

APPENDIX B

CONE PENETROMETER, SEISMIC CONE AND CROSSHOLE TESTS



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October 13, 1994
Report Number 0301-4108
Via Federal Express

Woodward-Clyde Consultants
2822 O'Neil Lane
Baton Rouge, LA 70816

Attention: Mr. Ara Arman
Mr. Bob Sanders

**CONE PENETROMETER TESTING
AND RELATED SERVICES
LIGO SITE
LIVINGSTON PARISH, LOUISIANA**

Dear Mssrs. Arman and Sanders:

Please find enclosed herewith the results of the cone penetrometer tests conducted at the above-referenced location. Also, results of the seismic cone penetrometer tests along with one (1) crosshole seismic test (B-W-35-SC) are included.

For your information, the soil stratigraphy was identified using Campanella and Robertson's Simplified Soil Behavior Chart. Please note that because of the empirical nature of the soil behavior chart, the soil identification should be verified locally.

Seismic Piezocone Test

At three (3) of the locations seismic piezocone tests were carried out. To design a foundation for dynamic loads, it is necessary to determine in-situ shear modules of the foundation soil. There are several methods to measure the shear modulus in-situ. One of the methods involves a penetrating cone in which geophones are incorporated to detect a shear wave which is generated at the surface. A shear wave is generated by means of a hammer blow against a wooden block. The shear wave travels to the piezocone in which three (3) seismometers are incorporated. A seismograph is triggered by the hammer blow and records the arrival of the shear waves. The results of the shear wave travel times versus depth are shown on Plates 1, 2, and 3. This can be repeated with both sides of the wooden beam to have polarized waves. After taking one set of measurements, the piezocone is pushed to the next depth, which is one-meter further. The difference in arrival time of the shear wave for the two penetrations is the travel time through the one-meter soil interval.

In this manner, a shear wave velocity profile can be given with one-meter intervals (Plate 5, 6, and 7).

Crosshole Testing

The crosshole seismic test was performed to measure in-situ shear wave velocities of the subsurface soils at the location of seismic cone penetrometer Sounding No. B-SW-35-SC. A schematic diagram of the

crosshole test arrangement is shown on Plate 4. The crosshole method consists of generating shear waves in the soil surrounding a source borehole and measuring the arrival times of the shear waves at each of two receiver boreholes.

The shear waves are generated by striking the drill rod from the ground surface with a hammer. The bottom of the drill rod is in contact with the soil in the source borehole. Each impact of the hammer on the drill excites an accelerometer attached to the drill rod, which in turn triggers the recording equipment. The recording equipment consists of a recording digital oscilloscope. The shear waves travel through the soil, and their arrivals are monitored with vertically-oriented geophones, or receivers, positioned in the receiver boreholes (borings R-1 and R-2) at the same depth as the bottom of the drill rod. The geophones are firmly coupled to the receiver borehole using pneumatic packers. The shear wave arrivals at the geophones are recorded with the digital oscilloscope. The test is repeated at 5-foot intervals down to a 50-foot depth.

The recorded waveforms show travel times of the shear waves between the source and receiver boreholes. The shear wave velocities are calculated with the measured travel times and travel path distances. By calculating the shear wave velocity at each tested depth, we established a shear wave velocity versus depth profile, shown on Plate 6.

Fugro Geosciences appreciates the opportunity to be of service to your organization. If you should have any questions, or if we can be of further assistance, please do not hesitate to contact us. We look forward to working with you in the future.

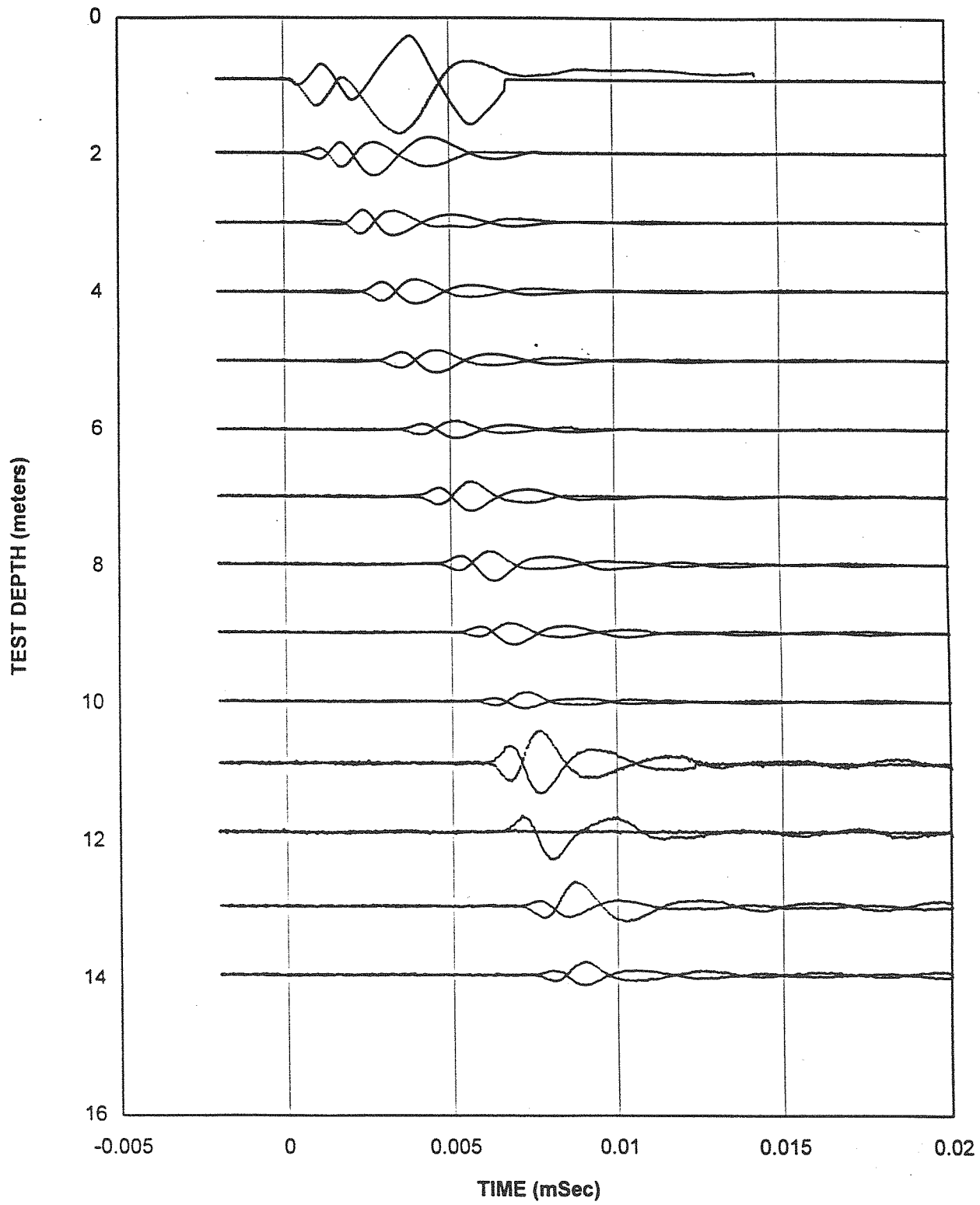
Very truly yours,
FUGRO GEOSCIENCES, INC.



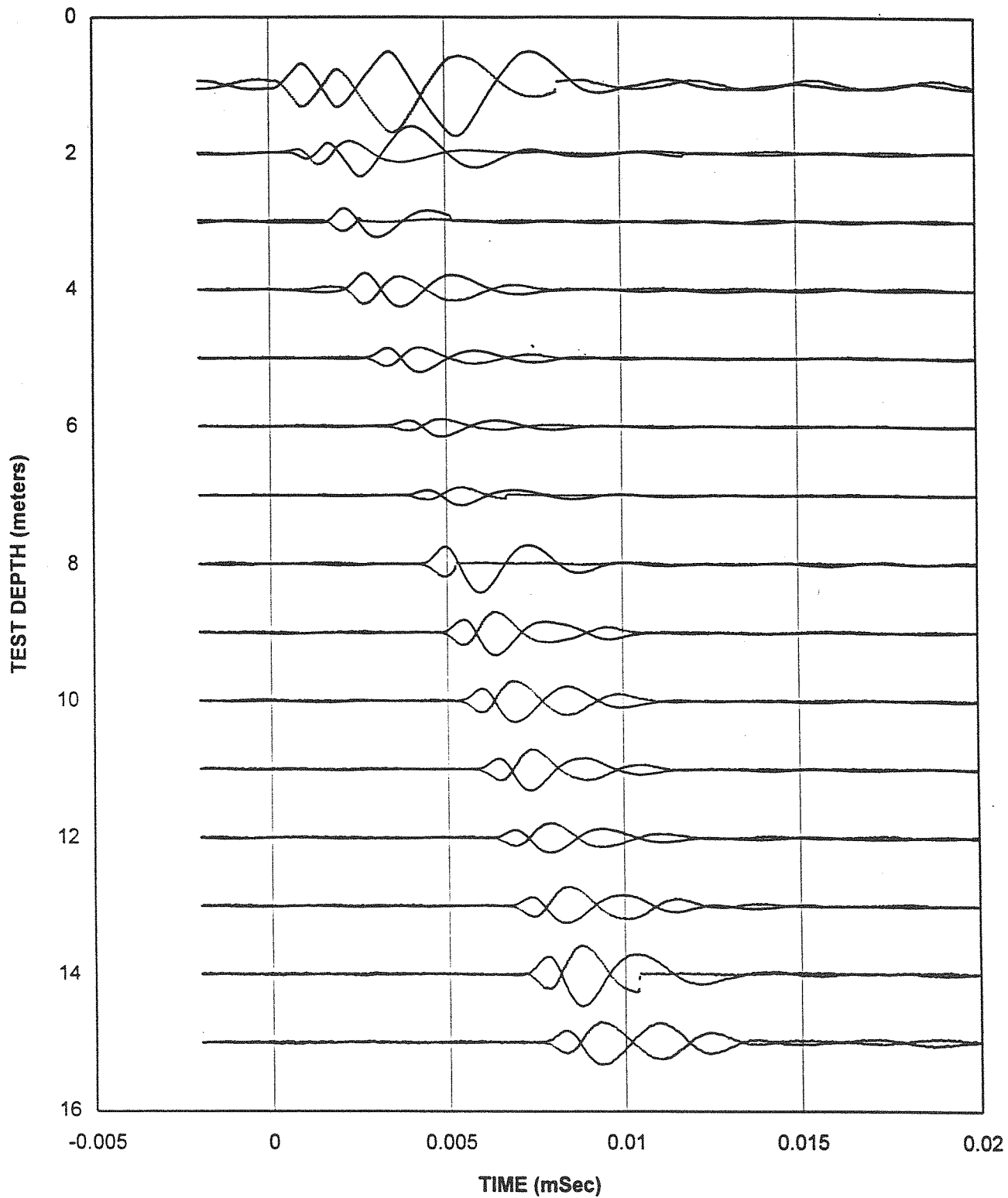
Recep Yilmaz
President

RY/cam

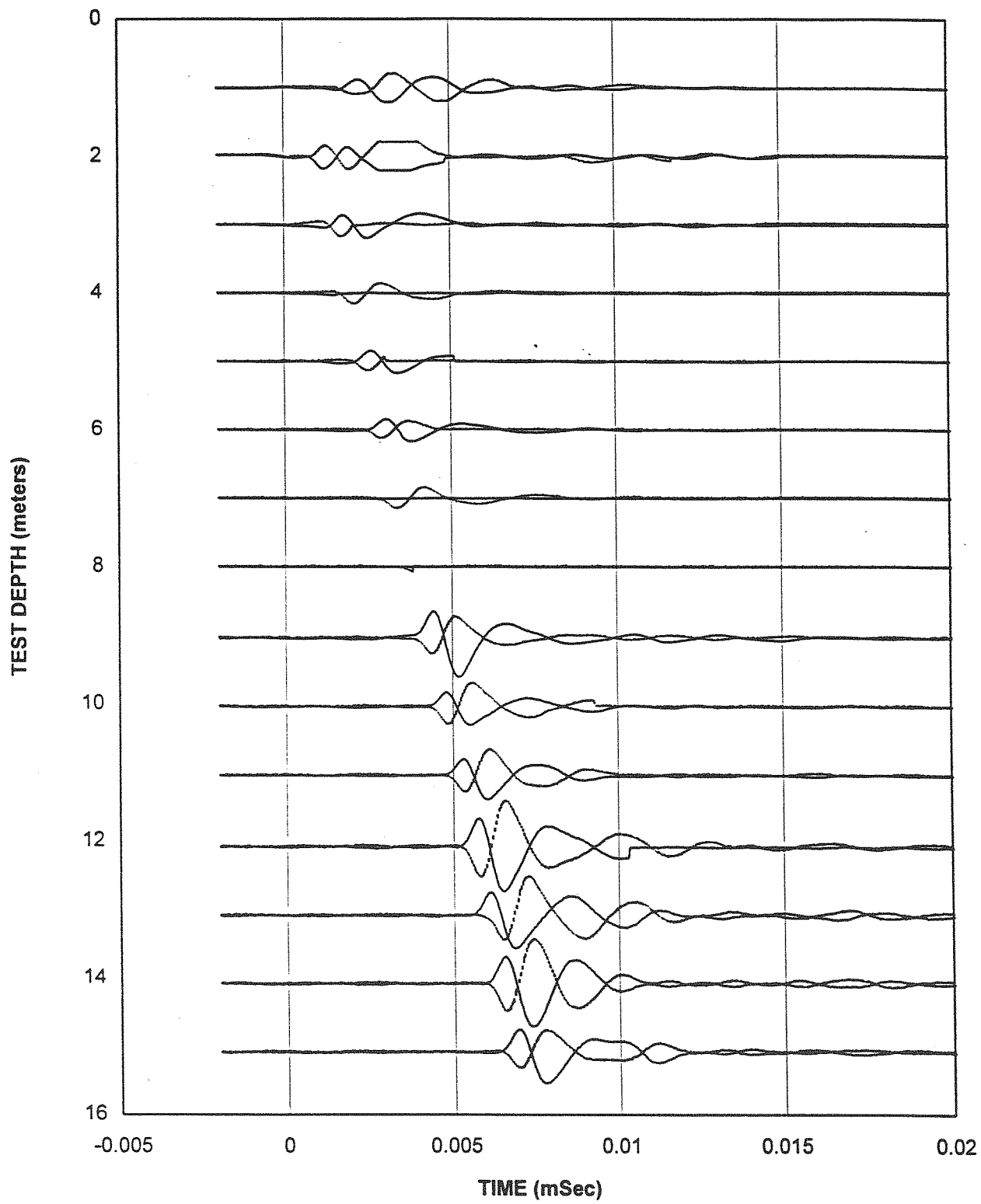
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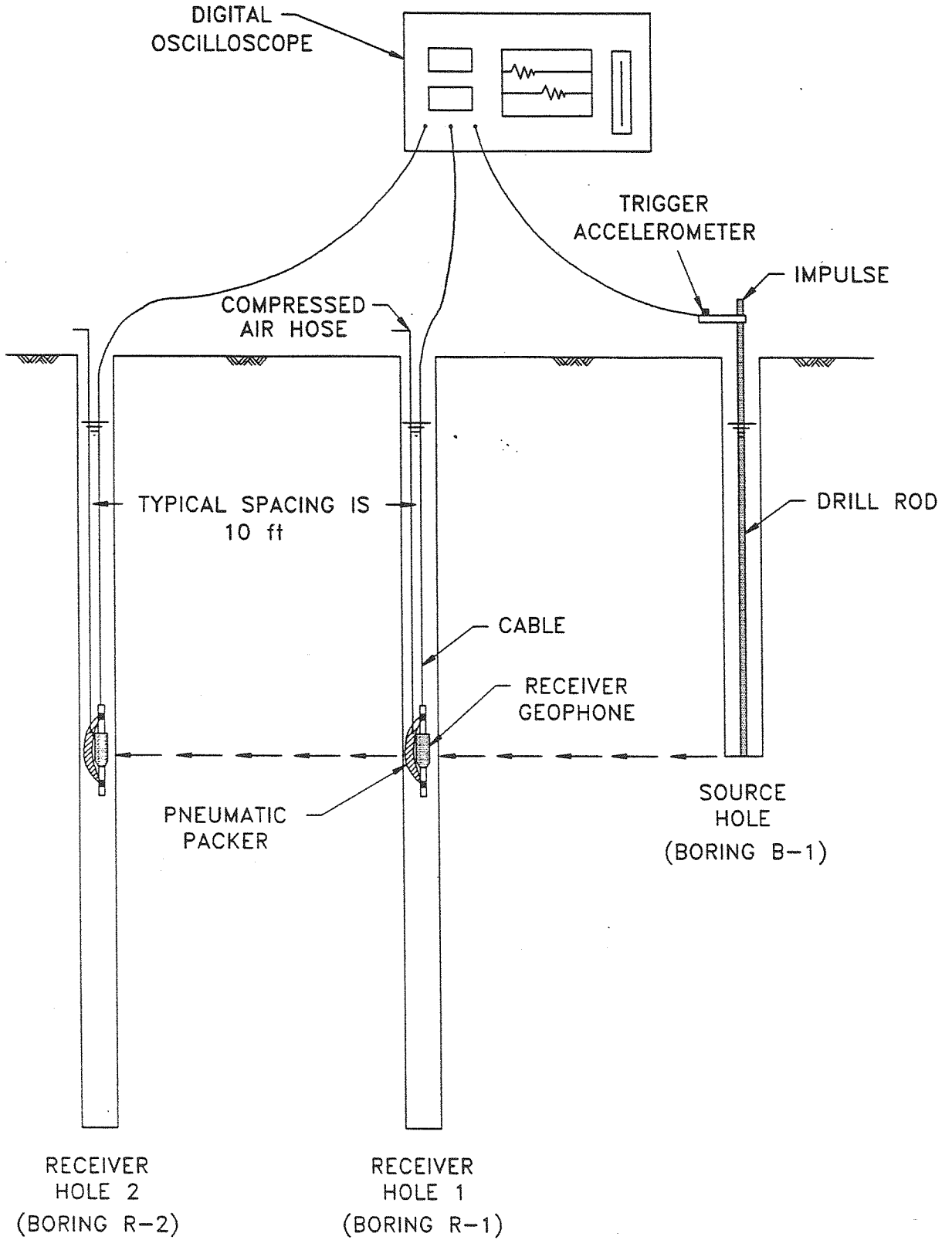


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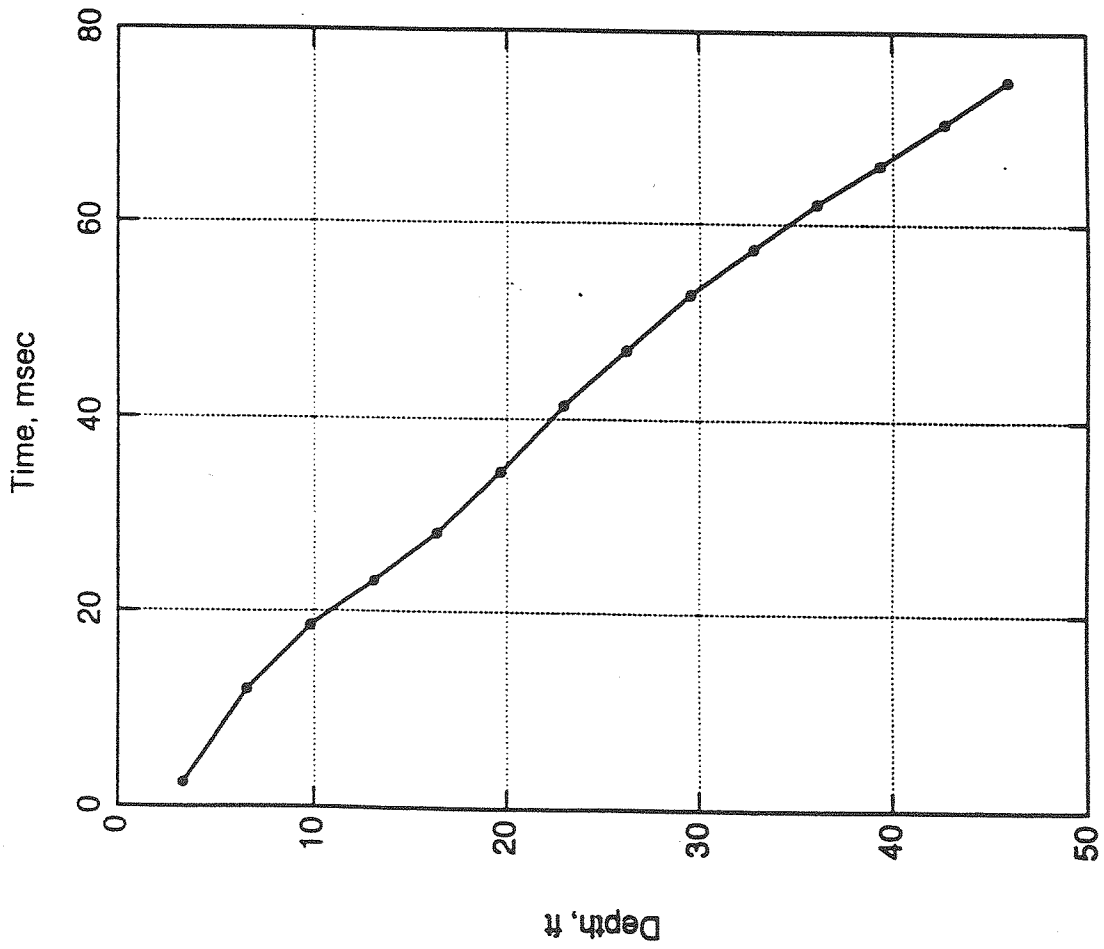
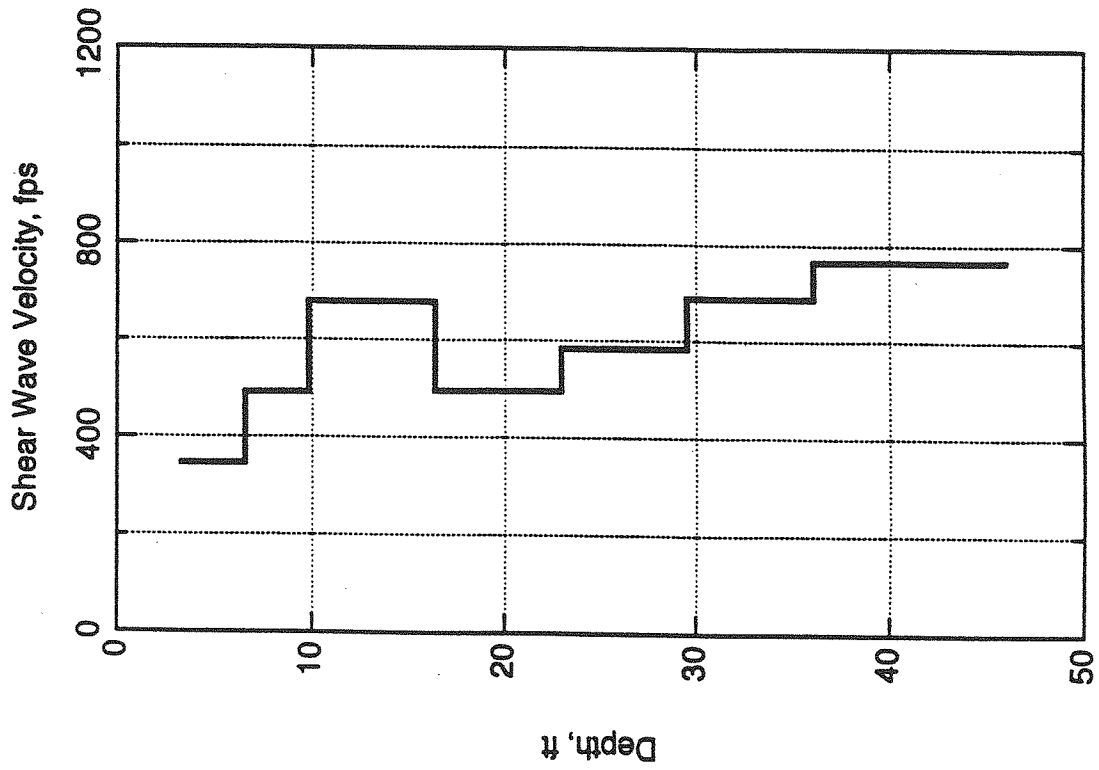


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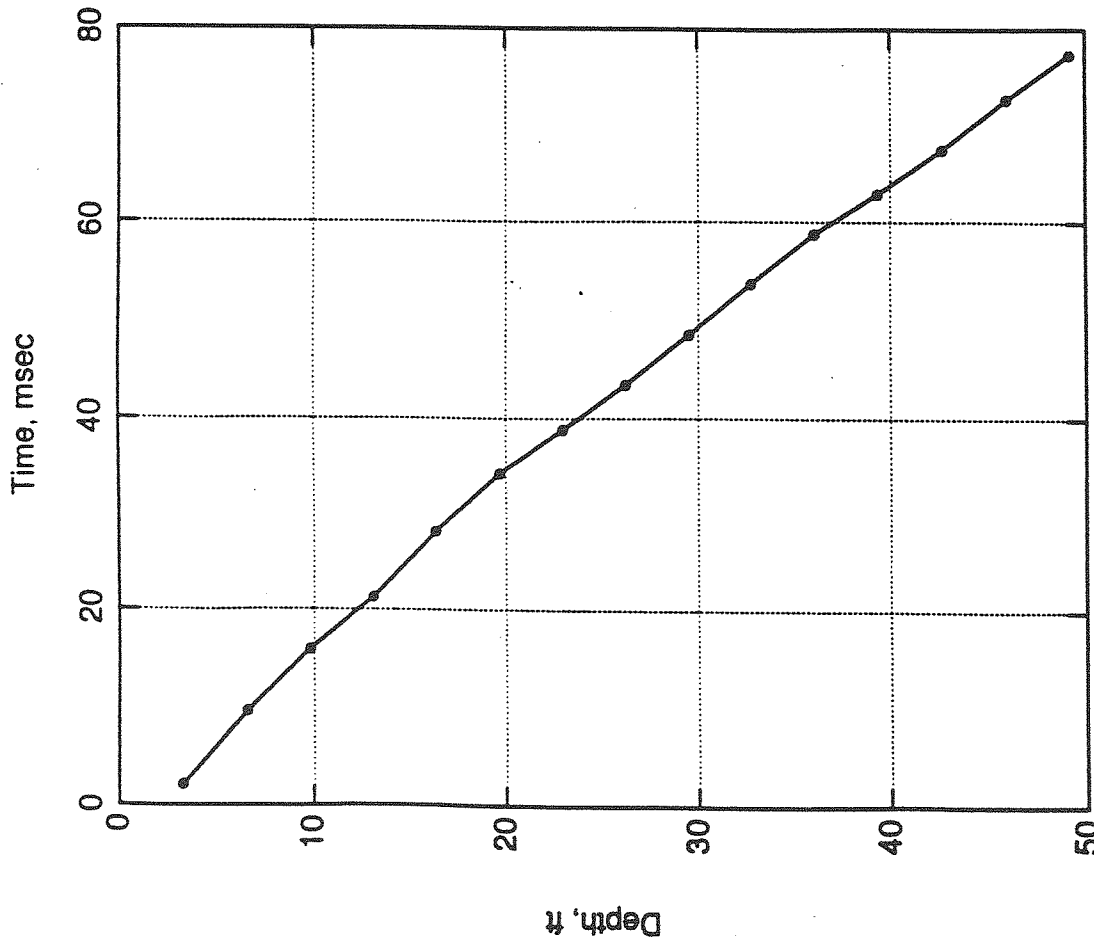
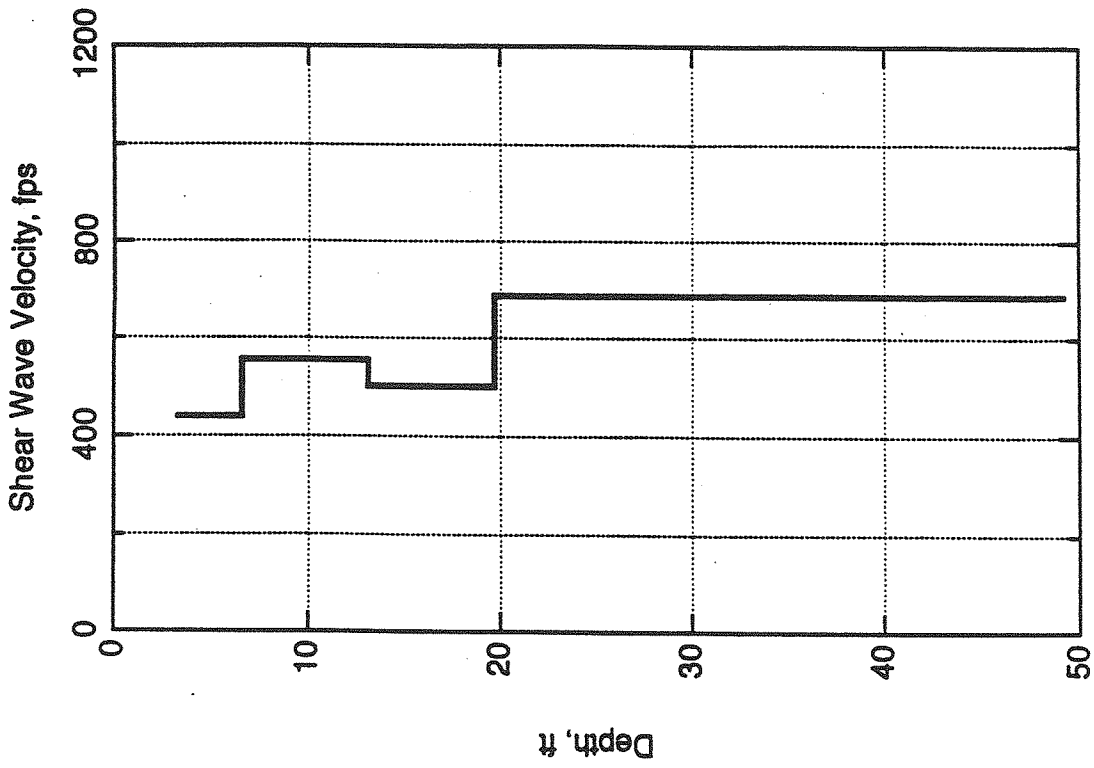




