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Geologic and Geotechnical Properties of the Fort Union Formation in Drill Cores from the Thunder Basin National Grassland, Campbell County, Wyoming

By D. S. Collins and A. T. Jenkins

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Geologic and Geotechnical Properties of the Fort Union Formation in Drill Cores from the Thunder Basin National Grassland, Campbell County, Wyoming

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Introduction

This report documents the geologic, geotechnical, and geophysical data acquired from one drill hole which was bored during the months of September and October 1977. The drill site is located in the NE 1/4 sec. 27, T. 42 N., R. 70 W. of the Thunder Basin National Grassland, Campbell County, Wyo. (fig. 1). Drilling began in dune sands (Pleistocene age), penetrated part of the Wasatch Formation of Keefer (1974), and ended within the Fort Union Formation (Paleocene age). The project was jointly supported by the Energy Lands program of the U.S. Geological Survey and by the Surface Environment and Mining project of the U.S. Forest Service. The data acquired from this project will be used to evaluate the engineering and environmental problems associated with mining and reclamation of this coal-bearing land.

The hole was drilled and the core recovered using a truck-mounted mobile B-52 auger/core drill. Shelby[1] tubes (7.2 cm in diameter) operating through a hollow stem auger were used to sample the first 3.8 m from the hole. Because of the increased hardness of the formational material below this depth, a Christensen NX-size wire line with a split inner barrel and diamond bit was used to advance the hole to a maximum depth of 130.6 m. Samples were obtained with split-tube inner core barrels 1.5 and 3.1 m in length. The hole was advanced with circulating drilling mud to a depth of 84.8 m, where circulation

[1]Use of trade names is for descriptive purposes only and does not necessarily constitute endorsement by the U.S. Geological Survey.

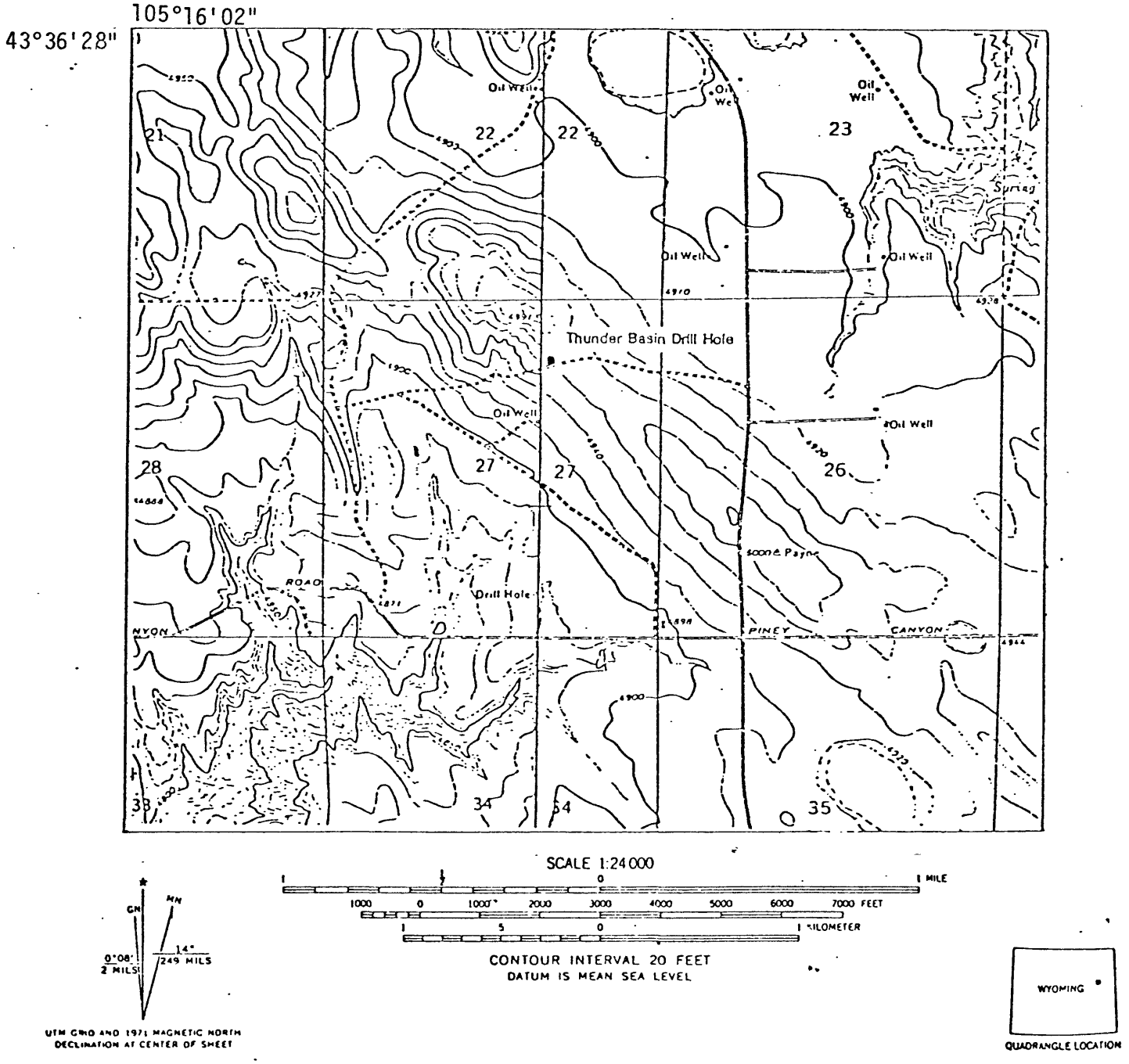


Figure 1.--Index map showing location of Thunder Basin drill hole in NE 1/4 sec. 27, T. 42 N., R. 70 W.

was lost. Thereafter the remainder of the hole was drilled with greased rods while water was pumped down the drill string to lubricate the bit and to flush cuttings away from the bit.

After reaching maximum drill depth, natural-gamma, gamma-gamma, and neutron logs were recorded through the drill string. A caliper log was also attempted, but because of caving, data for this log were limited to a depth of 45.7 m. Following the caliper measurement, the hole was redrilled, cased, and in-hole compressional- and shear-wave velocities were measured to a depth of 91 m.

Acknowledgments

P. S. Powers and D. M. Worley operated the drill and J. K. Odum made a preliminary log of the lithology of the core in the field. R. A. McCullough obtained the nuclear and caliper logs. C. H. Miller and J. K. Odum measured the in-hole seismic velocities and calculated the elastic moduli and Poisson's ratio from the resulting compressional and shear-wave velocity data. The geotechnical testing and analysis of the Thunder Basin core were conducted by J. A. Conrad, M. A. Go, N. A. Haver, T. L. Hermann, and D. L. Ritter. H. D. Gomez and M. C. Witmer aided the authors with the lithologic logging.

Experimental Procedures

In the field the core was removed from the split inner barrel of the drill system, wiped with a damp rag, scraped to remove drilling mud, logged, sealed in plastic sleeve bags, and then sent to the lab for detailed logging and geotechnical testing.

Continuous uncalibrated, gamma-gamma, neutron, and natural-gamma logs and a calibrated caliper reading were obtained from the drill hole using techniques described by Wyllie (1963) and Keys and MacCrary (1971). Also measured were the in-hole compressional and shear waves which were produced and recorded by techniques described by Gibbs, Fumal, and Borcherdt (1975) and Ohta and Shima (1967). These waves were generated on the surface by the impact of a sledge hammer on a steel plate and recorded in the hole by a package of three-component geophones.

In the lab, the core was logged in detail and the following tests on selected samples were performed according to ASTM standards: grain-size distribution, ASTM designation D 422-63; Atterberg limits, ASTM designation D 423-66; and the unconfined compressive strength test, ASTM designation D 2166-66 (American Society for Testing and Materials, 1978).

The results of other tests which lack ASTM standards are included in this study as research and experimental information. These tests include slake durability, as-received and dry bulk densities, pocket penetrometer, Schmidt hammer, point load, and X-ray clay mineral analysis. The slake durability test follows the procedures of Franklin and Chandra (1972) except that the total weight of each sample used in this test was 100-150 g. As-received densities were determined as described by Chleborad, Powers, and Farrow (1975), with the following exceptions: the samples were not oven dried prior to waxing and the known weight and density of the wax used was calculated from the as-received density values and moisture contents. Pocket penetrometer tests were attempted but samples tested were either too soft, too brittle, or too resistant to give results. Schmidt hammer tests were done in accordance with Aufmuth (1974) and the point-load strength test procedures were those described by Broch and Franklin (1972). X-ray clay mineral analysis techniques follow those presented by Schultz (1964) except that the results for each sample have been reported in four categories stating the relative abundance of each mineral group.

Results

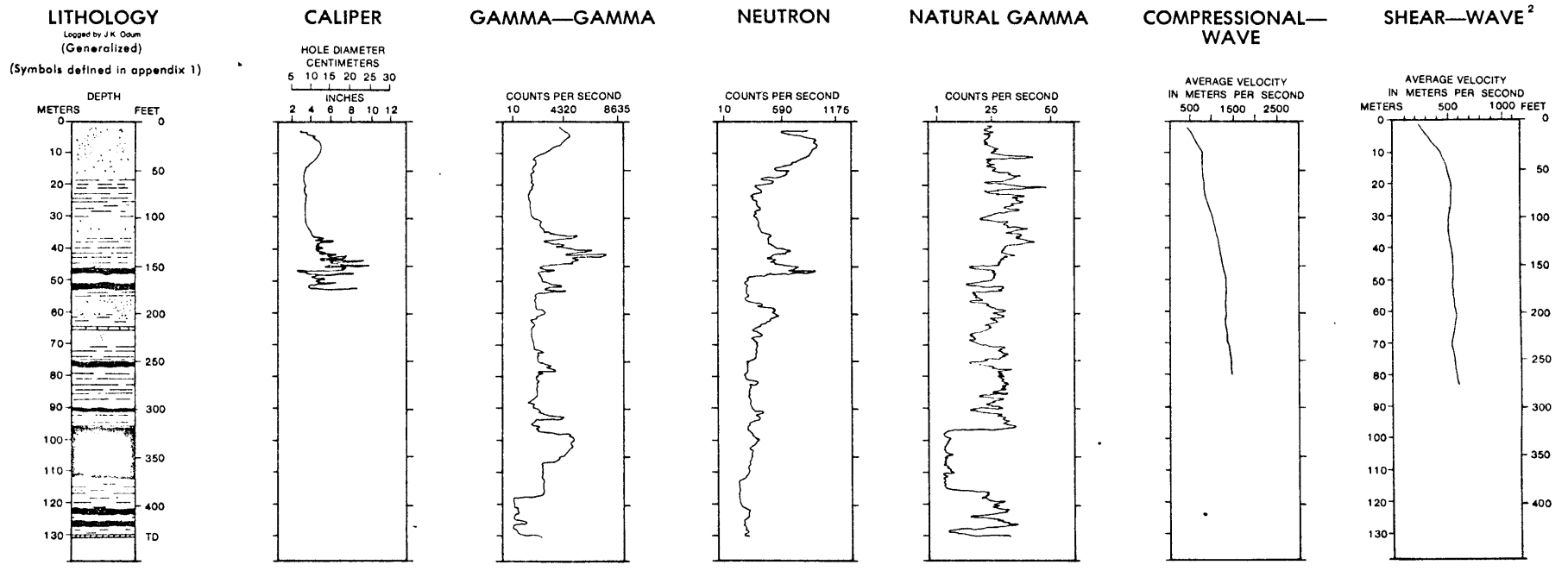
The detailed data and logs obtained in this study are documented in the appendix, and summaries of these data and logs are presented in figures 2 and 3.

Figure 2 summarizes of the lithology and to the geotechnical properties measured on selected samples from the core. Similarly figure 3 presents a summary of the caliper, nuclear, and seismic data, and calculated down-hole physical properties in relationship to a generalized lithologic log of the formations.

pages 5 thru 11 are oversize figures

CALIPER AND GEOPHYSICAL LOGS[1]

Thunder Basin National Grassland
Drill Hole Tb-1



[1] Caliper and nuclear logs run by R. A. McCullough (10/14/77) and velocity logs run by C. H. Miller and J. K. Odum (5/23/77).

[2] Detailed velocity logs and calculated elastic constants are included in appendix.

Figure 3

Summary of the Principal Rock Types and Their Geotechnical Characteristics

In figure 2, the upper 3 m of the section consists of weak surficial materials of Pleistocene age that were sampled with Shelby tubes but not analyzed in this study.

Underlying this surface material and extending to a depth of approximately 19 m, the lithology is composed of uncemented sand that is nearly uniform in composition and texture. The strength of this material and resistance to erodibility is low as indicated by the unconfined compressive strengths and slake durability values.

From about 19 m to 35 m, the sediments consist predominantly of clayey and silty materials. These materials possess a higher strength and resistance to erosion than the overlying sand. This higher strength and resistance is shown as unconfined compressive strengths and slake durability data. The clay materials, which are primarily noncalcareous, have medium to high plasticity and low as-received moisture contents compared to their liquid limits. The silty materials generally show a low to moderate reaction to HCl. This reaction suggests that a cementing agent (carbonate) is contributing to the strength of these sediments.

From 35 m to 55 m, most of the rocks are medium to high plasticity clay materials. These rocks are weaker than the overlying silty and clayey sediments; this is indicated by the unconfined compressive strength values and is suggested by the caliper, gamma-gamma, and neutron logs which reflect the erosion and caving that occurred in this unit during drilling. Physical weakness is also indicated by a number of slickensides present in the unit. This unit is noncalcareous, which is probably contributing to the lithologic incompetency in contrast to the immediately overlying section. Also present are three thin coal beds with strength higher than the other materials found within this section.

From 55 m to approximately 71 m, the rocks are mostly unconsolidated sand and siltstone with occasional thin beds of claystone and limestone(?). The strength within this section is similar to the overlying materials. The siltstone layers of this unit are slightly calcareous. A strong odor of H_2S gas was detected from the unconsolidated sand at 180-186.6 m. The interval

between approximately 71 m and 95.6 m consists predominantly of highly plastic silty clay material. This is found to be appreciably stronger and more resistant to erosion than the overlying materials. This greater strength is suggested by the unconfined compressive strengths and slake durability data. Other characteristics of this unit include no significant amount of carbonate, an abundance of slickensides, and the presence of two minor coal and siltstone beds.

A nearly continuous coal bed occurs from about 95.6 m to 114.3 m. The strength of this coal as indicated by the unconfined compression data is greater than the thin coal units found with the overlying sections. Although moisture contents in this coal bed were higher than in the surrounding material, this coal was believed to have been drier before being drilled. The high moisture content is believed to have resulted from the water used during drilling. The dip of this coal bed may be a factor in this dryness. Based on the elevations from the coal bed within the drill hole and in four nearby water wells, the bed, lying on the east limb of the basin, dips to the east.

Beneath the major coal bed and near the bottom of the hole, the lithology is composed of sandstone, siltstone, mudstone, and claystone with minor beds of coal and dolomite(?); although showing substantially higher unconfined compressive strength values, their resistance to erosion is only slightly higher than the interval lying above the major coal bed. This slightly higher resistance to erosion is probably due to weak cement in the material beneath the coal bed.

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Appendix

ENGINEERING GEOLOGY LABORATORY

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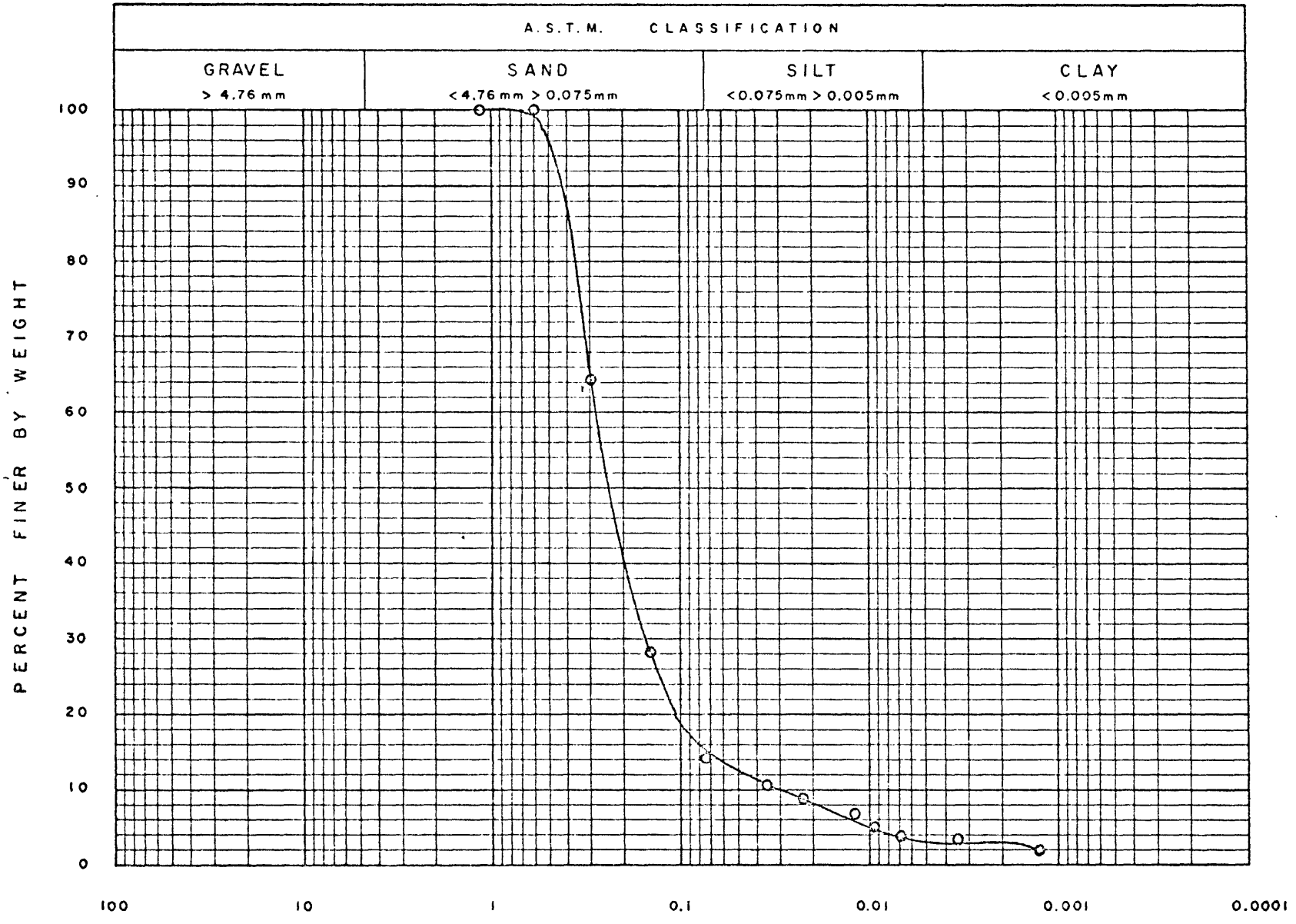

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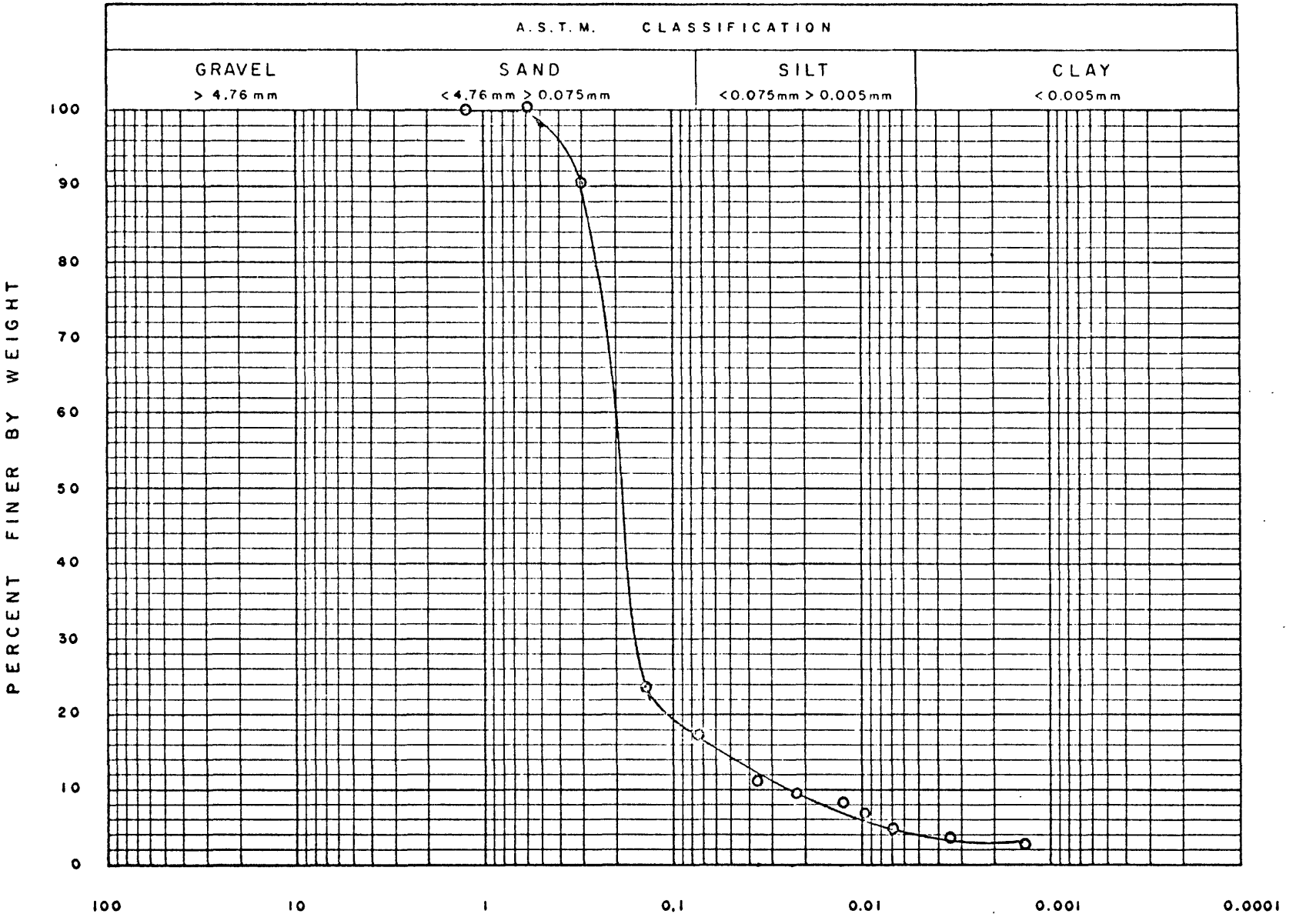

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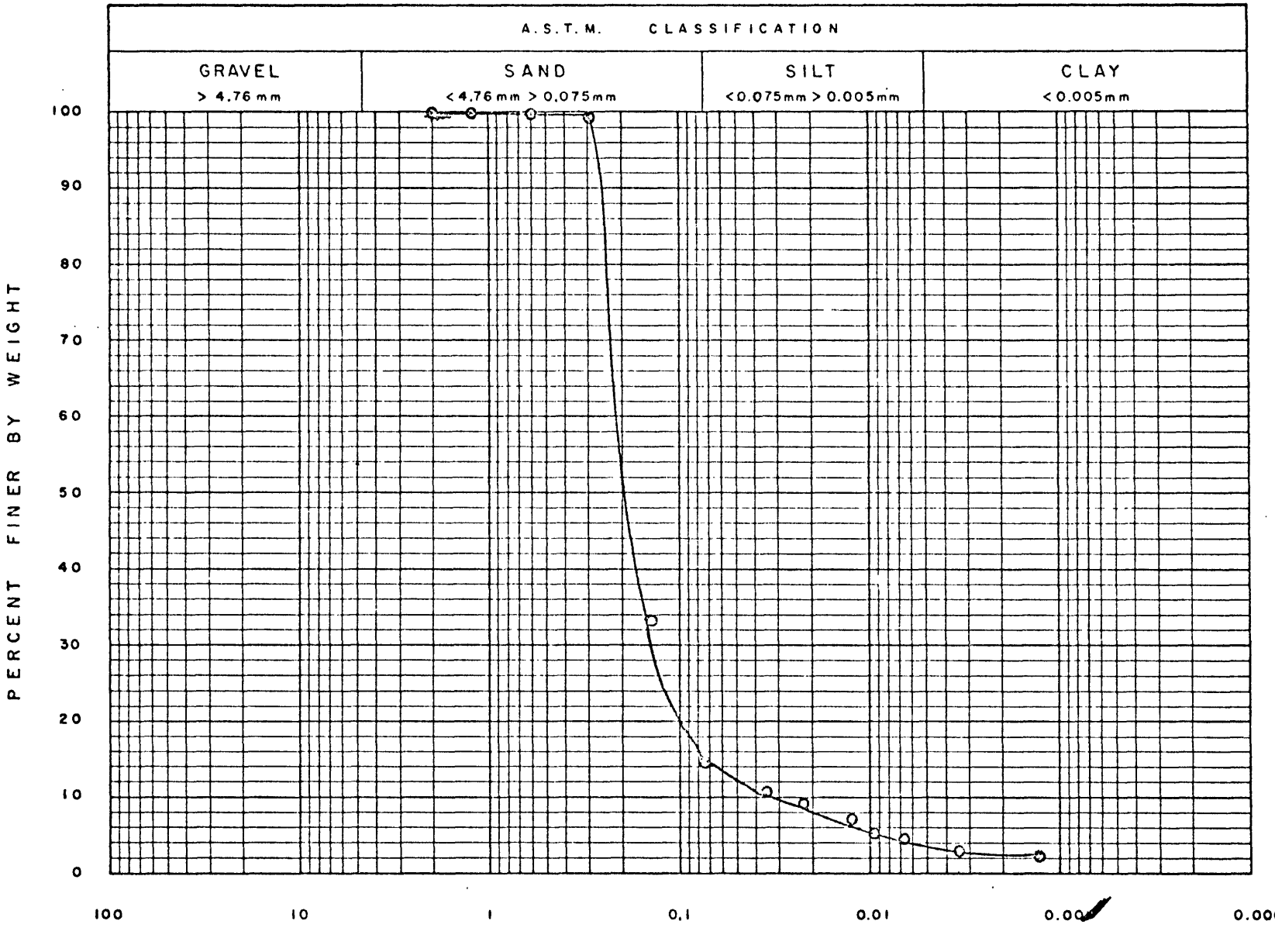

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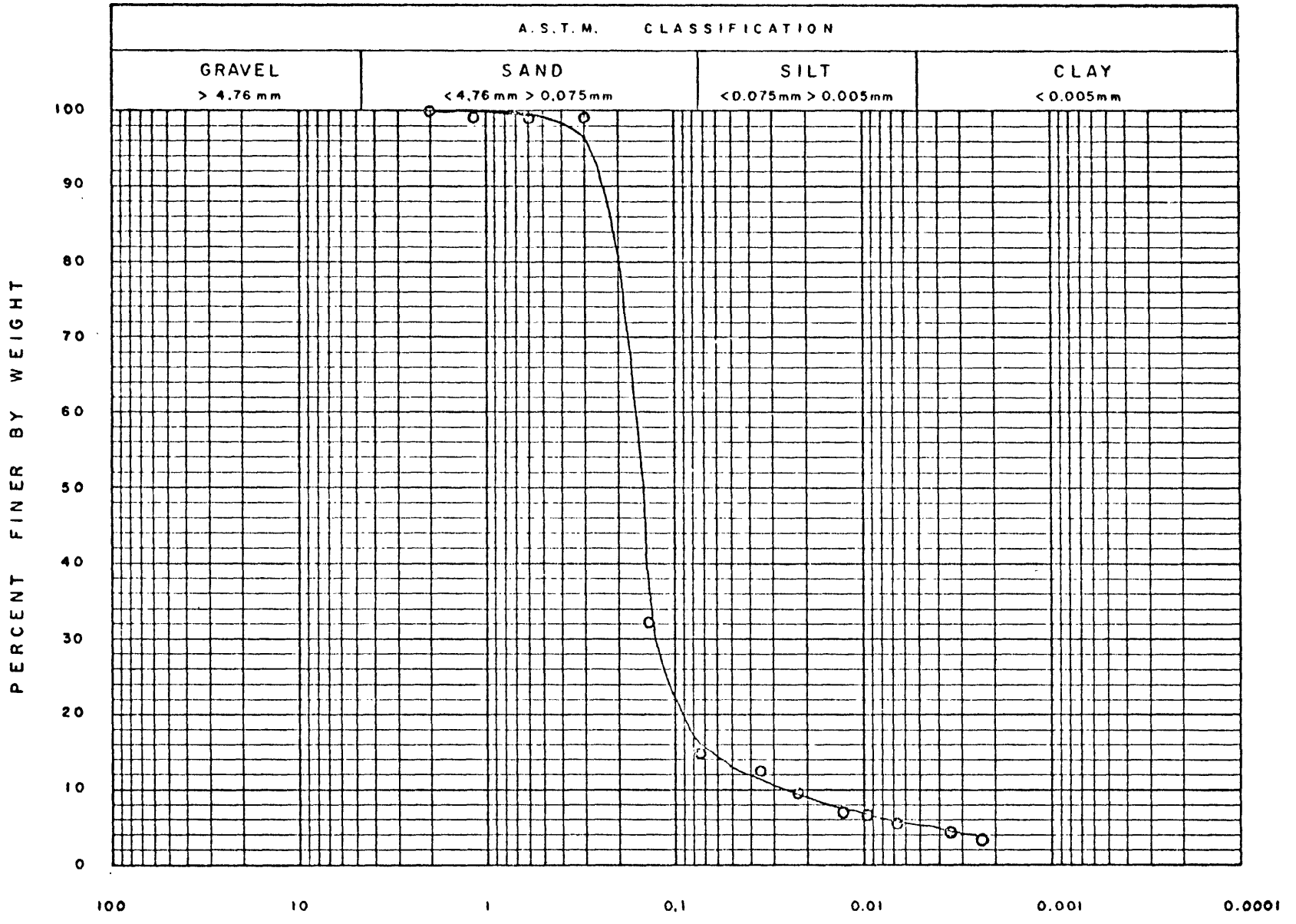

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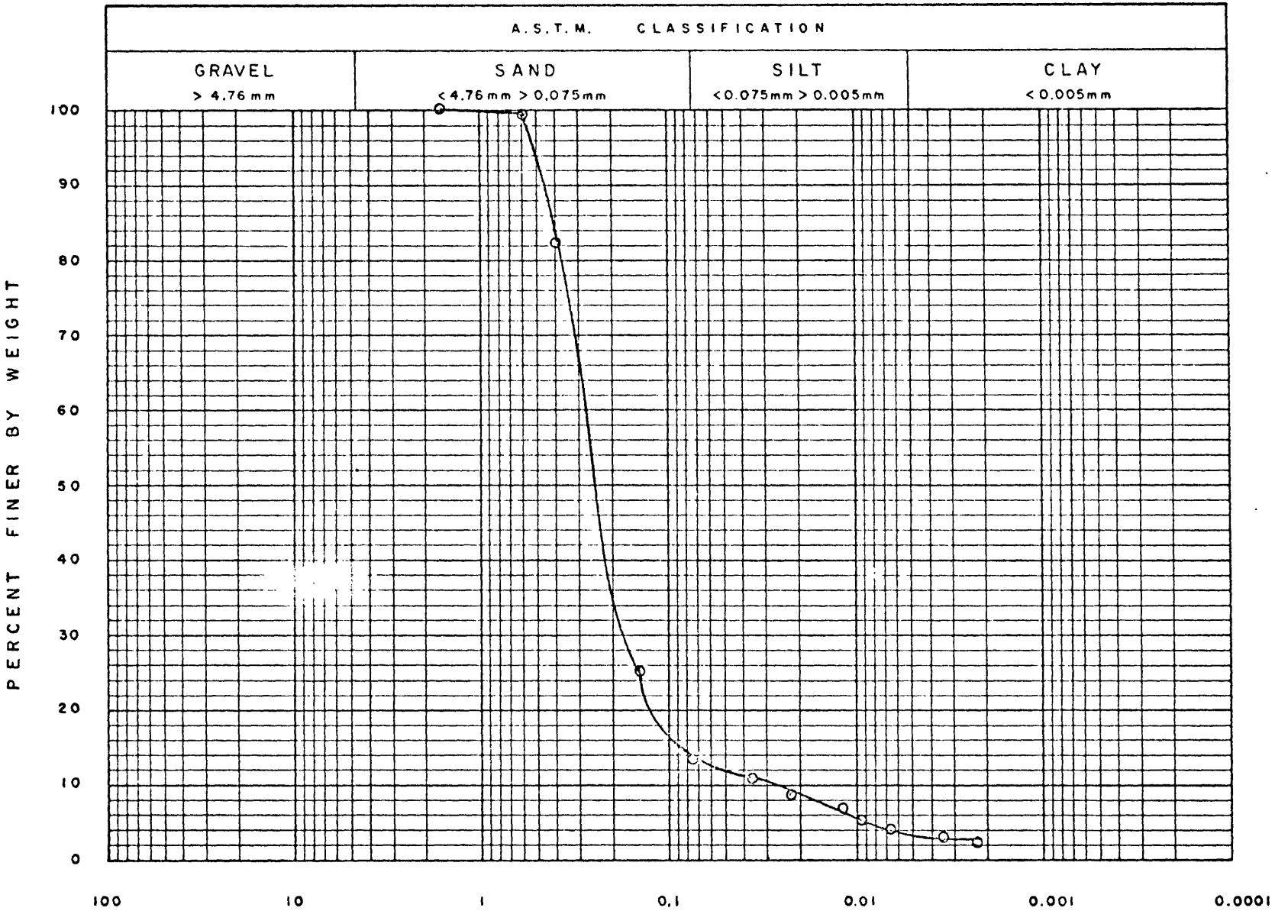

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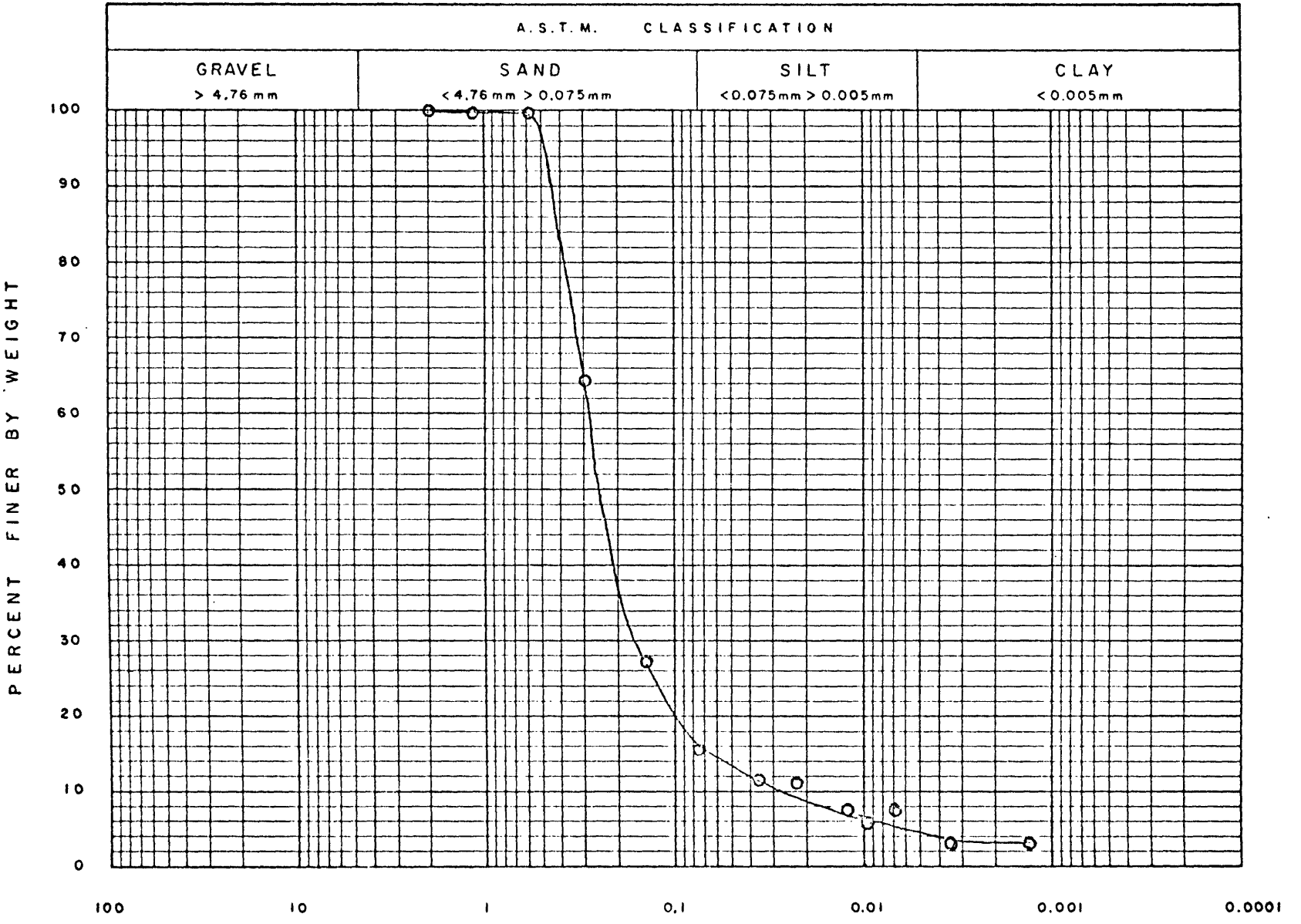

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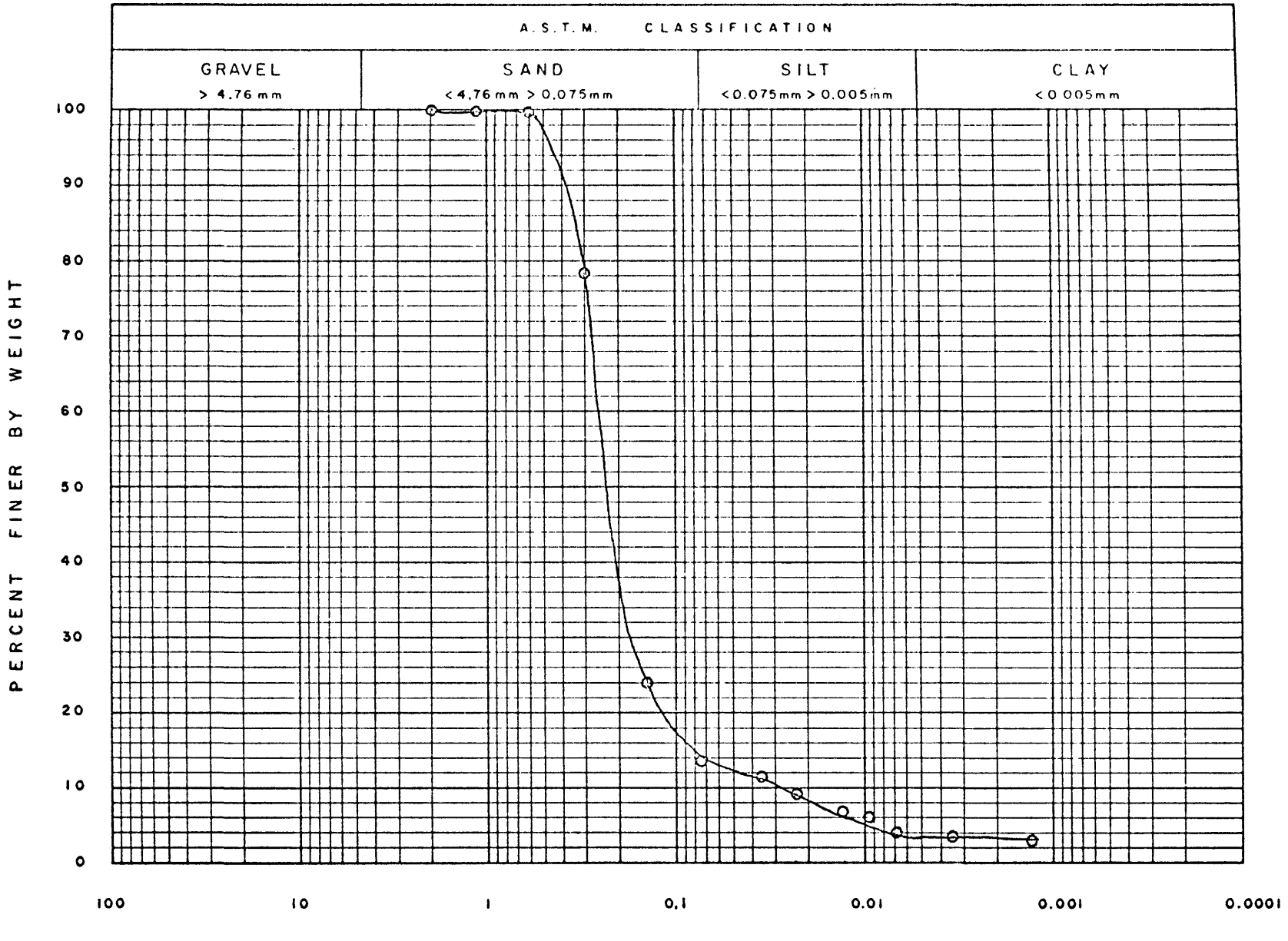

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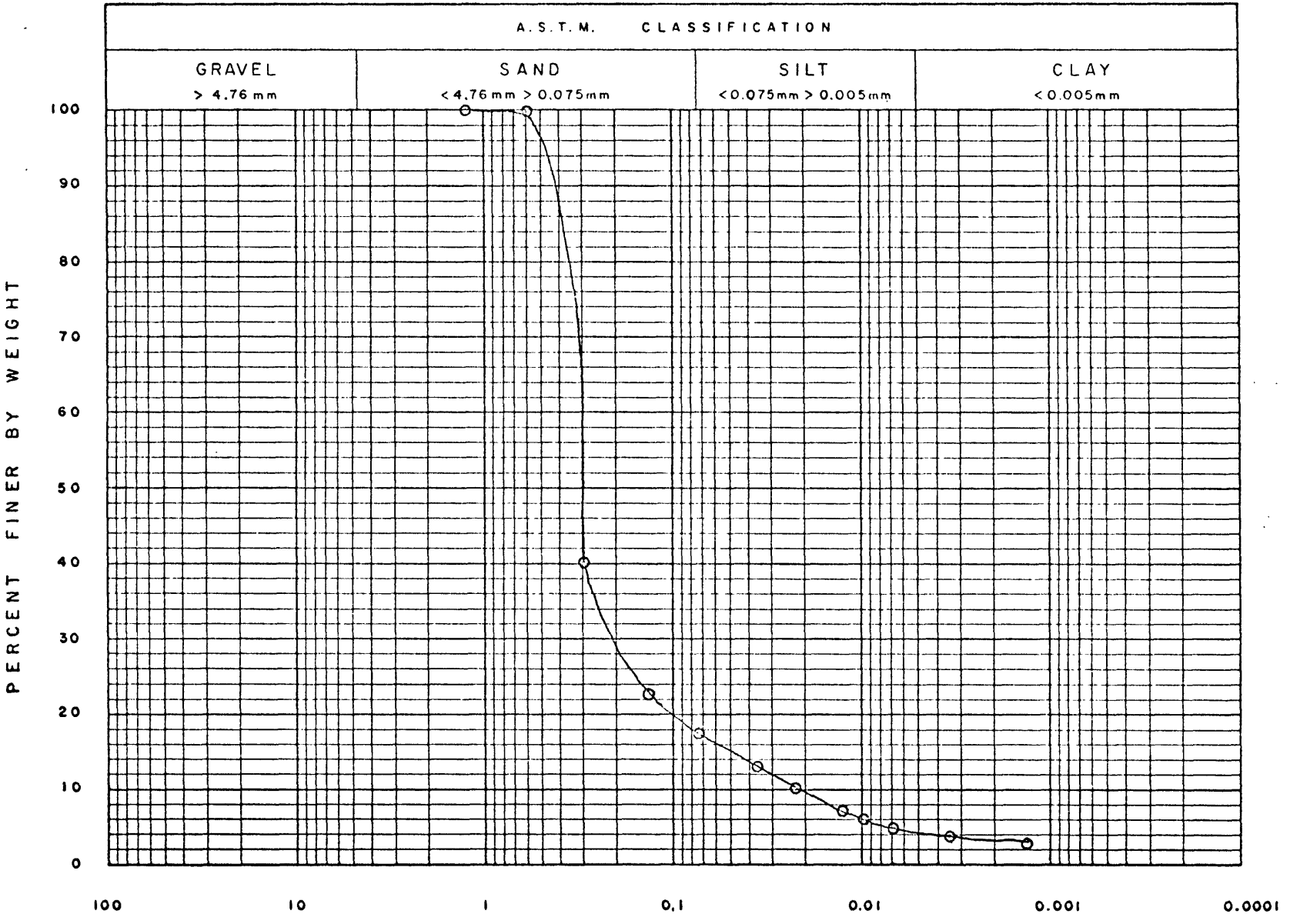

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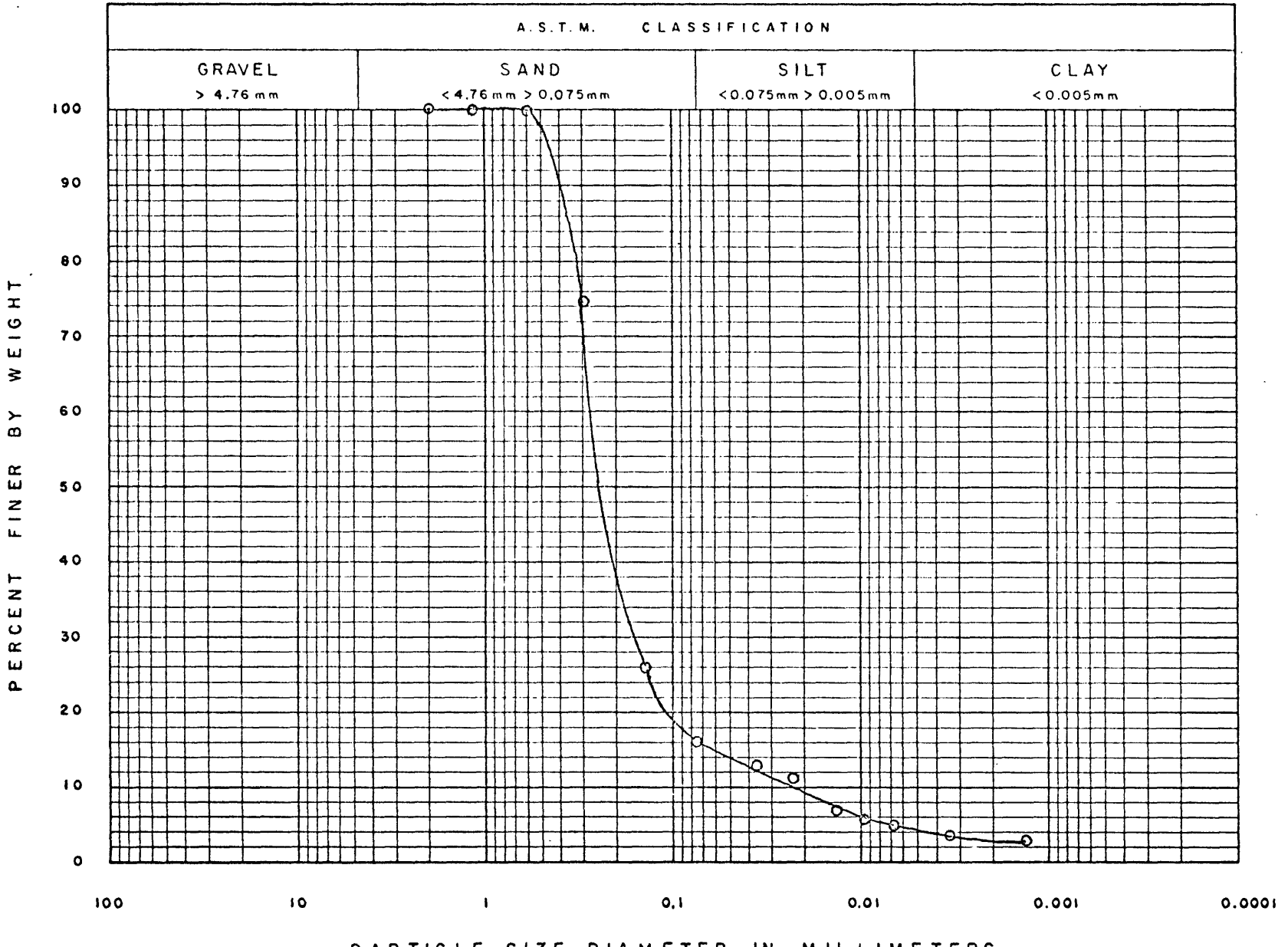

