



**GEOLOGICAL SURVEY OF CANADA**

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**Physical properties testing, Norman Wells  
Pipeline permafrost samples - 1991**

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**D.E. Patterson  
R. Warner  
F. Wright**

**1991**



**Physical Properties Testing**

**Norman Wells Pipeline Permafrost Samples - 1991**

Report to

M. Burgess

Geological Survey of Canada

Energy, Mines and Resources Canada

by

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Carleton University

Ottawa, Canada

1991

DSS File Number: 23397-0-1151/01-SS

## FOREWORD

This report documents work undertaken as part of the federal government's Permafrost and Terrain Research and Monitoring Program along the 868 km Norman Wells to Zama oil pipeline. The 324 mm diameter, shallow burial (1 m) pipeline, traverses the discontinuous permafrost zone of northwestern Canada and began operation in April 1985. A joint monitoring program with Interprovincial Pipe Line Inc. was established following the signing of an environmental agreement between the pipeline company and the Department of Indian and Northern Affairs (INAC) in 1983. INAC coordinates the government's monitoring program in which Energy, Mines and Resources' Geological Survey of Canada and Agriculture Canada's Land Resource Research Institute participate.

A major component of this research and monitoring program involves the detailed quantification of changes in the ground thermal regime and geomorphic conditions at a series of instrumented sites along the route. This project was developed in cooperation with the Terrain Sciences Division of the Geological Survey in order to examine and quantify the effects of pipeline construction, operation and maintenance in thaw sensitive terrain. Many components of this research are contracted out.

The work undertaken in this contract report describes but one aspect of these site investigations. Interpretations contained herein are often limited to the specific data base under analysis and may thus not present an integrated or comprehensive analysis of all site observations. The opinions and views expressed by the authors are their own and do not necessarily reflect those of the Geological Survey of Canada or Indian and Northern Affairs.

Funding for the research and analyses reported herein was largely provided by INAC's Northern Affairs Program.

Margo Burgess  
Scientific Authority  
Terrain Sciences Division  
Geological Survey of Canada

## 1. Sample Testing

A number of permafrost samples collected during 1984 and 1985 were analyzed for their grain size characteristics, water content and frozen density. Additional measurements on these core samples as well as measurements on other samples from the Norman Wells pipeline study sites are reported in Patterson (1989), Patterson and Riseborough (1988) and Patterson et al. (1988).

Not all samples analyzed for this report were tested for water content and density due to sample storage conditions. This necessarily excluded all samples from shelly tubes and some frozen samples (desiccated during long term storage). Grain-size characteristics were determined on all samples excluding peat materials.

The samples stored in shelly tubes were extracted and a representative sub-sample used for grain-size testing. Since the samples were completely dried out, this proved to be an exceptionally difficult and labour intensive task.

The frozen samples were thawed and sub-samples for grain-size analysis and water content were obtained. In almost all cases, the outer 0.5-1.0 cm of each sample were desiccated so water content samples were taken from the central portion of each core. Frozen density was determined from the total mass measurements and volume calculations; these values are undoubtedly lower than they were during sample collection.

## 2. Summary of Findings

The water content-density data are presented in the table in the Appendix. The grain-size results are plotted in the accompanying figures in the Appendix. Each sample which could be tested is included. The borehole number and depth range is indicated on each figure for identification. The borehole number is the first identifier appearing in the "sample identification" column of the table, eg. 2A, 8C. The location of the boreholes can be determined from the following table which list the sites and a brief description. The site locations are given in kilometers along the pipeline route, south of Norman Wells (km 0). The first two numbers of the site name refer to the year of its establishment, such that 85-8C would be the corresponding site for sample identifier 8C.

**TABLE OF SITE DESCRIPTIONS**

<b>No.</b>	<b>NAME</b>	<b>KM</b>	<b>DESCRIPTION (at time of establishment)</b>
84-1	Pump Station 1.....	0.02	<b>Widespread permafrost</b> Ice-rich silty clay; widespread permafrost
84-2	Canyon Creek .....		<b>Previously cleared alignment, thaw sensitive slopes, widespread permafrost.</b>
	A	19.0	Level location, frozen till with low ice content
	B	19.3	East-facing slope with a 1 m insulating wood chip cover
	C	19.6	Uninsulated section of west-facing slope
84-3	Great Bear River.....		<b>Joint IPL site with thaw sensitive slope</b>
	A	79.2	Stratigraphically complex ice-rich alluvial terrace deposits in widespread permafrost; cliff-base
	B	79.4	Cliff-top lacustrine deposits with aeolian veneer
85-7	Table Mountain.....		<b>Joint IPL site with thaw sensitive slopes</b>
	A	271.2	Ice-rich lacustrine plain(old seismic line)
	B	272.0	Drillpad clearing at bend on top of north facing slope, ice-rich lacustrine plain
	C	272.3	New clearing on ice-rich lacustrine plain
84-4	Trail River.....		<b>Pipeline previously traversed frozen ground</b>
	A	478.0	Unfrozen saturated sands/silts in dune hollow
	B	478.1	Dry sands and silts in dune crest
85-8	Manner's Creek.....		<b>Rapidly changing permafrost conditions</b>
	A	557.8	Thin peat with thick (10 m) permafrost
	B	558.2	Thick(2.7 m) peat with thin(4 m) permafrost
	C	558.3	Thin peat (1 m) with thin (1 m) permafrost
85-9	Pump Station 3.....	583.3	<b>Pipe previously traversed frozen section</b> Unfrozen granular soils
85-10	Mackenzie Highway South ...		<b>Unfrozen/frozen interface</b>
	A	588.3	Helipad clearing in unfrozen terrain
	B	588.7	Thin (3 m) permafrost with 2 m peat cover
85-11	Moraine South	597.4	Thin (<4 m) permafrost in helipad clearing
85-12	Jean Marie Creek.....		<b>Unfrozen/frozen interface</b>
	A	608.6	Thin unfrozen peat
	B	608.7	Thick ice-rich peat plateau; 4 m permafrost
85-13	Redknife Hills.....		<b>Frozen/unfrozen interface; single cables only</b>
	A	682.2	Frozen (6 m) terrain surrounding large fen
	B	682.4	Frozen (6 m) terrain at fen border
	C	682.6	Unfrozen terrain in fen
84-5	Petitot River North.....		<b>Degrading peat plateau</b>
	A	783.0	Ice-rich peat (3.5 m); (15-18 m) permafrost
	B	783.3	Very thick icy peat (7 m); 12 m permafrost
84-6	Petitot River South.....	819.5	<b>Peat plateau preceded by unfrozen fen</b> Thick (5 m) ice-rich peat; 7 m permafrost

## References

Patterson, D.E. (1989). Analysis of the physical and thermal properties of select Norman Wells pipeline core specimens. Final Report to the Terrain Sciences Division, Geological Survey of Canada, Energy, Mines and Resources by the Geotechnical Science Laboratories, Carleton University.

Patterson, D.E. and Riseborough, D.W. (1988). A detailed study of the physical and thermal properties of Norman Wells - Zama core specimens. Final report to Geological Survey of Canada, Energy, Mines and Resources, by Geotechnical Science Laboratories, Carleton University. Geological Survey of Canada Open File 1896, 60 pp + appendices.

Patterson, D.E., Riseborough, D.W. and Smith, M.W. (1988) Analysis of Norman Wells to Zama pipeline core samples. Final report to Geological Survey of Canada, Energy, Mines and Resources by Geotechnical Science Laboratories, Carleton University, April 1987. Geological Survey of Canada, Open File 1897, 60 pp + appendices.

**APPENDIX**

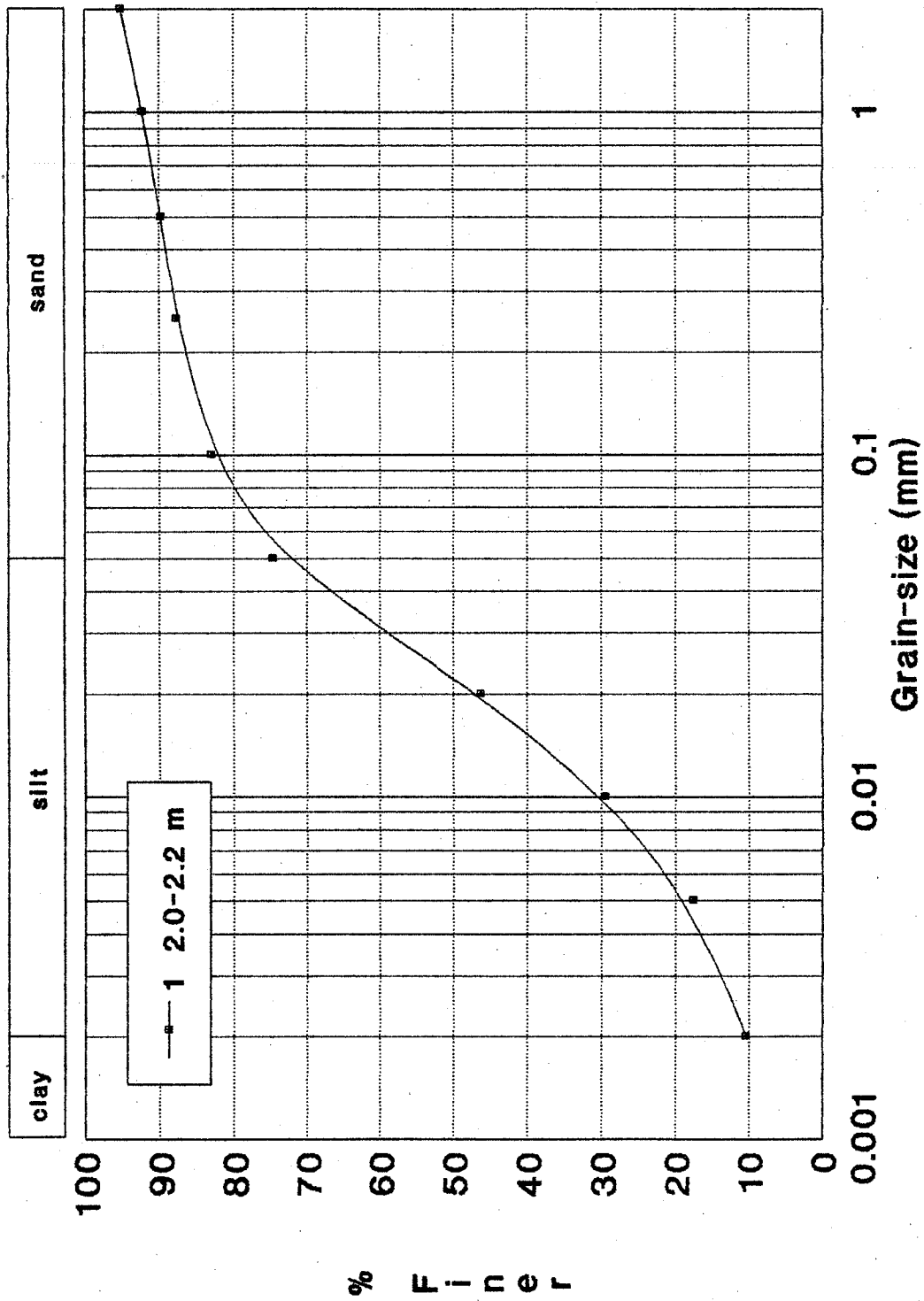
Sample Identification	Water Content g g <sup>-1</sup> , %	Frozen Density g cm <sup>-3</sup>
1 T3 2.0-2.2 m	18.93	2.064
2A GC1 2.4-2.8 m	21.59	2.399
2B T3-C2 1.9-2.1 m	11.85	1.900
2C TI-C1 0.9-1.16 m	14.47	2.333
2C TI-C2 1.26-1.50 m	18.44	2.355
2C T1-C3 1.65-1.95 m	15.49	2.243
3A G-C1 2.5-2.7 m	38.89	2.094
3A G-C2 3.7-4.0 m	28.35	1.897
3A G-C3 5.4-5.7 m	23.57	2.281
5A T3-C1 2.7-3.0 m	1,226.93	1.070
5A T3-C2 3.7-3.8 m	47.62	1.673
5A T3-C3 4.6-4.9 m	21.55	2.164
5A T3-C4 11.9-12.2 m	9.43	2.598
8C C2B 0.9-1.5 m	615.20	0.874
8C C2C 0.9-1.5 m	854.25	0.719
8C C3A 1.5-2.0 m	66.42	1.043
8C C4B 2.0-2.6 m	53.69	1.543
8C C4C 2.0-2.6 m	124.63	0.995
8C C5B 2.6-3.2 m	28.65	0.872
8C C5C 2.6-3.2 m	55.01	1.347
9 C1A 0.2-0.8 m	68.89	1.570
9 C1B 0.2-0.8 m	26.82	1.955
9 C1B 0.2-0.8 m	51.93	1.955
9 C2A 0.8-1.4 m	16.07	1.910
9 C2B 0.8-1.4 m	14.99	2.282
10A C1A 0.1-0.8 m	505.68	0.925
10A C1B 0.1-0.8 m	279.69	1.191
10B C1A 0.2-0.9 m	680.77	0.789
10B C1B 0.2-0.9 m	535.69	1.153



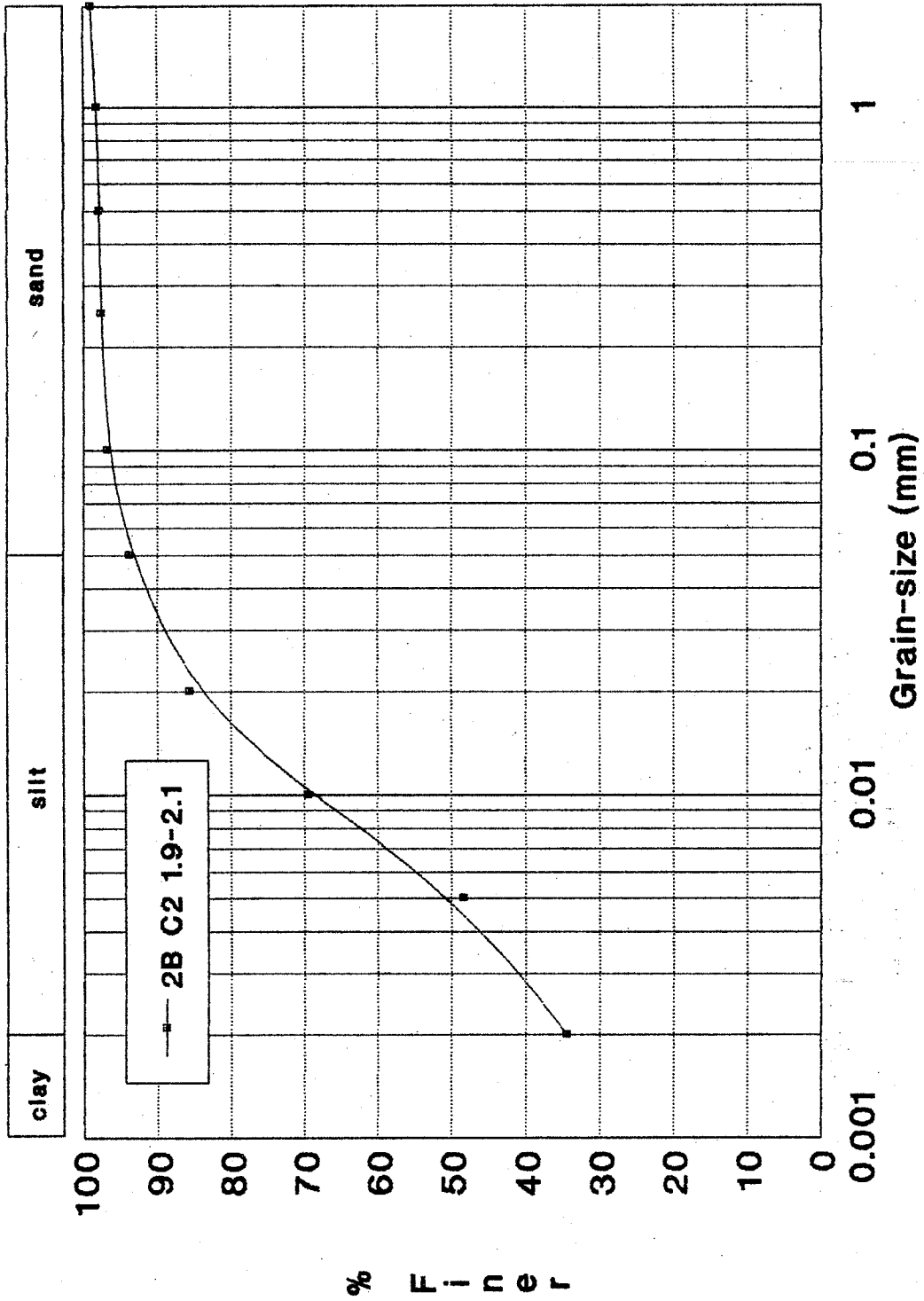
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10B C1C 0.2-0.9 m	613.22	1.069
10B C2A 0.9-1.5 m	747.49	0.845
10B C2B 0.9-1.5 m	870.10	0.957
10B C2C 0.9-1.5 m	743.26	1.017
10B C3A 1.7-2.6 m	549.23	1.023
10B C3B 1.7-2.6 m	839.03	0.886
10B C3C 1.7-2.6 m	365.40	1.030
11 C1A 0.2-0.8 m	338.50	0.891
11 C1B 0.2-0.8 m	27.14	1.612
11 C1C 0.2-0.8 m	69.16	1.804
11 C2A 0.8-1.5 m	22.87	2.098
11 C2B 0.8-1.5 m	20.85	2.009
11 C2C 0.8-1.5 m	24.51	2.330
11 C3A 1.5-2.3 m	22.89	2.048
11 C3B 1.5-2.3 m	13.57	2.048
11 C3C 1.5-2.3 m	27.60	2.164
11 C4 2.3-2.5 m	14.77	2.527
12A C1A 0.2-0.9 m	453.34	1.225
12A C1B 0.2-0.8 m	28.28	2.006
12A C1C 0.2-0.8 m	20.34	2.161
12A C2A 0.9-1.7 m	18.54	2.185
12A C2B 0.9-1.7 m	12.54	2.032
12A C2C 0.9-1.7 m	6.77	2.142
12A C3A 1.7-2.4 m	17.89	2.077
12A C3B 1.7-2.4 m	16.39	2.255
12A C3C 1.7-2.5 m	16.58	2.313
12B C1B 0.0-0.6 m	381.69	0.726
12B C2B 0.6-1.2 m	967.21	0.992
12B C2C 0.6-1.2 m	888.48	0.911
12B C3A 1.2-1.7 m	1,345.00	0.723

Sample Identification	Water Content $\text{g g}^{-1}, \%$	Frozen Density $\text{g cm}^{-3}$
12B C4B 1.5-2.3 m	5,958.89	0.847
12B T3-C1 0.4-0.5 m	16.47	2.038

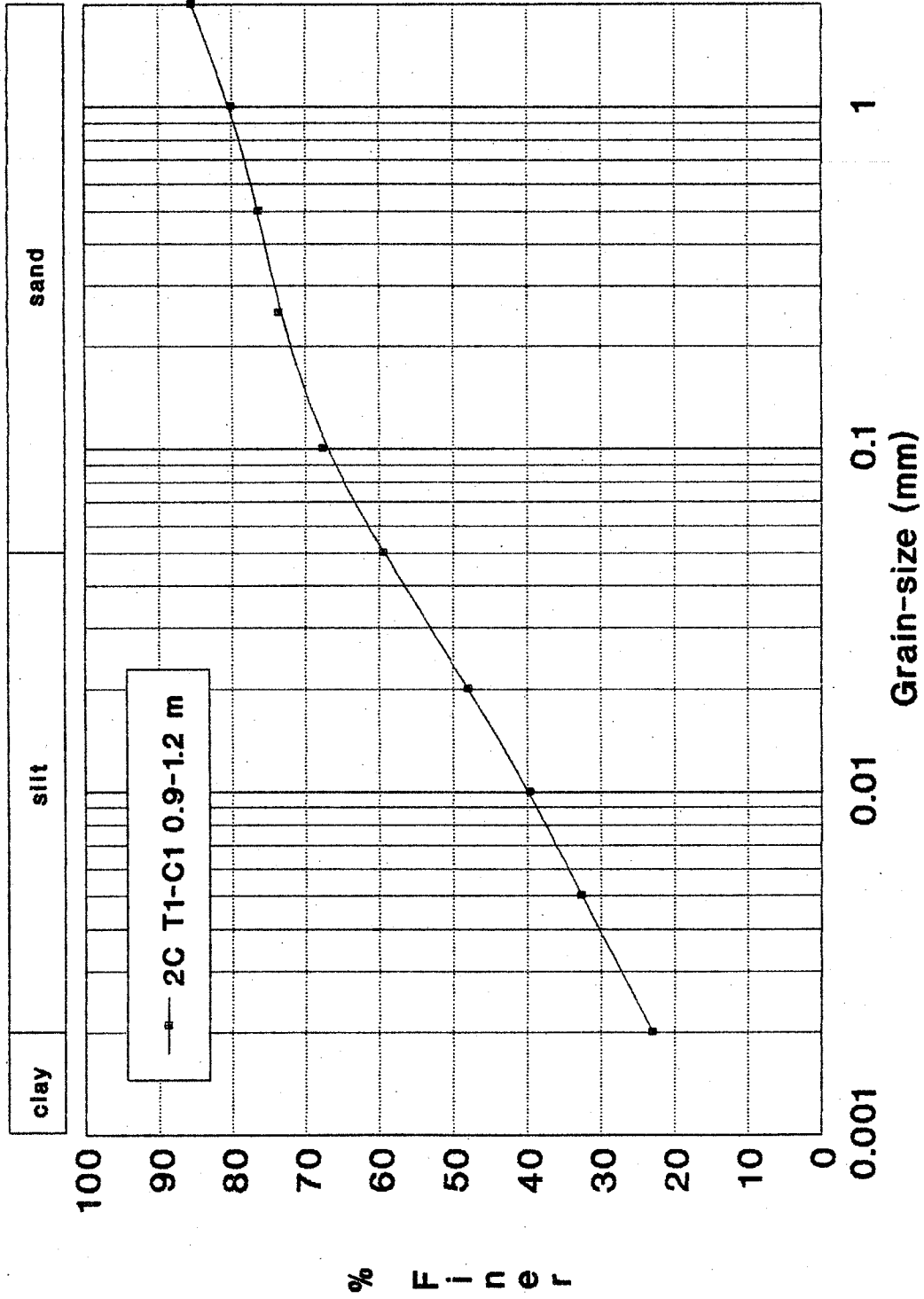
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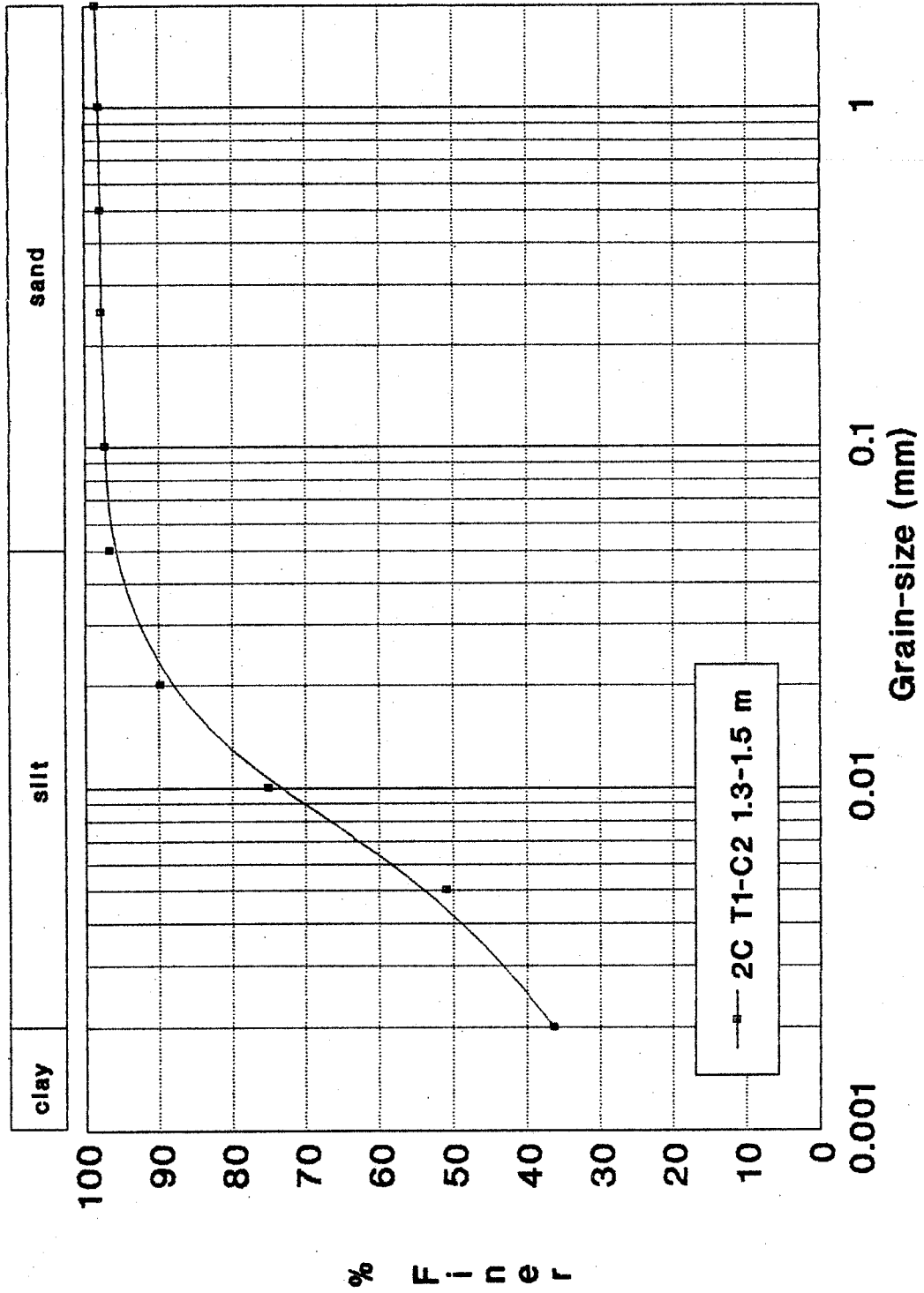
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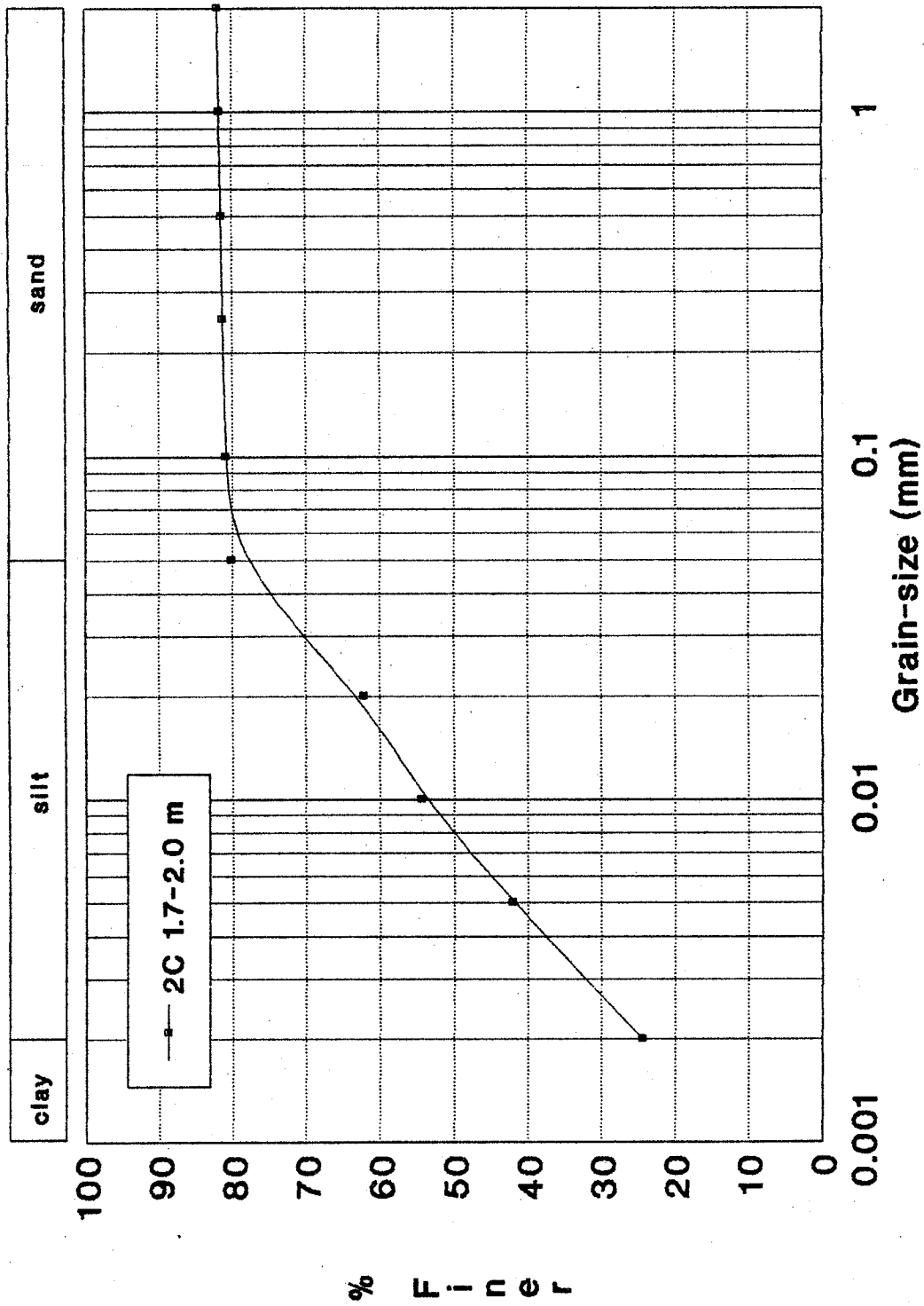
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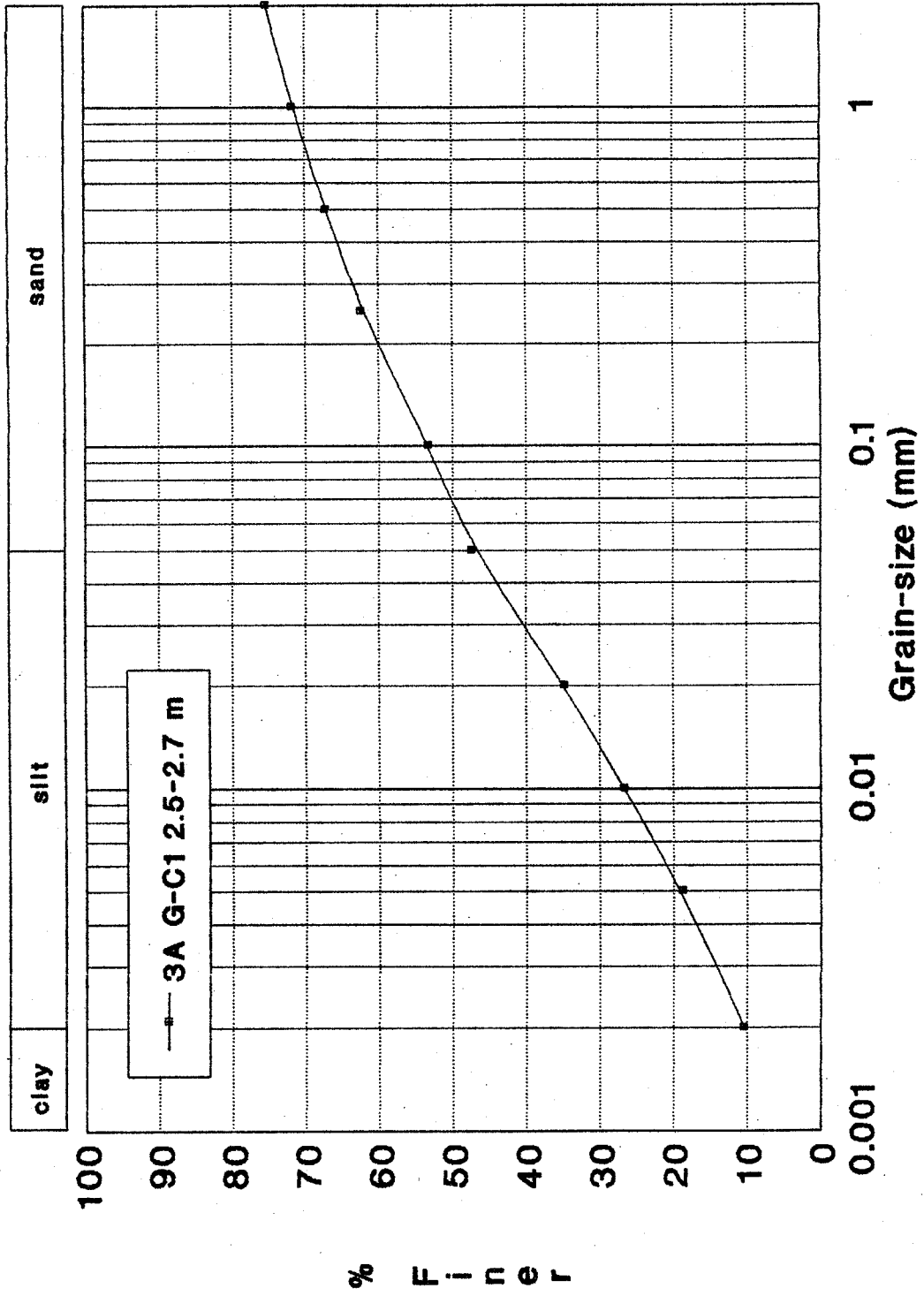
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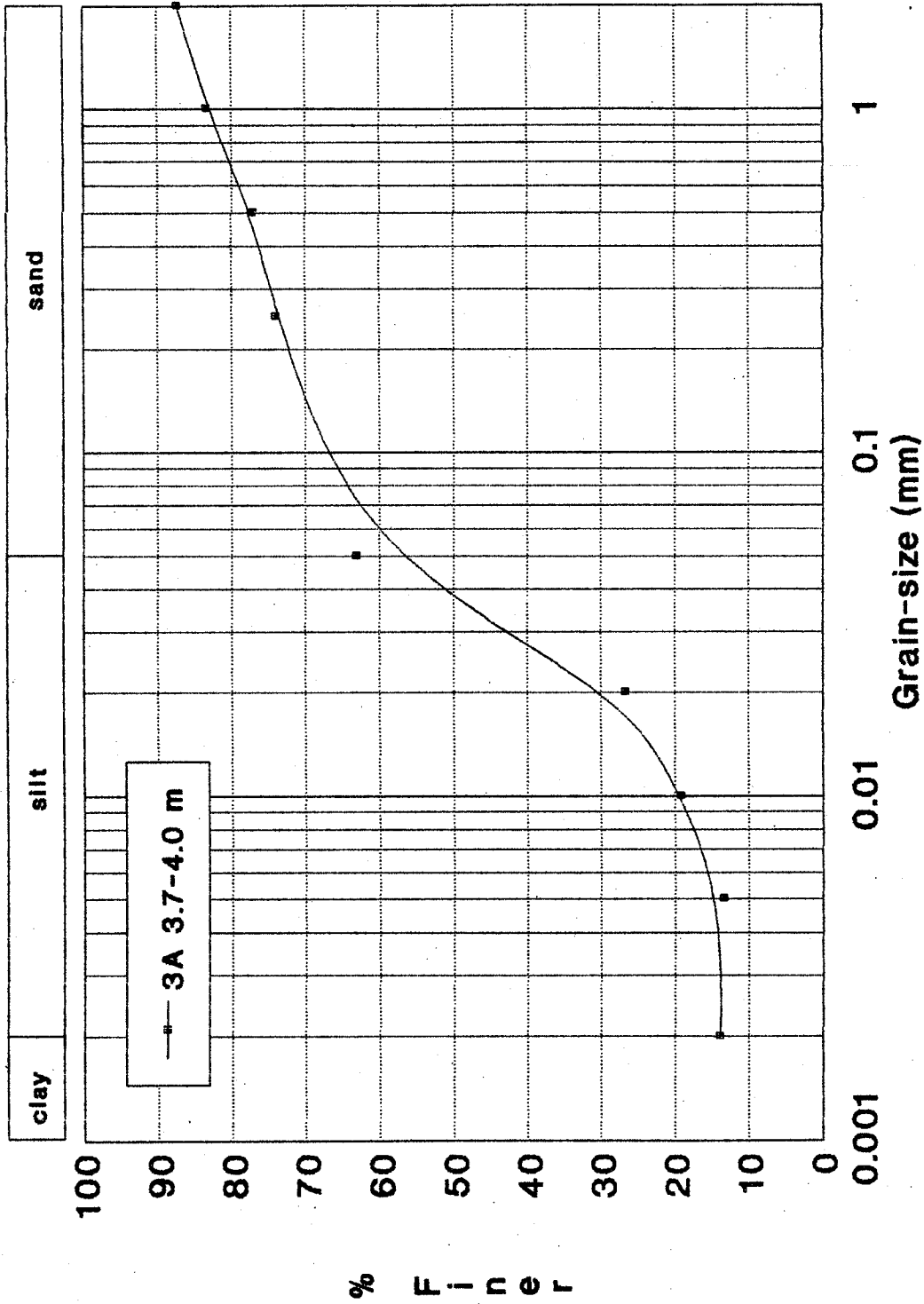