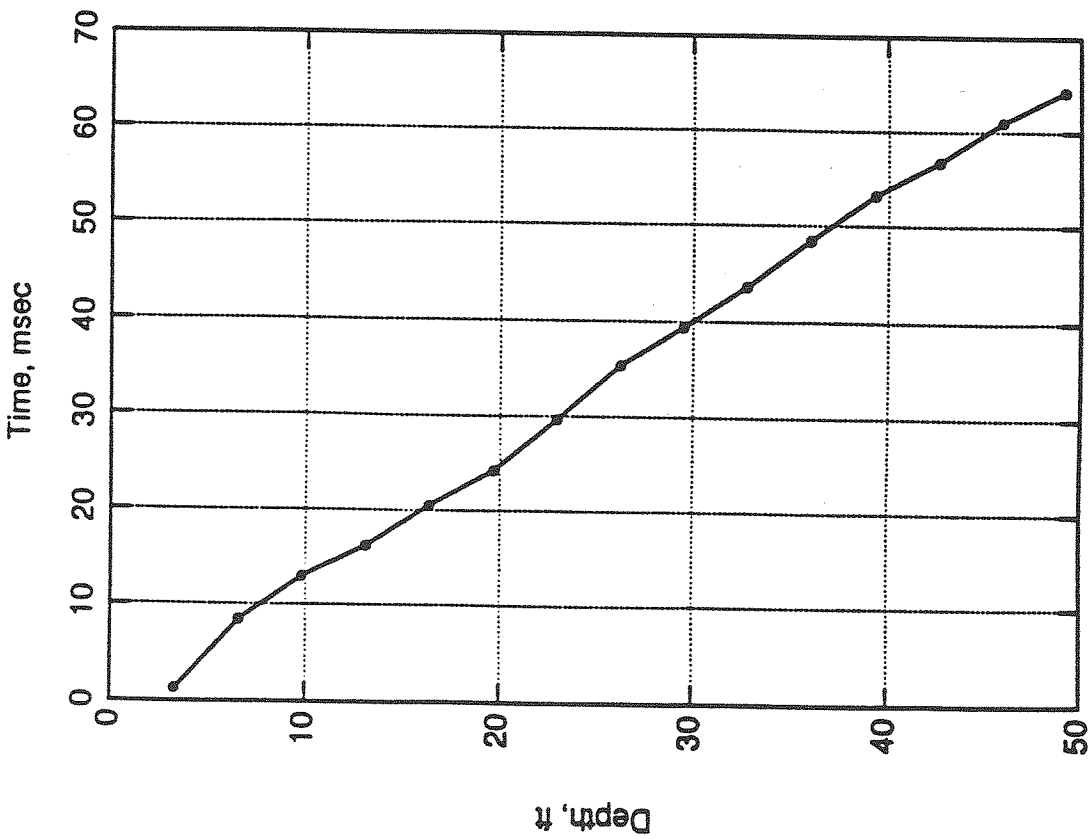
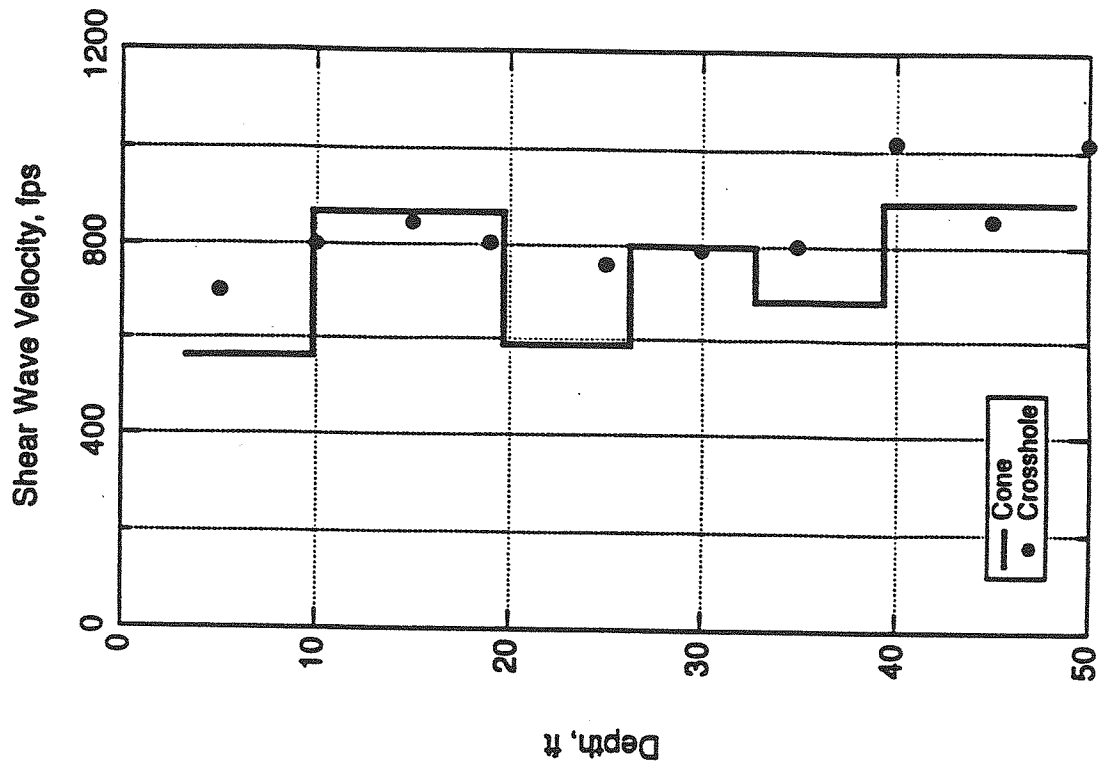
SCHEMATIC OF CROSSHOLE PROCEDURE
(Not to Scale)



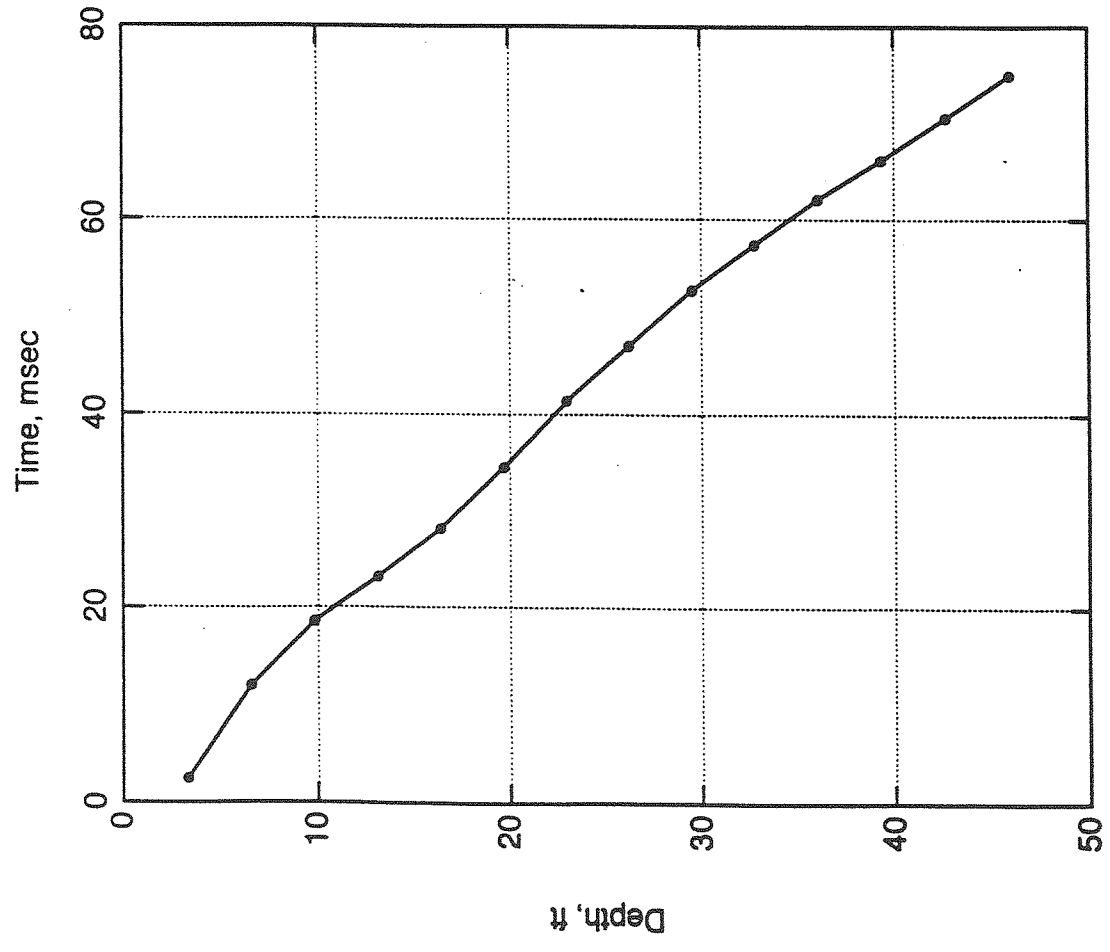
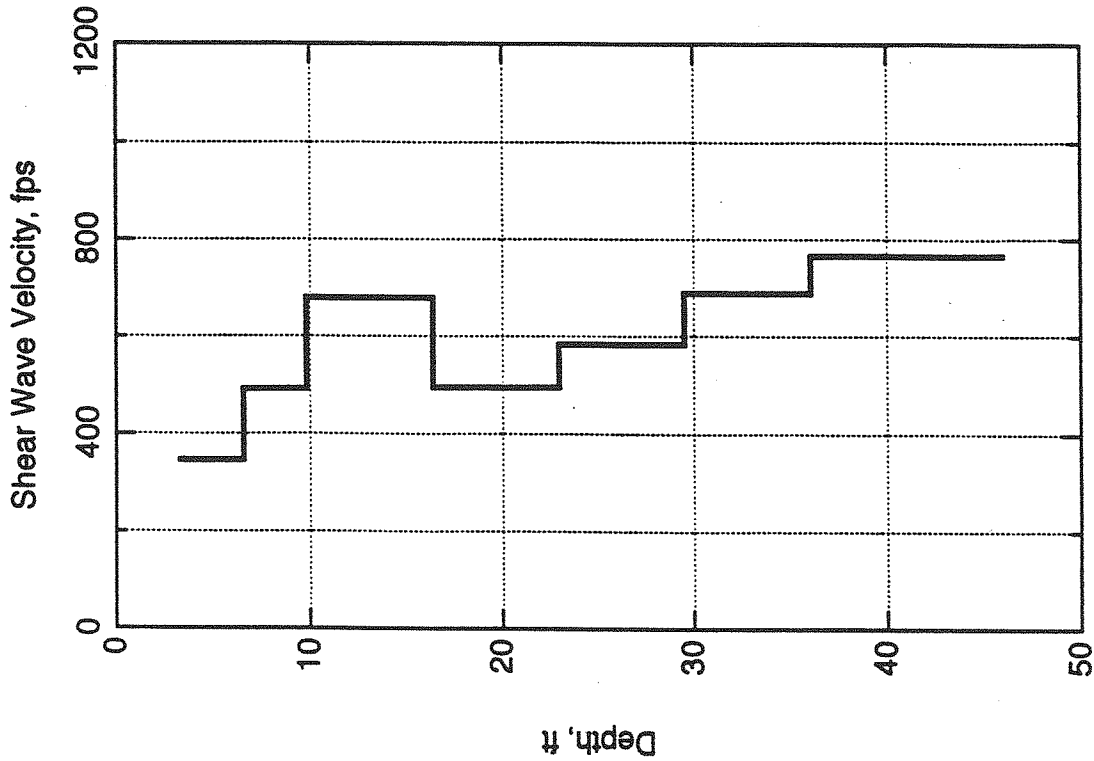
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CPT SOUNDING B-SW-01-SC**



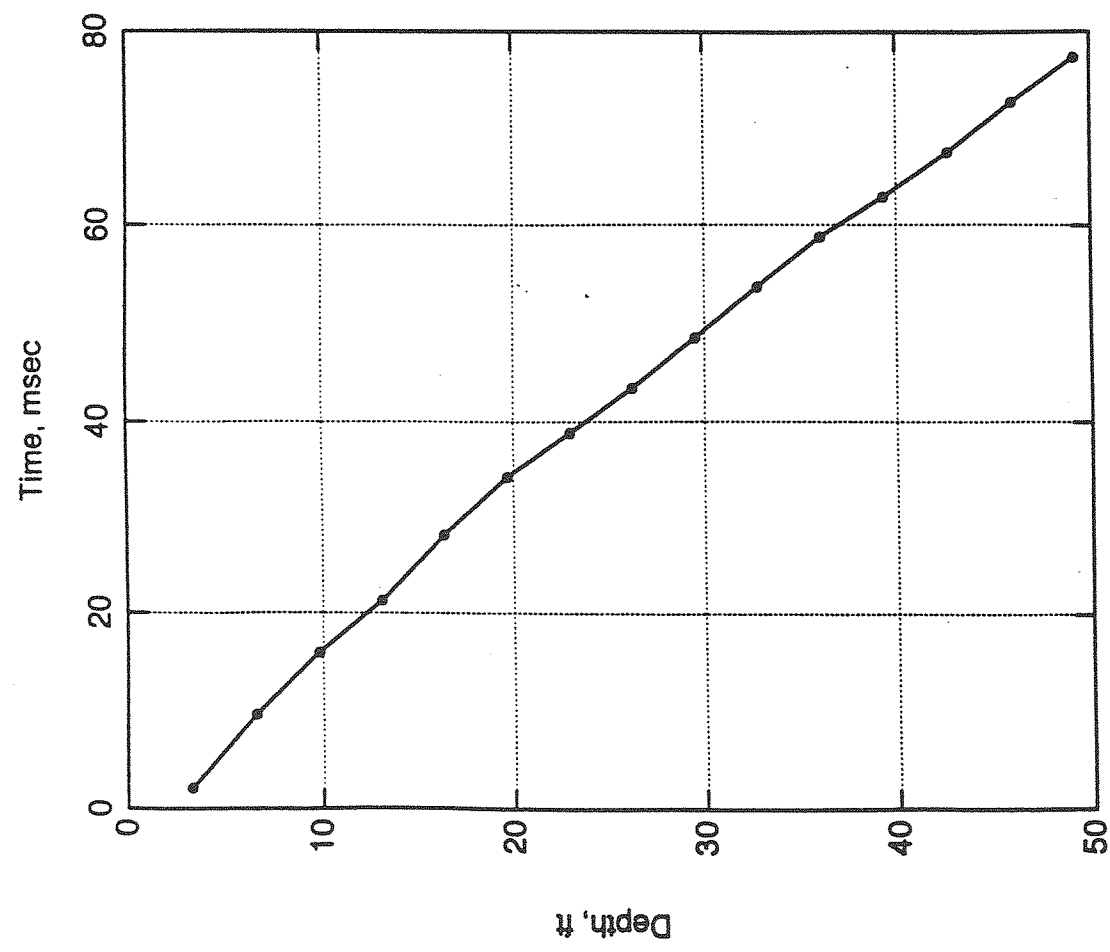
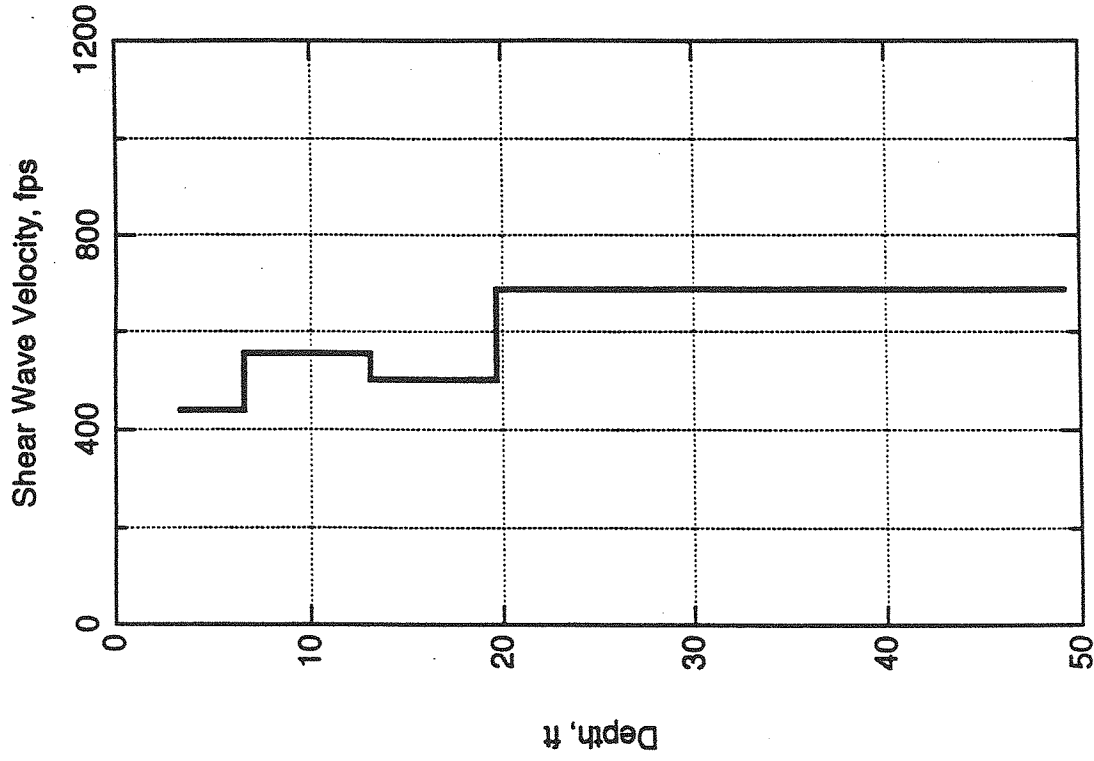
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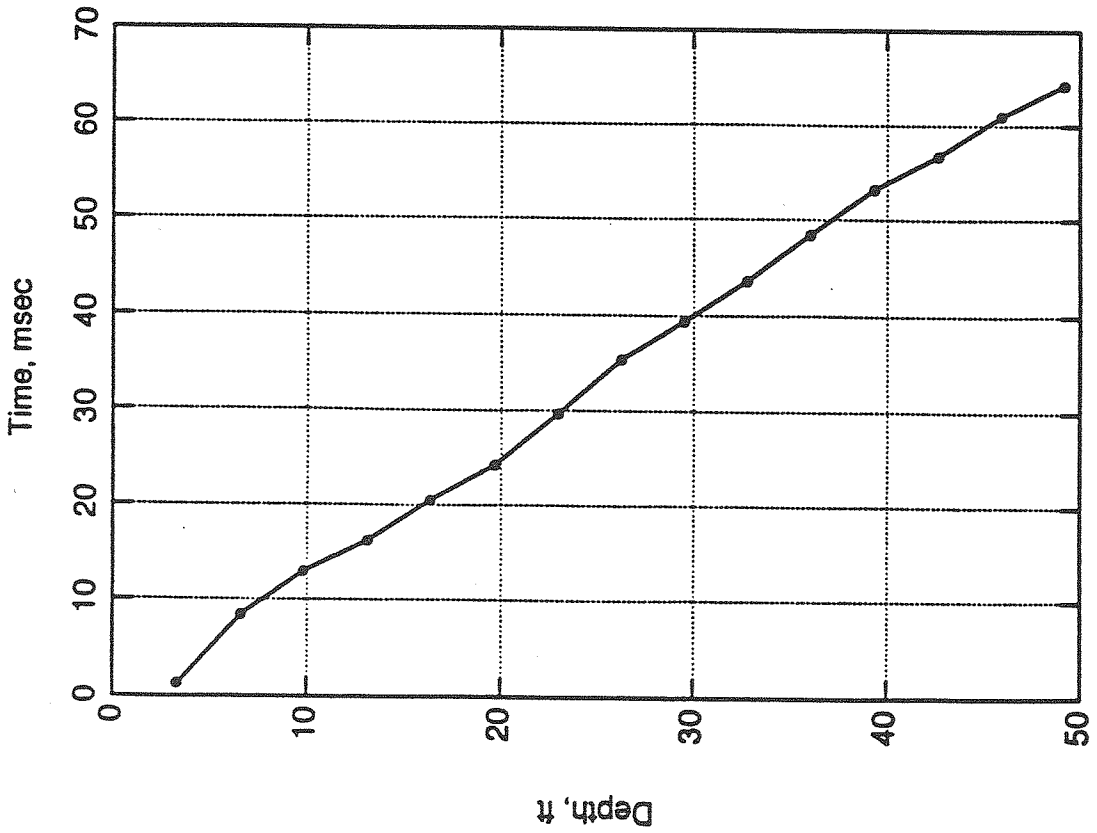
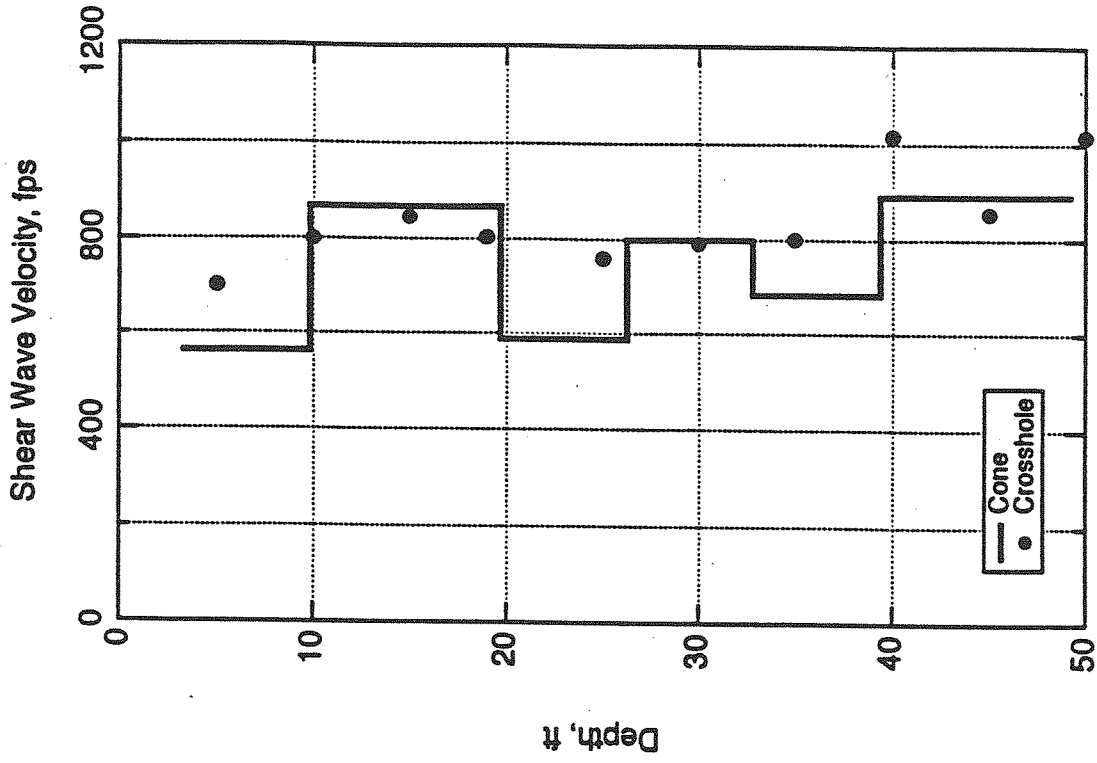
**SEISMIC CONE PENETROMETER RESULTS
WITH CROSSHOLE TEST RESULTS
CPT SOUNDING B-SW-35-SC**



SEISMIC CONE PENETROMETER RESULTS
CPT SOUNDING B-SW-01-SC

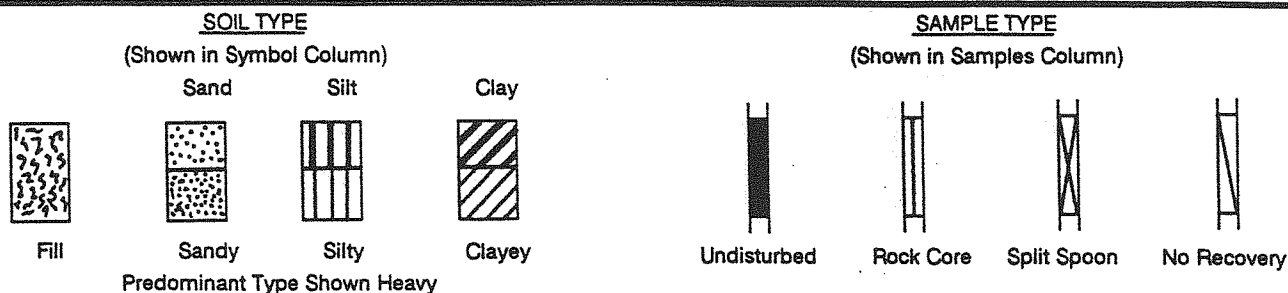


SEISMIC CONE PENETROMETER RESULTS
CPT SOUNDING B-SE-34-SC



**SEISMIC CONE PENETROMETER RESULTS
WITH CROSSHOLE TEST RESULTS
CPT SOUNDING B-SW-35-SC**

Key To Soil Classification and Symbols



TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (Major portion Retained on No. 200 Sieve)

Includes (1) clean gravels and sand described as fine, medium or coarse, depending on distribution of grain sizes (2) silty or clayey gravels and sands and (3) fine grained low plasticity soils ($PI < 10$) such as sandy silts. Condition is rated according to relative density, as determined by lab tests or estimated from resistance to sampler penetration.

Descriptive Term	Penetration Resistance*	Relative Density
Loose	0 - 10	0 to 40%
Medium Dense	10 - 30	40 to 70%
Dense	30 - 50	70 to 90%
Very Dense	Over 50	90 to 100%

* Blows/Foot, 140# Hammer, 30" Drop

FINE GRAINED SOILS (Major Portion Passing No. 200 Sieve)

Includes (1) inorganic and organic silts and clays, (2) sandy, gravelly or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests for soils with $PI \geq 10$.

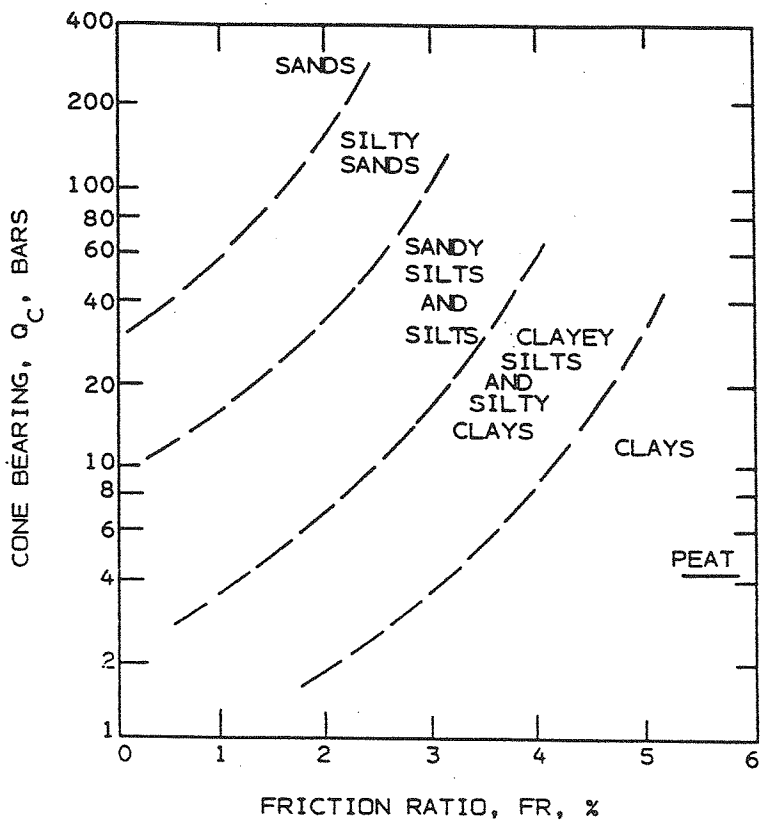
Descriptive Term	Cohesive Shear Strength Tons/Square Foot
Very Soft	Less Than 0.125
Soft	0.125 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 and Higher

Note: Slickensided and fissured clay may have lower unconfined compressive strengths than shown above because of planes of weakness or shrinkage cracks; consistency ratings of such soils are based on hand penetrometer readings.

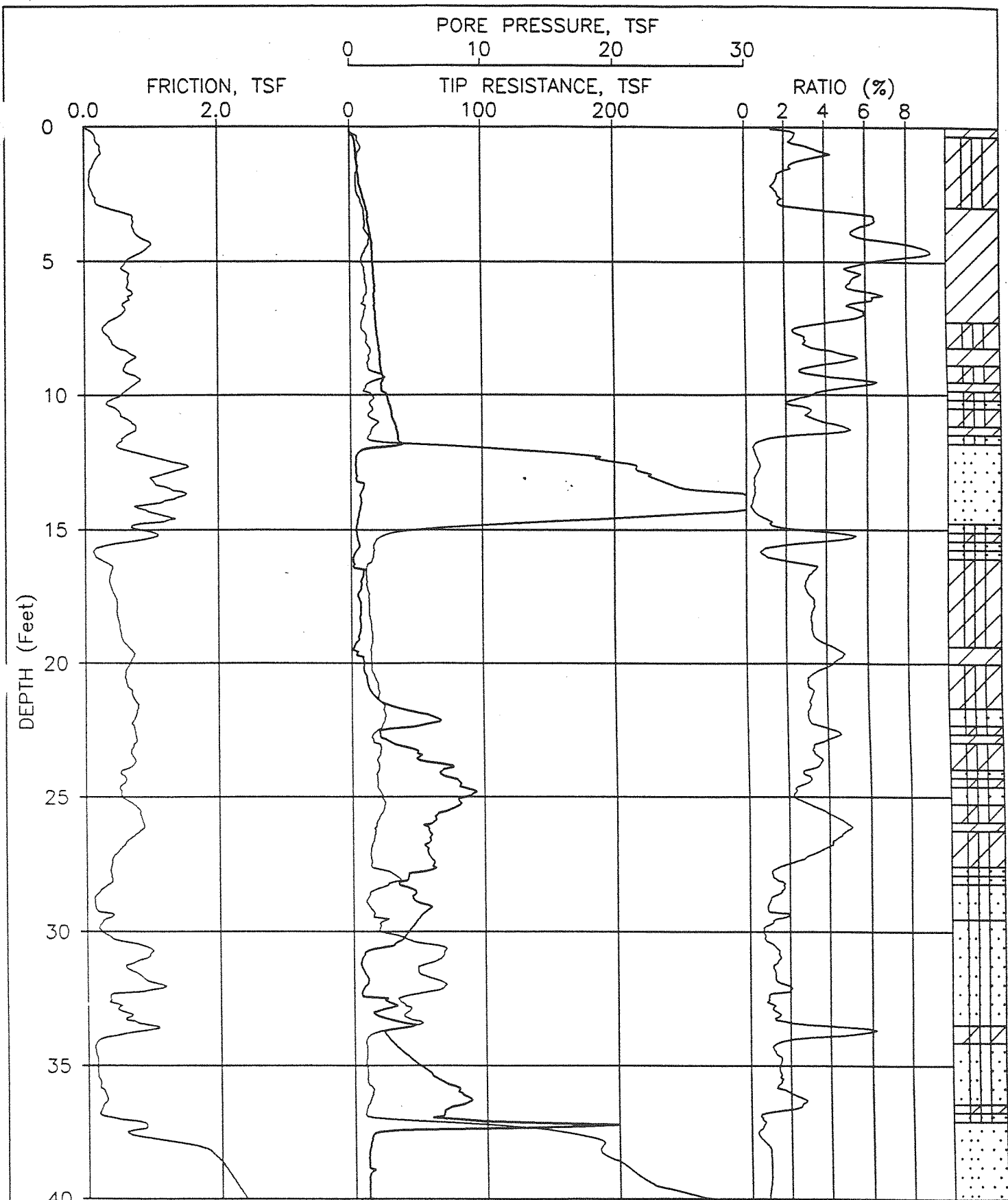
TERMS CHARACTERIZING SOIL STRUCTURE

<p>Parting: paper thin in size</p> <p>Seam: 1/8" to 3" thick</p> <p>Layer: greater than 3"</p> <p>Fissured: containing shrinkage cracks, frequently filled with fine sand or silt, usually more or less vertical</p> <p>Sensitive: pertaining to cohesive soils that are subject to appreciable loss of strength when remolded</p> <p>Interbedded: composed of alternate layers of different soil types</p> <p>Laminated: composed of thin layers of varying color and texture</p> <p>Calcareous: containing appreciable quantities of calcium carbonate</p> <p>Well Graded: having wide range in grain sizes and substantial amounts of all intermediate particle sizes</p> <p>Poorly Graded: predominantly of one grain size, or having a range of sizes with some intermediate size missing</p>	<p>Flocculated: pertaining to cohesive soils that exhibit a loose knit or flakey structure</p> <p>Slickensided: having inclined planes of weakness that are slick and glossy in appearance.</p> <p style="text-align: center;"><u>Degree of Slickensided Development</u></p> <p>Slightly Slickensided: slickensides present at intervals of 1' to 2', soil does not easily break along these plates</p> <p>Moderately Slickensided: slickensides spaced at intervals of 1' to 2', soil breaks easily along these planes</p> <p>Extremely Slickensided: continuous and interconnected slickensides spaced at intervals of 4" to 12', soil breaks along the slickensides into pieces 3" to 6" in size</p> <p>Intensely Slickensided: slickensides spaced at intervals of less than 4", continuous in all directions; soil breaks down along planes into nodules 1/4" to 2" in size.</p>
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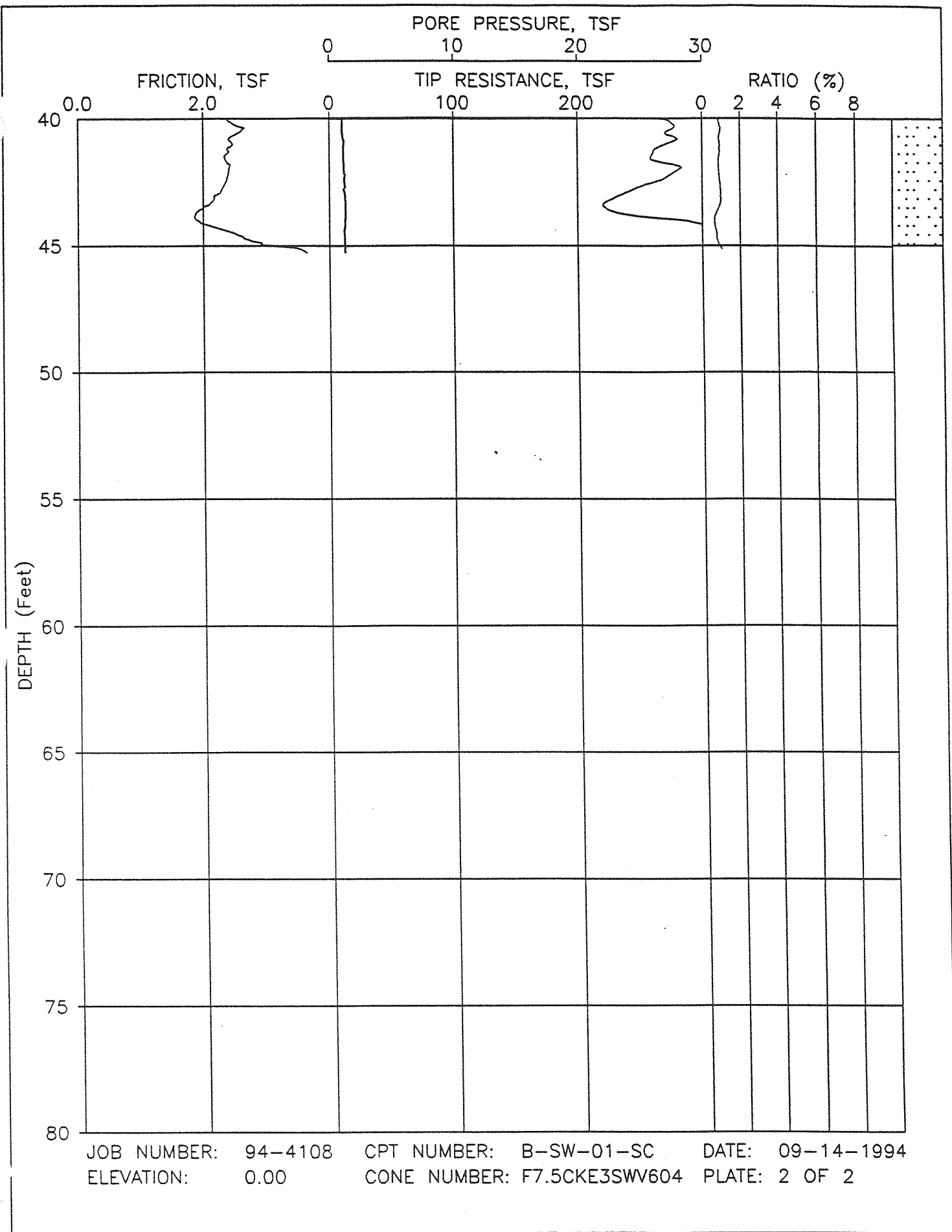
1 BAR = 100KPA = 1.02 KG/CM²