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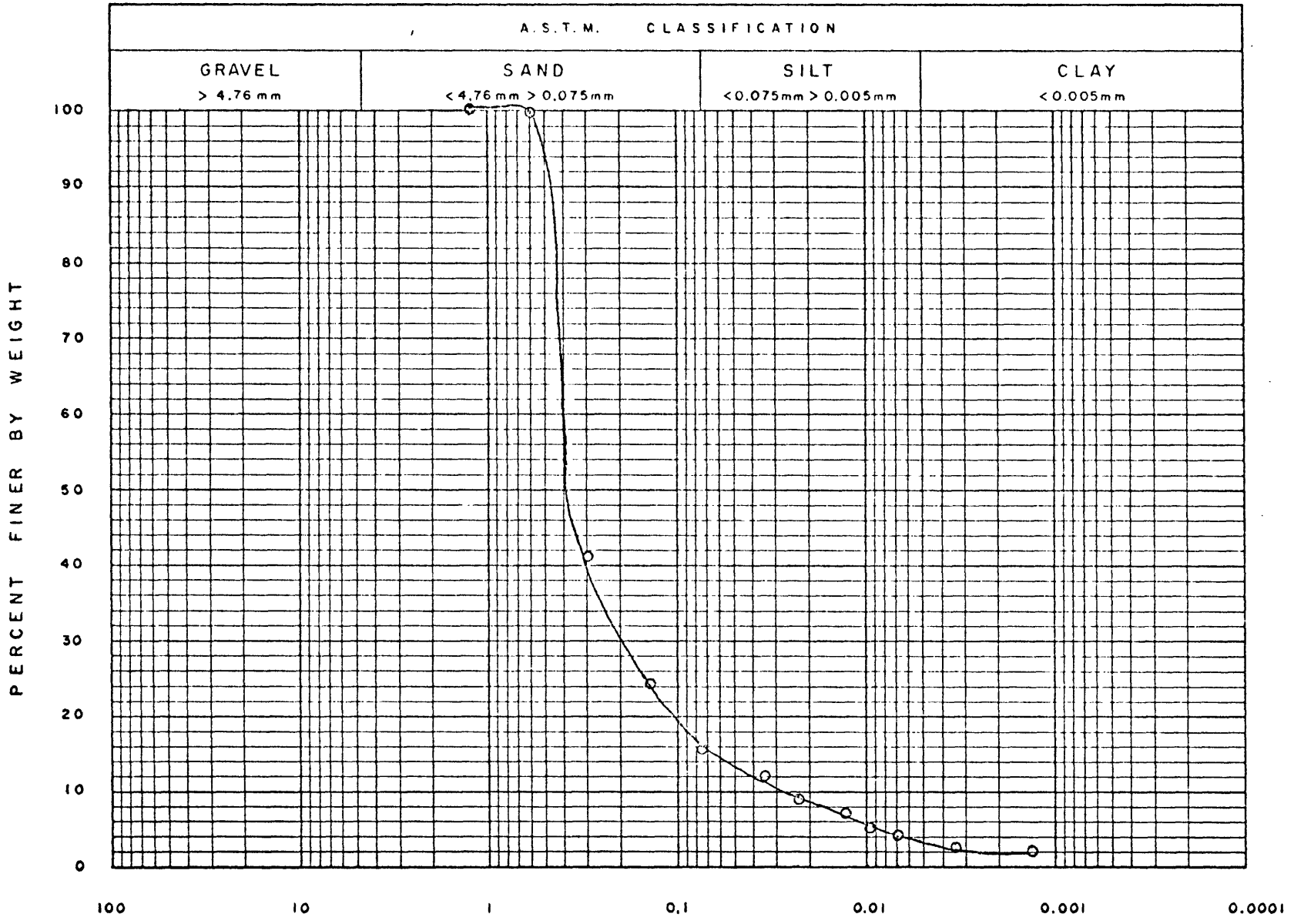

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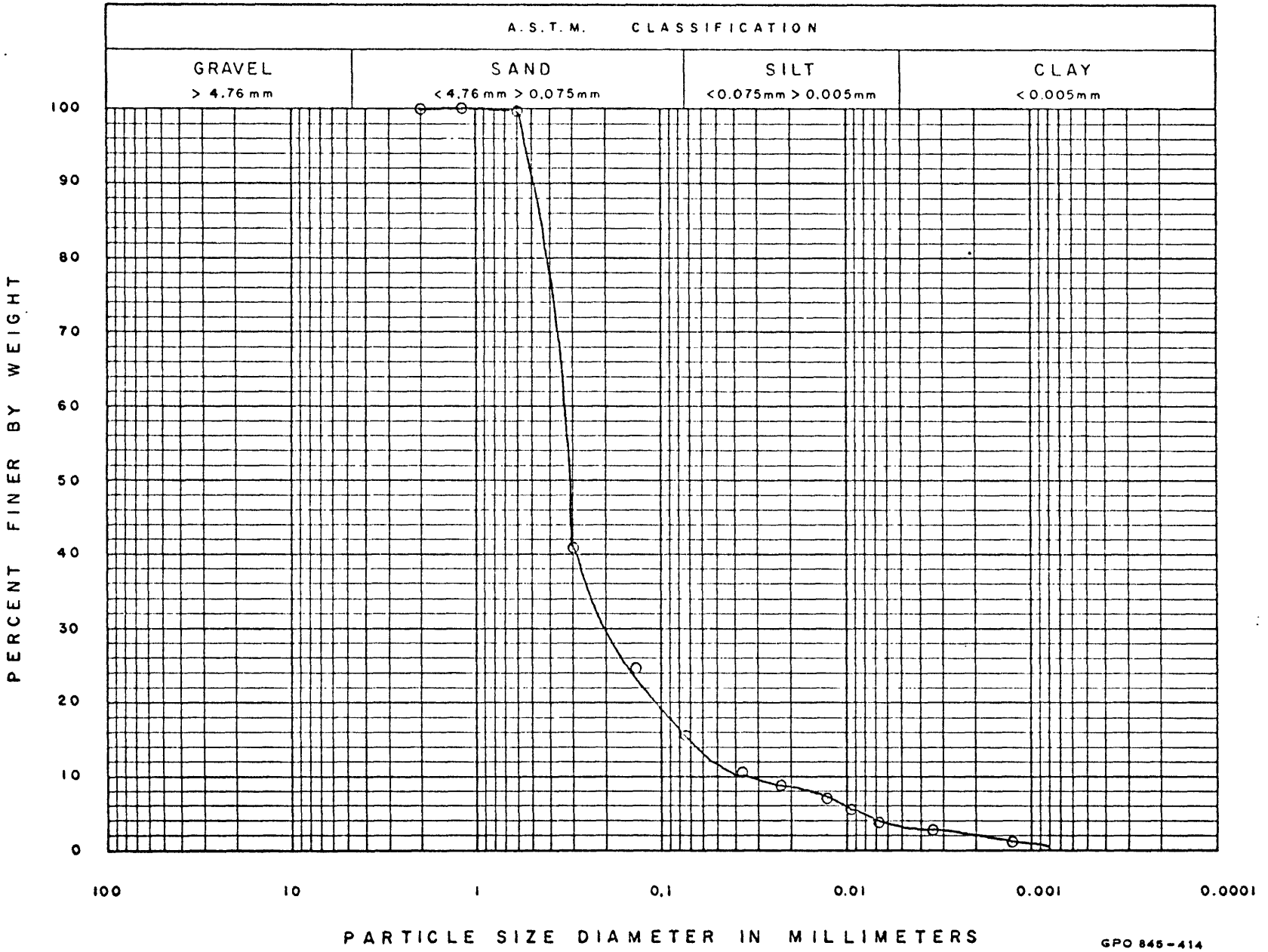

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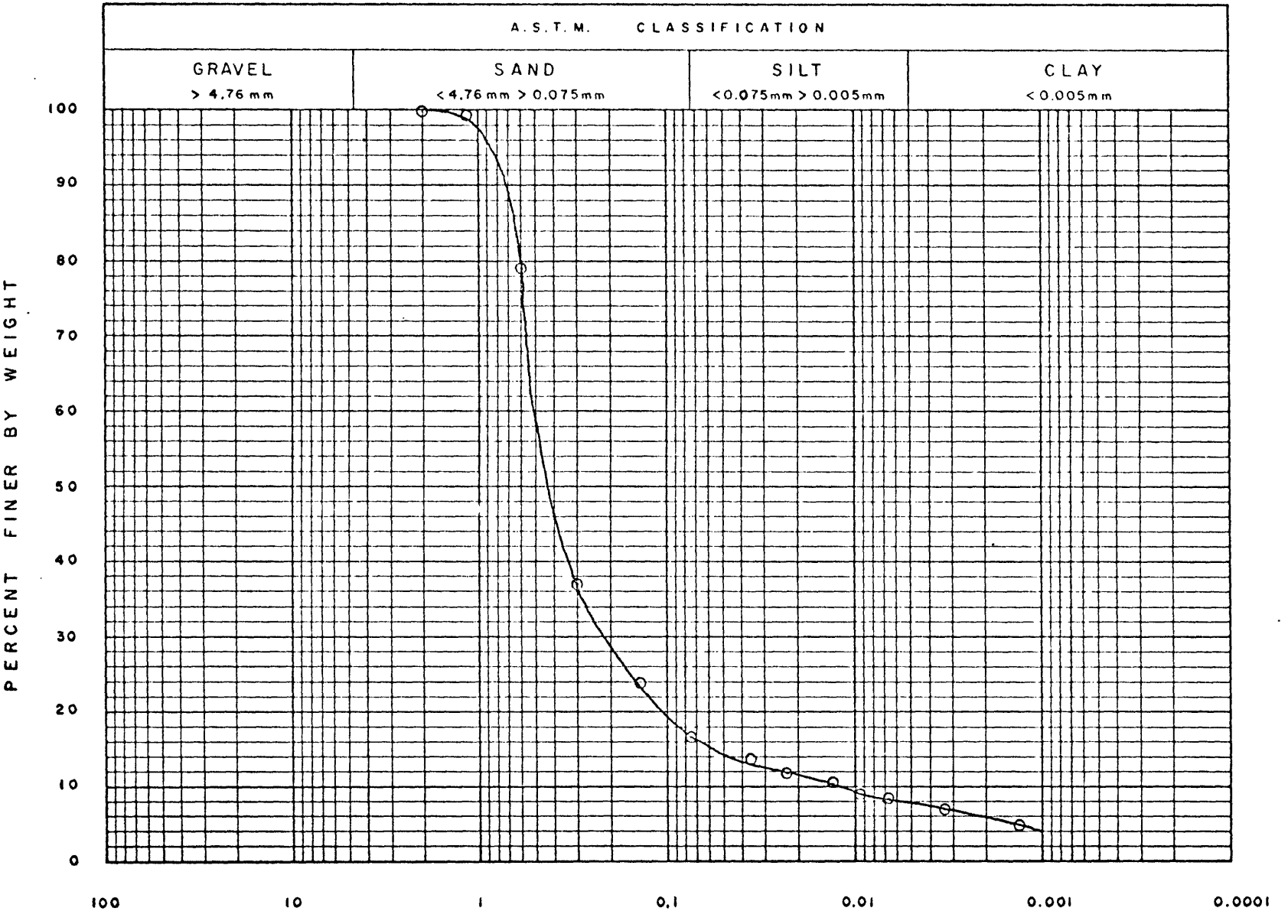

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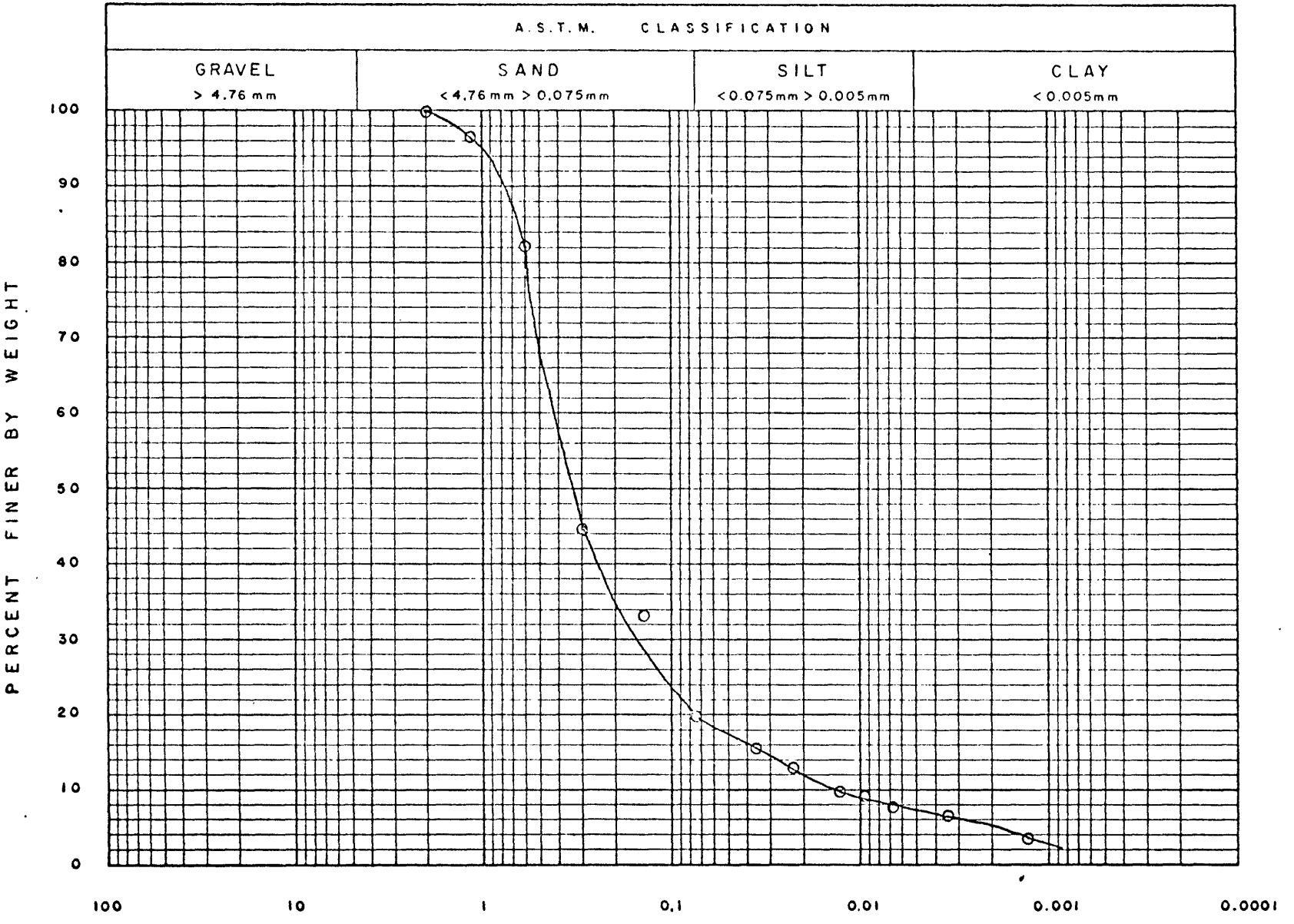

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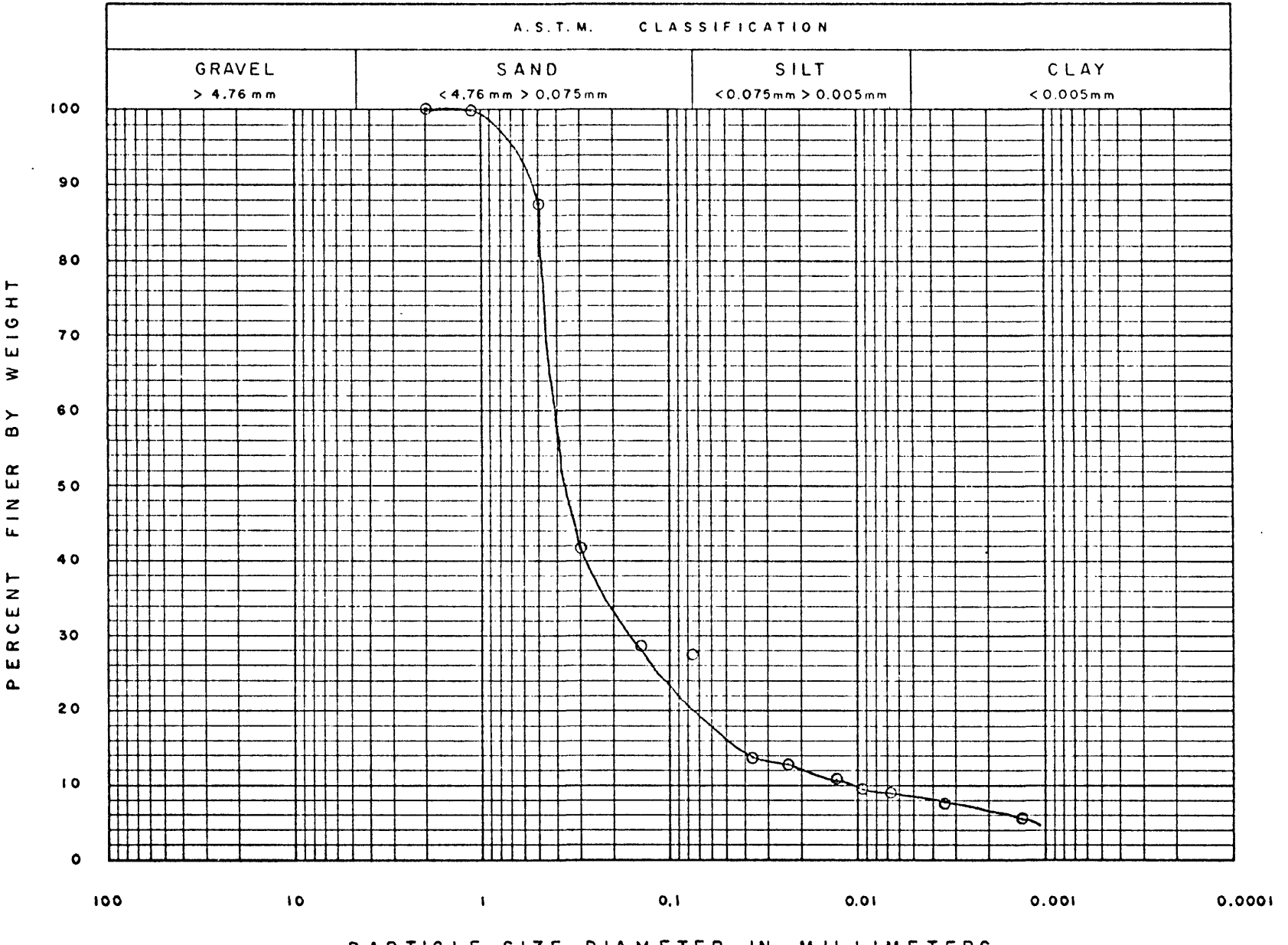

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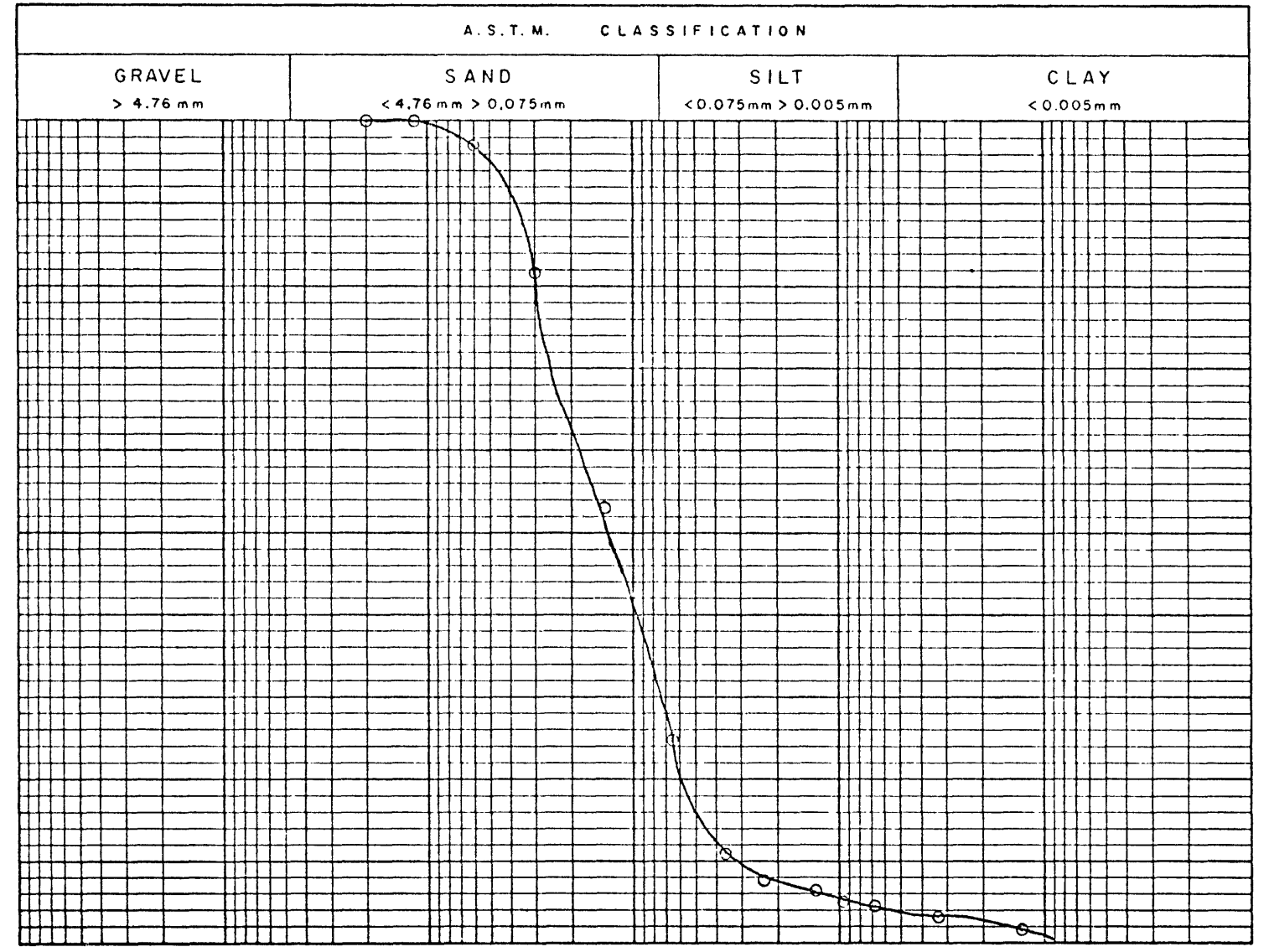

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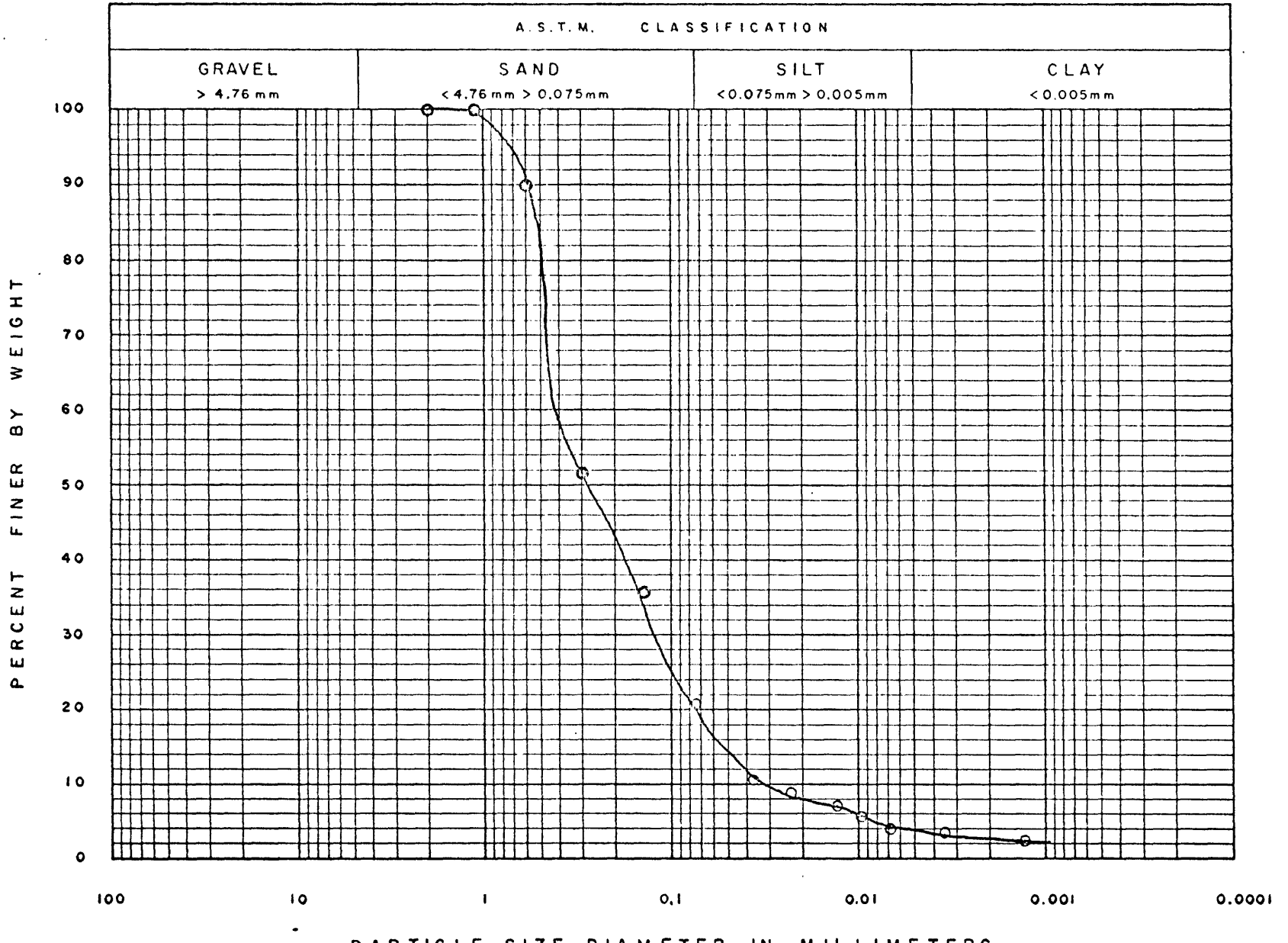

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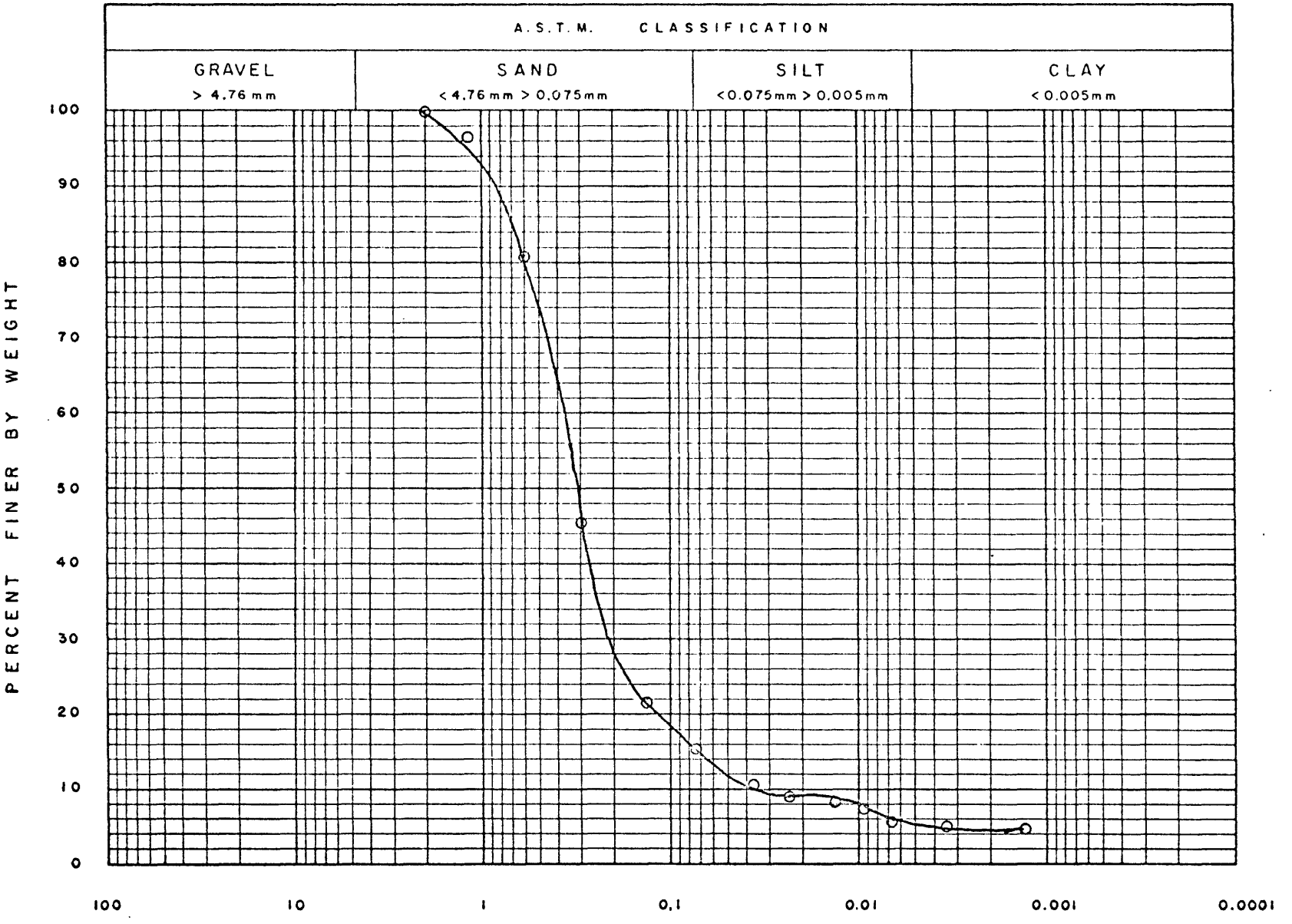

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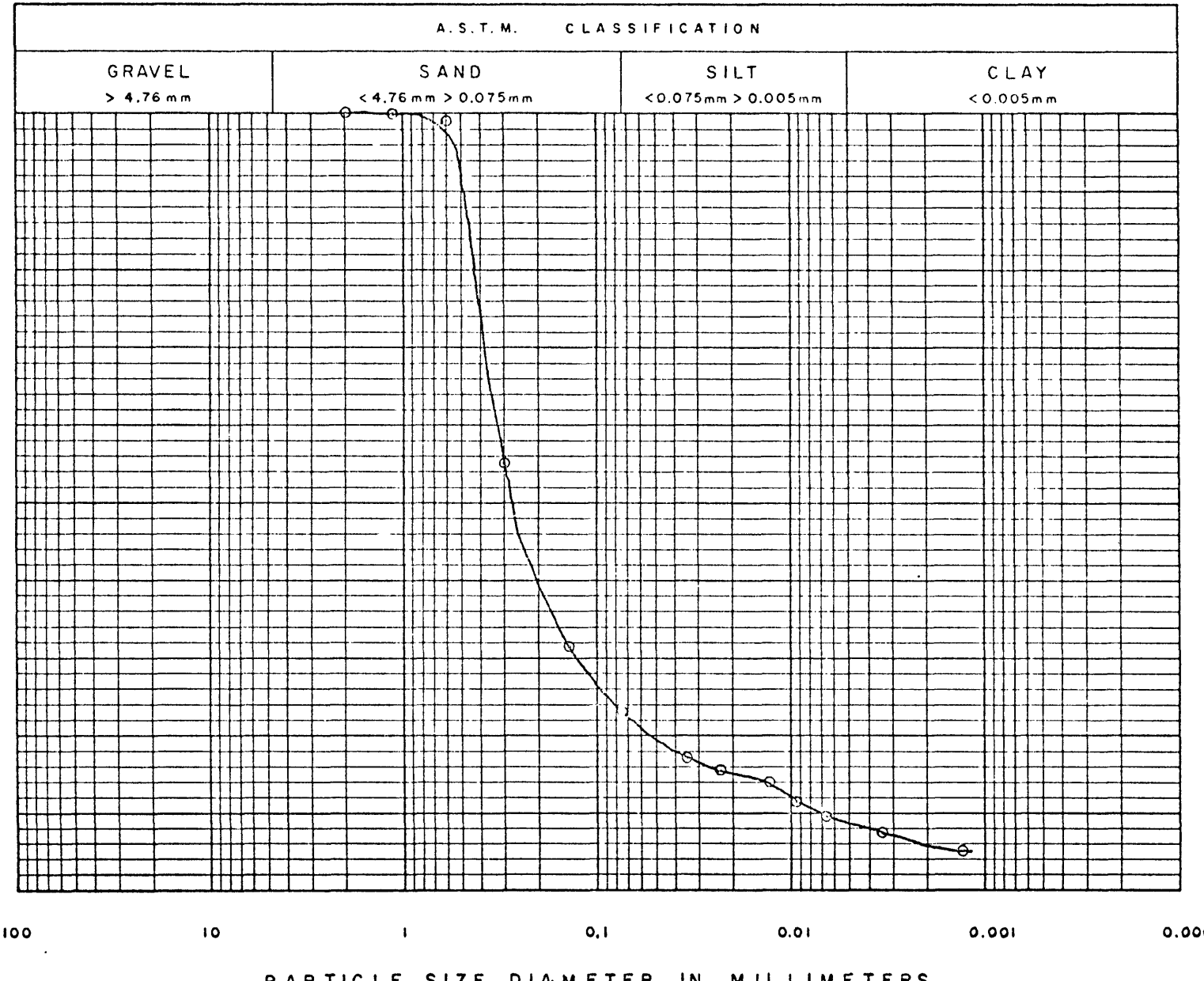

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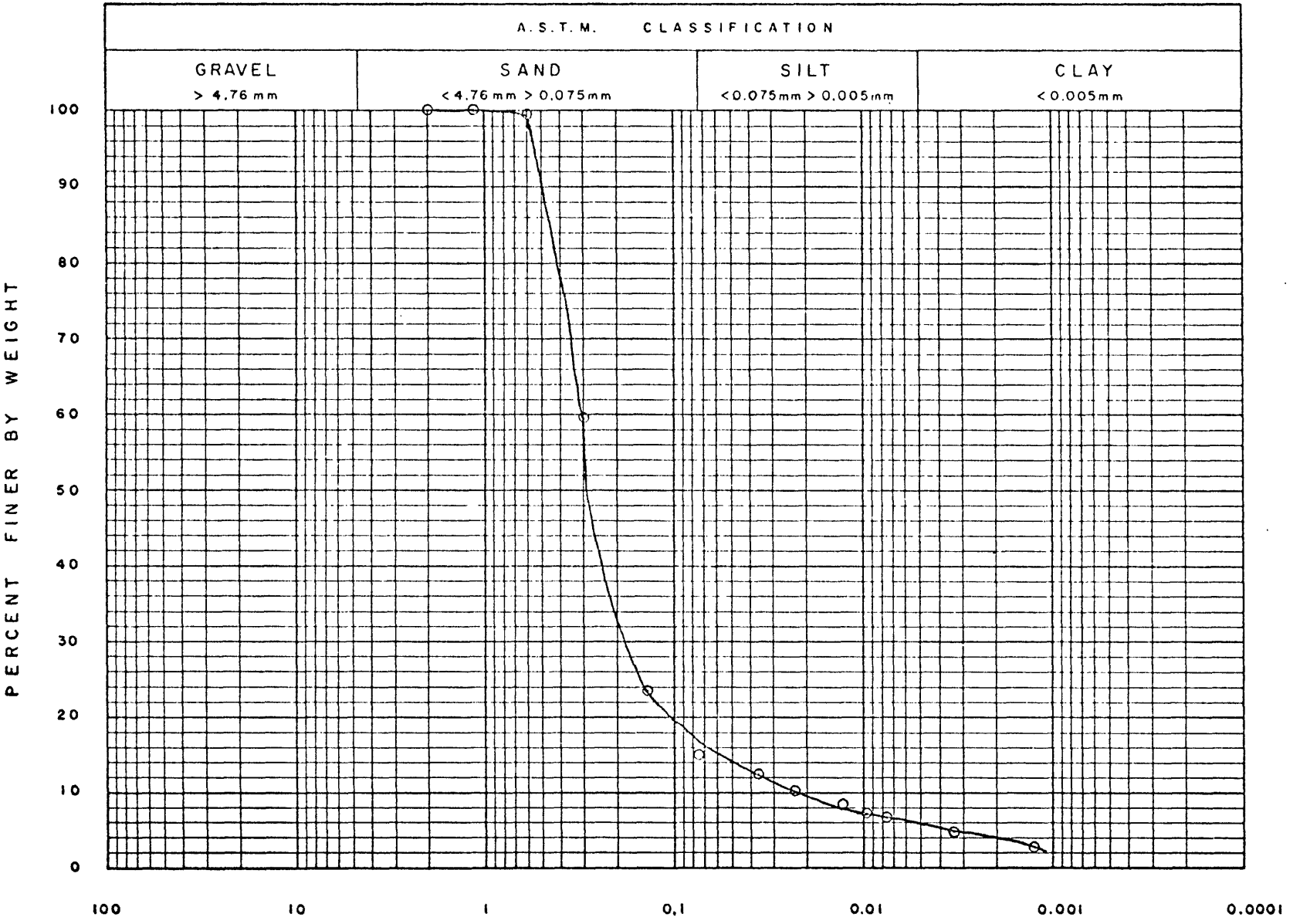

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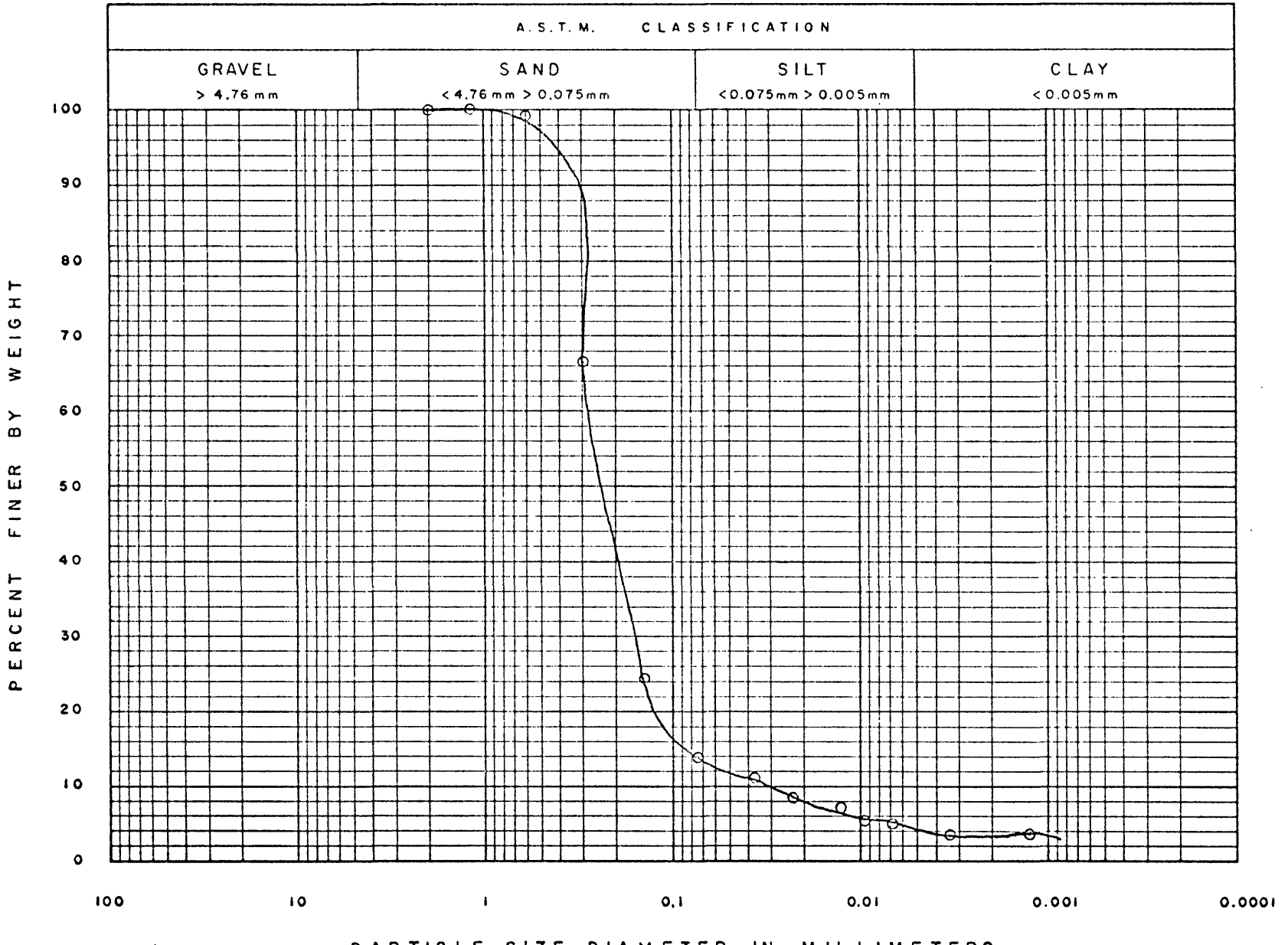

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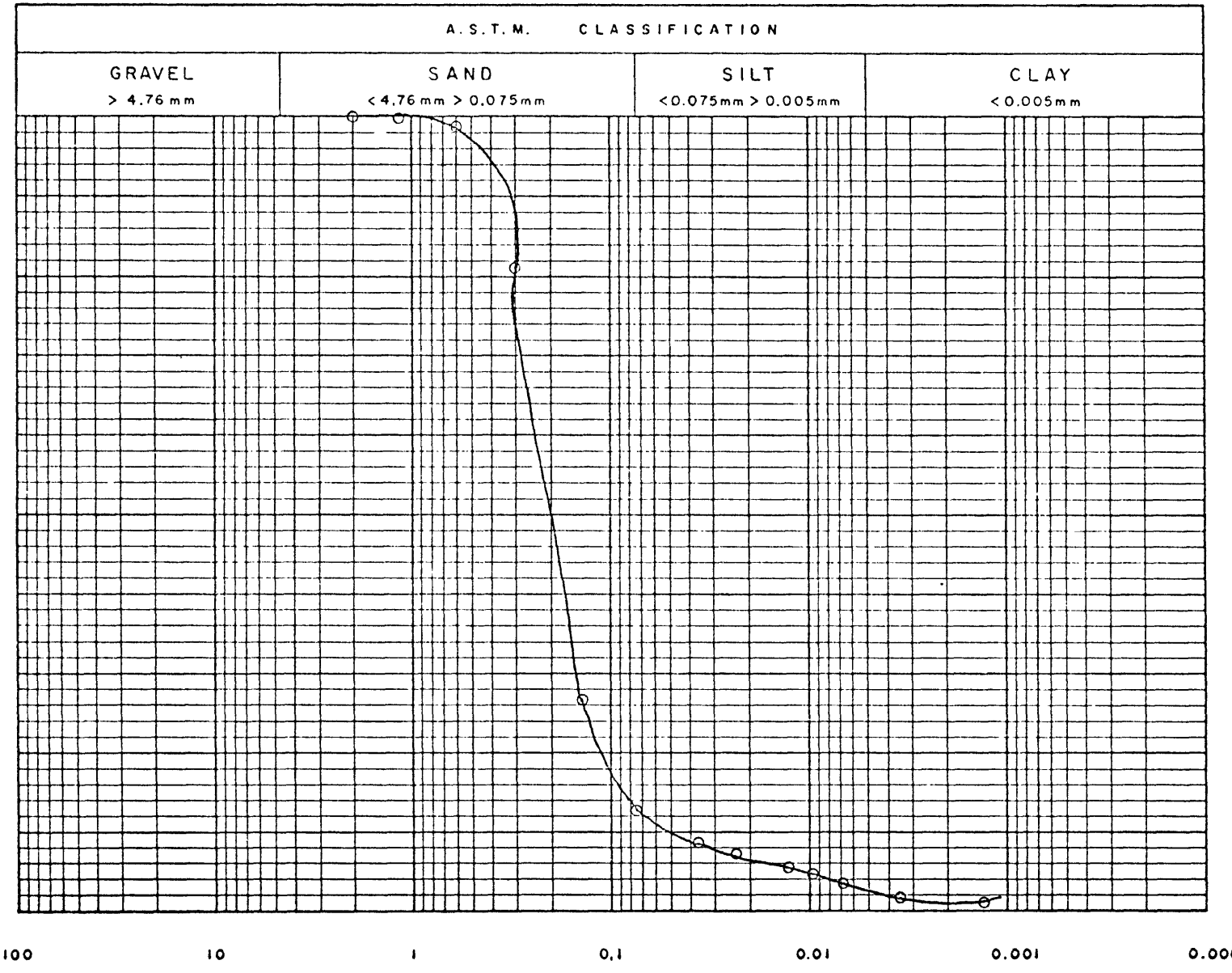