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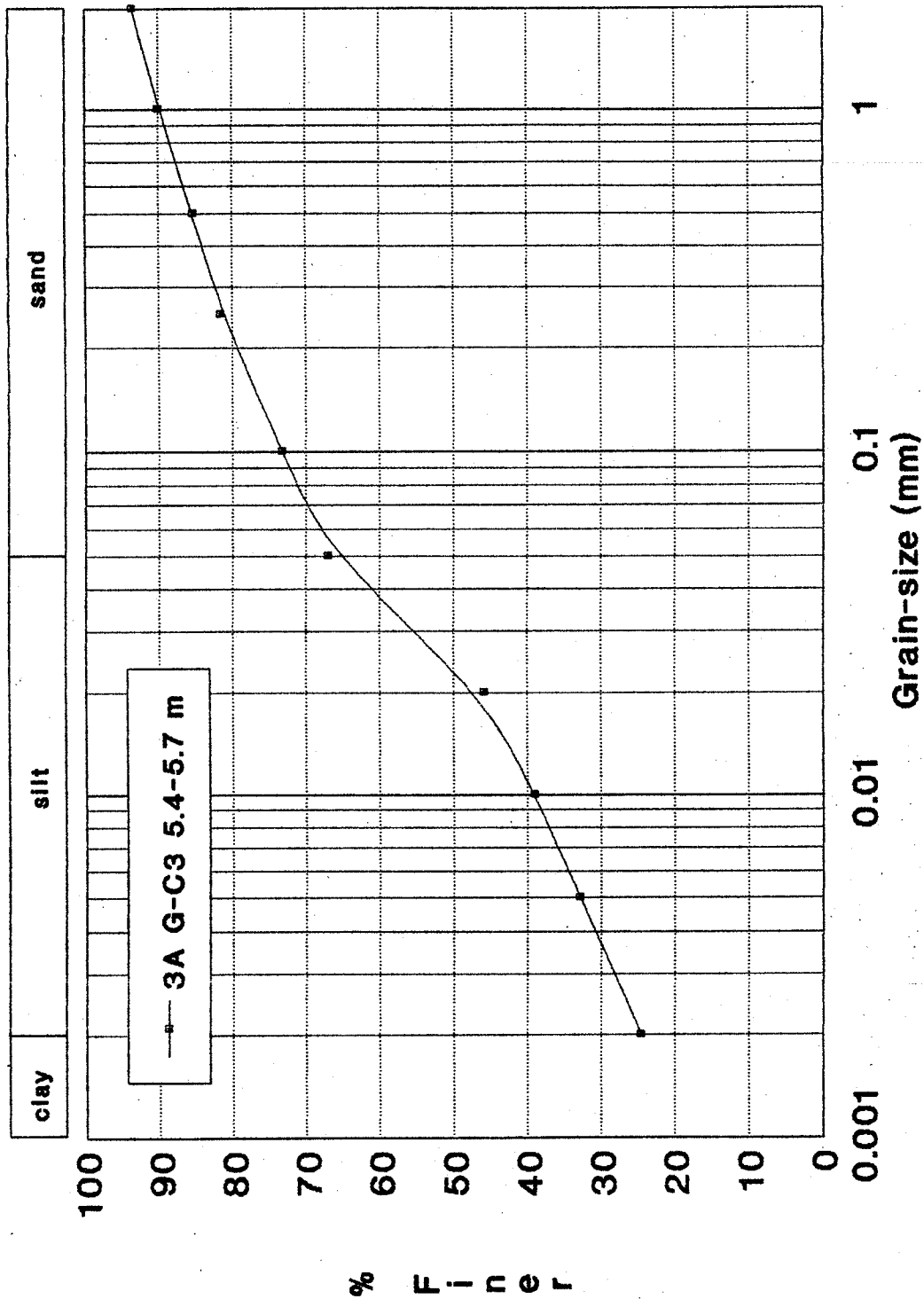




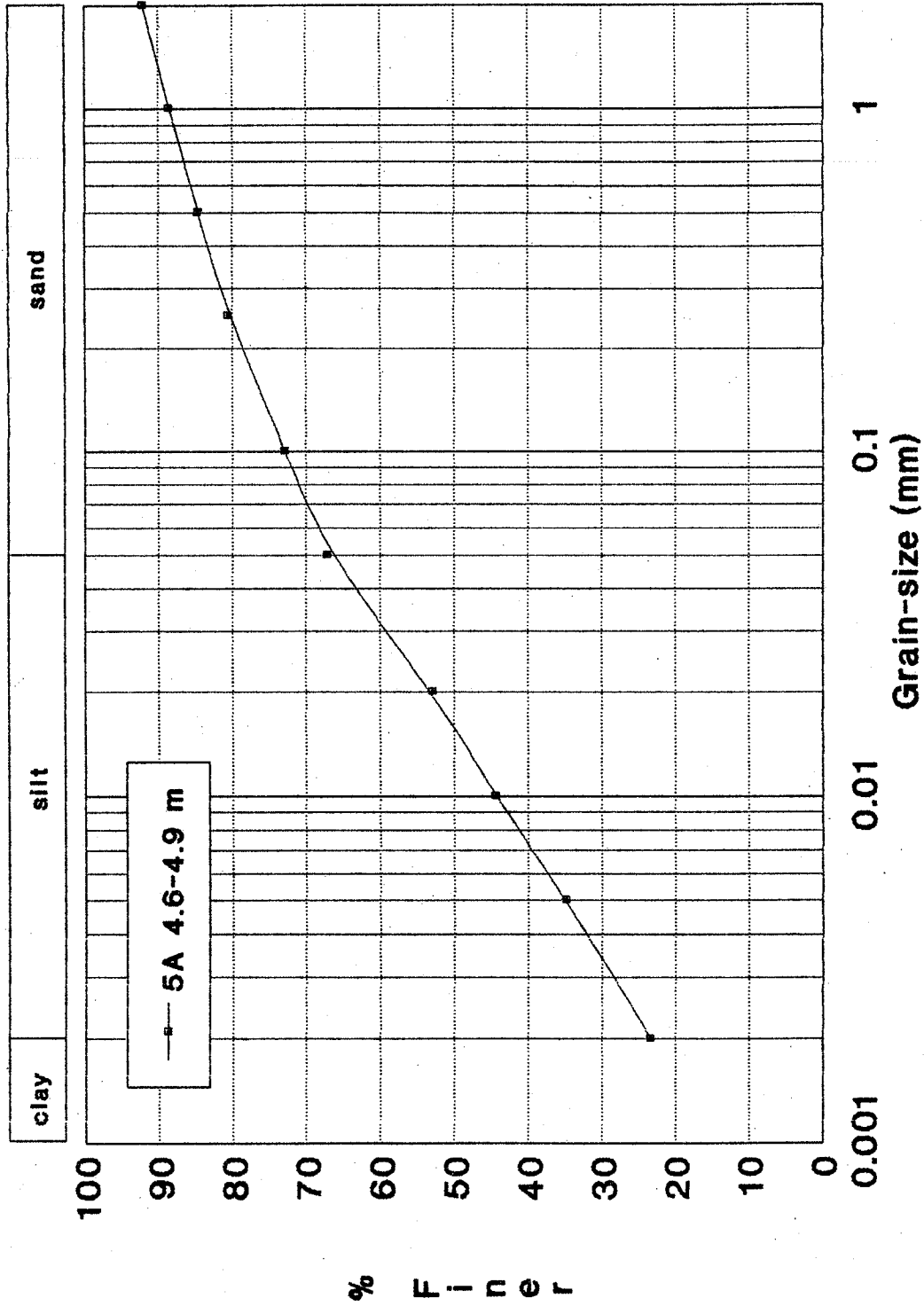
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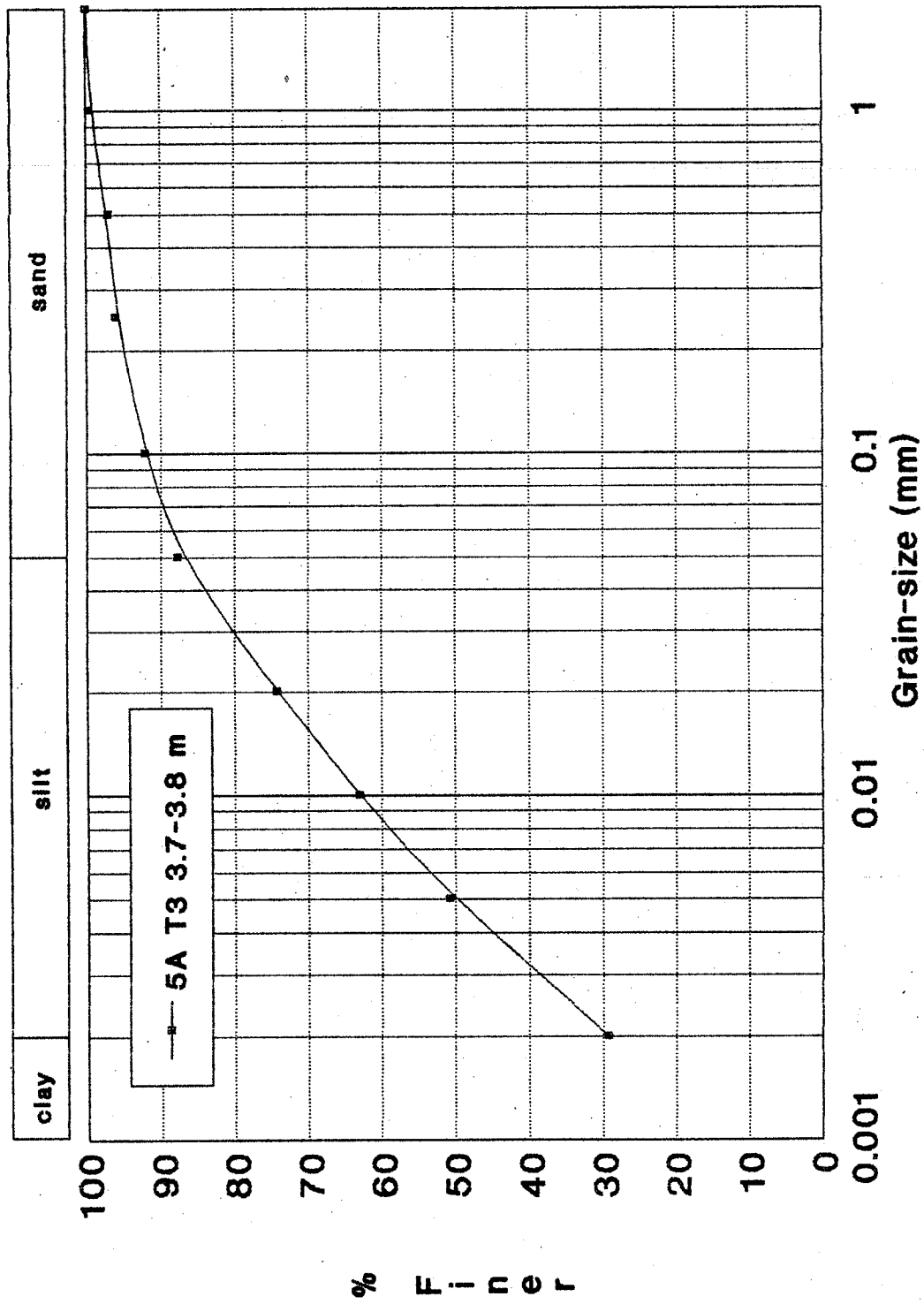
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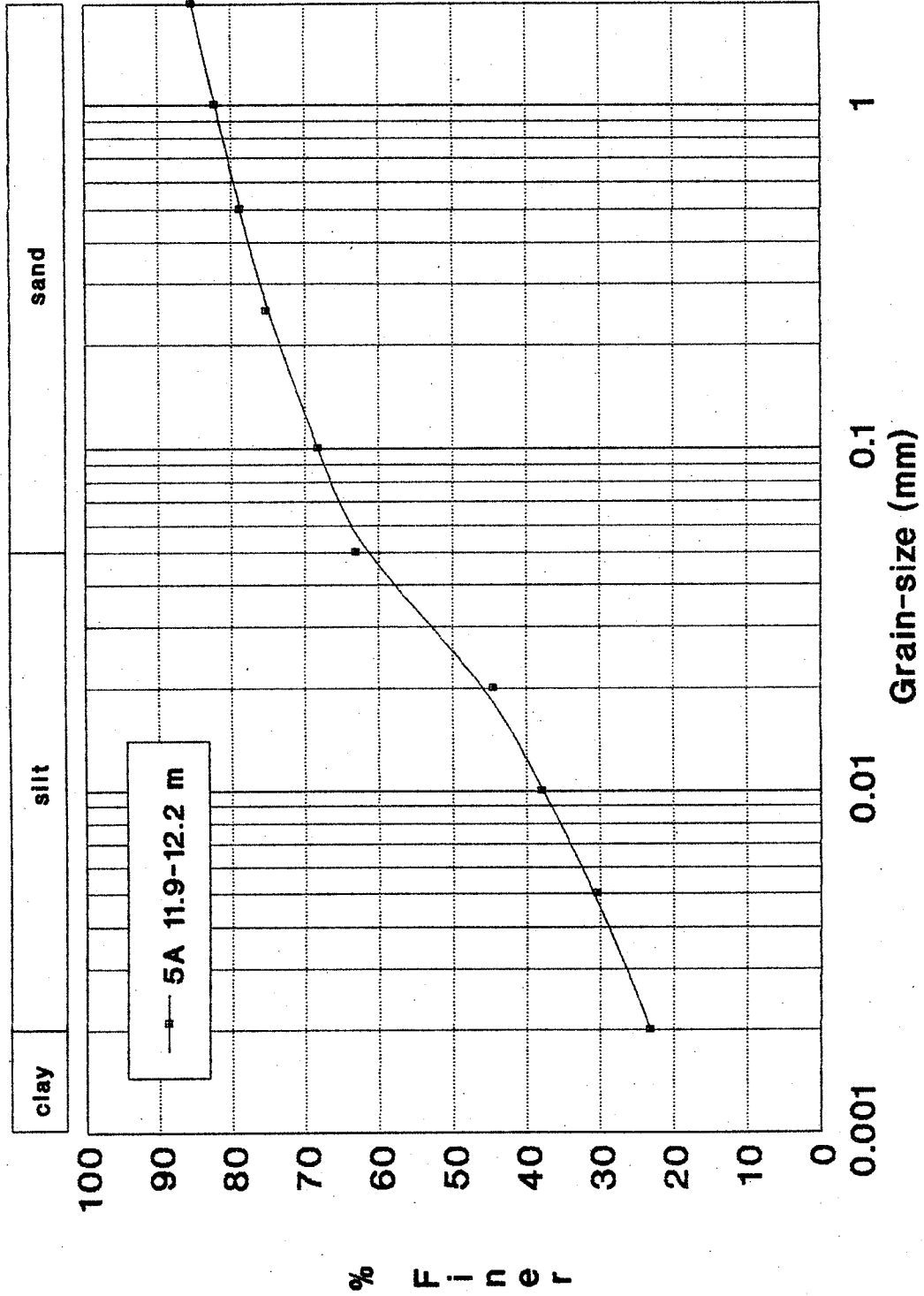
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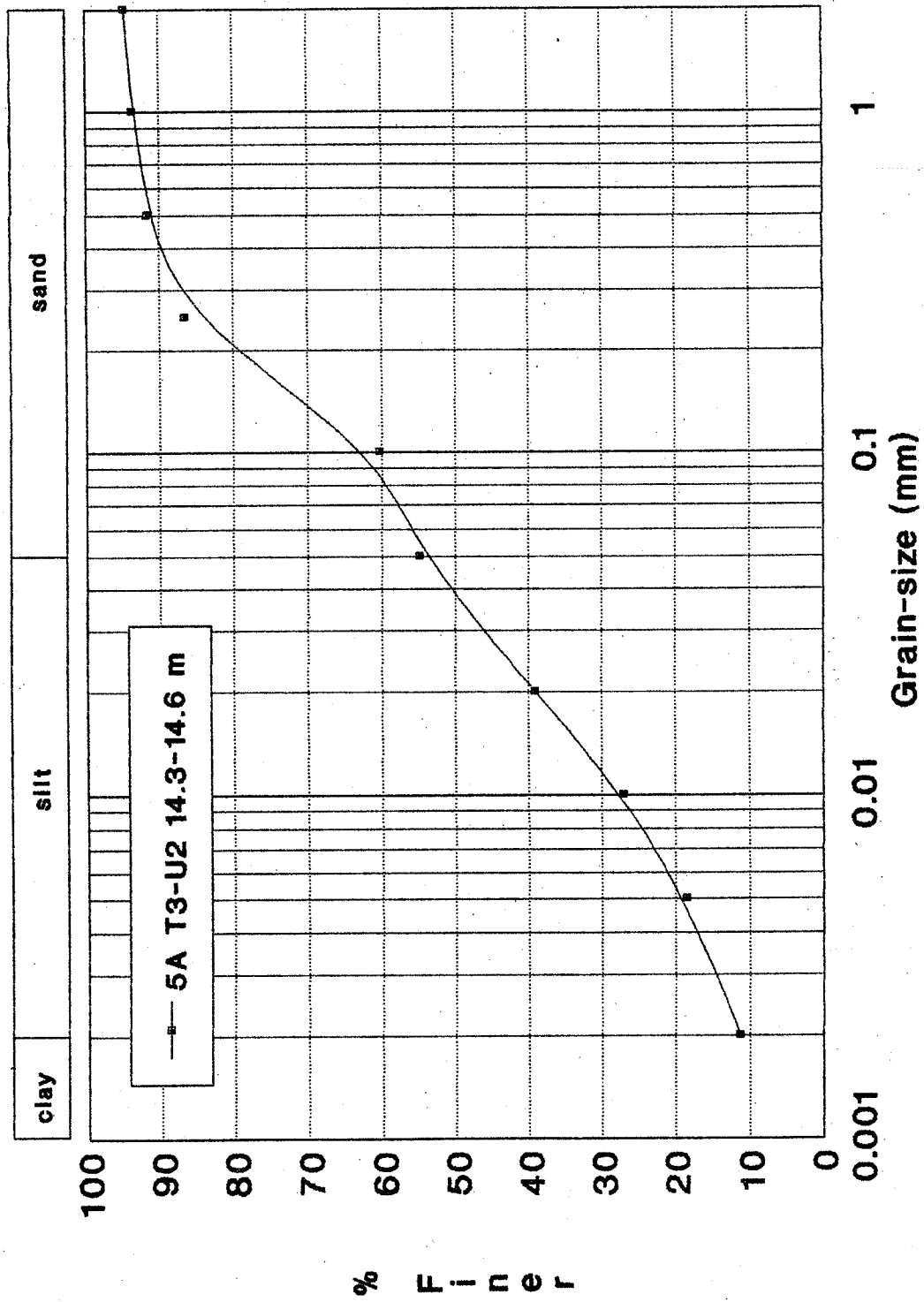
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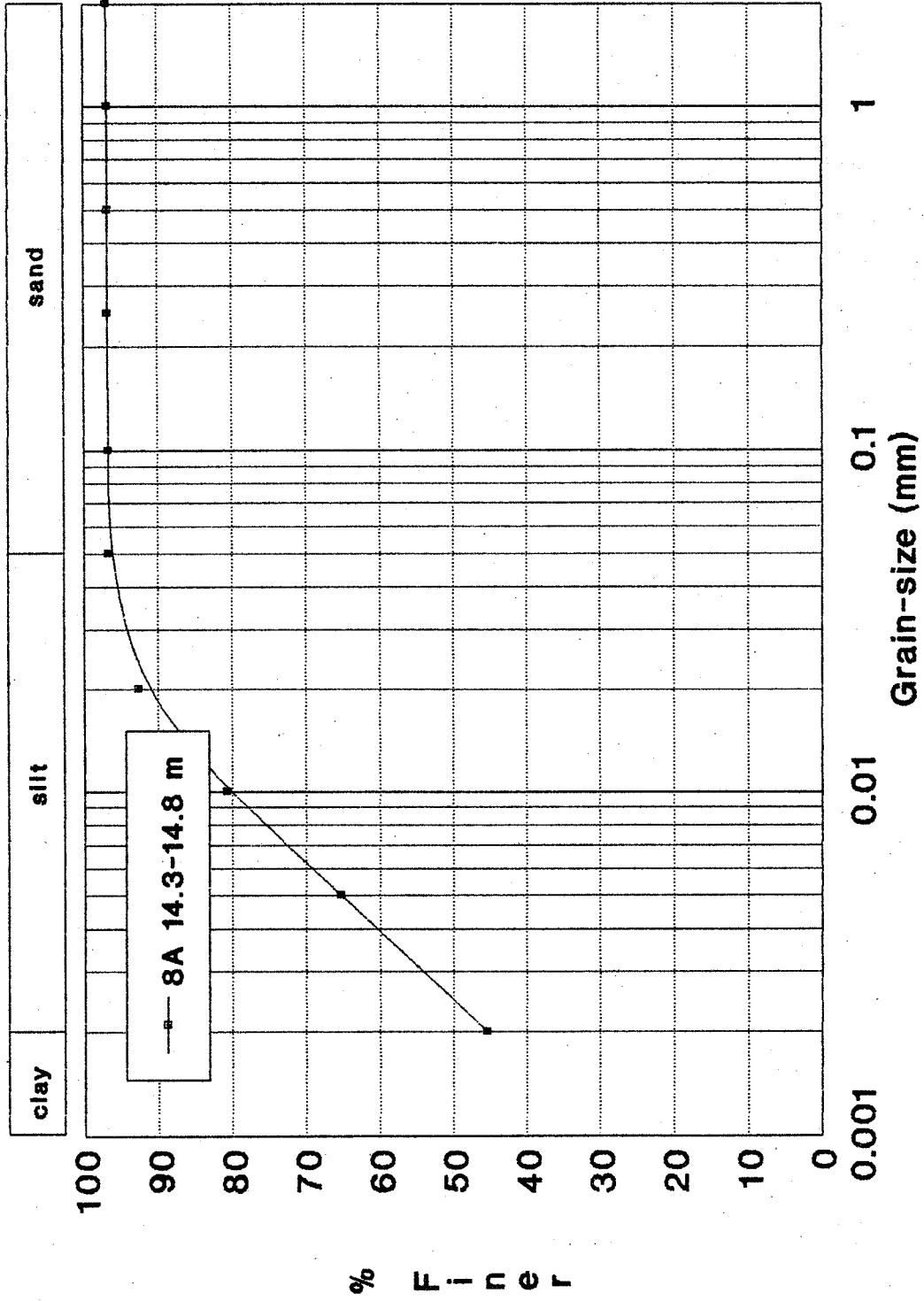
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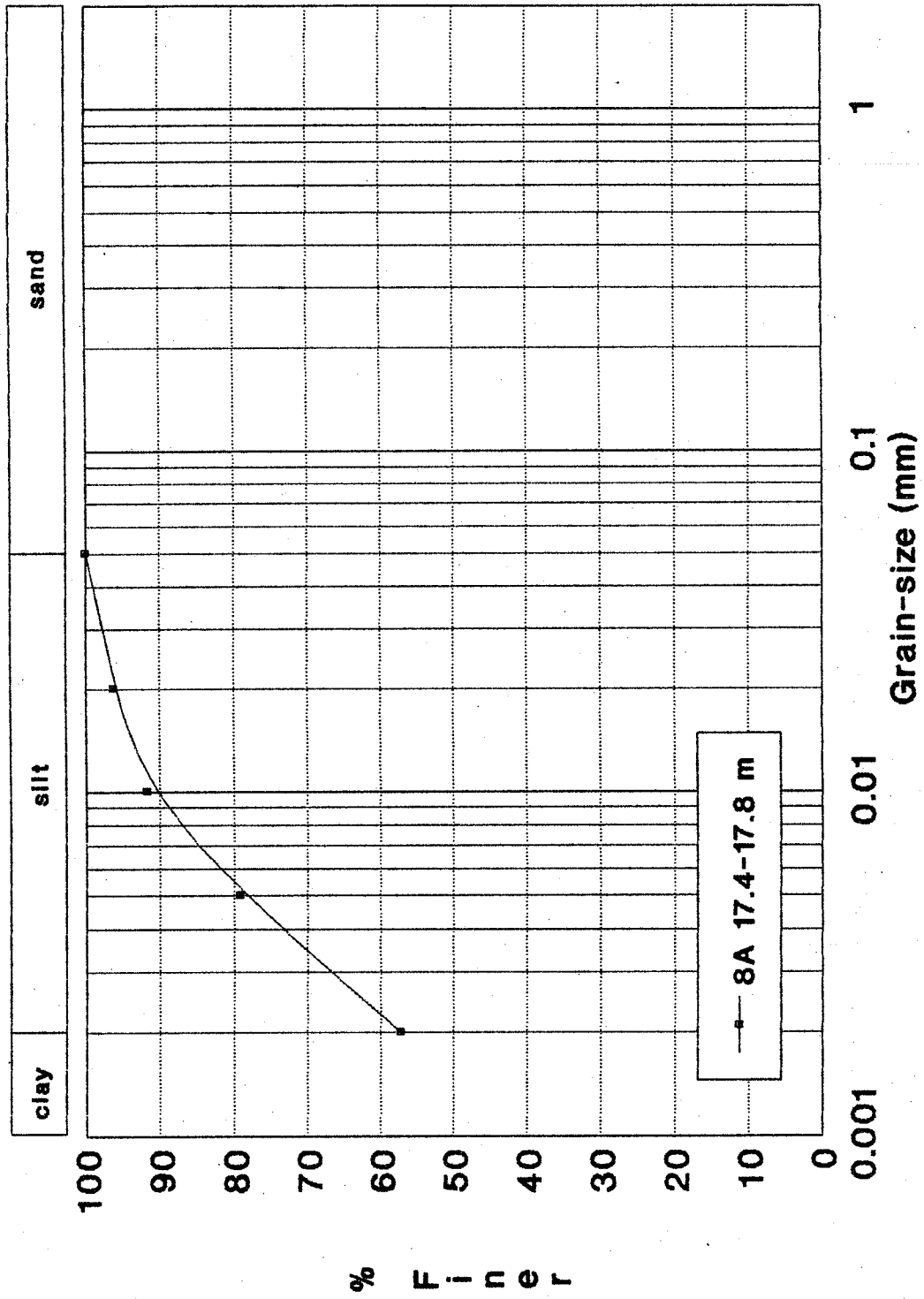
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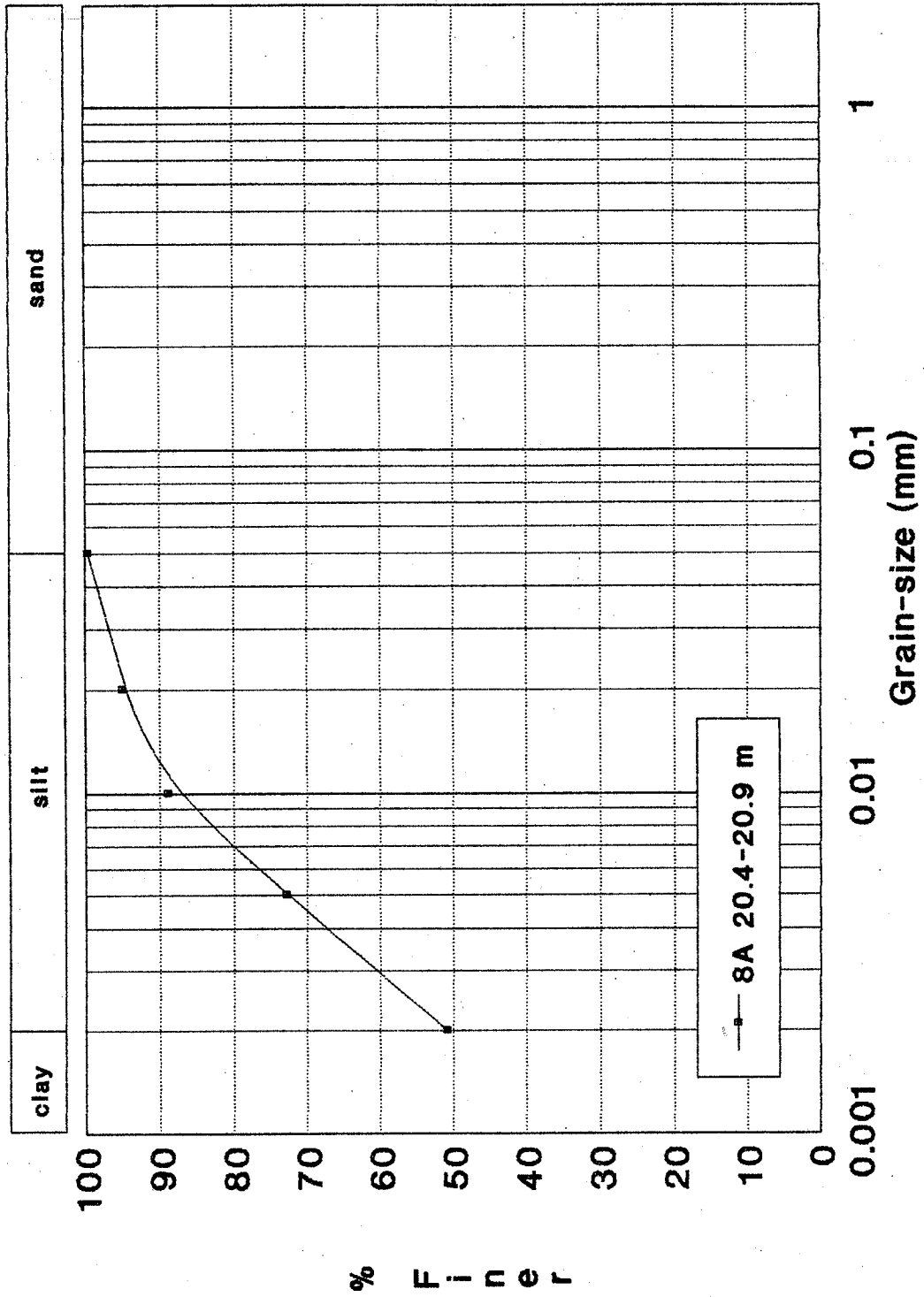


