4-452.9 ft)



ANCELL GROUP

ST. PETER SANDSTONE

Sandstone, light gray, fine- to medium-grained, bedding 0.2-1.2 ft thick, dolomitic, trace pyrite and glauconite, low-angle cross-beds and laminations (452.9-668.1 ft)

Figure 41 *continued.*

TEST HOLE ISGS F-17*

Location: NE 1/4 NE 1/4 NE 1/4 NW 1/4 Sec. 27, T38N, R5E
Property: Commonwealth Edison
Surface Elevation: 743 feet above m.s.l.
Total Depth: 668.1 feet

*ISGS F-17 was drilled to provide access for seismic and geophysical logging. An adjacent hole was drilled to bedrock; the drift was geophysically logged without casing in the hole. The logs are open file documents available at ISGS.

Stratigraphy

Bedrock

The stratigraphic column (fig. 41) shows the lithologies and depths of the drift and bedrock units encountered in ISGS F-17. The hole penetrated (from top to bottom) 144.4 feet of Galena Group dolomite, 143.5 feet of Platteville Group Dolomite and 215.2 feet of St. Peter Sandstone. F-17 was completed in St. Peter Sandstone at 668.1. A 0.09-foot thick mixed-clay bed (the Dygerts Bed) was encountered at 189.3 feet in the Galena Group.

Glacial Drift

The drift at ISGS F-17 is 165 feet thick. The upper 3 feet are composed of mottled Richland Loess, which is gray and orange silt loam. The Equality Formation (from 3 to 17 feet) consists of yellowish-orange poorly sorted, stratified silt loam, sandy loam and stratified gravel. The underlying Wedron Formation is composed of 20 feet of gray to pinkish brown, poorly stratified silt loam till underlain by 20 feet of sand and gravel that coarsens downwards (Malden Till Member). Between 57 and 102 feet is a pinkish brown massive loam to clay loam till (Tiskilwa Till Member) underlain by 20 feet of laminated silty clay, sand and loam (Peddicord Formation). From 122 to 150 feet are intercalated, thin, dark brown peat and gray loam beds (Robein Silt). Features indicative of soil formation, such as manganese nodules, argillans (soil fabric), and paucity of carbonate minerals were observed. Between 150 to 156 feet is a brown, loam till (Kellerville Till Member), Glasford Formation). The basal drift (9 ft) is brown coarse gravel or rock rubble.

Geophysical Logging

A complete suite of logs was run on this hole. Additional logs, including spontaneous potential, gamma ray, caliper compressive and shear velocity, and full wave form sonic were recorded by Schlumberger and are open file documents at the ISGS. Logging depth was limited by blockage of the hole at a depth of about 390 ft. The gamma ray-neutron log is presented in Figure 42. A prominent deflection at 385-390 feet indicates fractures in bedrock where there was a loss of circulation during drilling. Prominent log deflections at 355 to 358 feet correspond to shaly intervals present in the core. The highest moisture content shown on the neutron log in glacial drift is opposite sand and gravel (between 40 and 45 feet) and in till (at 80-100 feet) at the base of the Tiskilwa Till Member of the Wedron Formation.

Hydrogeologic Data

■ Pressure Testing

The results of the individual pressure test intervals for this boring are listed in Table 24. Hydraulic conductivity estimated for the test interval (shown graphically in Figure 42) ranges from 4.7×10^{-5} to less than 1.0×10^{-6} cm/sec.

■ Piezometer

The test interval for the piezometer in ISGS F-17 was between depths of 349.0 and 328.0 feet and was in dolomite of the Platteville Group. After an initial water level of 23.0 feet (9-17-85), the depth fluctuated between 16.3 feet (12-12-85) and 20.4 feet (5-15-85, table 6). The water depth may correspond to the shallow bedrock aquifer or deep sandstone aquifer (Visocky and others, 1985). The last water level recorded was 18.6 feet (7-17-86). The piezometer was plugged and abandoned by August 15, 1986 (table 6).