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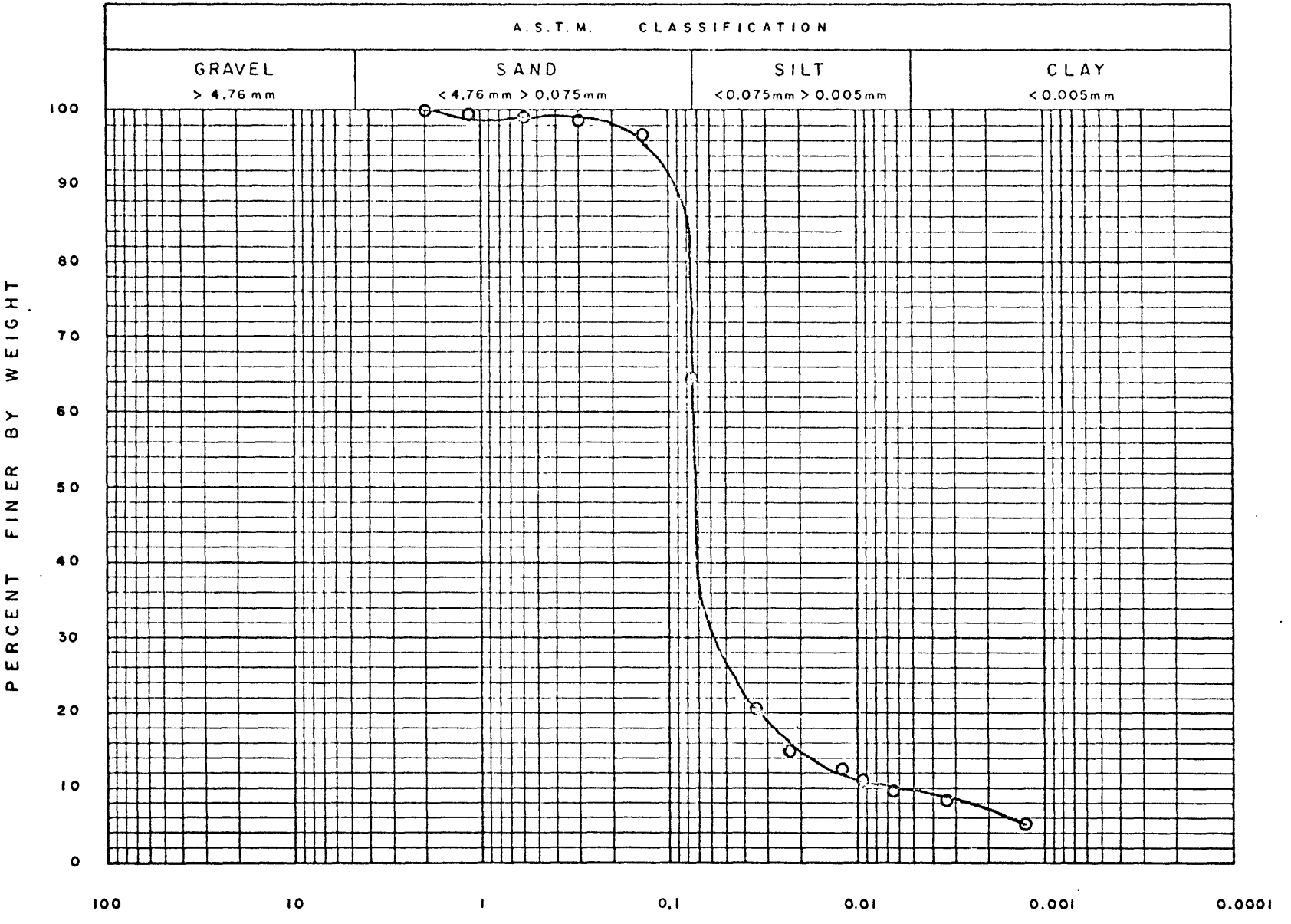

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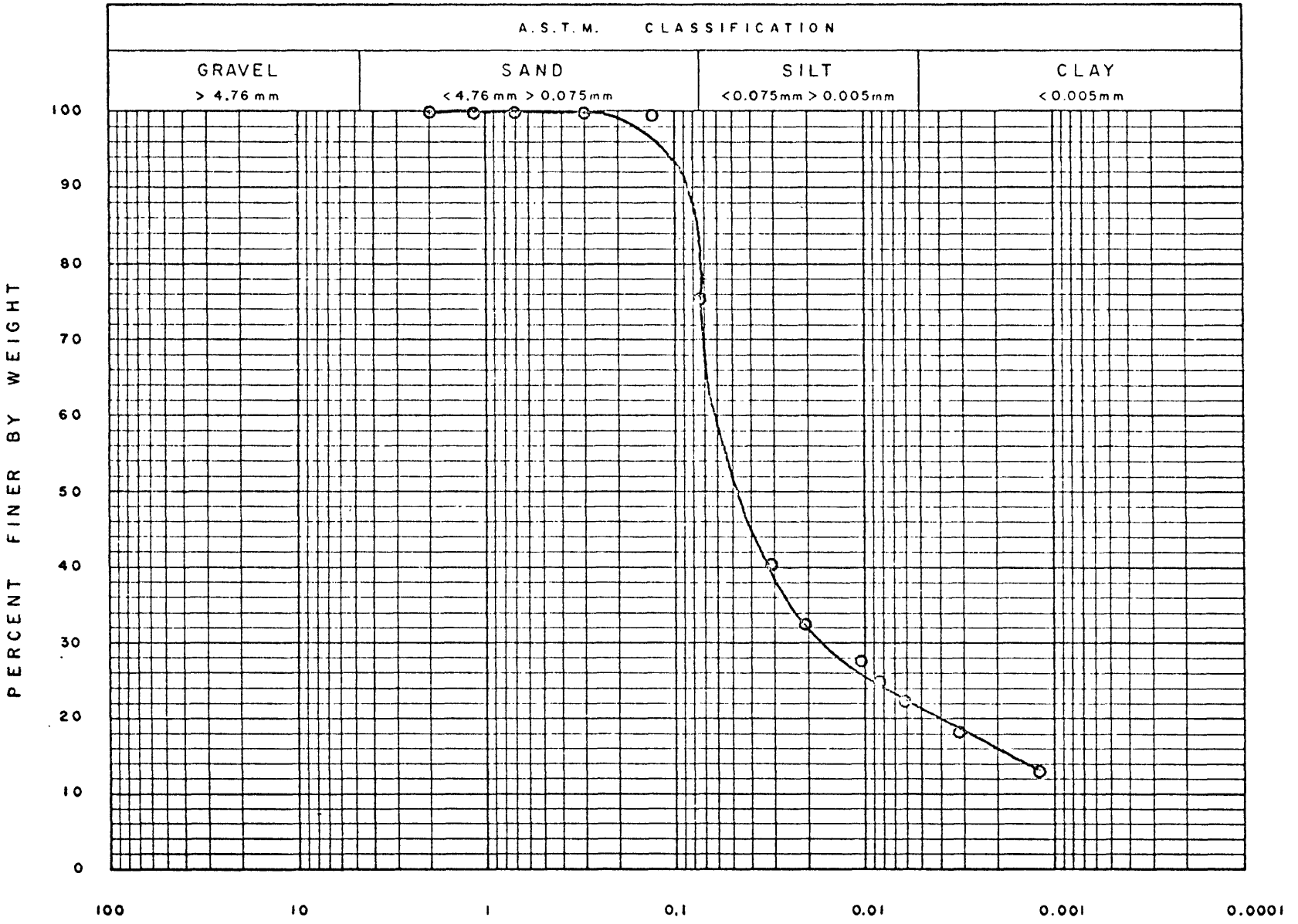

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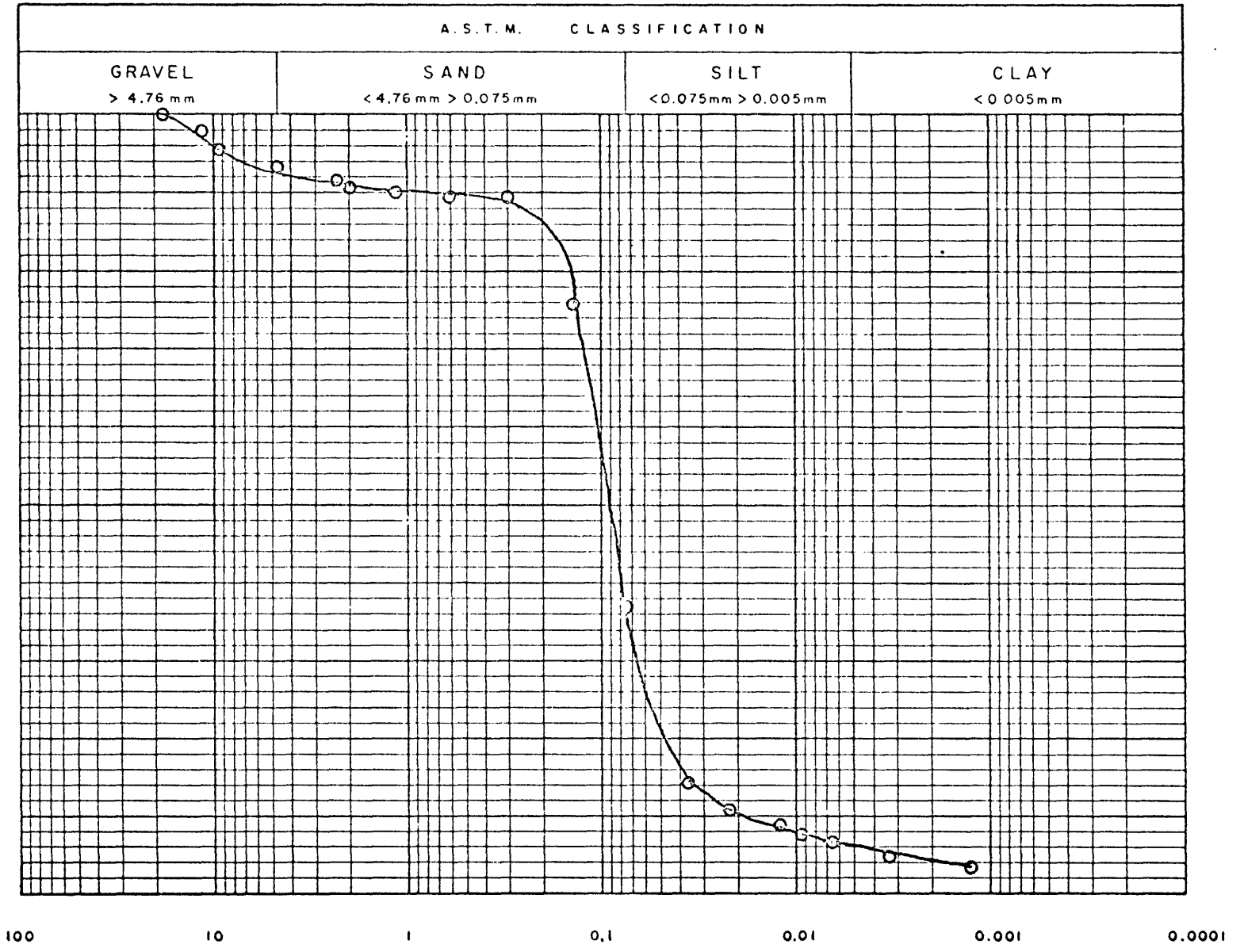

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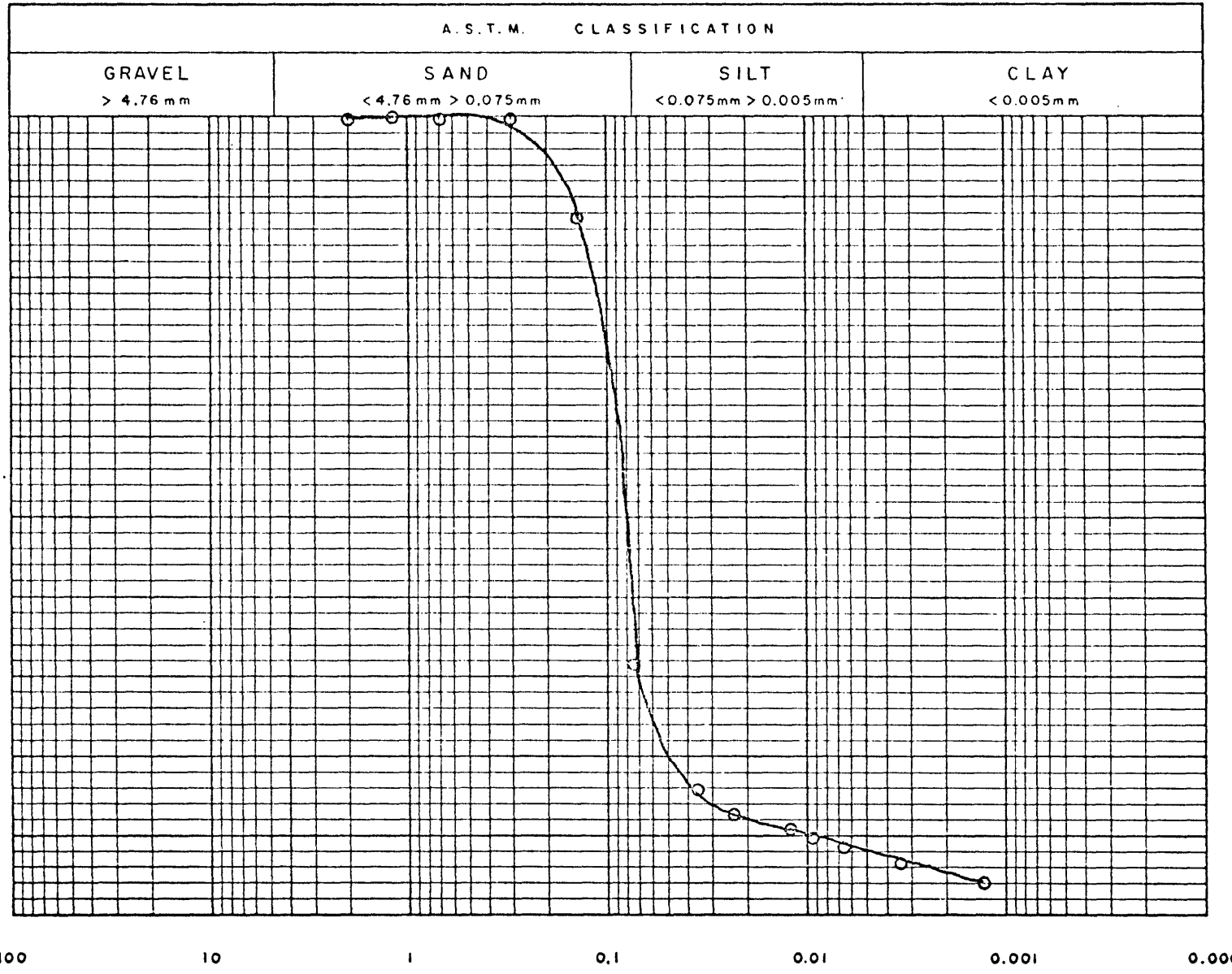

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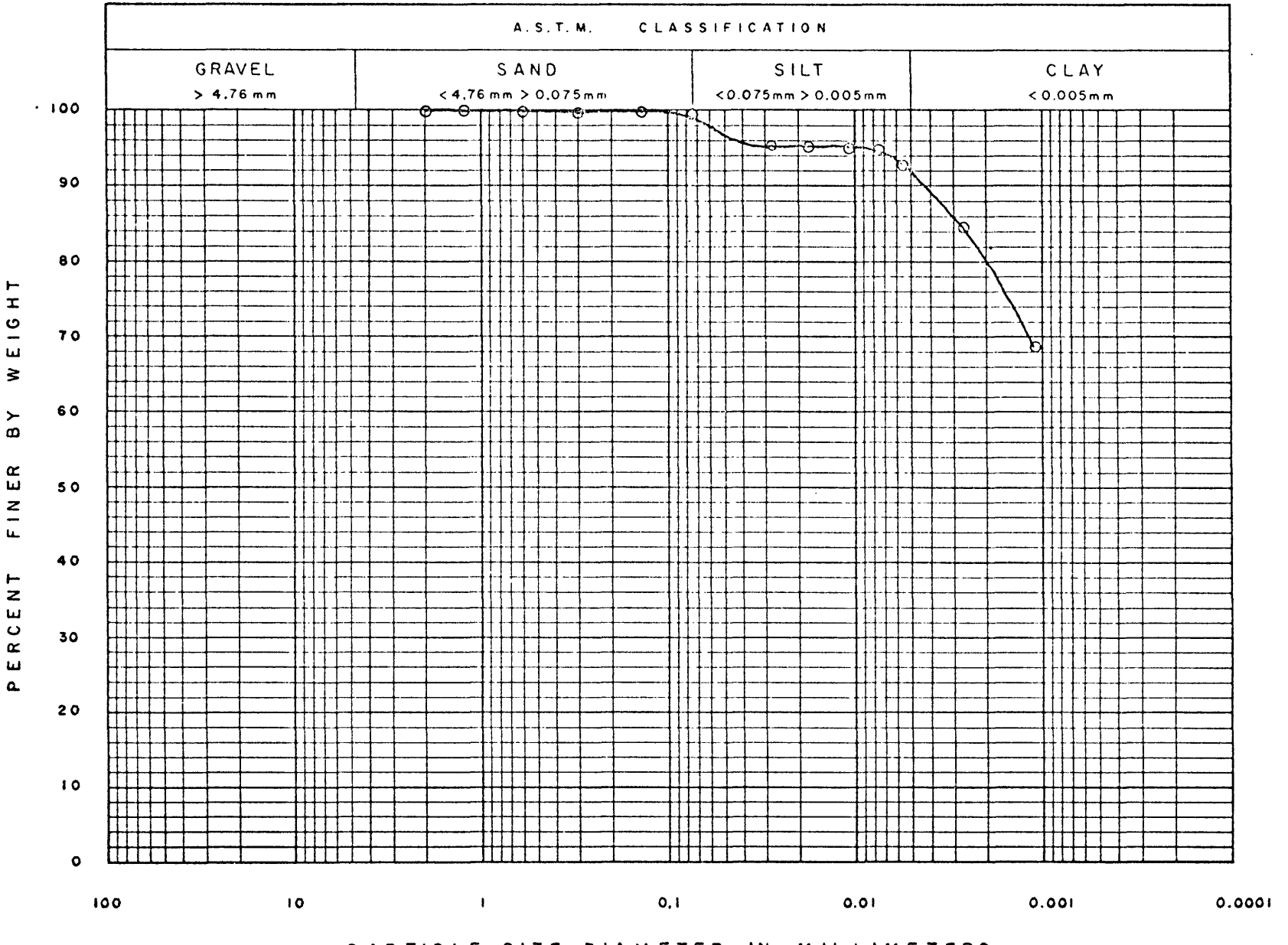

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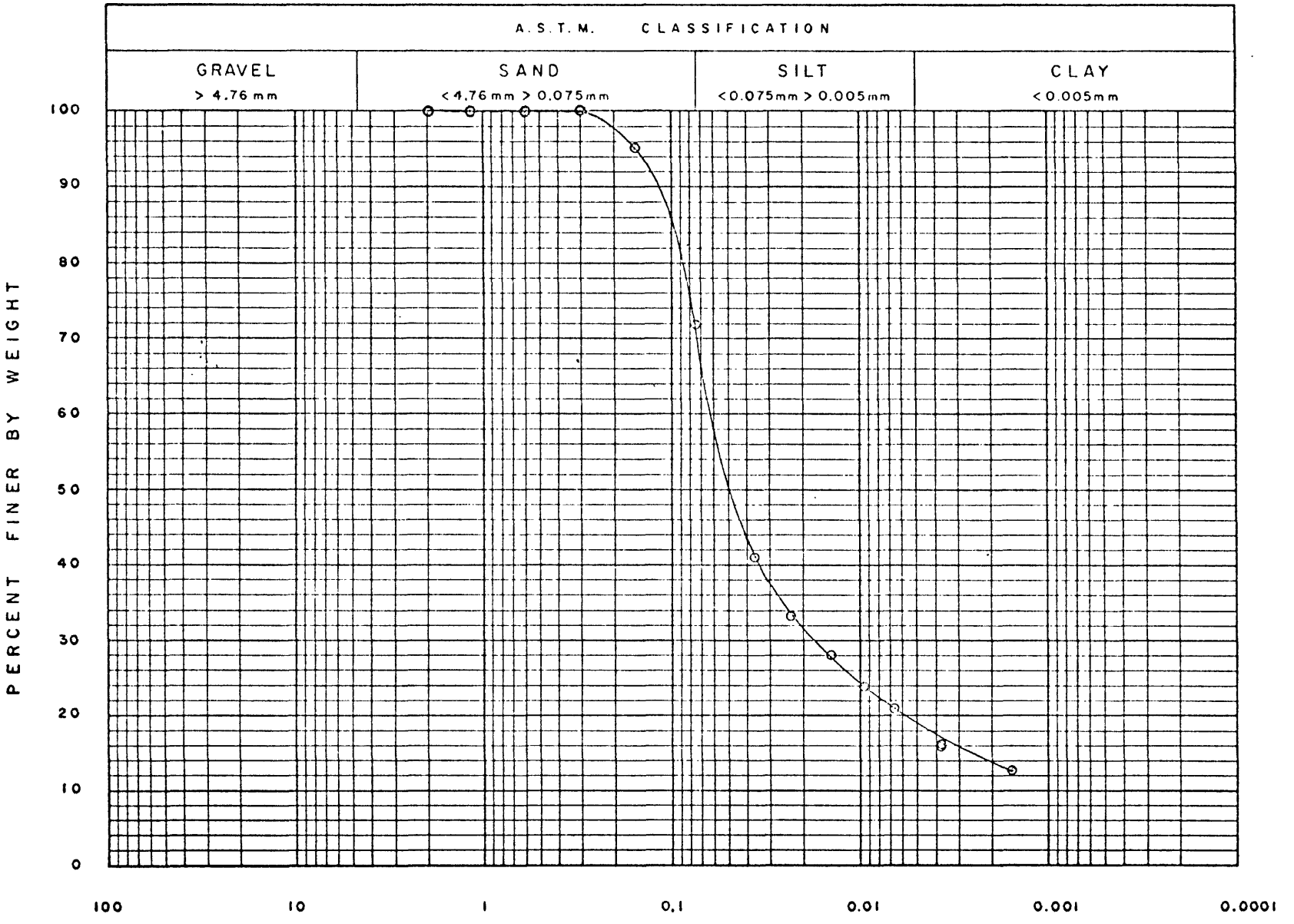

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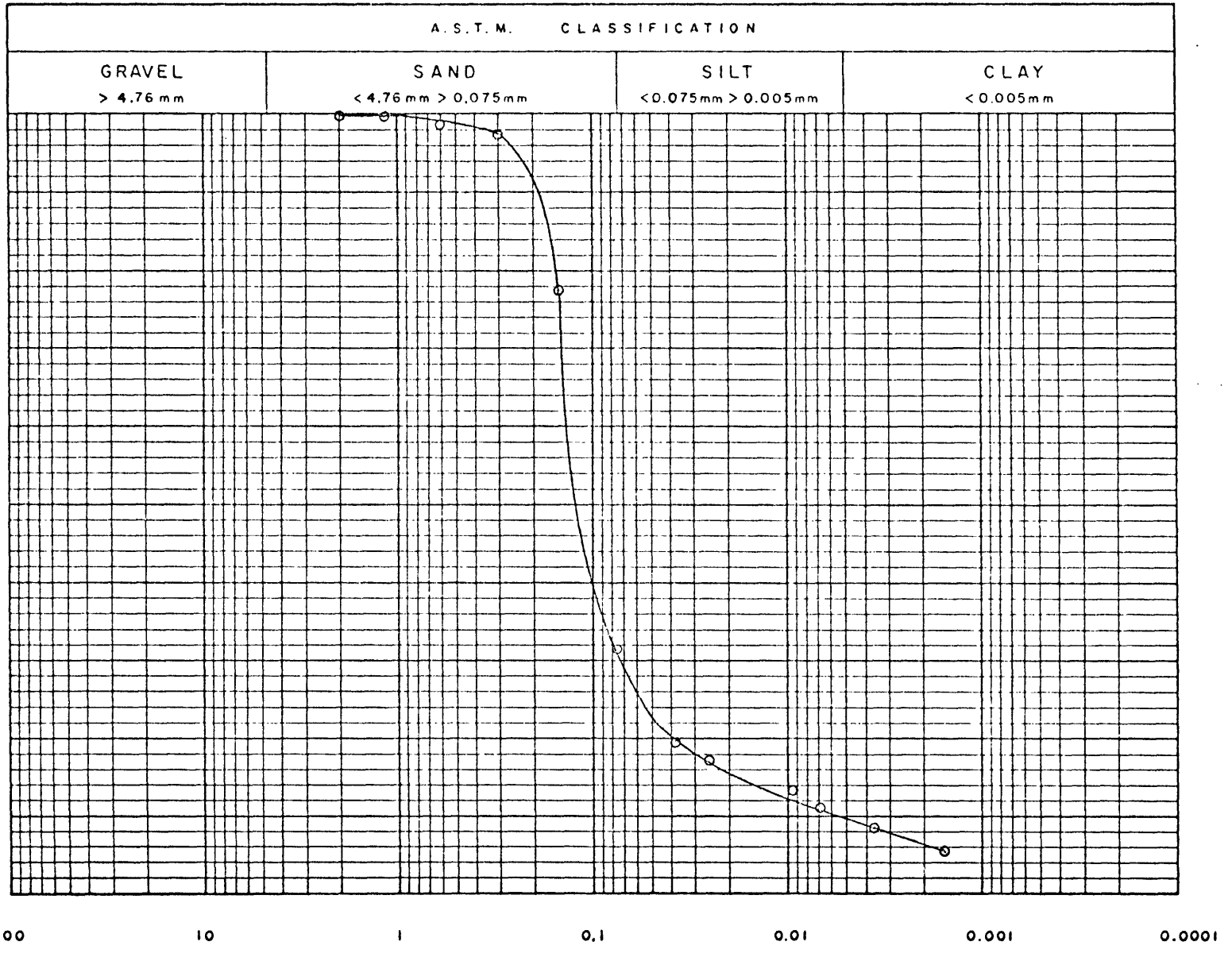

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PARTICLE SIZE DISTRIBUTION CURVE

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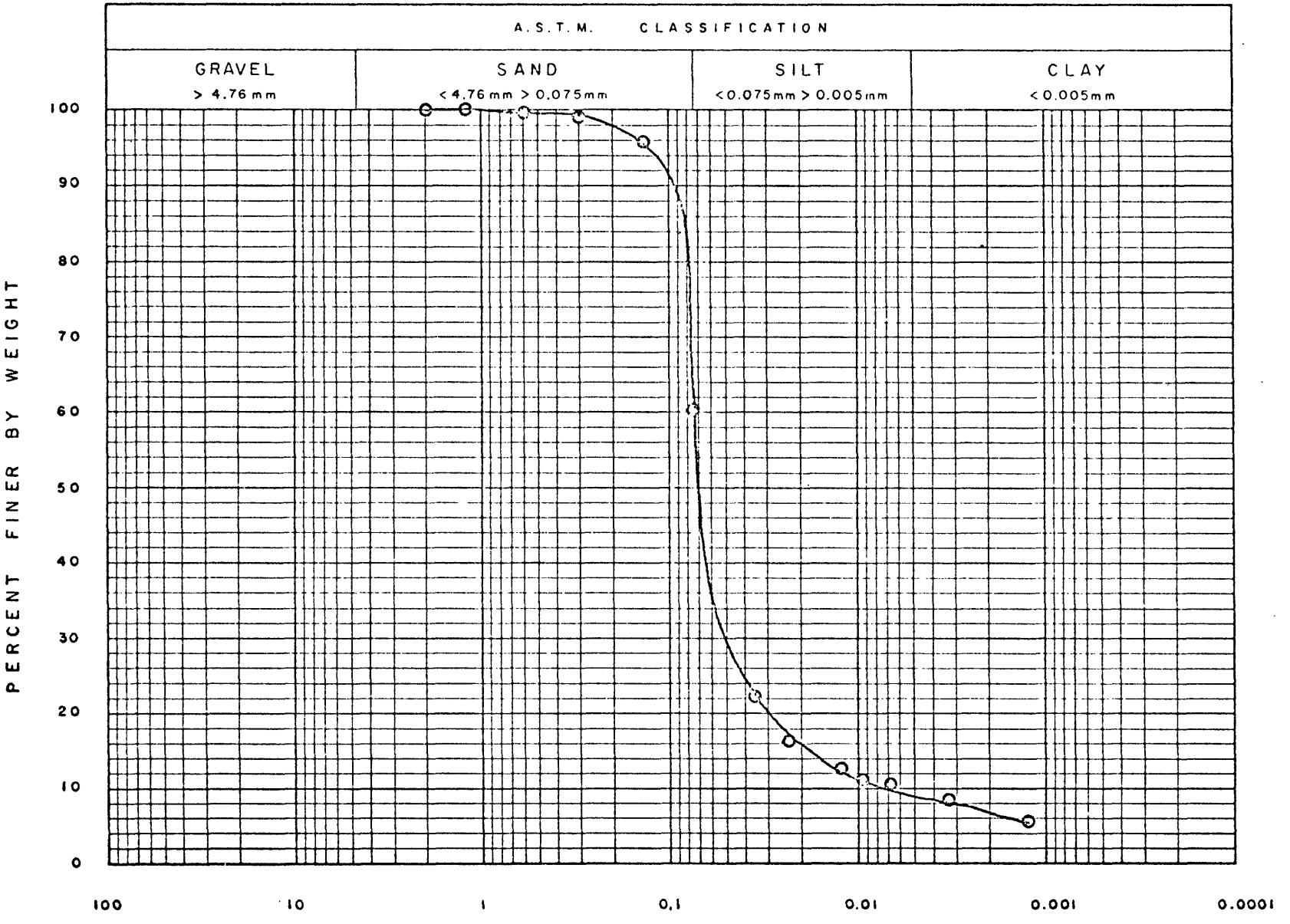

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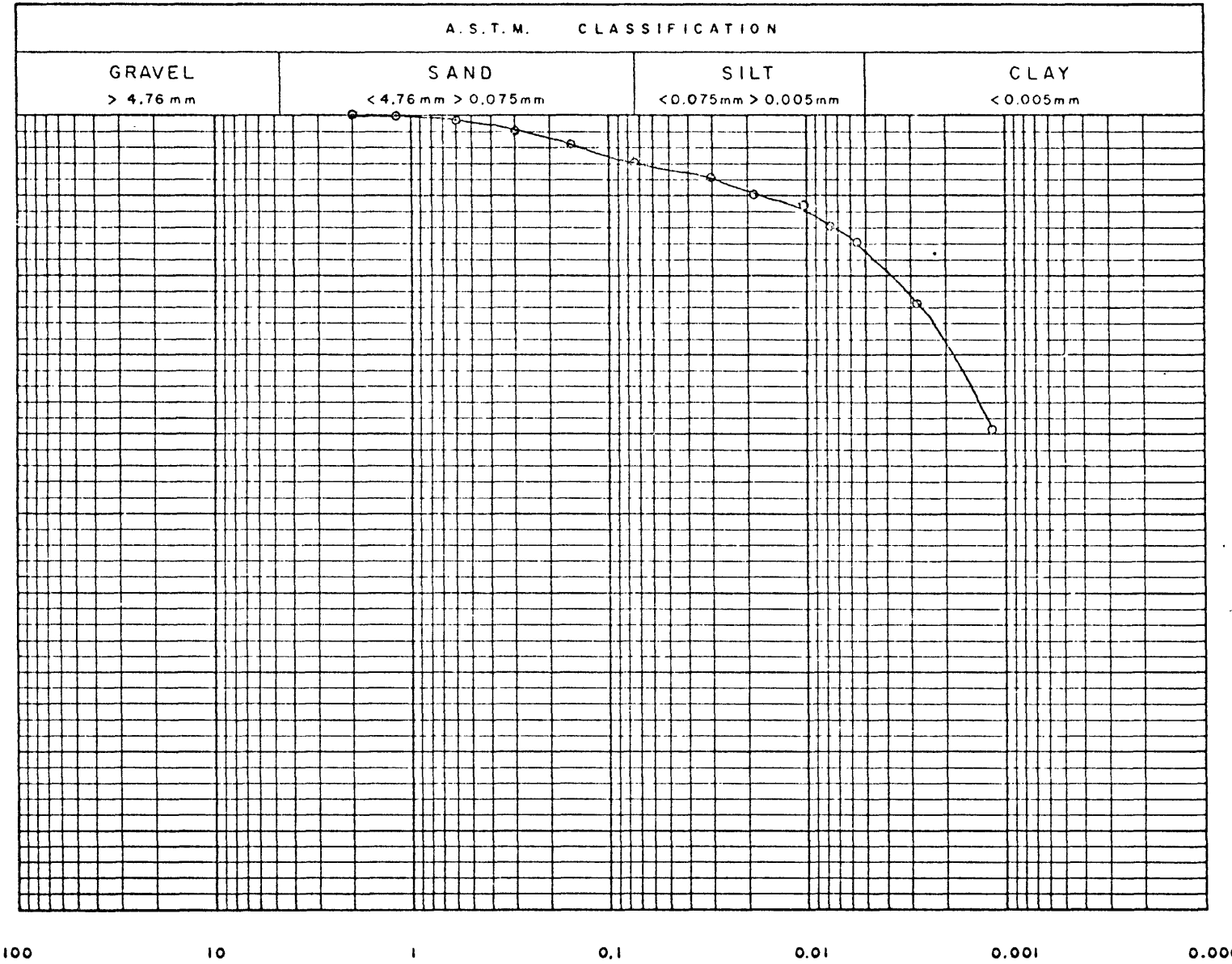
PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 22.40-22.49 m



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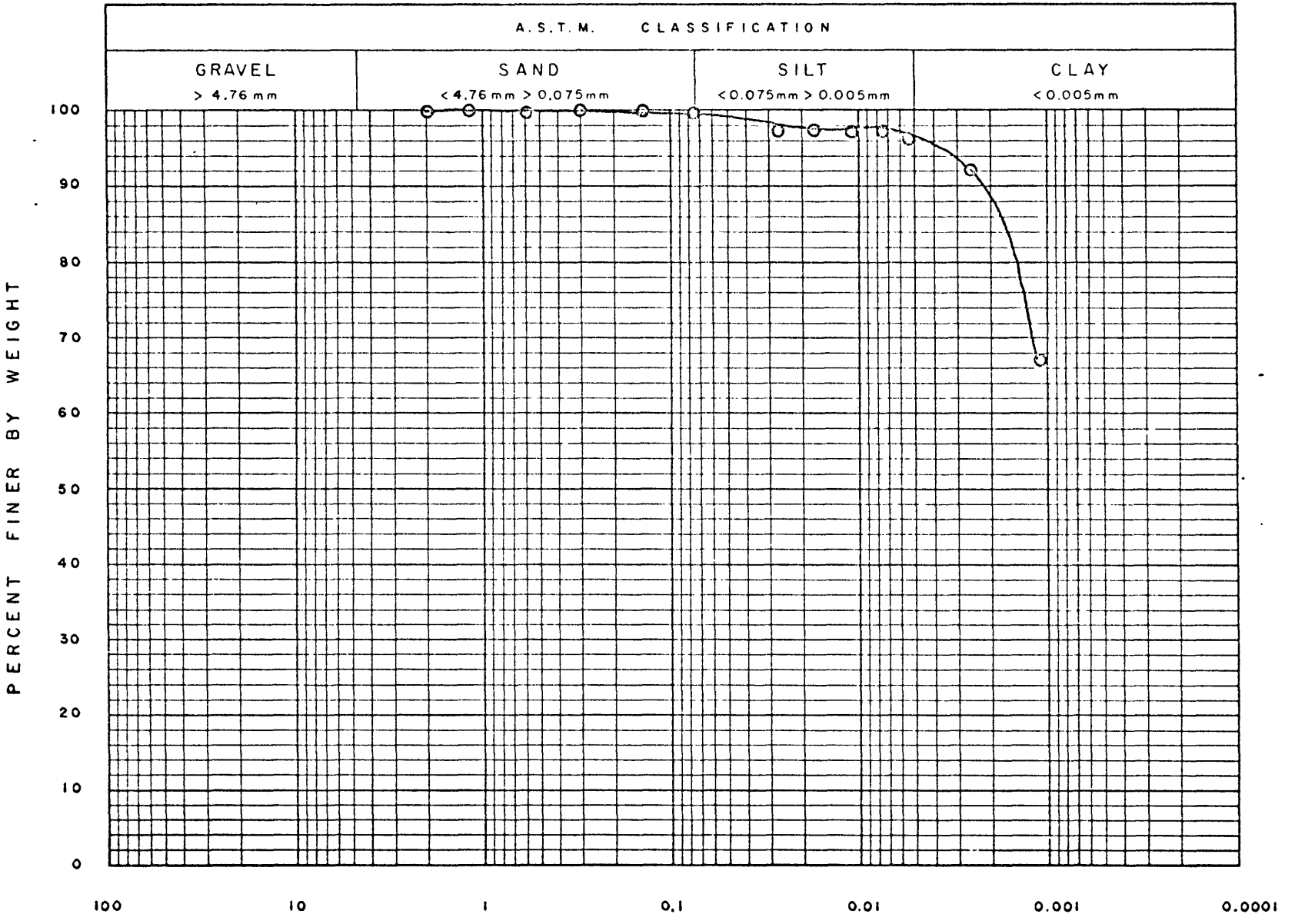
PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 22.95-23.04 m



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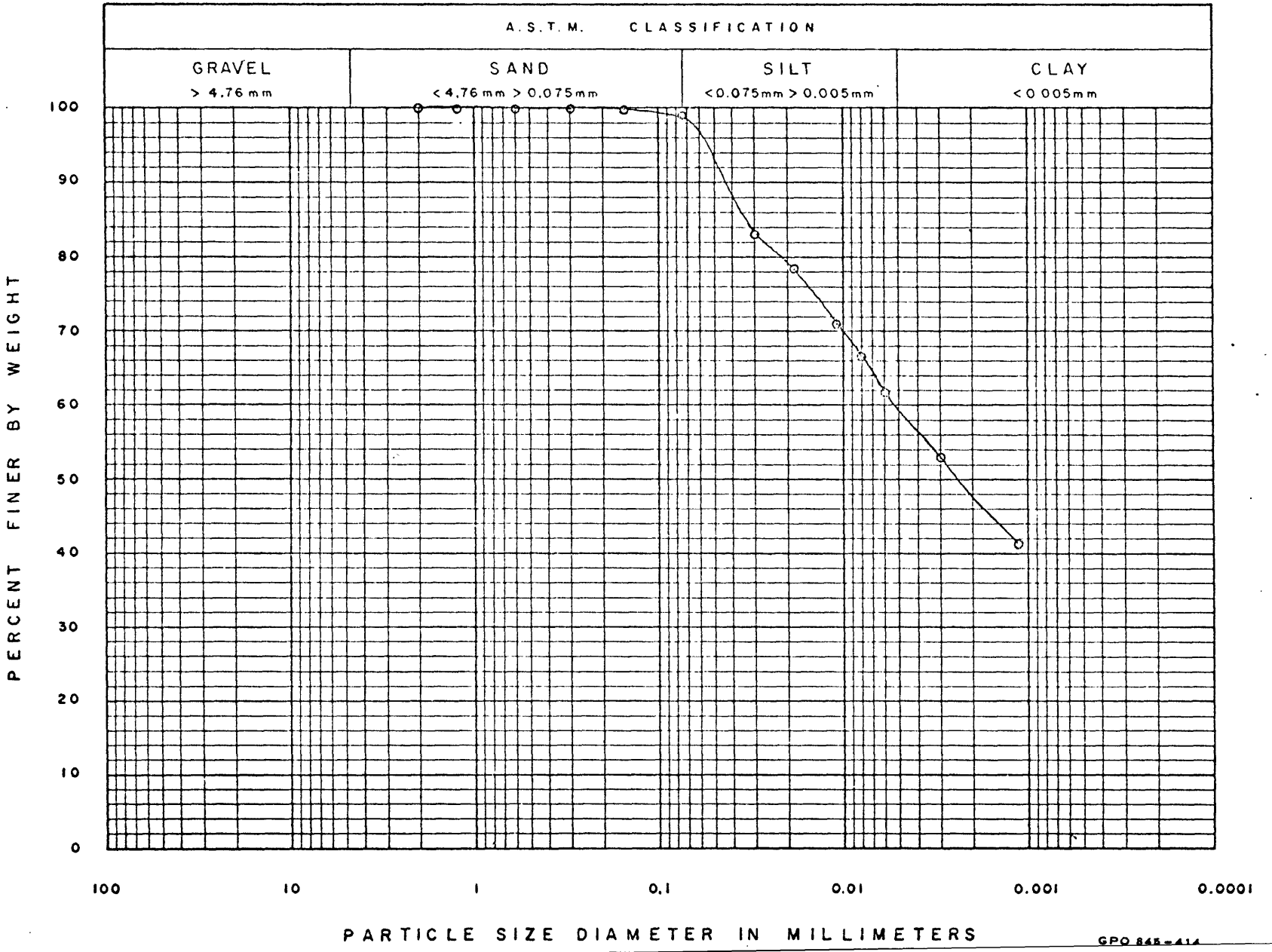
PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 23.41-23.47 m



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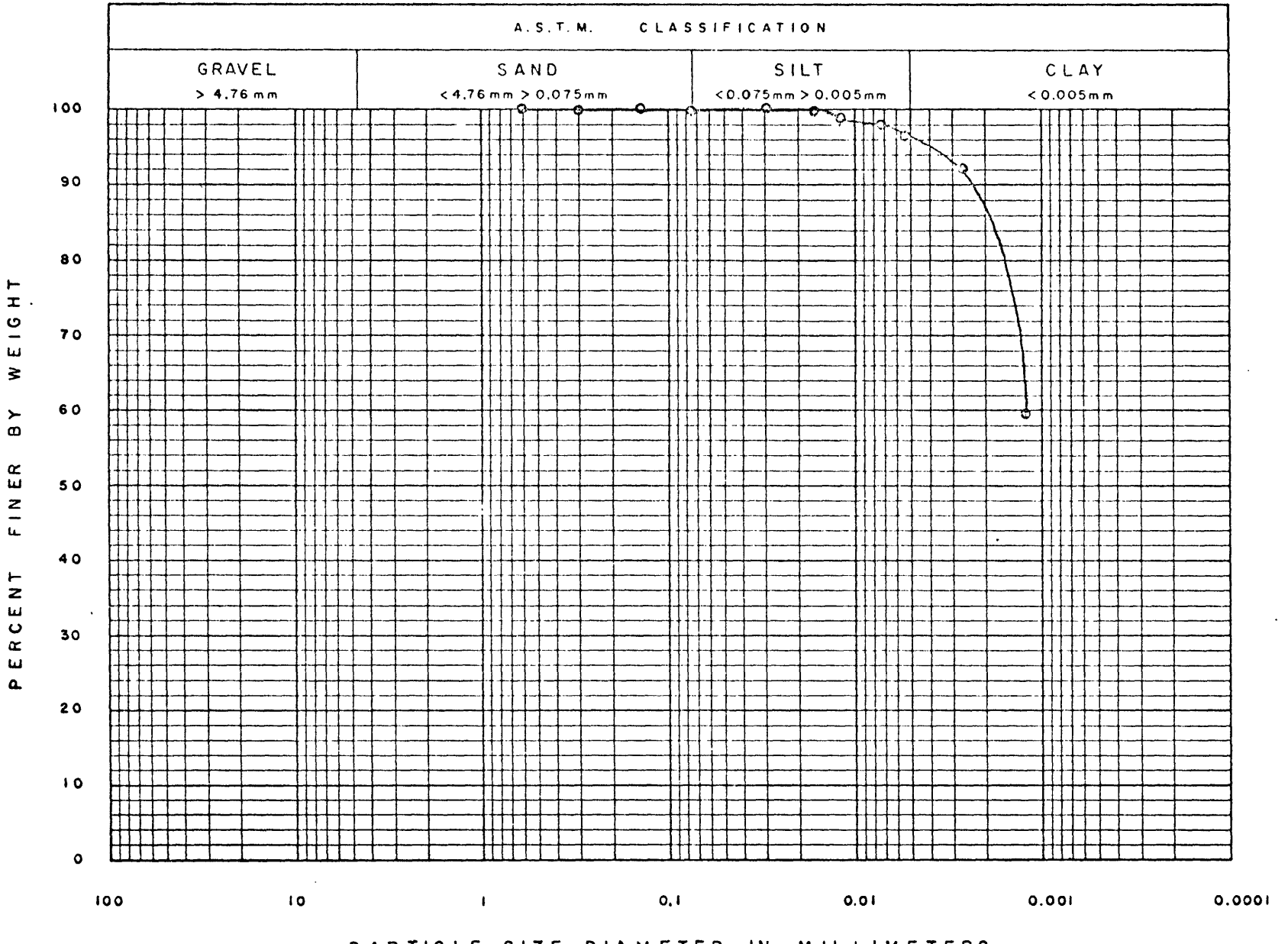
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 23.83-23.93 m



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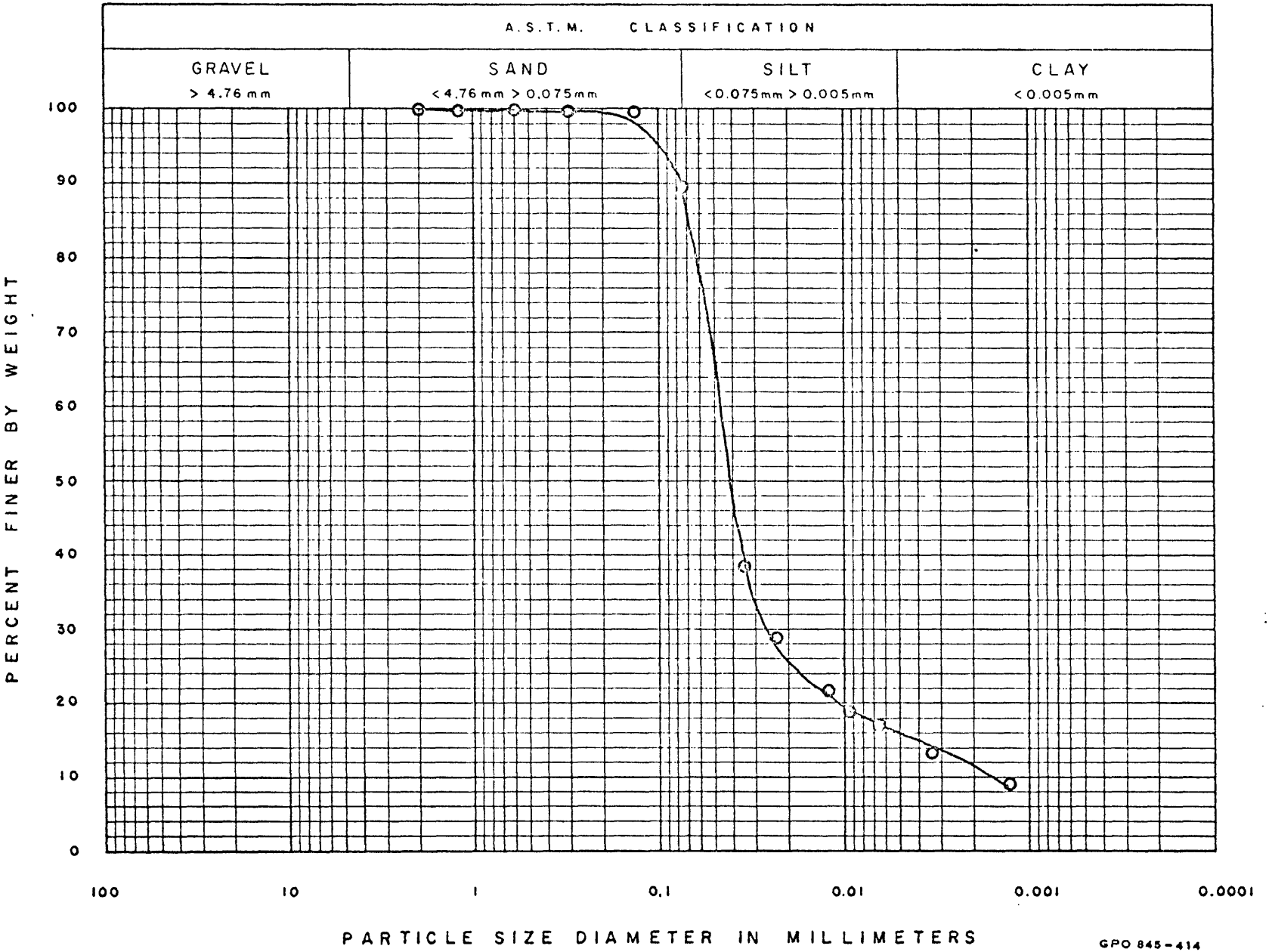
PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 24.23-24.32 m