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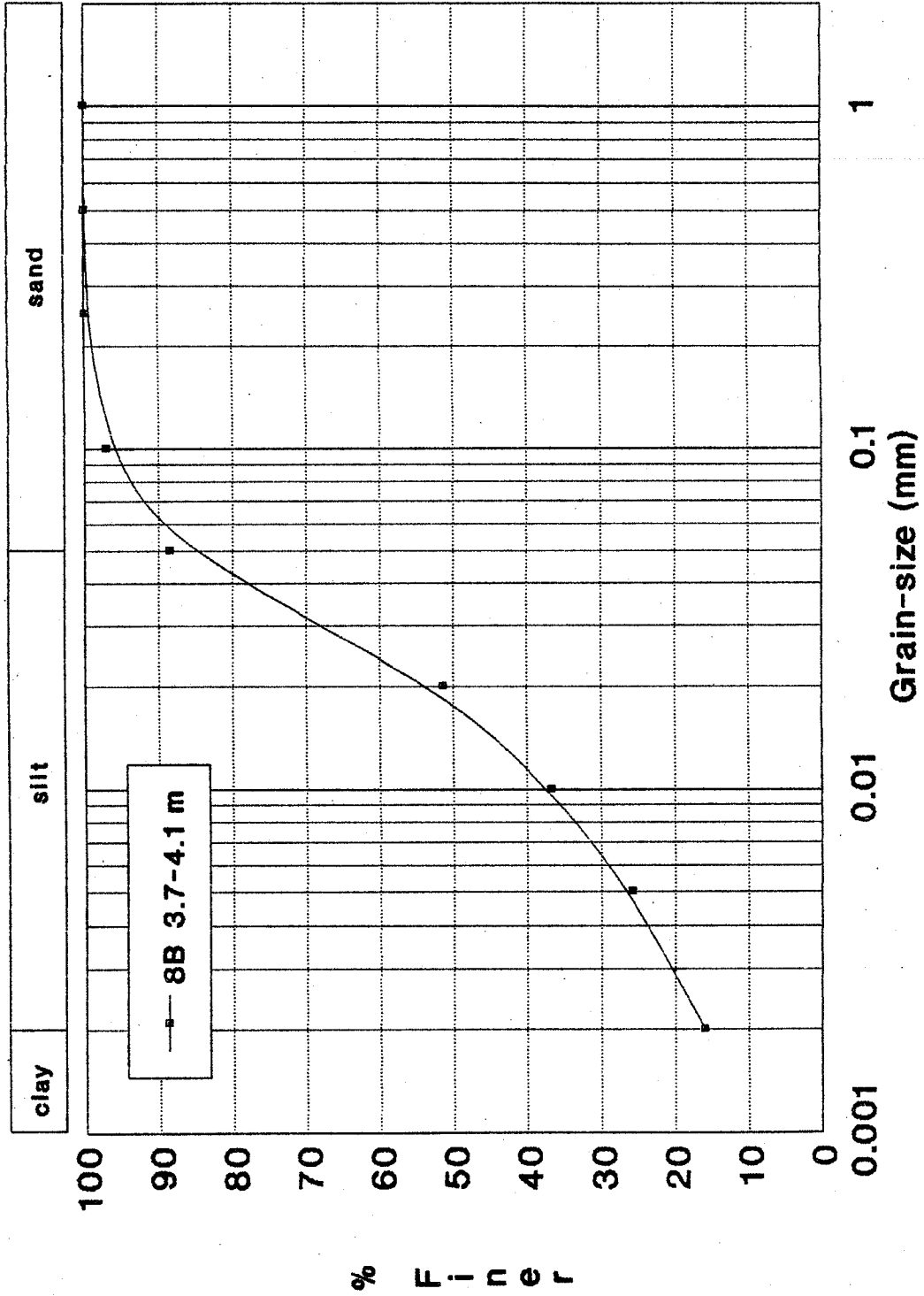




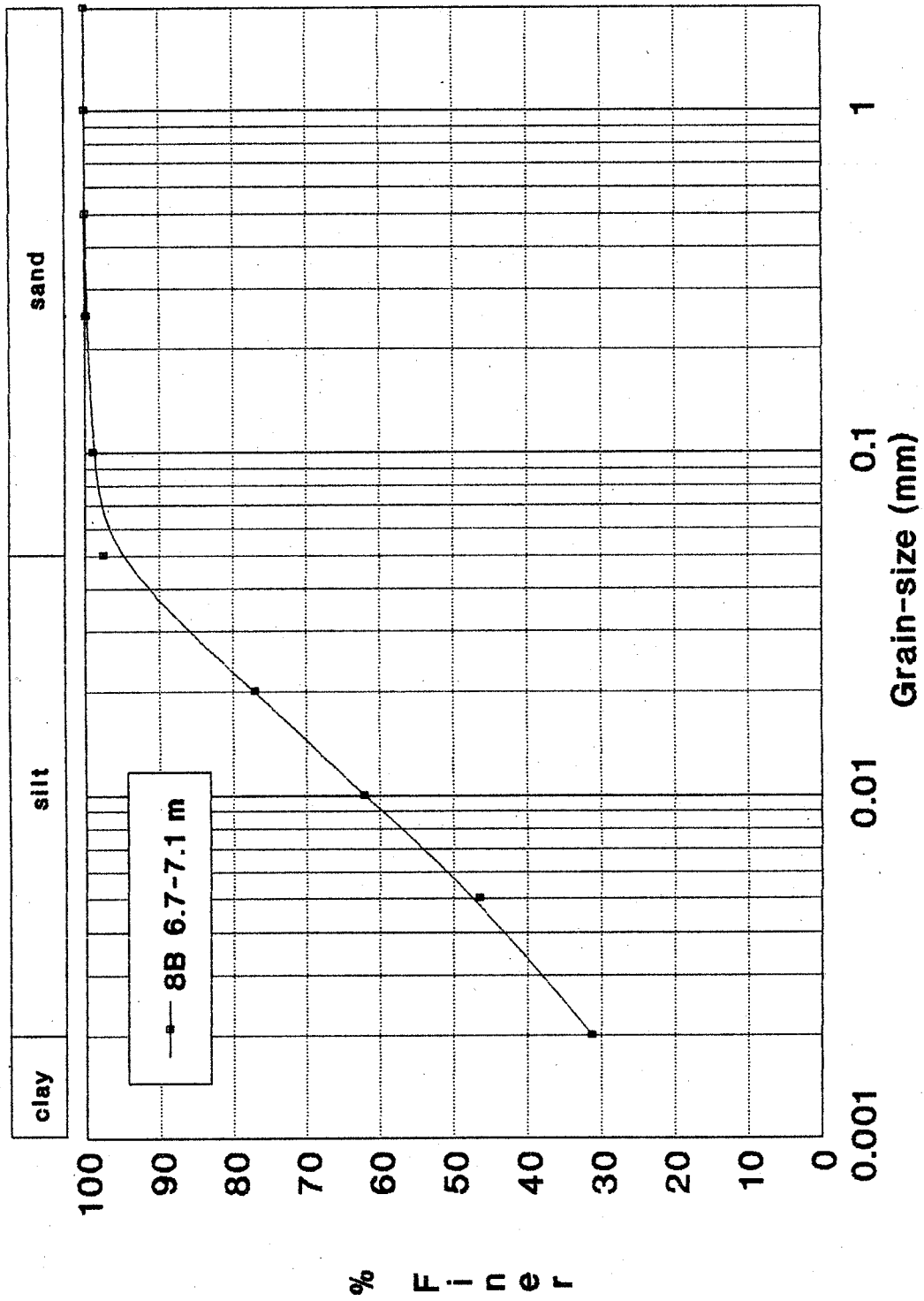
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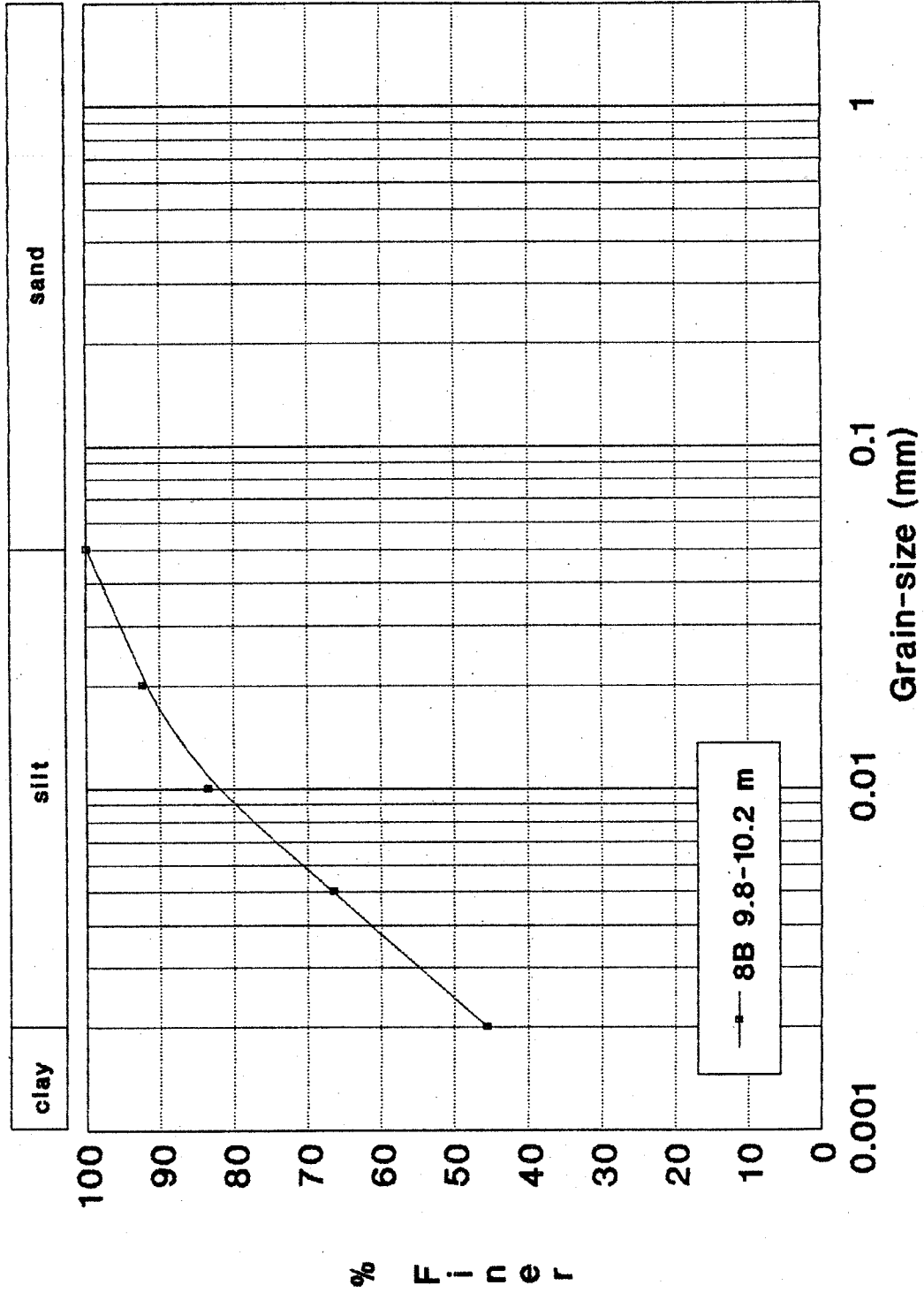
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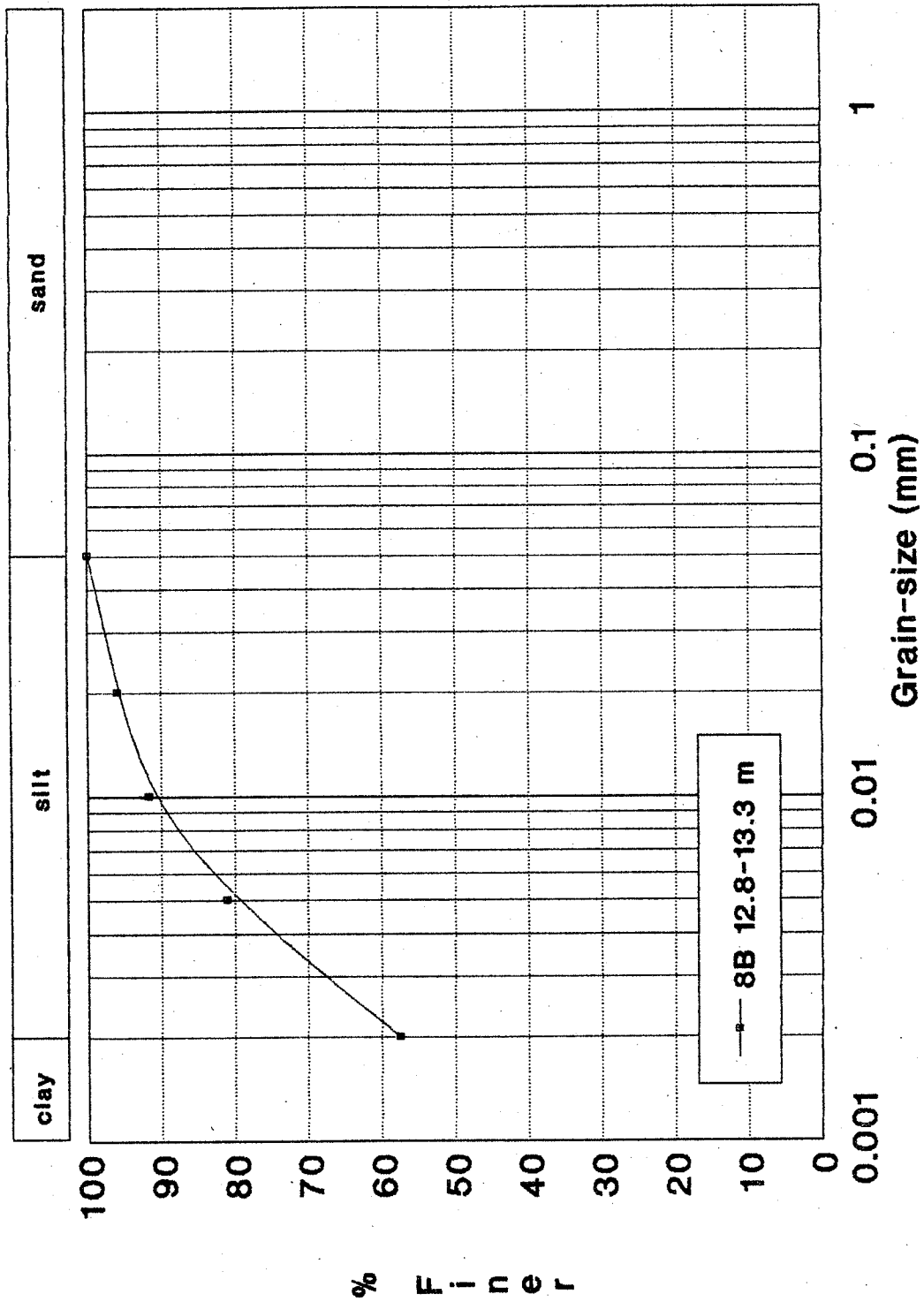
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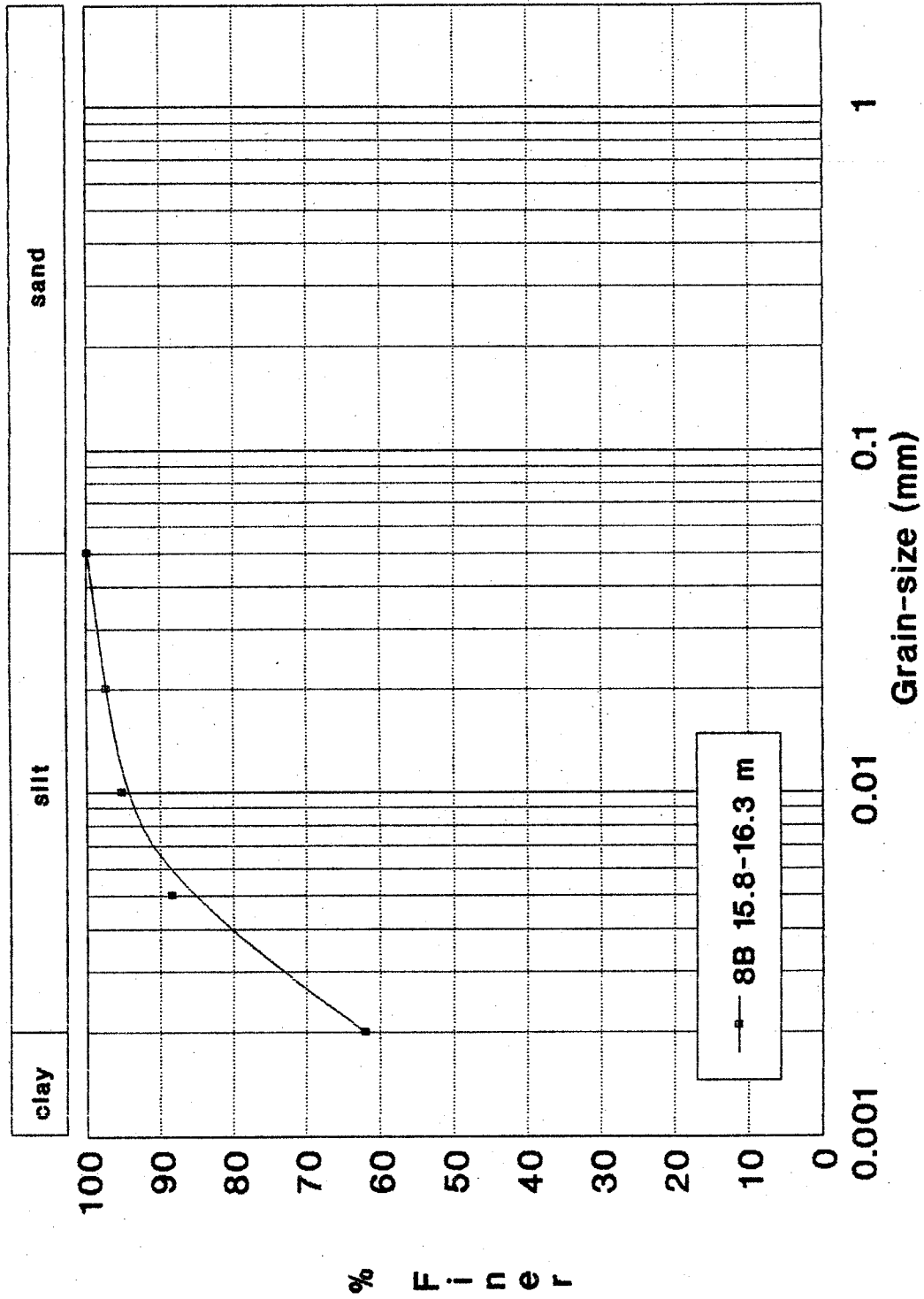
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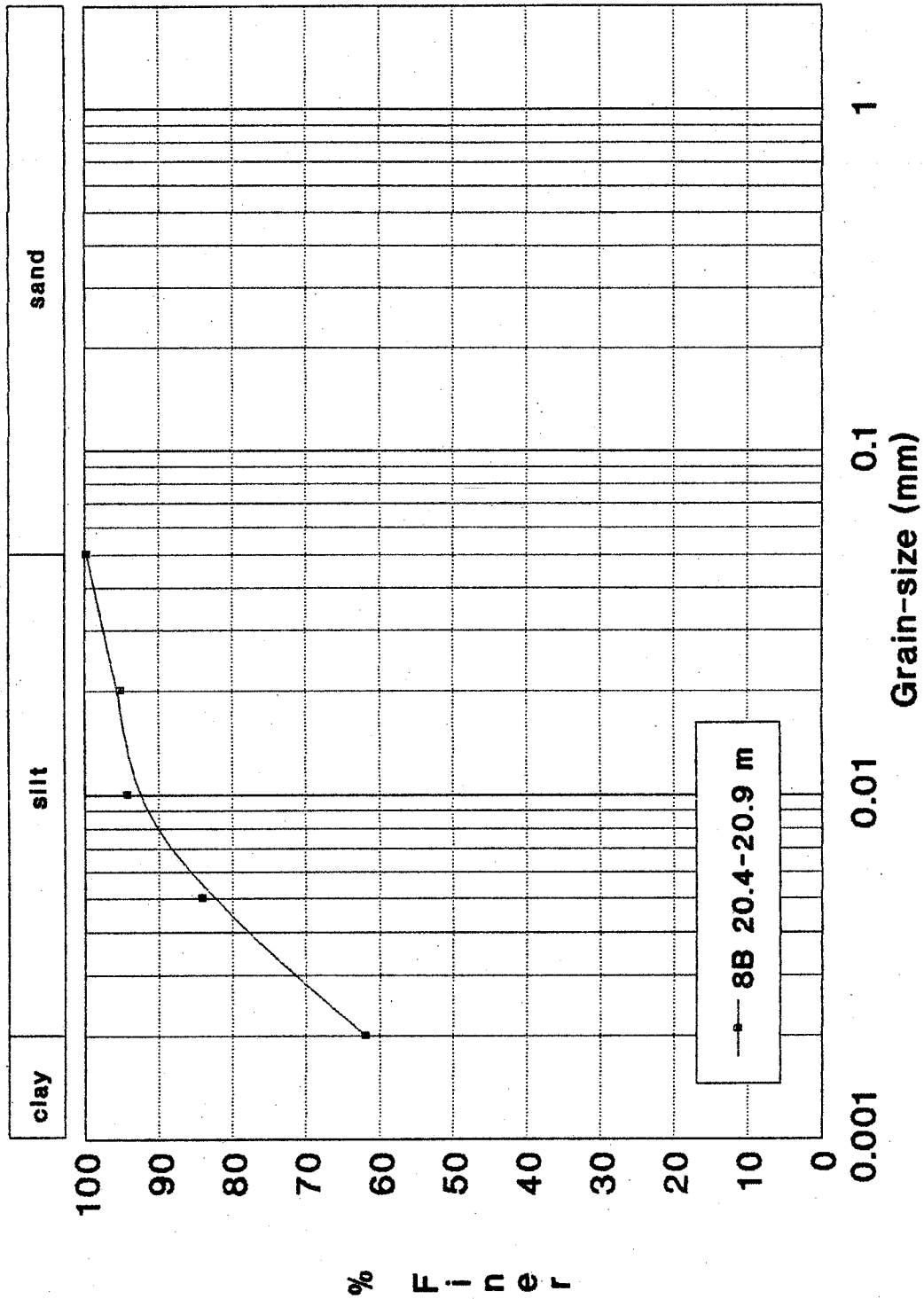
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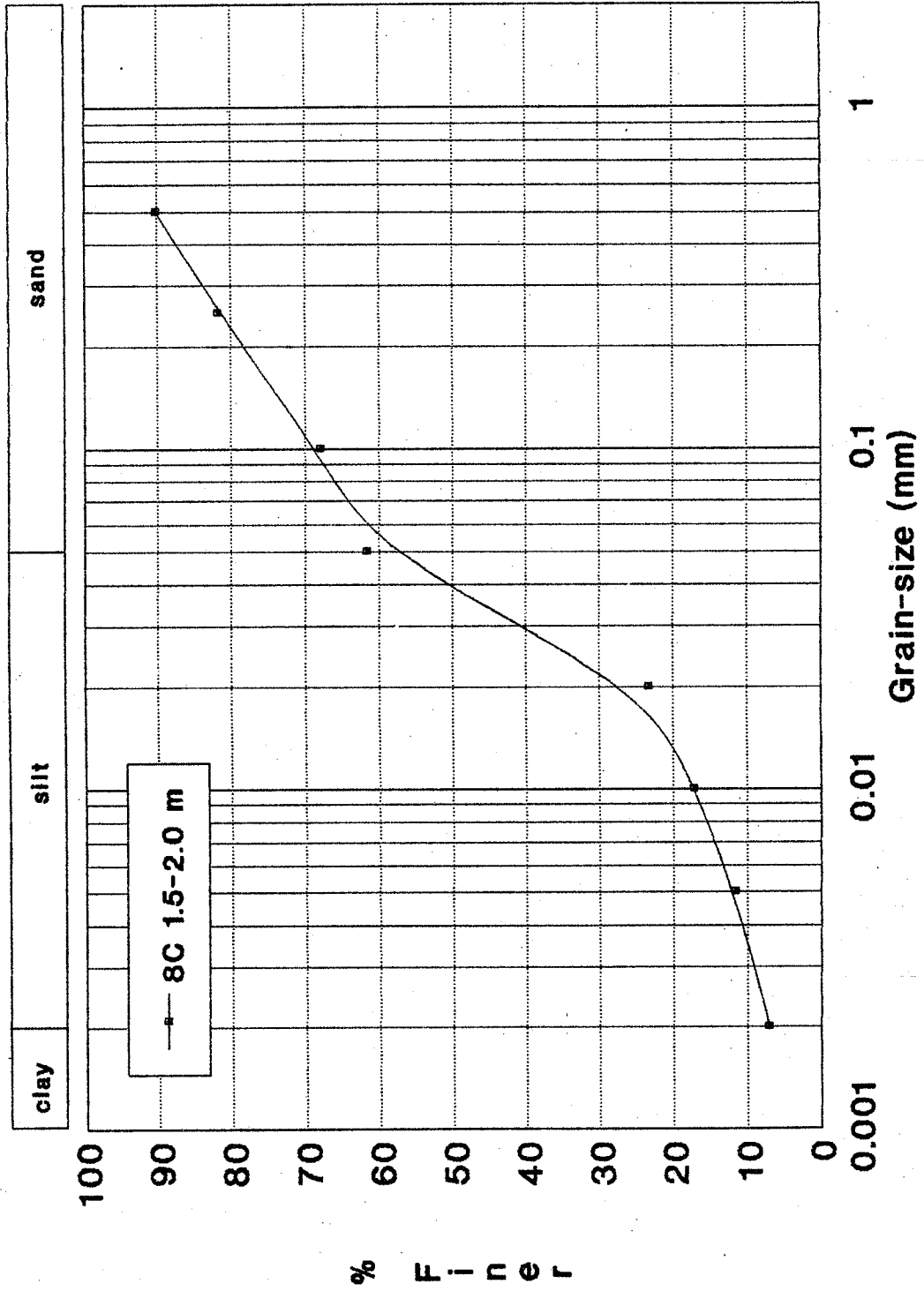
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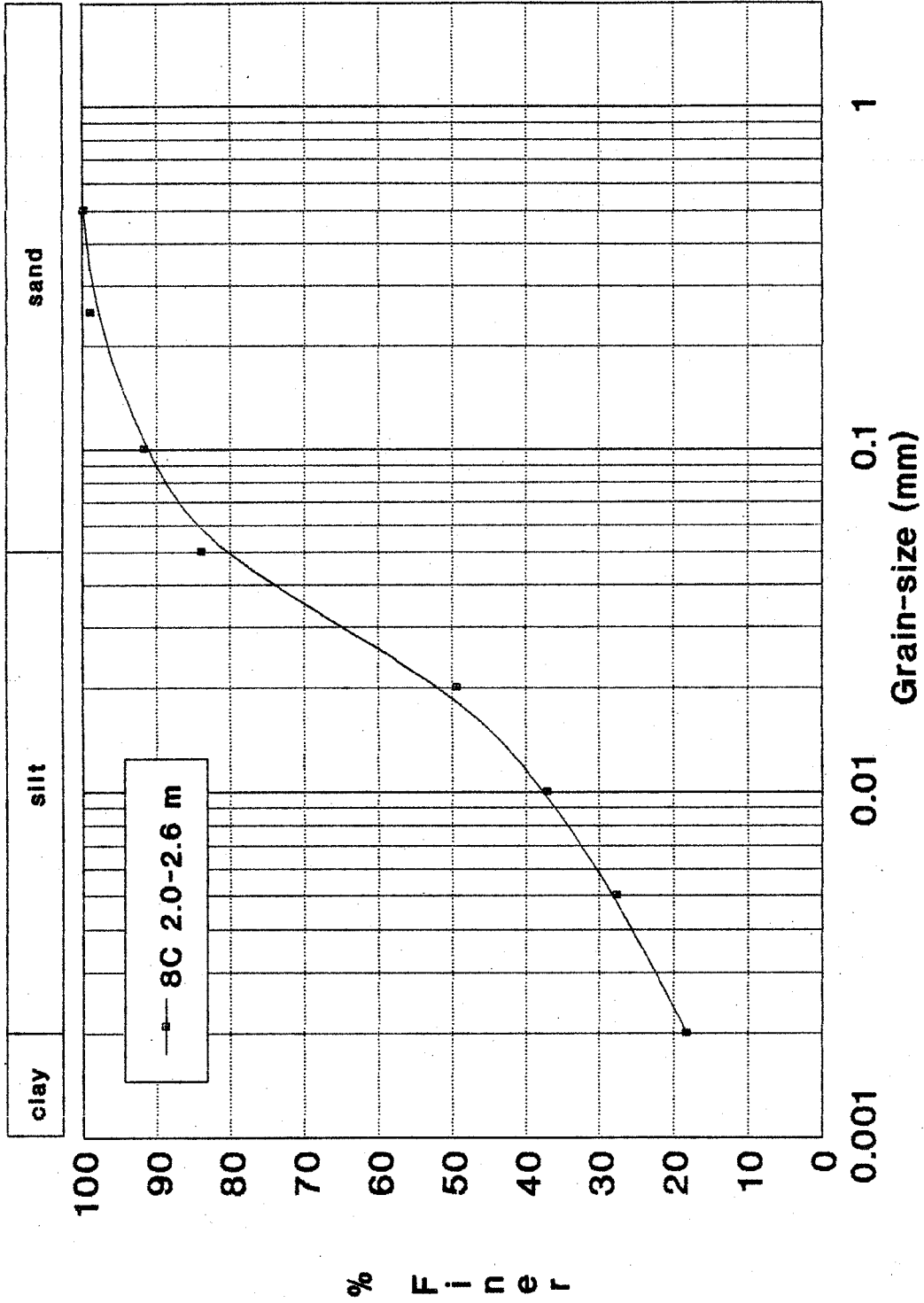