Geotechnical Data

Bedrock

Borehole F-17 began losing circulation at 243 feet below the ground surface. A total loss occurred at 383 feet and did not return for the remainder of the coring. Water level readings taken prior to coring each morning showed that the level decreased and stabilized between 36 to 44 feet. The water level was recorded at 38.5 feet below the ground surface at the time of water pressure testing. This borehole encountered many fractures distributed throughout the Maquoketa, Galena (Wise Lake and Dunleith), and Platteville (fig. 42). One hundred and sixteen predominantly vertical fractures were found in 453 feet of core, but no fractures were recorded in the St. Peter Sandstone. Ninety percent of the joints have dips greater than 70° (figs. 43, 44, and 45). Eighty-eight percent of the joints had no filling. Six joints in the Galena and five joints in the Platteville have partial clay filling with one completely clay-filled joint in the Galena. All the joints are wavy or uneven with rough asperities on joint surfaces (except three in the Platteville that have slickensides). Average core recovery and RQD values (tables 9 and 10) vary with the rock formation. In the Galena and St. Peter, values were excellent; in the Platteville, values were good. Low recovery values are 96, 100, 18, and 60 percent and low RQD values are 88, 100, 0, and 60 percent for the Galena (Wise Lake), Galena (Dunleith), Platteville, and St. Peter, respectively. The low core recovery and RQD values occur at approximately 384 through 418 feet in the Platteville, where two vertical joints intersected the borehole; and at approximately 528 through 550 feet in the St. Peter, where either the core washed away or there were core catcher malfunctions.

Drift

The drift in ISGS F-17 between 0 and 17 feet is composed of stratified sediment with medium to low bearing capacity and relatively high moisture content (about 21 percent, table 25). Between 17–37 and 57–102 feet is loam or clay loam till with generally very high bearing capacity whereas between 37–57 and 102–122 feet are stratified sand and gravel. The interval between 122 and 150 feet is composed of thin, organic-rich beds (0.2–2.0 in. thick) and gray loam till interbeds that have high bearing capacity. The organic-rich beds have about 0.9 percent organic carbon content (Richard Cahill, personal communication) and relatively high expandable clay content (up to 73 percent), which suggests that there is the potential for shrinking and swelling. The lowermost units (between 150 and 165 feet) are composed of loamy till over gravel or rock rubble, both with high bearing capacity.