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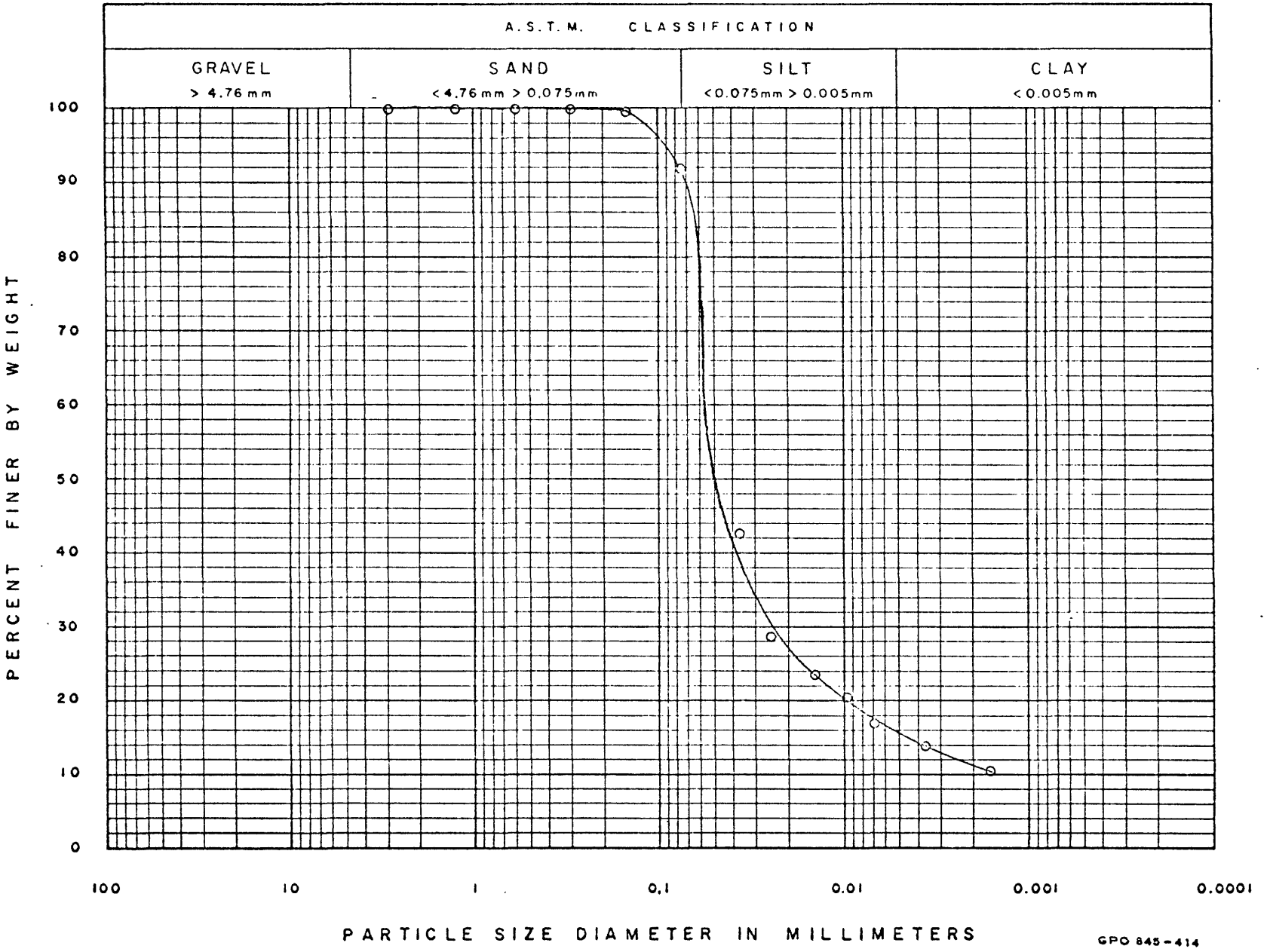
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 24.54-24.72 m



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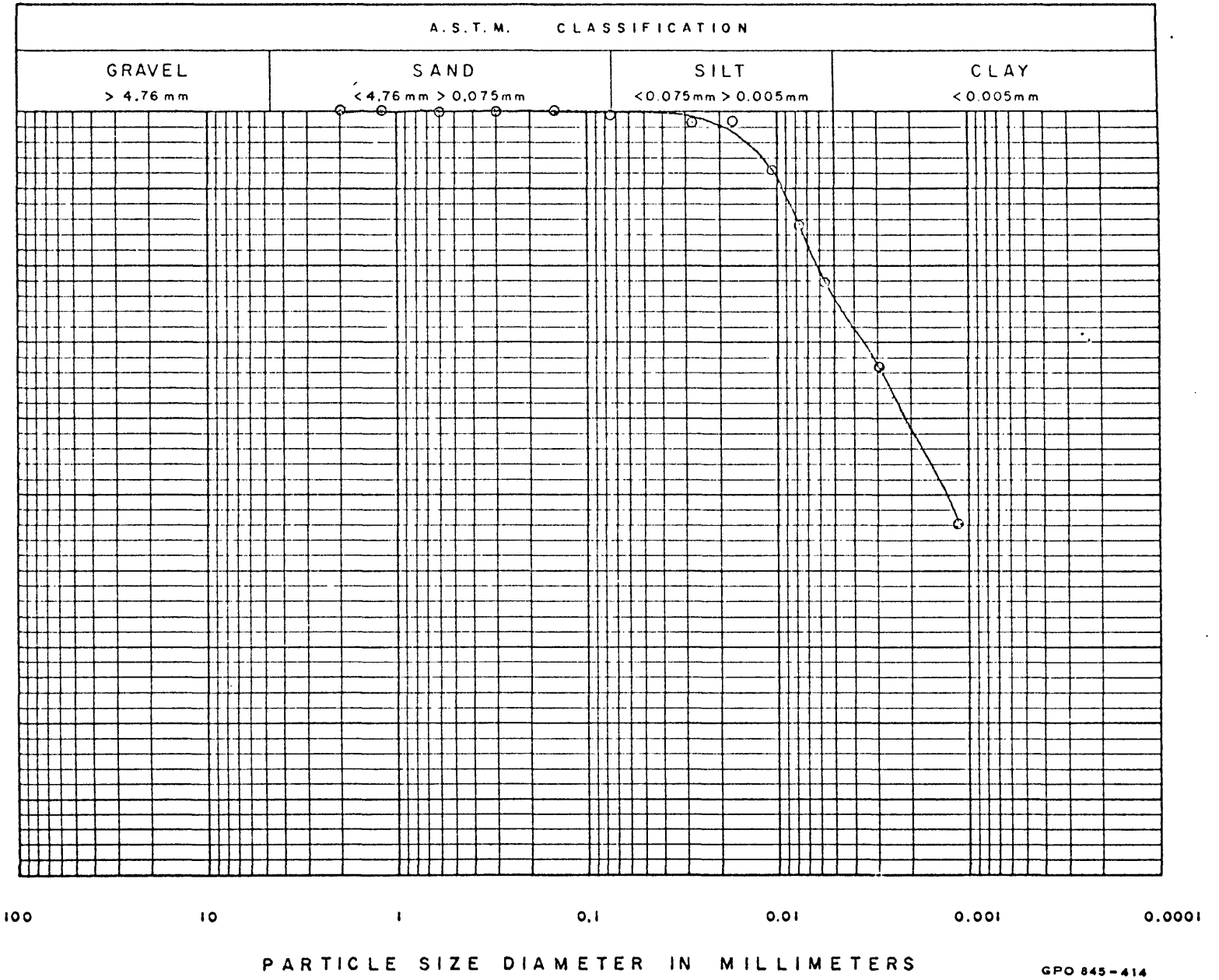
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 26.61-26.76 m



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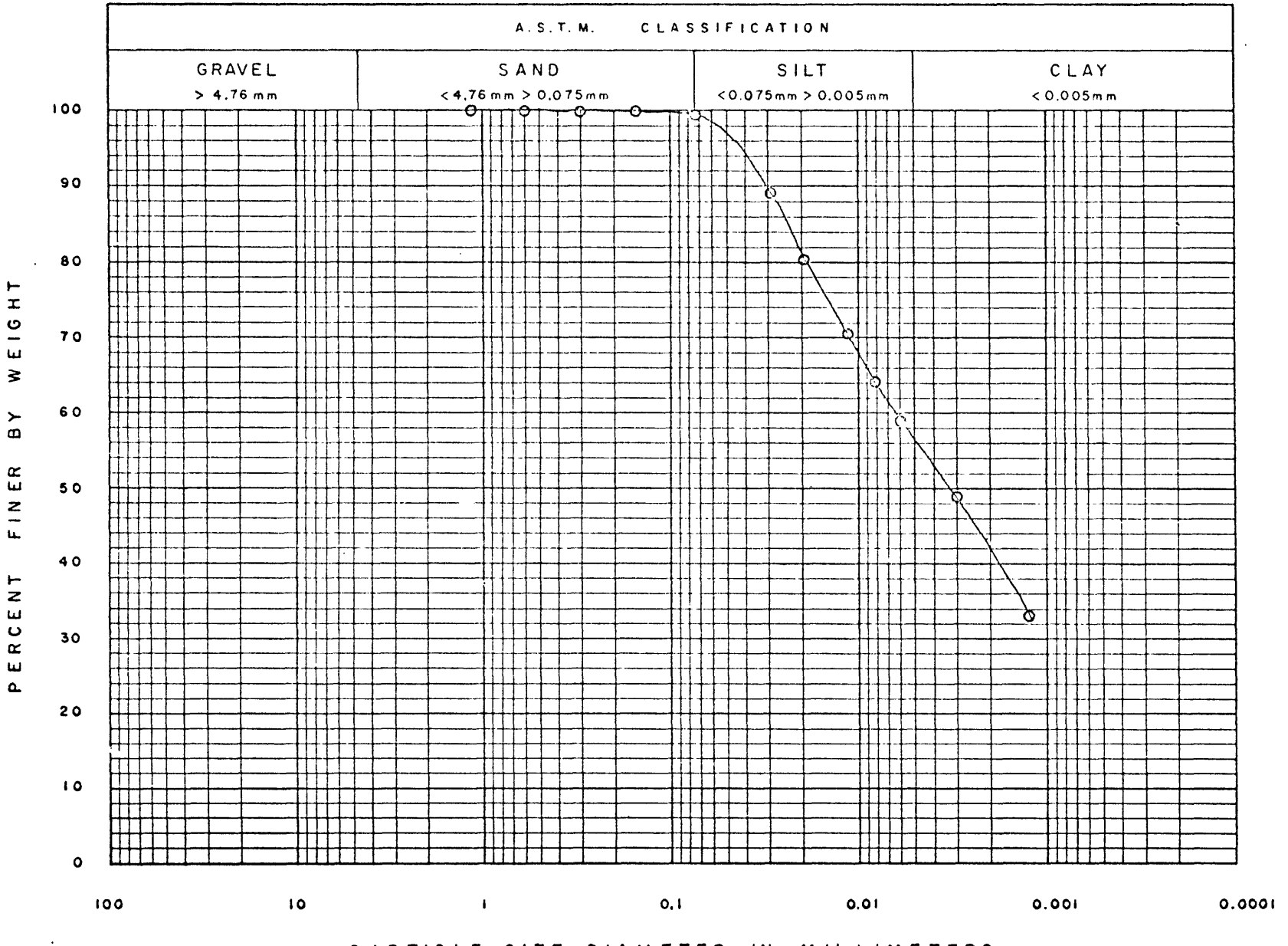
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 28.13-28.22 m



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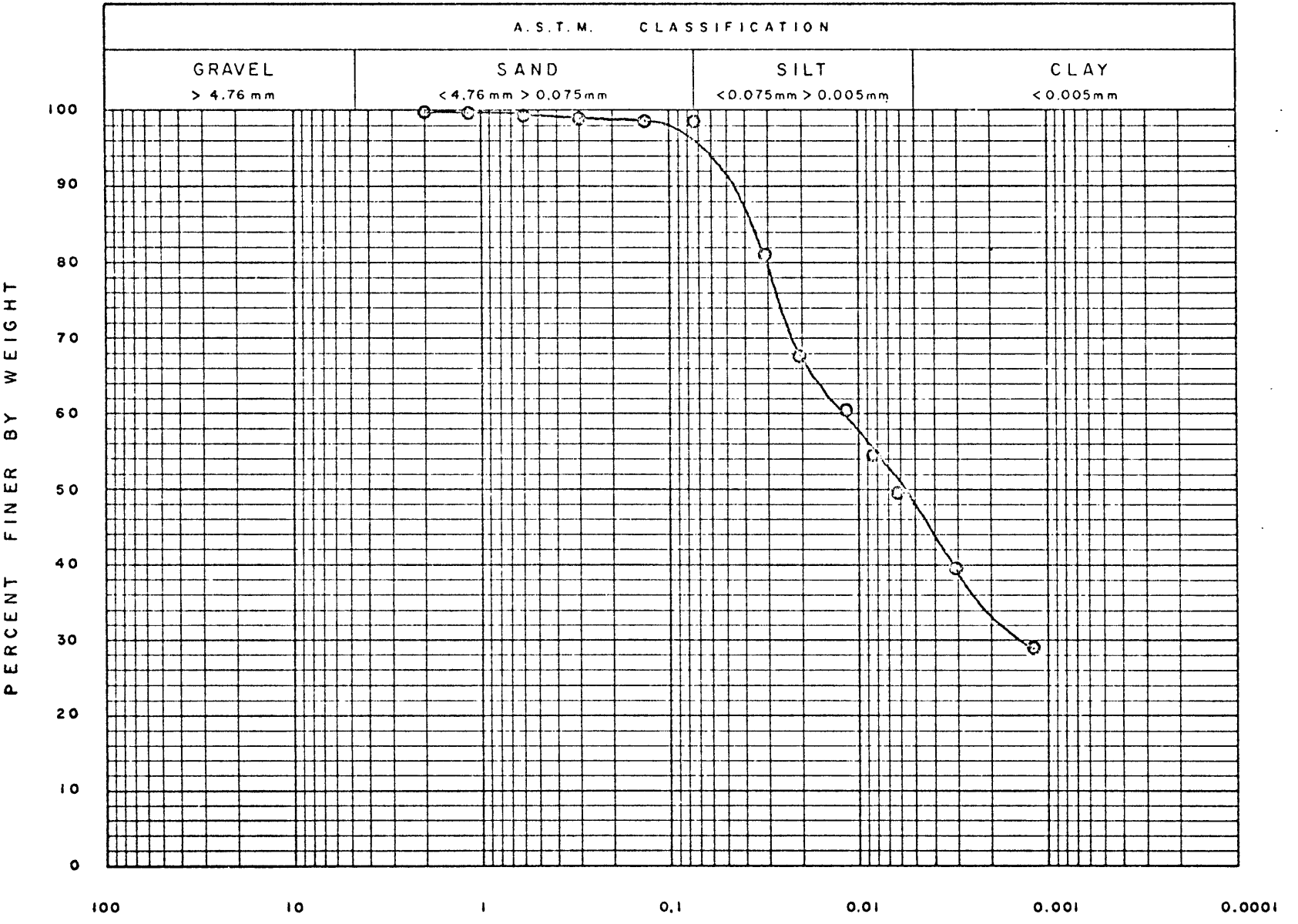
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 29.60-29.87 m



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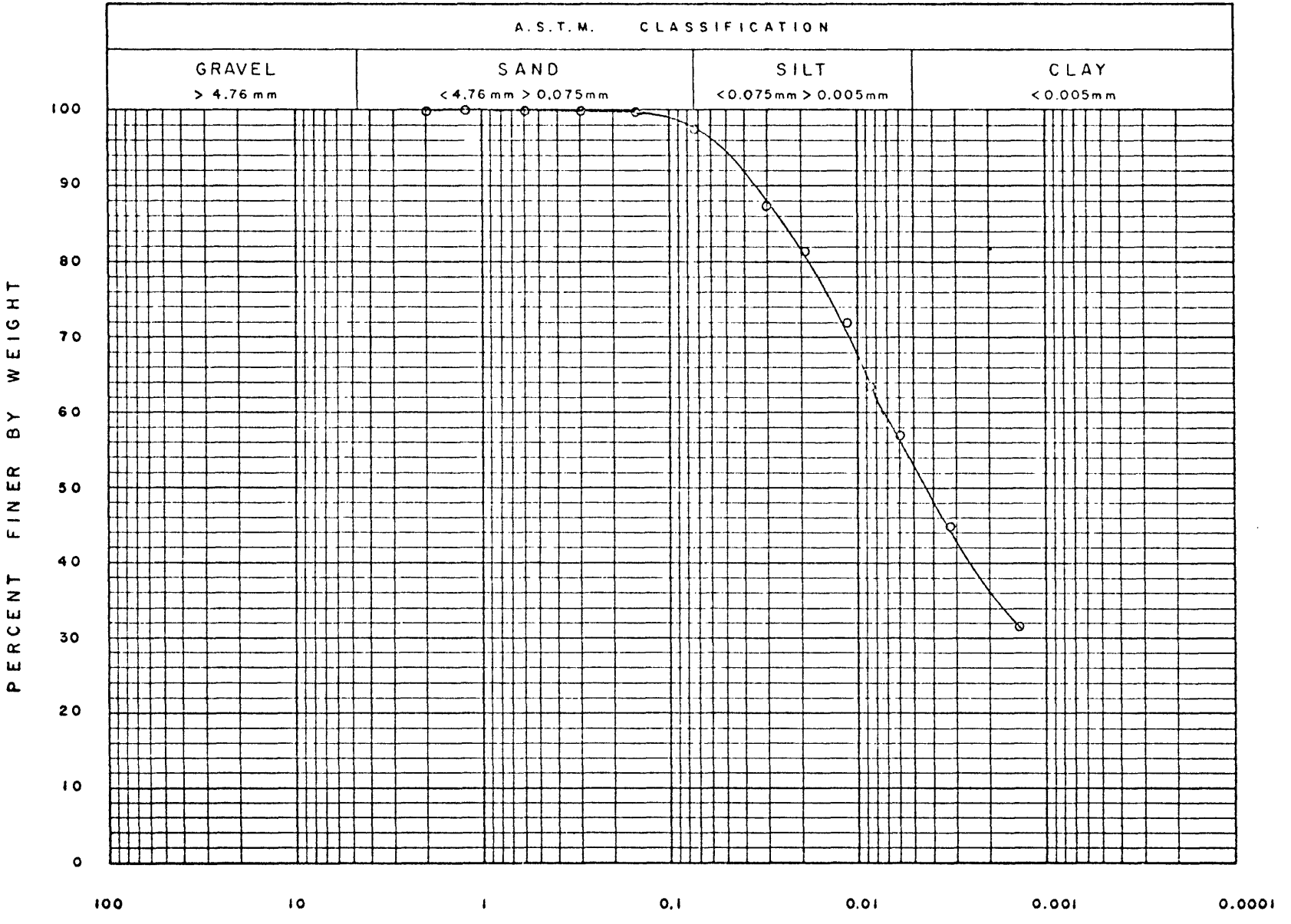
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 30.94-31.09 m



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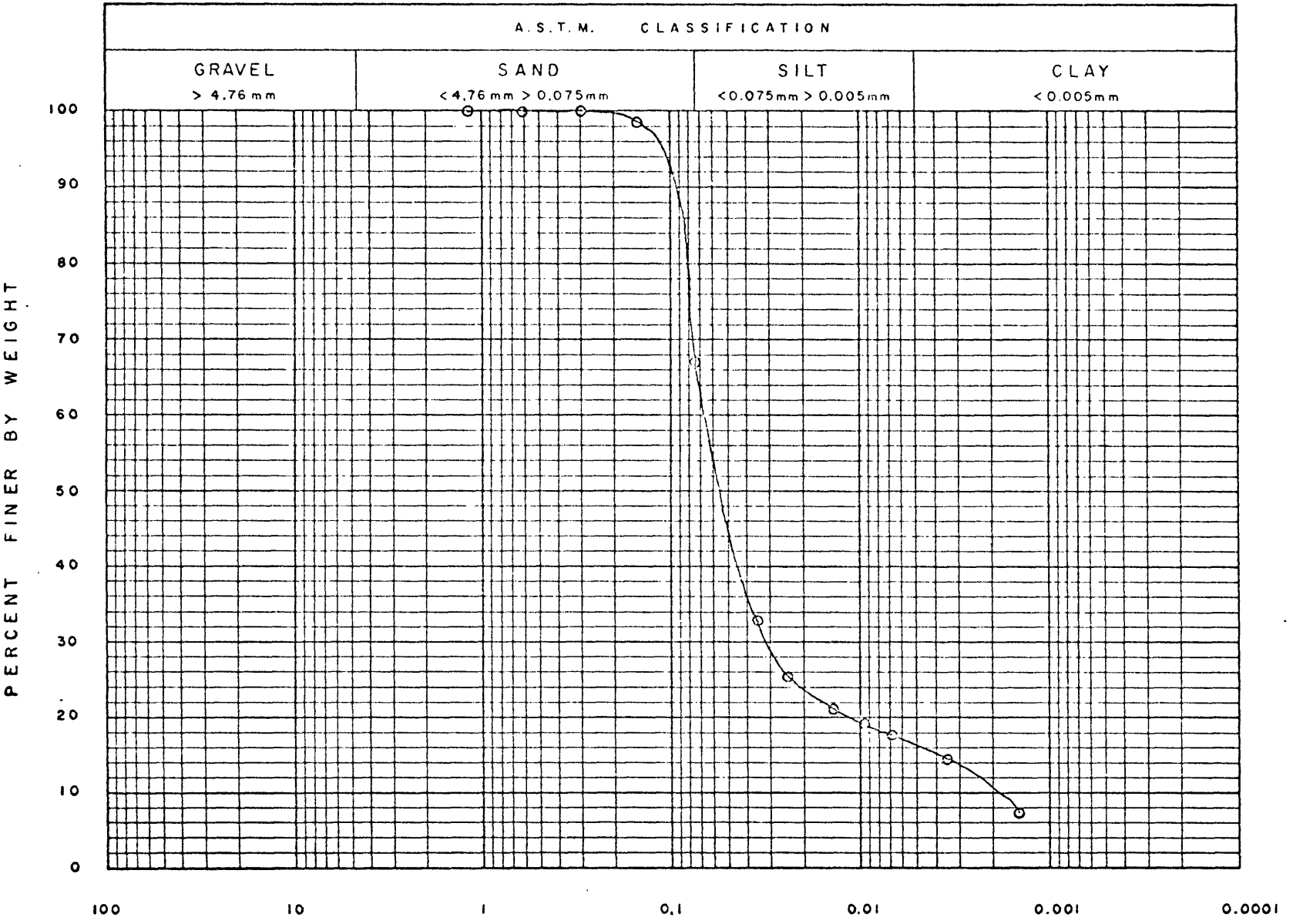
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

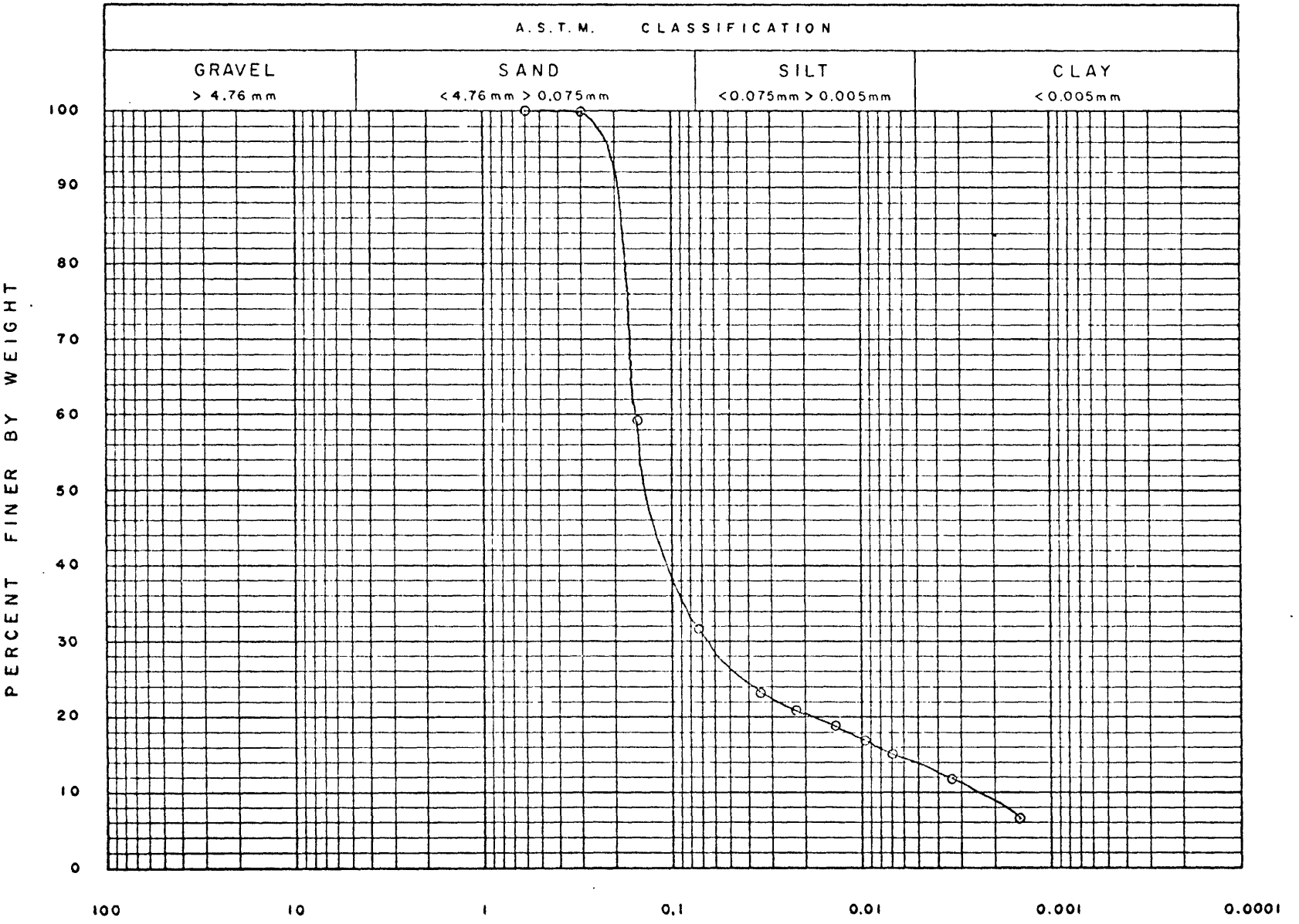
SAMPLE NUMBER 31.55-31.73 m



ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

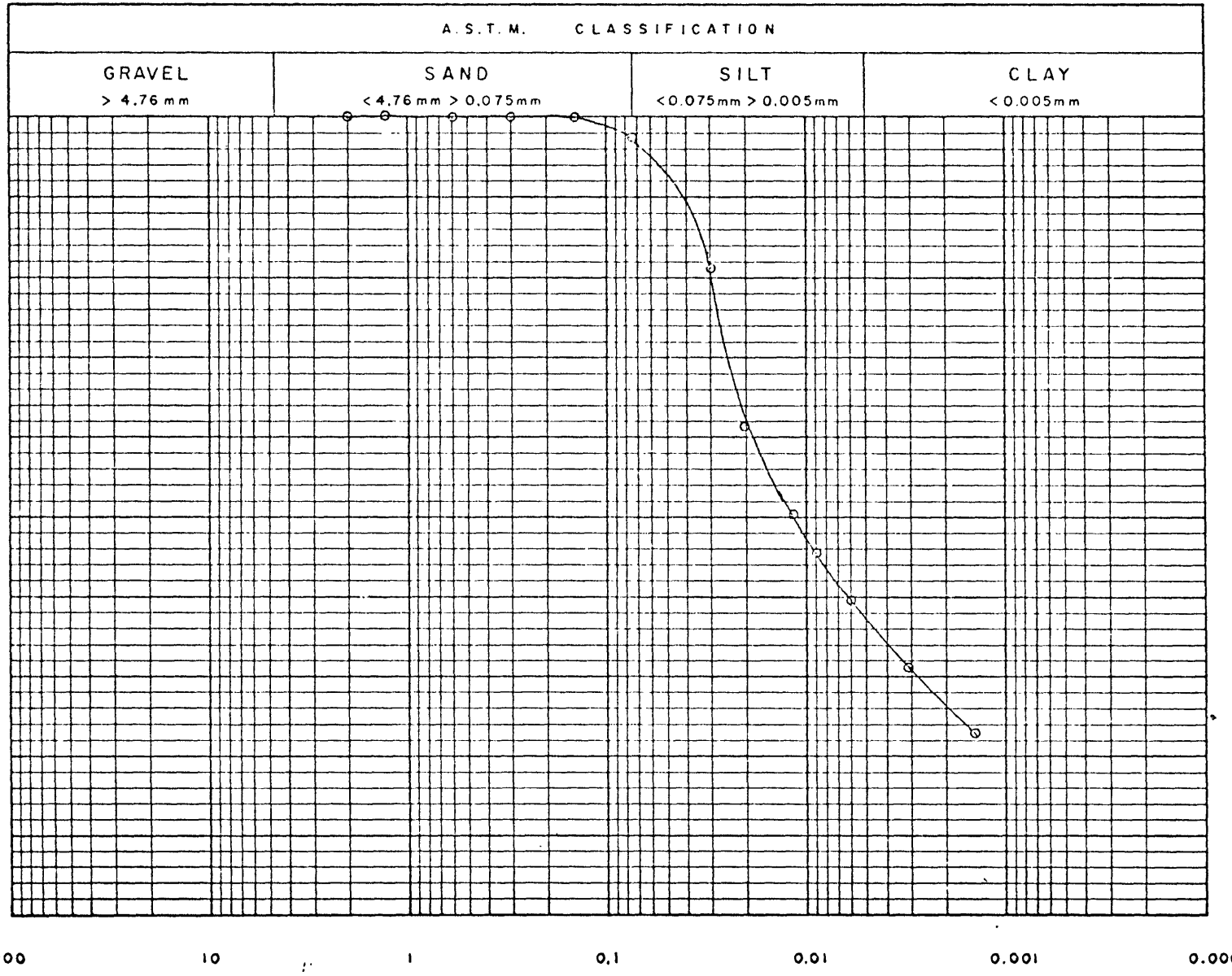
SAMPLE NUMBER 32.77-32.96 m



ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

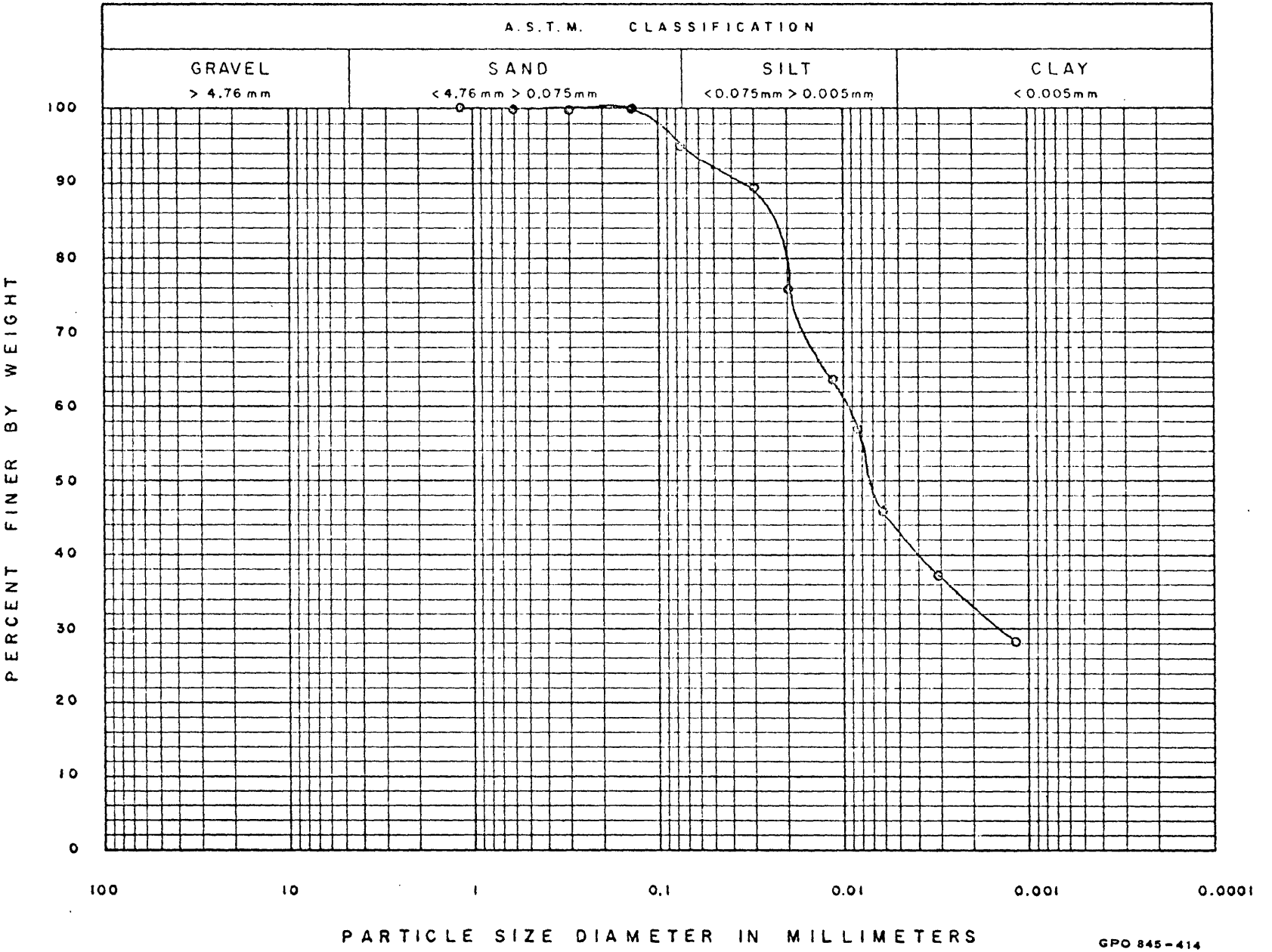
SAMPLE NUMBER 34.23-34.35 m



ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 34.87-35.02 m



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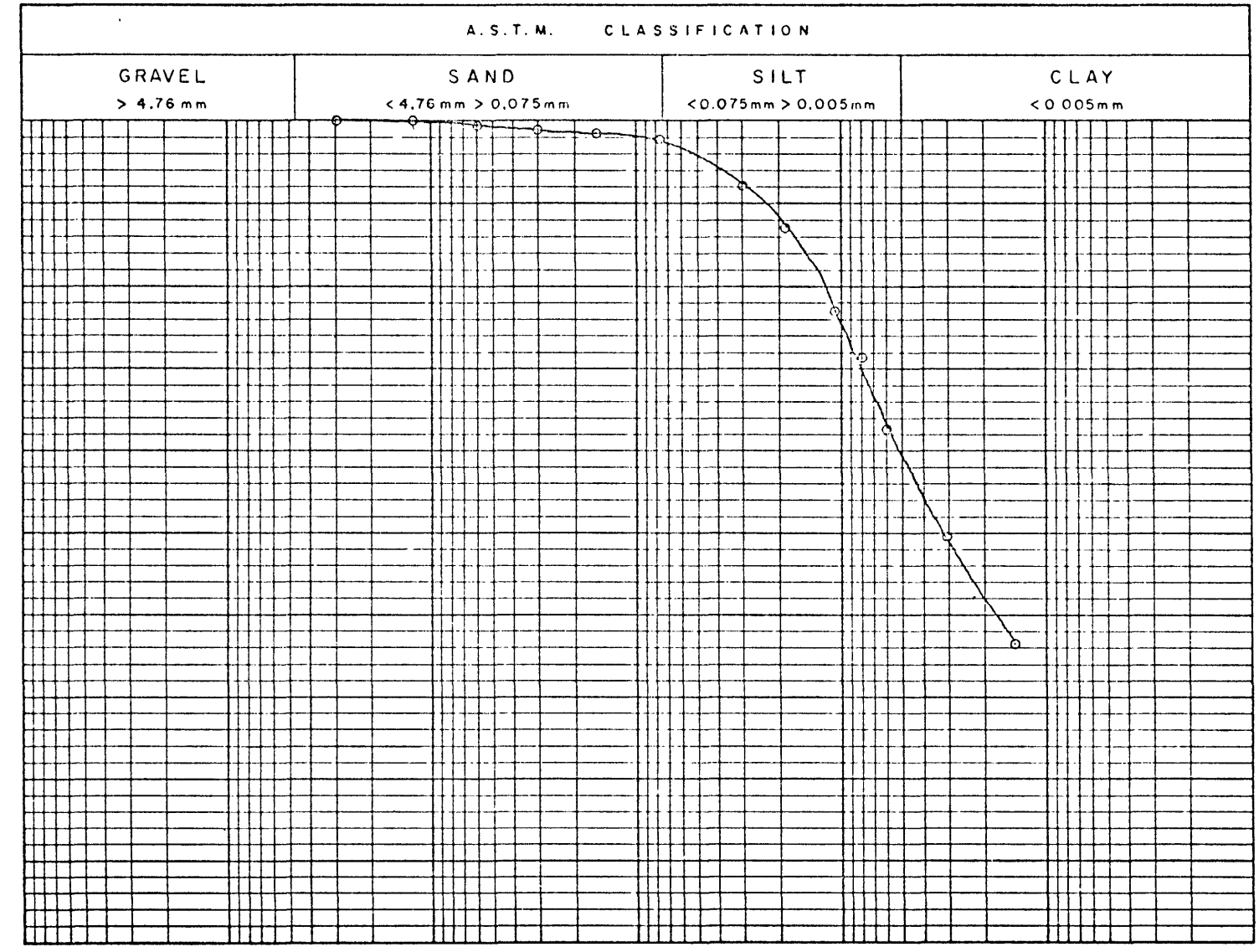
PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 35.57-35.78 m



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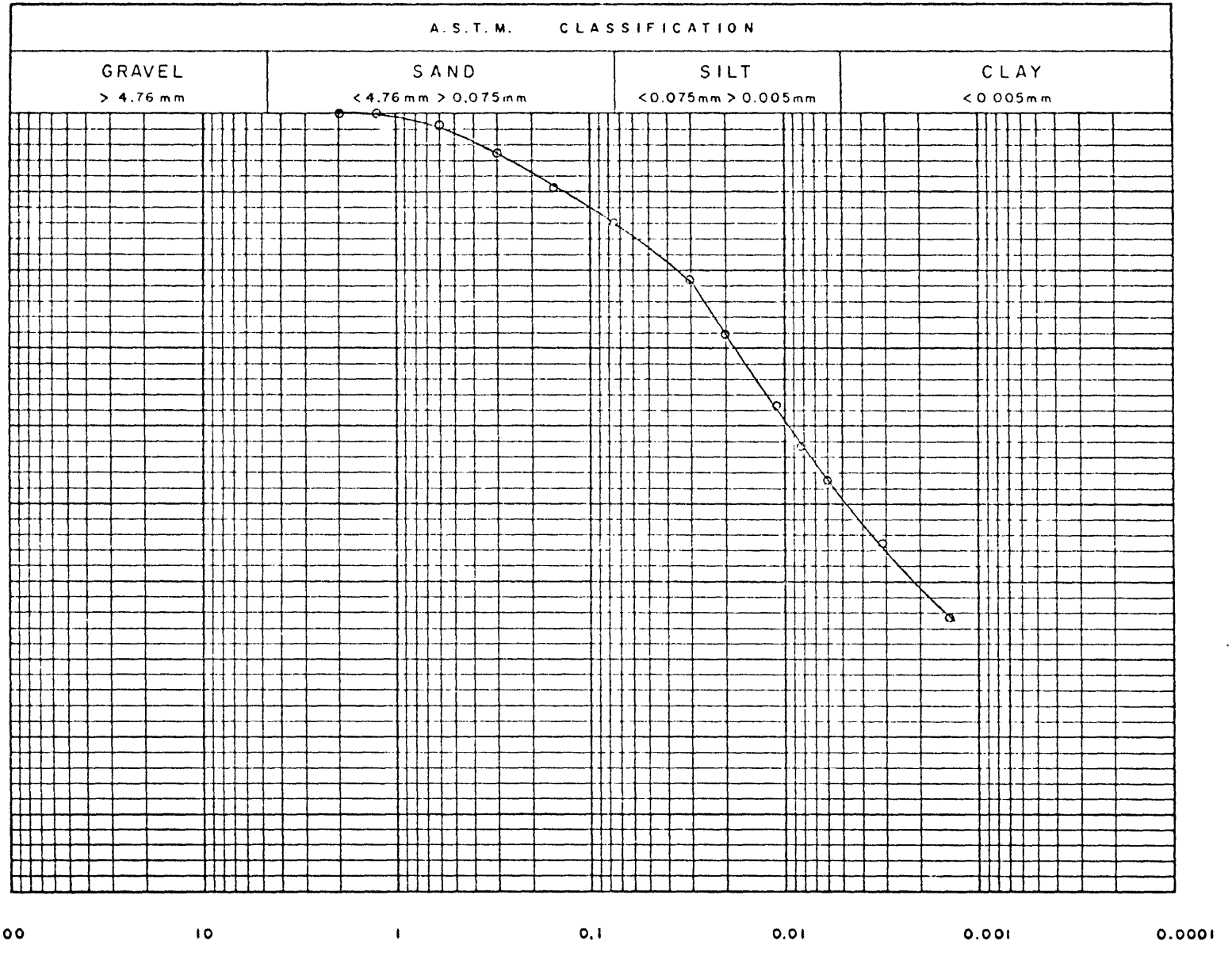
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 36.91-37.12 m



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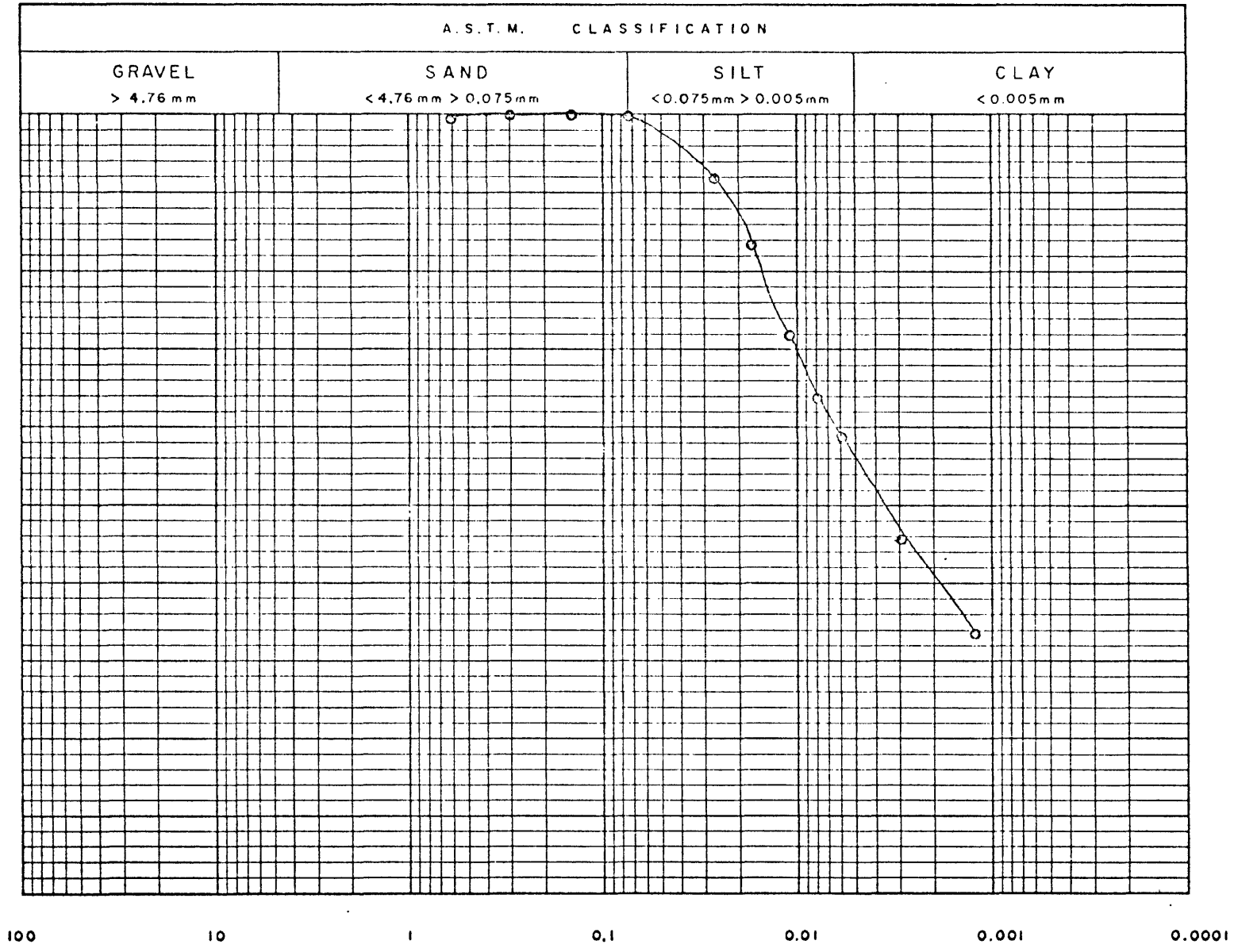
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 38.95-39.11 m