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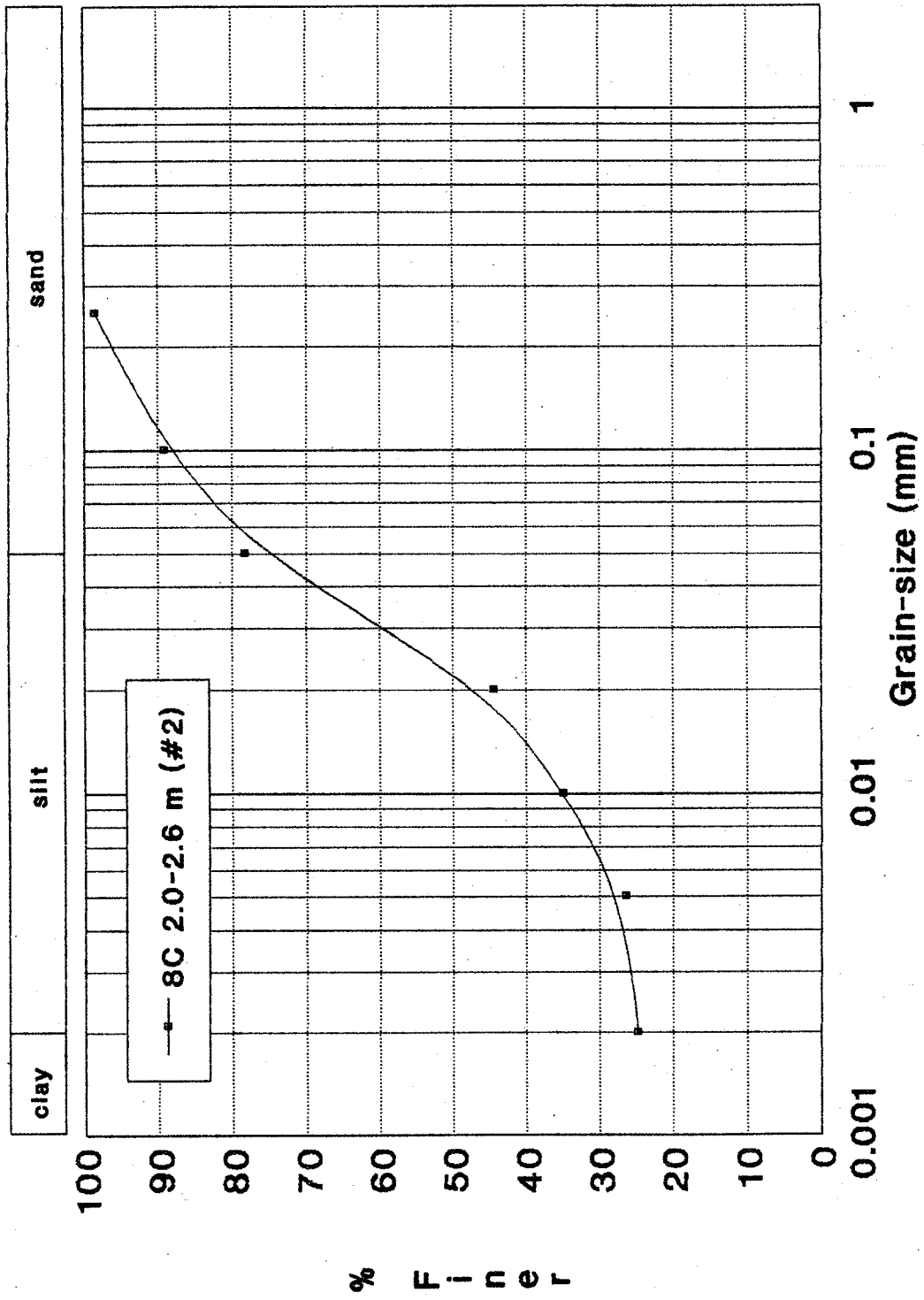




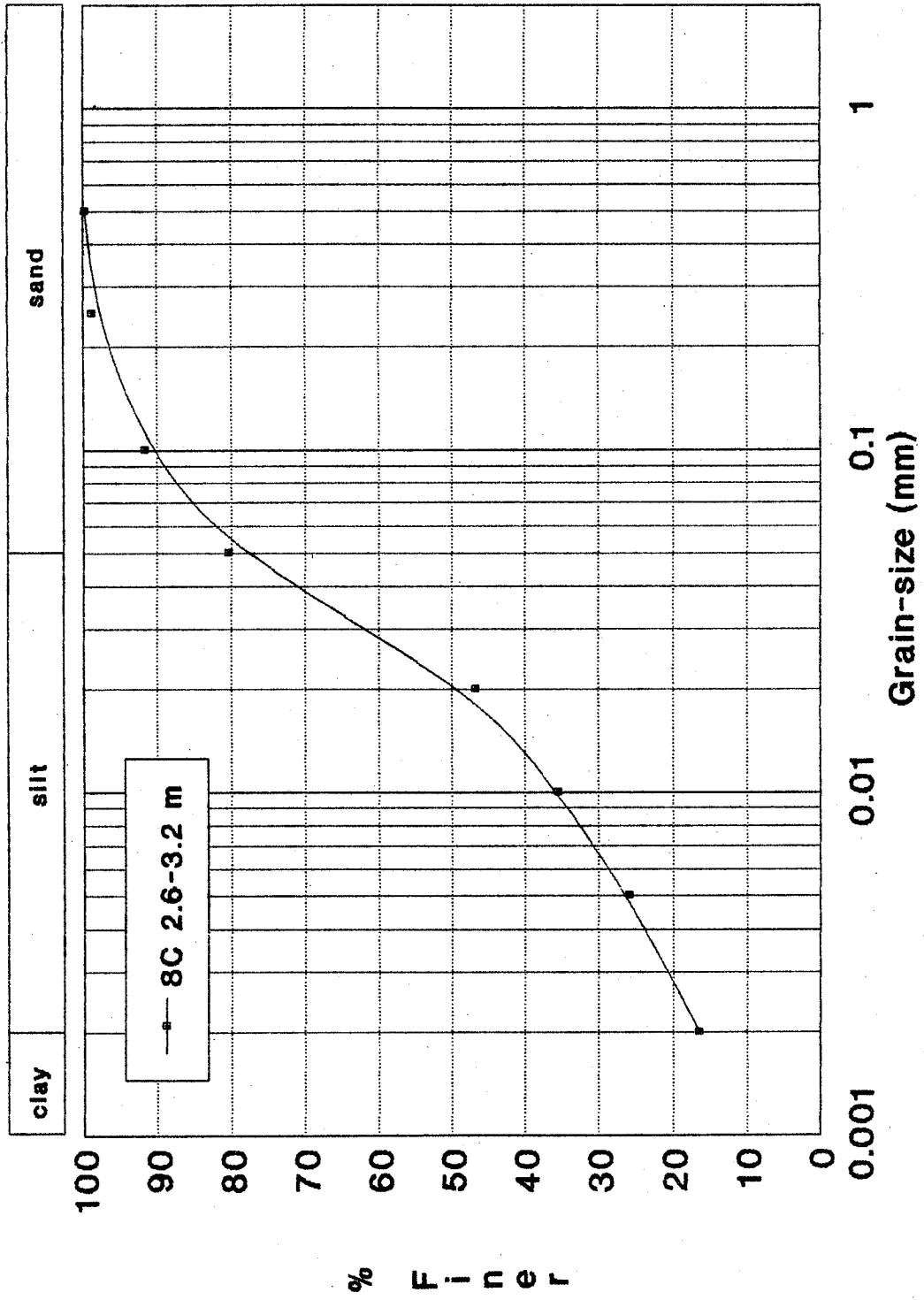
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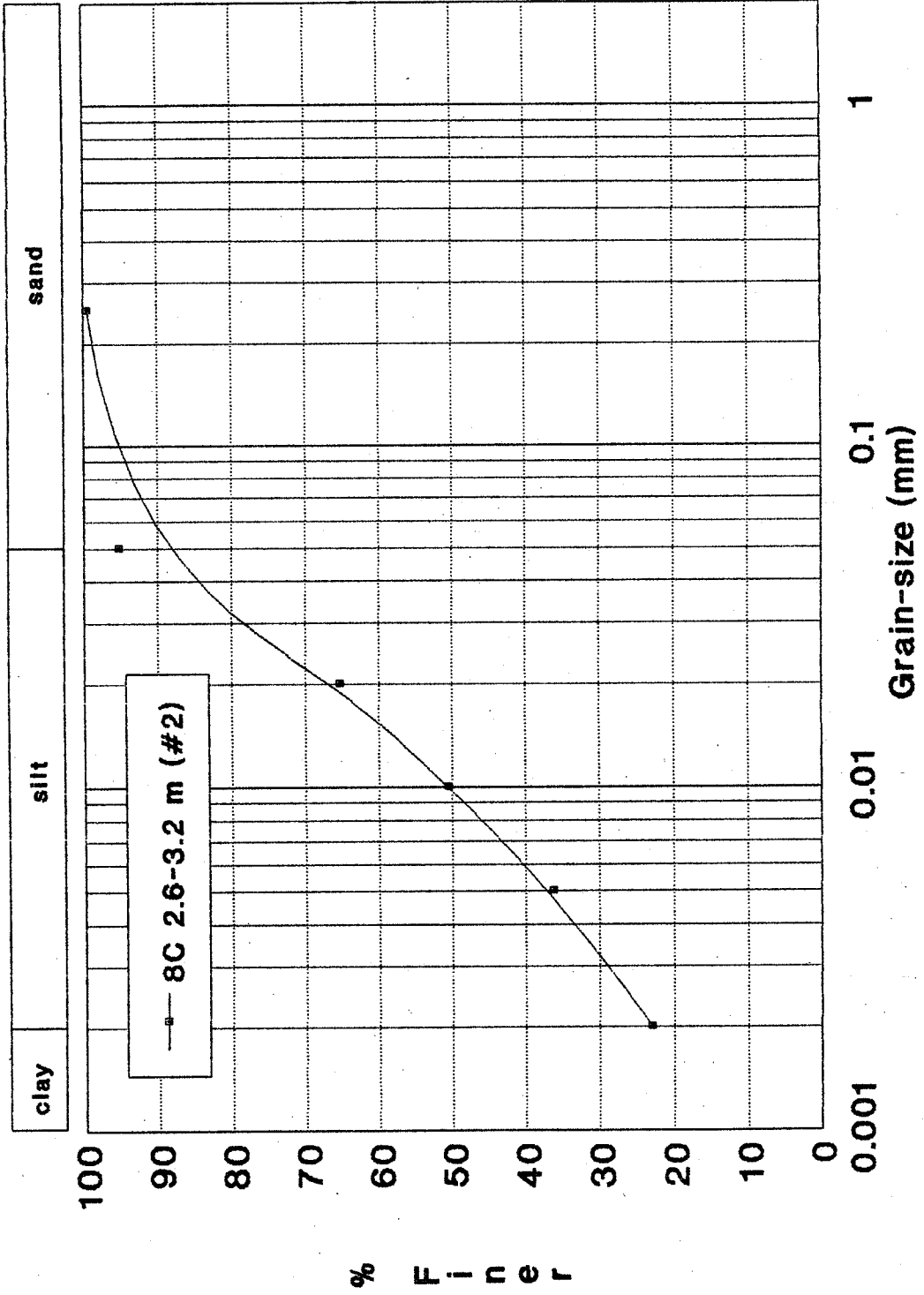
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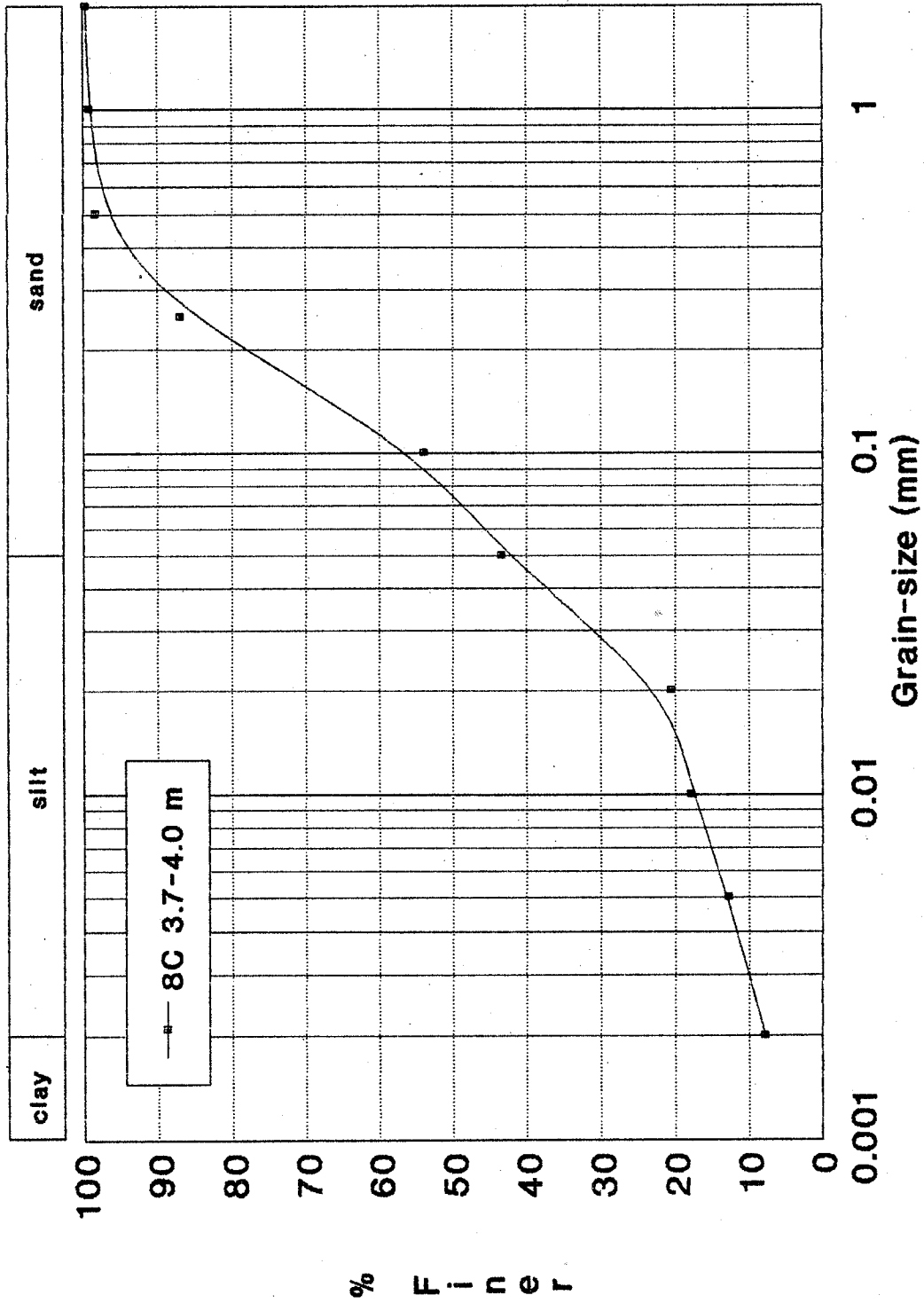
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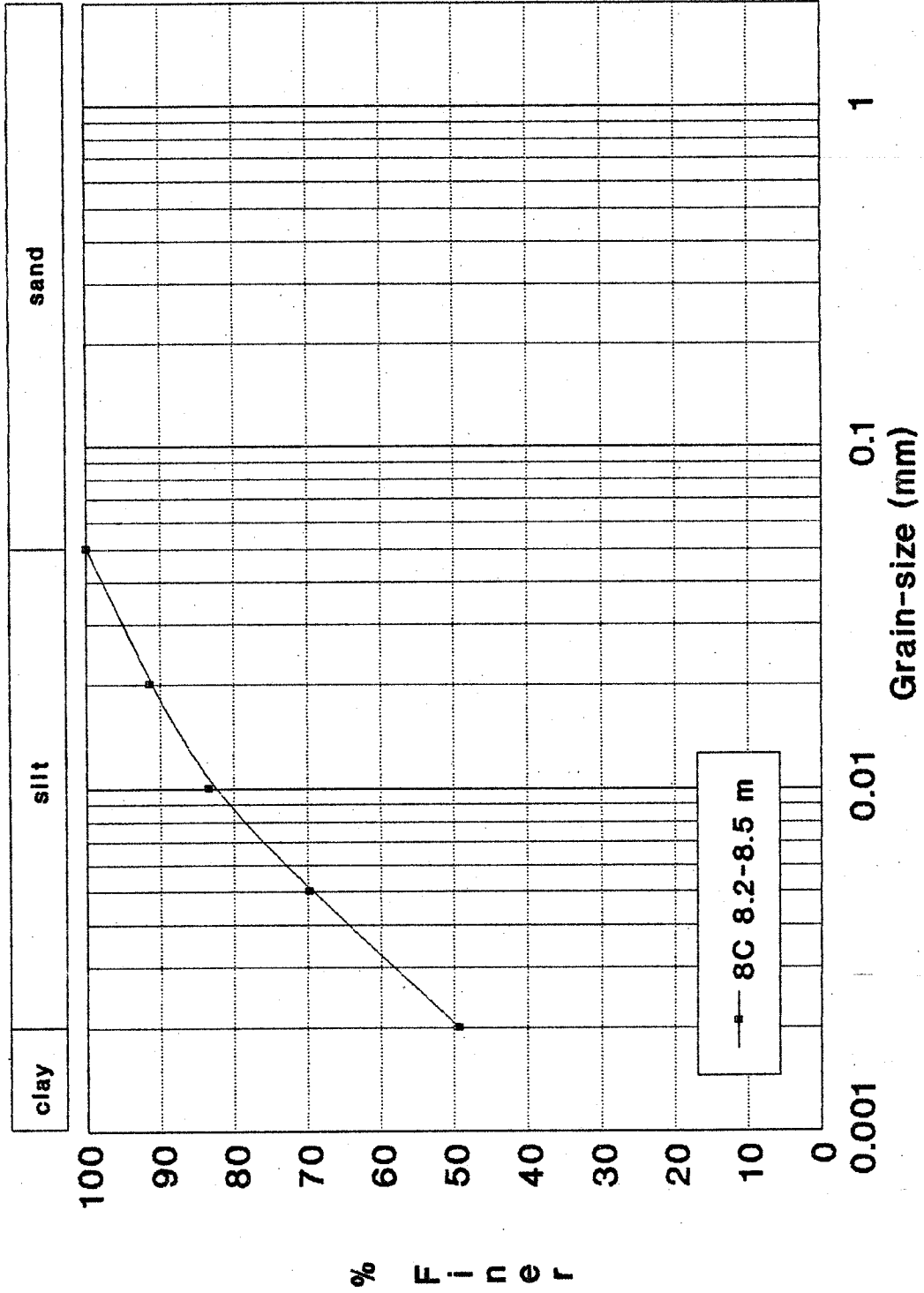
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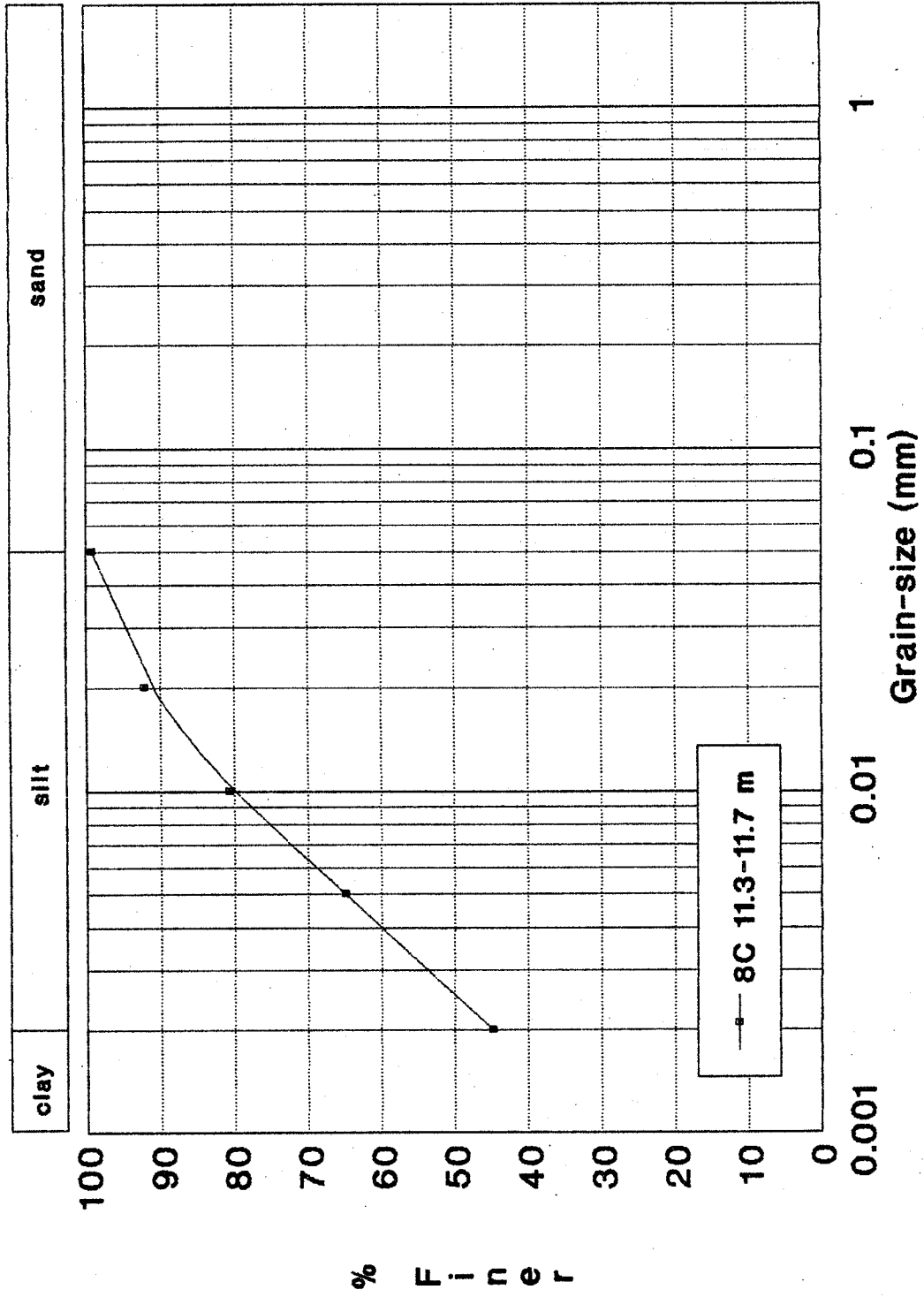
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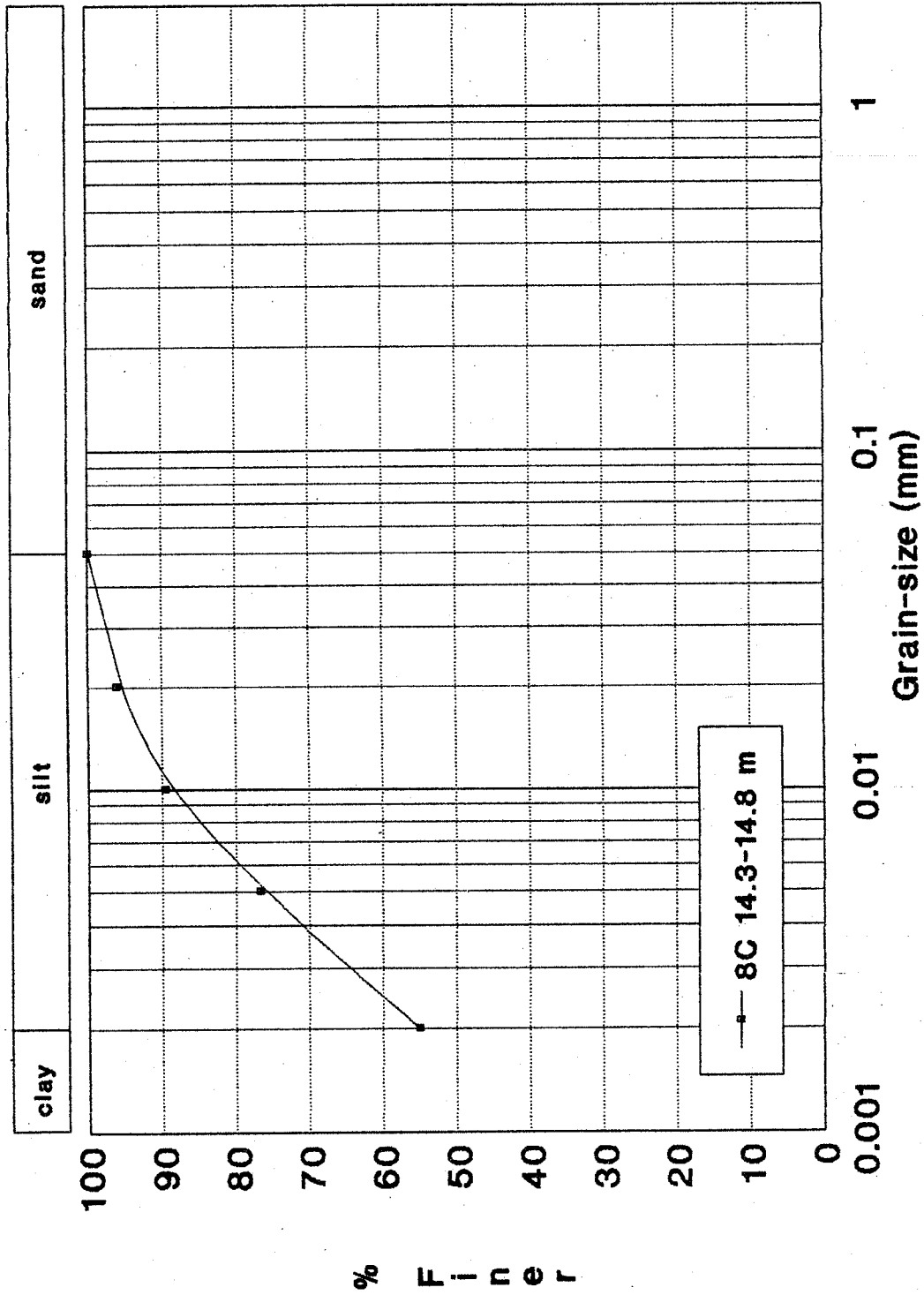
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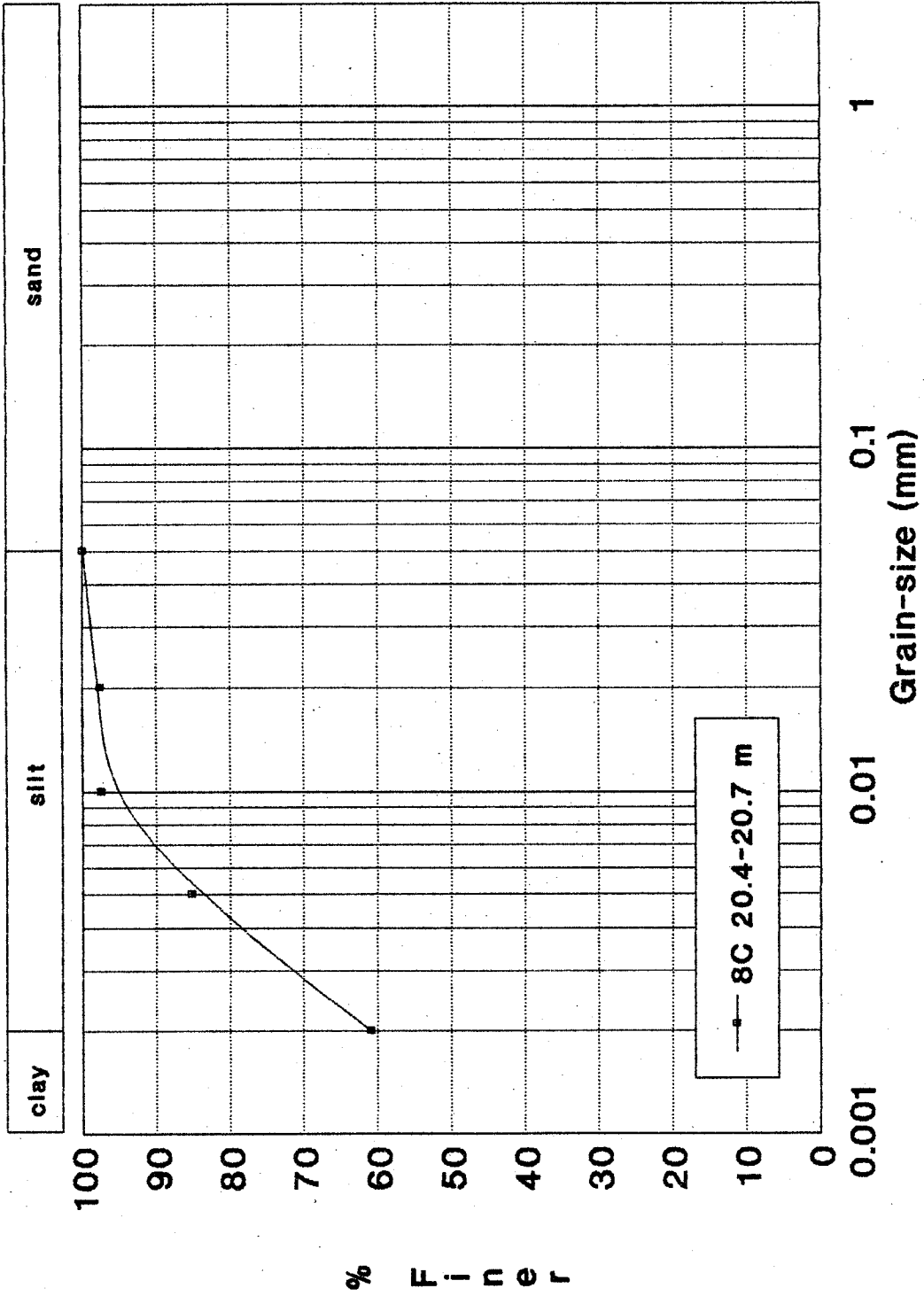