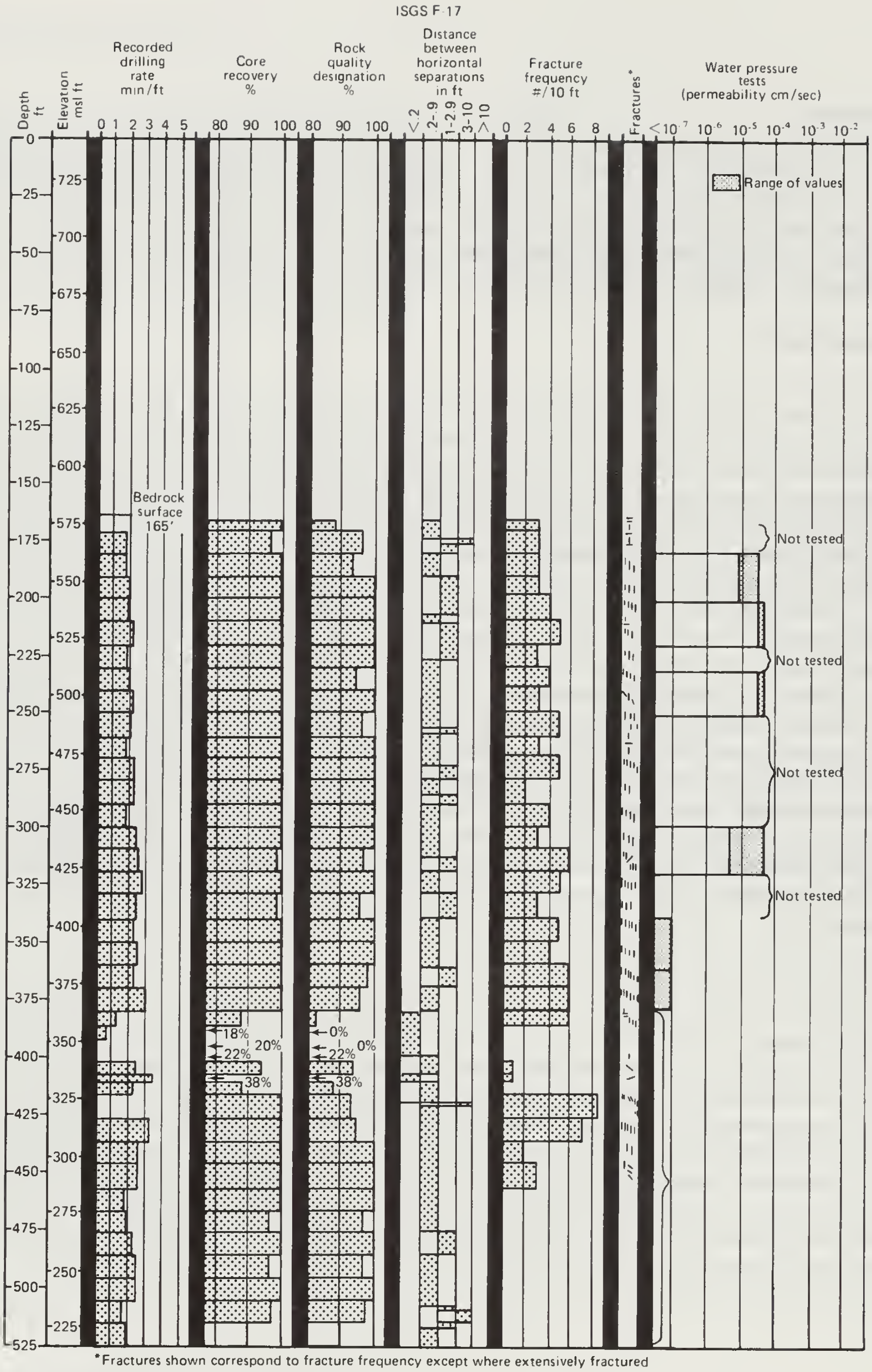


Figure 42 Summary diagram for Test Hole F-17.