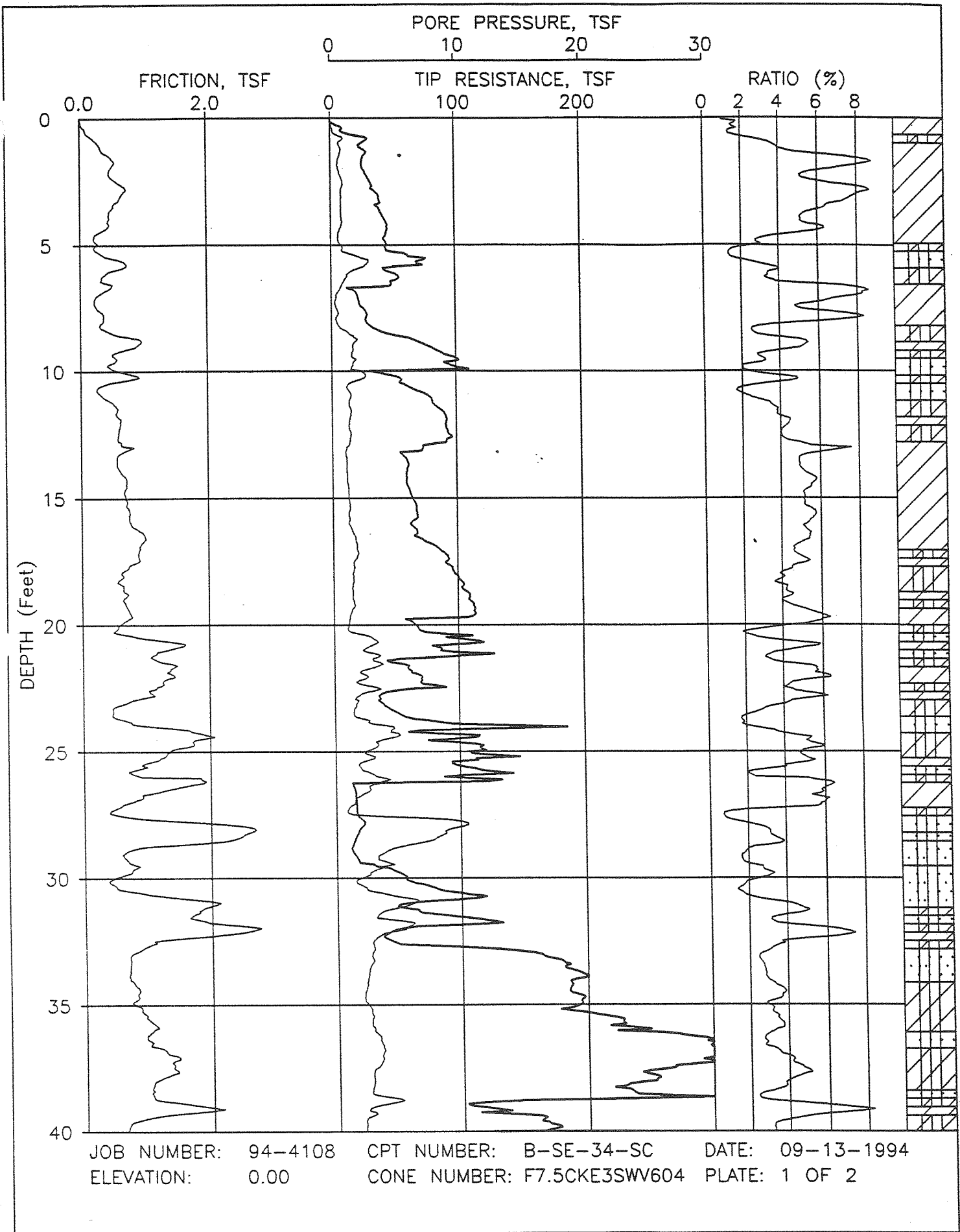
CAMPANELLA AND ROBERTSON CLASSIFICATION CHART



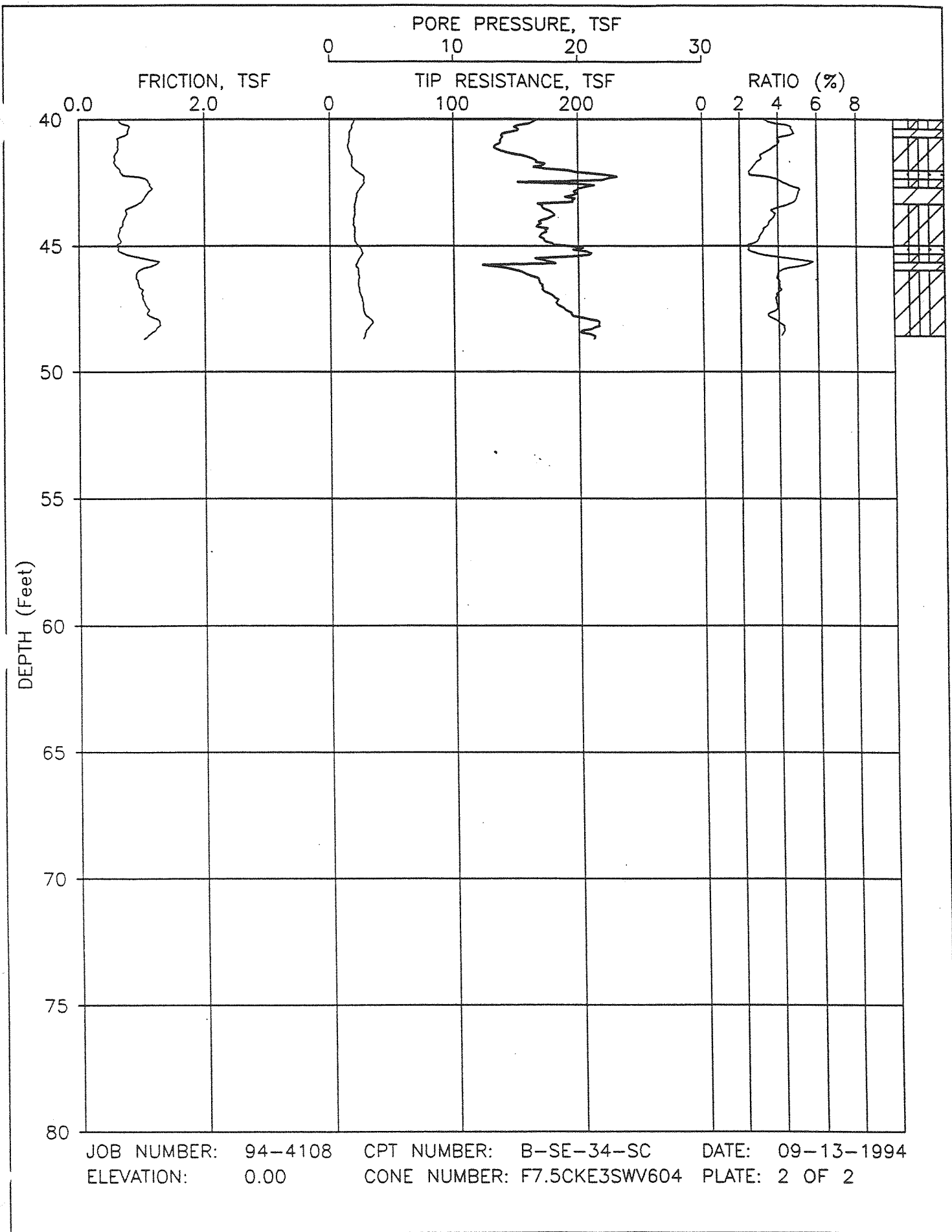
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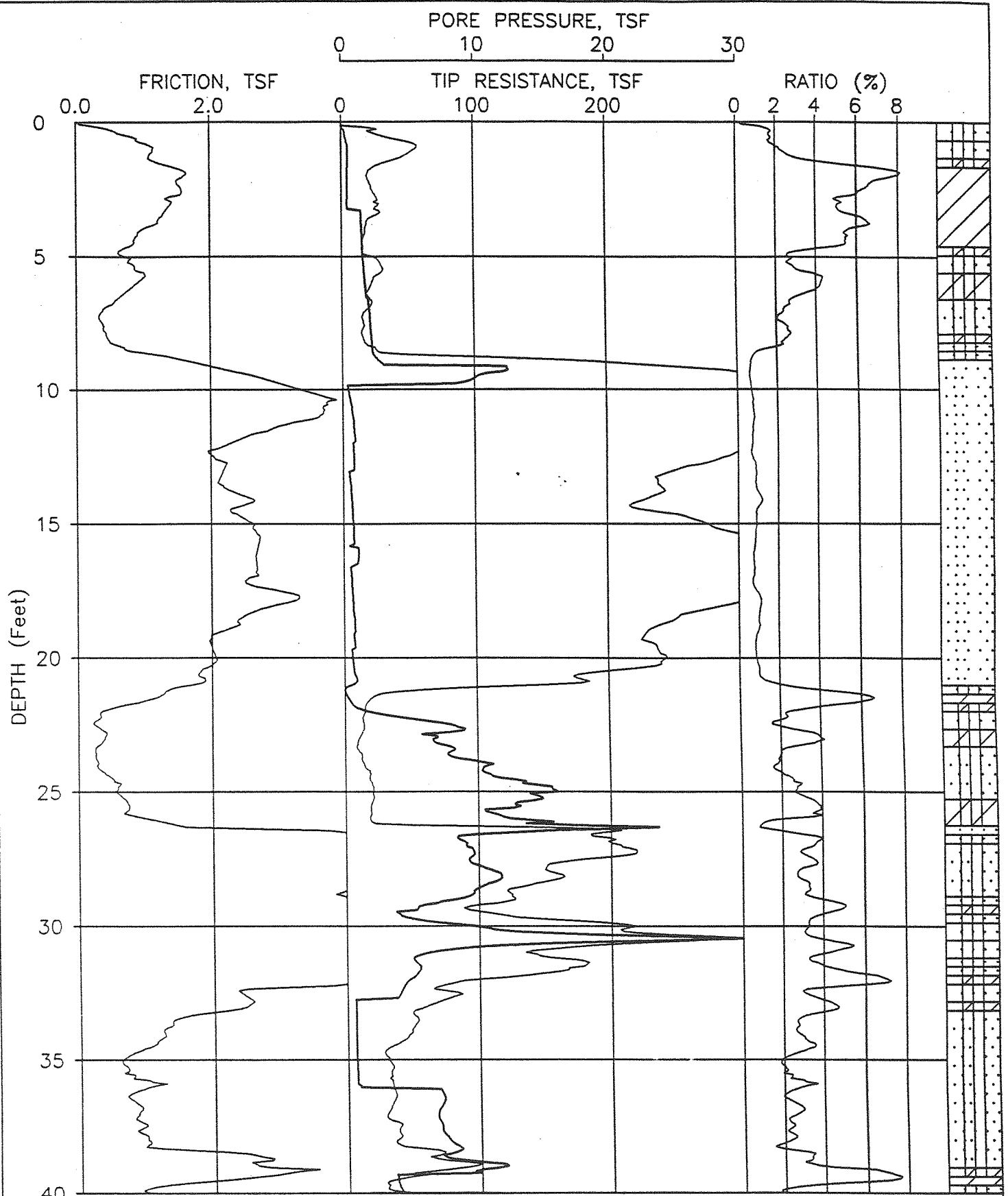
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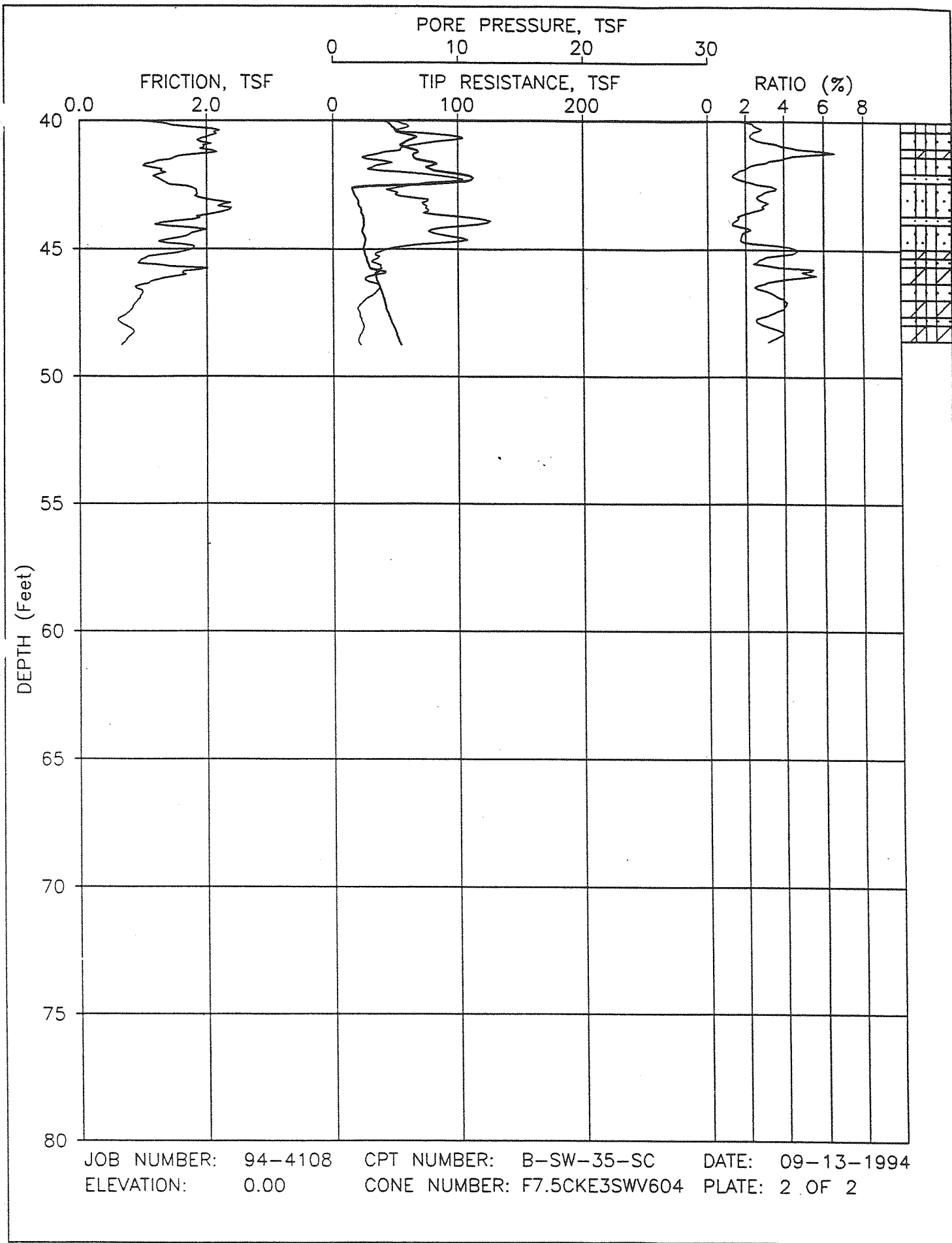
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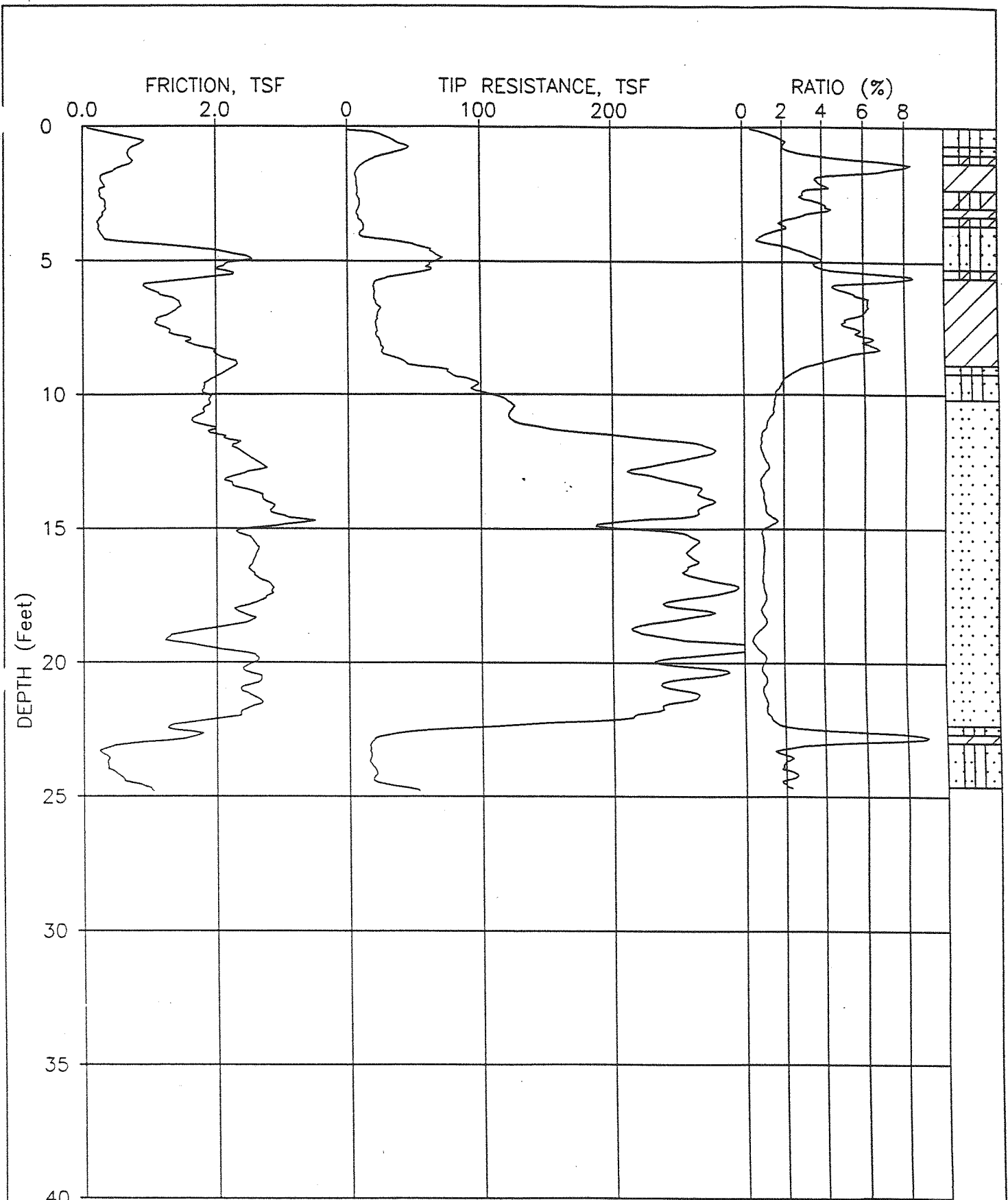


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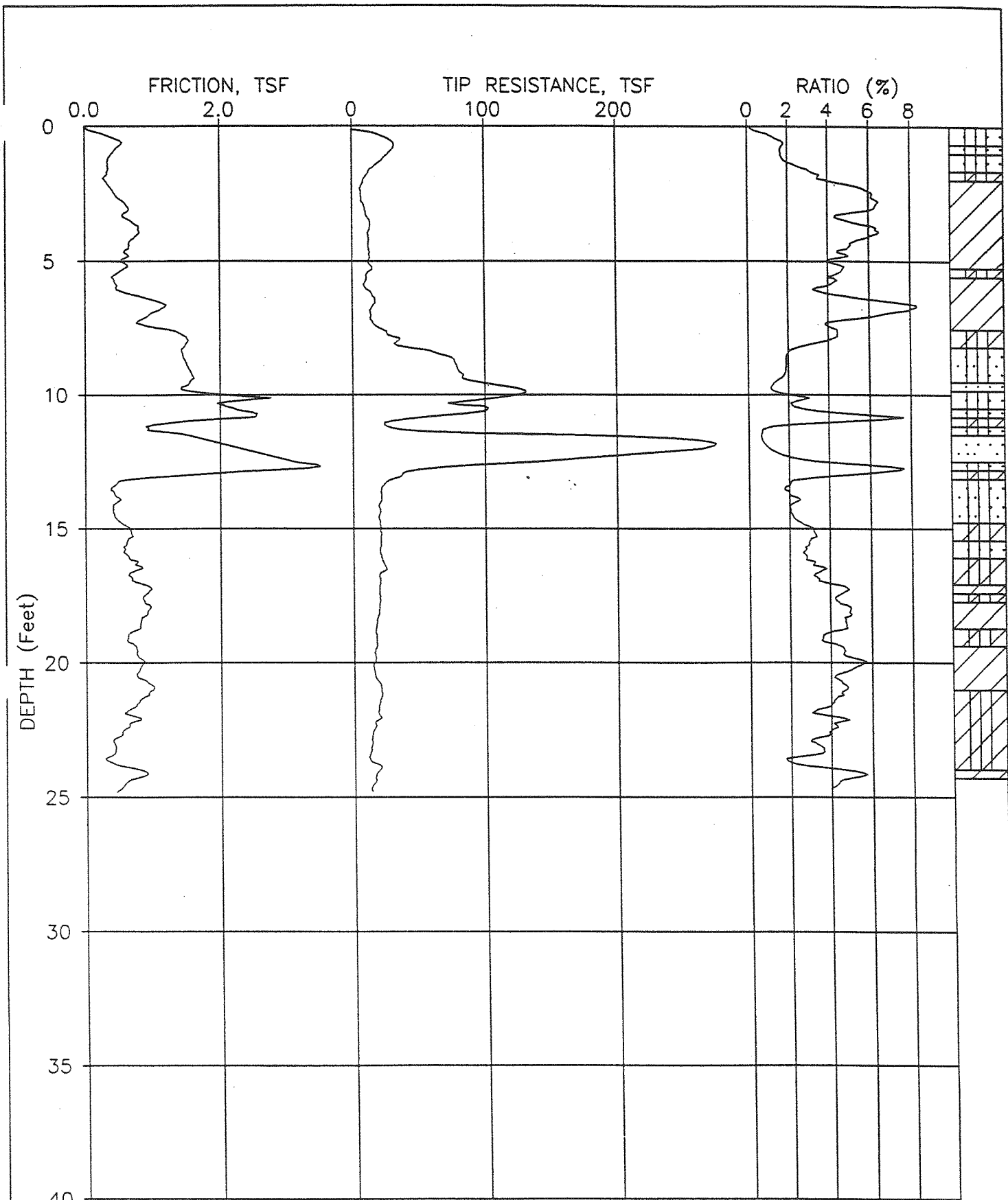