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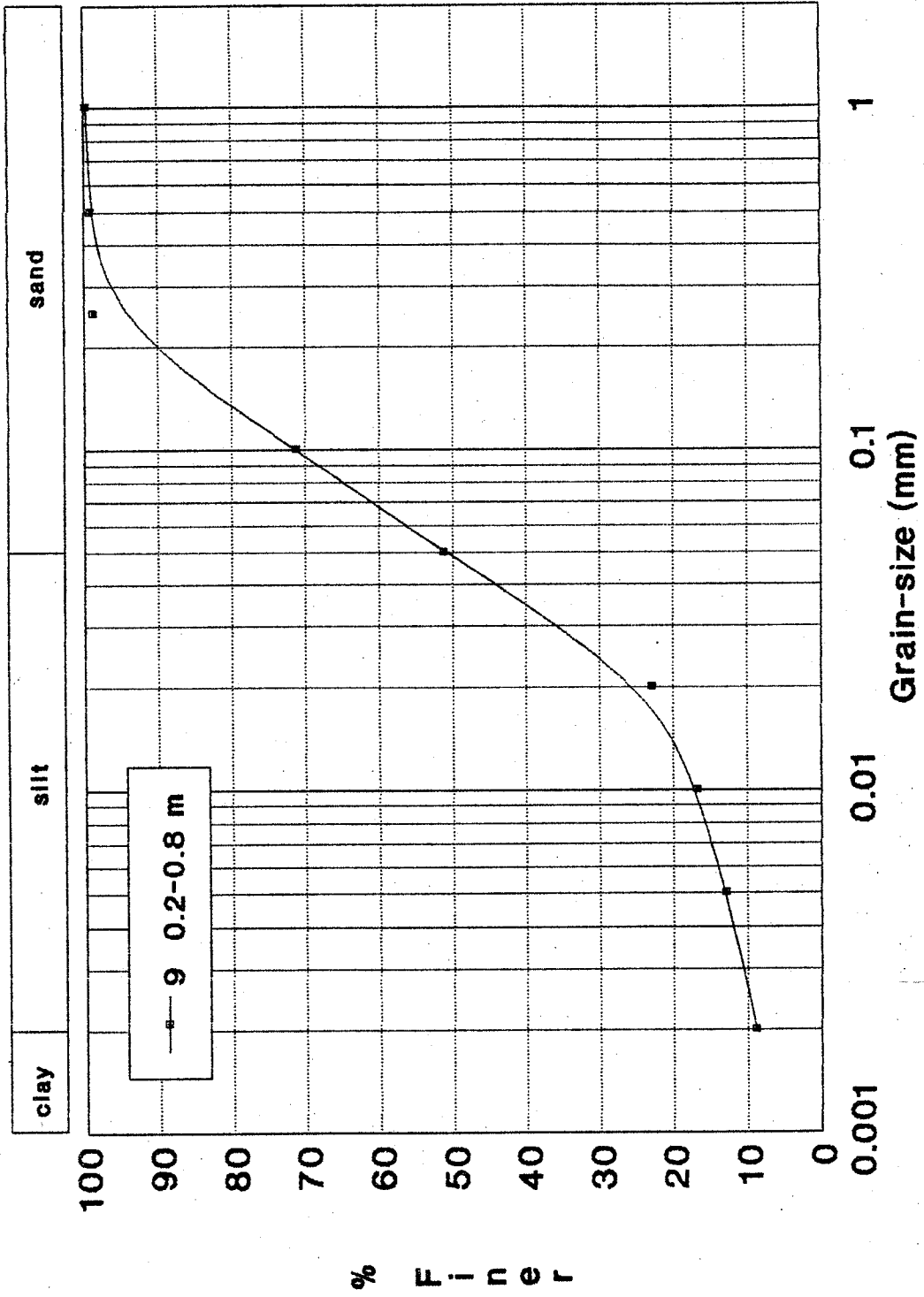




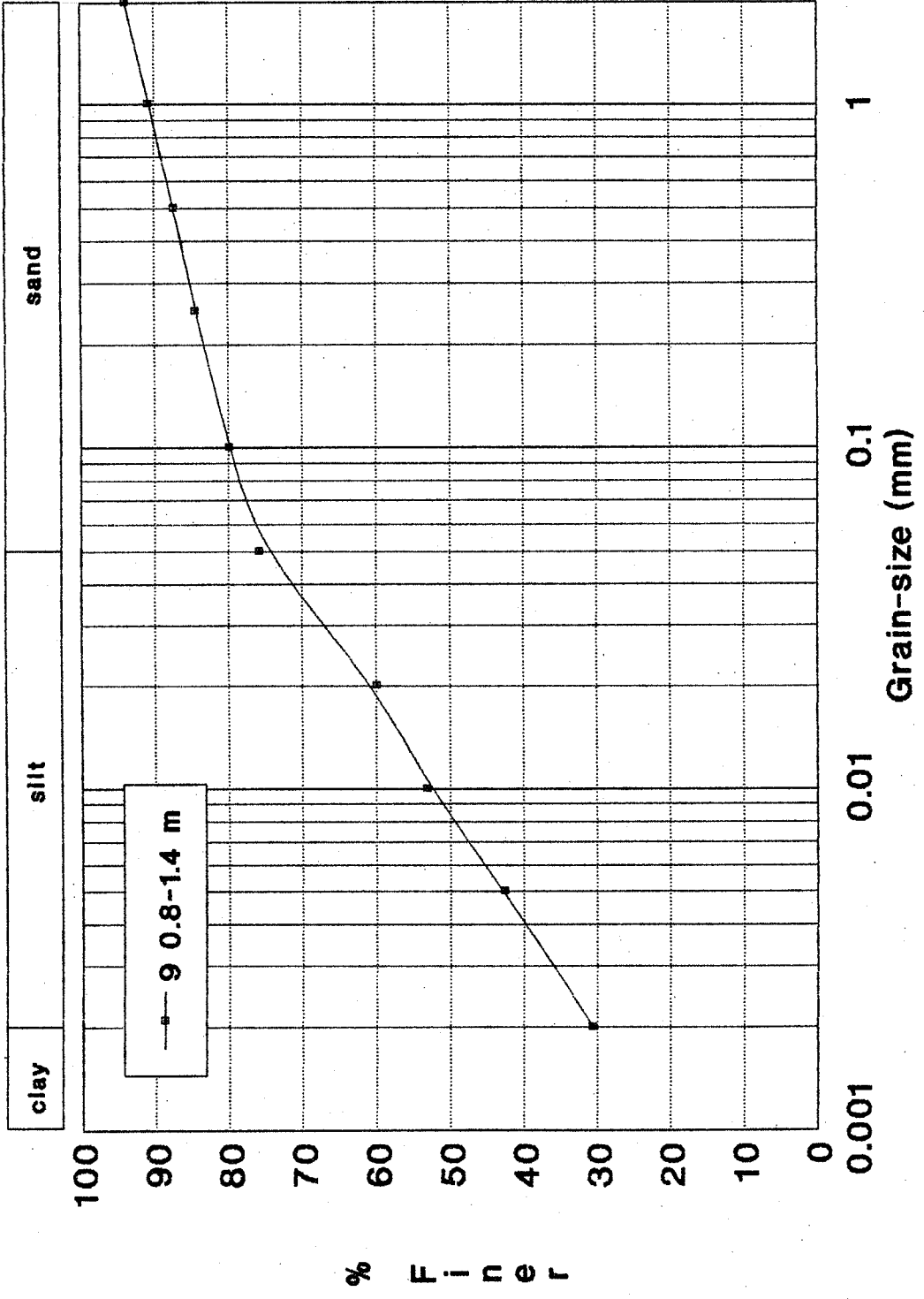
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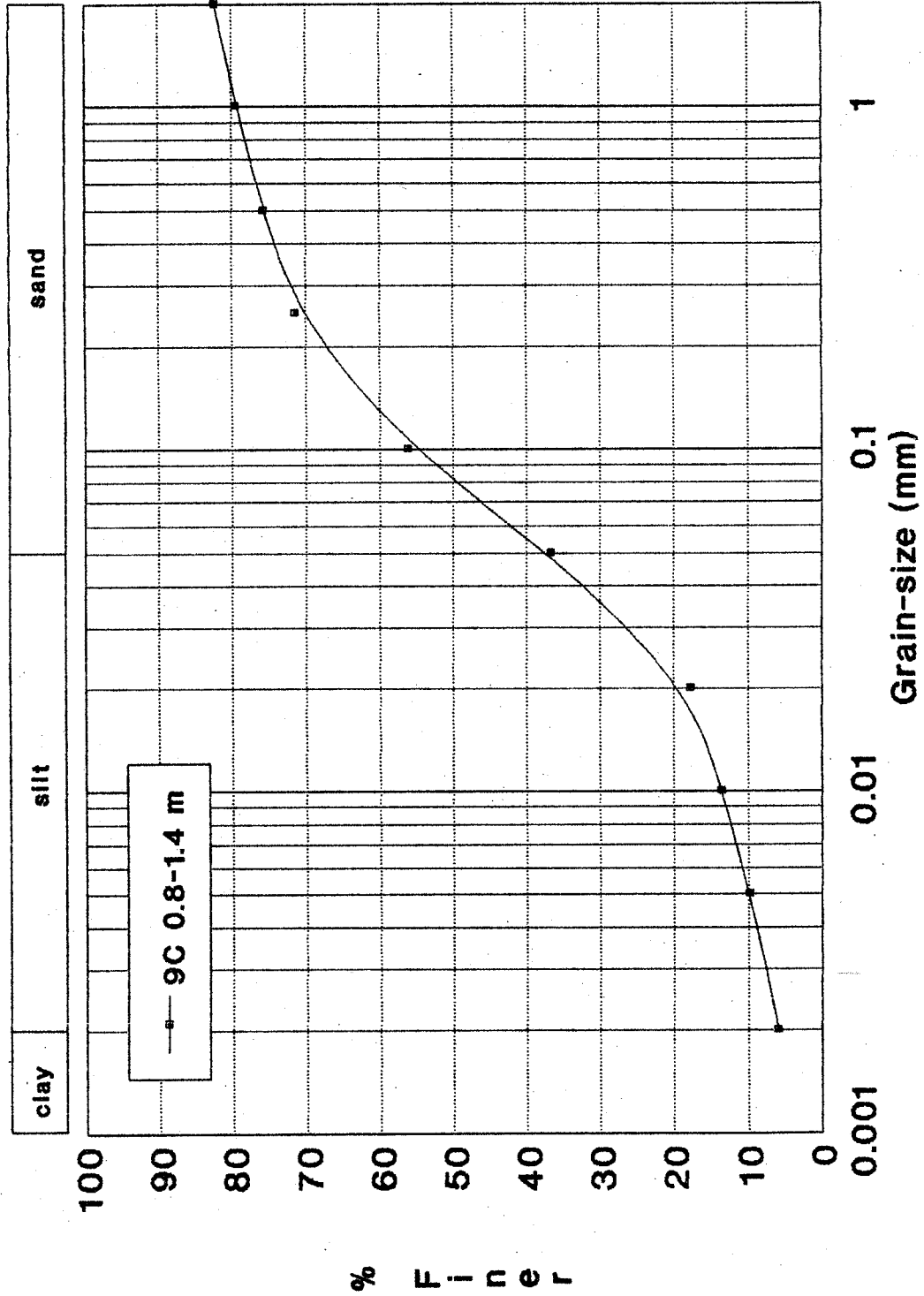
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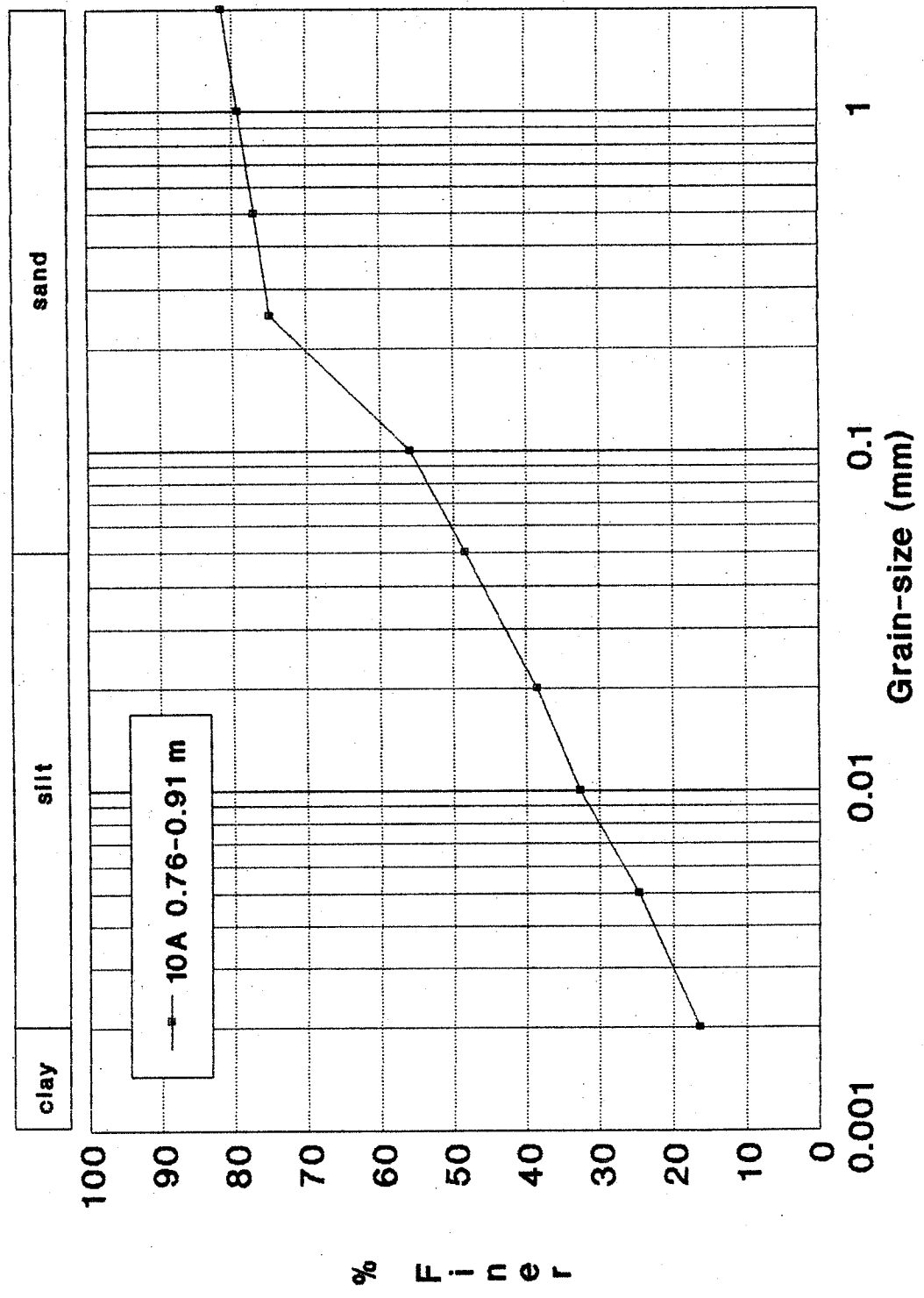
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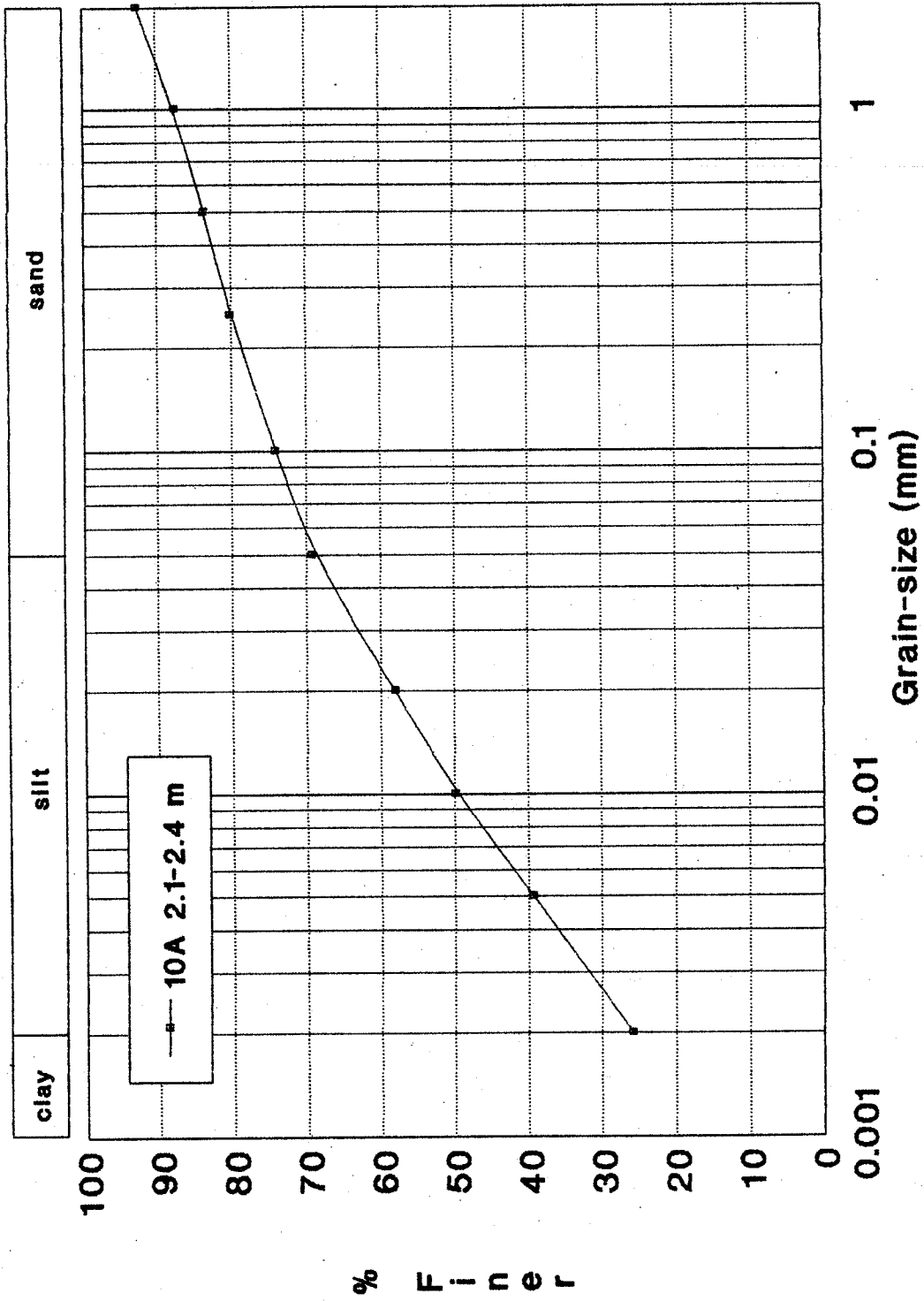
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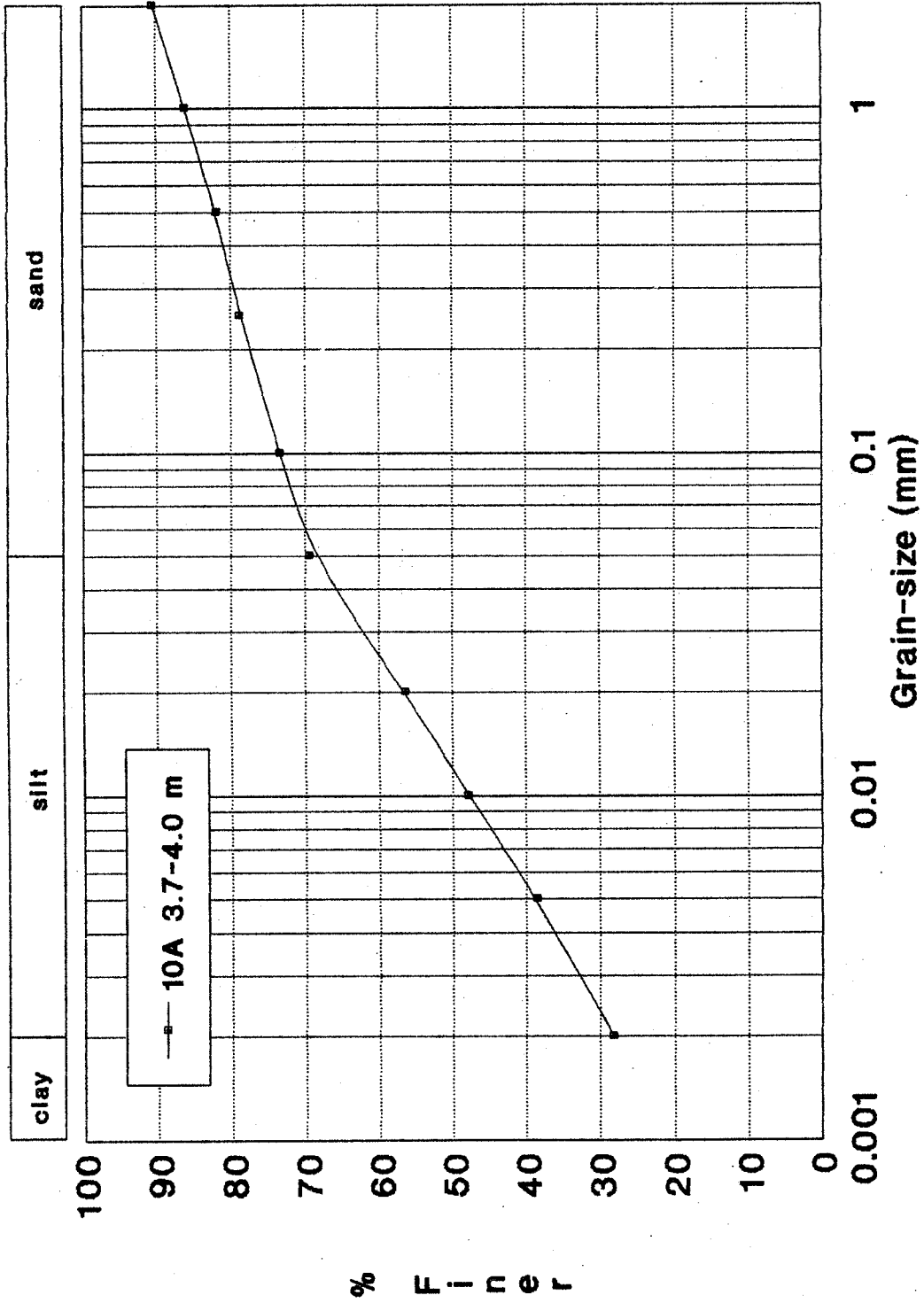
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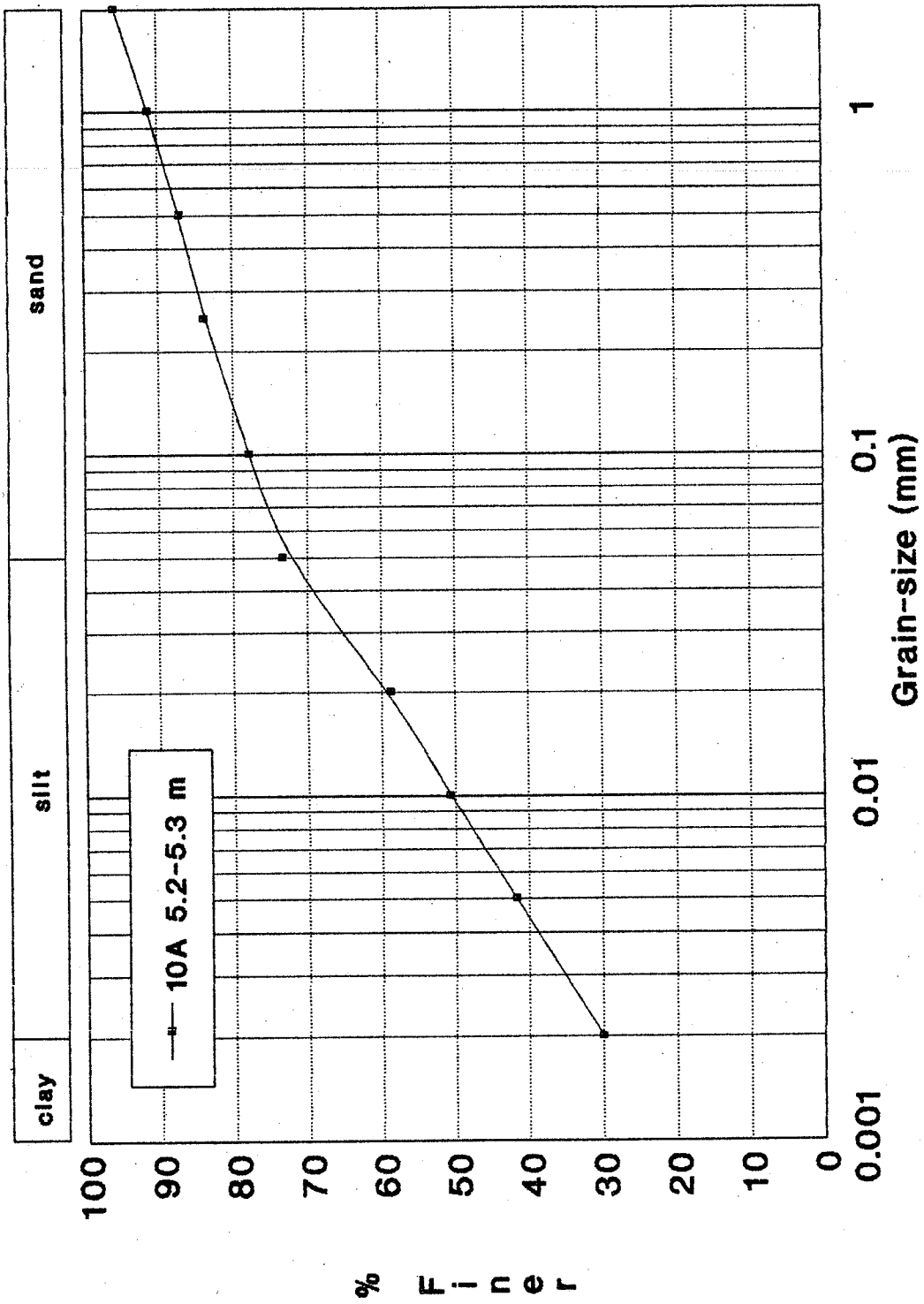
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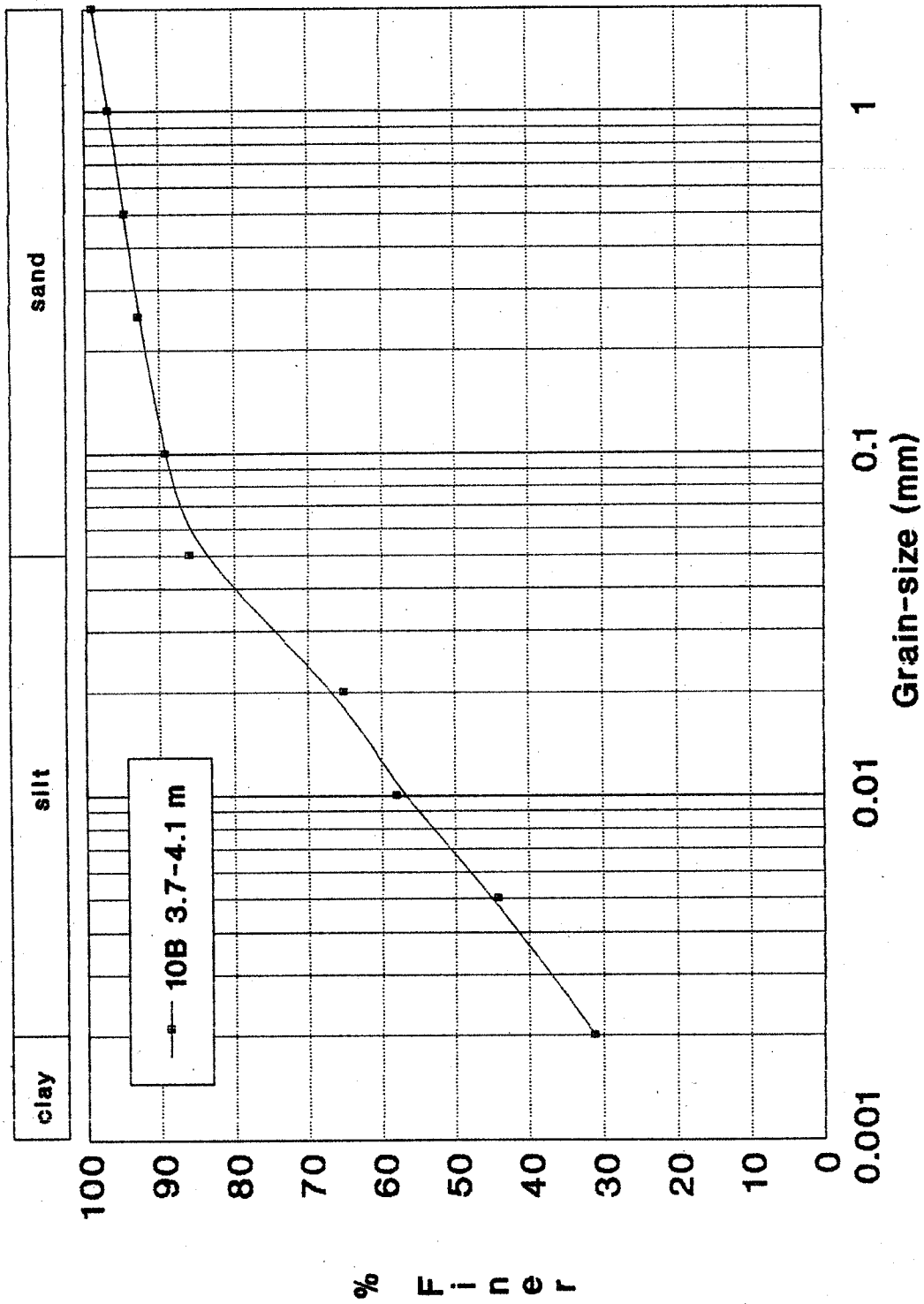