Figure 42 *continued.*

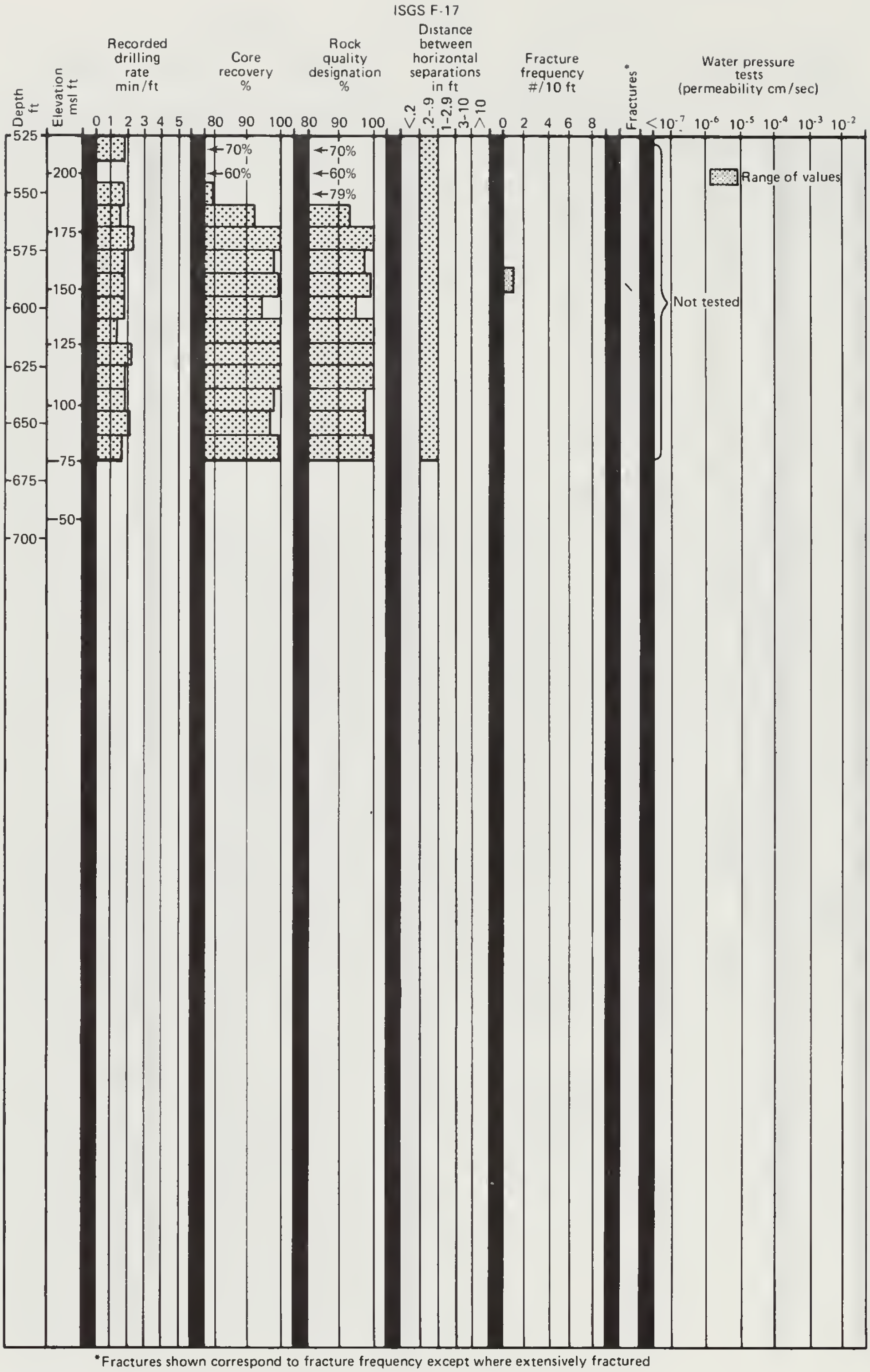


Figure 42 *continued.*

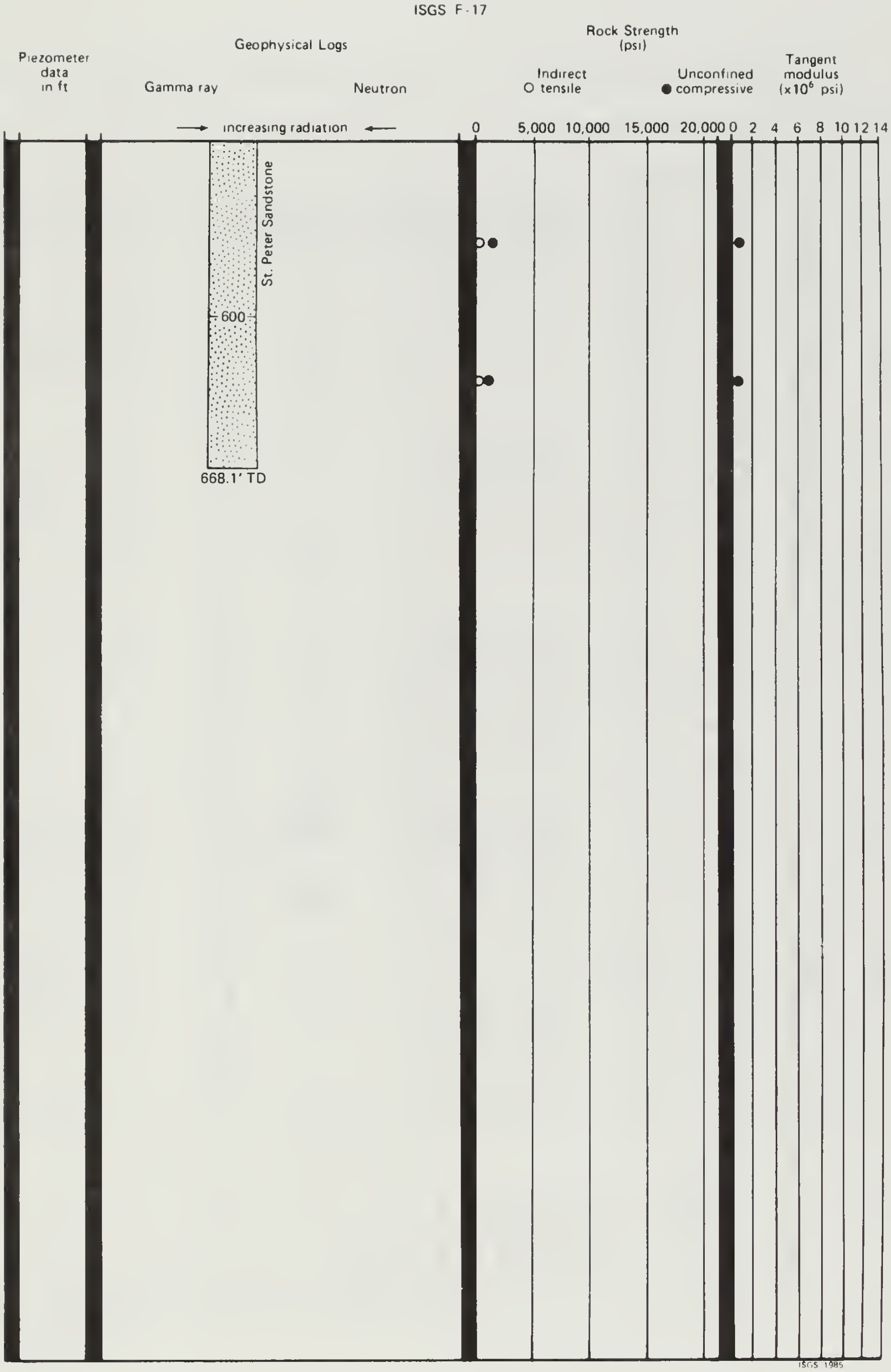


Figure 42 *continued.*

Table 24. Hydraulic conductivity (cm/sec) calculated from pressure tests in Test Hole ISGS F-17

Test intervals (ft)	P_1	P_2	P_3	P_4	P_5
382-361	--	--	--	--	--
362-341	--	--	--	--	--
322-301	1.5×10^{-5}	1.3×10^{-5}	2.9×10^{-5}	6.4×10^{-6}	6.4×10^{-6}
252-231	4.2×10^{-5}	4.1×10^{-5}	4.3×10^{-5}	2.6×10^{-5}	2.6×10^{-5}
222-201	4.7×10^{-5}	4.5×10^{-5}	4.4×10^{-5}	2.7×10^{-5}	2.8×10^{-5}
202-181	2.3×10^{-5}	1.3×10^{-5}	1.9×10^{-5}	7.7×10^{-6}	8.5×10^{-6}

Notes:

For all intervals:
P_1 = 35 psi
P_2 = 70 psi
P_3 = 100 psi

-- indicates value below detection limit of 1.0×10^{-6} cm/sec.

Table 25. Engineering properties and particle-size analysis of drift for Test Hole ISGS F-17