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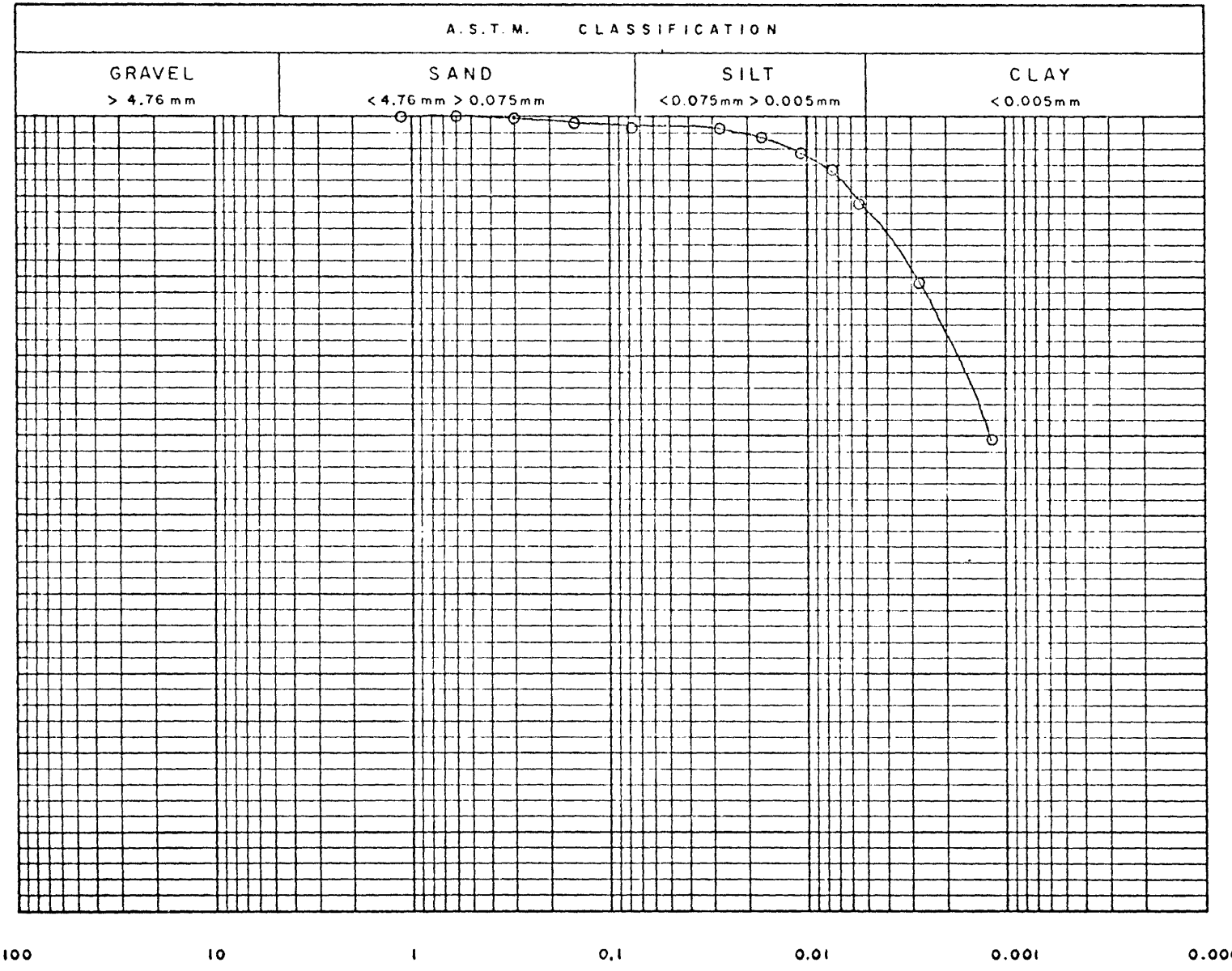
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

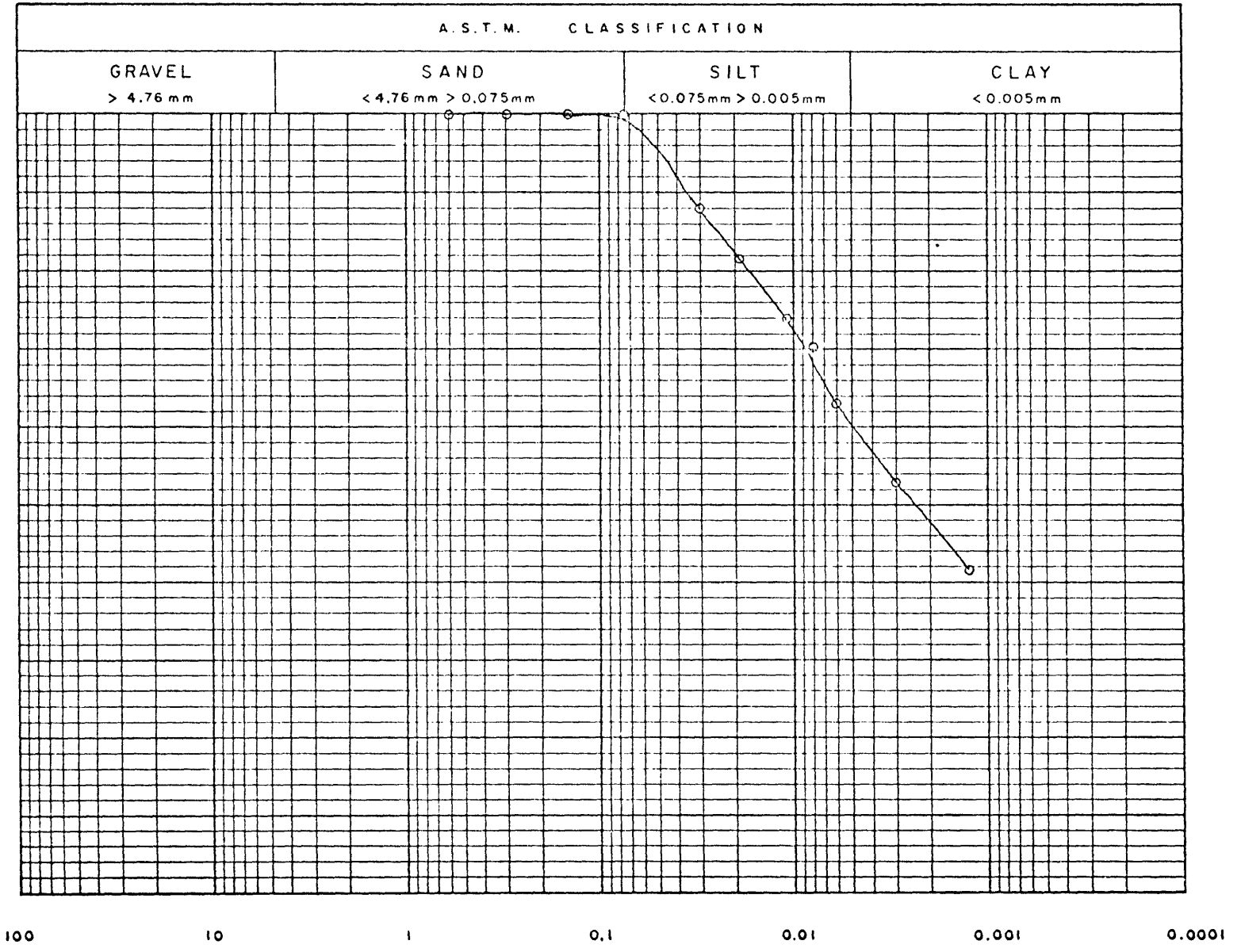
SAMPLE NUMBER 40.72-40.93 m



ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 43.98-44.17 m



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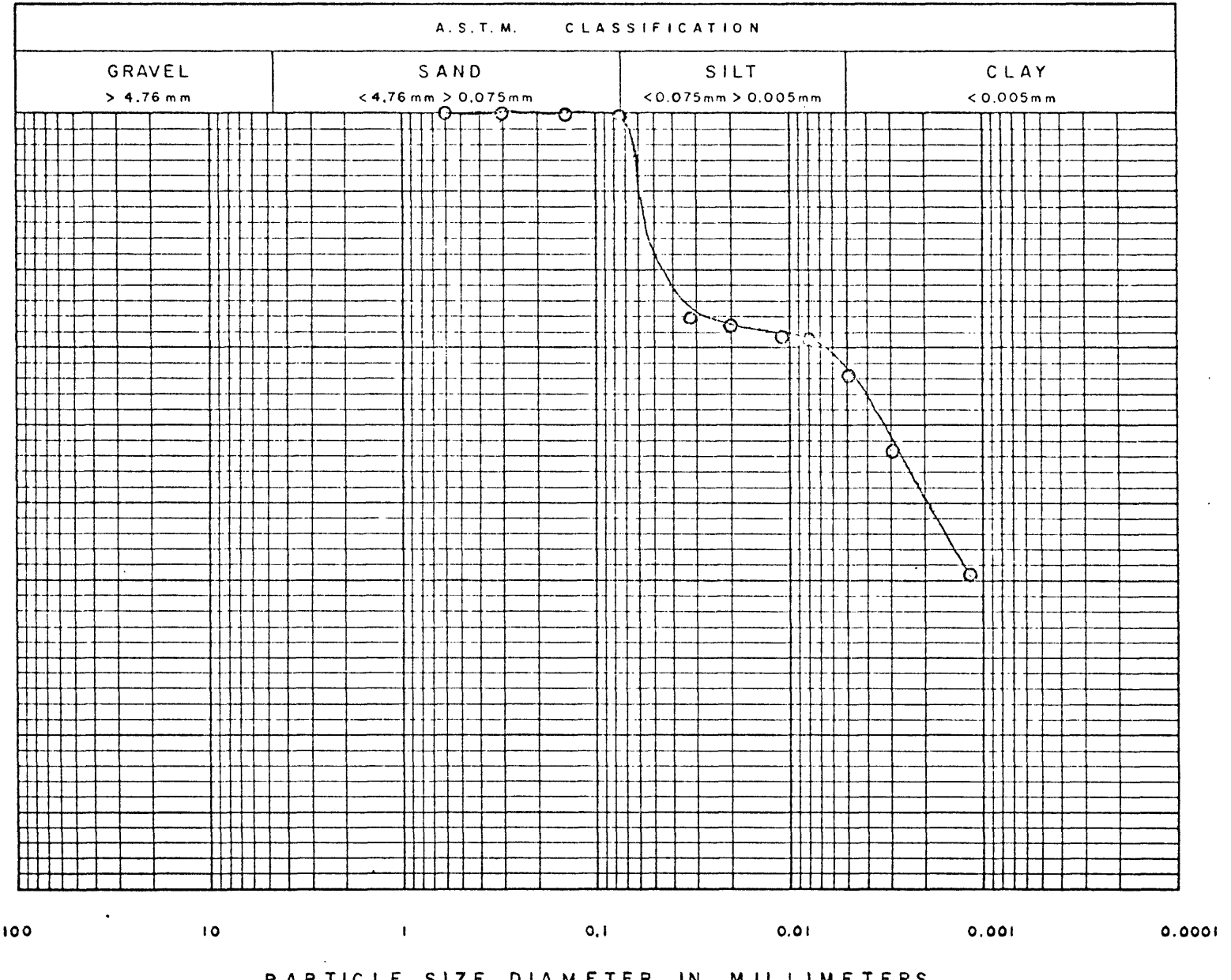
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 48.46-48.65 m



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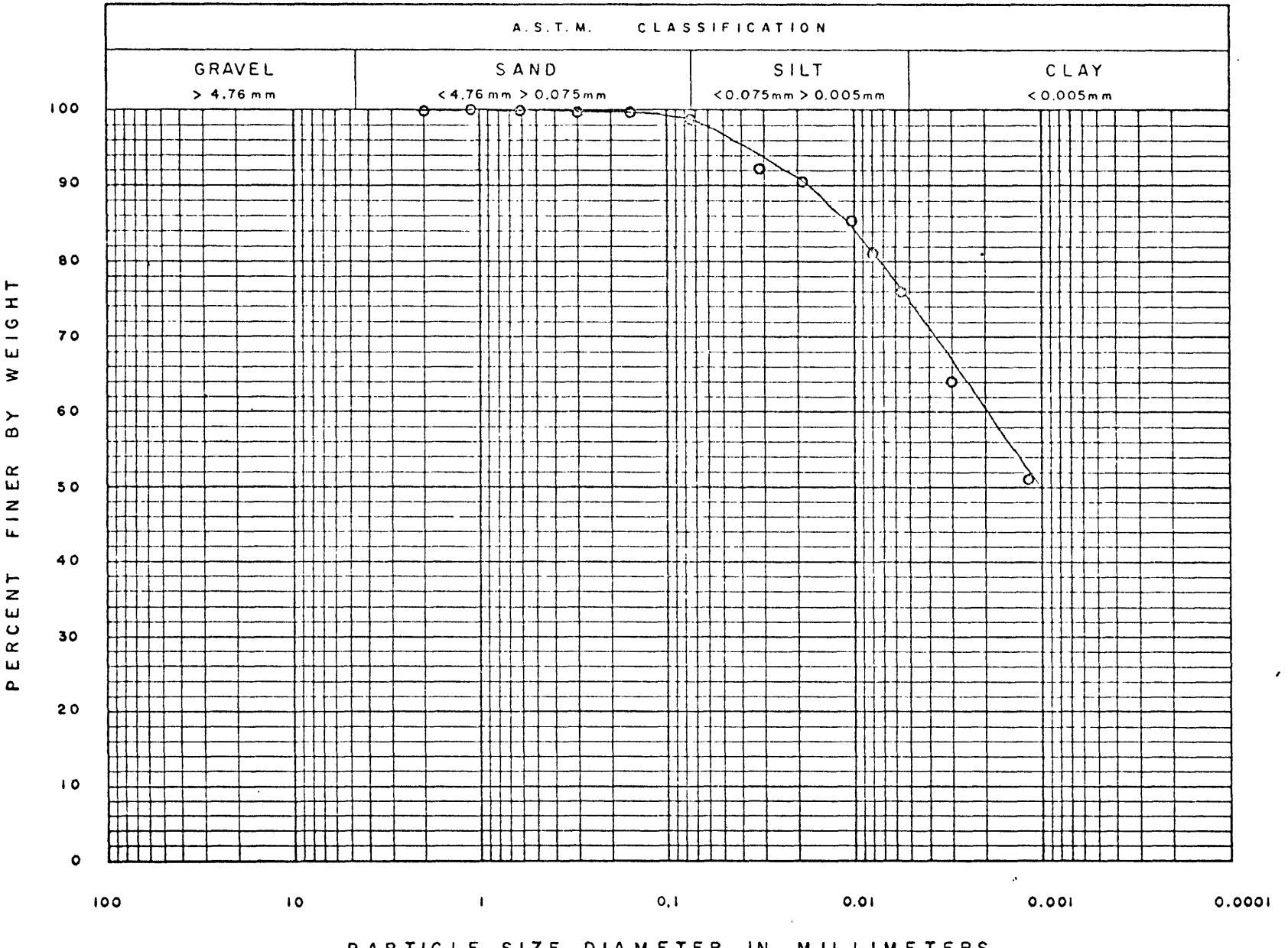
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 52.97-53.13 m



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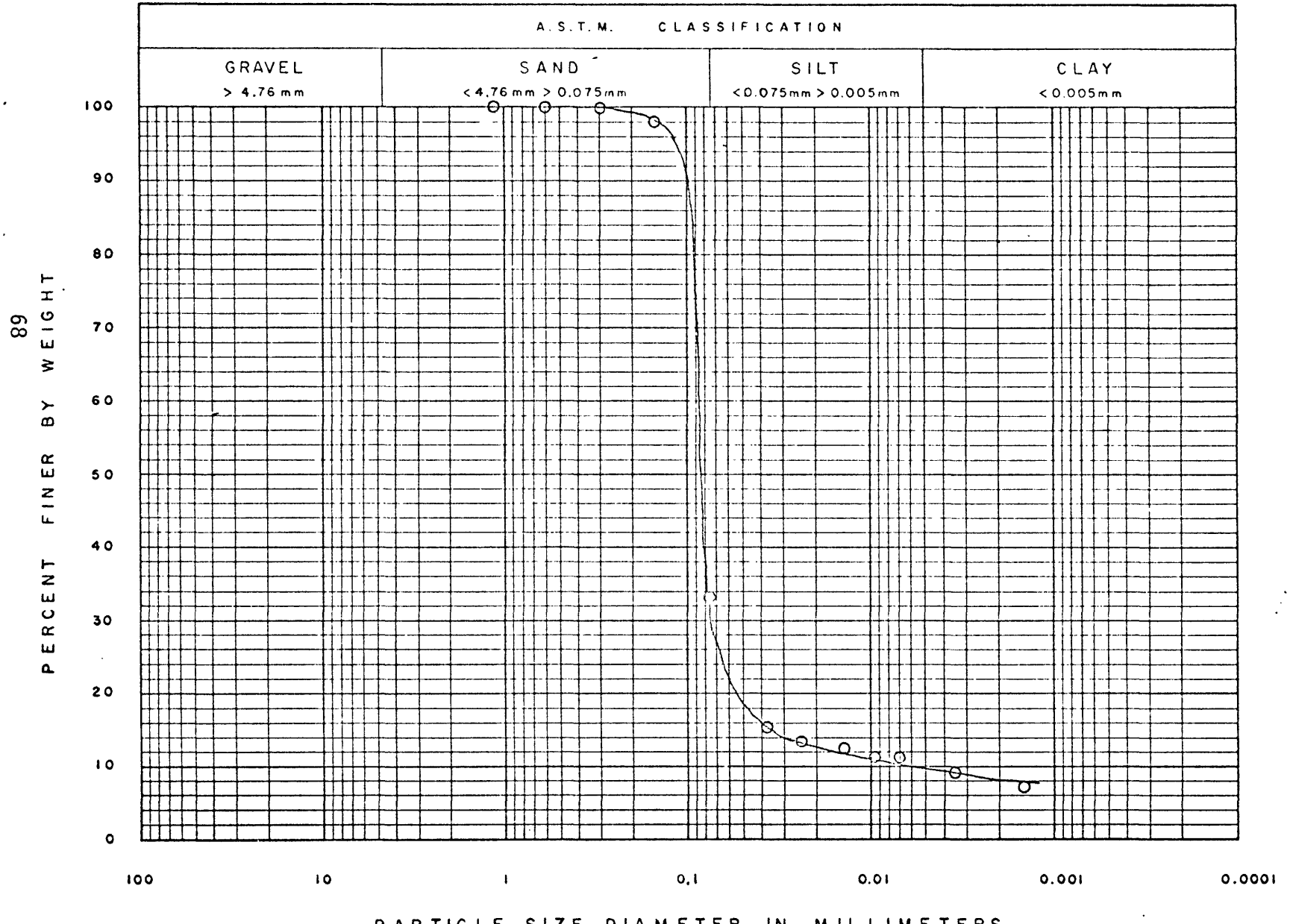
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 54.99-55.26 m



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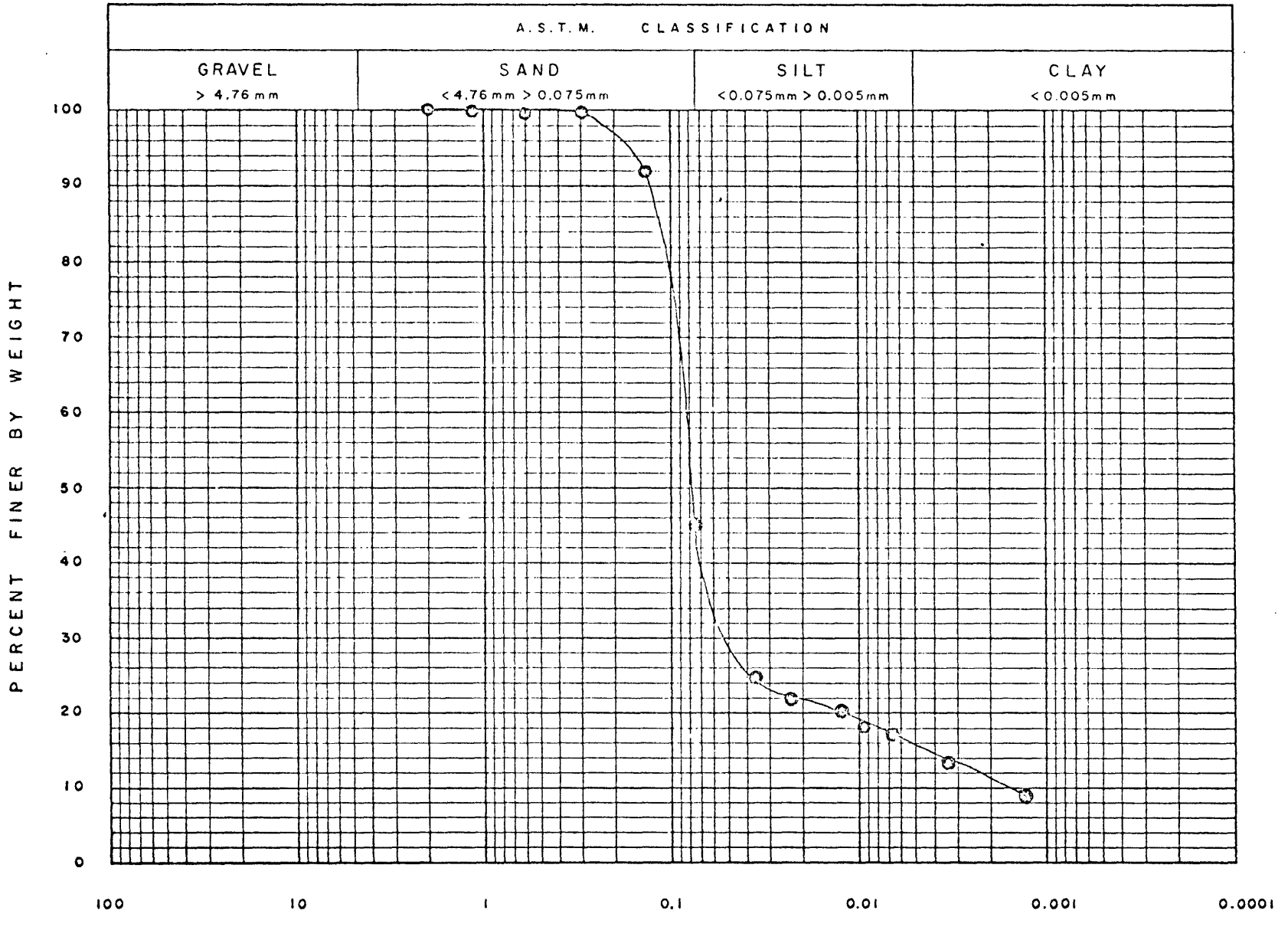
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

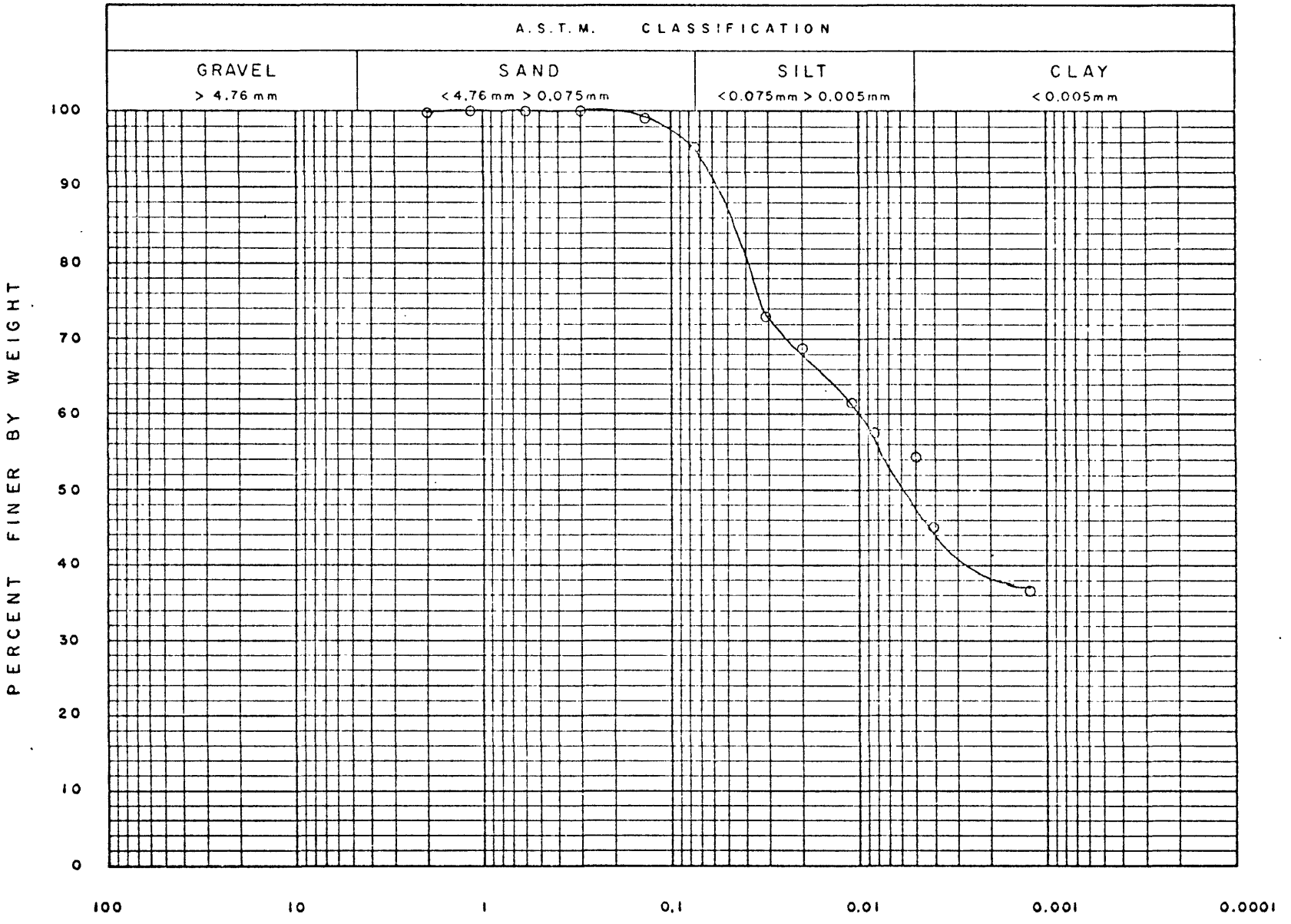
SAMPLE NUMBER 57.09-57.64 m



ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 59.89-60.11 m



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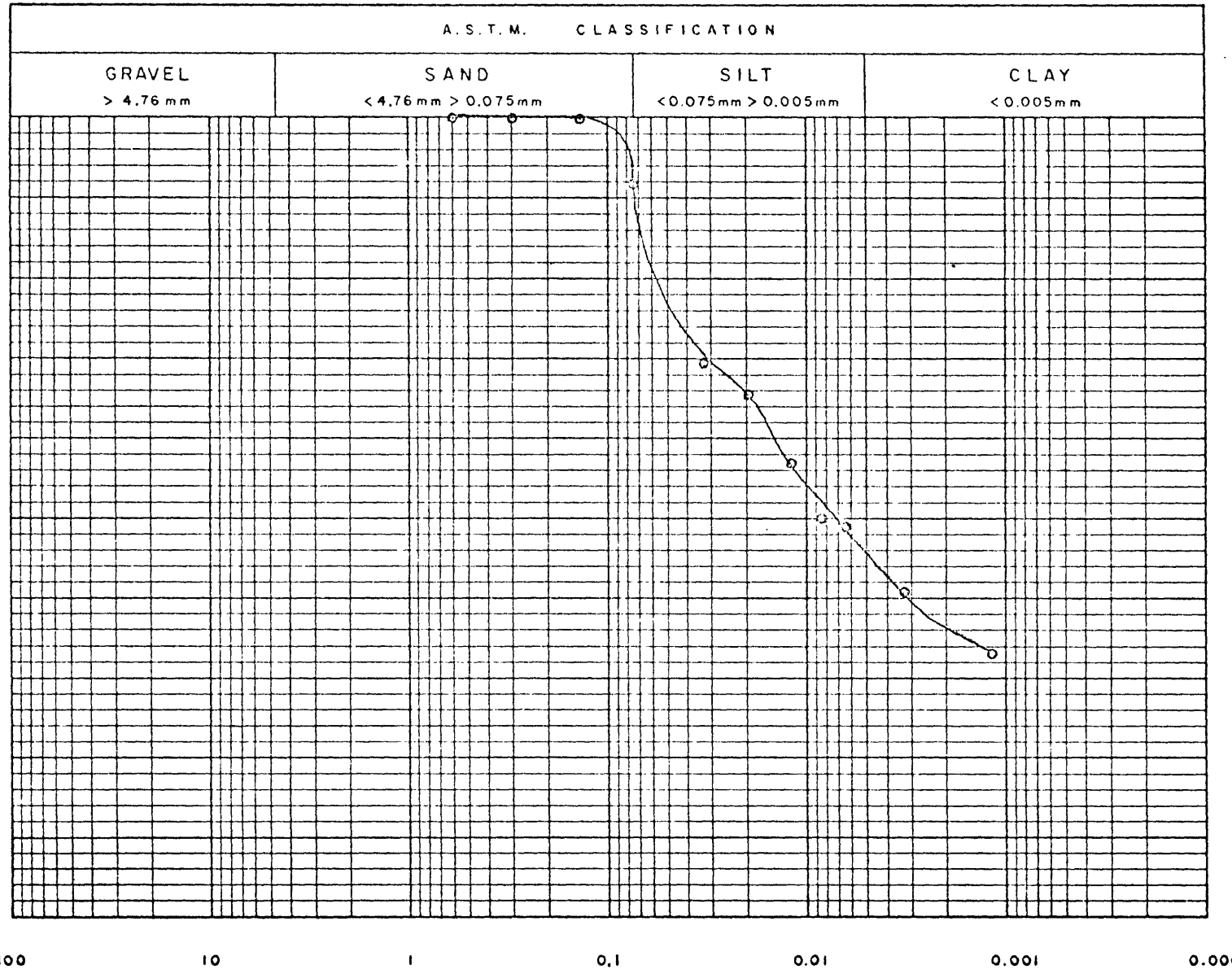
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 61.05-61.26 m



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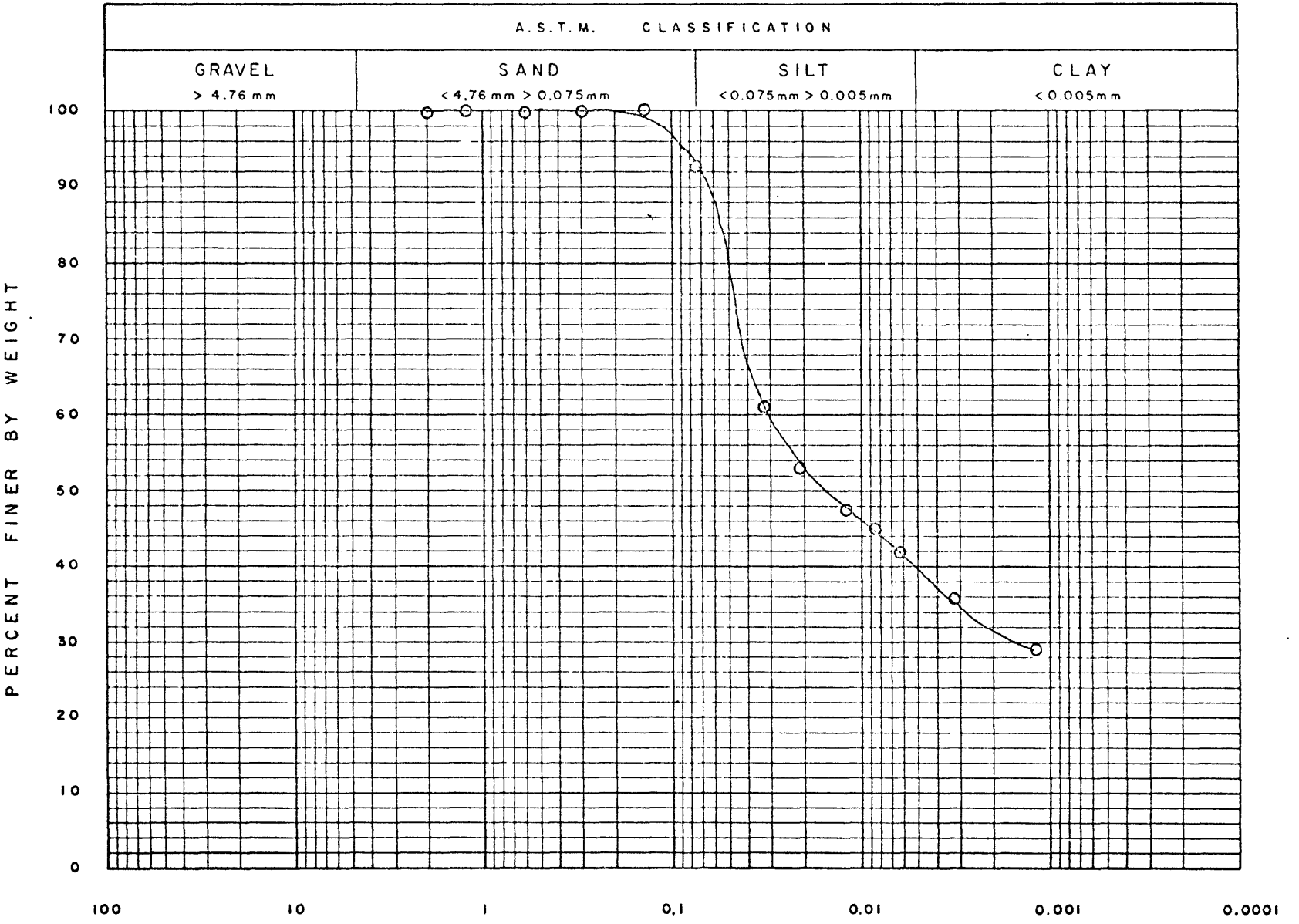
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 63.89-64.01 m

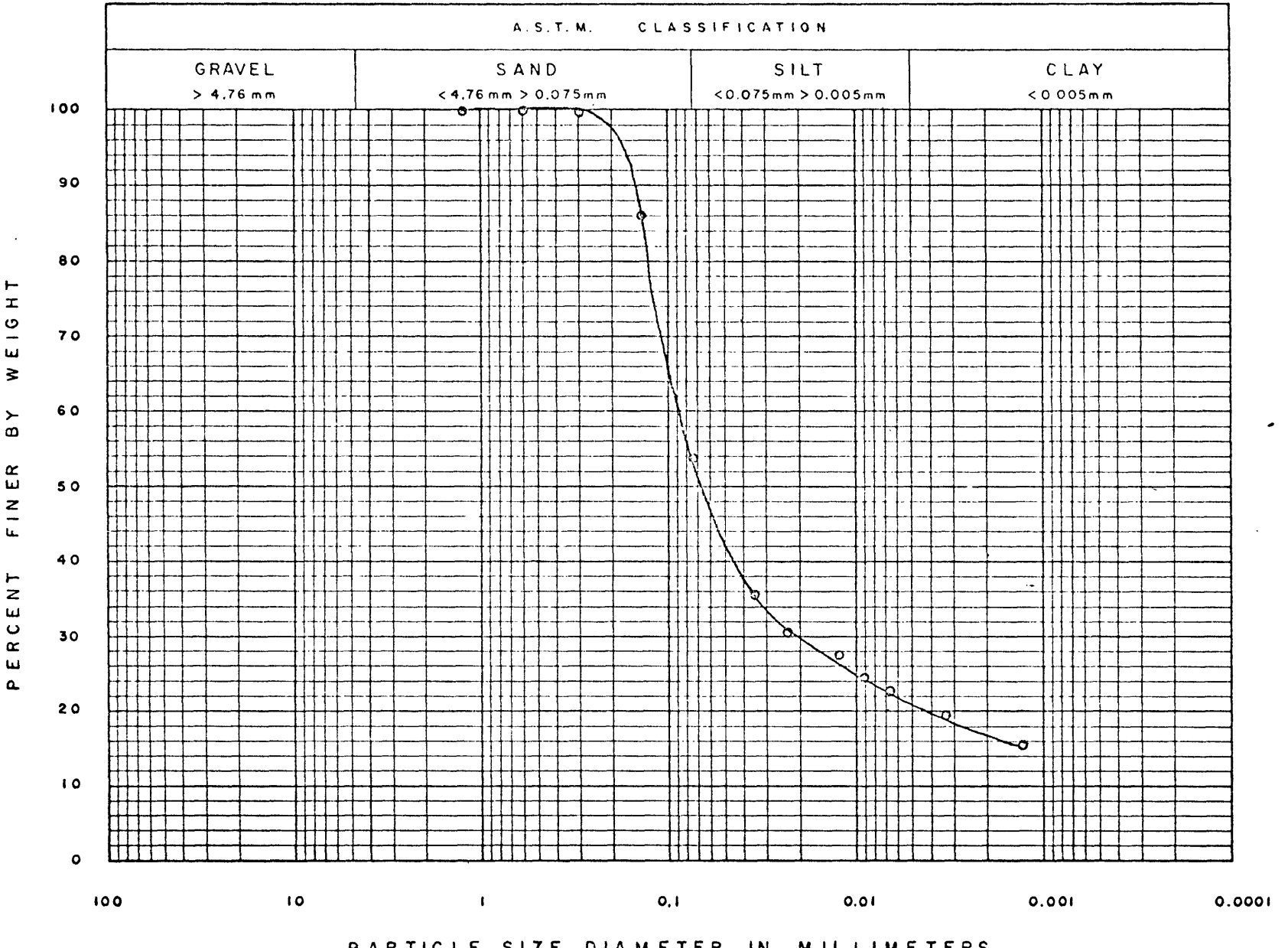


GPO 845-414

ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 65.78-65.93 m



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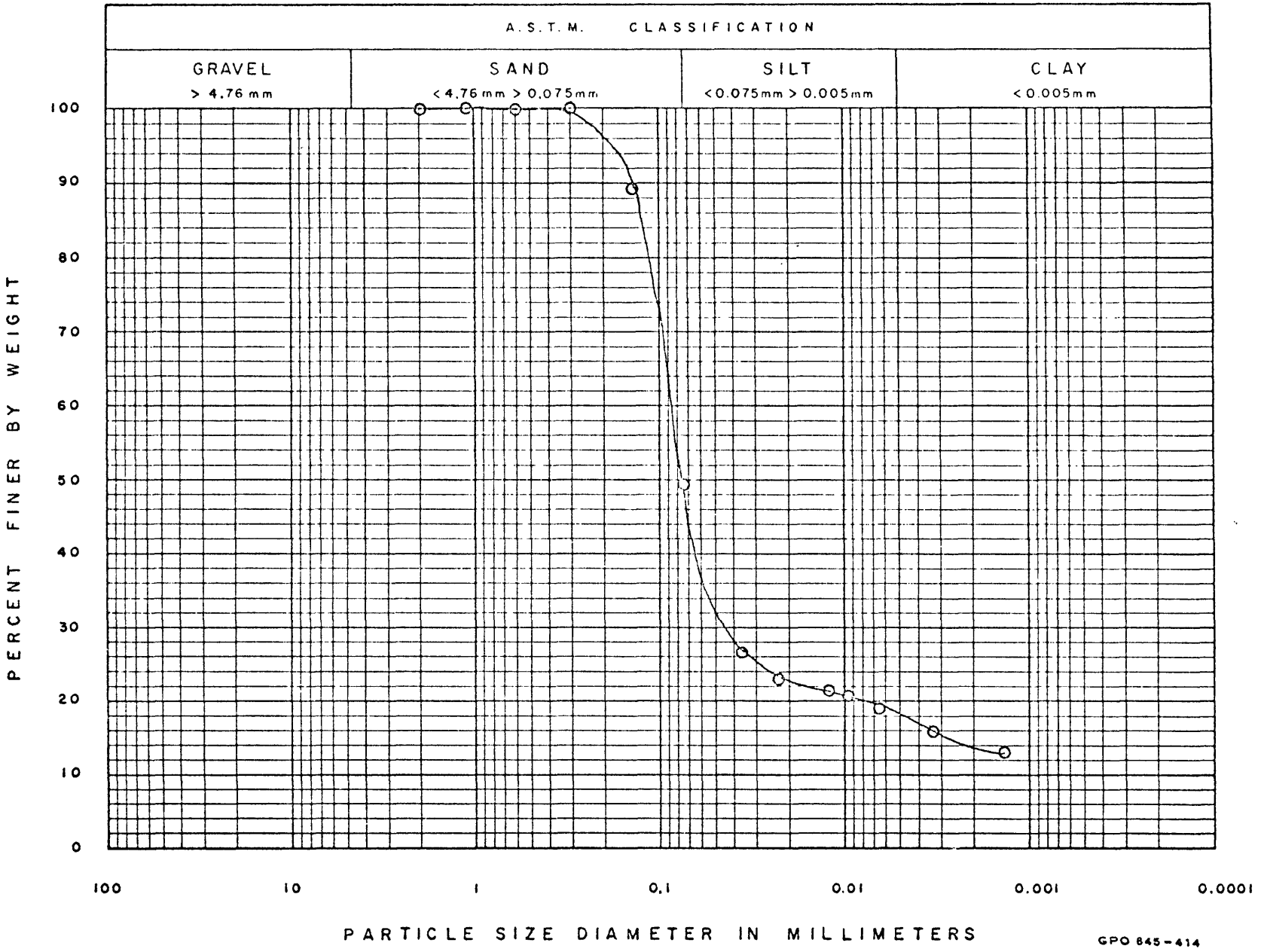
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 67.24-67.36 m