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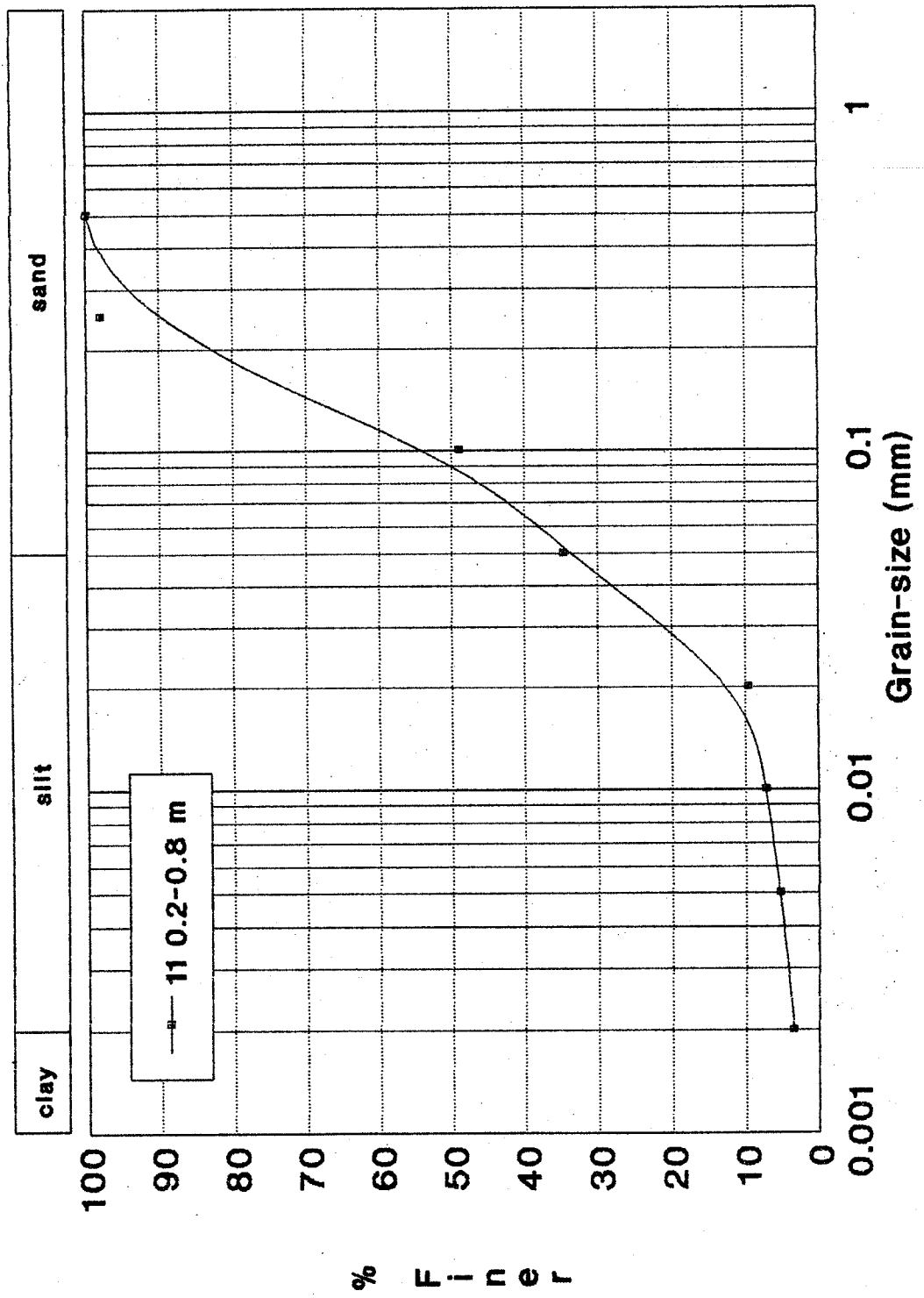




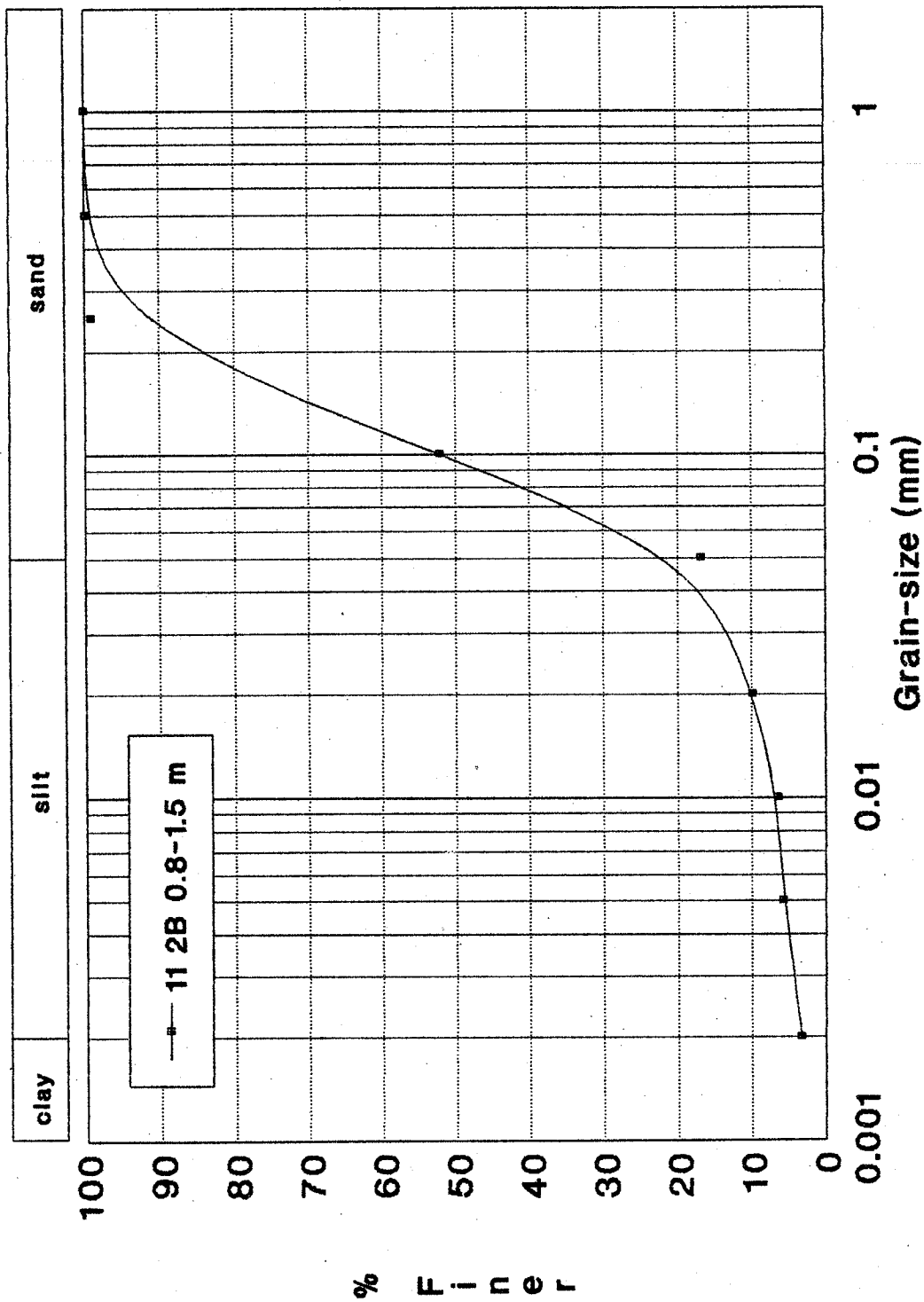
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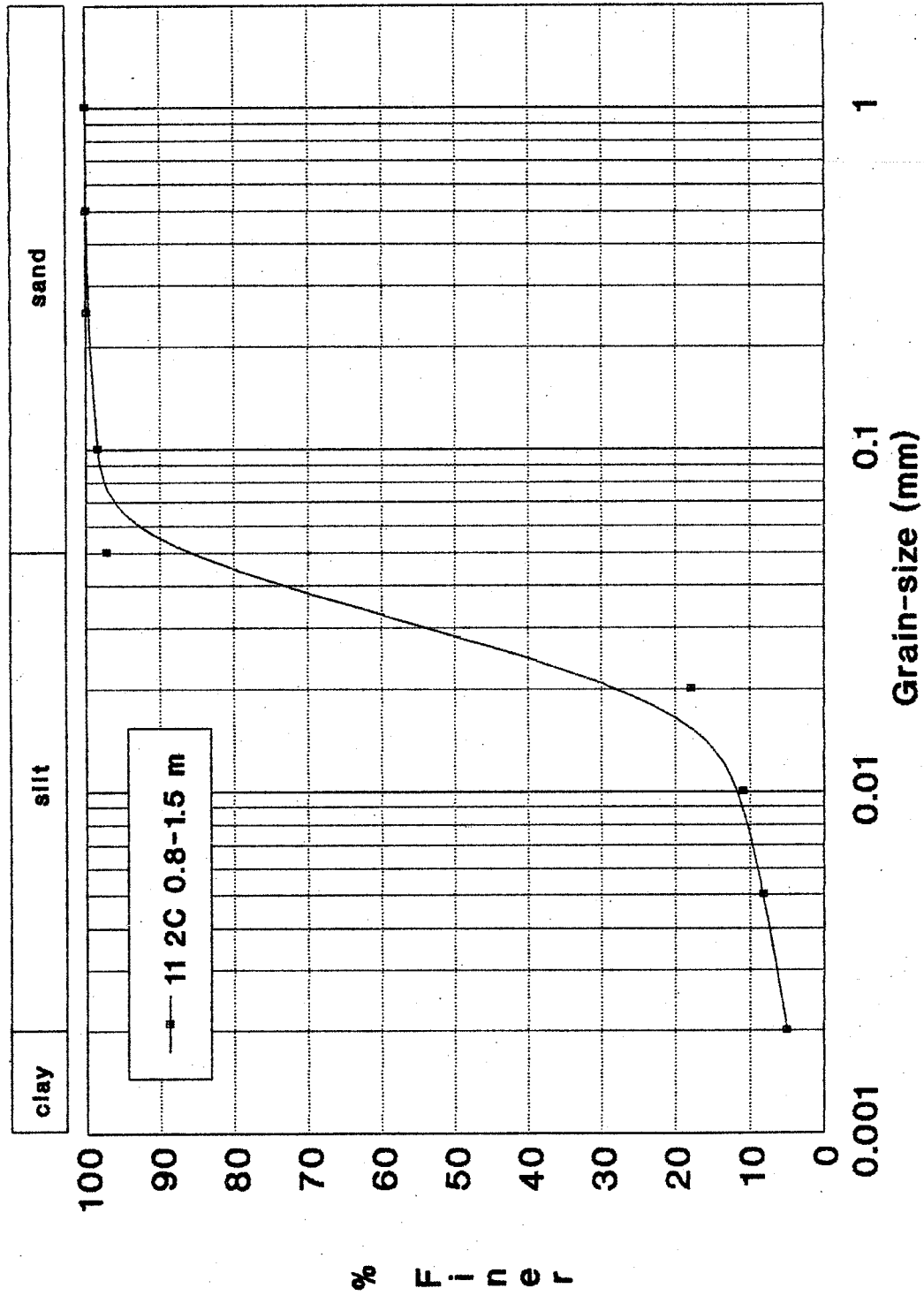
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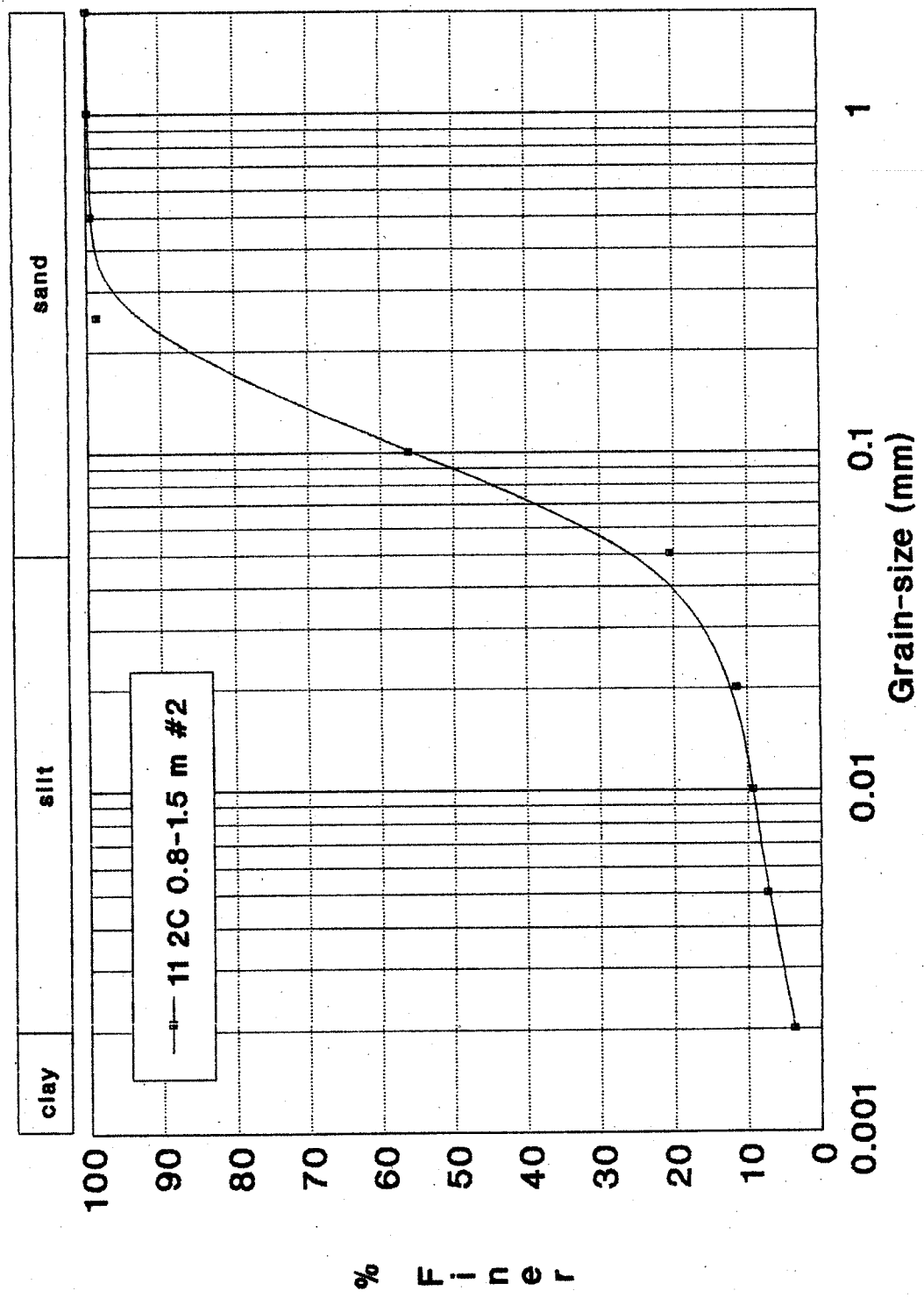
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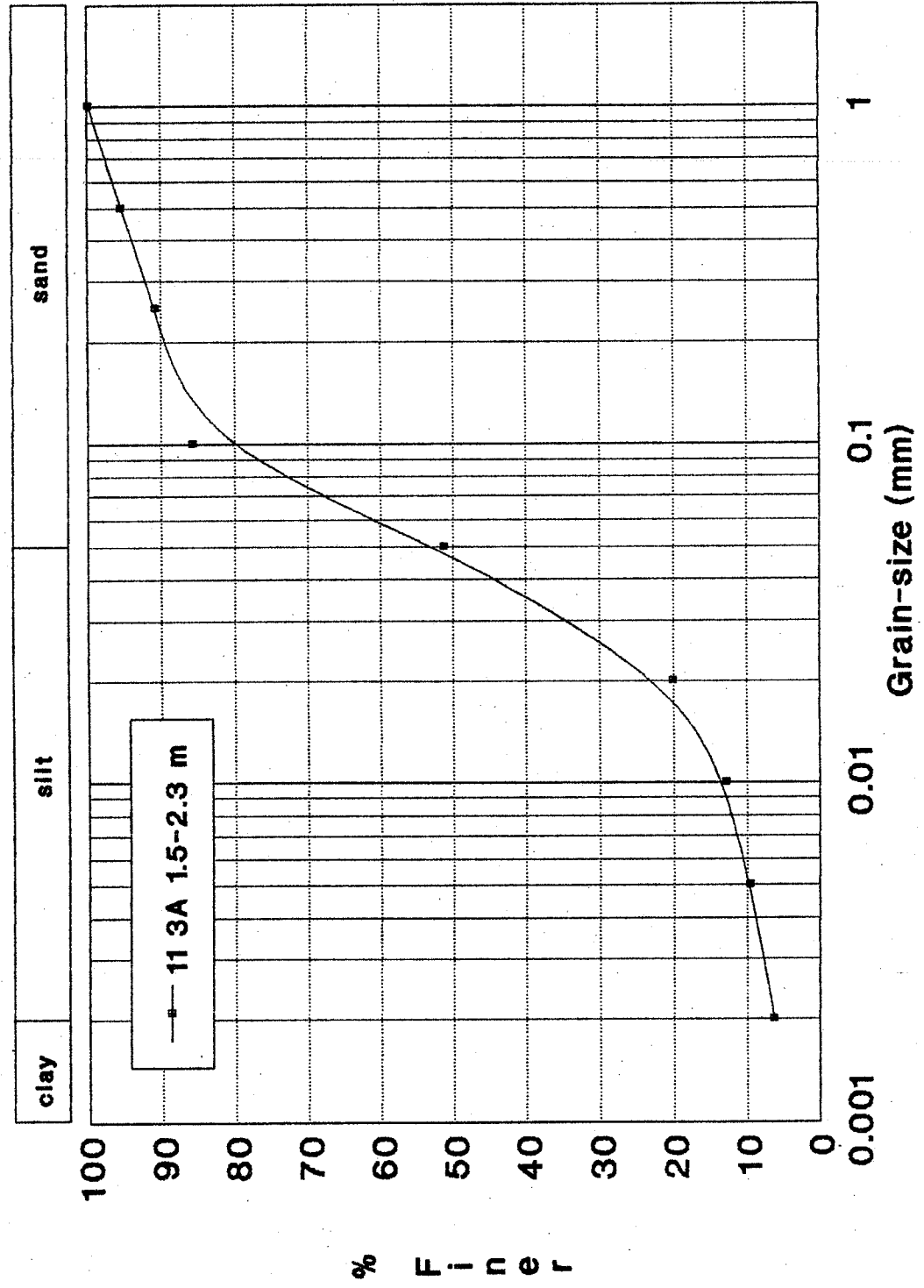
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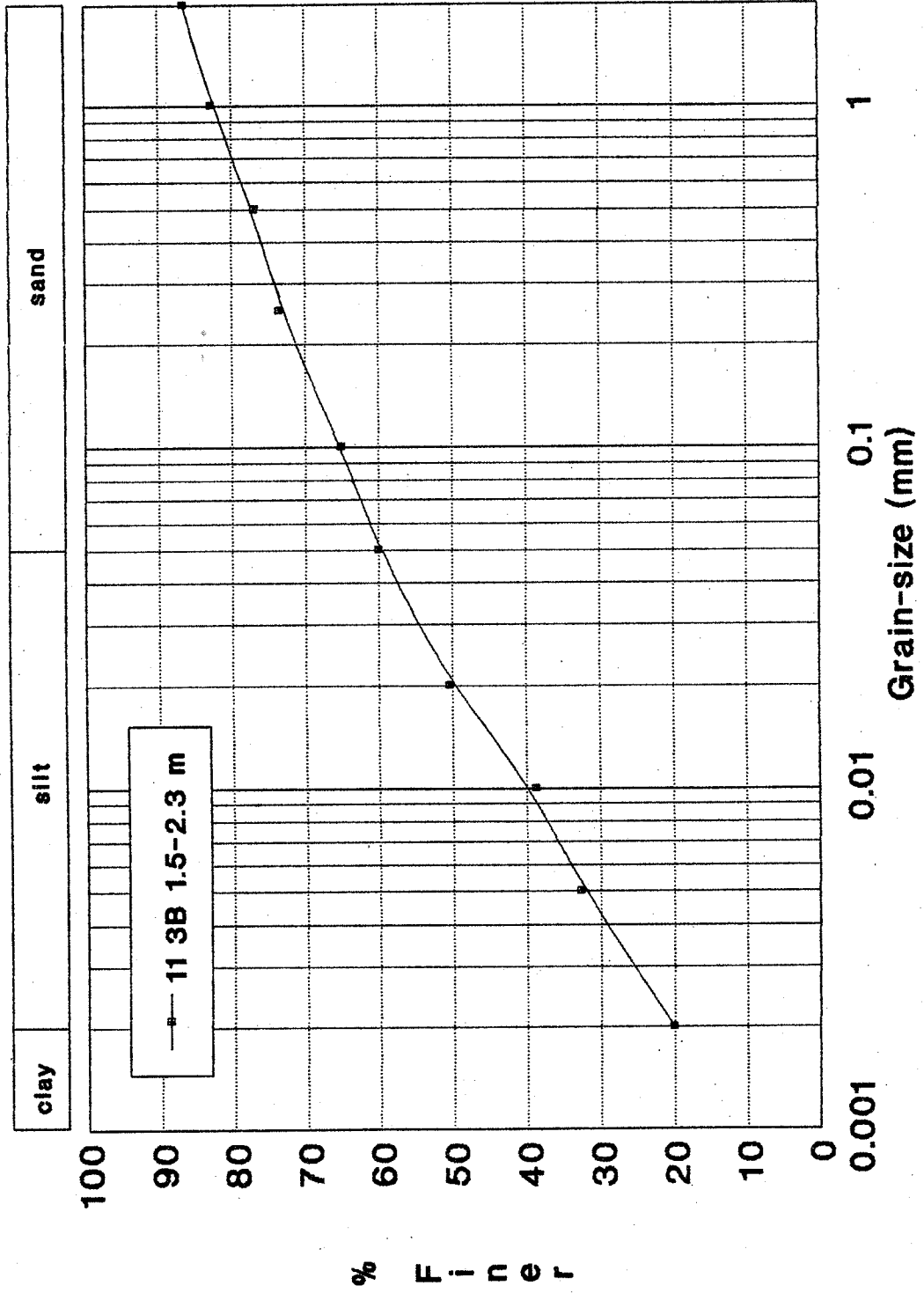
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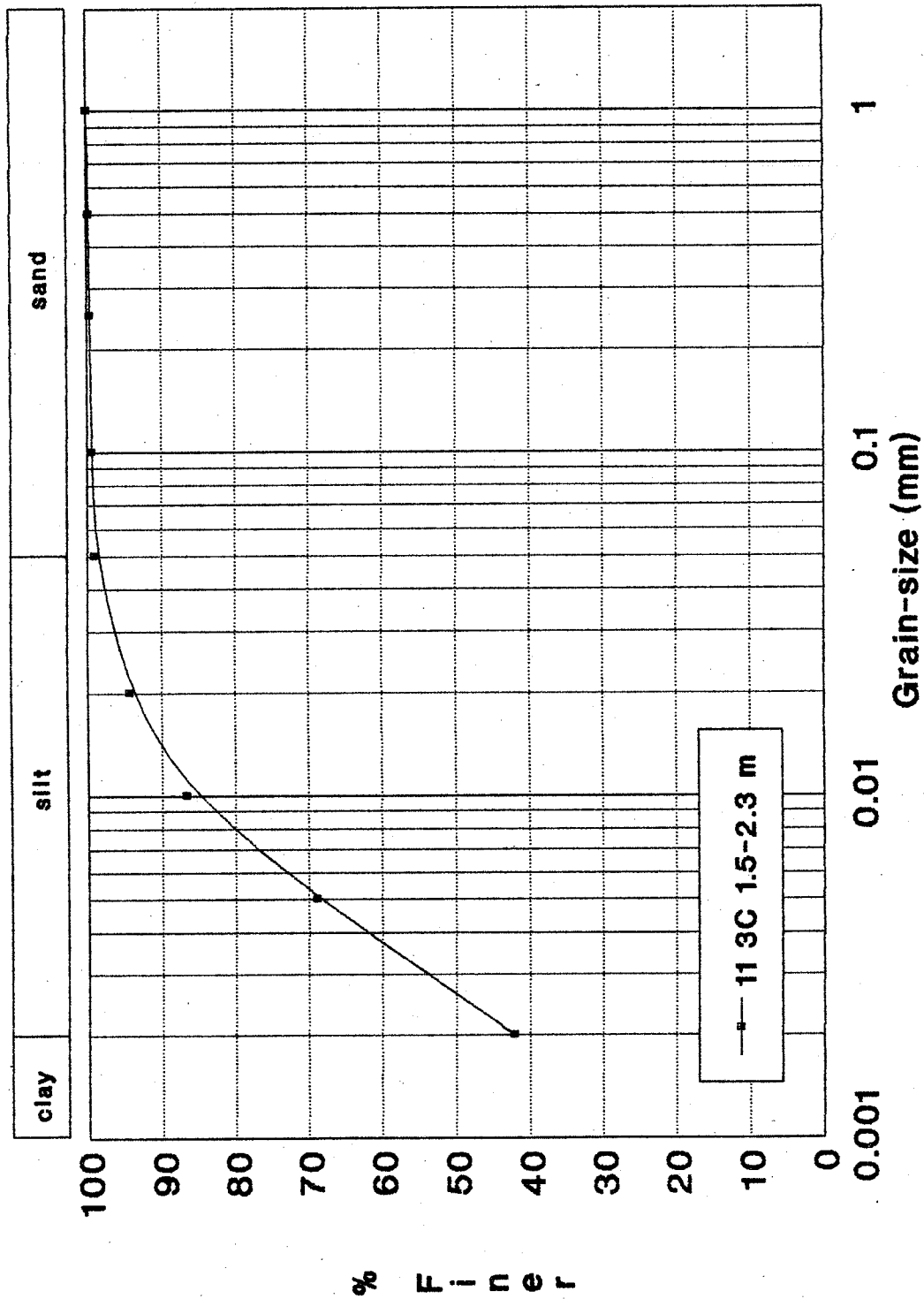
# Norman Wells Pipeline Route Grain-size Analysis