Depth of sample (ft)	Unit description	N (blows per ft)	Qp (tons/ft^2)	Moisture content(%)	Dry density (gm/cm^3)	Moist density (gm/cm^3)	Particle Size: Gvl (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)	Unified Soil Classification
4.0-5.5	A	7	2.0	21.1	--	--	0.1	27.5	55.2	17.3	ML
9.0-10.5	8	10	0.8	20.1	--	--	1.6	10.4	72.0	17.7	ML
13.5-15.0		45	--	--	--	--	0.3	75.4	20.3	4.3	SP
18.5-20.0	gray to	44	--	--	--	--	--	--	--	--	CL
20.0-21.0	pinkish brown	--	1.5	11.6	--	--	5.6	39.8	39.8	20.4	CL
23.5-25.0	loam till	41	3.5	9.4	2.32	2.57	9.1	39.0	39.7	21.5	CL
			10.6								
28.5-30.0		24	4.5	9.5	--	--	8.8	35.9	42.2	21.5	CL
33.5-35.0		39	--	--	--	--	8.9	34.9	43.2	21.9	CL
38.5-40.0	reddish	39	--	--	--	--	--	--	--	--	GW
43.5-45.0	brown sand	47	>4.5	--	--	--	21.2	40.9	34.4	24.8	CL,GW
48.5-50.0	and gravel	100	--	--	--	--	--	--	--	--	GW
53.5-55.0		90	--	--	--	--	--	--	--	--	GW
58.5-60.0	pinkish	63	2.0	9.7	--	--	22.6	50.5	30.5	19.0	CL
63.5-65.0	brown	37	2.0	10.7	2.55	2.82	14.5	39.9	31.6	28.5	CL
	clay		9.7								
68.5-70.0	loam to loam	65	4.0	8.7	--	--	9.0	46.8	30.9	22.3	CL
73.5-75.0	till	155	--	--	--	--	8.9	47.5	27.9	24.5	CL
78.5-80.0		115	>4.5	8.3	--	--	9.6	42.9	24.9	27.2	CL
83.5-85.0		140	4.5	9.9	2.40	2.63	9.5	39.3	32.8	27.9	CL
			9.5								
88.5-90.0		R	>4.5	10.7	2.13	2.39	17.5	34.9	34.4	30.7	CL
			11.9								
93.5-95.0		100	4.5	11.2	2.23	2.56	10.3	34.7	33.3	32.1	CL
			11.9								
98.5-100.0		R	4.5	12.7	--	--	8.9	26.5	37.0	36.6	CL
103.5-105.0	stratified	106	4.5	19.7	1.88	2.27	0.0	4.0	37.6	58.4	CL
	pinkish		21.0								
109.0-110.5	brown loam	78	4.5	13.5	--	--	--	--	--	--	CL
113.0-114.5		22	0.6	10.4	2.29	2.54	3.4	37.2	45.3	17.5	CL
			10.8								
118.0-119.5		88	>4.5	--	--	--	11.3	43.6	40.0	16.4	OL
123.0-124.5	interbedded	R	>4.5	9.3	--	--	6.3	37.8	43.0	19.3	OL,CL
128.0-129.5	organic-rich	R	3.0	16.6	--	--	0.0	25.8	60.6	13.6	OL,CL
133.0-134.5	loam and	R	--	--	--	--	--	--	--	--	OL,CL
138.0-139.5	silty clay	R	4.0	17.7	--	--	--	--	--	--	OL,CL
143.0-144.5	loam	R	>4.5	13.2	--	--	3.3	39.3	34.2	26.5	OL,CL
148.0-149.5		R	>4.5	--	--	--	--	--	--	--	OL,CL
153.3-154.5	C	--	--	--	--	--	2.8	53.1	35.2	11.7	CL
158.0-159.5	gravel	<------NO SAMPLE------>									GW
	bedrock										

Notes:

Qp = unconfined compressive strength as measured by pocket penetrometer
Gravel measured as percentage of whole sample; sand, silt, clay measured as percentage of <2-mm fraction
R = refusal; unable to drive split spoon more than one foot
A gray and orange silt loam
8 stratified silt and sand
C brown sandy loam till