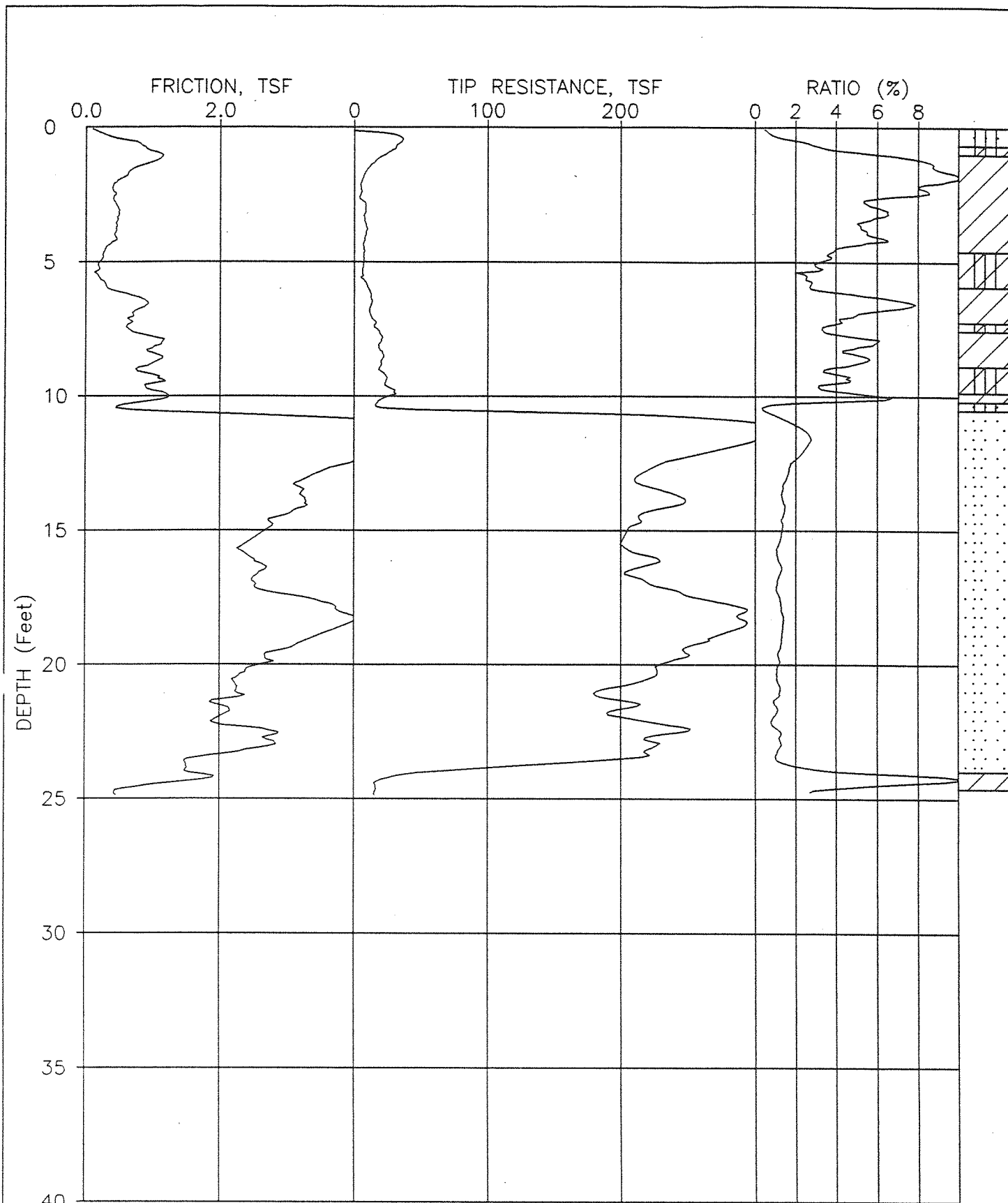
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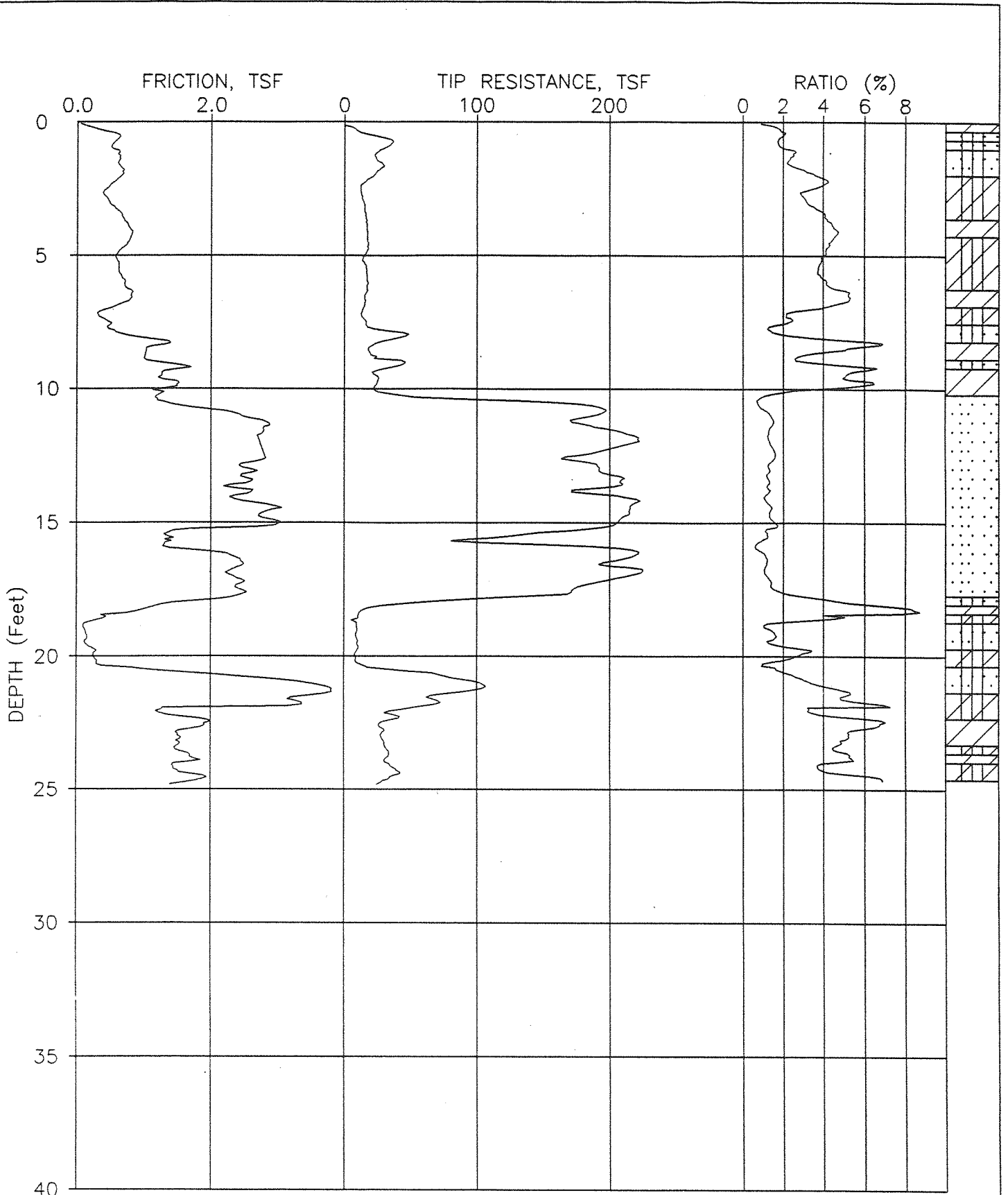
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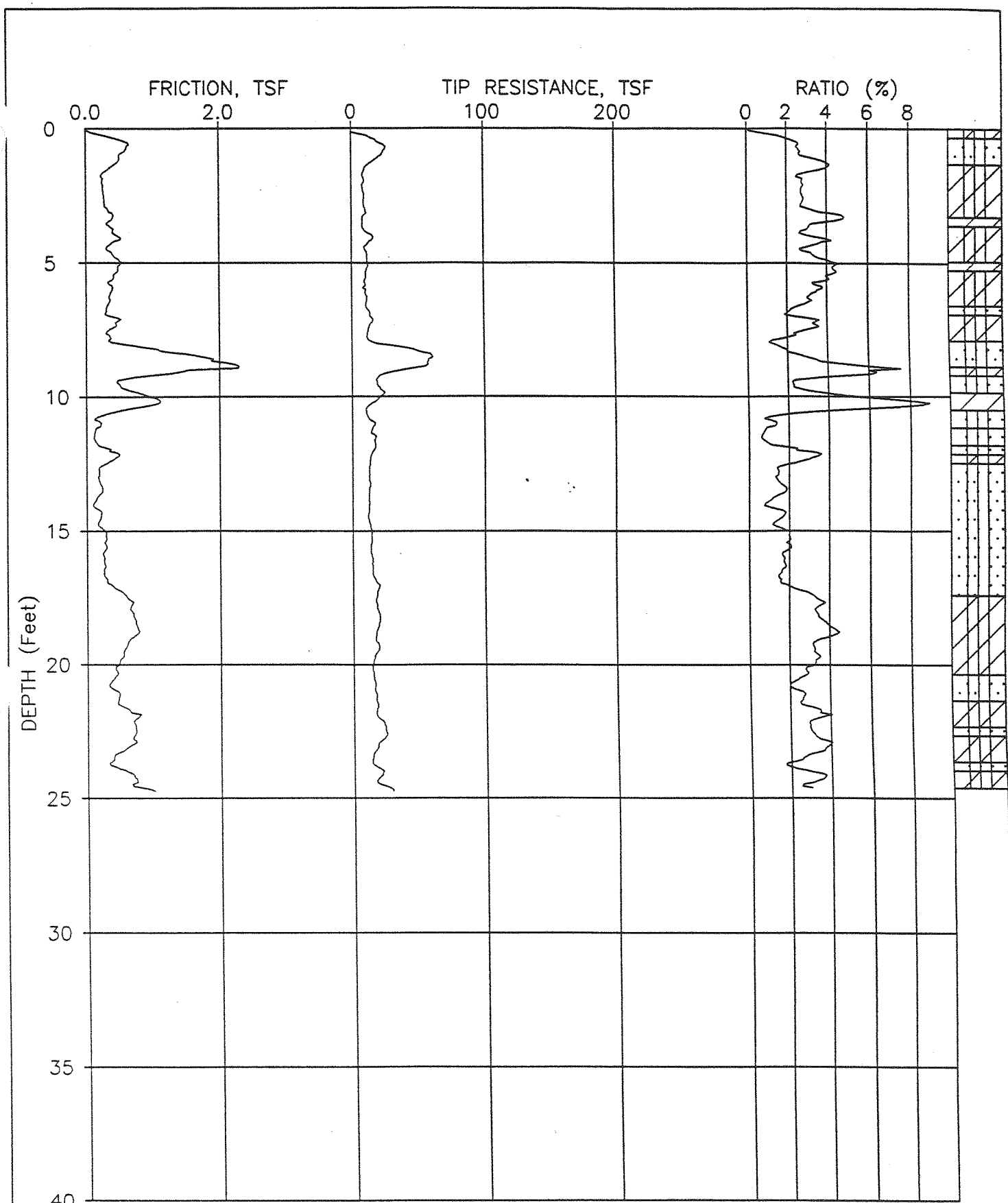
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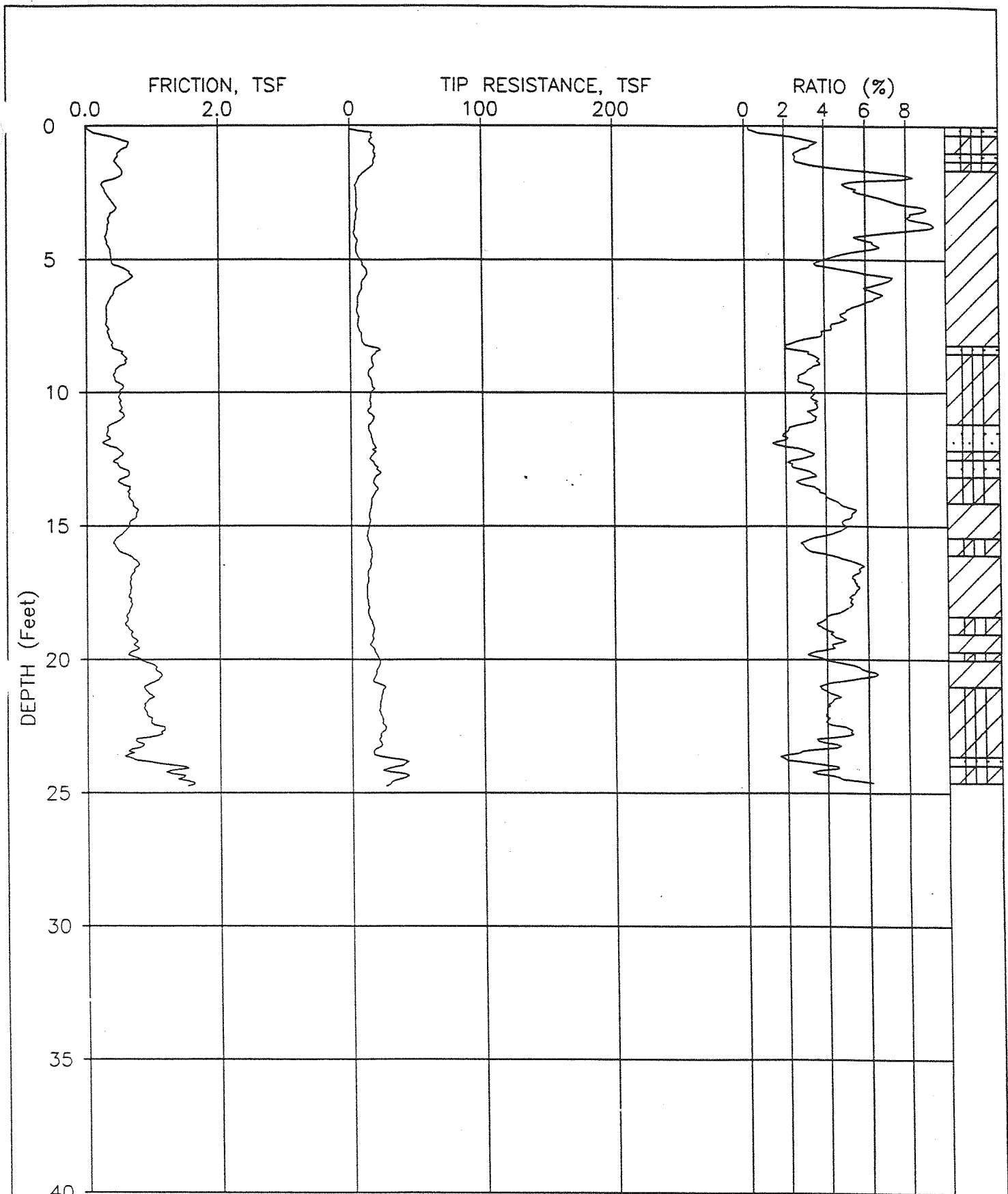
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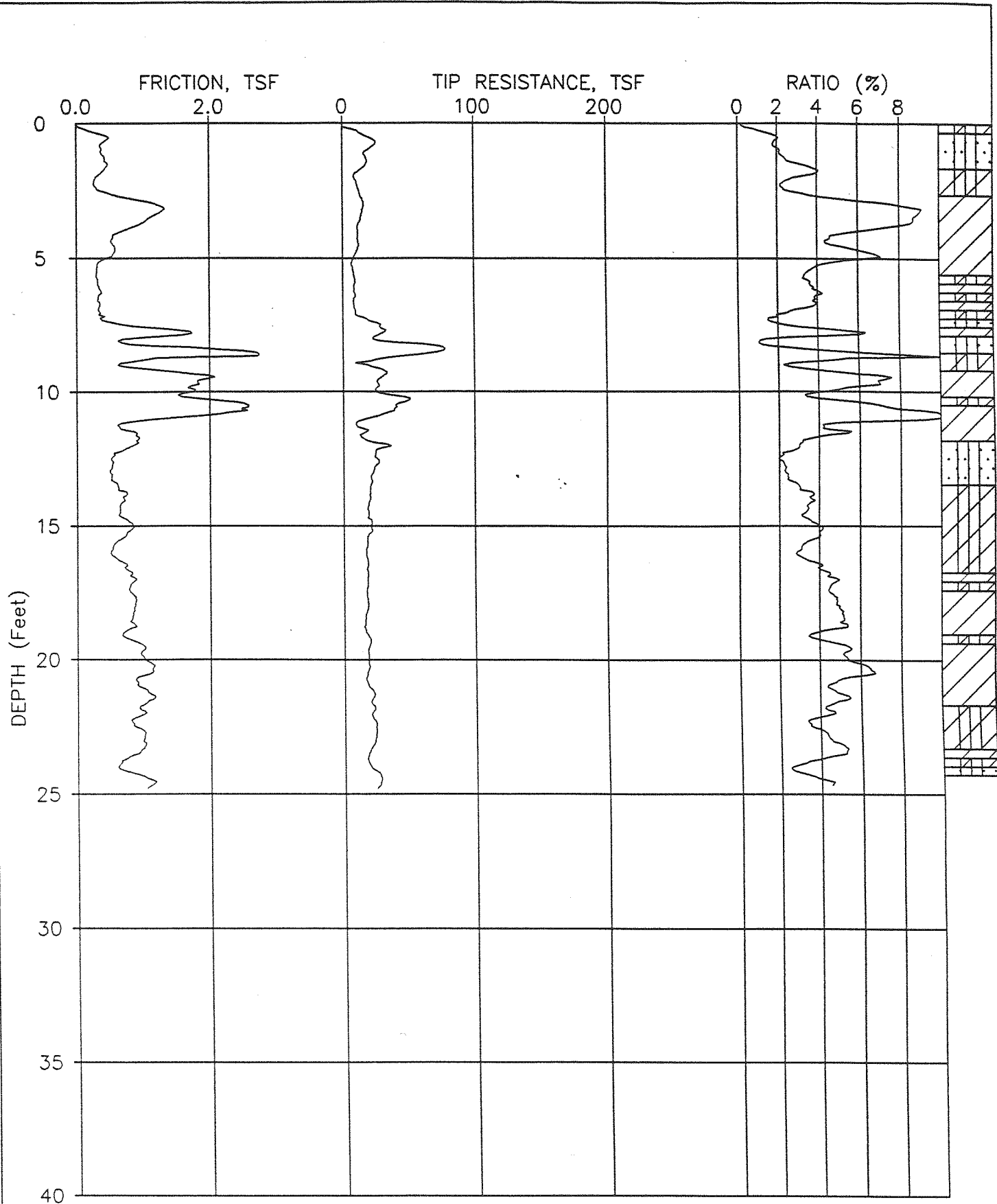
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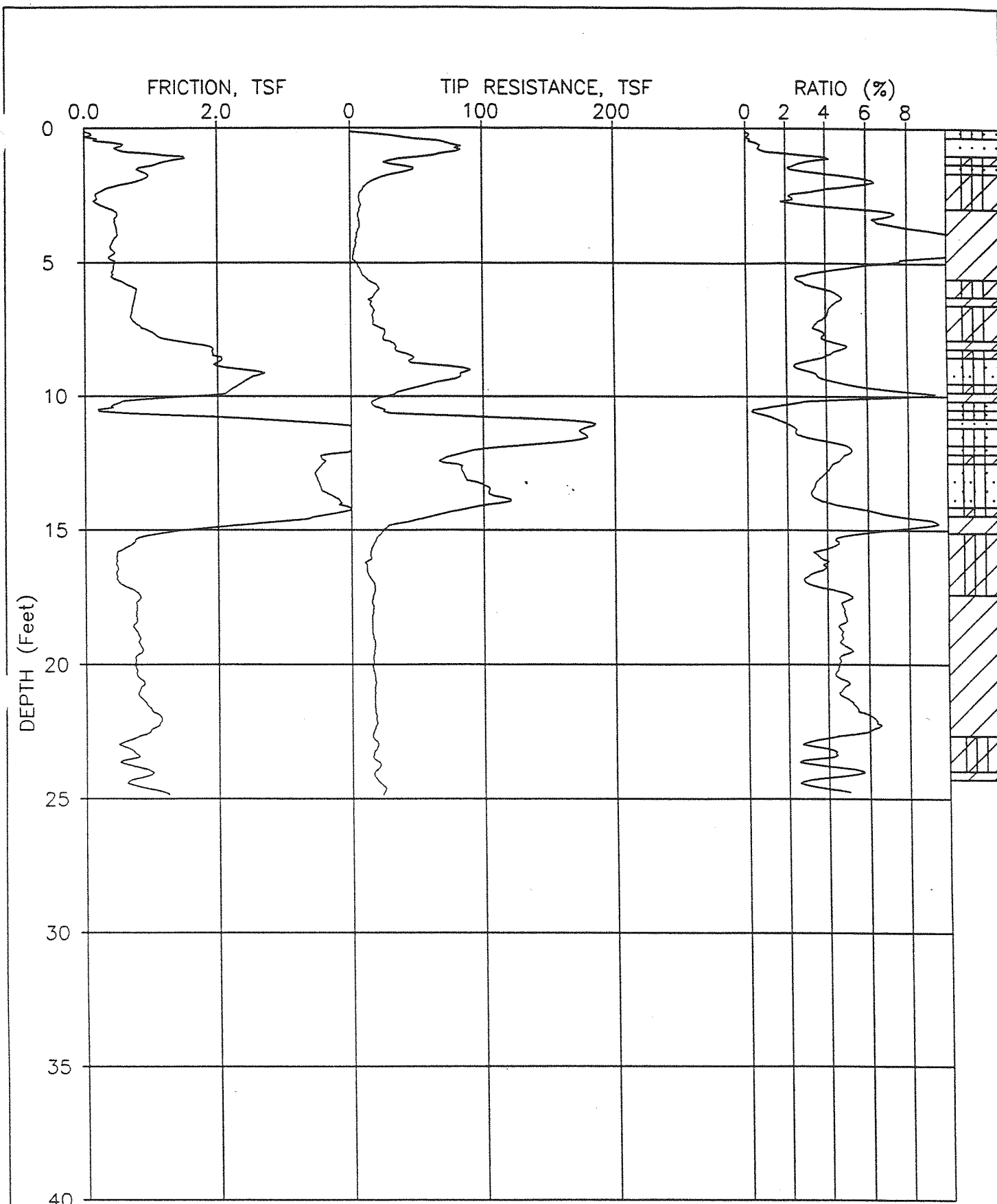
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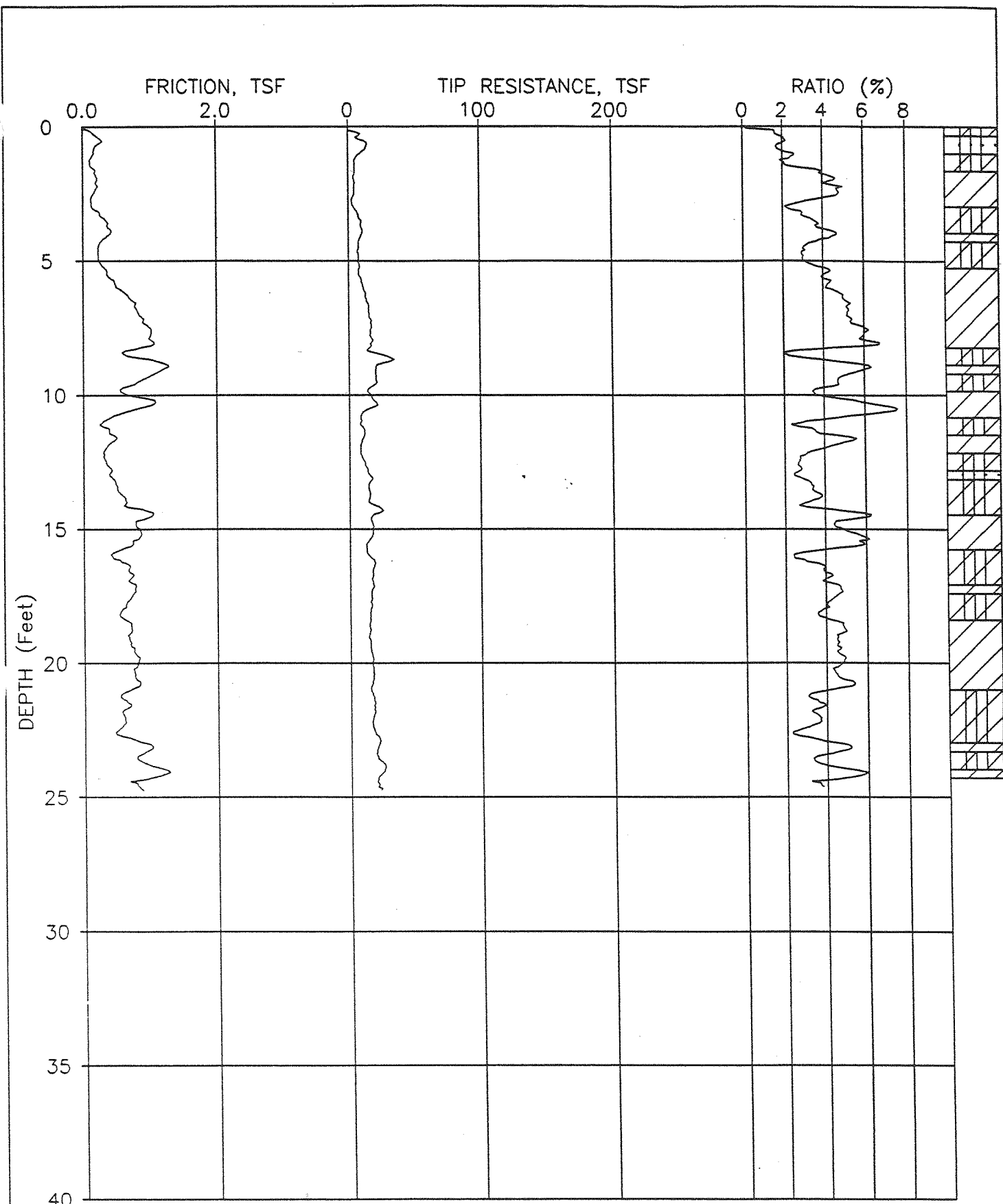
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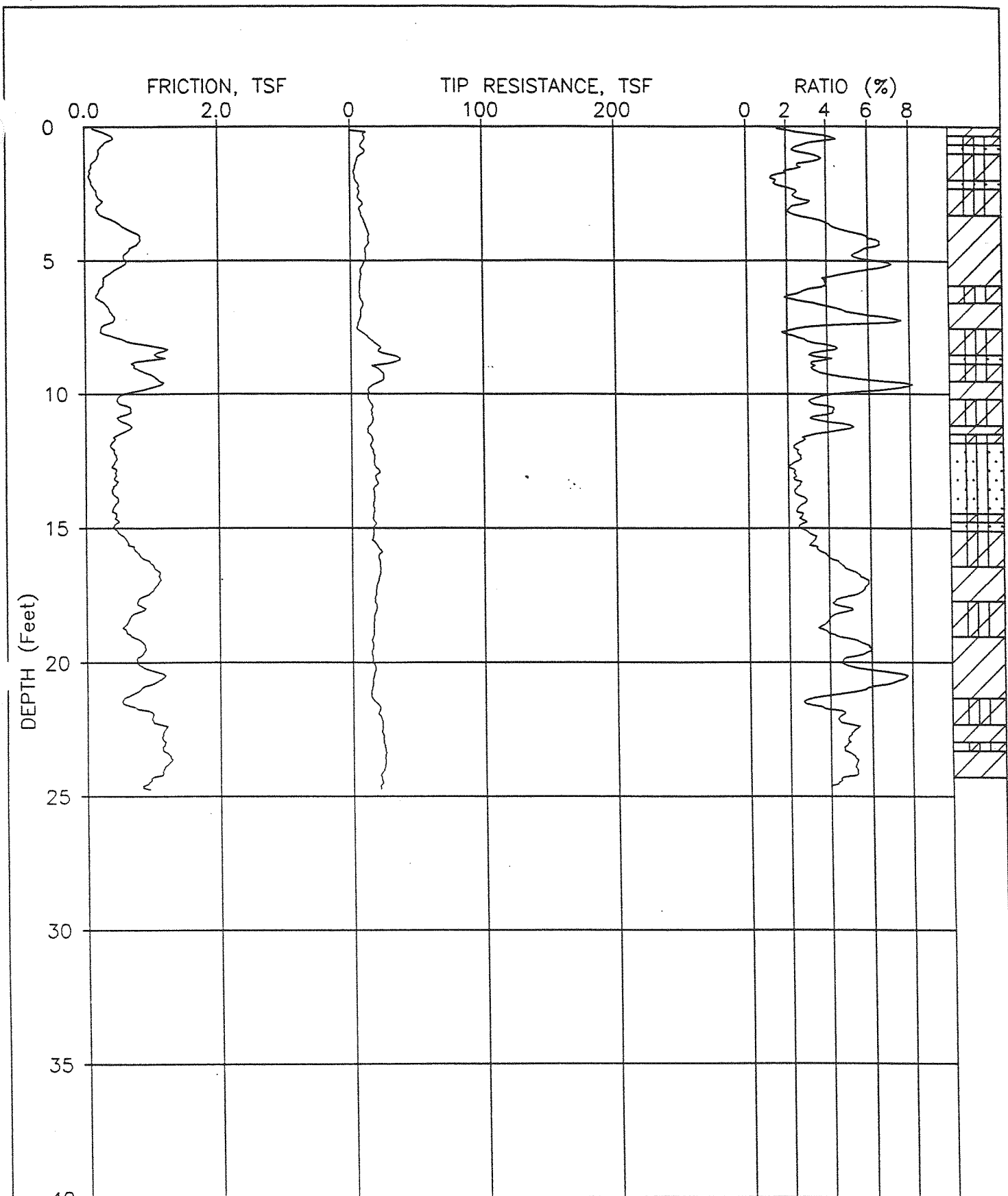
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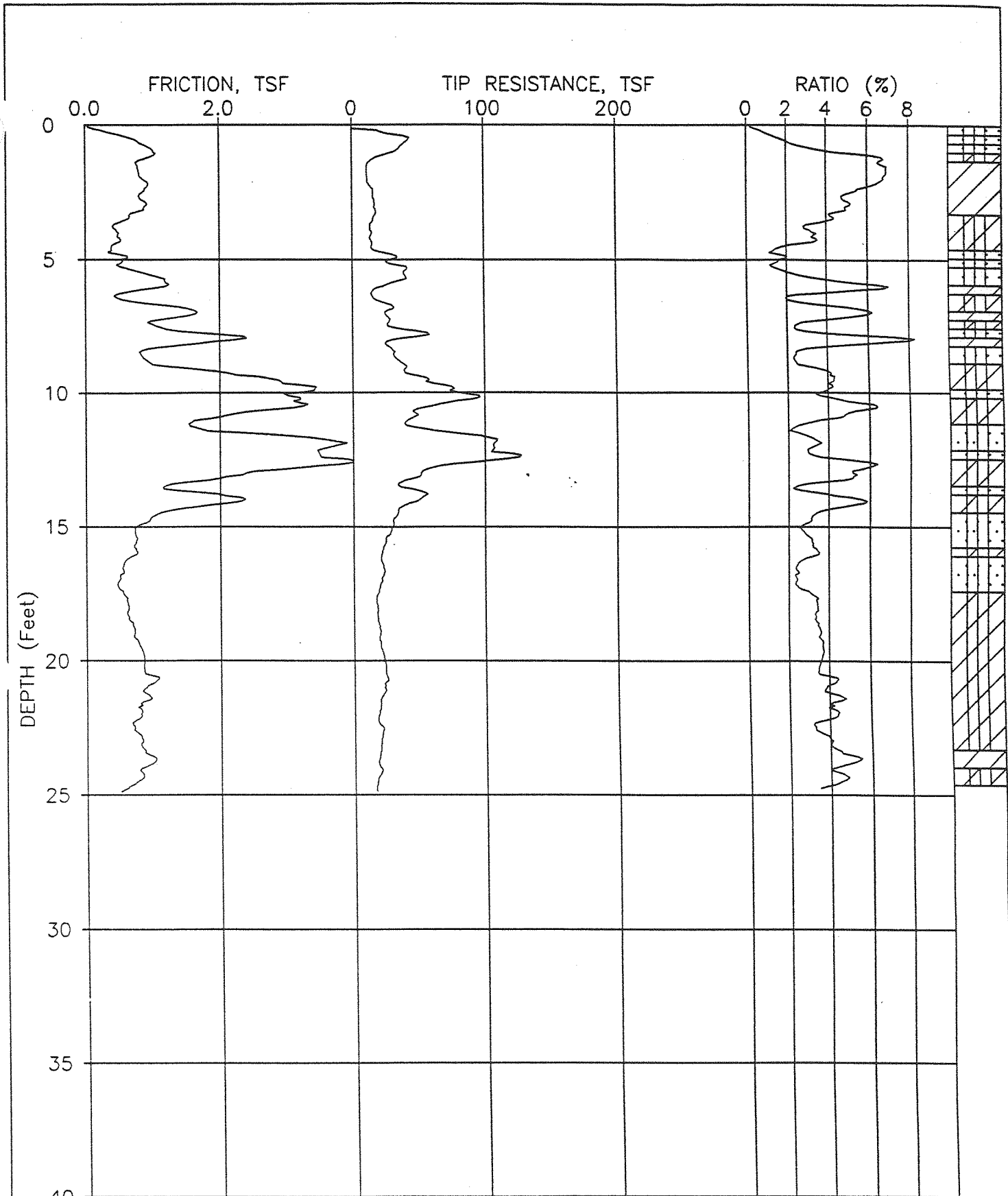
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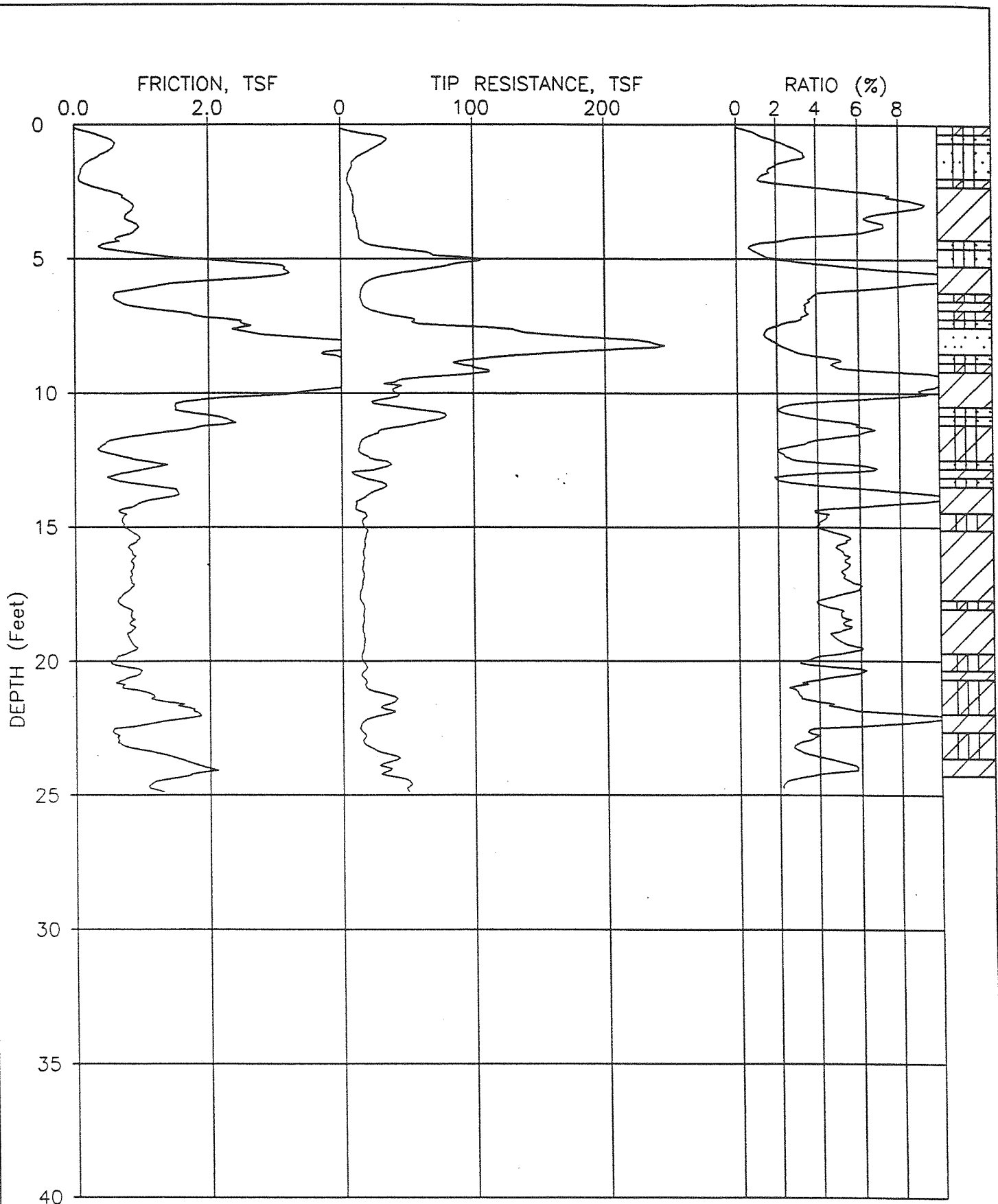
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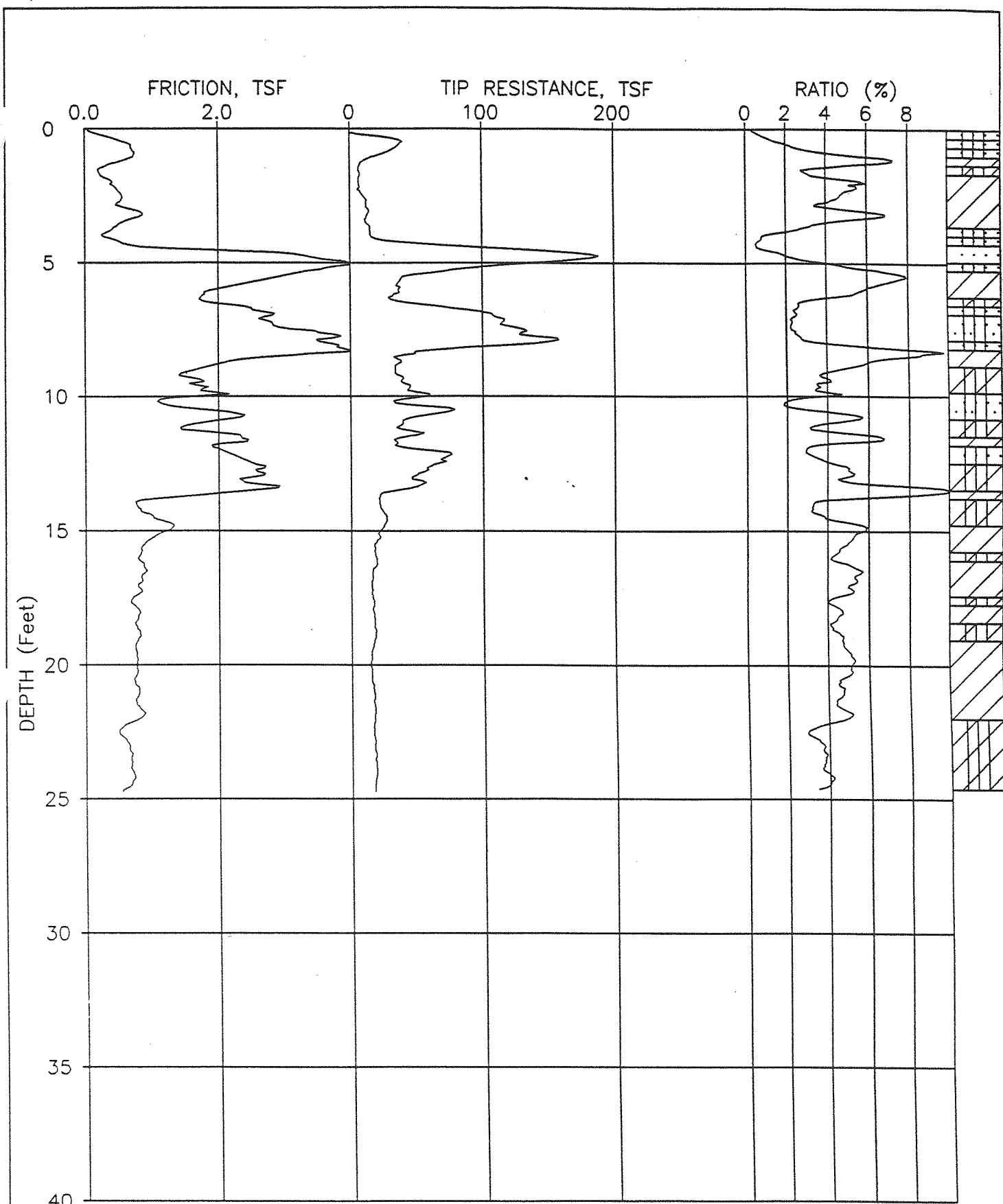
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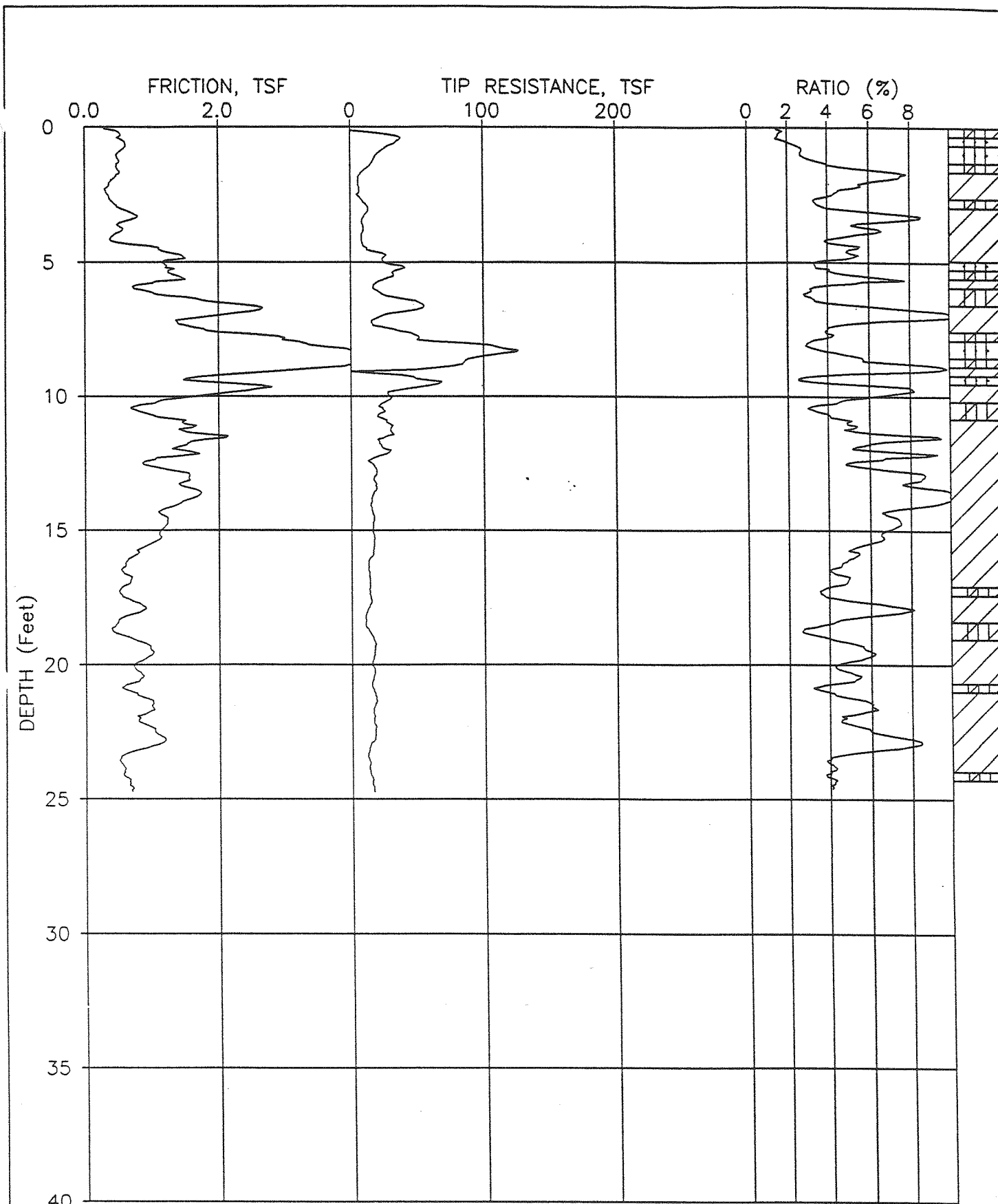
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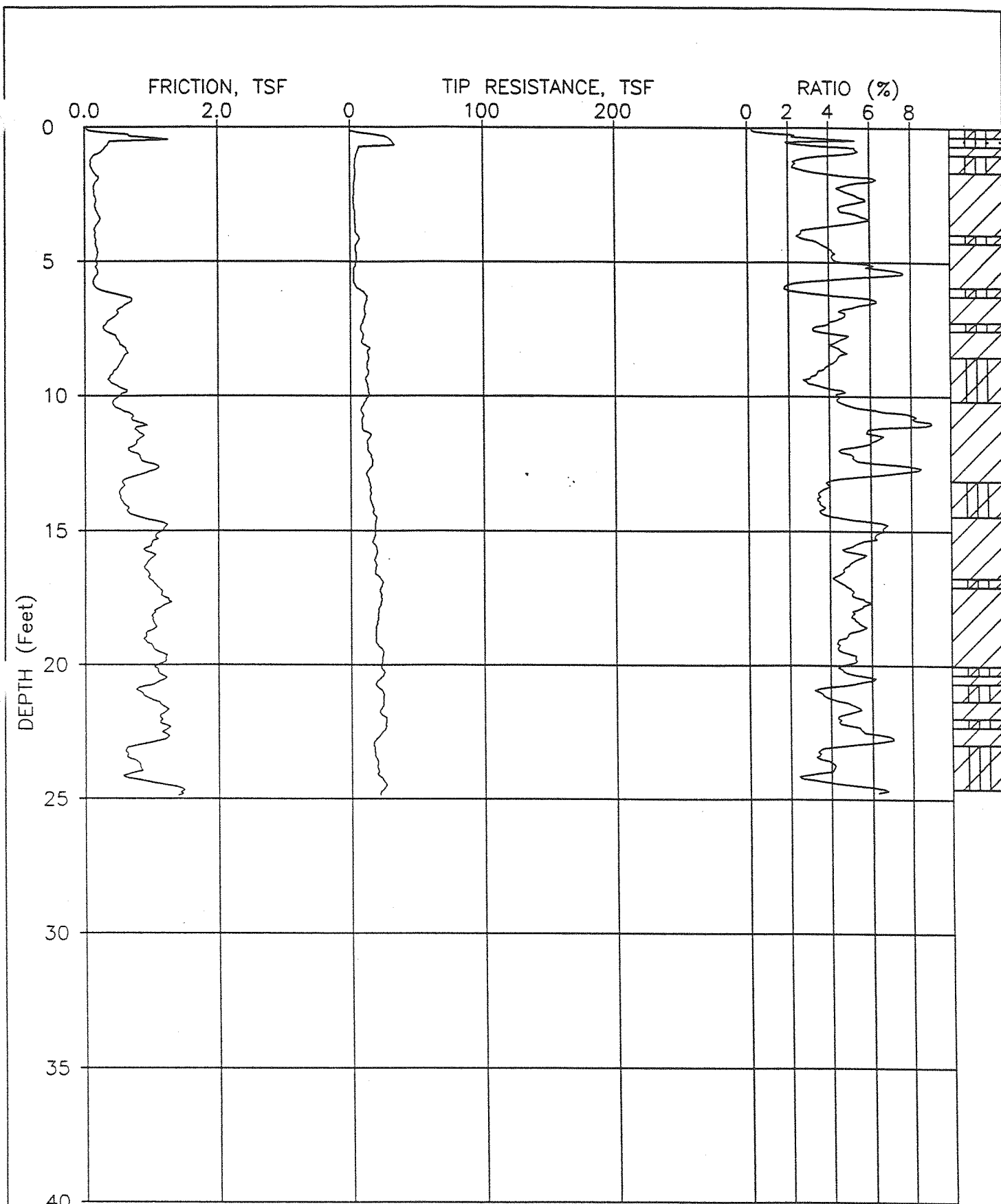
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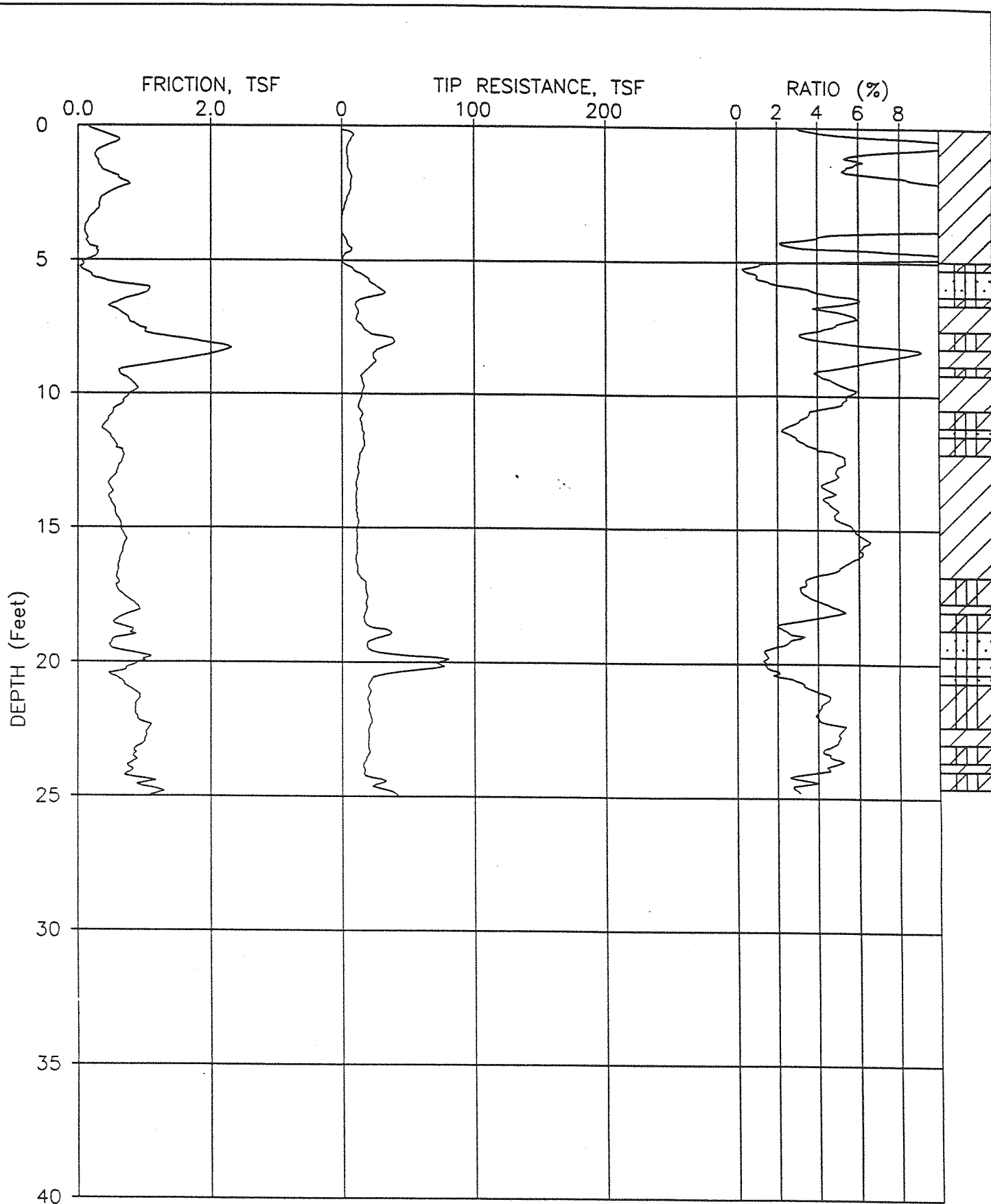