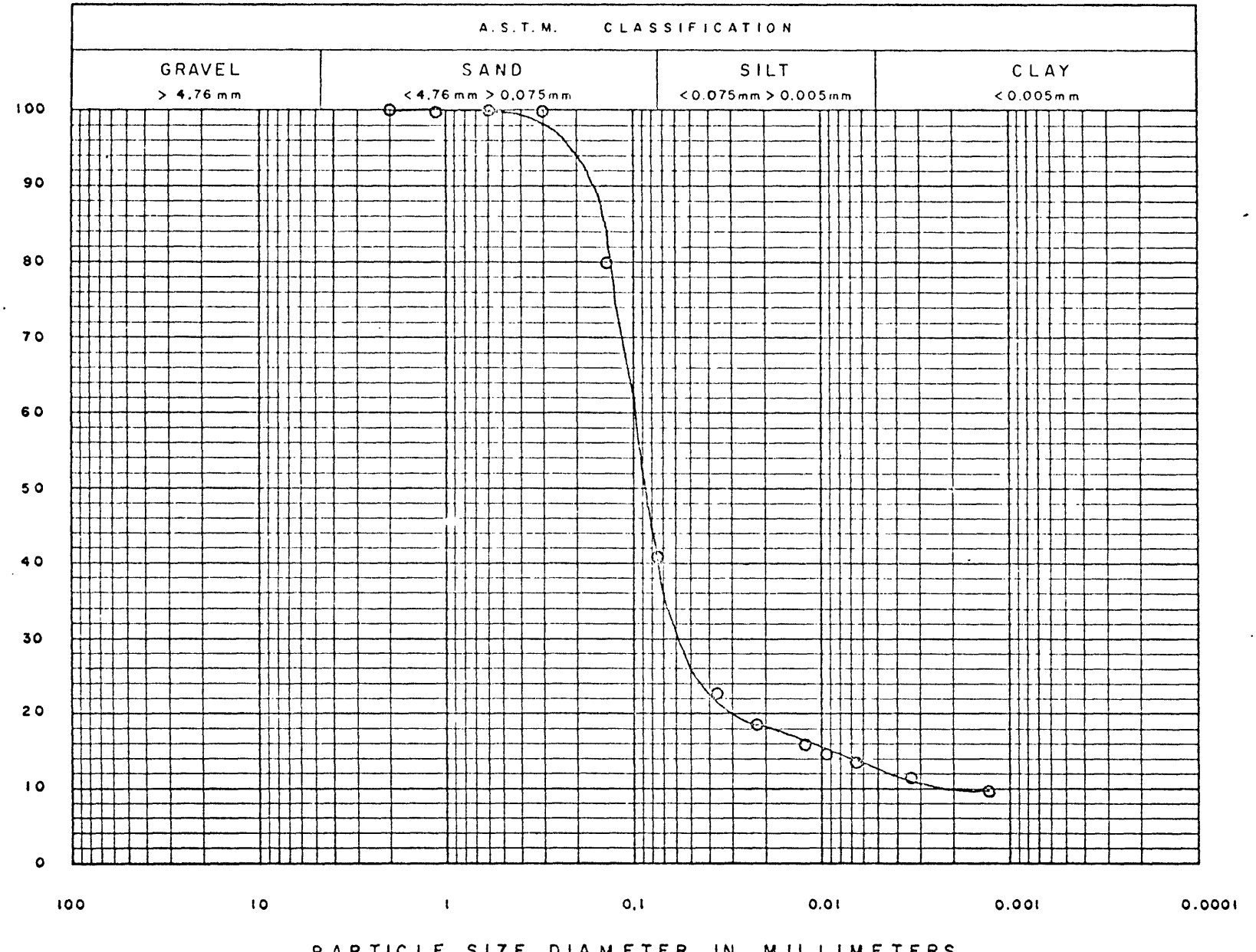


GPO 845-414

ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 68.58-68.78 m

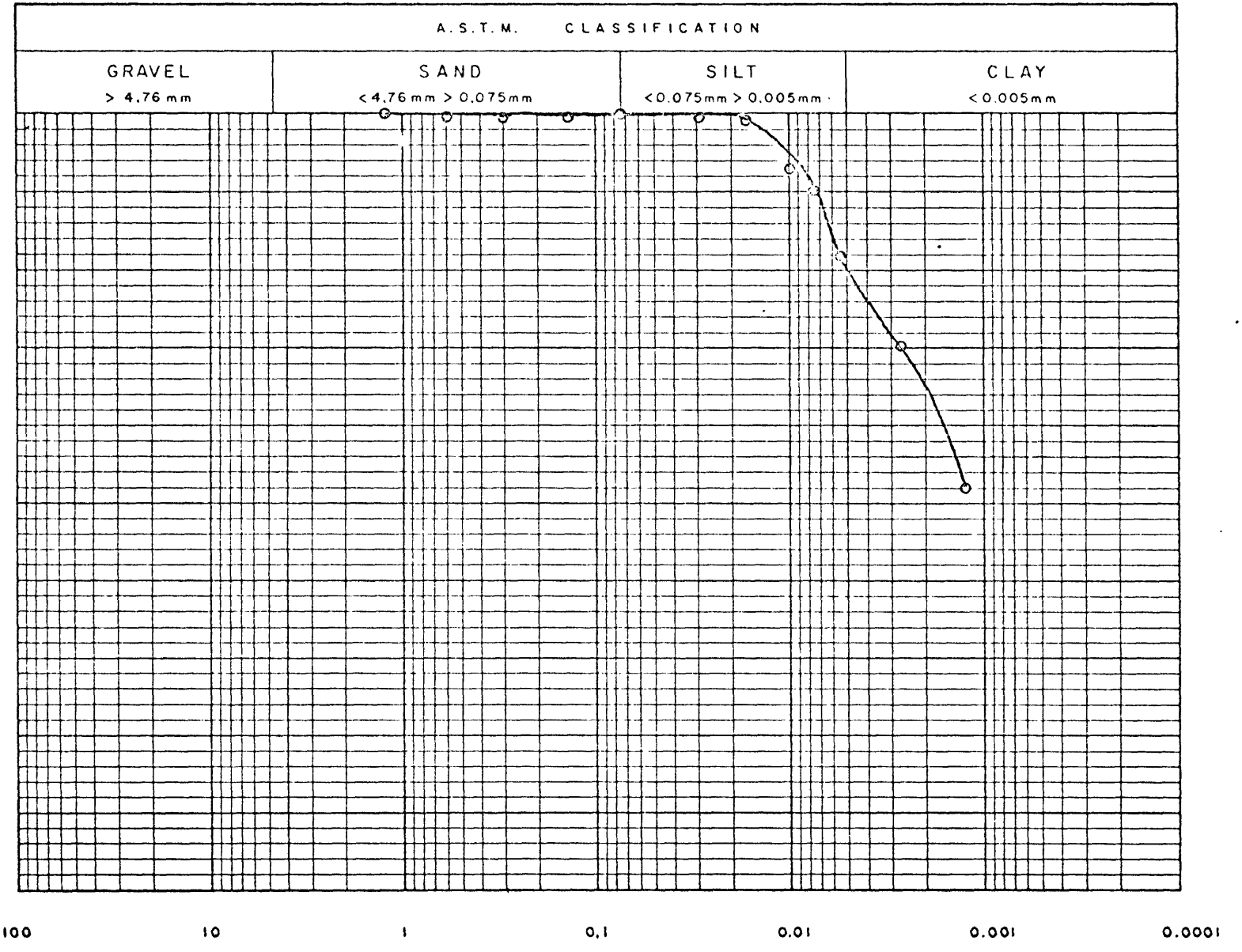


GPO 845-414

ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 71.51-71.75 m



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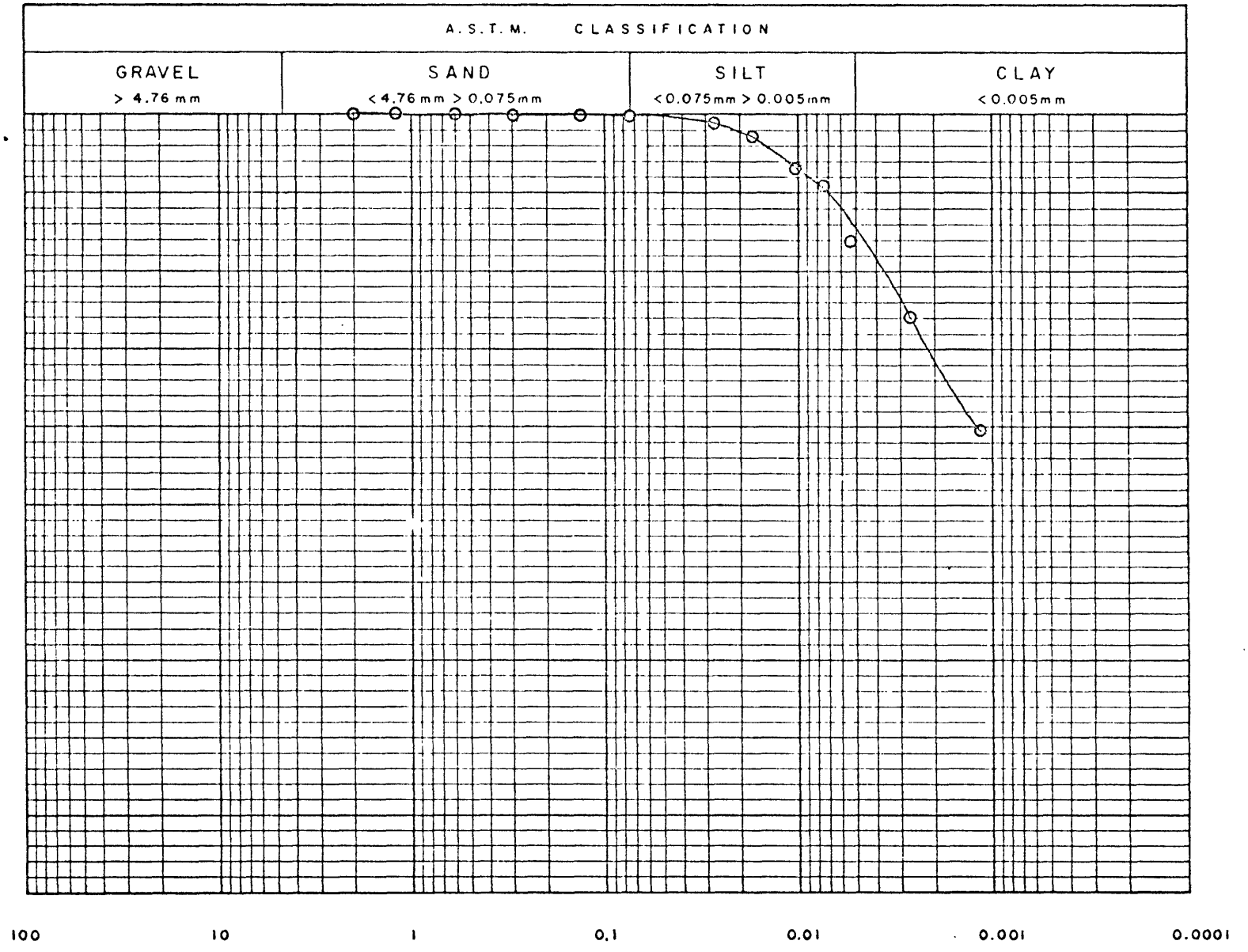
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 72.24-72.45 m



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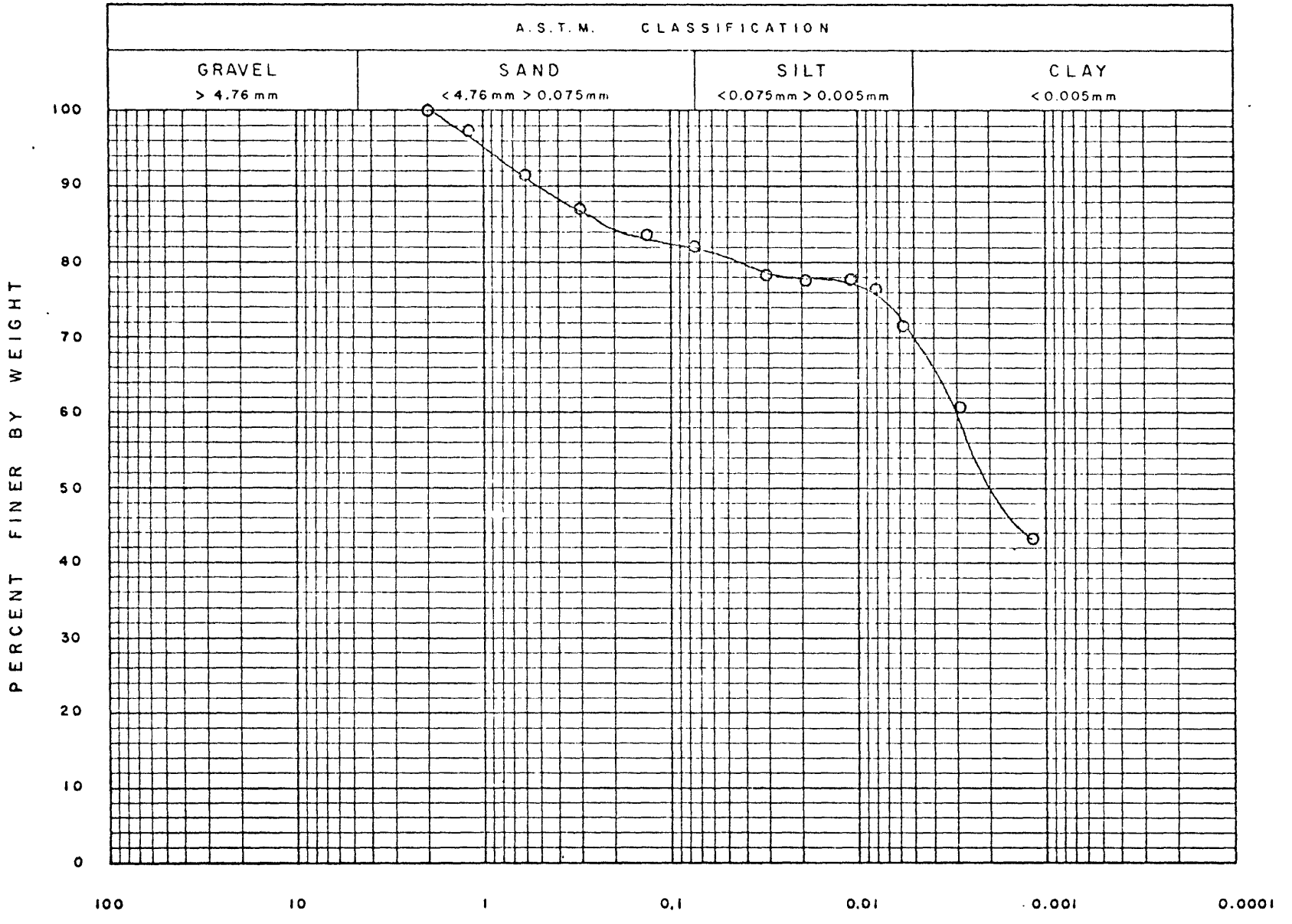
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 74.52-74.71 m



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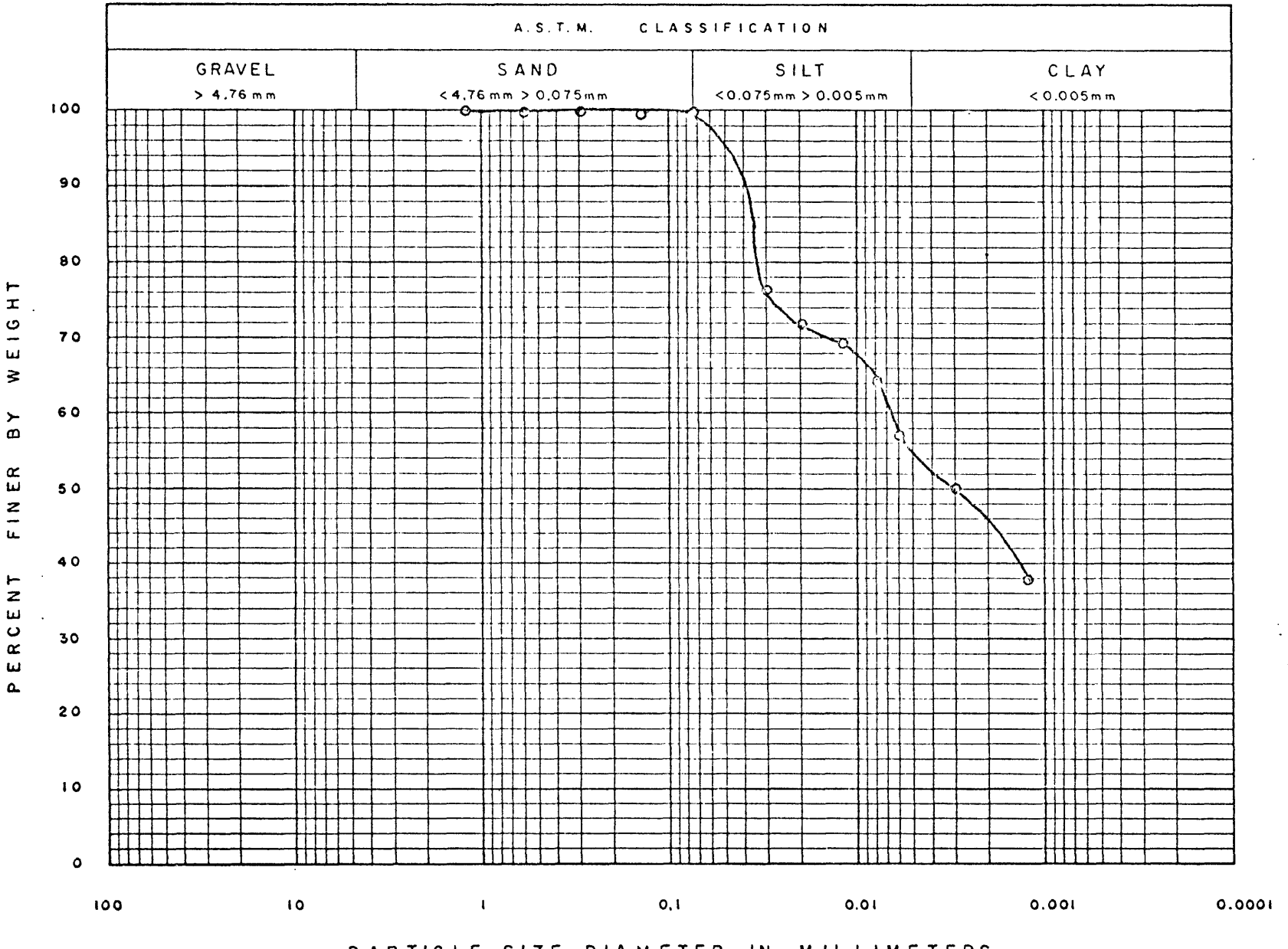
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 78.00-78.18 m



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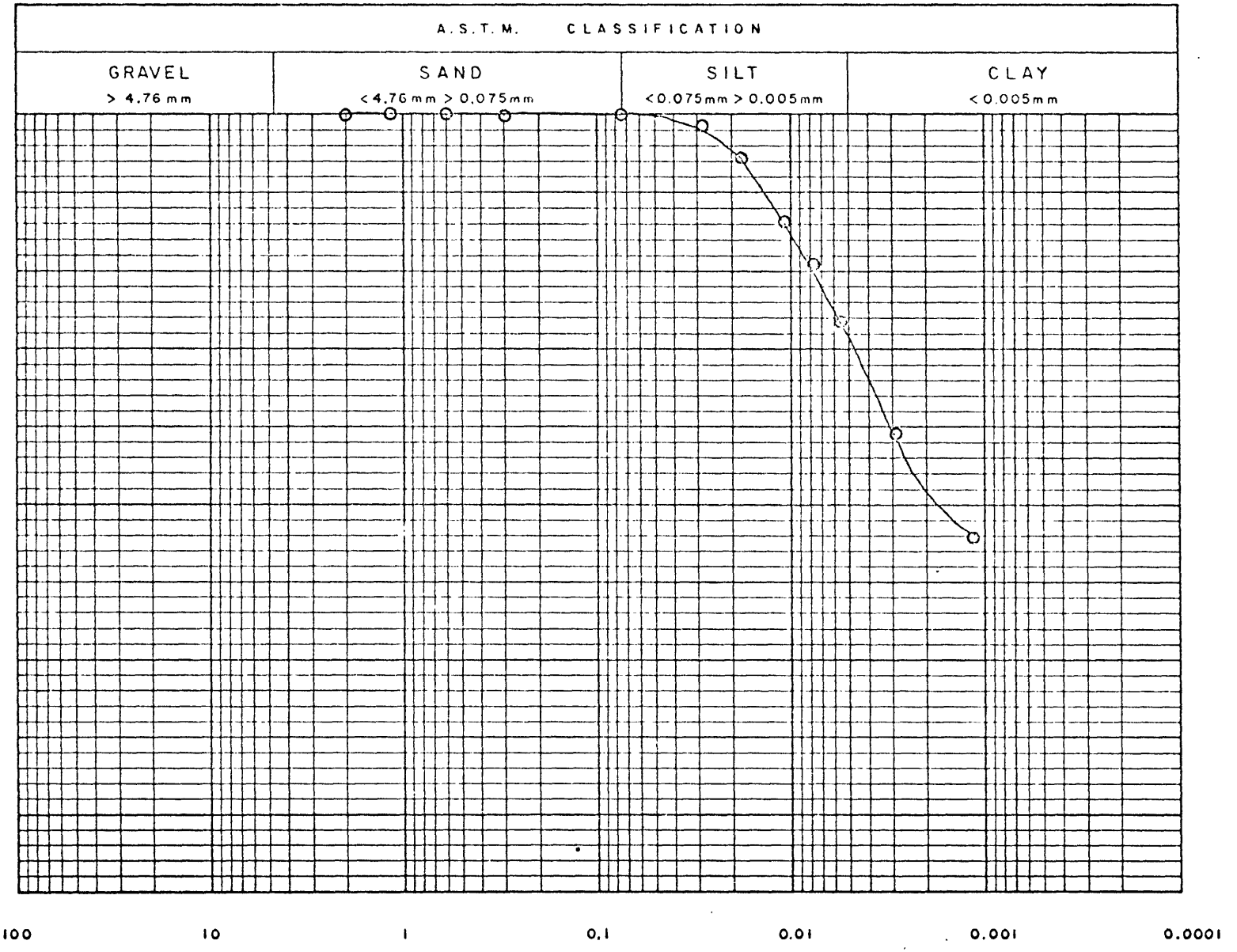
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 81.47-81.69 m



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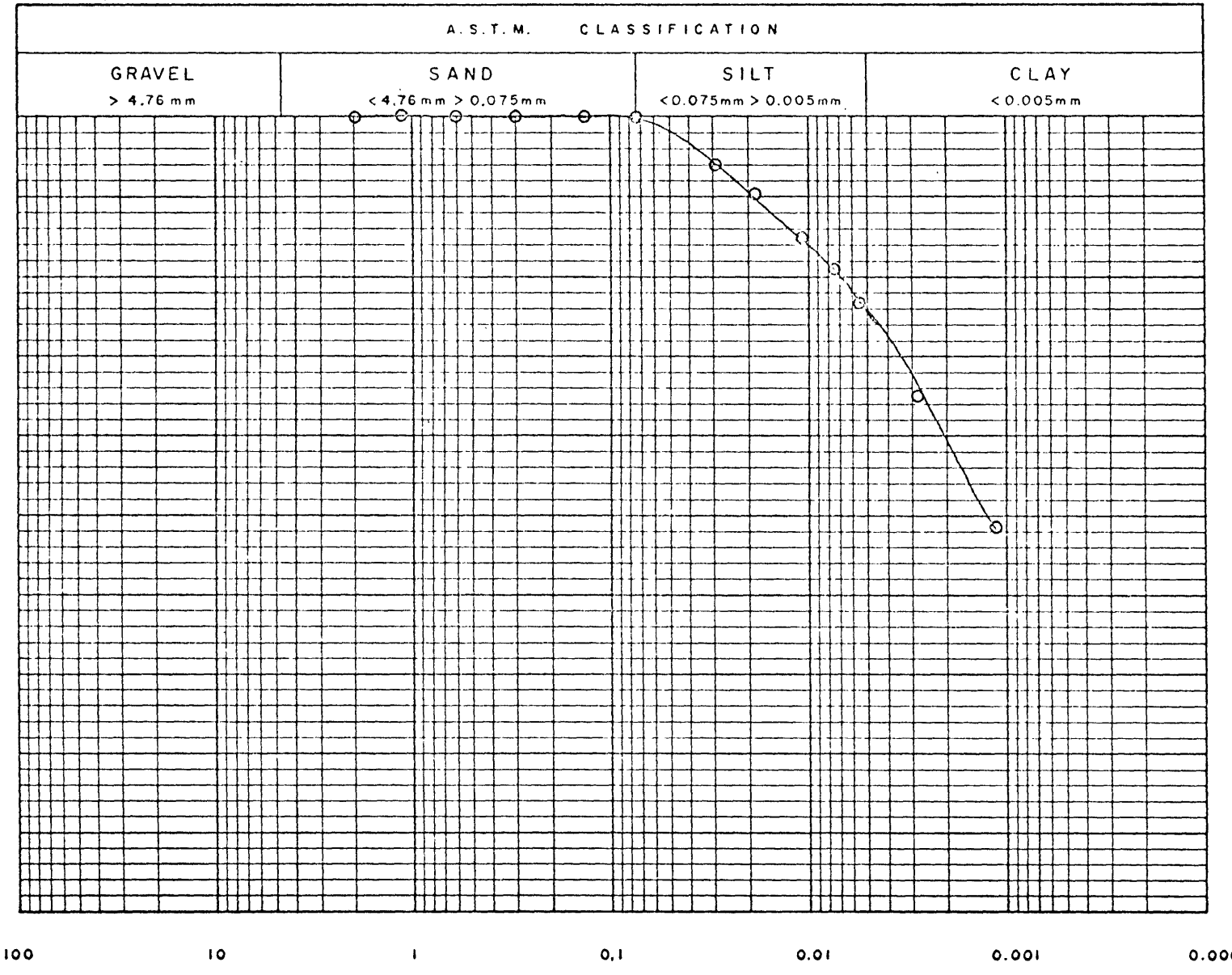
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 85.04-85.34 m

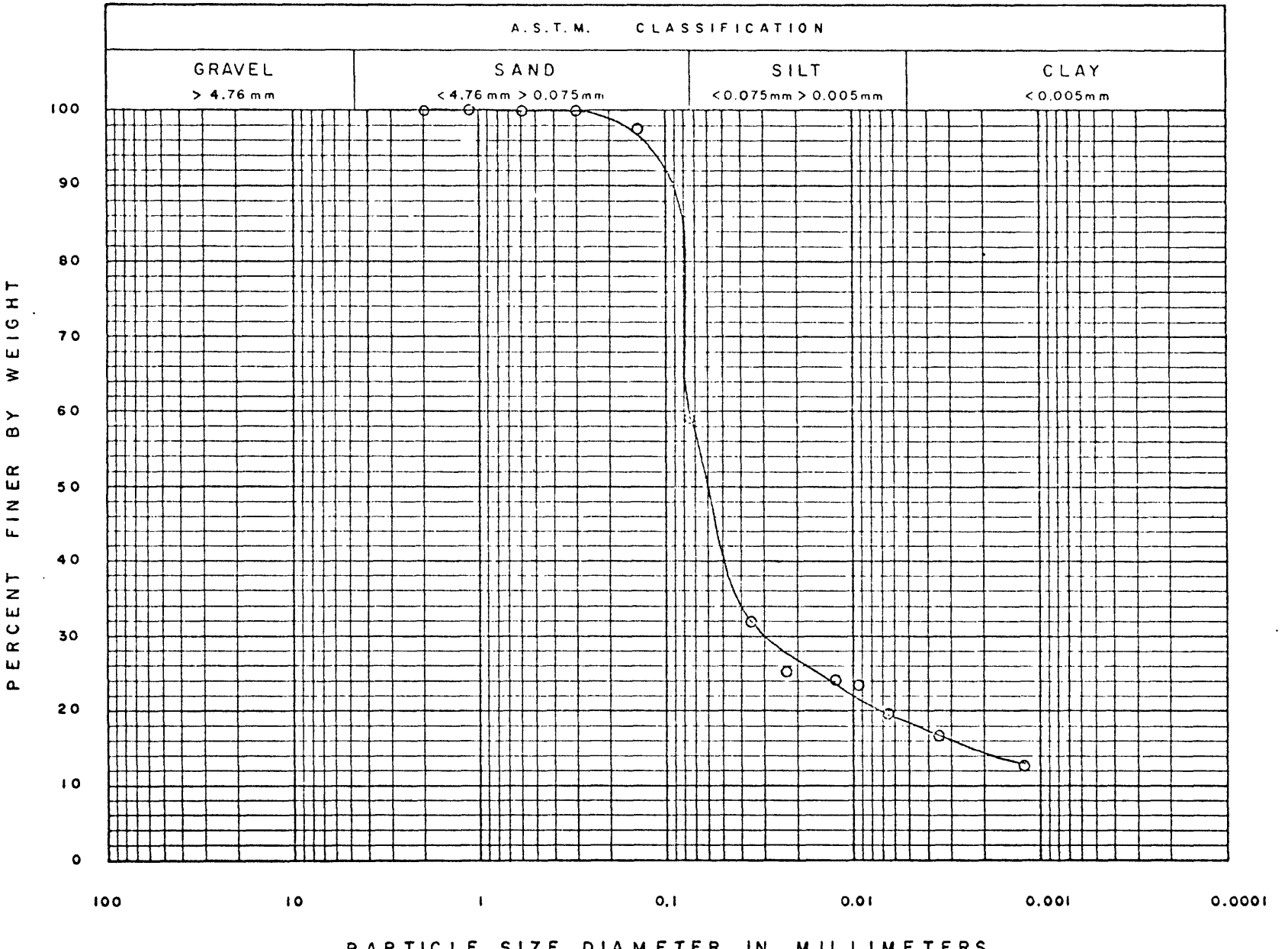


GPO 845-414

ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 88.39-88.48 m



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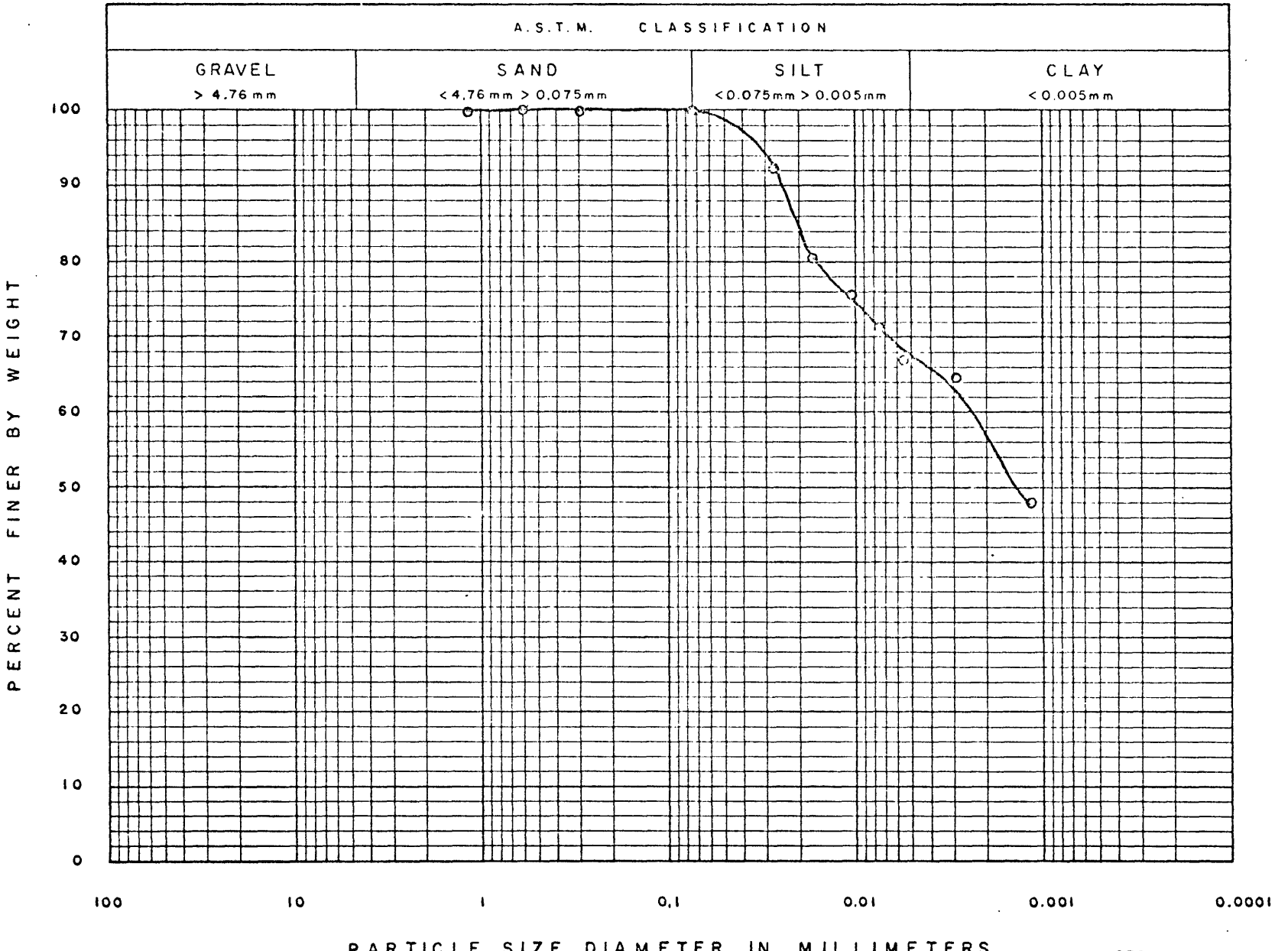
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 89.37-89.61 m



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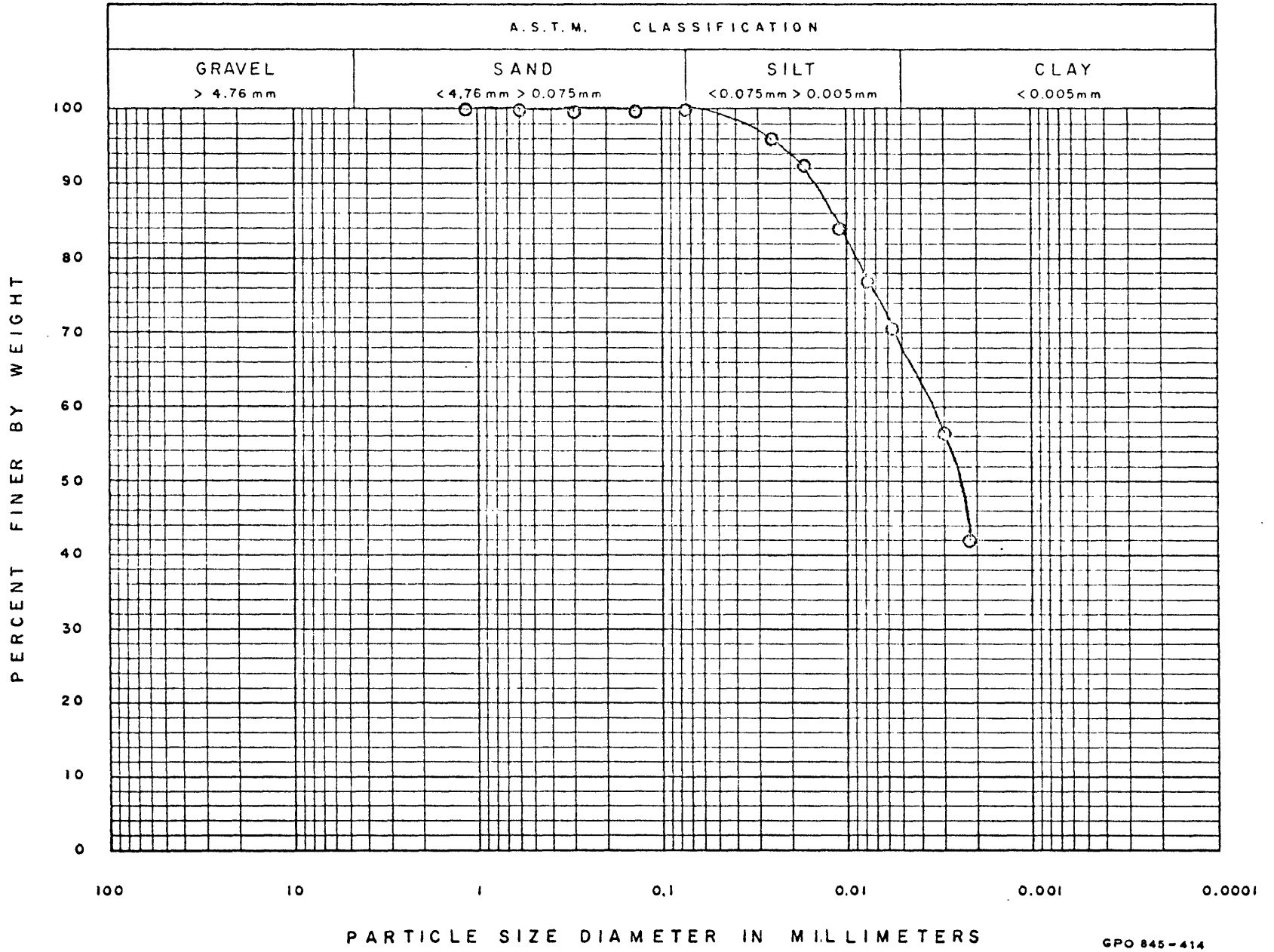
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 91.53-91.74 m



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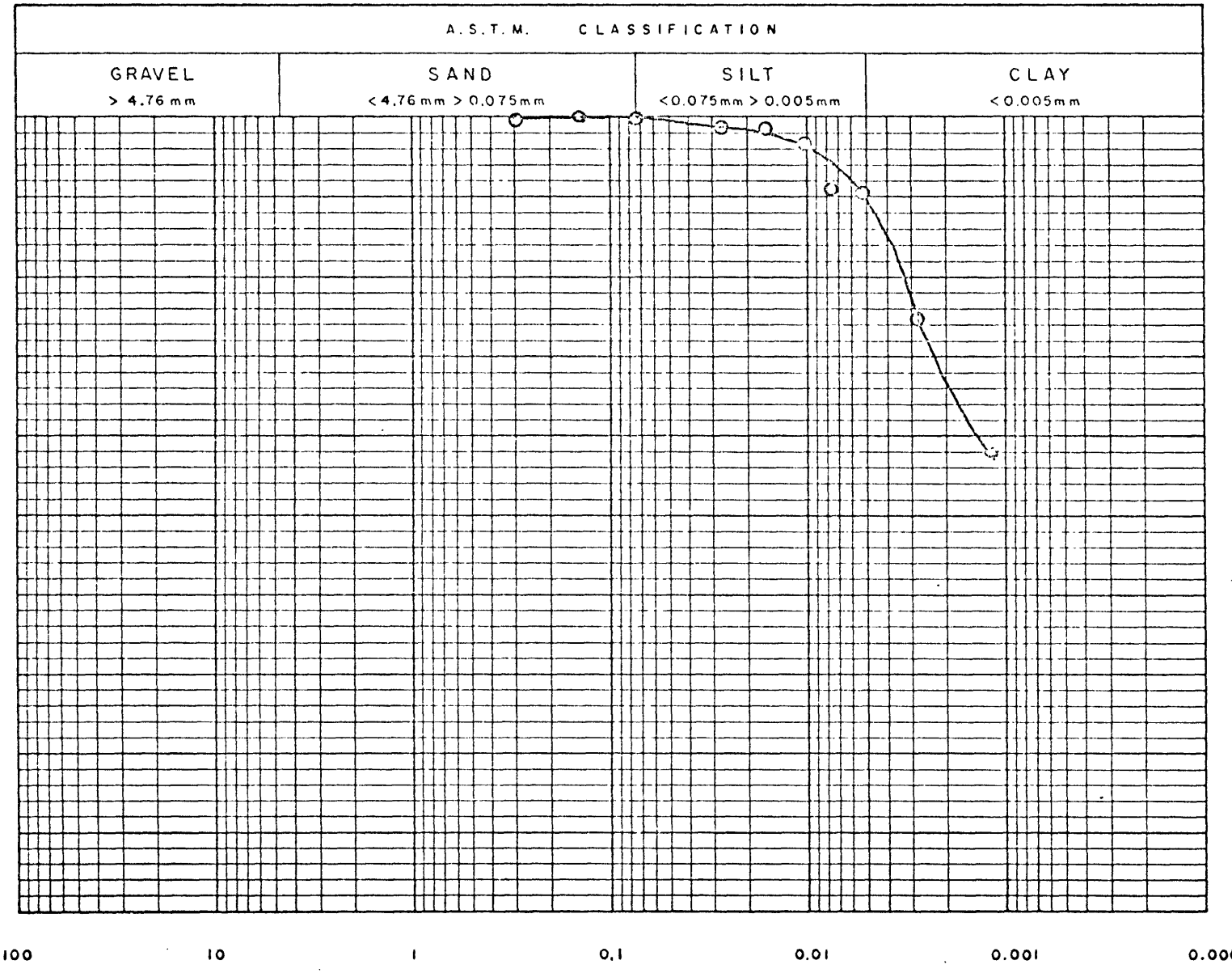
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 95.01-95.19 m



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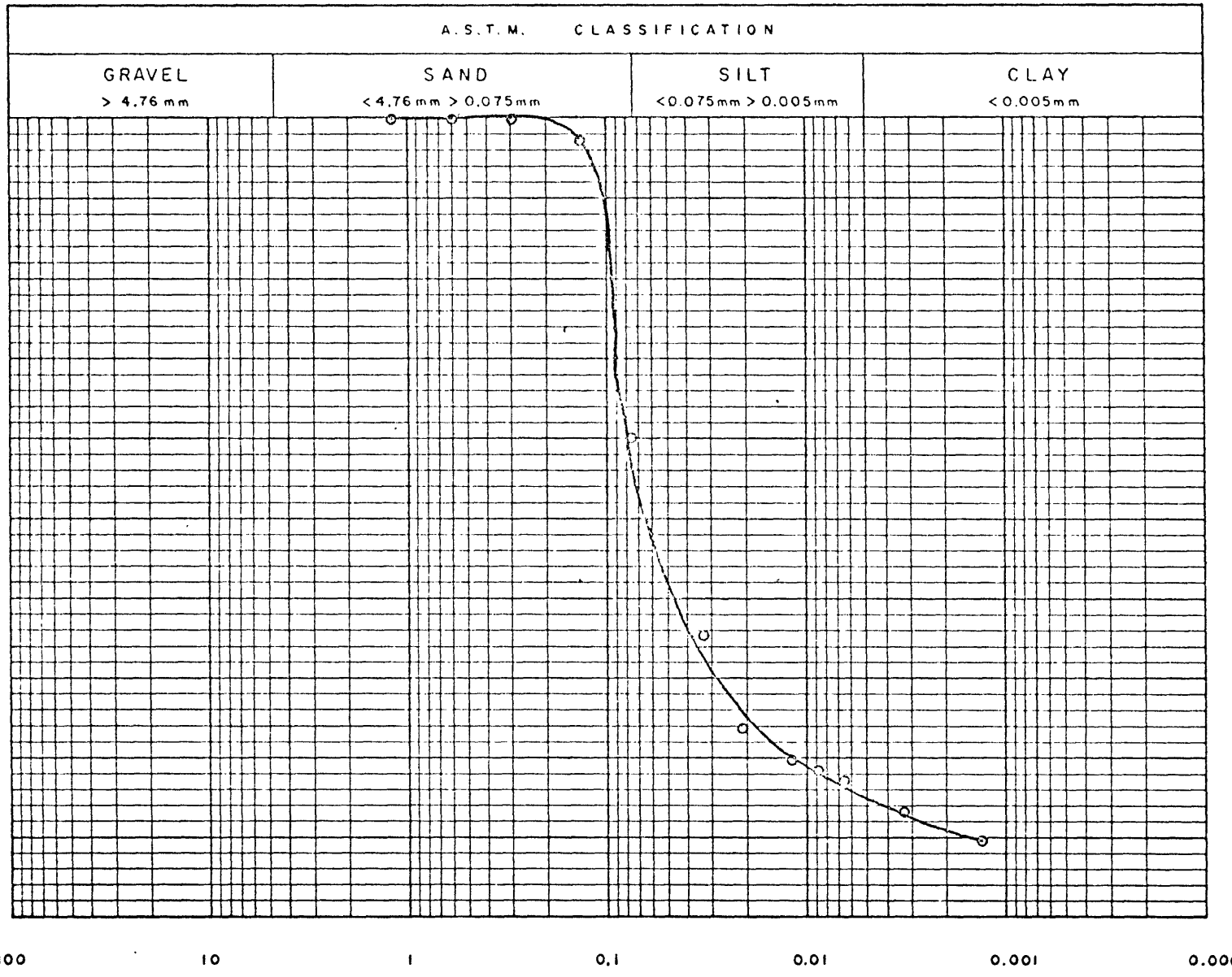
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 115.06-115.31 m



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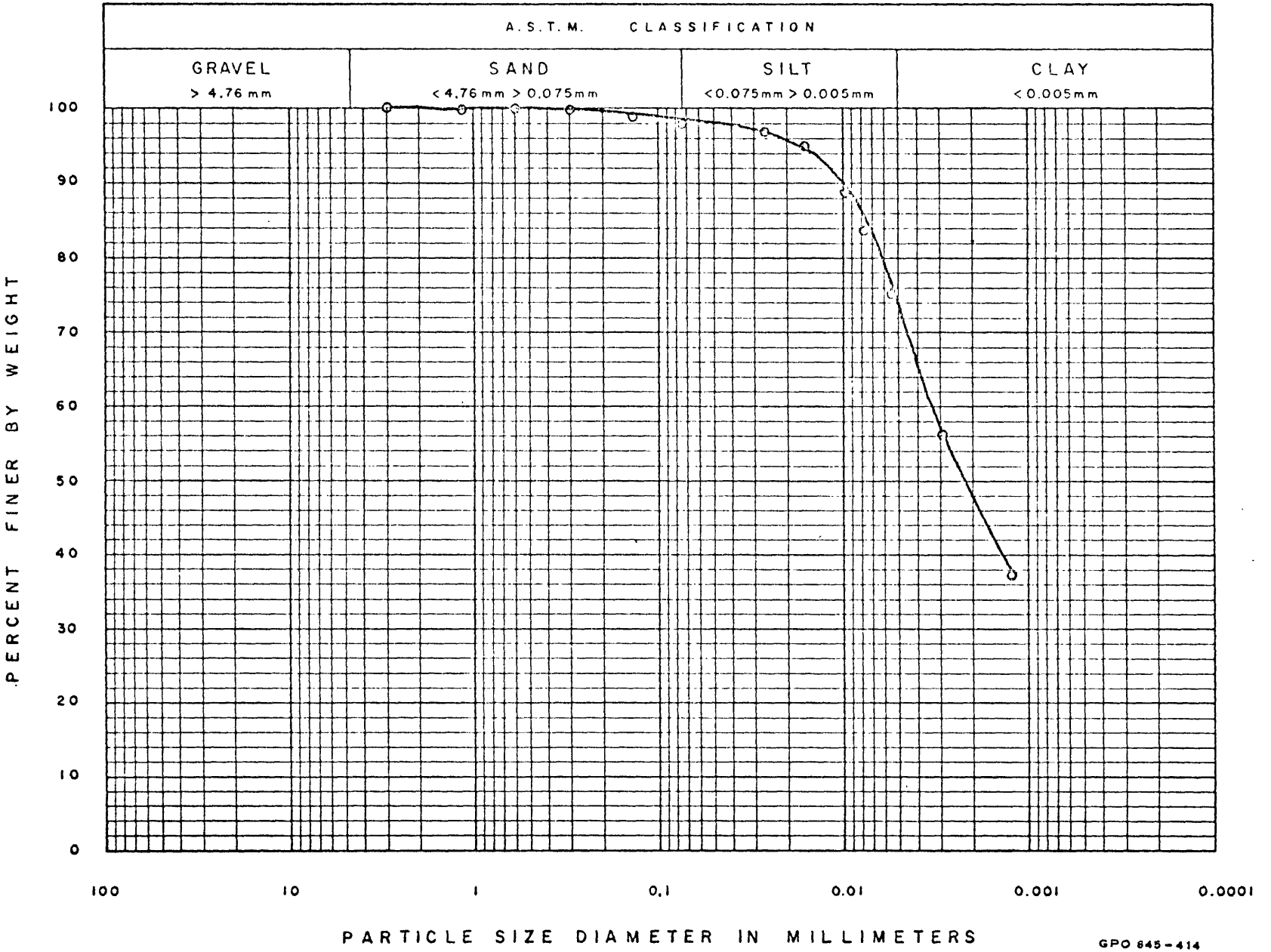
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 119.73-119.94 m