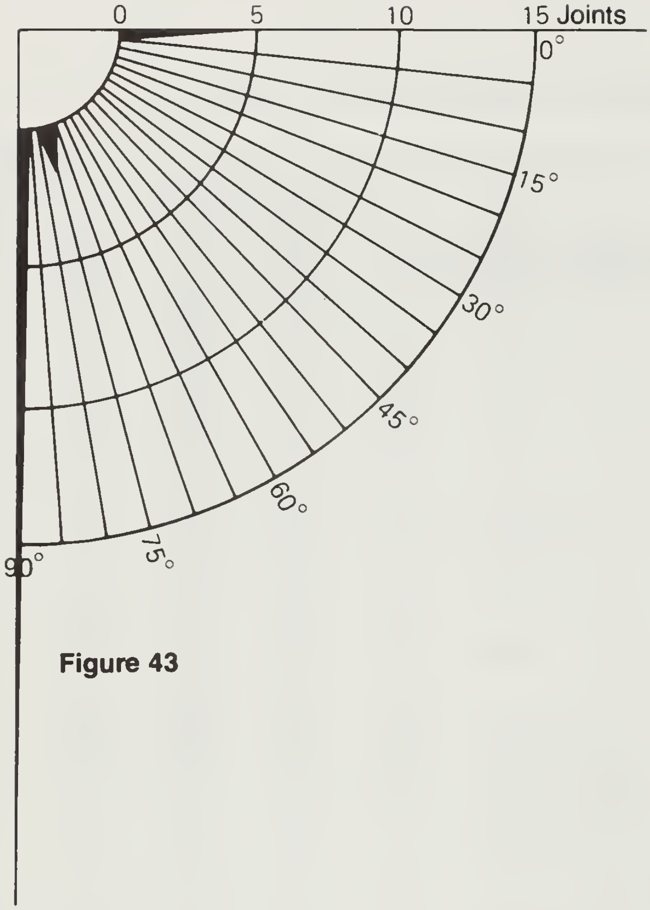


Figure 43

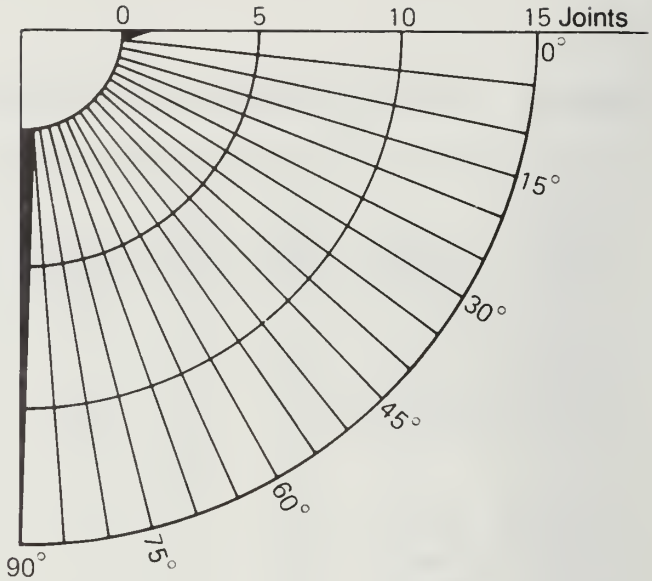


Figure 44

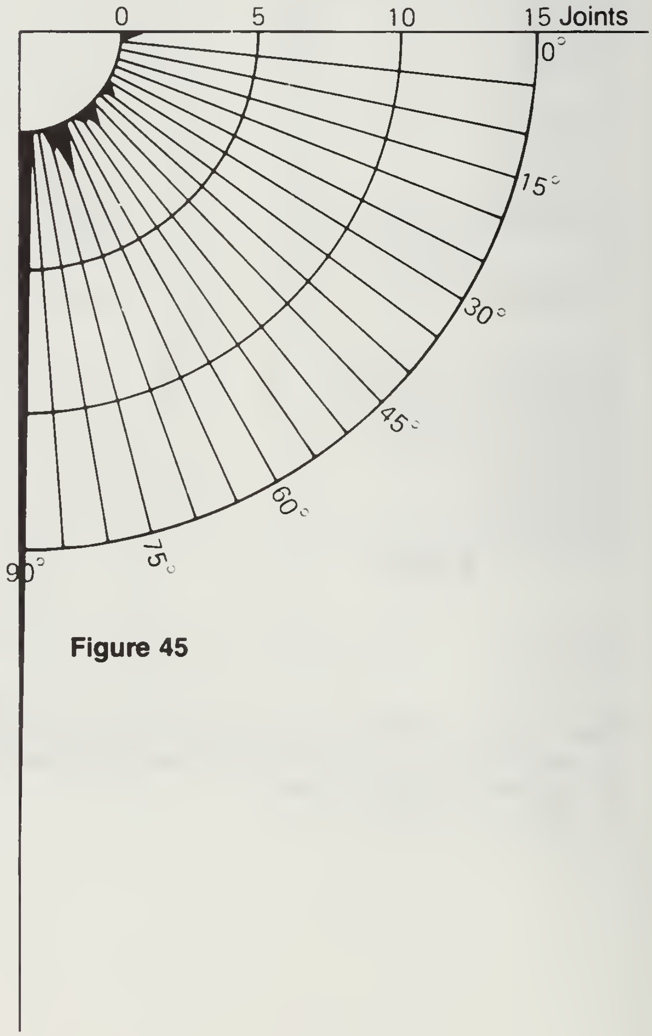


Figure 45

Number and angle of dip of joints in core from Test Hole ISGS F-17

43 97.6 feet of Galena (Wise Lake) Group strata.
44 46.8 feet of Galena (Dunleith) Group strata.
45 143.5 feet of Platteville Group strata.

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