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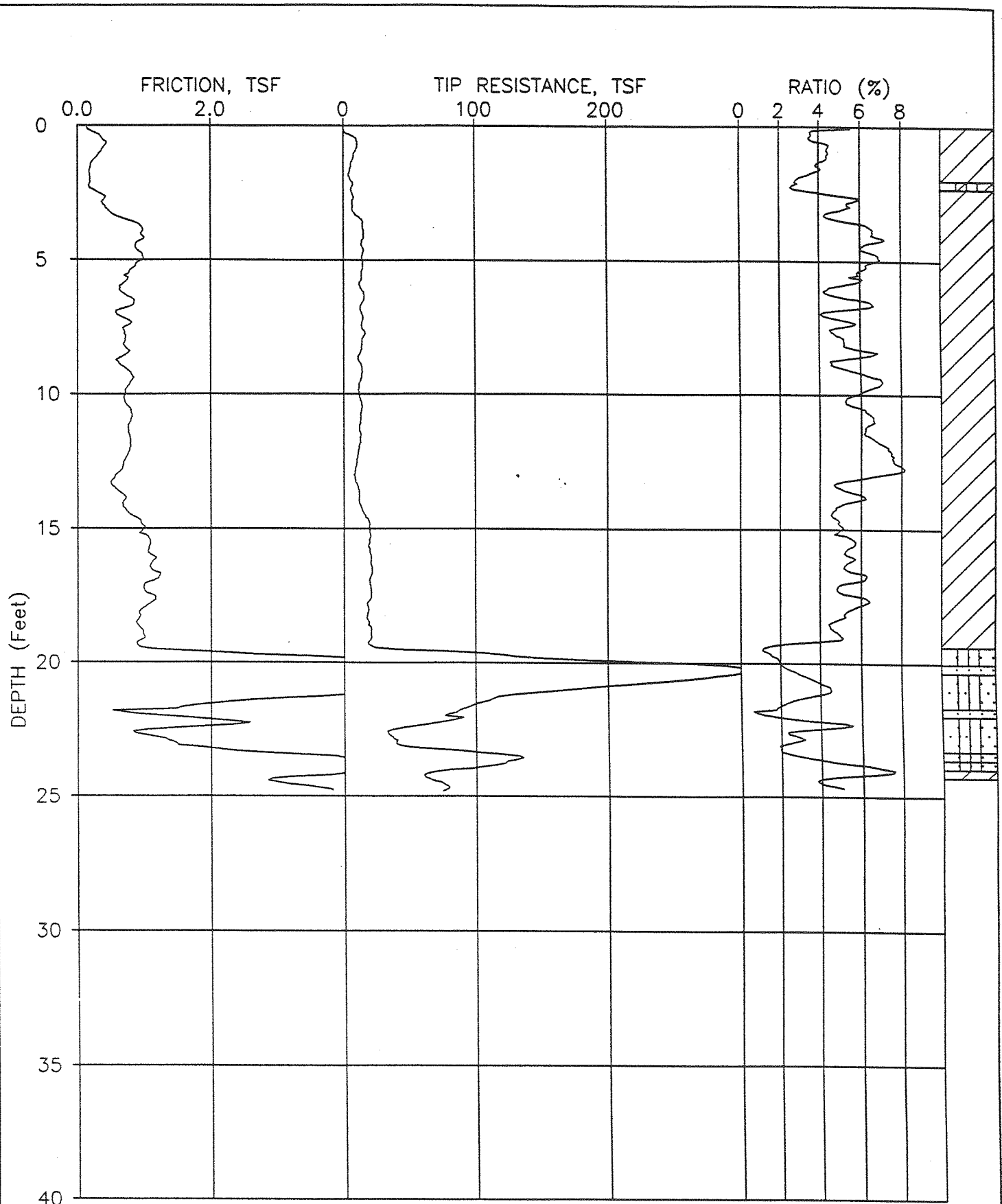
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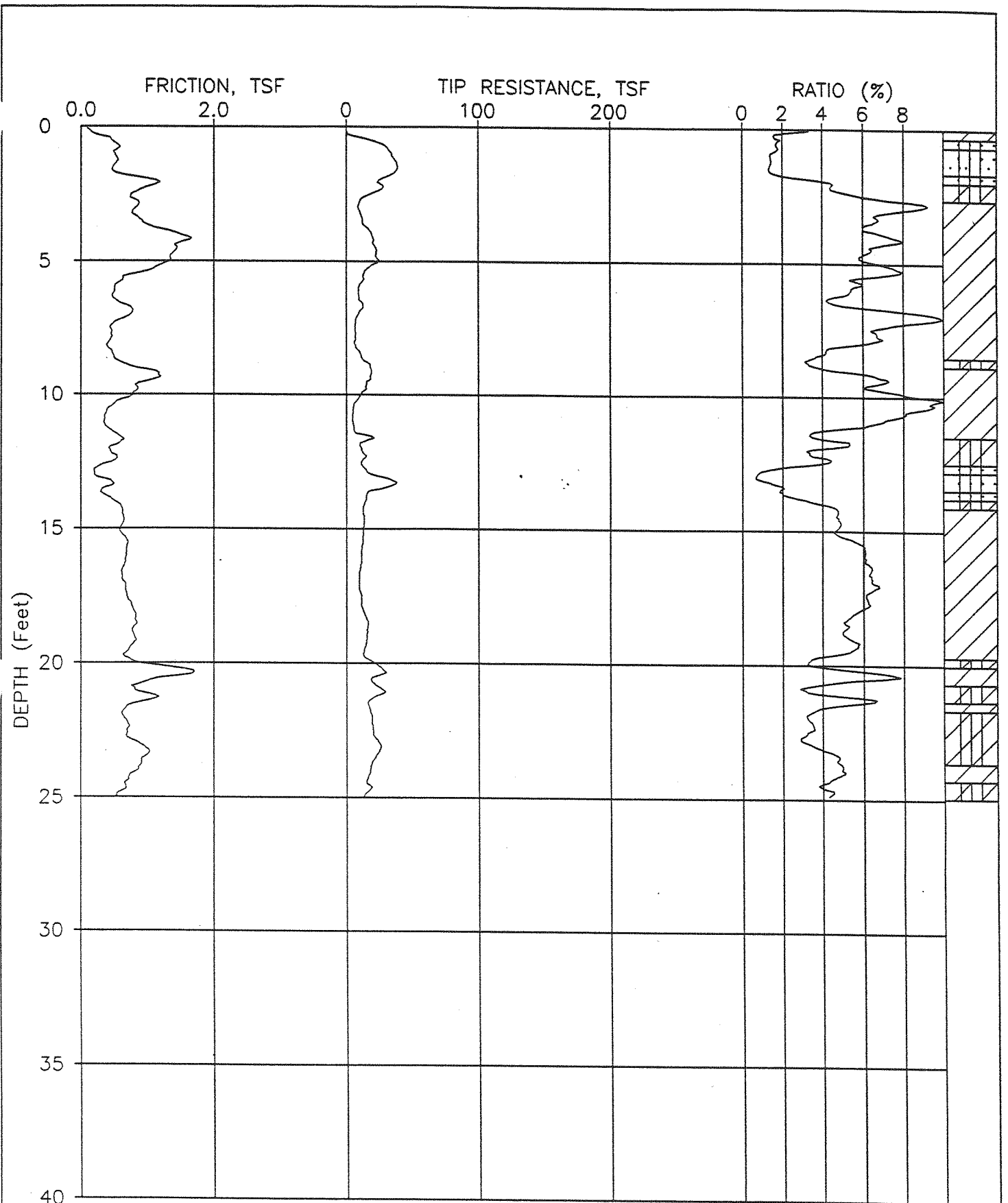
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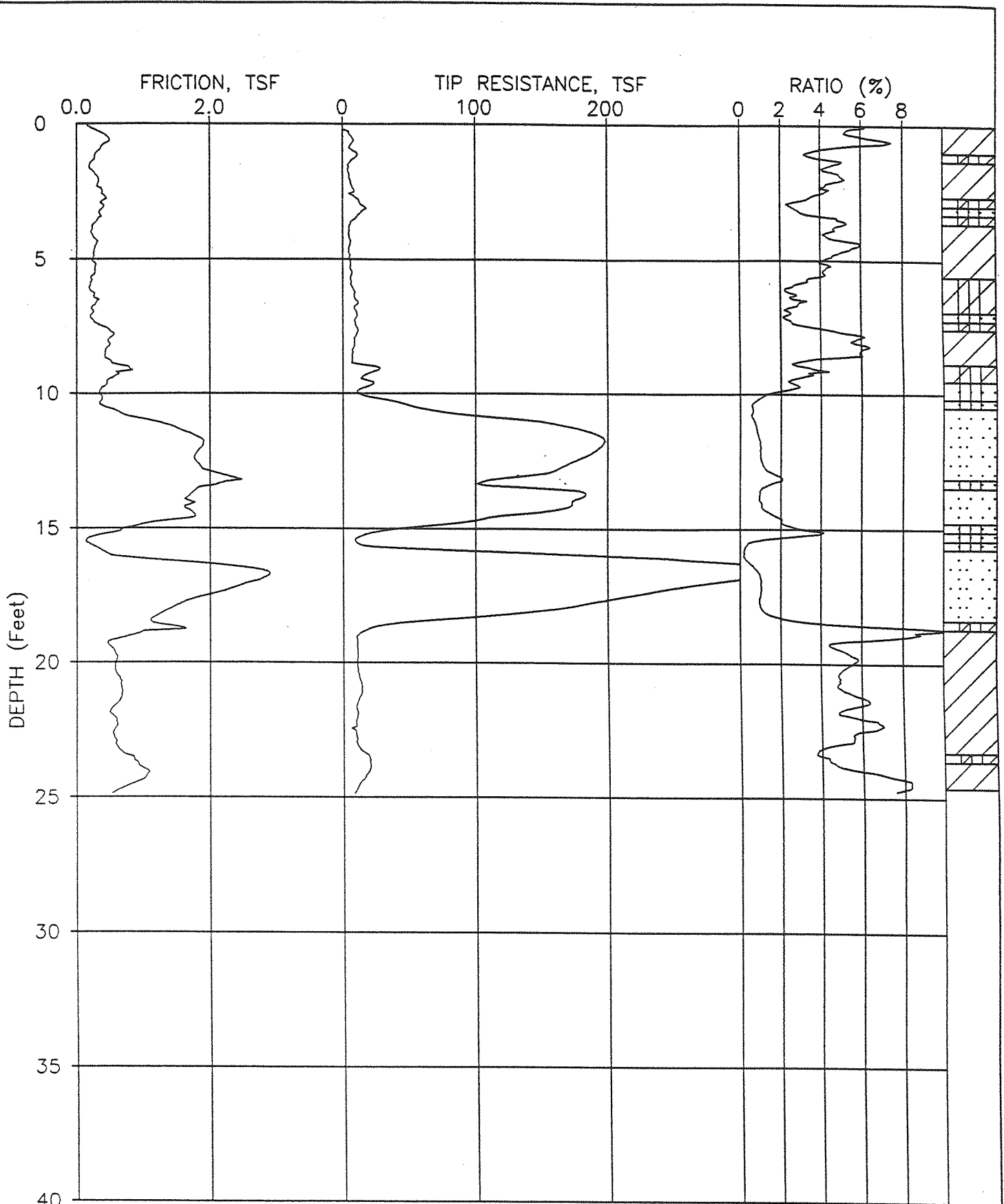
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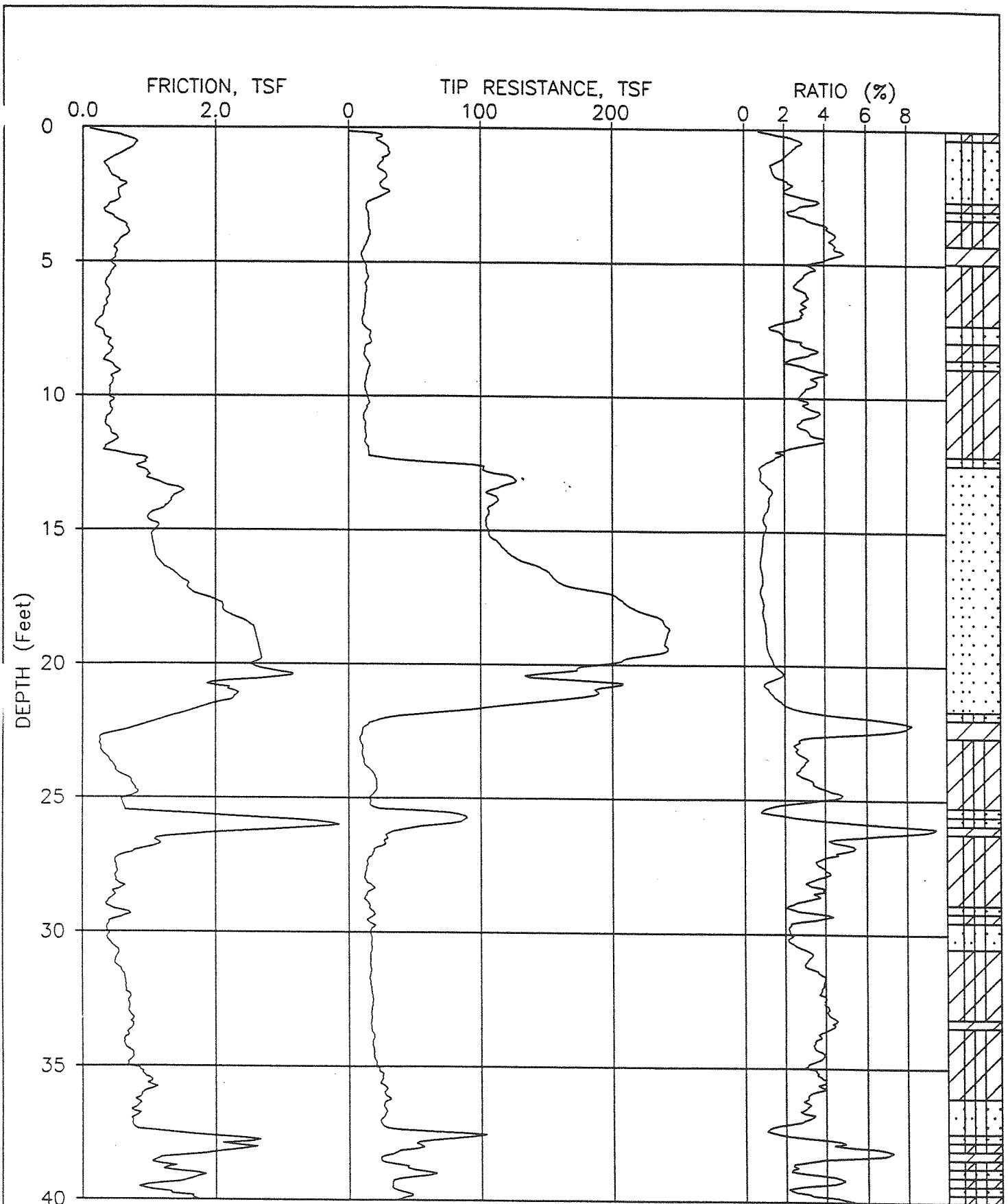
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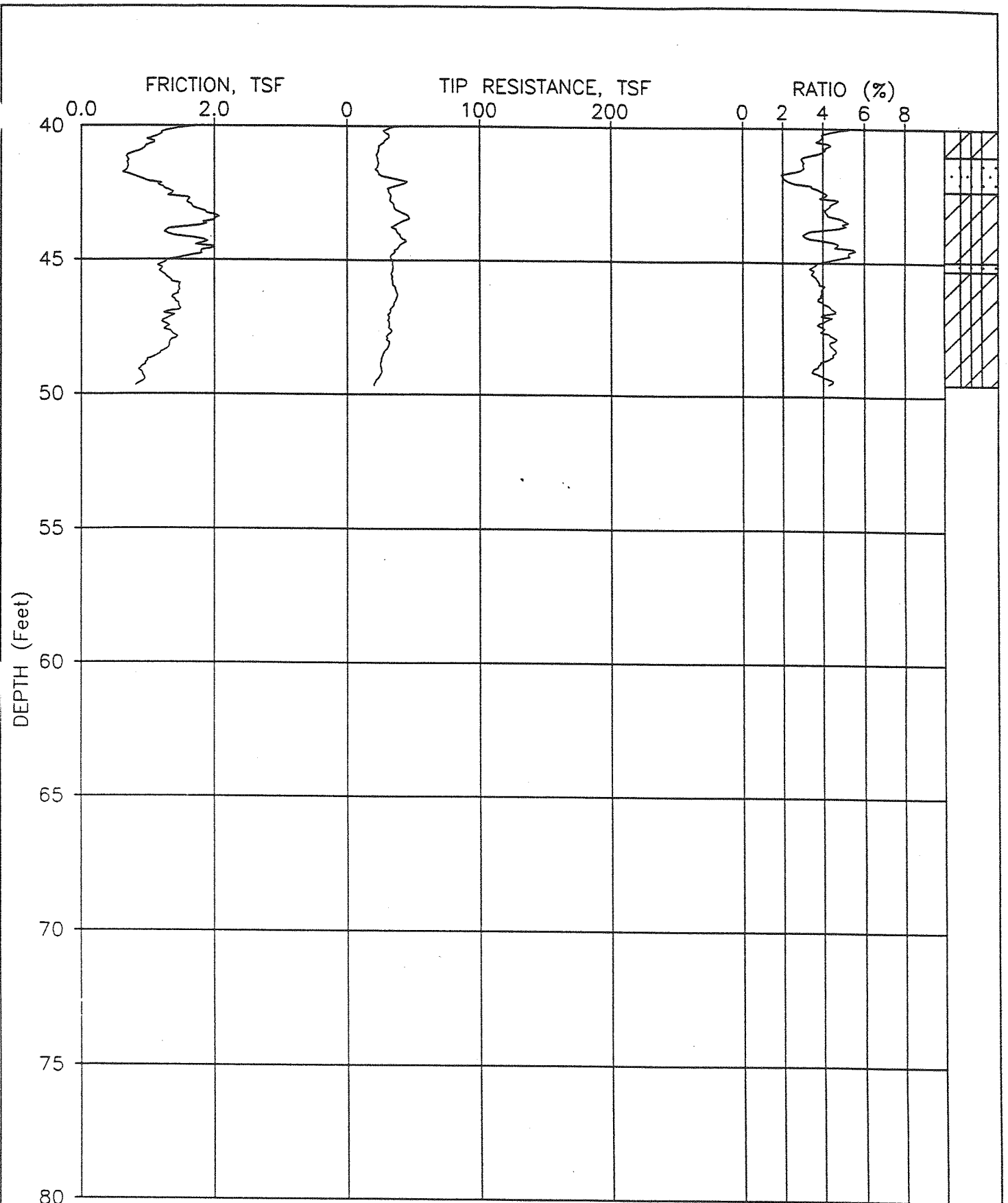
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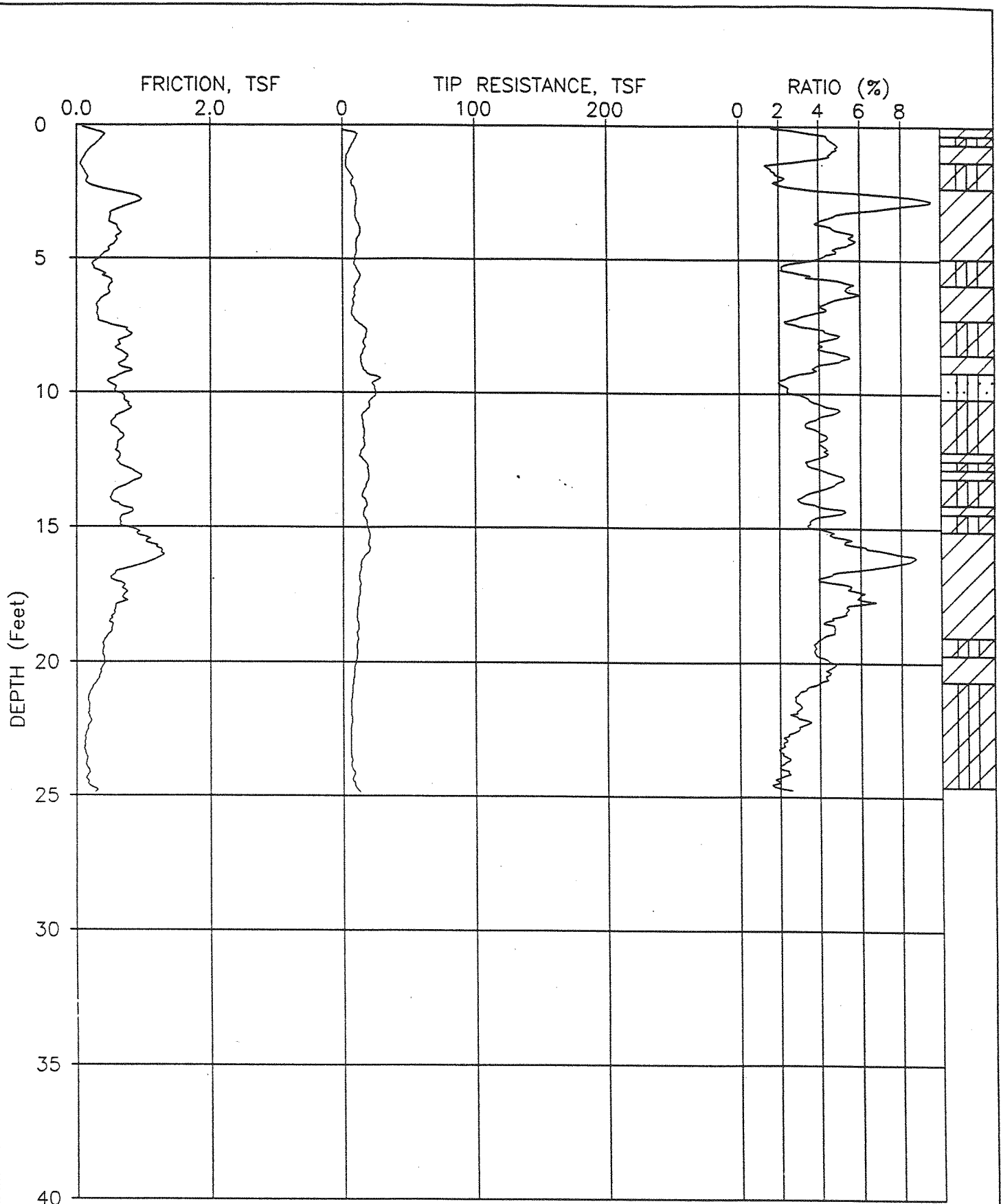
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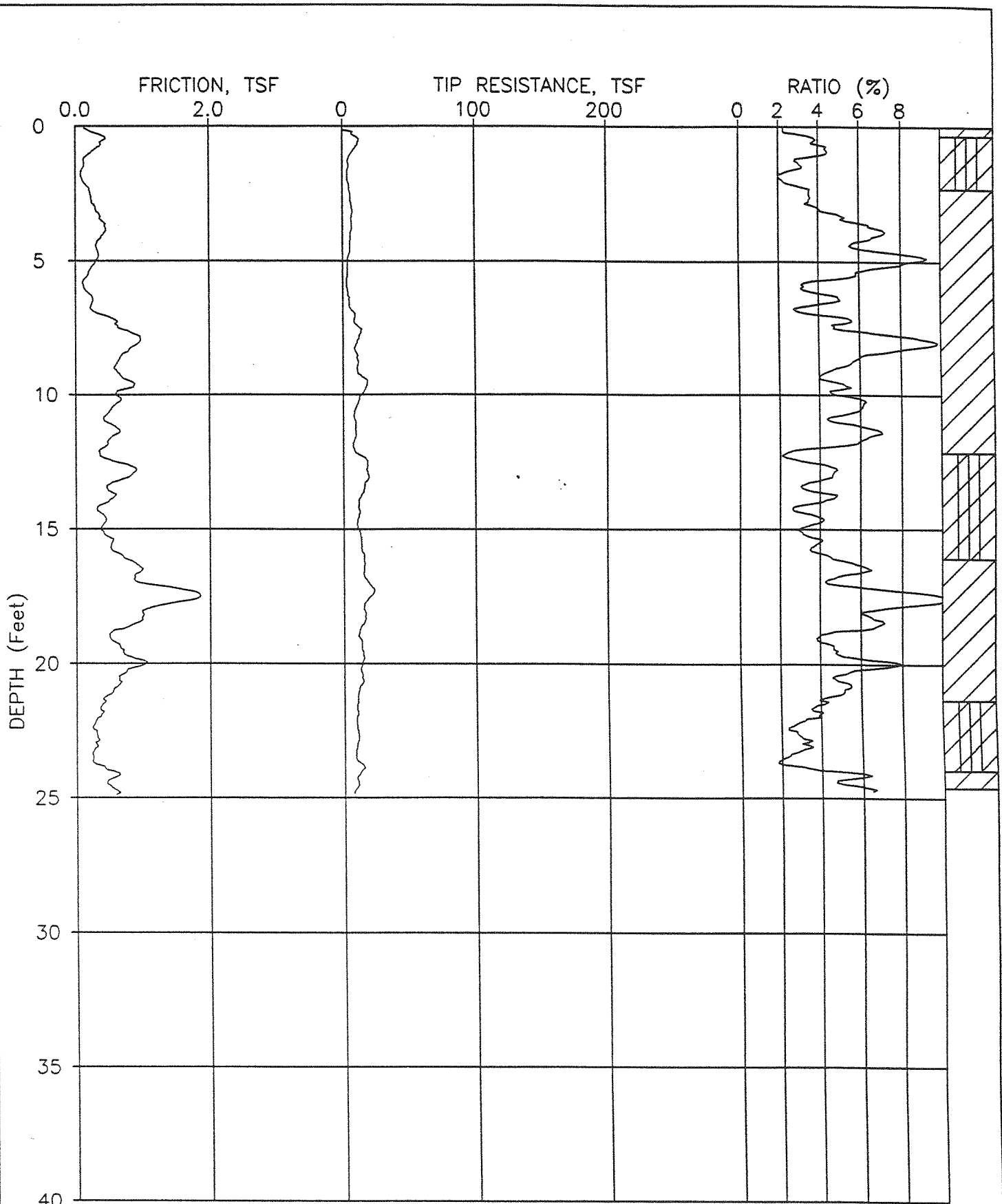
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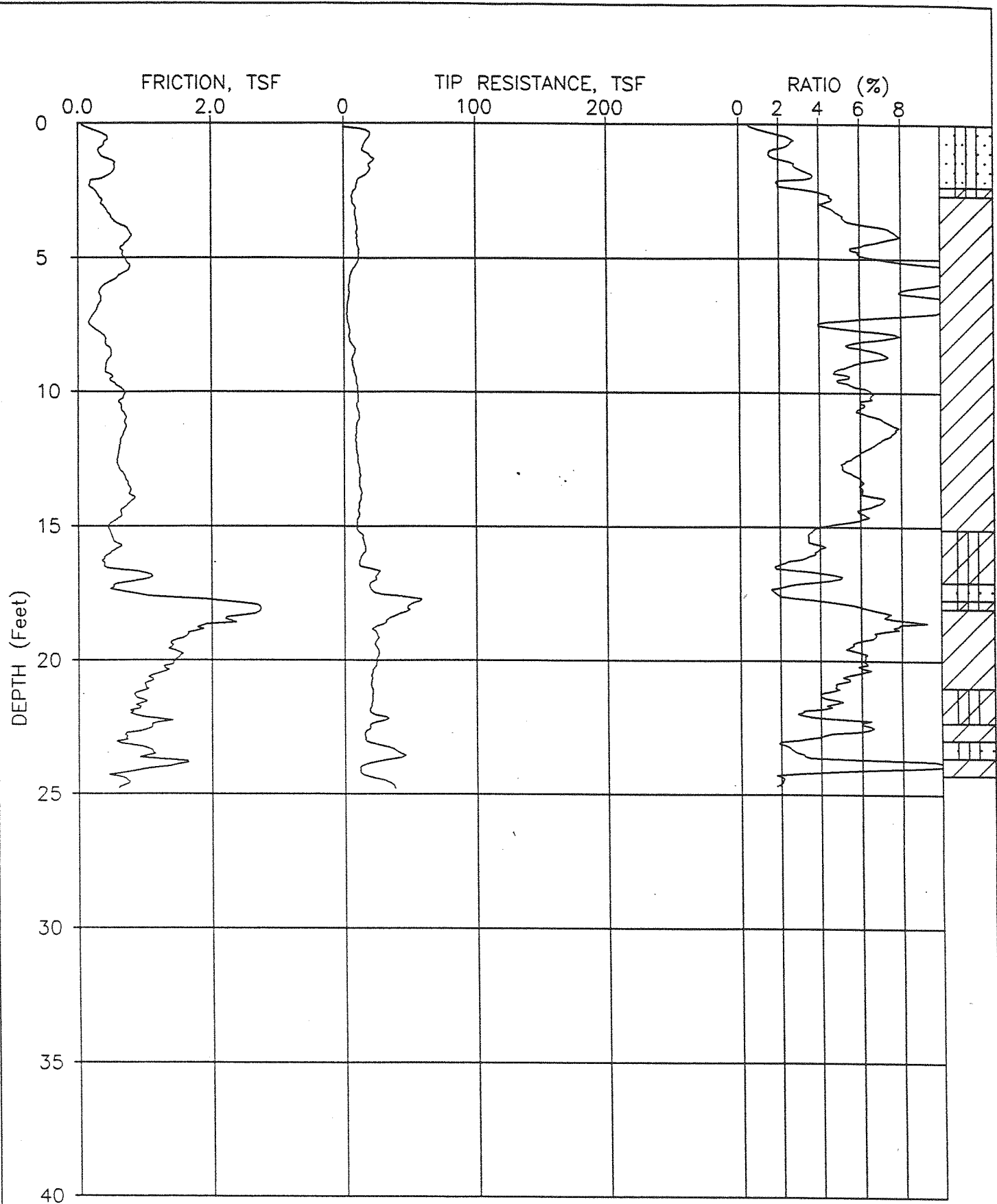
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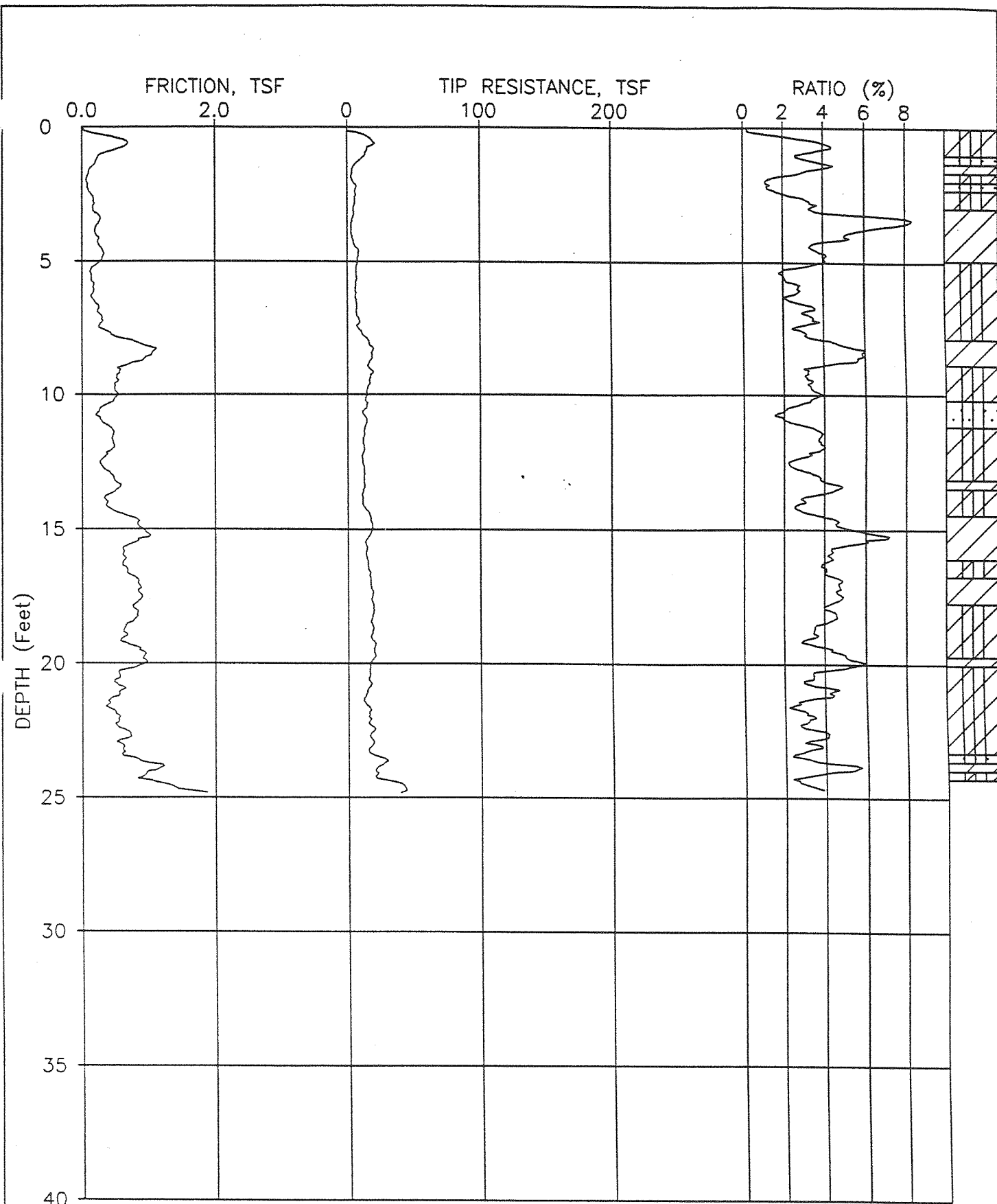
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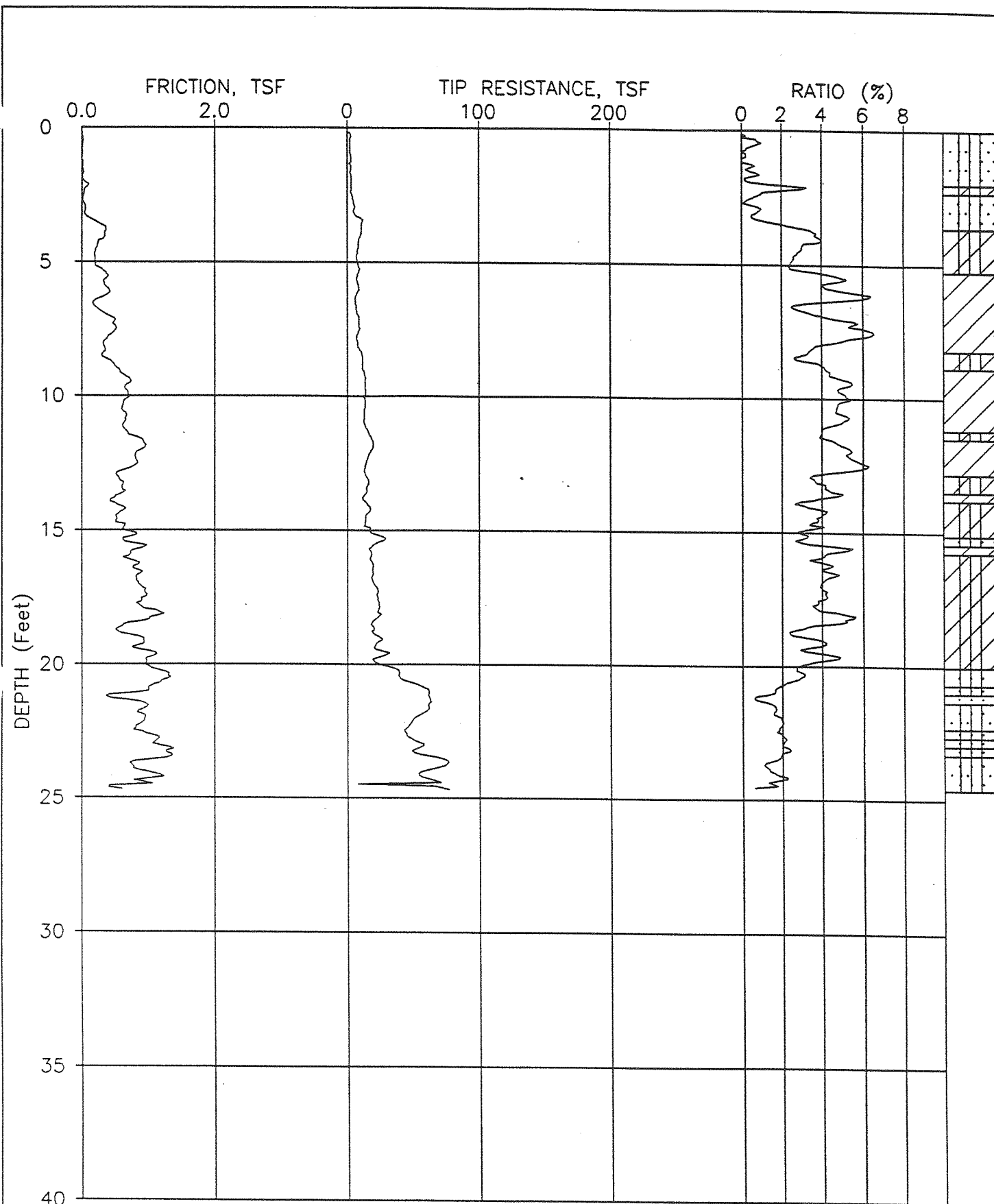
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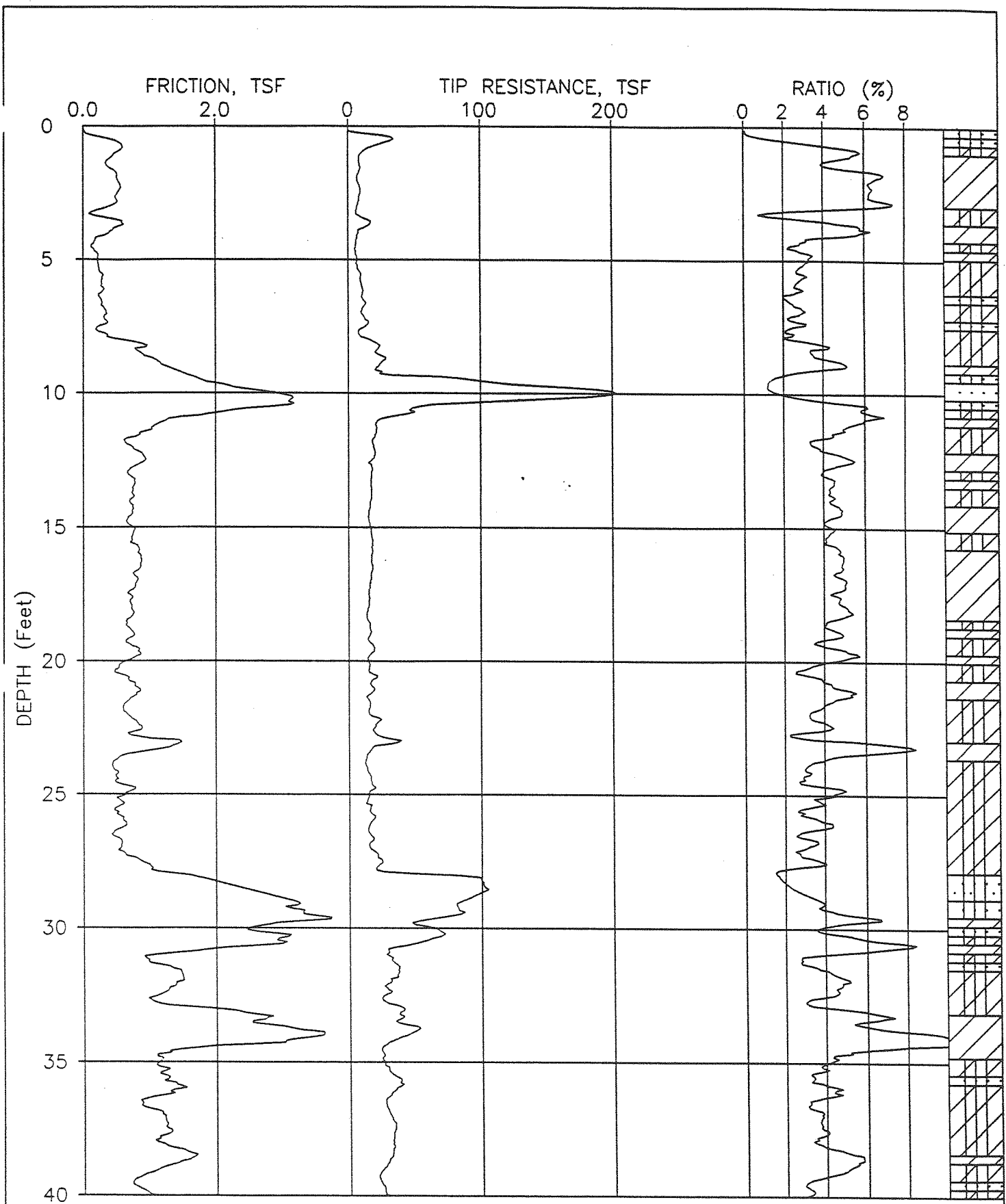
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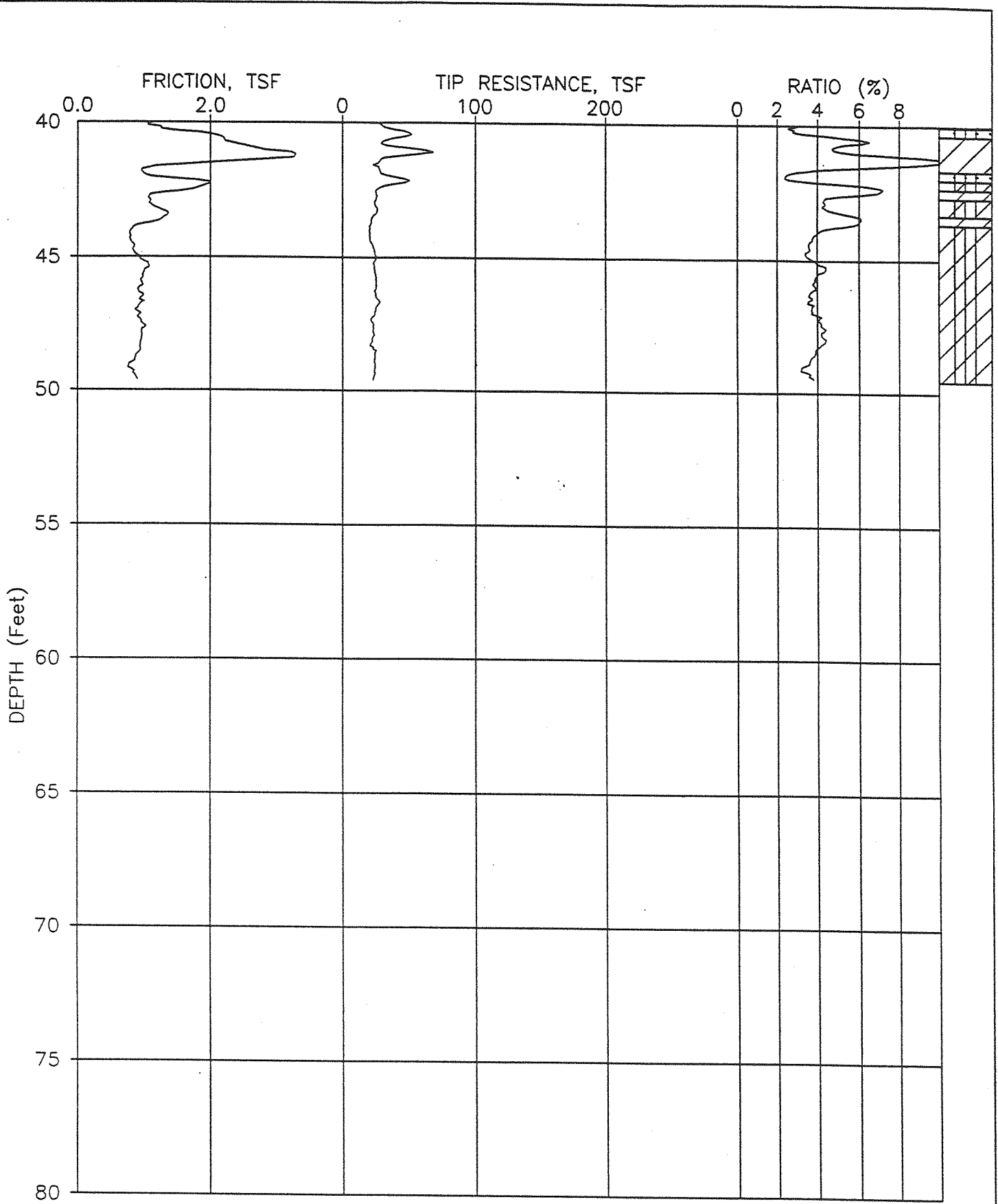
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 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV091 PLATE: 1 OF 1