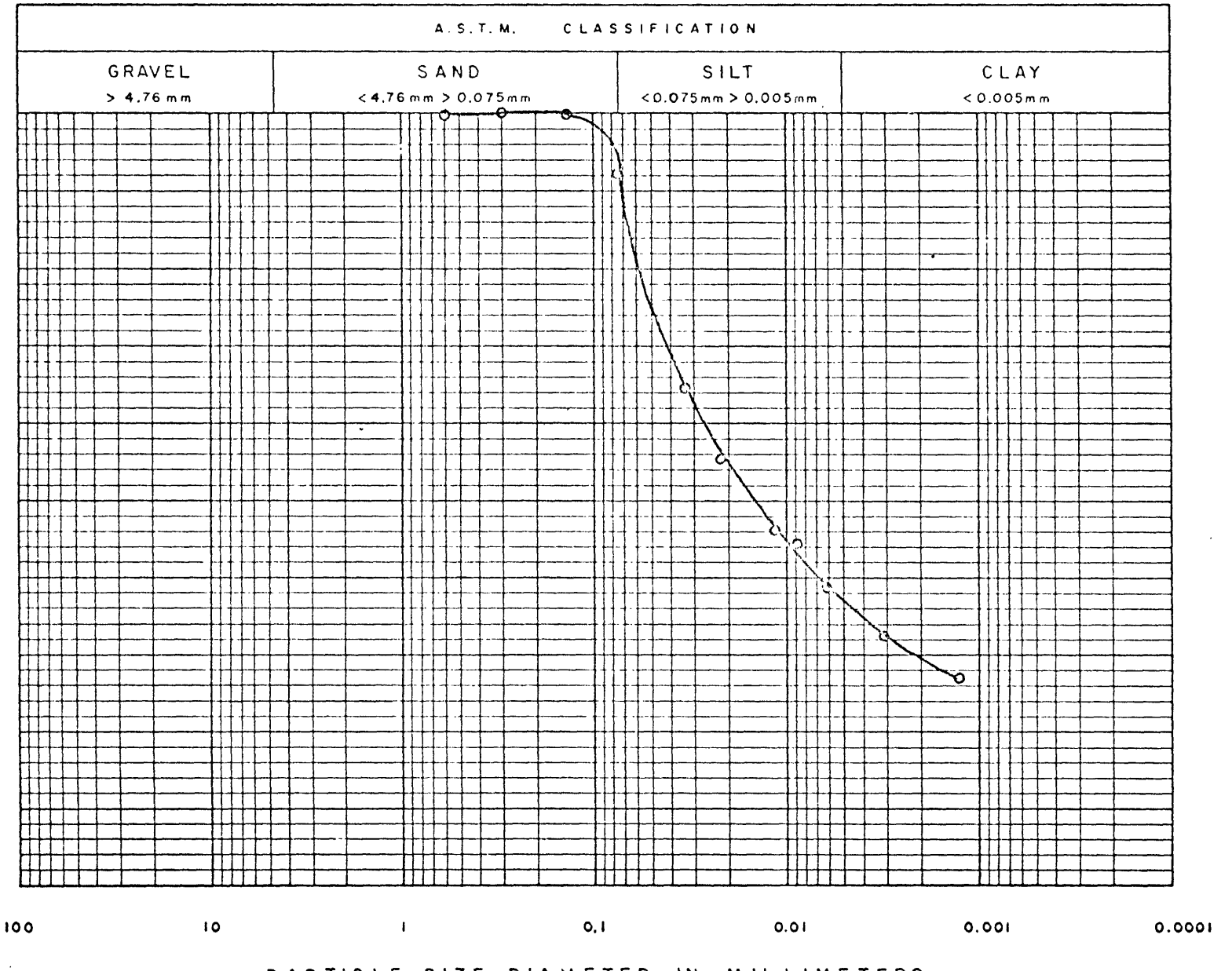


GPO 645-414

ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 123.14-123.32 m



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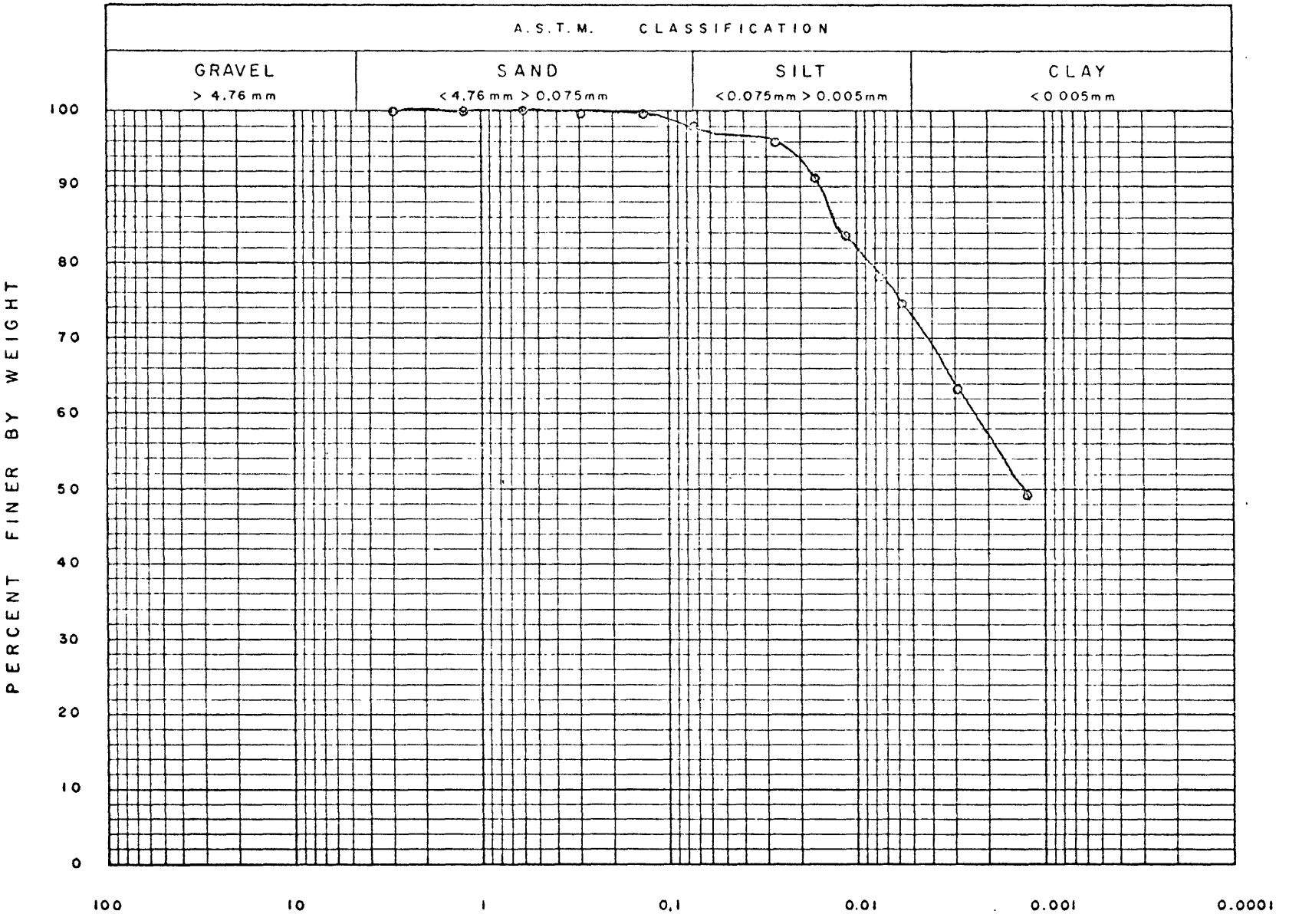
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 125.00-125.27 m



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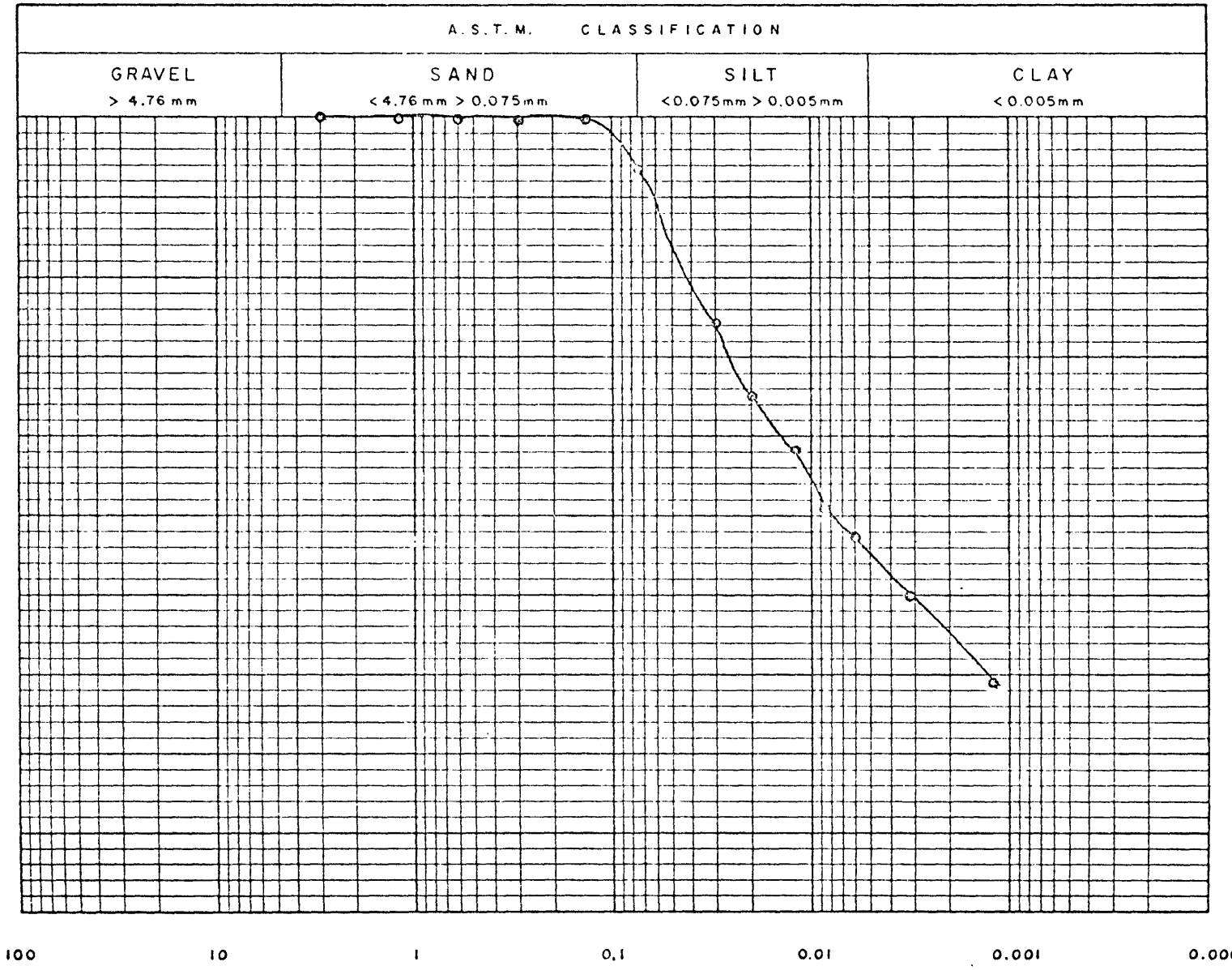
ENGINEERING GEOLOGY LABORATORY

PARTICLE SIZE DISTRIBUTION CURVE

SAMPLE NUMBER 128.38-128.63 m



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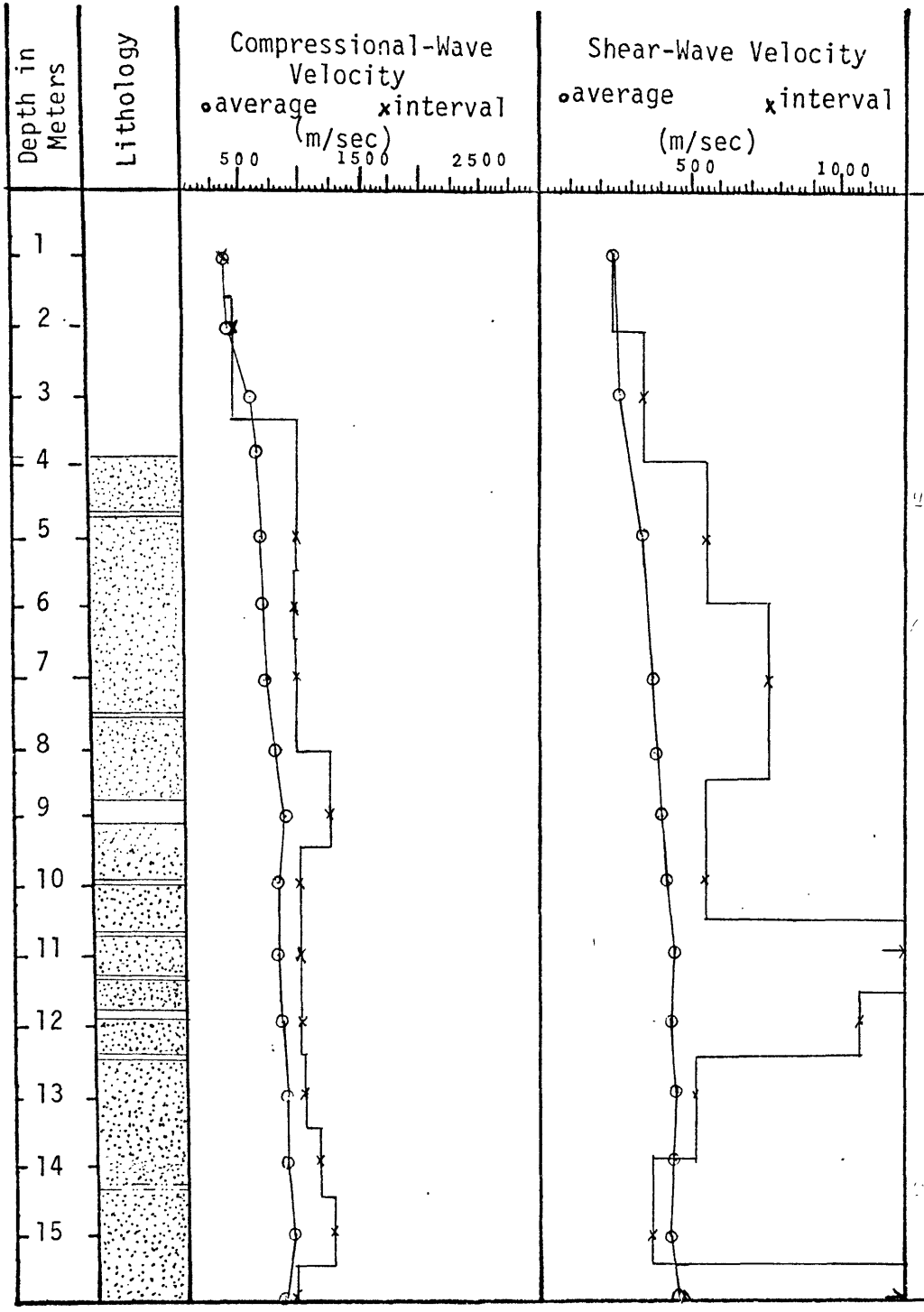
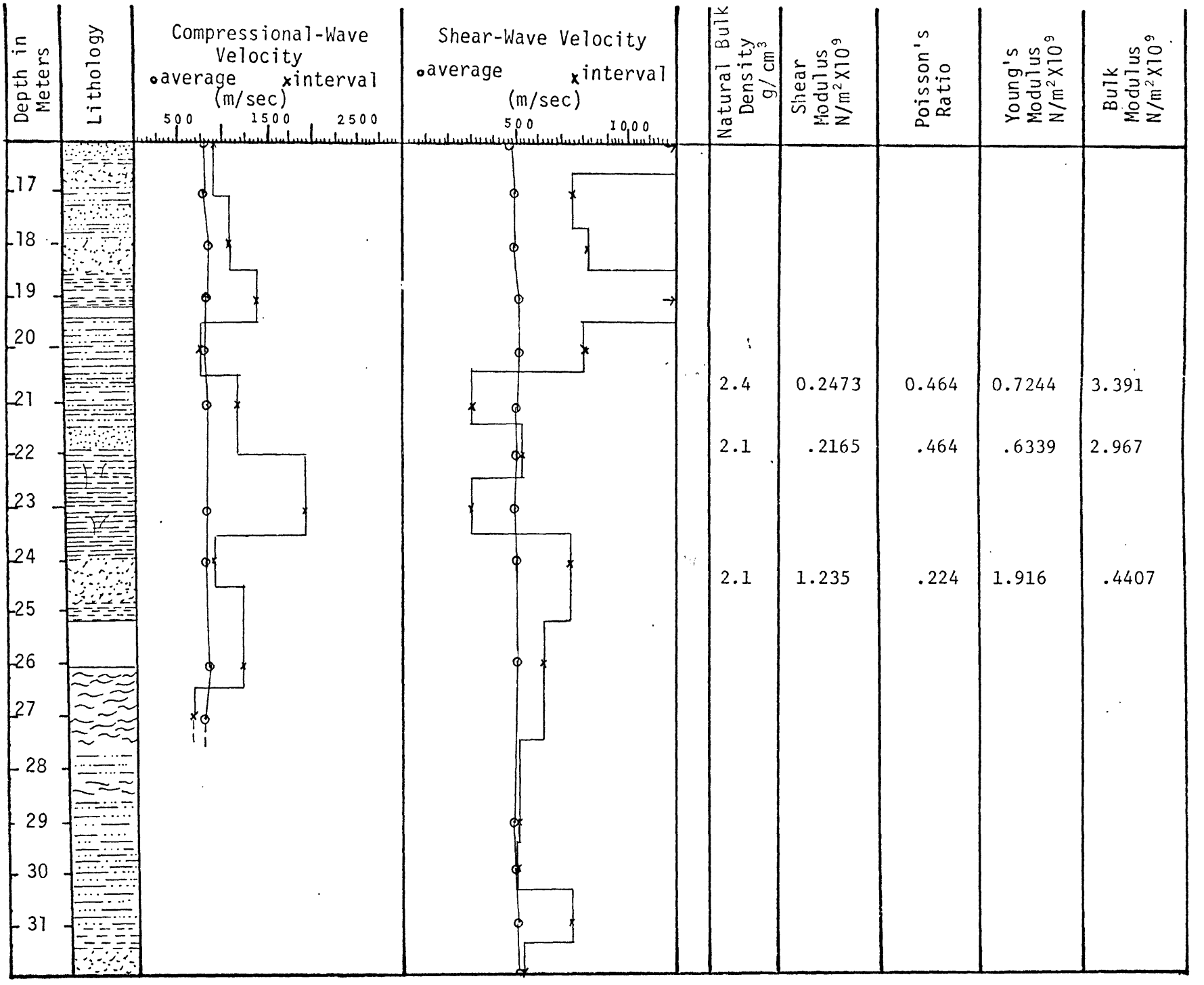
GPO 845-414

DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES



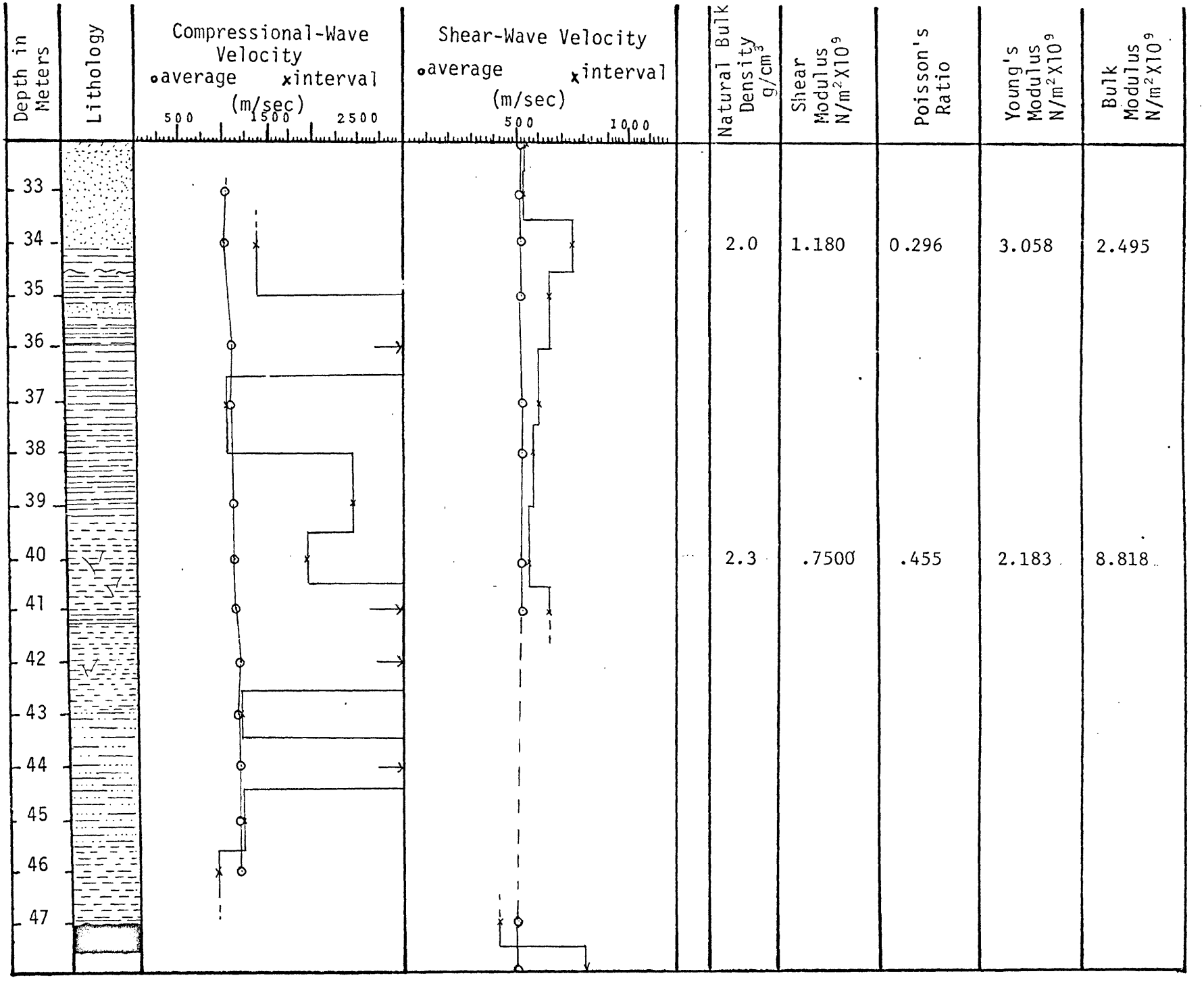
Natural Bulk Density g/cm³	Shear Modulus N/m²X10⁹	Poisson's Ratio	Young's Modulus N/m²X10⁹	Bulk Modulus N/m²X10⁹
2.3	0.7396	0.202	1.777	0.9941
2.0	1.171	.352	1.515	.2961
2.3	.3626	.443	1.046	3.054

DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES



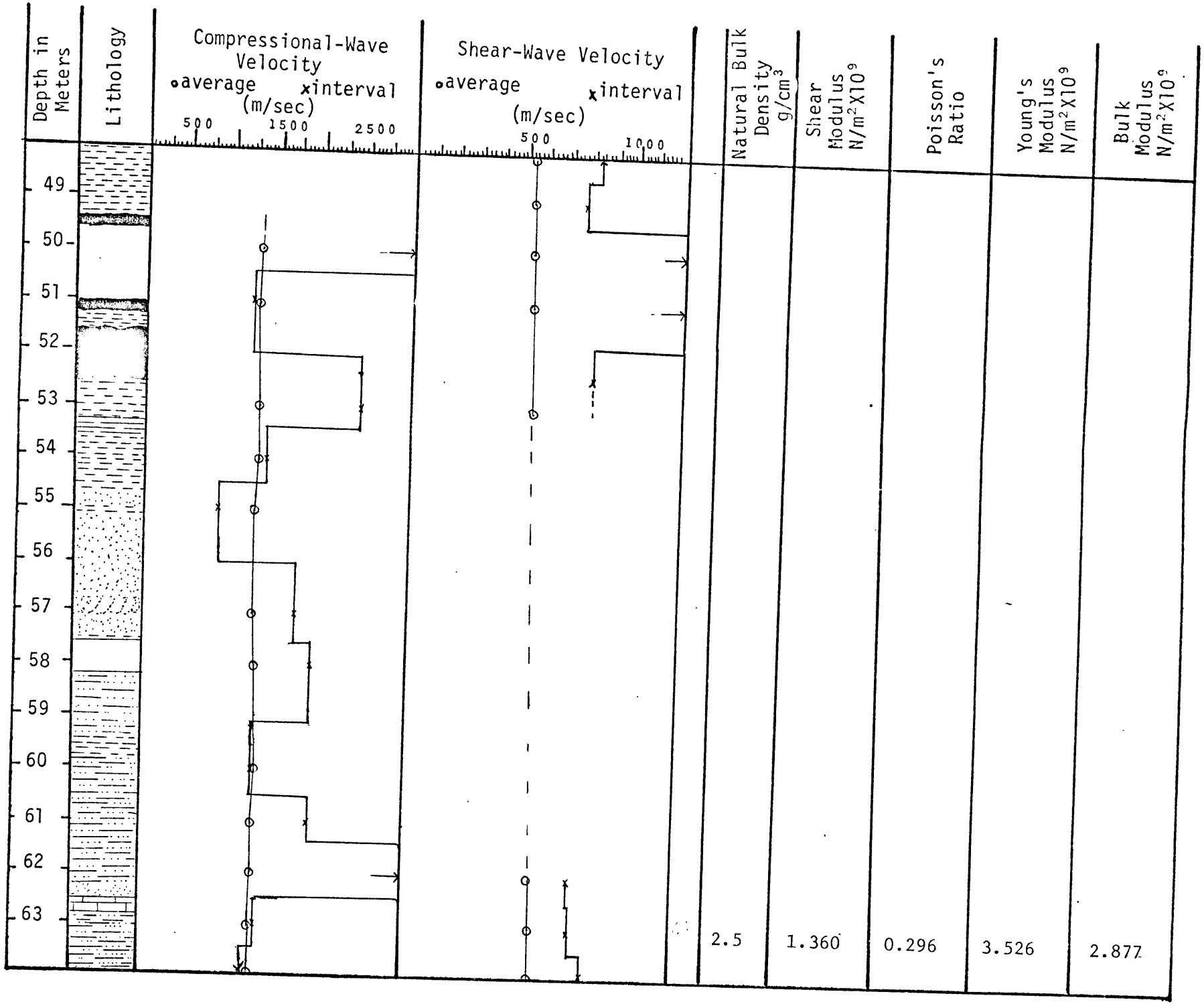
Natural Bulk Density g/cm³	Shear Modulus N/m²X10⁹	Poisson's Ratio	Young's Modulus N/m²X10⁹	Bulk Modulus N/m²X10⁹
2.4	0.2473	0.464	0.7244	3.391
2.1	.2165	.464	.6339	2.967
2.1	1.235	.224	1.916	.4407

DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES

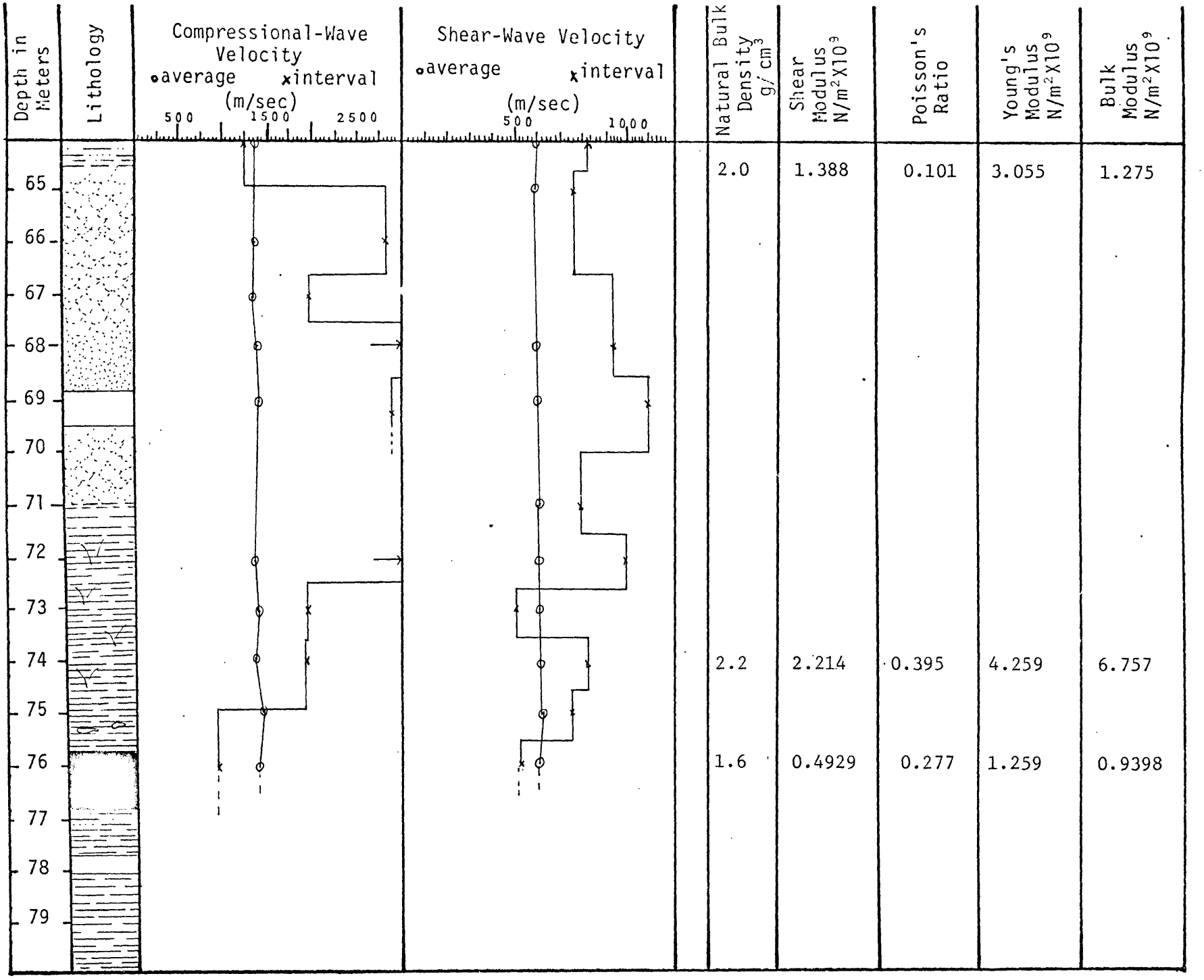


Natural Bulk Density g/cm^3	Shear Modulus N/m^{2}X10^9	Poisson's Ratio	Young's Modulus N/m^{2}X10^9	Bulk Modulus N/m^{2}X10^9
2.0	1.180	0.296	3.058	2.495
2.3	.7500	.455	2.183	8.818

DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES

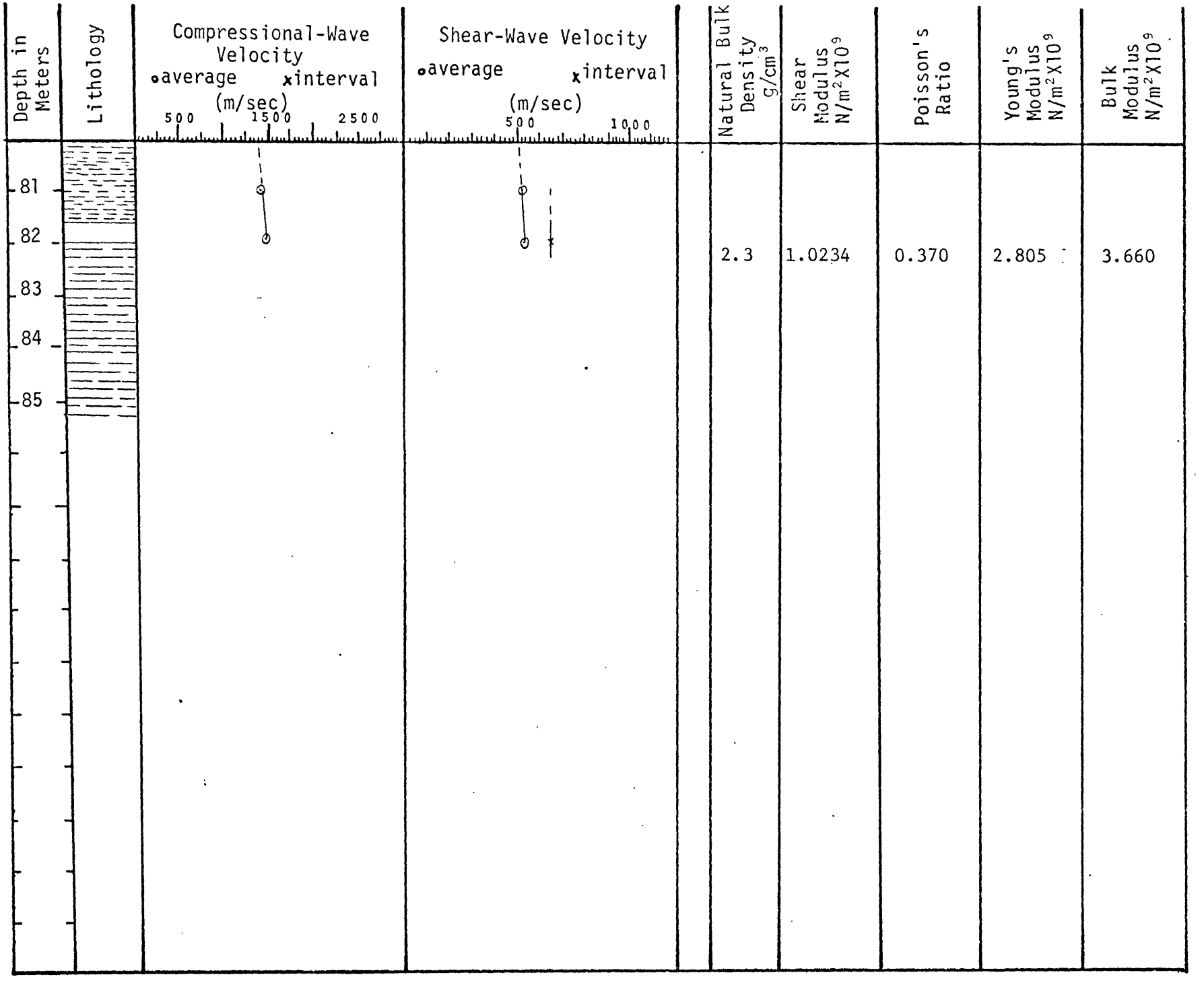


DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES

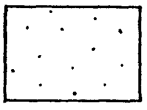


Natural Bulk Density g/cm³	Shear Modulus N/m²X10⁹	Poisson's Ratio	Young's Modulus N/m²X10⁹	Bulk Modulus N/m²X10⁹
2.0	1.388	0.101	3.055	1.275
2.2	2.214	0.395	4.259	6.757
1.6	0.4929	0.277	1.259	0.9398

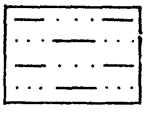
DETAILED VELOCITY WAVE LOGS AND CALCULATED PHYSICAL PROPERTIES

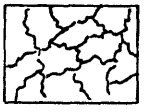


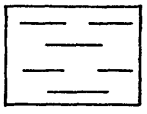
LITHOLOGIC SYMBOLS

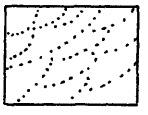

Sandstone

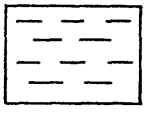

Coal

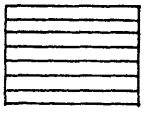

Siltstone

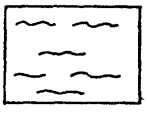

Bony Coal

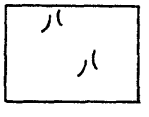

Shale

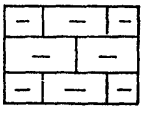

Crossbedded

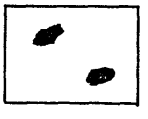

Claystone

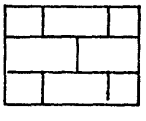

Carbonaceous

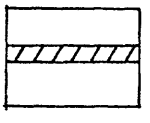

Mudstone

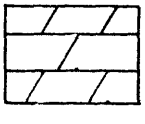

Slickensides


Argillite


Nodules


Limestone


Gypsiferous Zone

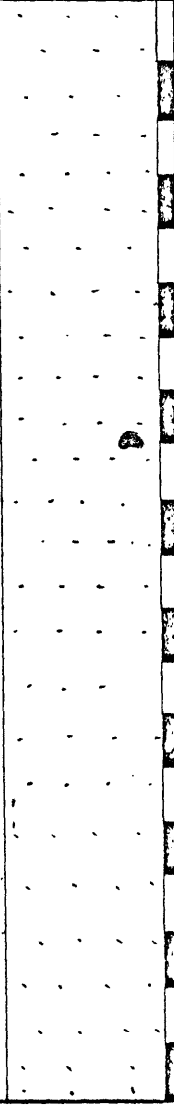

Dolomite

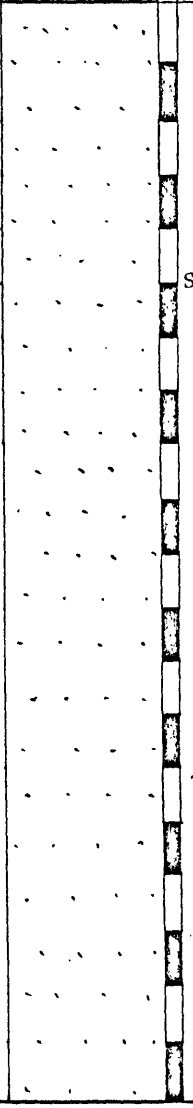
DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 0 - 4 meters
			The surficial material was penetrated with Shelby tube sampling to a depth of 3.8 m
X			

Sample	Lithology	5 Cm.	Description 4 - 5 meters
X			
	Core missing		
			Sand, olive (5Y 5/4), very fine to medium grained, well sorted, angular to subangular, noncalcareous and contains 80 pct. quartz, 10 pct. feldspar, and 10 pct. dark materials

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 5 - 6 meters
X			
			Same as above

Sample	Lithology	5 Cm.	Description 6 - 7 meters
X			
			Same as above but is moderately sorted. Calcareous and contains 75 pct. quartz, 10 pct. feldspar, 15 pct dark minerals
X			
			Sand, olive (5Y 5/4), very fine to fine, same as above

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 7 - 8 meters
	Core missing		
X			

Sample	Lithology	5 cm	Description 8 - 9 meters
	Core missing		
	Core missing		

DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 9 -10 meters
	Core missing		
X			
X			Silty sand, olive (5Y 4/3), medium grained, poorly sorted, angular to subrounded, noncalcareous and contains 80 pct. quartz, 15 pct. feldspar, 5 pct. dark minerals
X			Sand, light olive brown (2.5Y 5/4), very fine to medium grained, poorly sorted, subangular to subrounded, noncalcareous and contains 80 pct. quartz, 15 pct. feldspar, 5 pct. dark minerals
	Core missing		

Sample	Lithology	5 CM.	Description 10 - 11 meters
X			
	Core missing		
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 11 - 12 meters
			Same as above except light brown gray (2.5Y 6/2)
	Core missing		
	Core missing		

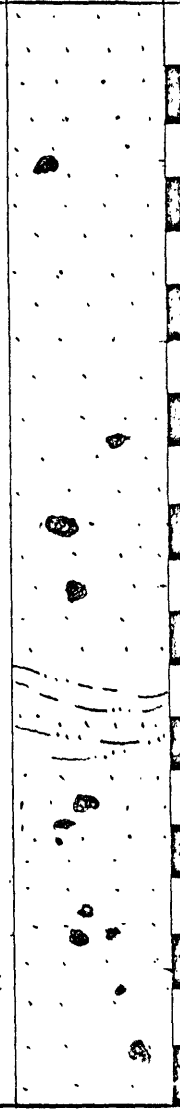
Sample	Lithology	5 cm	Description 12 - 13 meters
X			Sand, brown gray (2.5YR 5/2), coarse to fine grained, poorly sorted, angular to subangular, noncalcareous and contains 85 pct. quartz, 13 pct. feldspar, 2 pct. dark minerals. Also present are fragments of claystone
	Core missing		
X			Same as above except light gray (5Y 7/2) coarse to very fine grained. Several bands (5 cm wide) of iron? stained sand, pale yellow (5Y 7/3), present

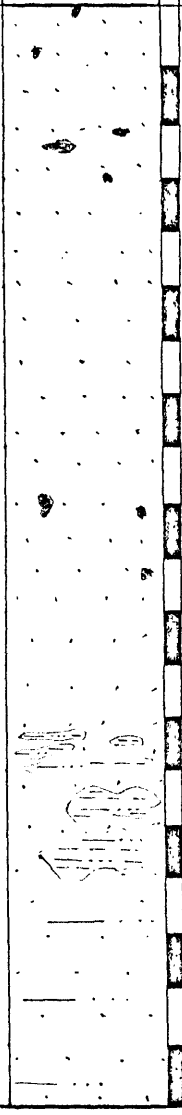
DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 13 - 14 meters
			Sand, yellow brown (10YR 5/8), fine to very coarse grained, poorly sorted, angular to subangular, noncalcareous, and contains 85 pct. quartz, 13 pct. feldspar, 2 pct. dark minerals. Also present are claystone fragments
X			
X			
X			Silty sand, same as above but very fine to medium grain size

Sample	Lithology	5 CM.	Description 14 - 15 meters
			Same as above. Also present is a quartz nodule and organic material
X			
			Sand, yellow brown (10YR 5/6), fine to silt size grains, poorly sorted, angular to subangular & noncalcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 15 - 16 meters
X X			Sand, gray brown (2.5Y 5/2), very fine to medium grained, poorly sorted, sub-angular to rounded, noncalcareous, limonitic? nodules present
X X			
X			

Sample	Lithology	5 cm	Description 16 - 17 meters
X			
			Sand, gray brown (2.5Y 5/2), very fine grained to medium, poorly sorted, angular to subrounded, with limonitic? nodules and claystone fragments
X			Sand, olive brown (2.5Y 4/4) silt to very fine grained, poorly sorted, sub-angular to subrounded, noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 17 - 18 meters
X			Silty clay, dark gray (2.5Y 4/0), with some quartz grains
			Gypsum (selenite) zone approximately 5 mm thick
X			
			Sandy silt, dark gray brown (2.5Y 4/0), the sand is very fine grained, angular to subangular, noncalcareous. Also present are limonitic? nodules
X			
			Double layer of gypsum (selenite) ∿ 5 mm thick
X			Silty sand, olive gray (5Y 5/2), very fine to silt grained, angular to subangular, noncalcareous. Also present are limonitic? nodules, and gypsum (selenite) ∿ 2 mm thick

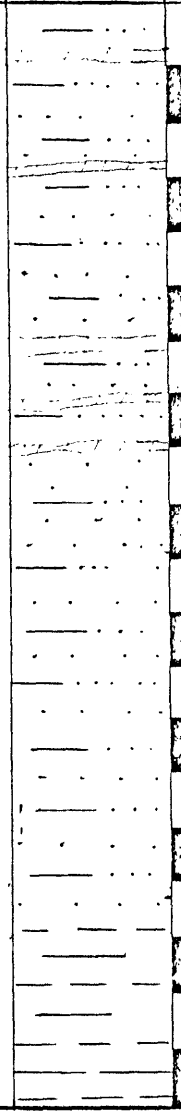
Sample	Lithology	5 Cm.	Description 18 - 19 meters
			Silty sand, gray (5Y 5/1), very fine to silt grained, moderately sorted, crossbedded; subrounded to subangular, noncalcareous, also limonite? nodules present
			Claystone, dark brown (2.5Y 4/2), noncalcareous, with iron sulfide minerals present
X			

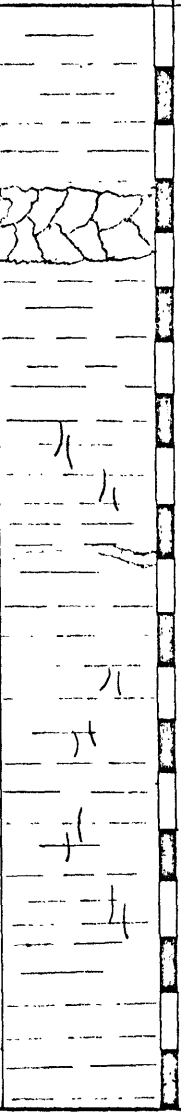
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 19 - 20 meters
			Shaley claystone, very dark gray (10 YR 3/1), noncalcareous
	Core missing		
X			Silty claystone, dark gray (5Y 4/1), noncalcareous

Sample	Lithology	5 cm	Description 20 - 21 meters
X			Silty claystone, gray (5Y 5/1), noncalcareous
X			Silty sand, gray (5Y 5/1), very fine grained, moderately sorted, angular to subangular, noncalcareous, and contains 85 pct. quartz, 10 pct. feldspar, 5 pct. dark minerals
			Silty sand, gray (5Y 5/1), very fine grained, poorly sorted, subangular, noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 20 - 21 meters
X			Silty sand, light gray (5Y 6/1), very fine grained, sorted, angular to subangular, slightly calcareous, and contains 80 pct. quartz, 15 pct. feldspar, and 5 pct. dark minerals
X			
X			
X			Shaley clay, gray (5Y 5/1), noncalcareous to calcareous and with carbonaceous plant material

Sample	Lithology	5 cm.	Description 21 - 22 meters
X			Claystone, dark olive gray (5Y 3/2), noncalcareous with gypsum and coal fragments. Slickenside common
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 23 - 24 meters
			Shaley, claystone, very dark gray (5Y 3/1) noncalcareous. Slickensides present. Also present are gypsum and carbonaceous material
	Core missing		
X			Claystone, very dark gray (5Y 3/1), noncalcareous. Color changes to dark gray (5Y 4/1)
			Color changes to black (5Y 2/1)
X			

Sample	Lithology	5 cm	Description 24 - 25 meters
X			Siltstone, gray (5Y 5/1), cross-bedded? or contorted bedding, moderately calcareous
X			
			Color changes to dark gray (5Y 4/1)
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 25 - 26 meters
			Same as above
			Argillite, gray (5Y 6/1) calcareous
			Dolomite? (light gray (5Y 7/1)
			Claystone, very dark gray (5Y 3/1), calcareous
			Shale, gray (5Y 6/1) calcareous
			Shale, gray (2.5Y 4/0), calcareous; carbonaceous plant fragments present

Sample	Lithology	5 cm	Description 26 - 27 meters
			Silty shale
			Claystone, gray (2.5Y 5/0), slightly calcareous
X			Mudstone, gray (2.5Y 6/0), gray (2.5Y 5/0), slightly calcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 27 - 28 meters
X			Clayey siltstone, gray (2.5Y 5/0), carbonaceous plant film, slightly to noncalcareous

Sample	Lithology	5 cm.	Description 28 - 29 meters
X			Muddy siltstone, dark gray (2.5Y 4/0), fossil shells, carbonaceous plant material, very calcareous
			Siltstone, light gray (2.5Y 7/2), limy
			Mudstone, gray (2.5Y 5/0), carbonaceous plant material, slightly calcareous
X			Clayey siltstone, gray (2.5Y 5/0), and gray (2.5Y 6/0), noncalcareous
			Selenite crystals on core. Size ∿ ½ mm in width

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 29 - 30 meters
X			Muddy siltstone, gray (10YR 6/1), mud increases downward, calcareous
X X			

Sample	Lithology	5 Cm.	Description 30 - 31 meters
X			Claystone, gray (2.5Y 5/0, carbonaceous film, fragments, and plant material
			Clayey siltstone, gray (10YR 5/1), clay decreases downward, sand increases downward, noncalcareous
X			Sand, gray (10YR 6/1), crossbedded very fine grained, poorly sorted, angular to subrounded; contains some carbonaceous fragments, increases in clay and silt downward; calcareous, contains 65 pct. quarts, 35 pct. feldspar, 5 pct. dark accessory minerals
			Shaley-silty claystone, dark gray (5Y 4/1), slightly calcareous
X			Color changes to yellowish brown (10YR 5/8)

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 31 - 32 meters
X			
X			
			Sand, gray (5Y 6/1), crossbedded, very fine to fine grained, poorly sorted; angular to subrounded, calcareous; contains 92 pct. quartz and 8 pct. dark accessory minerals
X X			
X			
X			
			sulfide mineral (pyrite?) fragments present

Sample	Lithology	5 cm.	Description 32 - 33 meters
			Sand, same as above, but containing 90 pct. quartz, 5 pct. feldspar, and 5 pct. dark accessory minerals
			Sand, same as above, except lacking crossbedding and only slightly calcareous
X			
X			
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 33 - 34 meters
			Sulphide nodules present
			Sand, same as above, but contains 85 pct. quartz, 5 pct. feldspar and 10 pct. dark accessory minerals.
			Shale, dark gray (2.5Y 5/0), abundant carbonaceous plant fragments present, slightly calcareous
			Mudstone, dark gray (5Y 4/1), carbonaceous plant material present, non-calcareous

Sample	Lithology	5 CM.	Description 34 - 35 meters
			Discontinuous sand laminae present gray (5Y 5/0)
X			
X			
			Claystone, gray (2.5Y 6/0), slightly calcareous
			Claystone, gray (5Y 5/1), slightly calcareous. Also present are discontinuous calcareous sand laminae
X			
			A stained zone, strong brown (7.5YR 5/6)
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 35 - 36 meters
			Sand, gray (5Y 6/1), very fine to fine grained, poorly sorted; angular to subrounded, calcareous; contains 85 pct. quartz, 5 pct. feldspar, and 10 pct. dark accessory minerals
			Sulphide mineral nodules present
			Shale, black (5Y 2/1), carbonaceous, noncalcareous
X			
X			
			Shale, dark gray (2.5Y 4/0), contains occasional carbonaceous plant fragments
			Core missing

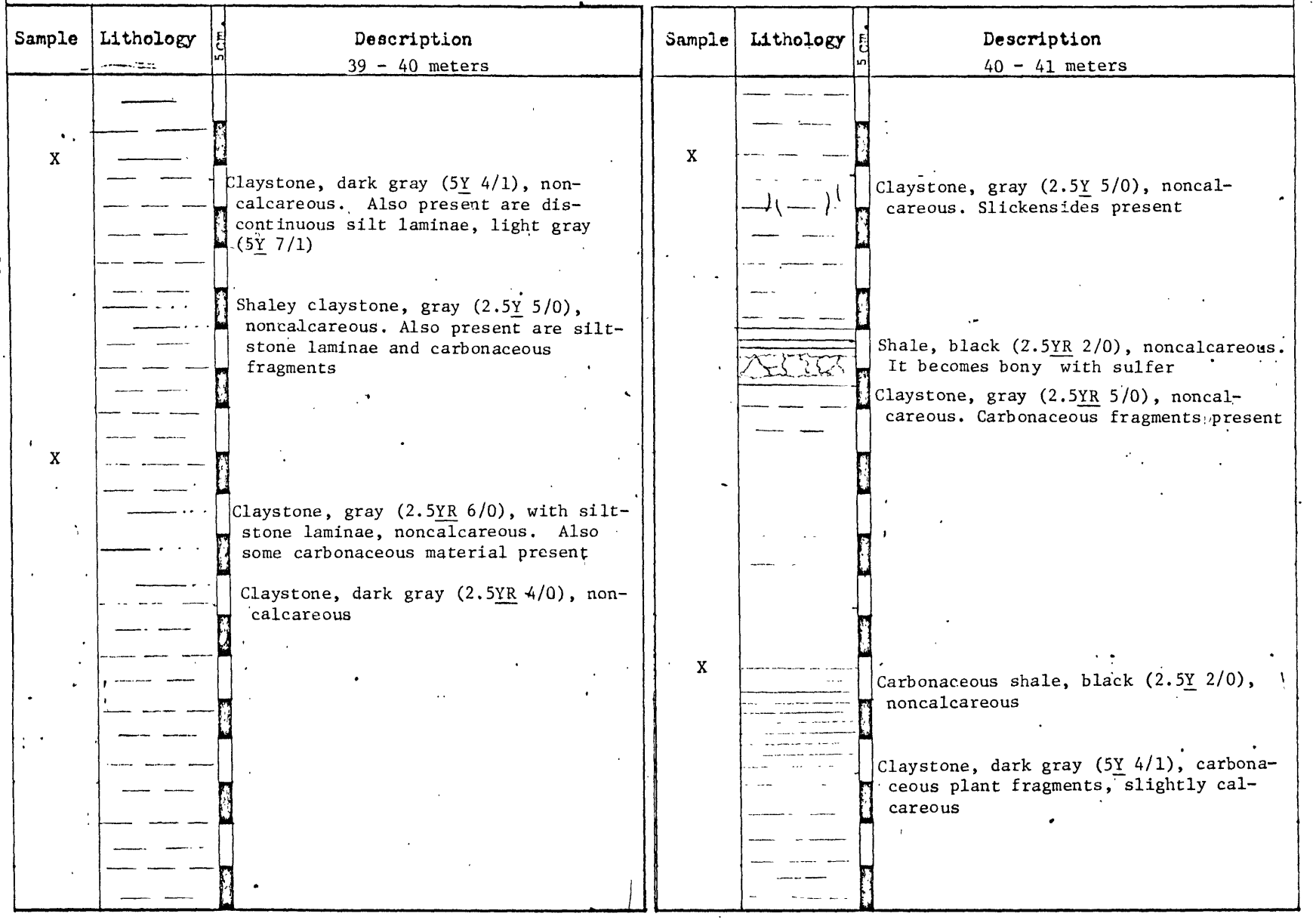
Sample	Lithology	5 cm	Description 36 - 37 meters
			Core missing
			Shale, dark gray (5Y 4/1), occasional carbonaceous plant fragments, non-calcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 CM	Description 37 - 38 meters
			Becomes silty and calcareous
X			

Sample	Lithology	5 CM	Description 38 - 39 meters
			Becomes slightly silty
X			
X			

DETAILED LITHOLOGY



DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 41 - 42 meters
			Carbonaceous shale, black (2.5Y 2/0), noncalcareous
X			
			Shaley claystone, gray (5Y 3/0), carbonaceous plant fragments, slightly calcareous. Also slickensides present
			Carbonaceous shale, black (2.5Y 2/0), noncalcareous
			Claystone, dark gray (5Y 4/1).