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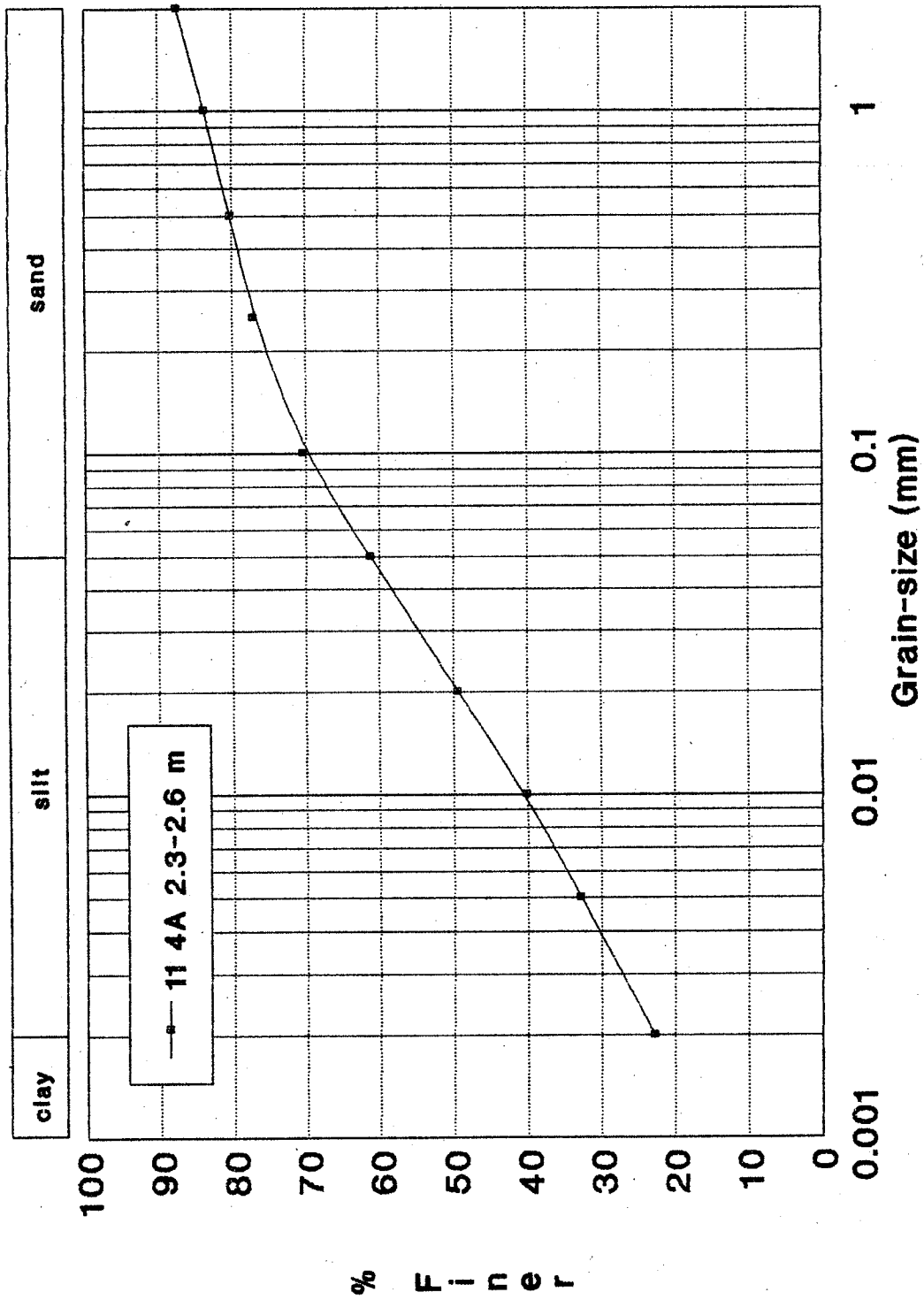


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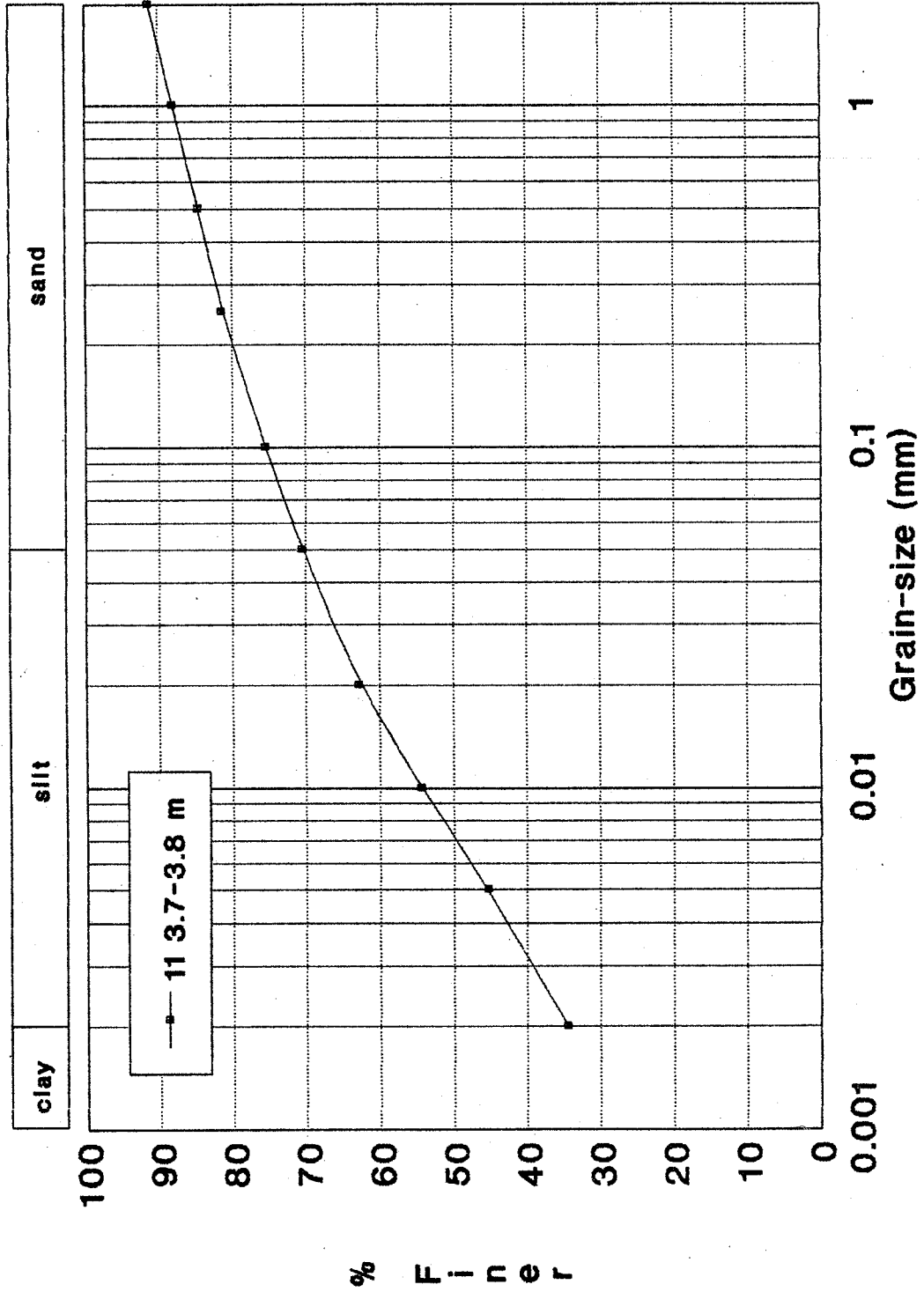




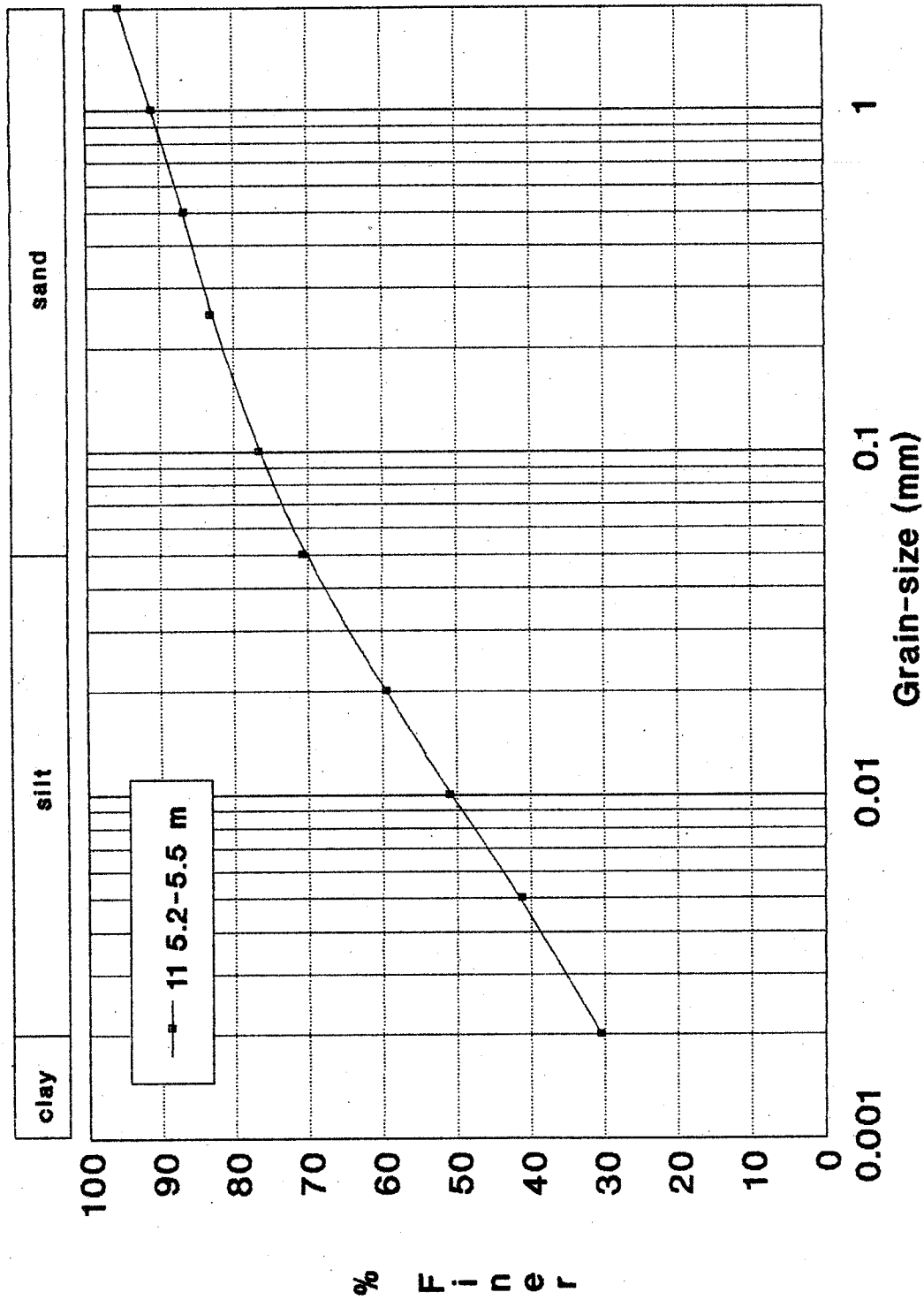
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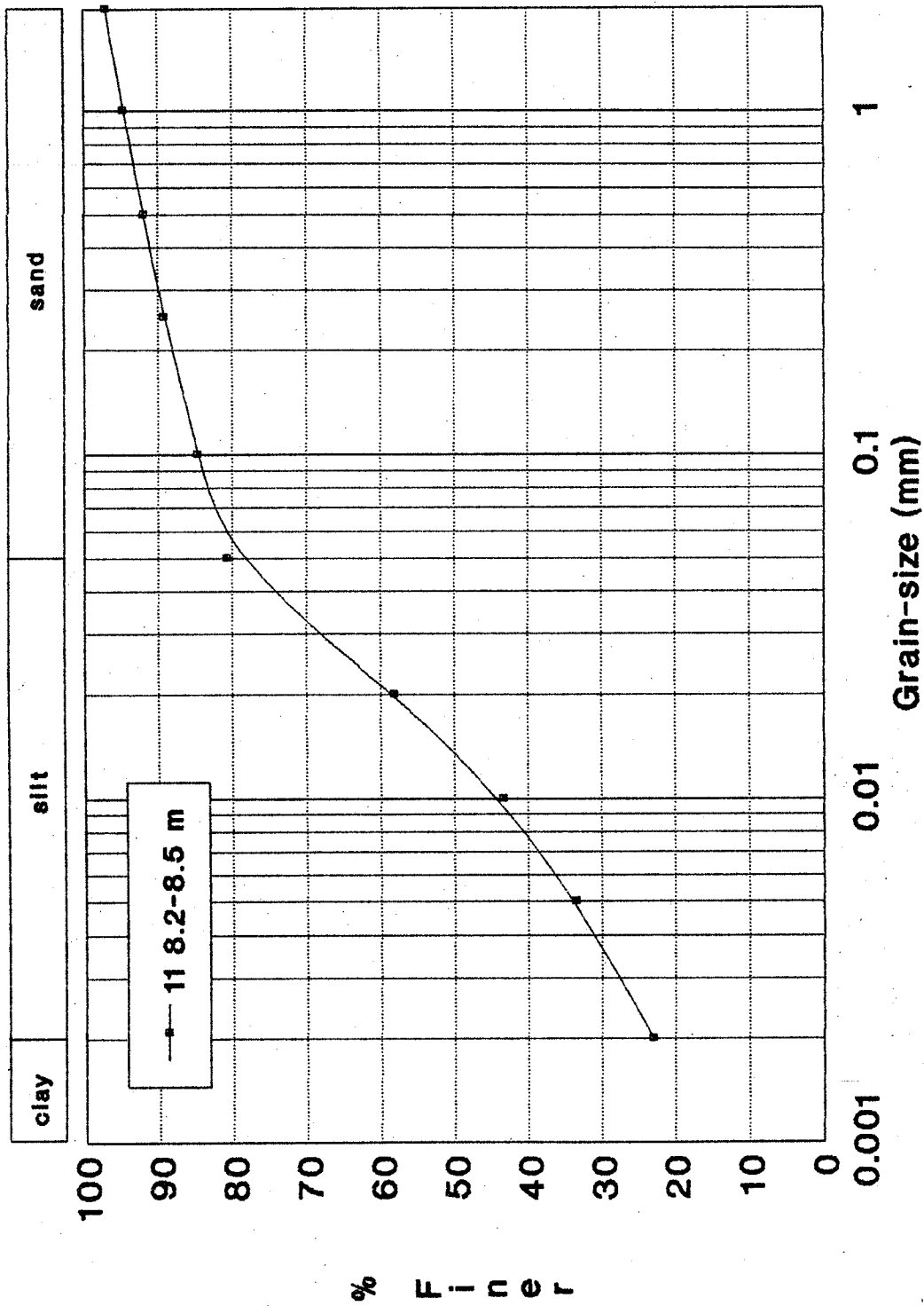
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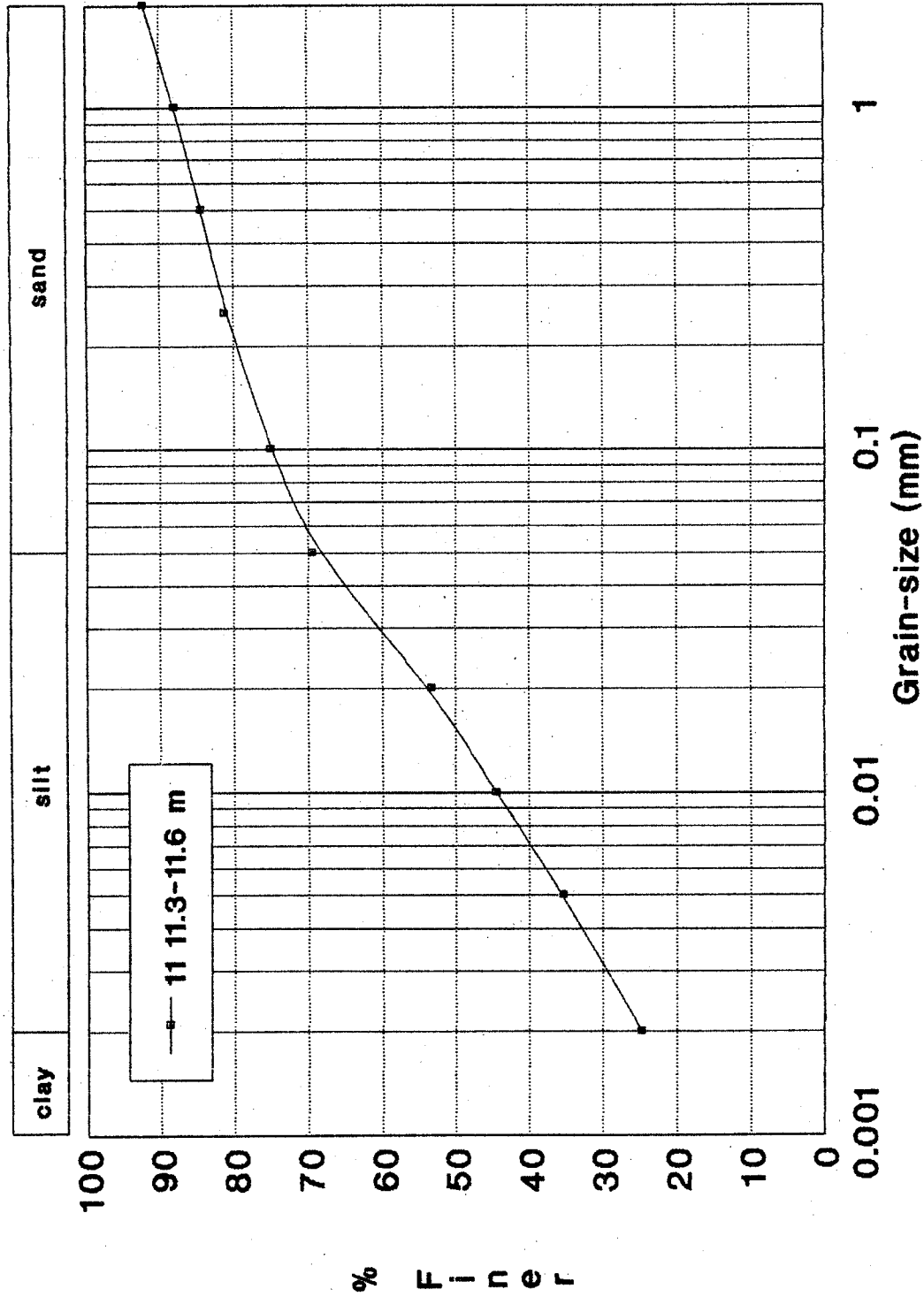
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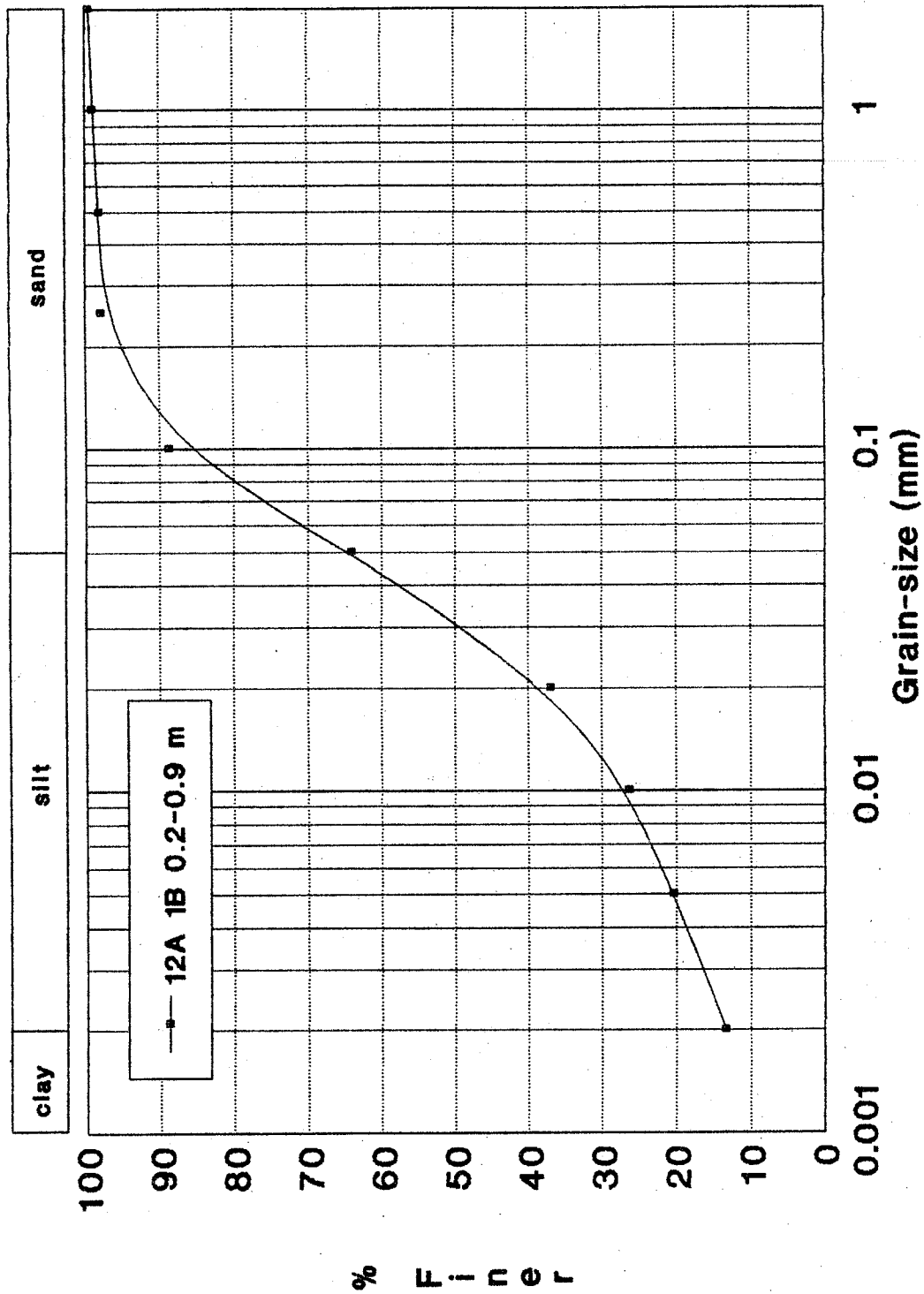
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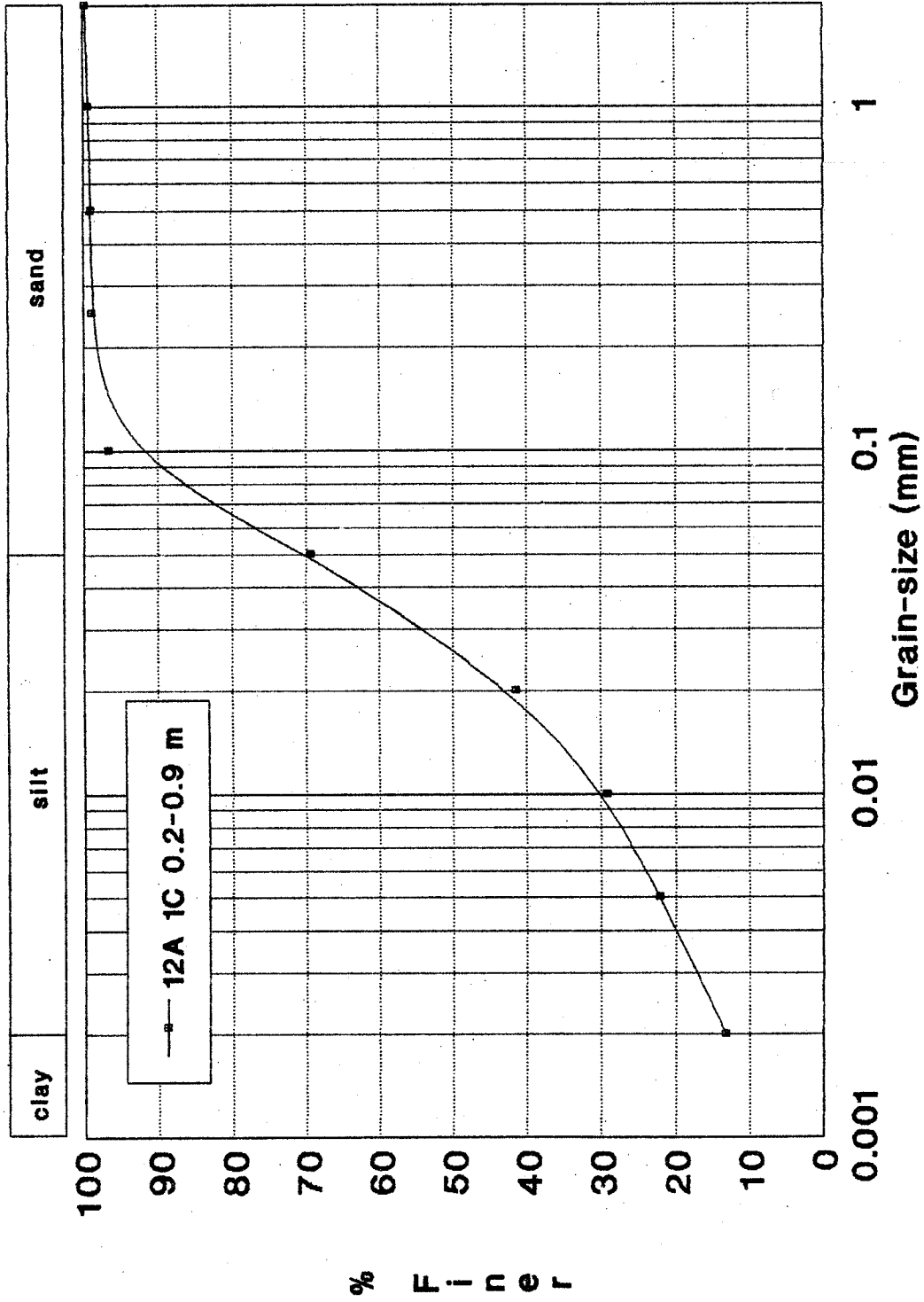
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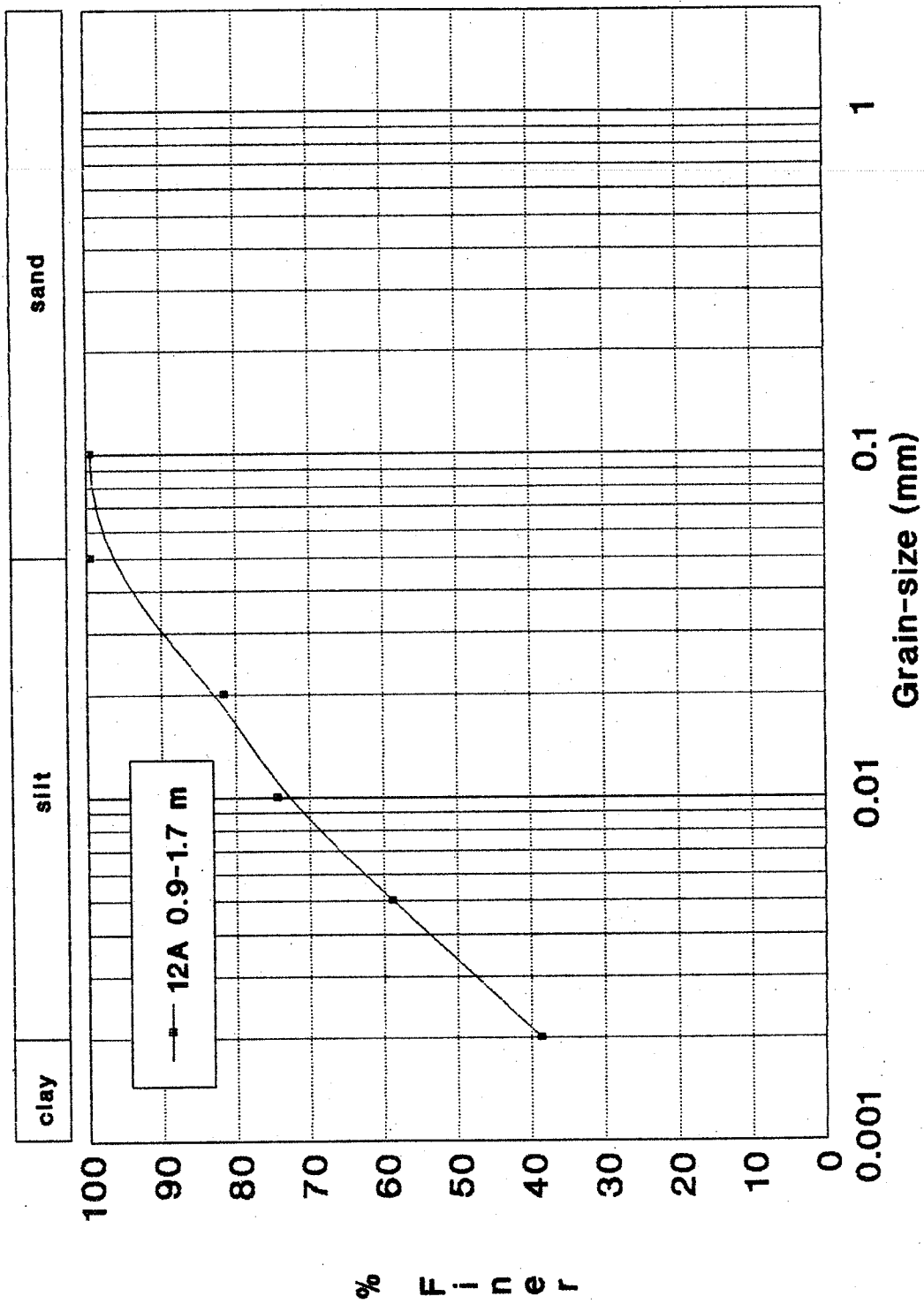
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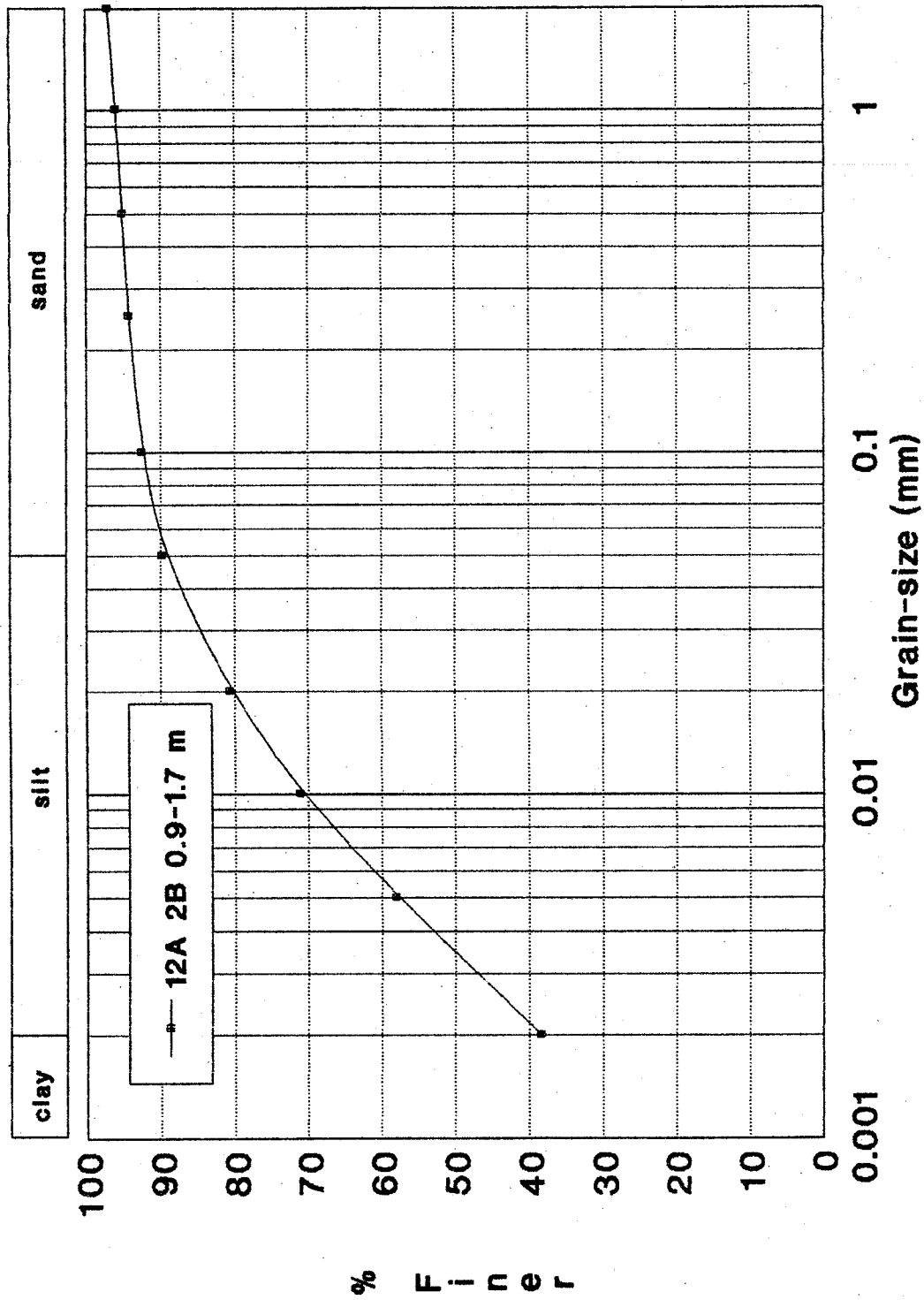