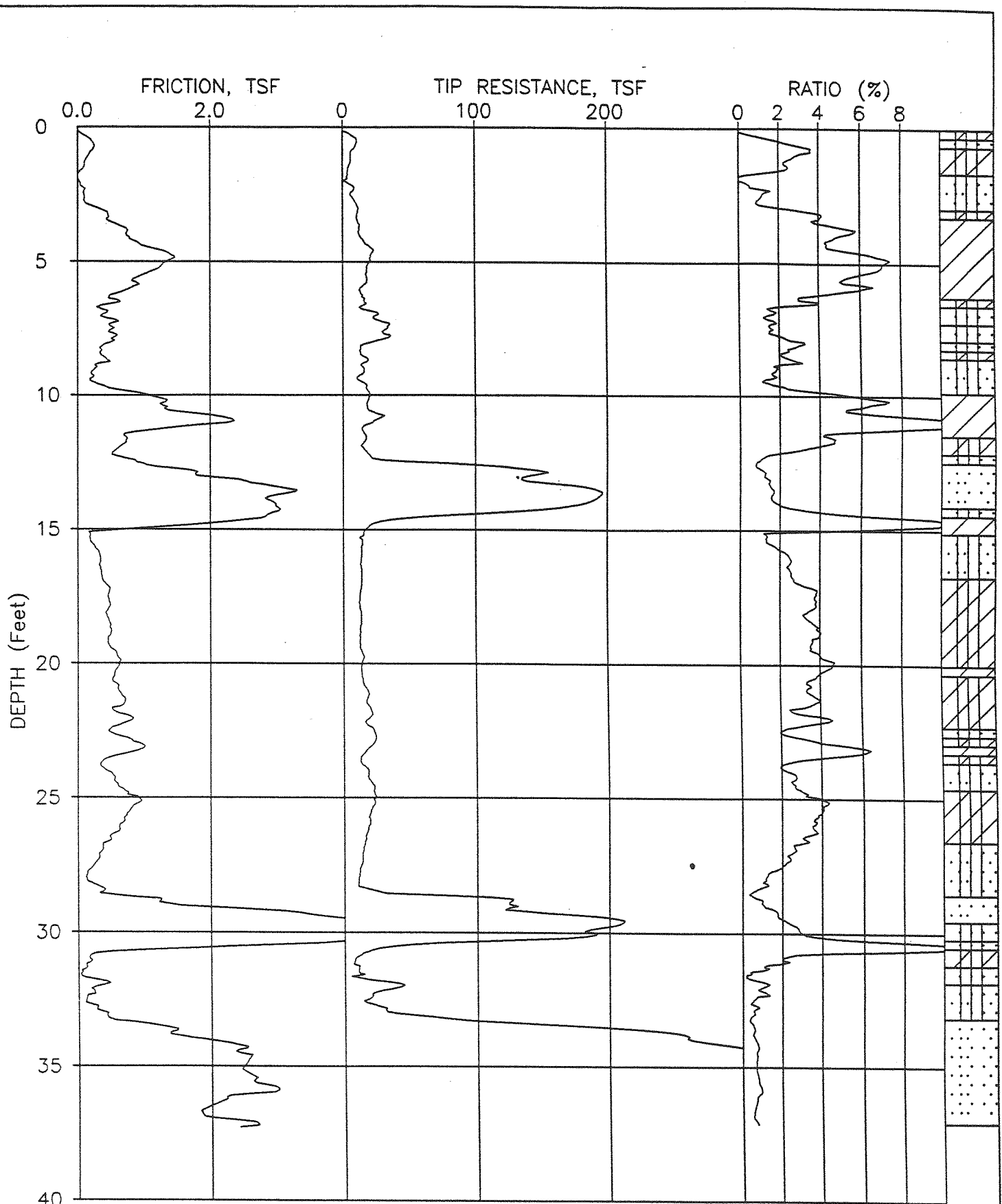
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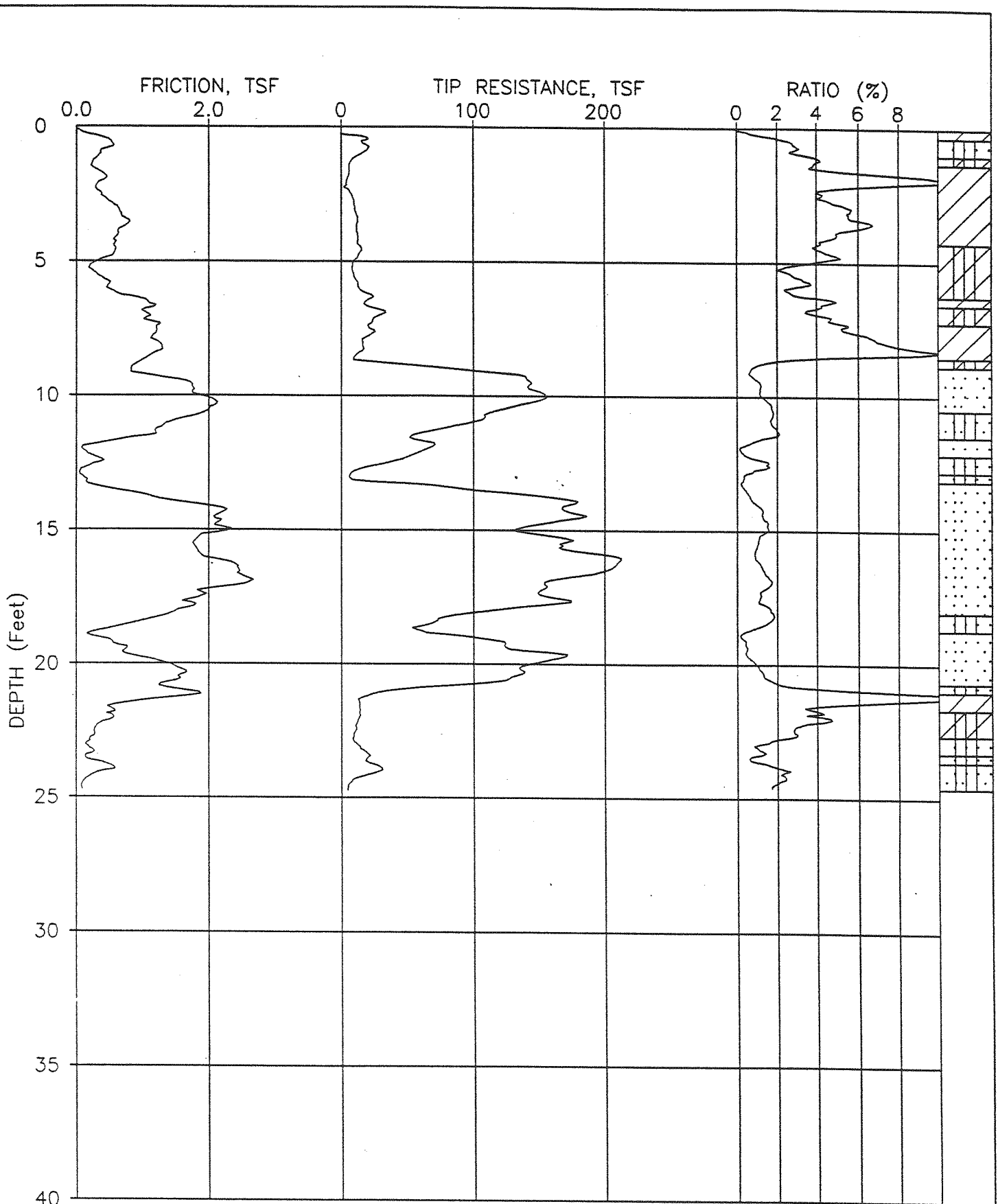
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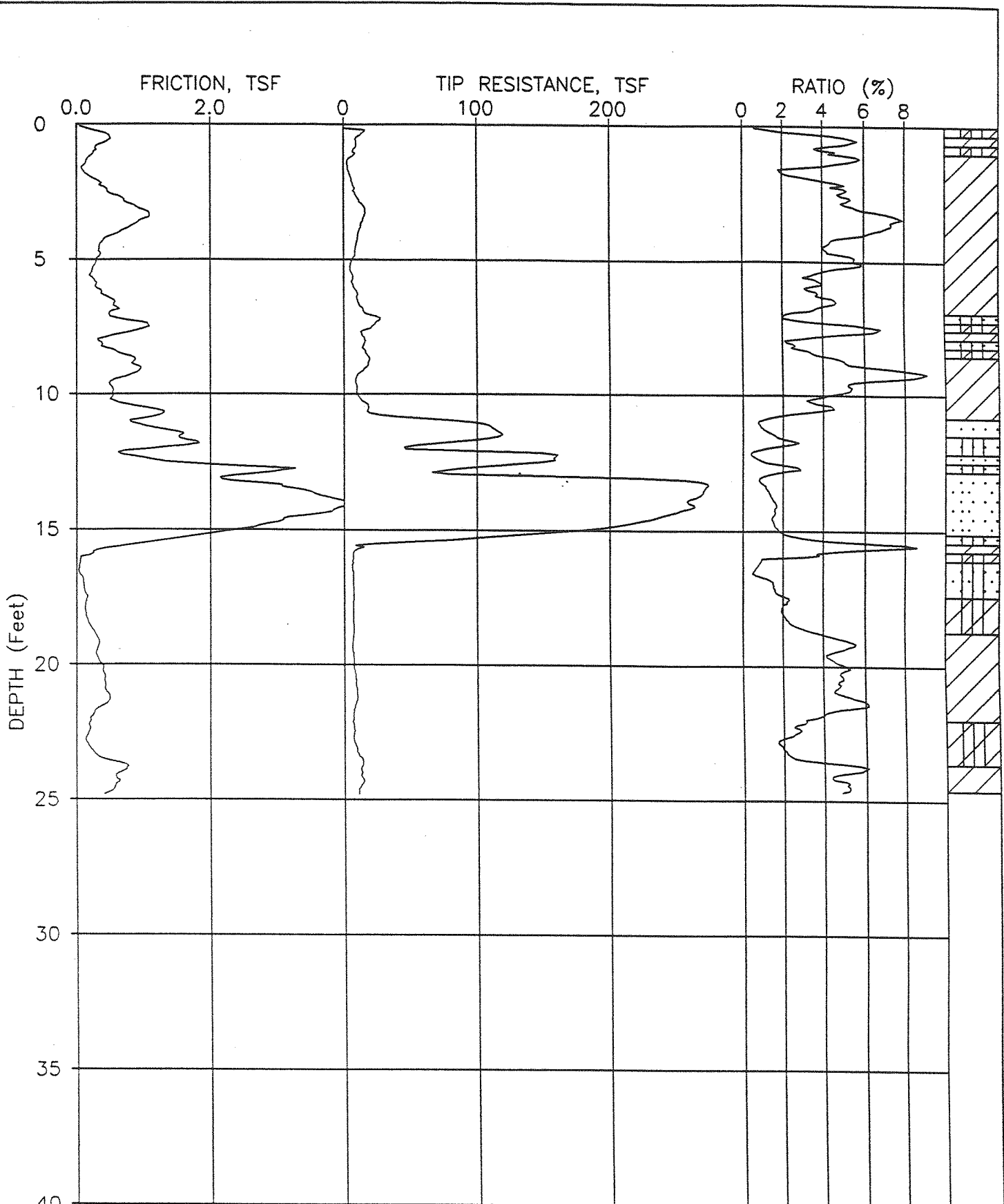
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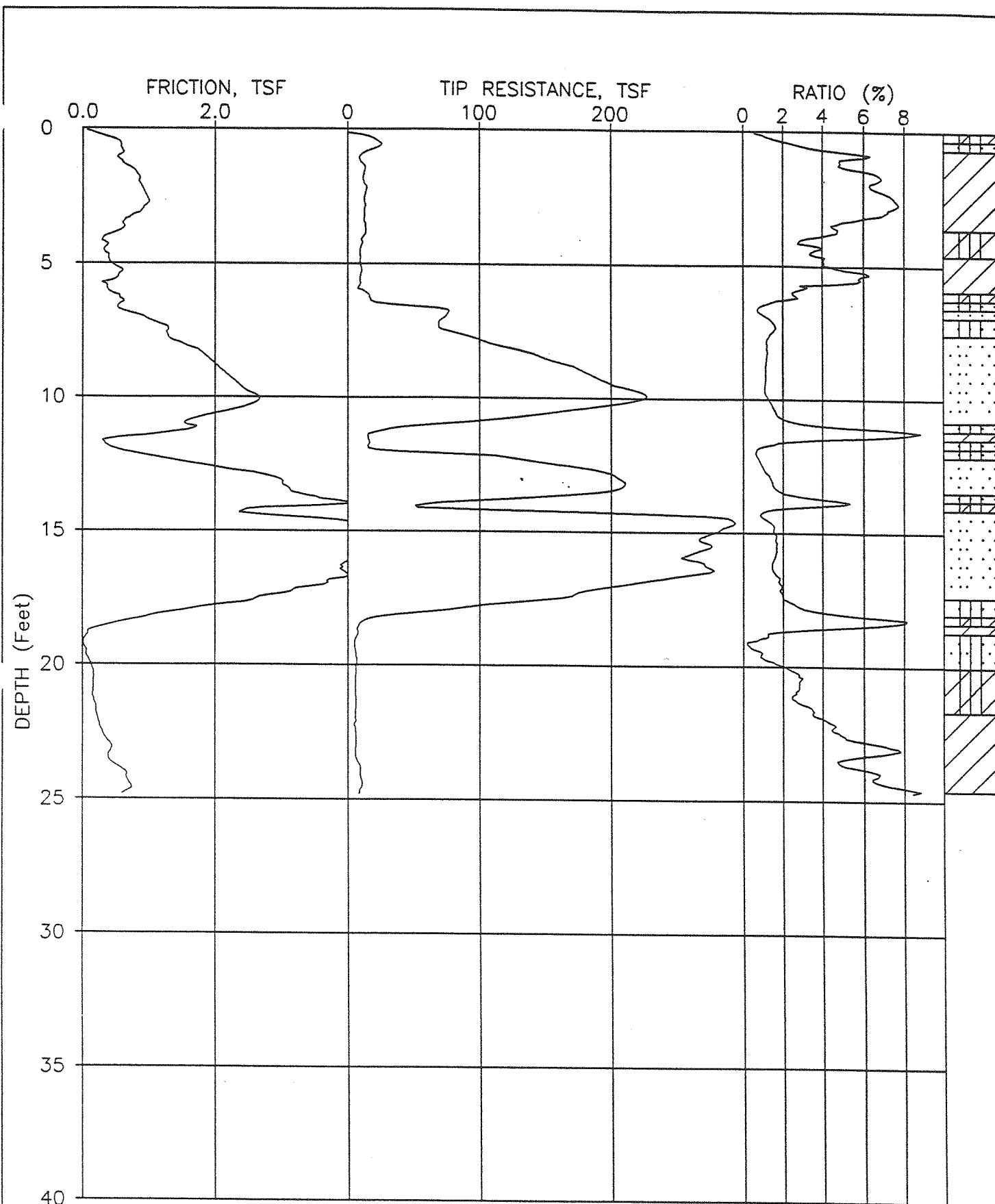
JOB NUMBER: 94-4108 CPT NUMBER: B-SW-3-CP DATE: 09-09-1994
 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV091 PLATE: 1 OF 1