Sample	Lithology	5 Cm.	Description 42 - 43 meters
X			carbonaceous plant material slightly calcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 43 - 44 meters
			Siltstone, olive gray (5Y 5/2), slightly calcareous
			Shale, dark gray (5Y 4/1), noncalcareous
X			
X			
X			

Sample	Lithology	5 cm.	Description 44 - 45 meters
			Carbonaceous plant material present
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 45 - 46 meters
			Shaley siltstone, gray (5Y 5/1), noncalcareous
			Carbonaceous plant material
			Claystone, gray (5Y 5/1), slightly calcareous. Slickensides present

Sample	Lithology	5 cm	Description 46 - 47 meters
X			
X			
			Claystone, dark gray (5Y 4/1), slightly calcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm	Description 47- 48 meters
			Coal and carbonaceous shale, black (2.5Y 2/1), noncalcareous
			Coal, black (7.5Y 2/0), slickensides present
X			
	Core missing		

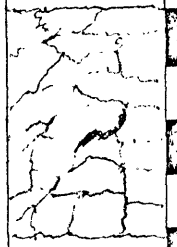
Sample	Lithology	5 Cm	Description 48 - 49 meters
			Claystone, dark gray (5Y 4/0), carbonaceous material present, noncalcareous
X X			
			Becomes very dark gray (5Y 3/1)

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 49 - 50 meters
X			
			Coal (lignite), black (2.5Y 2/0)
			Claystone, very dark gray (5Y 3/1), noncalcareous
X			Carbonaceous claystone, black (5Y 2/0 to 2.5Y 2.0), noncalcareous
			Carbonaceous shale, black (2.5Y 2/0), calcareous

Sample	Lithology	5 cm	Description 50 - 51 meters
			Claystone, dark olive gray (5Y 3/2) with carbonaceous plant material, noncalcareous
			Changes to dark gray (5Y 4/1)
X X			Changes to dark olive gray (5Y 3/2)
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 51 - 52 meters
			Bony coal, black (2.5Y 2/0), resin blebs present
			Carbonaceous claystone, black (2.5Y 3/0), noncalcareous
			Shaley coal, black (2.5Y 2/0)
			Carbonaceous claystone, very dark gray (5Y 3/1)
			Coal, black (2.5Y 2/0)
X			

Sample	Lithology	5 cm	Description 52 - 53 meters
X			Carbonaceous claystone, black (2.5Y 2/0)
			Claystone, dark gray (5Y 4/1), carbonaceous plant material present, calcareous
X X			

DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 53 - 54 meters
X			Carbonaceous shale, black (2.5Y 2/0), leached sulphur present, noncalcareous
			Claystone, dark gray (5Y 4/1), carbonaceous plant fragments, slightly calcareous
X			

Sample	Lithology	5 CM.	Description 54 - 55 meters
X X			Sand, light gray (5Y 6/1), very fine to fine grained, poorly sorted, angular to subrounded, noncalcareous and contains 95 pct. quartz and 5 pct. dark minerals
X			
			Claystone, dark gray (5Y 4/1), carbonaceous material, noncalcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 55 - 56 meters
			Sand, light gray (5Y 6/1), very fine grained, subangular to subrounded, noncalcareous, 90 pct. quartz, 5 pct. feldspar, and 5 pct. dark minerals.

Sample	Lithology	5 Cm.	Description 56 - 57 meters
			Same as above, but 85 pct. quartz, 10 pct. feldspar, and 5 pct. dark minerals, noncalcareous, poorly sorted
X			Sand, light gray (5Y 6/1), fine to very fine grained, sorted, subangular to subrounded, tightly packed, noncalcareous, 80 pct. quartz, 10 pct. feldspar, 5 pct. dark minerals

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 57 - 58 meters
X X			
			Claystone, dark gray (2.5Y 4/0), calcareous
	Core missing		
X			

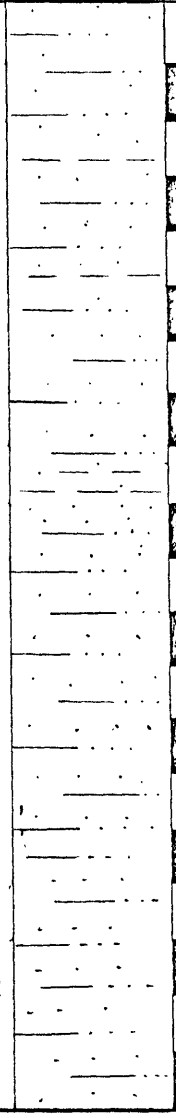
Sample	Lithology	5 cm.	Description 58 - 59 meters
X	Core missing		
			Sandstone, light gray (5Y 6/1), very fine grained, well sorted, subangular to subrounded, calcareous to noncalcareous, 95 pct. quartz, 2 pct. feldspar, and 3 pct. dark minerals. Clayey in places
X			

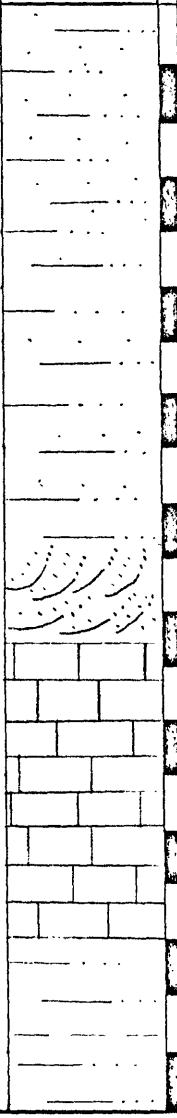
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 59 - 60 meters
			Claystone, very dark gray (5Y 3/1), with sandstone laminae, light gray (5Y 7/1), very fine grained to silt. Subangular to angular, poorly sorted, calcareous
X			
X			Becomes silty, dark olive gray (5Y 3/2)

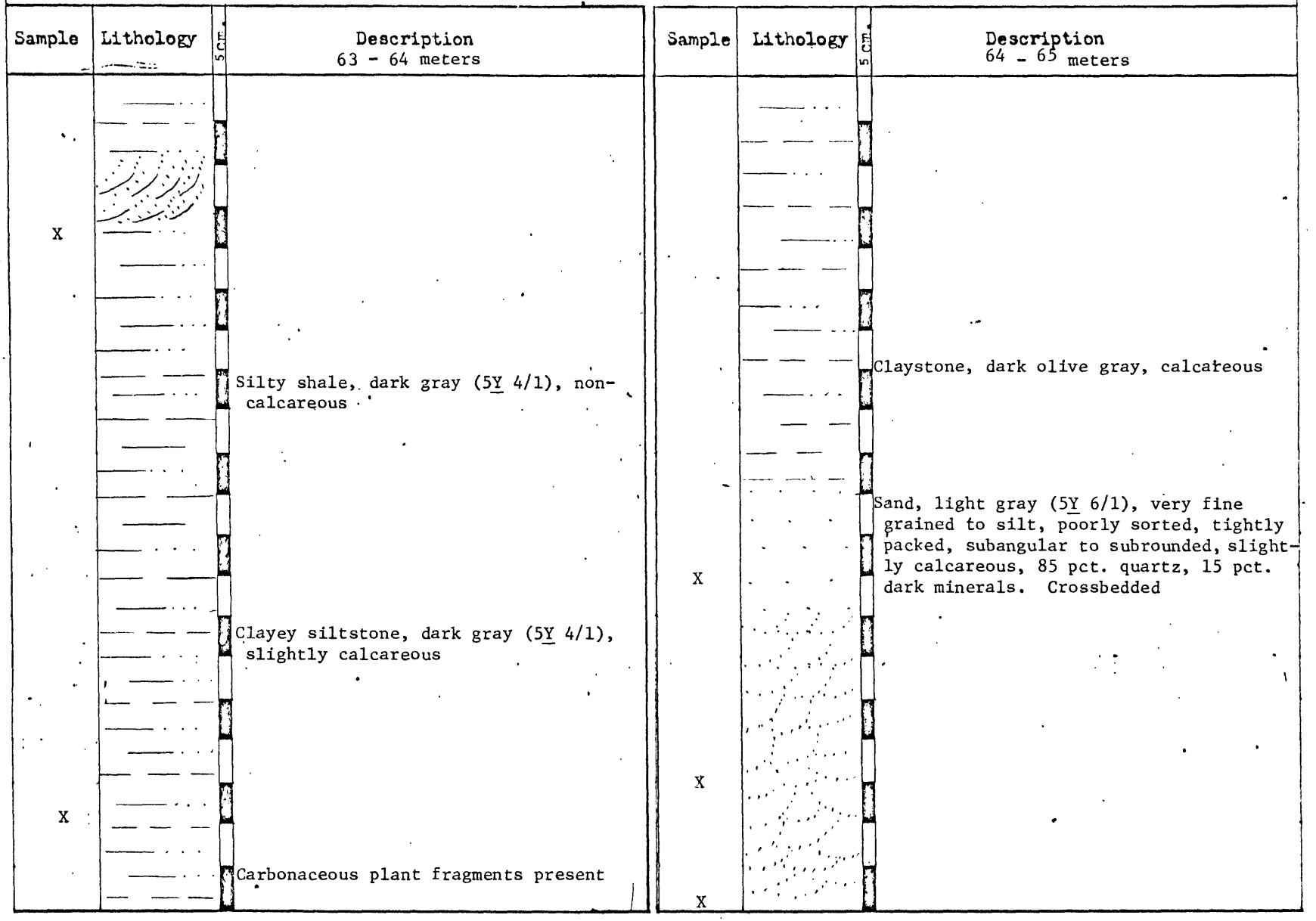
Sample	Lithology	5 cm	Description 60 - 61 meters
X			Clayey siltstone, gray (5Y 4/1), non-calcareous. Also thin-bedded claystone, gray (5Y 4/1)
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 61- 62 meters
X			Sandy siltstone, light gray (5Y 7/1 to 5 Y 6/1), sand grains are very fine grained, slightly calcareous, also some claystone laminae

Sample	Lithology	5 cm	Description 62 - 63 meters
X			Same as above, but lacking claystone laminae, calcareous Crossbedded siltstone and sandstone Limestone?, gray (2.5Y 5/0) Sandy, clayey siltstone, light gray (5Y 6/1), limy and becomes crossbedded
X			

DETAILED LITHOLOGY

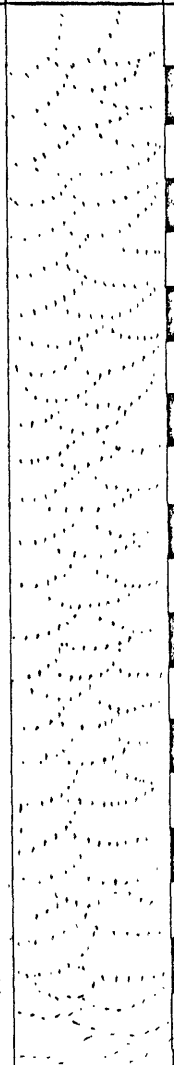


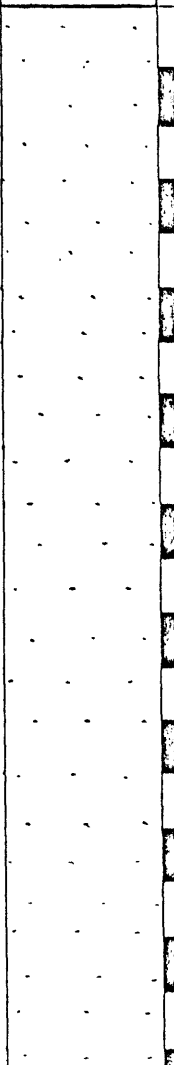
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 65- 66 meters
			213.5
X			
			Claystone laminae, very dark gray found often
X			80 pct. quartz, 5 pct. feldspar, 15 pct. dark minerals

Sample	Lithology	5 cm	Description 66 - 67 meters
X			Same as above, except non-crossbedded, 87 pct. quartz, 3 pct. feldspar, 10 pct. dark minerals

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 67 - 68 meters
X			Same as above except very fine grained, well sorted, 75 pct. quartz, 5 pct dark minerals, 20 pct dark minerals
X			

Sample	Lithology	5 cm.	Description 68 - 69 meters
X			Same as above except noncrossbedded, subrounded to rounded, well sorted, noncalcareous, 80 pct. quartz, 5 pct. feldspar, 15 pct. dark minerals

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 69 - 70 meters
			Subrounded, 75 pct. quartz, 5 pct. feldspar, 20 pct. dark minerals
	Core missing		

Sample	Lithology	5 cm	Description 70 - 71 meters
	Core missing		
			Sand, light gray (5Y 6/1), very fine grained, sorted, subrounded, noncalcareous, crossbedded, 50 pct. quartz, 20 pct. feldspar, 30 pct. dark minerals
X			Pyrite crystals and nodules
			Claystone, dark gray (5Y 4/1), noncalcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 71 - 72 meters
			Shale, dark gray (5Y 4/1), carbonaceous material, noncalcareous
X			
X			

Sample	Lithology	5 cm.	Description 72 - 73 meters
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 73 - 74 meters
X			

Sample	Lithology	5 cm	Description 74 - 75 meters
			Becomes a very dark gray (5Y 3/1)
X X			Vitrain, black (2.5Y 2/0)
			Carbonaceous claystone, black (2.5Y 2/0), abundant carbonaceous plant fragments, noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 75 - 76 meters
			Coal (lignite), black (2.5Y 2/0)
X			
			Claystone, gray (5Y 5/1), carbonaceous material, noncalcareous
			Clayey coal, black (2.5Y 2/0) conchoidal fracture present

Sample	Lithology	5 cm.	Description 76 - 77 meters
X			Siltstone, light gray (5Y 7/2), carbonaceous plant fragments, noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 77 - 78 meters
			Shale, gray (5Y 5/1), noncalcareous
X			
	Core missing		

Sample	Lithology	5 cm	Description 78 - 79 meters
X			Same as above except carbonaceous plant material present
			Becomes silty
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 79- 80 meters
			Changes to dark gray (5Y 4/1) and calcareous
X			
X			
			Claystone, dark gray (5Y 4/1), noncalcareous
			Becomes light gray (5Y 7/1)
			Becomes dark gray (5Y 4/1)

Sample	Lithology	5 cm.	Description 80 - 81 meters
X			

DETAILED LITHOLOGY

Sample	Lithology	5 CM	Description 81 - 82 meters
X			Core missing

Sample	Lithology	5 CM	Description 82 - 83 meters
			Claystone, very dark gray (5Y 5/1), non-calcareous
X			Shale, gray (5Y 5/1), noncalcareous
X			
X			
			Abundant carbonaceous material and leached.
X			
			Core missing

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 83 - 84 meters
	Core missing		

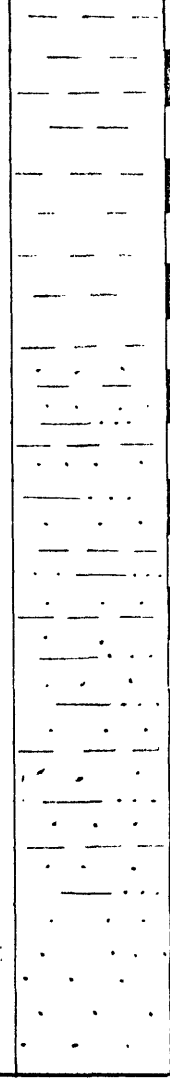
Sample	Lithology	5 cm	Description 84 - 85 meters
	Core missing		Claystone, dark gray (5Y 4/1) calcareous

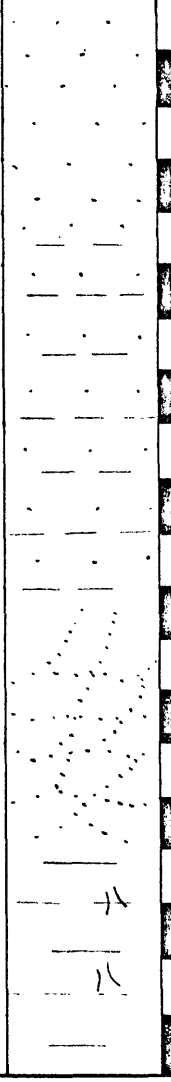
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 85 - 86 meters
X			Shale, dark gray (2.5Y 4/0), noncalcareous
X			

Sample	Lithology	5 cm	Description 86 - 87 meters
			Siltstone, gray (2.5Y 6/0), noncalcareous
			Claystone, light gray (5Y 6/1), noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 87 - 88 meters
X			Interbedded and laminae claystone, siltstone, and sandstone. Claystone, gray (5Y 7/1), noncalcareous. Siltstone, light gray (5Y 6/1), noncalcareous. Sandstone, white (5Y 9/1), very fine grained, poor sorting, angular to subrounded, noncalcareous, 87 pct. quartz, 3 pct. feldspar, 10 pct. dark minerals
X			Sandstone, light gray (5Y 6/1), very fine grained, well sorted, angular to subangular, noncalcareous, 85 pct. quartz, 3 pct. feldspar, 12 pct dark minerals

Sample	Lithology	5 cm.	Description 88 - 89 meters
			Discontinuous claystone laminae, noncalcareous
X			
X			
X			Same as above except lacking claystone laminae and is crossbedded, sorted, and has subangular grains
			Shale, very dark gray (5Y 3/1), noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 89 - 90 meters
			Claystone, dark gray (5Y 4/1), noncalcareous
X			
X			
			Carbonaceous claystone, black (2.5Y 2/0), noncalcareous

Sample	Lithology	5 cm	Description 90 - 91 meters
			Coal, black (2.5Y 2/0), vitrain, resin blebs, conchoidal fracture and cleat
X			
			Shale, dark gray (5Y 4/1), carbonaceous plant material, noncalcareous
X			
			Changes to very dark gray to gray (5Y 3/1 to 2.5Y 5/0) and to slightly calcareous

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 91 - 92 meters
X			

Sample	Lithology	5 Cm.	Description 92 - 93 meters
X			Large carbonaceous plant fragments present
			Shale, dark gray (5Y 4/1) becomes silty, noncalcareous
			Pyrite?

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 93 - 94 meters
X			Shale, dark gray to gray (5Y 4/1 to 2.5Y 5/0), carbonaceous plant material, noncalcareous
			Claystone, dark gray (5Y 4/1), carbonaceous material near top, noncalcareous

Sample	Lithology	5 cm	Description 94 - 95 meters
X			
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 95 - 96 meters
X			Becomes very dark gray (5Y 3/1)
			Coal, black (2.5Y 2/0)
X			

Sample	Lithology	5 cm	Description 96 - 97 meters

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 97 - 98 meters

Sample	Lithology	5 cm	Description 98 - 99 meters
	Core missing		Believe this mud to be part of drilling mud

DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 99 -100 meters
X			

Sample	Lithology	5 CM.	Description 100 - 101 meters

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 101 - 102 meters

Sample	Lithology	5 Cm.	Description 102 - 103 meters
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 103 - 104 meters

Sample	Lithology	5 Cm.	Description 104 - 105 meters
X	Core missing		

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 105 - 106 meters
	Core missing		

Sample	Lithology	5 Cm.	Description 106 -107 meters
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 107 - 108 meters
X			
	Core missing		

Sample	Lithology	5 Cm.	Description 108 - 109 meters
	Core missing		

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 109 - 110 meters
	Core missing		

Sample	Lithology	5 cm	Description 110 - 111 meters
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 111 - 112 meters

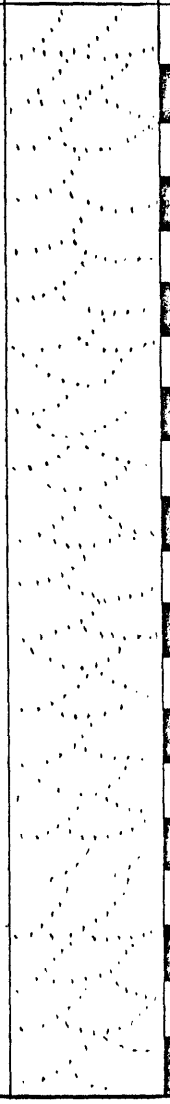
Sample	Lithology	5 cm.	Description 112 - 113 meters
X			
X			

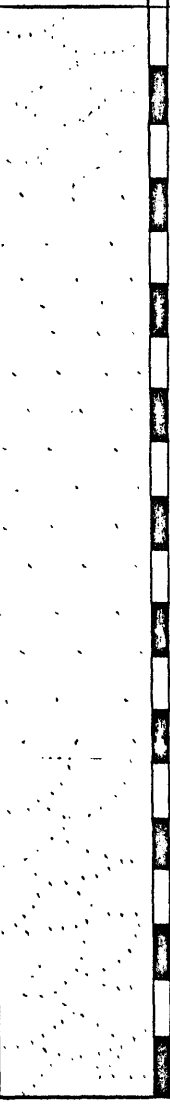
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 113 - 114 meters

Sample	Lithology	5 cm	Description 114 - 115 meters
			Mudstone, dark olive gray (5Y 3/2), carbonaceous plant material, noncalcareous Siltstone, light gray to gray (5Y 6/1 to 5Y 5/1), noncalcareous. Also sandstone laminae in crossbed. Same color as siltstone, very fine grained, subangular, poorly sorted, noncalcareous

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 115 - 116 meters
X			Sandstone, light gray (5Y 6/1), very fine grained to silt, poorly sorted, subangular, crossbedded, noncalcareous. There are numerous silty and clayey laminae in this unit; 92 pct. quartz, 3 pct. feldspar, and 5 pct. dark minerals
			Same as above, except subangular to subrounded, 87 pct. quartz, 10 pct. feldspar, and 3 pct. dark minerals

Sample	Lithology	5 cm	Description 116 - 117 meters
			
			Same as above, except the lack of cross-bedding and a color change to gray (5Y 5/1)
X			
X			
			Same as above, but crossbedded
X			

DETAILED LITHOLOGY

Sample	Lithology	5 cm.	Description 117 - 118 meters
			Claystone, dark gray (2.5Y 4/0), with numerous sandstone laminae, light gray (5Y 6/1), slightly calcareous. Vitrain laminae
			Claystone color change to dark gray (5Y 4/1). Sand decreasing downwind
X			
X			

Sample	Lithology	5 cm.	Description 118 - 119 meters
			Coal laminae, black (2.5Y 2/0)
	No core		

DETAILED LITHOLOGY

Sample	Lithology	5 Cm	Description 119 - 120 meters
	Core missing		
			Coal, black (2.5Y 2/0)
			Shale, dark gray (5Y 4/1), noncalcareous
X			

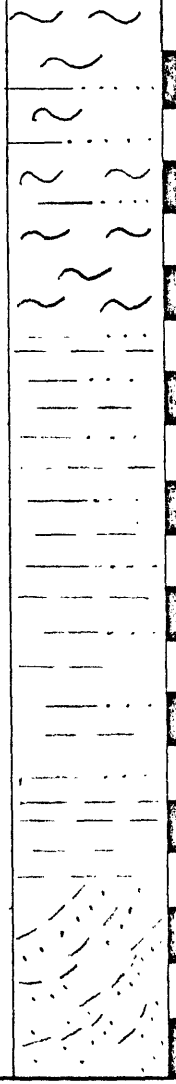
Sample	Lithology	5 Cm	Description 120 - 121 meters
			Shale, dark gray (2.5Y 4/0), carbonaceous plant material
X			
X			

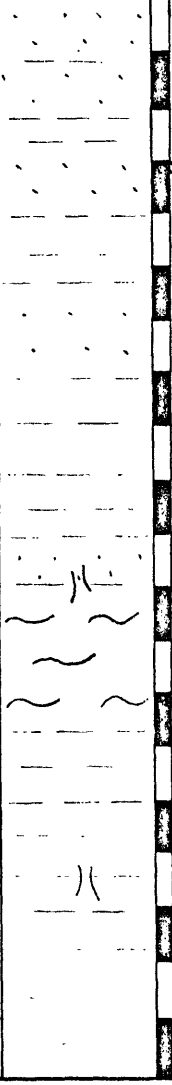
DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 121 - 122 meters
			Sandstone, laminae, light gray (5Y 7/1), noncalcareous claystone, dark gray (5Y 4/1), noncalcareous
			Mudstone, gray (5Y 5/1), noncalcareous
X			Sandstone, light gray (5Y 6/1), very fine grained to silt, poorly sorted, angular to subrounded, noncalcareous, crossbedded, 77 pct. quartz, 3 pct. feldspar, and 20 pct. dark minerals
	Core missing		
			Same as above, expect lack of crossbedding and 92 pct. quartz, 3 pct. feldspar, and 5 pct. dark minerals
			Coal, black (2.5Y 2/0), very clayey with plant fragments

Sample	Lithology	5 cm	Description 122 - 123meters
			Coal cleated and shows woody structure.
			Coal, black (2.5Y 2/0), very clayey with abundant plant fragments. Coal cleated and shows woody structure
X			
X			
			Mudstone, dark gray (5Y 4/1), silty to clayey, carbonaceous plant fragments, noncalcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm.	Description 123 - 124 meters
X			Silty claystone, gray (5Y 4/1), noncalcareous
X			
			Claystone, dark gray (2.5Y 4/0), interbedded with sandstone, light gray (5Y 7/1), very fine grained to silt; both are noncalcareous and crossbedded

Sample	Lithology	5 Cm.	Description 124 - 125 meters
			Same as above, but not crossbedded
			Sandstone becomes white (5Y 8/1), 85 pct. quartz, 5 pct. feldspar, 10 pct. dark minerals. Claystone changes color to very dark gray (5Y 3/1)
X			
			Mudstone?, noncalcareous
X			
			Claystone, very dark gray (5Y 3/1), carbonaceous material, noncalcareous
X			

DETAILED LITHOLOGY

Sample	Lithology	5 CM.	Description 125 - 126meters
X			Sandstone light gray (5Y 6/1), very fine to silt, poorly sorted, angular to subrounded, noncalcareous, 70 pct. quartz, 25 pct. feldspar, 5 pct dark minerals Claystone laminae,gray (5Y 5/1) capping coal, black (2.5Y 2/0), with siltstone lamina near top; coal cleated
X			

Sample	Lithology	5 CM.	Description 126 - 127 meters

DETAILED LITHOLOGY

Sample	Lithology	5 cm	Description 127 - 128 meters
			Shale, black (5Y 2/1), calcareous
X			
X			
X			

Sample	Lithology	5 cm	Description 128 - 129 meters
			Siltstone, gray (5Y 5/1) shale, and clayey, carbonaceous plant material, noncalcareous
X			
X			
X			
X			

DETAILED LITHOLOGY

Sample	Lithology	5 Cm	Description 129 - 130 meters
			Shale, dark olive gray (5Y 3/2), calcareous
X			Dolomite? olive brown (2.5Y 4/4)

Sample	Lithology	5 Cm	Description 130 - 131 meters
X			Shale, gray (2.5Y 5/0), noncalcareous
	Core missing		

Sample Number in meters	Unified[1] Soil Class.	Particle Size Distribution (percentage of dry soil wt.)				Atterberg Limits (percentage of dry soil wt.)			Reaction[2] with HCL 25%	Clay Mineralogy[3]					Natural Moisture (percentage of dry soil wt.)	Densities g/cm^3			Unconfined Compressive Strength kg/cm^2	Pocket Penetrometer kg/cm^2	Schmidt Hammer Index[4]	Point-load Strength Indices kg/m^2[5]		Anisotropy Index[6]	Slake durability index (wt. of dry soil weight retained)	
		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Chlorite	Illite	Kaolinite	Montmorillonite	Mixed Layer		Grain Density	As-Received	Dry Bulk				Δ	0		1st Cycle	2nd Cycle
4.08	CL-ML					26	19	7	n																	
4.11		0	85	12	3				n						0.11	2.58	1.9	1.7	4.89							
4.38																						--	--			
6.51															11.07		2.3	2.1								
5.12		0	83	13	4				n																	
6.94		0	85	12	3				n																	
6.19									n						18.56	2.65	2.0	1.7								
6.43		0	84	11	5				n																	
7.86		0	86	11	3				n																	
9.14		0	84	12	4				n																	
9.36		0	86	11	3				n							2.61										
9.59		0	83	13	4				n																	
10.21		0	84	12	4				n																	
10.61		0	84	13	3				n																	
10.92		0	84	13	3				n																	
12.10		0	83	9	8				n																	
13.68		0	80	13	7				n																	
13.26		0	80	11	9				n																	
13.62		0	75	21	4				n																	
13.72		0	80	16	4				n																	
14.45		0	85	10	5				n						17.56		2.3	2.0								
14.76		0	77	14	9				n	3	2	1	3	4												
15.18		0	83	11	6				n							2.62										
15.22															13.27		2.0	1.8	4.17							
15.54		0	86	10	4				n																	
15.71															13.33		1.9	1.7	4.58							
15.95															16.26		1.9	1.7	5.87							
16.05		0	87	11	2				n	4	2	1	4	4												
16.23															16.63		2.0	1.8								
16.85		0	36	54	10				n	4	2	1	4	4	20.29	2.61	2.1	1.7								
17.07	CL					42	19	23		3	1	2	3	4												
17.37		0	25	54	21				n						18.39		2.1	1.8								
17.53		8	55	31	6				n	3	1	2	3	4	15.71		2.0	1.8								
17.74		0	69	23	8				n						18.44		2.0	1.7								
18.00															15.05		2.2	1.9								
18.20										3	2	2	1	4												
18.41	CH	0	1	7	92	65	29	36	n	3	2	1	2	4	21.91		2.1	1.7								
19.01	ML/OL					48	29	19		4	2	1	3	4												
19.35	CL					45	25	20							11.73		2.4	2.1								
2.12	CL					49	18	31		4	2	1	2	4	12.97		2.3	2.1								
21.51	CL					43	19	24							11.99	2.65	2.4	2.1								
21.73	CL	0	28	53	19	30	22	8	n																	
21.18		0	69	21	10	NON PLASTIC			n																	
21.59																			11.92							
21.64		0	40	51	9				n						17.36	2.67	2.1	1.8								
21.79	CL					45	26	19	n	4	2	1	4	4		2.60										
22.40	MH/OH	0	6	11	83	65	43	22	n	4	3	1	3	4		2.21										
22.95	MH/OH	0	0	4	96	56	33	23	n																	
23.41	CL	0	1	40	59	50	15	35	n	3	2	1	3	4		2.49										
23.83		0	0	4	96				w																	

Explanatory notes:

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-- Test attempted but failed

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[5] Δ tested parallel to bedding
0 tested perpendicular to bedding

[6] $\frac{\Delta}{0}$

Detailed Geotechnical Log

Sample Number in meters	Unified[1] Soil Class.	Particle Size Distribution (percentage of dry soil wt.)				Atterberg Limits (percentage of dry soil wt.)			Reaction[2] with HCL 25%	Clay Mineralogy[3]					Natural Moisture (percentage of dry soil wt.)	Densities g/cm^3			Unconfined Compressive Strength kg/cm^2	Pocket Penetrometer kg/cm^2	Schmidt[4] Hammer Index	Point-load[5] Strength Indices MN/m^2		Anisotropy[6] Index	Slake durability index (pct. of dry soil weight retained)	
		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Chlorite	Illite	Kaolinite	Montmorillonite	Mixed Layer		Grain Density	As-Received	Dry Bulk				Δ	0		1st Cycle	2nd Cycle
24.23		0	11	73	16				m																	
24.53	ML/OL	0	8	76	16	31	28	3	m	4	2	1	4	4	14.45	2.68	2.1	1.9								
24.99																										
26.61	CH	0	1	13	76	51	27	24	n	4	2	1	3	4	11.45	2.59	2.2	2.0	40.10							
26.76																										
27.59																									18.90	0.14
27.61															11.60		2.3	2.1								
28.12																						0.268	0.942	3.51		
28.13	CL	0	1	43	56	45	23	22	w						13.05	2.61	1.9	1.7	25.91							
28.65																										
29.17																									9.39	0.32
29.20															10.46		2.3	2.1								
29.26										4	2	1	3	3								0.127	0.274	2.94		
29.60	CL	0	3 49	48	45	25	20	m		4	2	1	3	3	12.67	2.64	2.4	2.1	38.38							
30.08																	2.3	2.1								
30.72																									45.36	6.17
30.75															12.94		2.2	2.0								
30.94	CL	0	2	45	53	44	20	24	n	4	1	2	2	3		2.52	2.2	2.0				0.105	0.204	1.94		
31.09																										
31.12																										
31.19																						0.081	0.442	5.46		
31.55		0	33	51	16				w	4	2	1	4	4	18.84	2.67	2.0	1.7	3.91						72.87	45.95
31.73																			14.27							
31.76															20.10		2.0	1.7				0.035	0.061	1.74		
31.91																						--	--			
32.21															18.24		2.0	1.7								
32.37																						0.028	0.031	1.11		
32.71																										
32.77		0	63	18	14				n	4	3	1	4	4		2.66	2.0	1.7							0.00	0.00
32.96																										
34.23		0	3	60	37				w	3	2	1	3	4	20.01		2.0	1.7								
34.53															11.96	2.65	2.3	2.0	37.29							
34.67		0	5	52	43				m	4	2	1	4	2	12.98		2.3	2.0								
34.96																	2.0	1.7								
35.24															18.99		2.0	1.7								
36.57	CL	0	2	38	60	49	20	29	w	4	2	1	3	4		2.69	2.3	2.0				--	--			
36.75																	2.3	2.0								
36.91	CL	0	14	36	50	48	18	30	n	4	3	1	2	2	11.81	2.63	2.0	2.0								
37.04																										
37.27															13.16		2.2	2.0								
38.65																									28.38	1.96
38.81															11.41		2.4	2.2								
39.02	CL	0	0	44	56	42	16	26	n	4	3	1	3	3		2.65	2.4	2.2							36.05	4.38
39.09																										
39.47															10.15		2.3	2.1								
40.08															10.50		2.3	2.1				0.115	0.433	3.77	53.10	5.35
40.69																						--	--			
40.72	CH	0	1	11	88	65	25	40	n	4	3	1	4	2		2.51						--	--			
41.36															23.90		1.7	1.4								
41.76																						--	--			

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Detailed Geotechnical Log

Sample Number in meters	Unified[1] Soil Class.	Particle Size Distribution (percentage of dry soil wt.)				Atterberg Limits (percentage of dry soil wt.)			Reaction[2] with HCL 25%	Clay Mineralogy[3]					Natural Moisture (percentage of dry soil wt.)	Densities g/cm³			Unconfined Compressive Strength kg/cm²	Pocket Penetrometer kg/cm²	Schmidt[4] Hammer Index	Point-load[5] Strength Indices MN/m²		Anisotropy[6] Index	Slake durability index (pct. of dry soil weight retained)	
		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Chlorite	Illite	Kaolinite	Montmorillonite	Mixed Layer		Grain Density	As-Received	Dry Bulk				Δ	0		1st Cycle	2nd Cycle
42.06																									0.00	0.00
42.70															14.63		1.9	2.2								
43.37															11.54		2.3	2.1								
43.47															12.16		2.3	2.0								
43.49																						0.194	0.361	1.86		
43.93	CH	0	0	40	60	51	19	32	n	4	4	1	3	2		2.55										
44.36																						--	--			
44.59															12.40		2.3	2.0							40.75	7.21
45.47																						--	--			
45.64																						--	--			
46.15															13.60		2.3	2.0								
46.17															13.32		2.3	2.0								
46.39															13.89		2.3	2.0	14.18							
46.79															17.82		2.1	1.8							3.90	0.00
46.82																									3.90	0.00
47.34															42.74		1.3	0.9								
47.65																						--	--			
47.81																						--	--			
48.46	CH	0	0	33	67	56	26	30	n	4	3	1	4	2		2.62										
49.10																									11.83	0.09
49.68																									55.35	5.48
49.74																						0.294	0.418	1.71		
49.94															13.20		1.9	1.7								
50.07															20.61		2.2	1.8	3.99							
50.39															34.69											
50.54																						--	--			
50.97																										
51.27	CH	0	1	24	75	59	23	36	n	4	3	1	3	2		2.56						--	--			
51.42																									9.18	0.25
51.77															15.21		2.2	1.9								
51.91															15.23		2.0	1.7				0.098	0.252	2.57	27.96	0.00
51.99															10.44		2.0	1.8	16.99							
52.09		0	77	13	10				n	4	3	1	4	4		2.73										
52.39															20.22		1.9	1.6								
52.69		0	55	29	16				n	4	3	1	4	4		2.67										
52.93															14.20		2.0	1.8	12.24							
53.67															11.40		2.1	1.9								
53.73															11.79		2.2	2.0								
53.99	CH	0	5	47	48	51	22	29	n	4	3	1	4	2		2.67										
54.11																									56.79	9.55
54.52															8.35		2.3	2.1								
54.70															10.37		2.4	2.4	44.13							
54.86	CL	0	9	45	46	42	17	25	w	4	3	1	3	2		2.62										
62.49																						0.496	0.387	0.78		
63.12															9.48		2.4	2.2								
63.74															3.90		2.5	2.4								
63.99															12.01		2.3	2.0	17.10							
64.09	CL	0	7	53	40	41	18	23	n							2.65										
64.59															11.83		2.0	1.8								
64.85															8.11		2.2	2.0								

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Detailed Geotechnical Log

Sample Number in meters	Unified[1] Soil Class.	Particle Size Distribution (percentage of dry soil wt.)				Atterberg Limits (percentage of dry soil wt.)			Reaction[2] with HCL 25%	Clay Mineralogy[3]					Natural Moisture (percentage of dry soil wt.)	Densities g/cm³			Unconfined Compressive Strength kg/cm²	Pocket Penetrometer kg/cm²	Schmidt Hammer Index[4]	Point-load Strength Indices MN/m²		Anisotropy Index[6]	Slake durability index (pct. of dry soil weight retained)	
		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Chlorite	Illite	Kaolinite	Montmoril-lonite	Mixed Layer		Grain Density	As-Received	Dry Bulk				Δ	0		1st Cycle	2nd Cycle
64.89																										
65.35															11.23		2.2	2.0	9.90			0.080	0.163	2.04		
65.78		0	46	33	21				n	4	3	1	4	3		2.66										
66.89															12.39		1.9	1.7								
67.24		0	51	31	18				n							2.70										
67.97															20.57		2.0	1.7								
68.73		0	59	28	13				n							2.67										
70.65															1.72		2.3	2.3								
70.87															10.35		2.3	2.1	33.09							
70.90															10.26		2.4	2.2								
71.51	CH	0	0	20	80	63	25	38	n	4	3	1	4	2		2.58										
71.81															13.42		2.3	2.0								
72.24	CH	0	0	15	85	64	20	44	n	4	3	2	4	1		2.54										
72.58																									7.66	0.00
73.85															12.70		2.2	2.0								
74.52	CH	0	18	12	70	56	29	27	n	4	2	1	4	3		2.22										
75.13															30.88		1.3	1.0								
76.32															40.19		1.6	1.1								
76.99															10.45		2.1	1.9	23.5							
77.85															10.89		2.2	2.0								
78.50	CH	0	0	45	55	53	15	38	n							2.56										
78.49															8.52		2.4	2.2	54.2						75.70	44.58
79.03																									52.00	6.69
79.34																						0.492	0.397	0.81		
79.40															12.26		2.3	2.1								
81.47	CL	0	0	29	71	50	18	32	n	4	3	1	4	2		2.64										
82.08															13.47		2.2	1.9								
82.32																									68.92	30.77
82.27															9.55		2.3	2.1								
95.04	CH	0	0	25	75	52	20	32	n	4	3	1	4	2		2.65										
96.92															11.93		2.3	2.1								
97.33															11.00		2.1	4.9								
97.97															11.47		2.1	1.9	33.4							
98.32																									27.31	16.26
98.39		0	41	41	18				n							2.70										
99.24															9.23		2.2	2.1								
99.29															15.18		2.1	1.8								
99.37	CH	0	0	33	67	60	21	29	n	4	3	1	4	3		2.69										
99.64															12.32		2.0	1.8								
99.47															38.40		1.2	0.9								
99.32																									43.64	3.41
99.35															10.64		2.2	2.0								
99.53	CH	0	0	32	68	52	19	33	n	4	4	1	4	2		2.68										
99.32																									39.77	13.82
99.24															9.45		2.3	2.1								
99.27															9.86		2.4	2.2	37.6							
99.18																									6.10	0.00
99.24										4	4	1	4	3	10.13		2.3	2.1								
99.64															11.27		2.3	2.1								
99.61	CH	0	0	10	90	53	27	26	n	4	4	1	4	3		2.56										

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		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Chlorite	Illite	Kaolinite	Montmorillonite	Mixed Layer		Grain Density	As-Received	Dry Bulk				Δ	0		1st Cycle	2nd Cycle
95.95															43.32		1.3	0.9								
97.14															38.66		1.2	0.9								
99.39															33.22		1.3	0.9								
102.23															44.95		1.3	0.9								
104.24															47.37		1.3	0.9								
106.27															36.74		1.3	1.0	171.0							
107.38															46.92		1.2	0.8								
110.25															41.32		1.3	0.9	191.3							
110.89															41.24		1.2	0.9								
112.11															27.90		1.3	1.0								
113.78															41.75		1.3	0.9								
114.54															8.86		2.4	2.2	33.65							
115.06		0	40	55	15				n							2.67										
115.28															11.39		2.1	1.9								
116.22																									71.38	57.83
116.28															13.45		2.1	1.9								
116.31																						0.124	0.367	2.96		
116.39															10.01		2.2	2.0	86.8						2.05	0.00
117.74																										
117.78															11.46		2.3	2.0								
119.73	CL	0	2	27	73	47	21	26	n	4	2	1	4	4		2.49										
120.46															8.20		2.4	2.2								
120.58																									46.74	4.73
120.85																						--	--			
121.32															6.02		2.4	2.3	140.8							
122.45															53.38		1.3	0.8								
122.90															7.98		2.4	2.2								
123.55															8.43		2.3	2.1							84.35	67.43
123.58																						0.521	0.772	1.49		
123.14	CL	0	8	63	37	34	18	16	n	4	3	1	4	4		2.65	2.3	2.1								
124.28															9.52		2.3	2.1								
124.60															7.98		2.4	2.2								
124.76																									3.65	0.88
126.00	CH	0	2	25	73	61	27	34	w	4	4	1	4	2		2.61										
126.75																			41.99							
126.83															37.92				131.1							
127.26																						0.050	0.950	19.00		
127.83																									10.17	0.02
127.92															18.25		2.0	1.7								
128.28	CL	0	6	49	45	34	15	14	w	4	3	1	4	2		2.67	2.3	2.1								
128.63															9.15		2.3	2.1								
129.63																									54.22	14.46
130.21															1.40	3.33	3.3		867.8							

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