JOB NUMBER: 94-4108 CPT NUMBER: B-SW-4-CP DATE: 09-09-1994
 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV091 PLATE: 1 OF 1



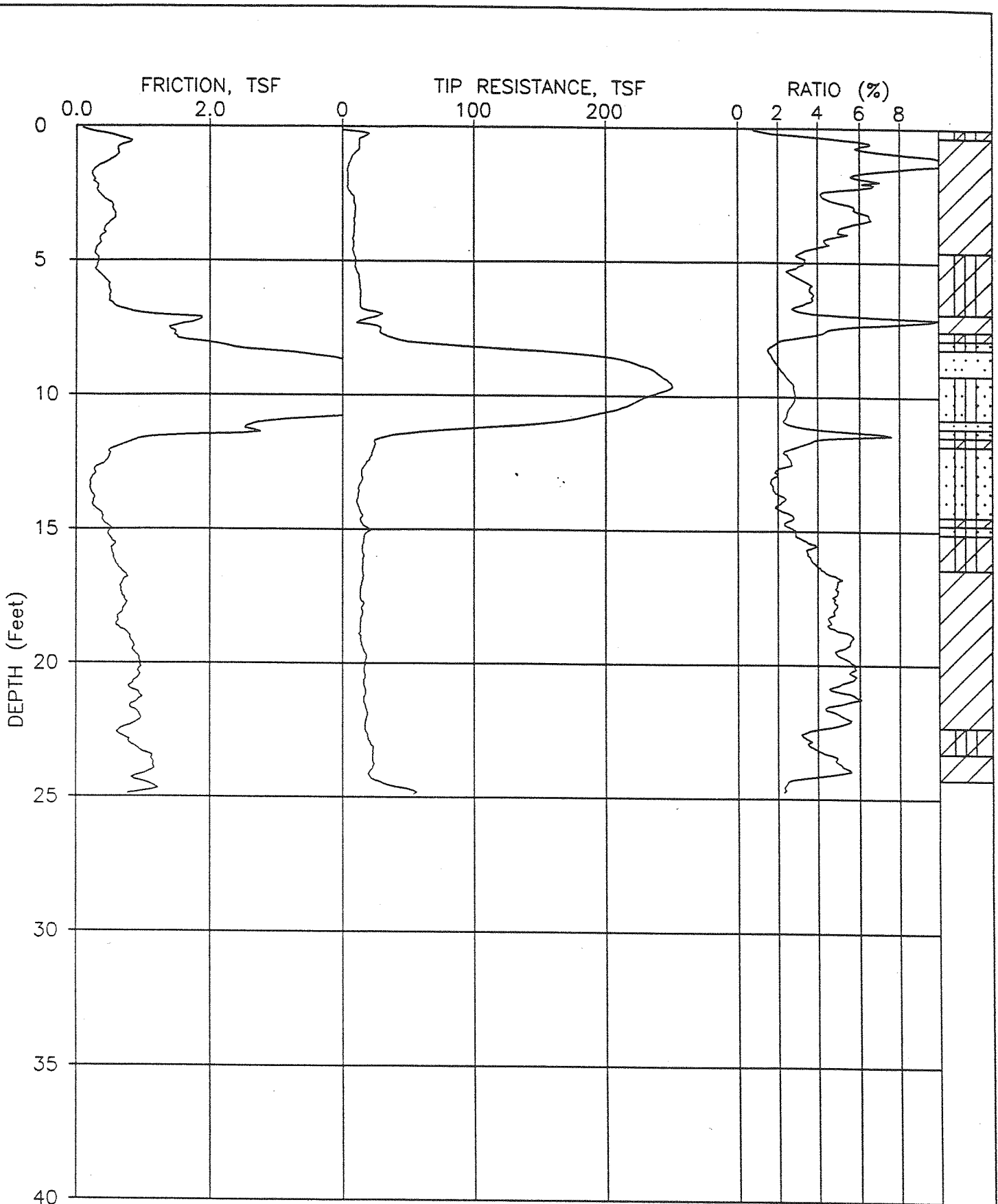
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 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV091 PLATE: 1 OF 1



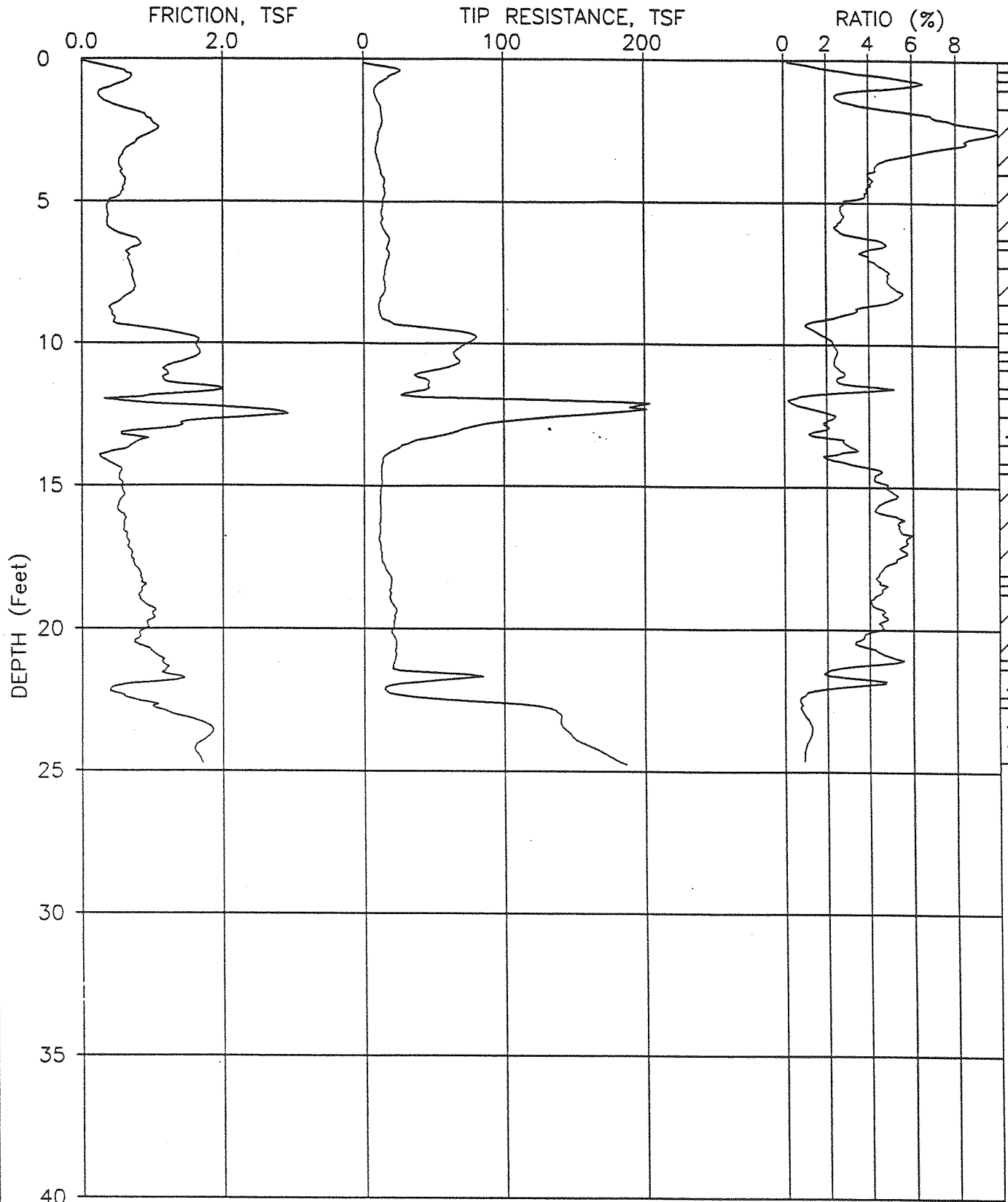
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 ELEVATION: 0.00

CPT NUMBER: B-SW-7-CP
 CONE NUMBER: F7.5CKEV091

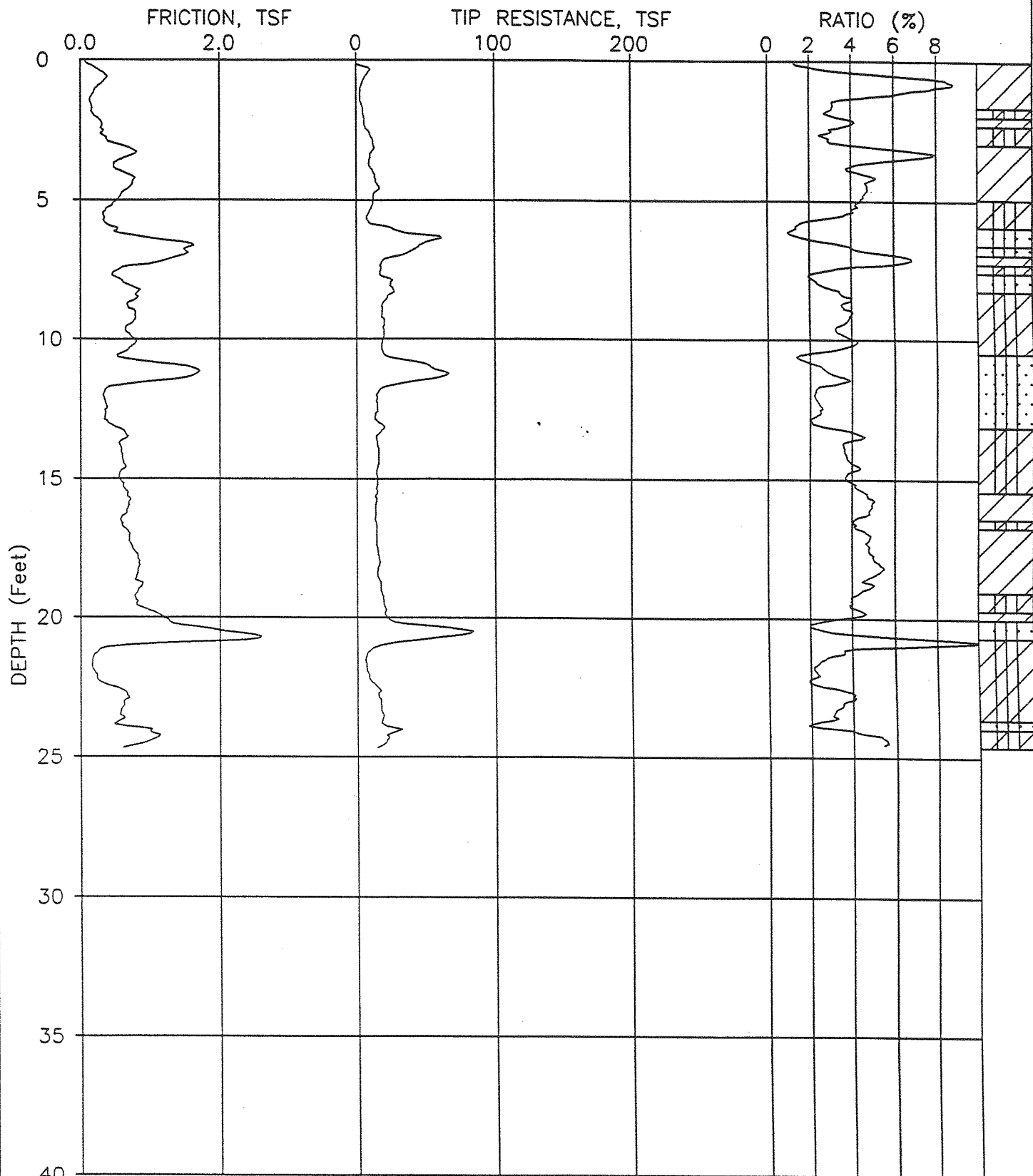
DATE: 09-09-1994
 PLATE: 1 OF 1



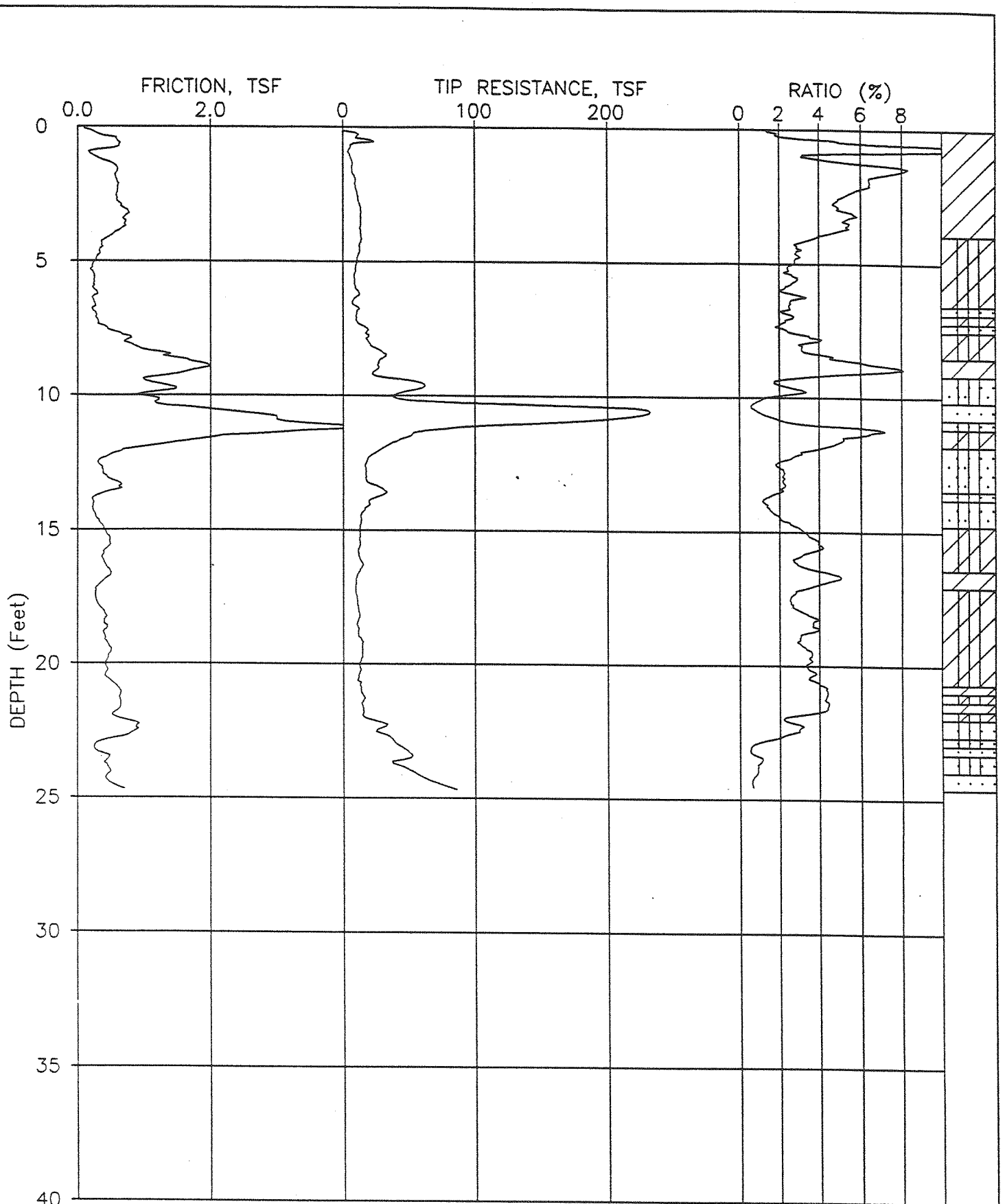
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 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV091 PLATE: 1 OF 1



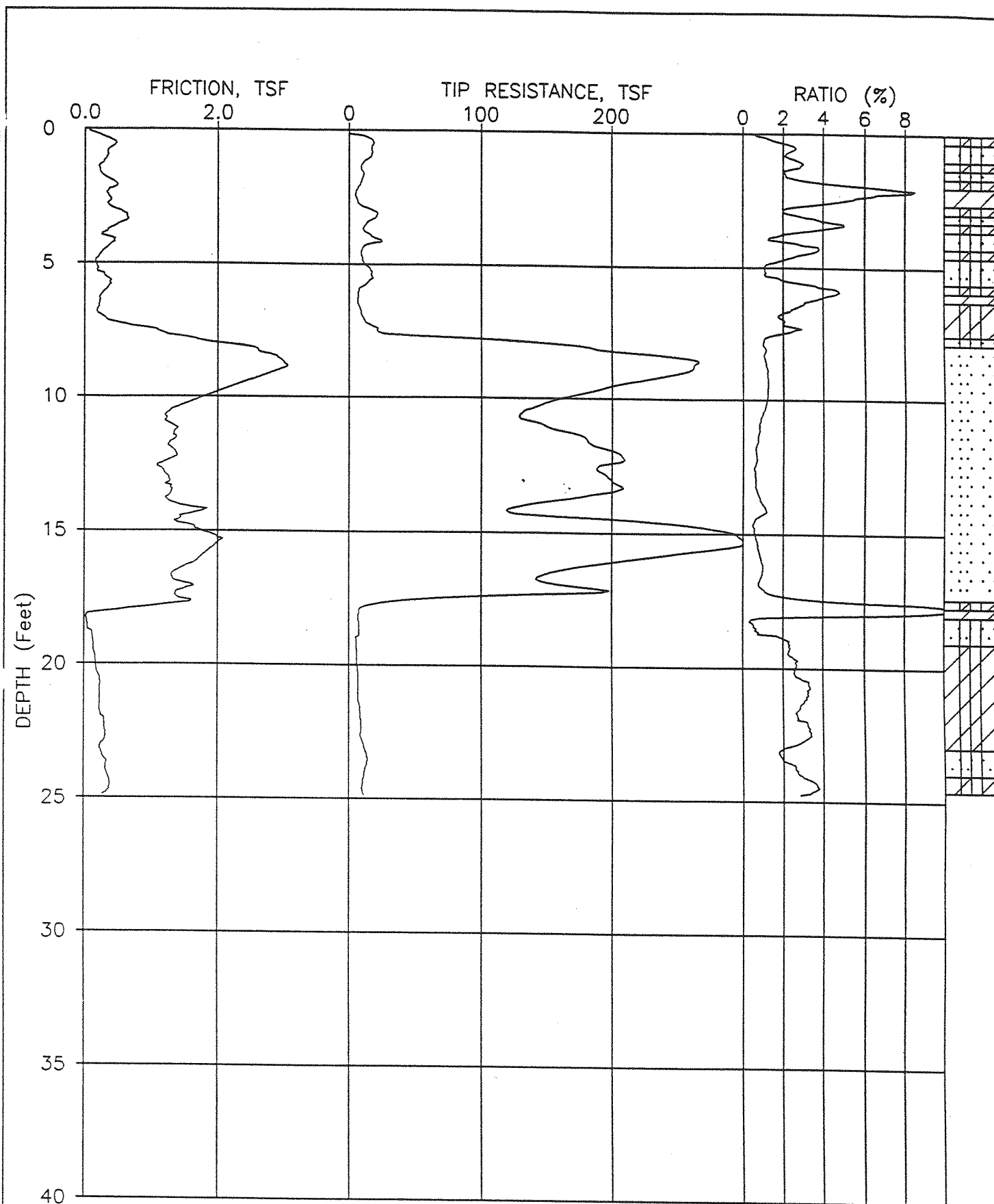
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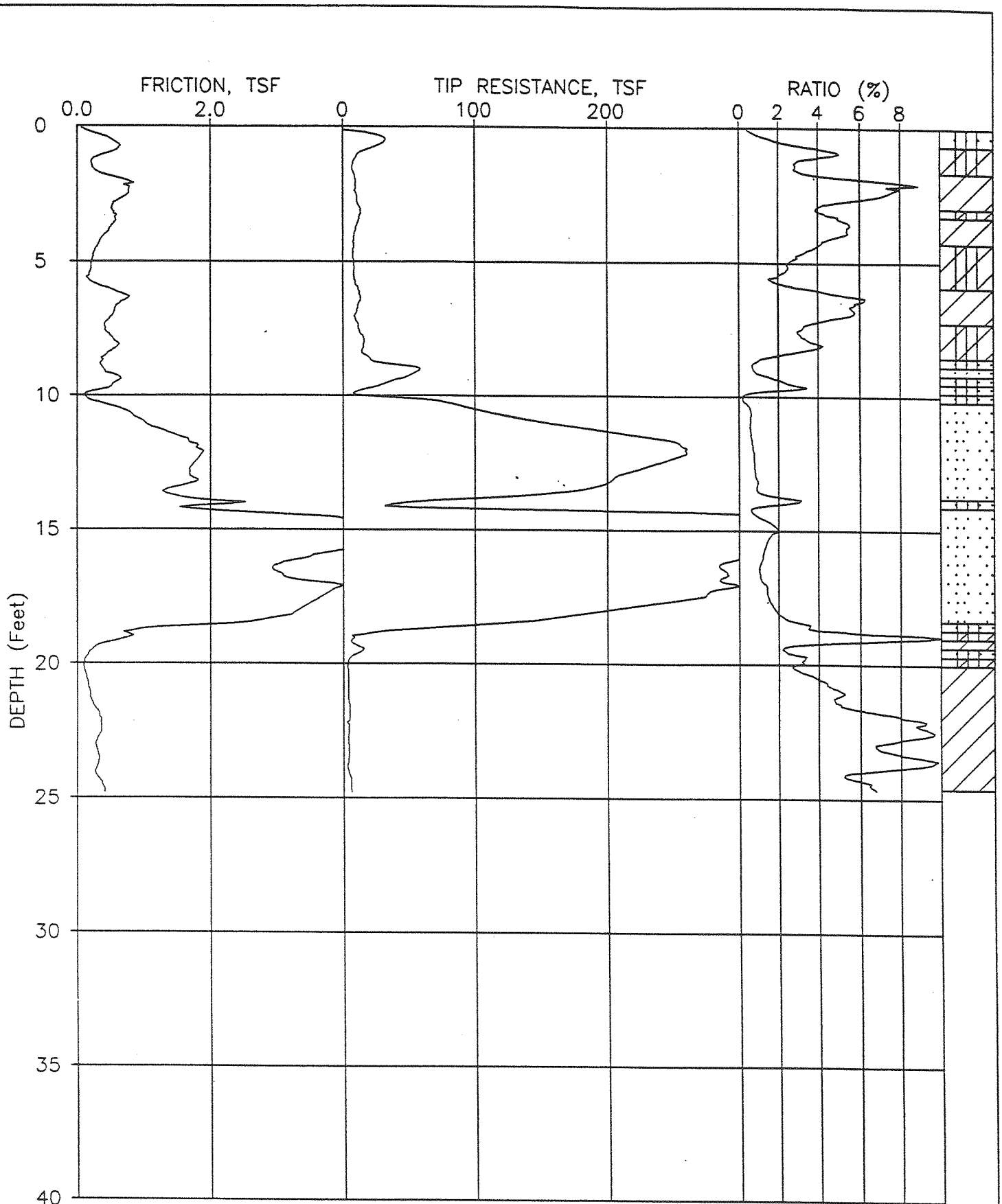
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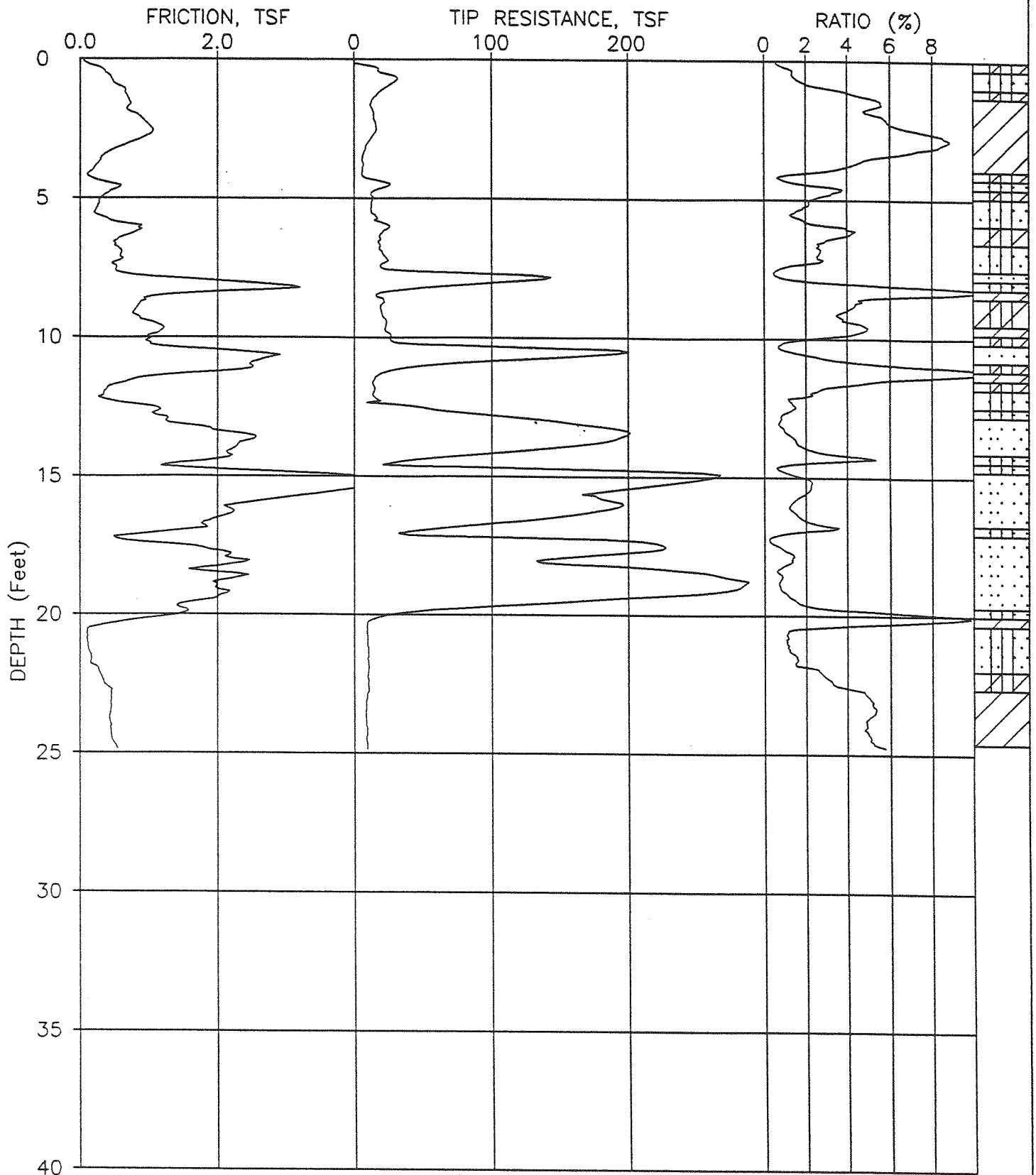
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 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1



JOB NUMBER: 94-4108 CPT NUMBER: B-SW-15-CP DATE: 09-12-1994
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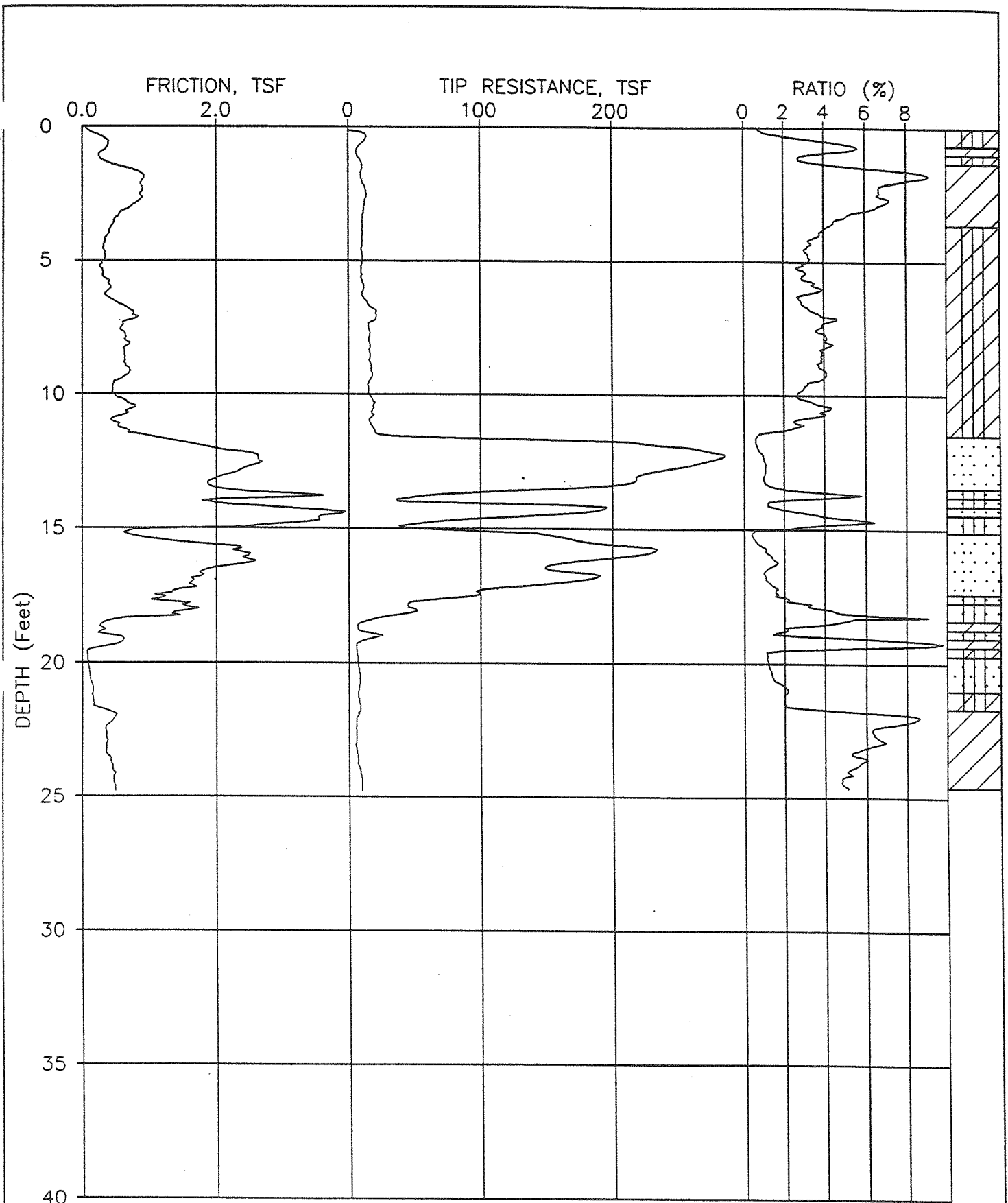
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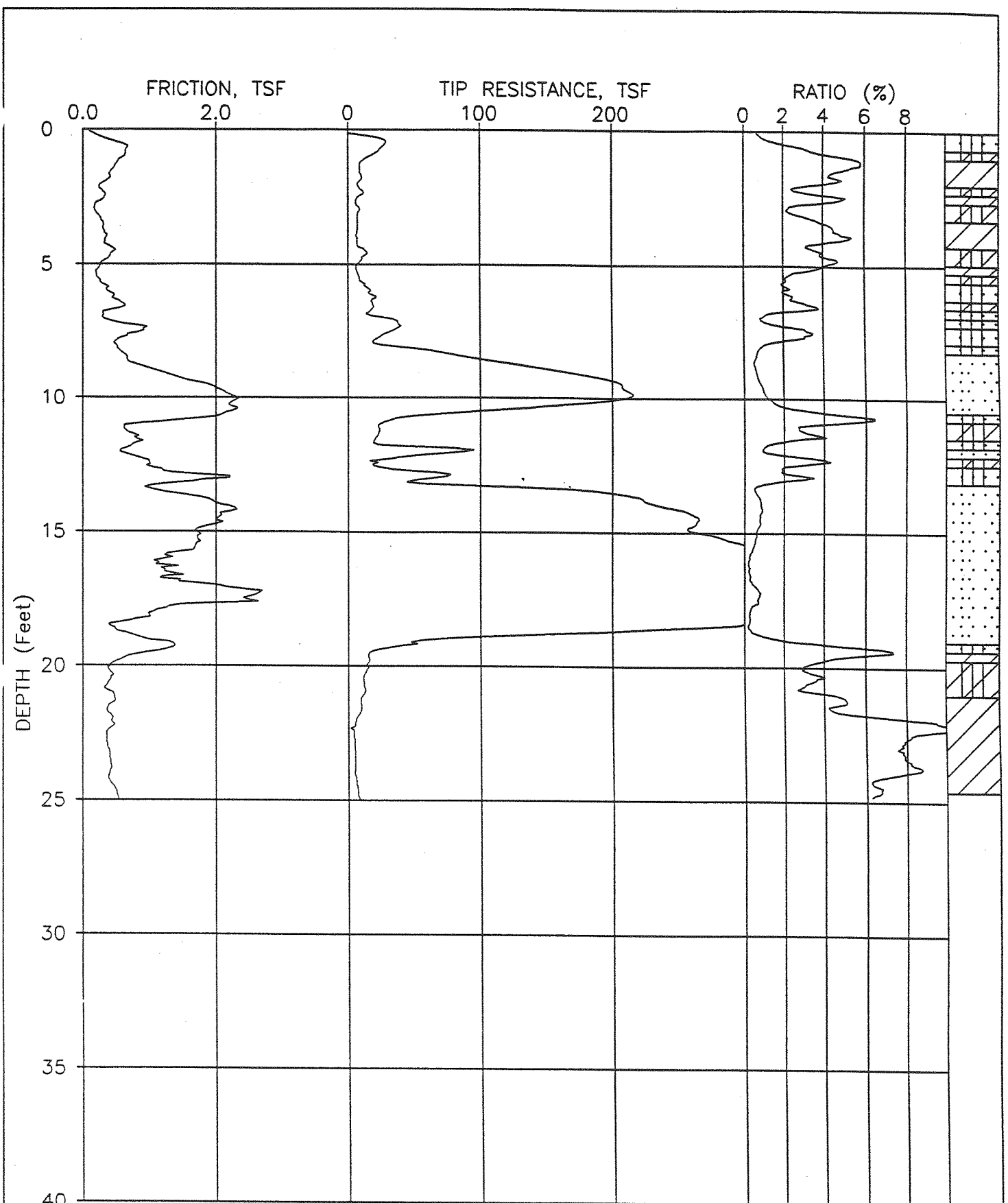
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CPT NUMBER: B-SW-18-CP
 CONE NUMBER: F7.5CKEV080

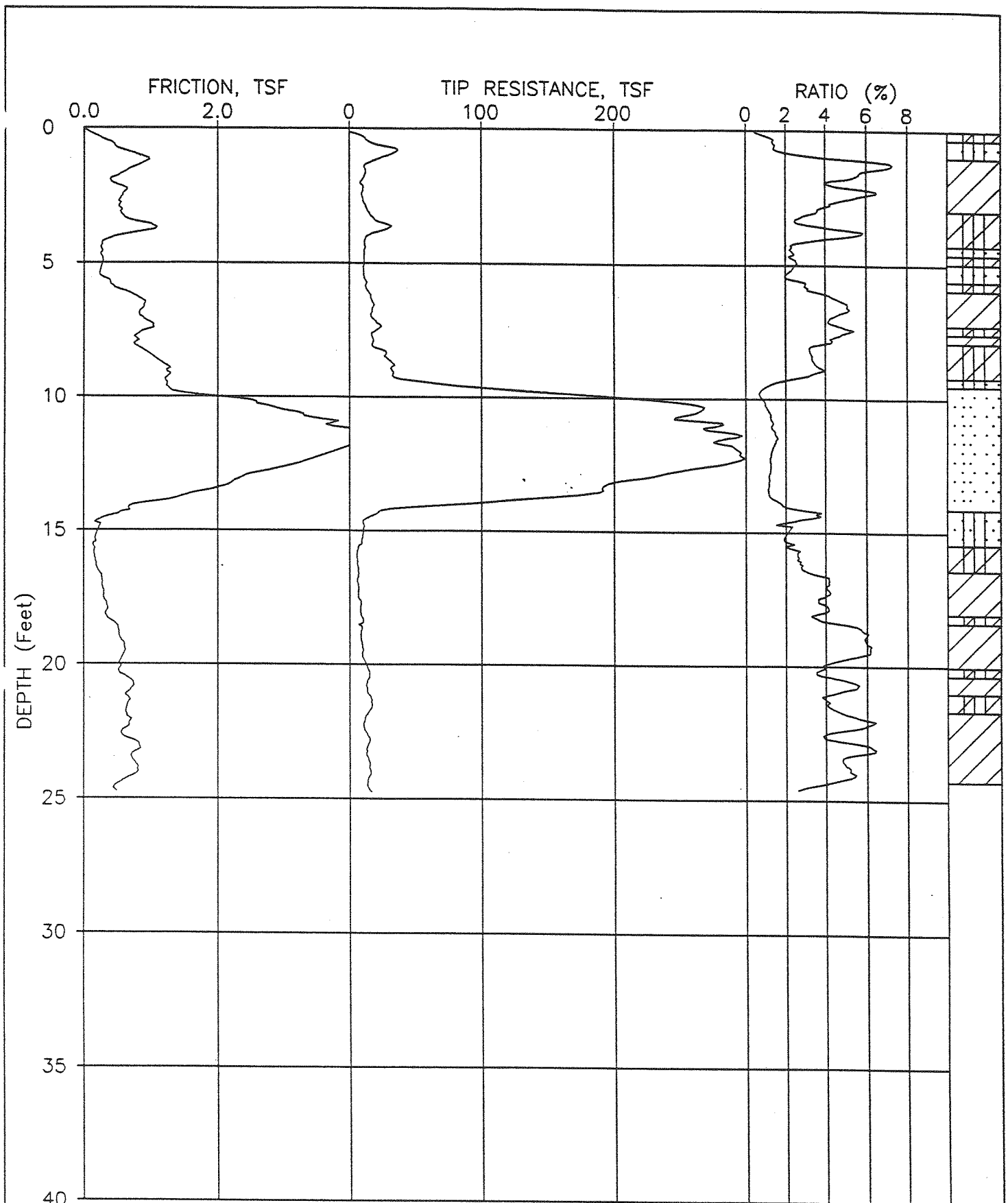
DATE: 09-12-1994
 PLATE: 1 OF 1



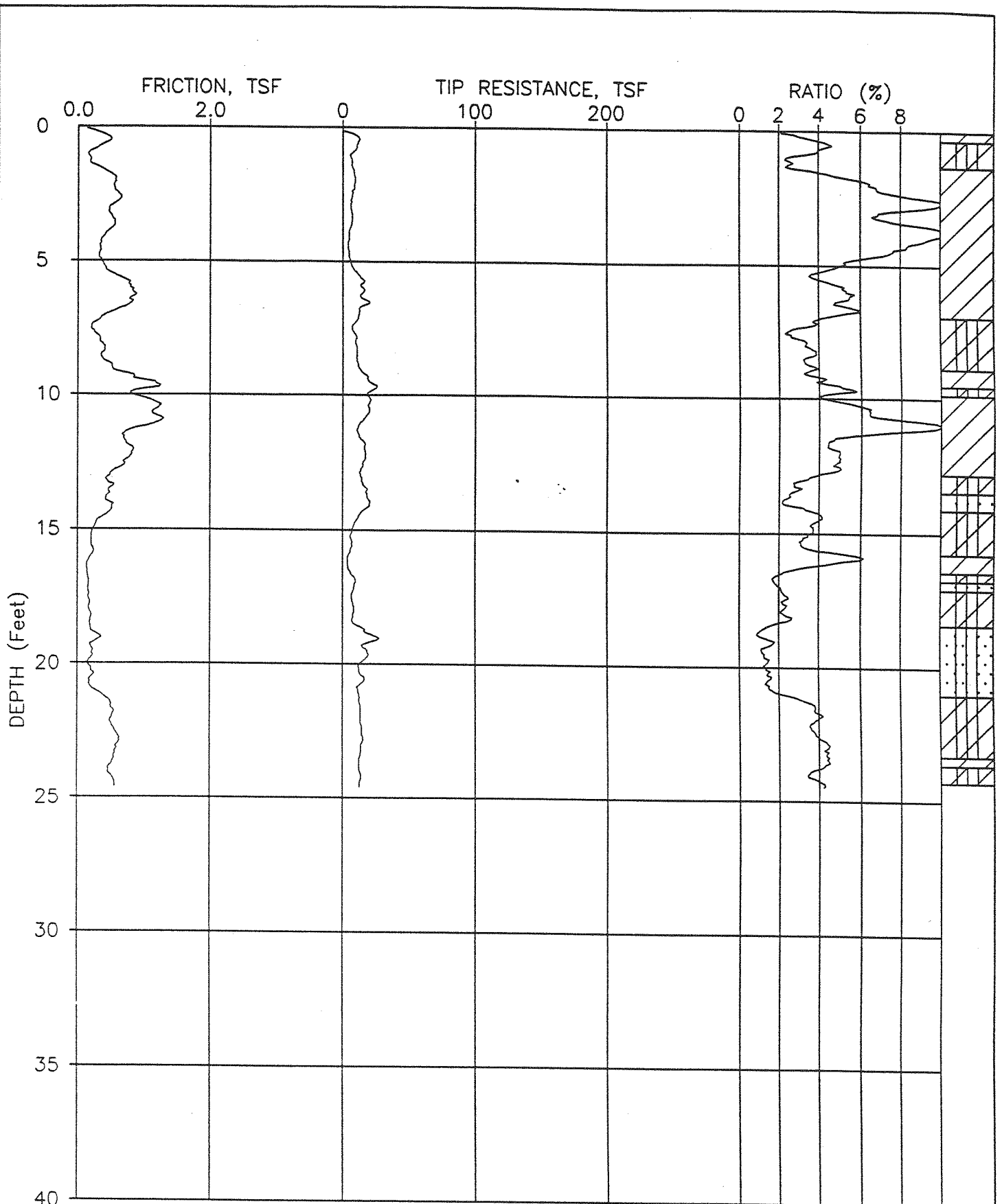
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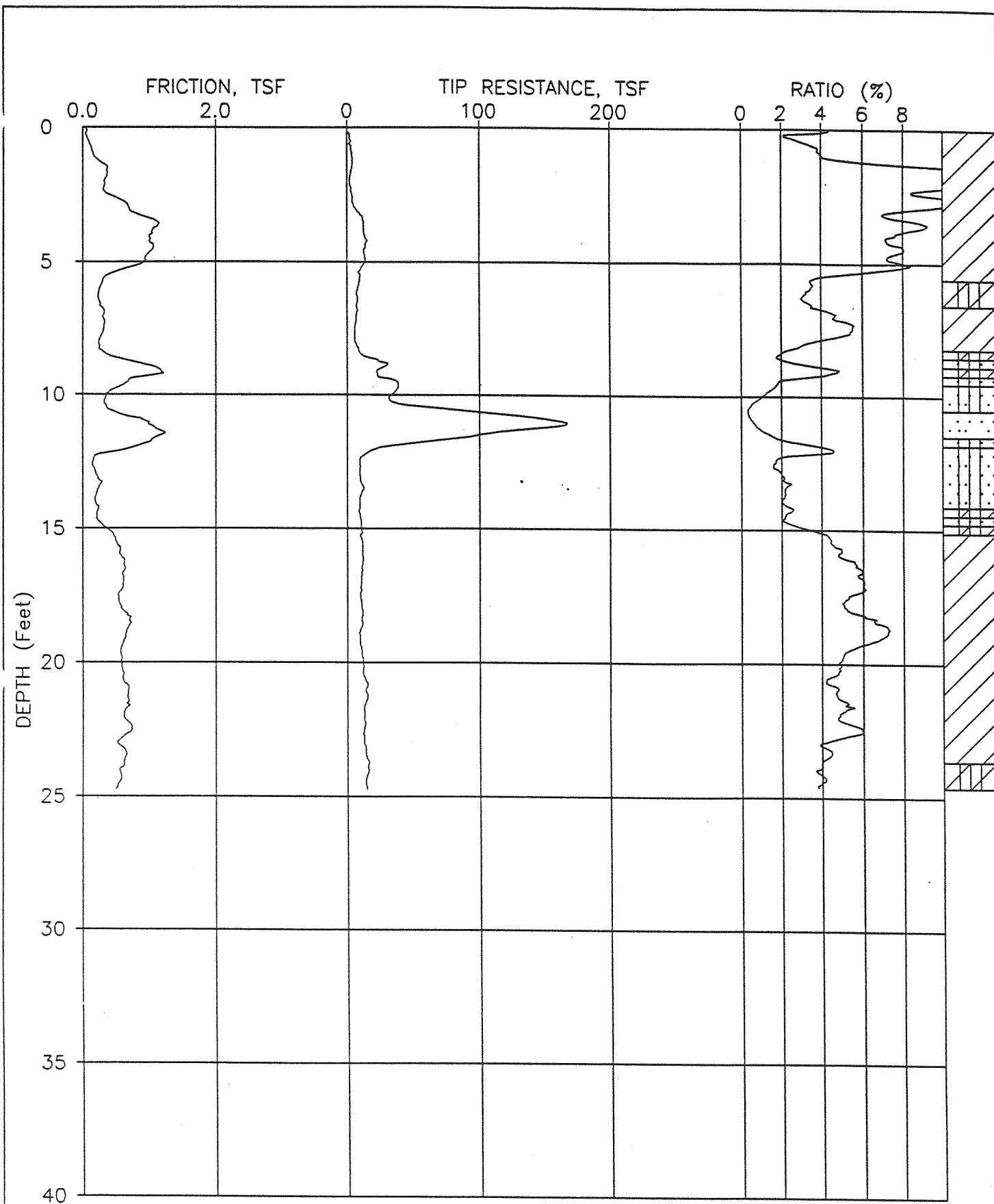
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 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1



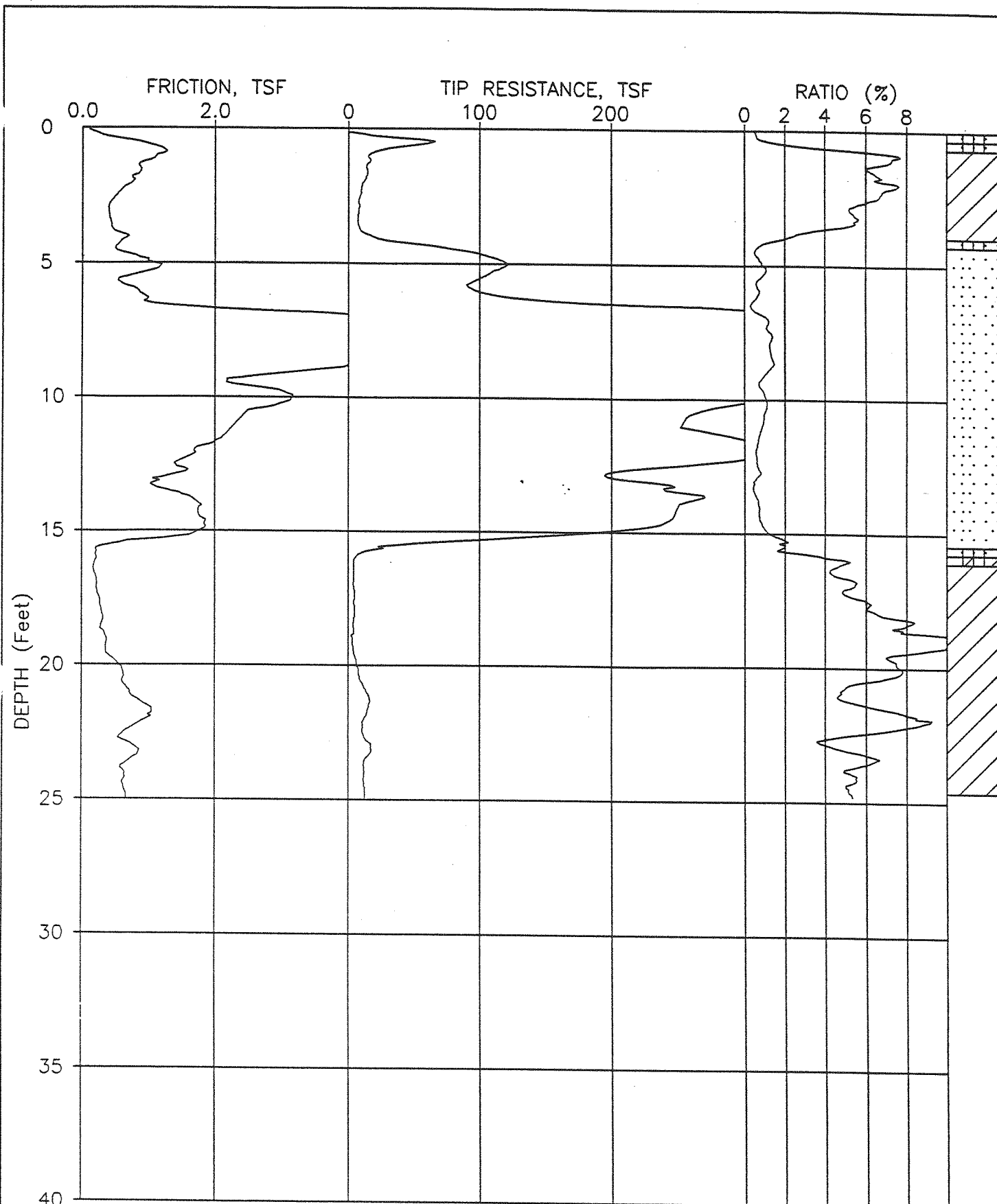
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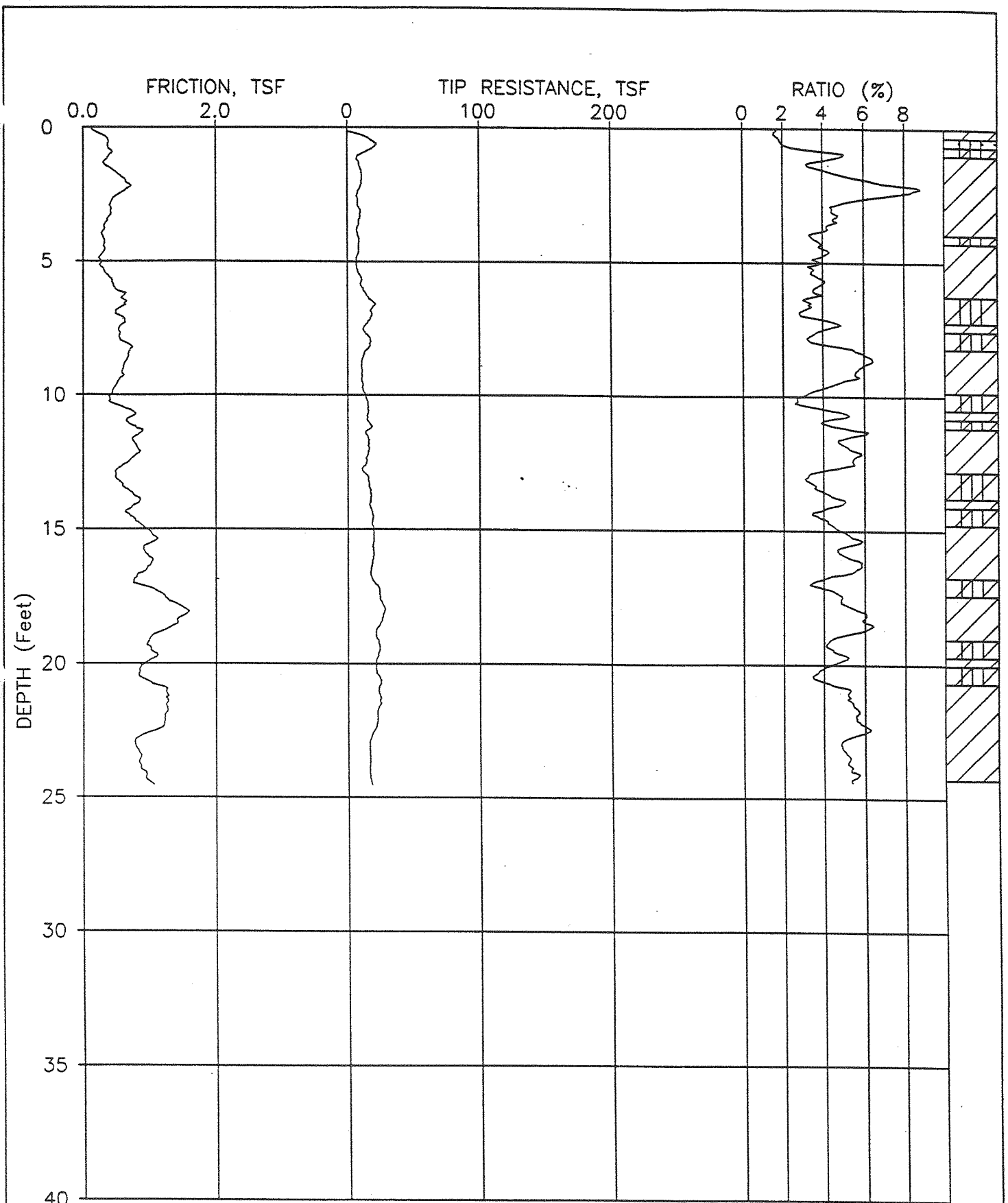
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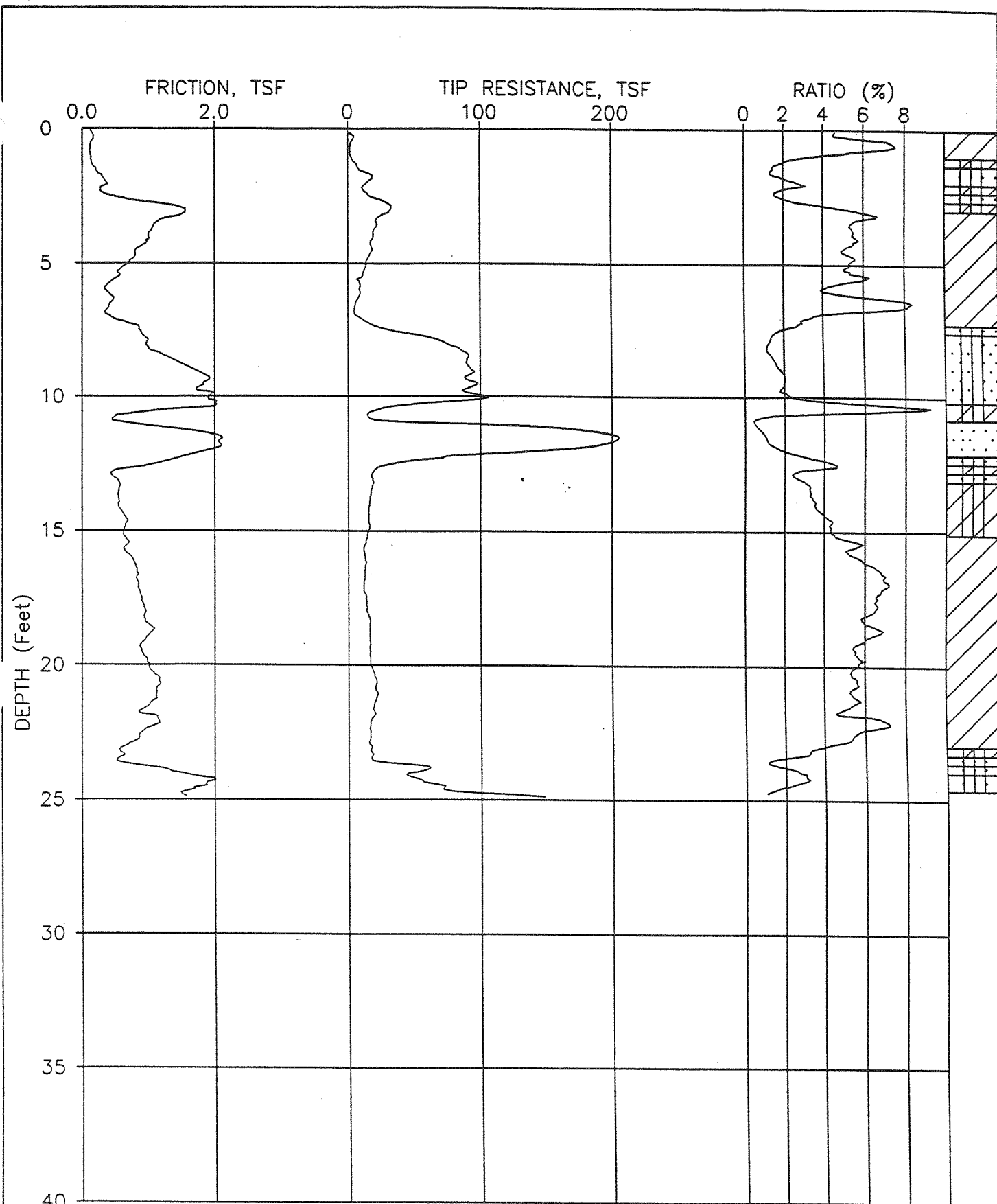
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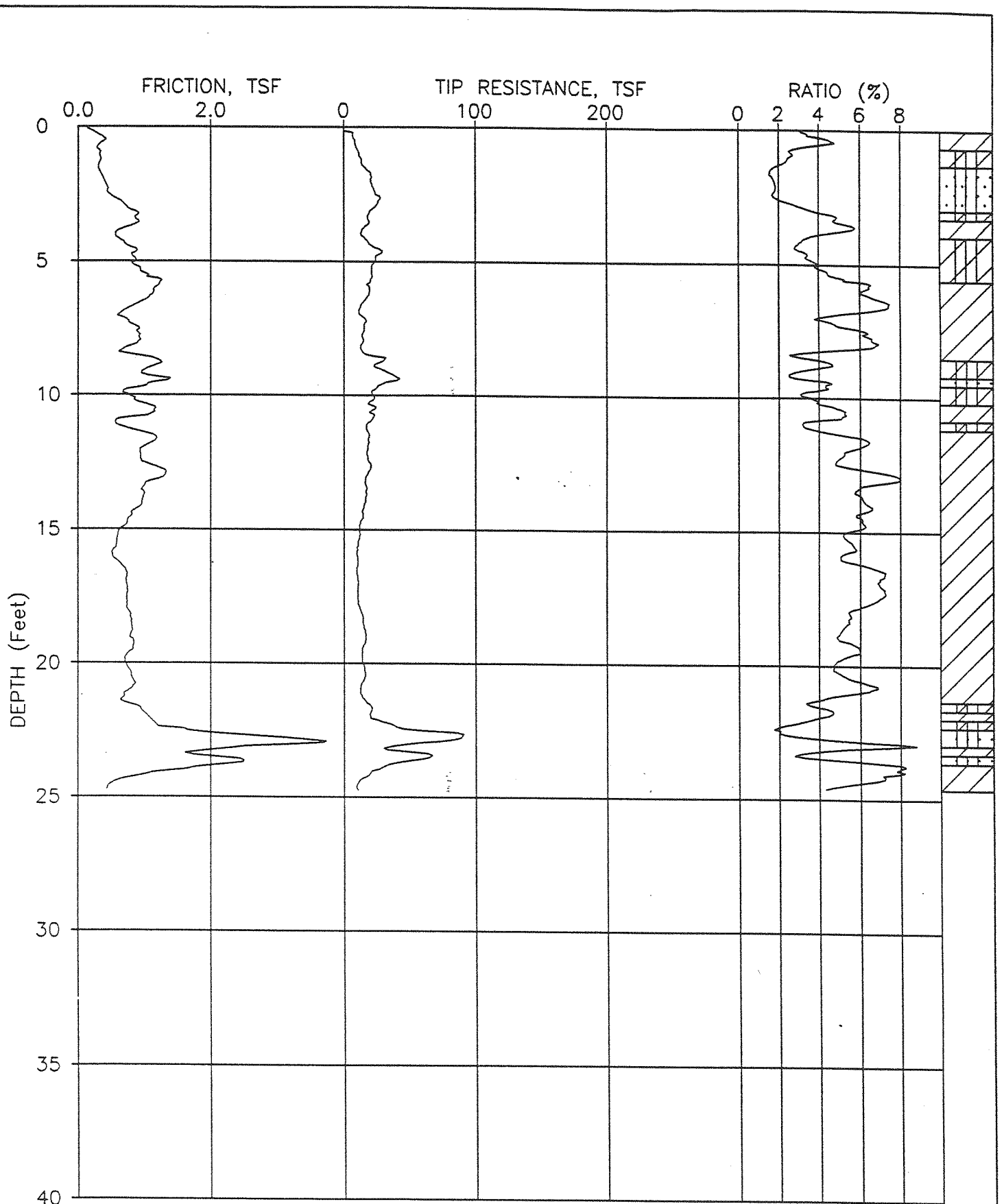
JOB NUMBER: 94-4108 CPT NUMBER: B-SW-26-CP DATE: 09-12-1994
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JOB NUMBER: 94-4108 CPT NUMBER: B-SW-27-CP DATE: 09-12-1994
 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1



JOB NUMBER: 94-4108 CPT NUMBER: B-SW-28-CP DATE: 09-14-1994
 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1



JOB NUMBER: 94-4108 CPT NUMBER: B-SW-30-CP DATE: 09-14-1994
 ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1