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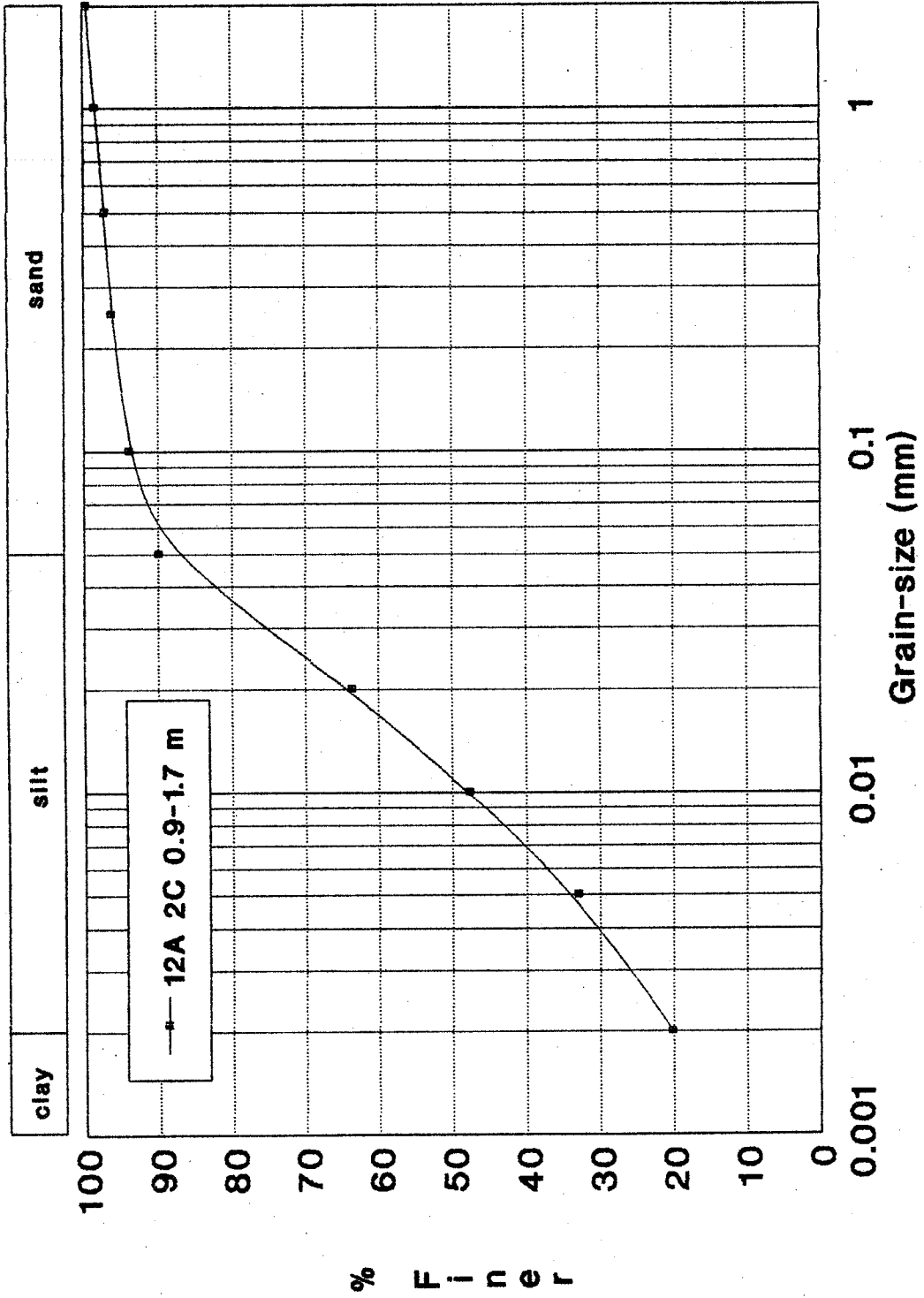




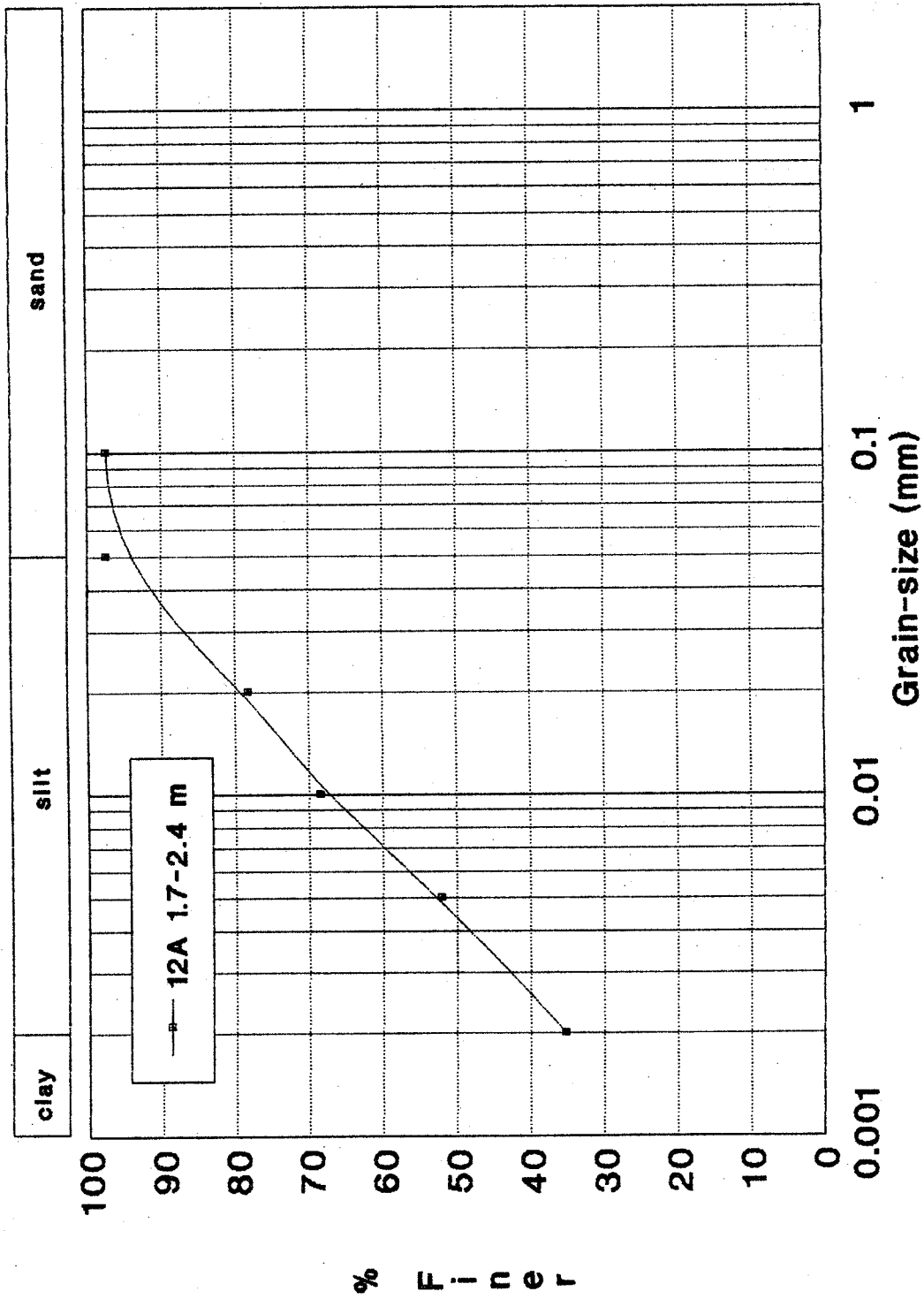
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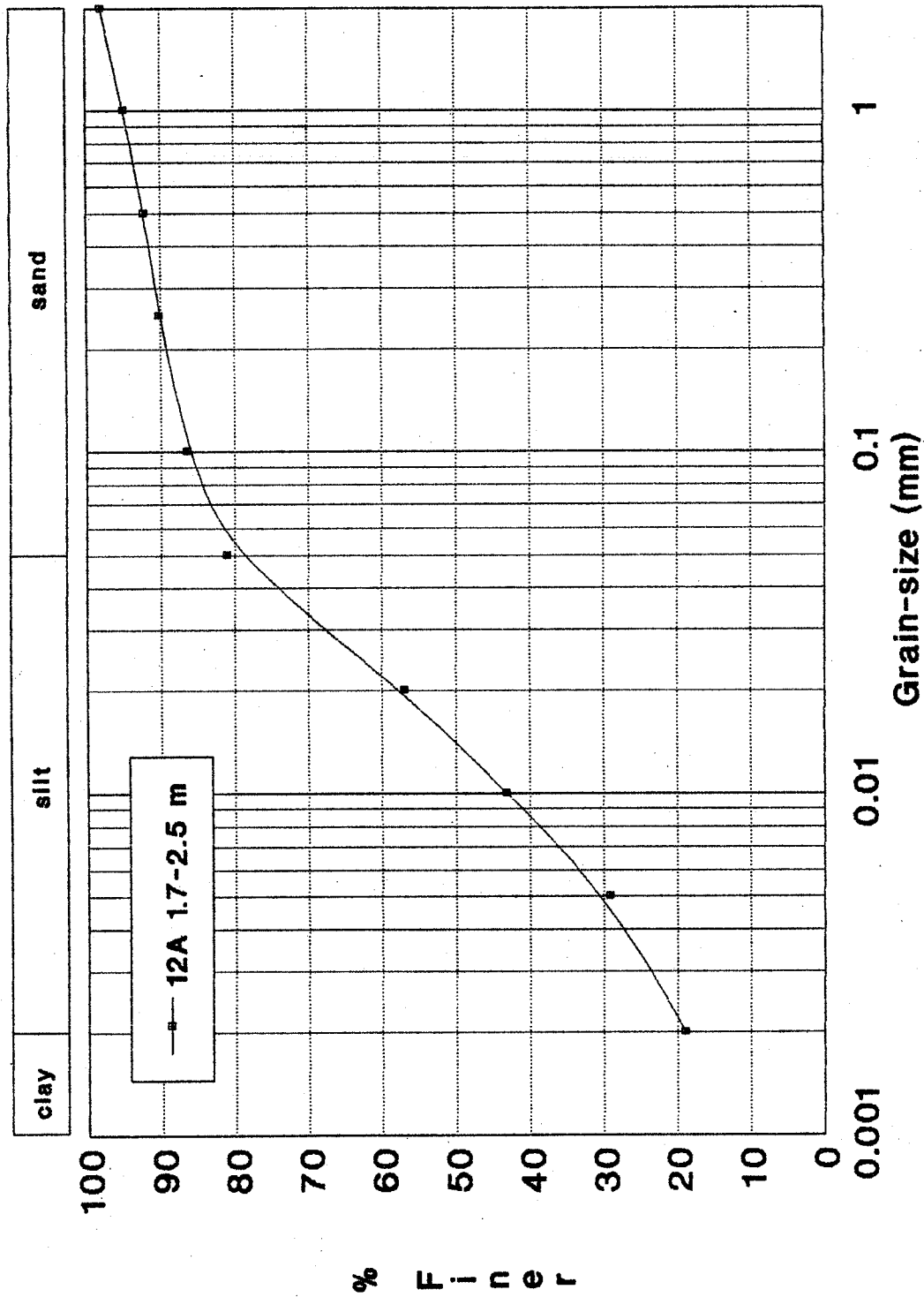
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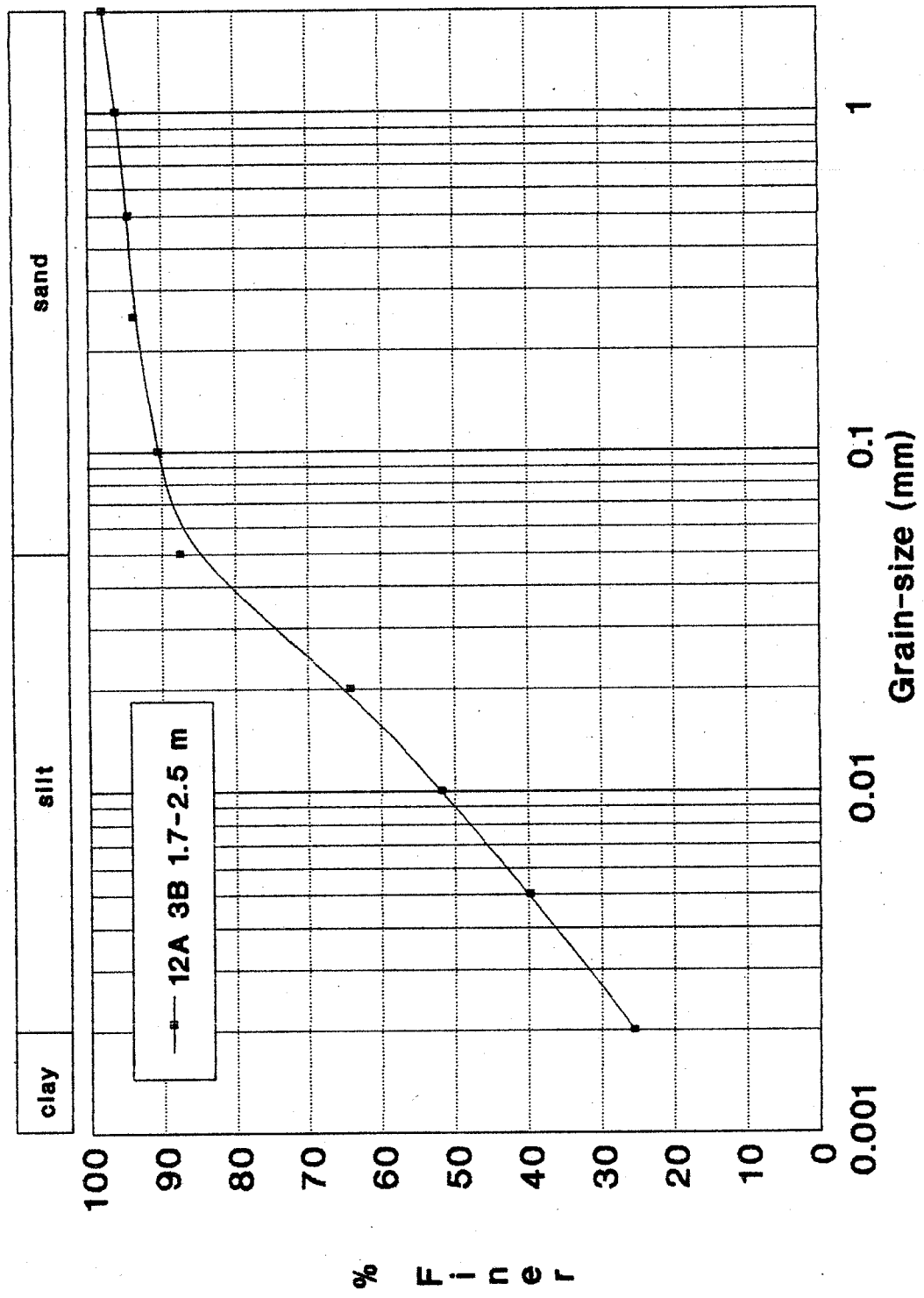
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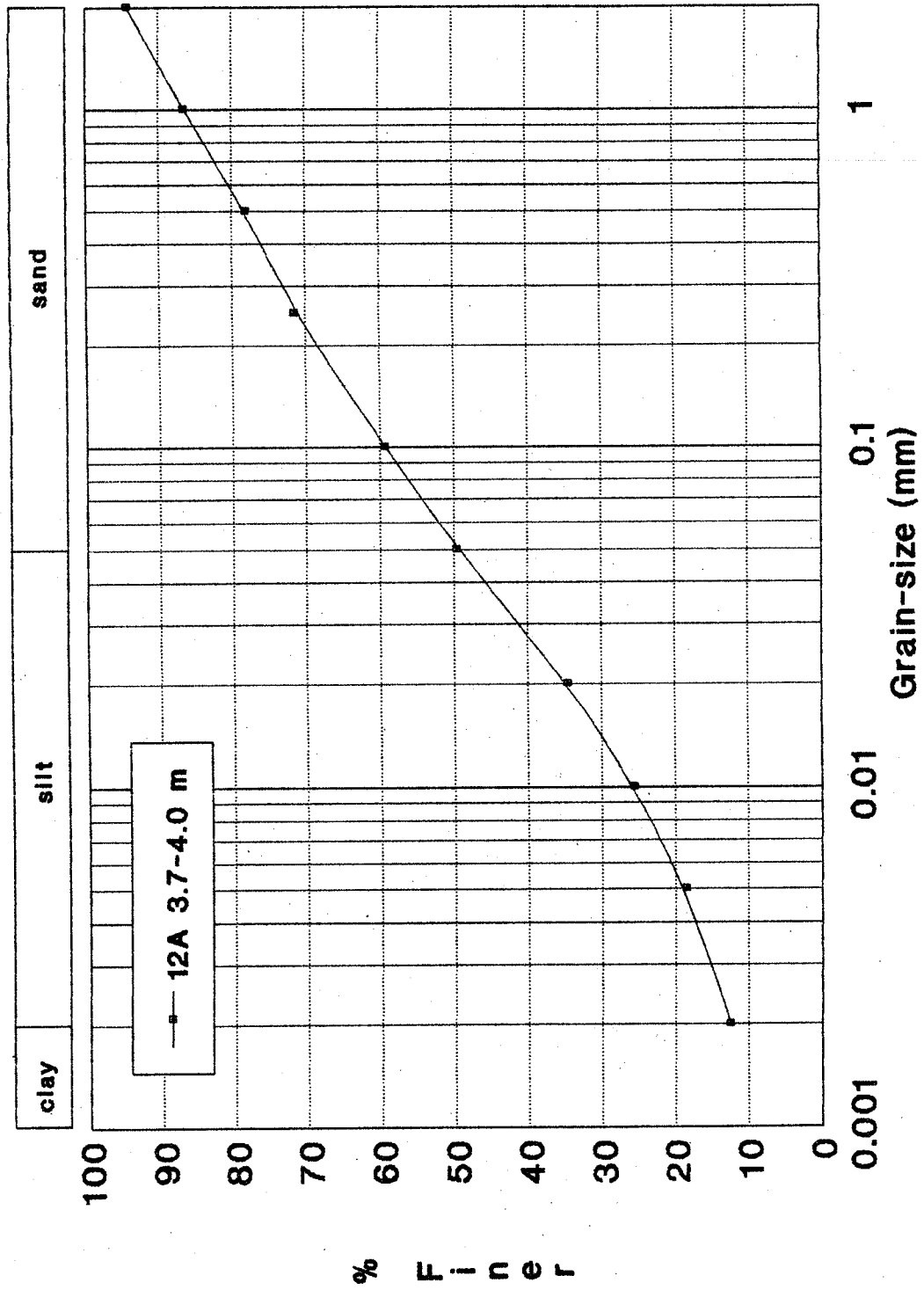
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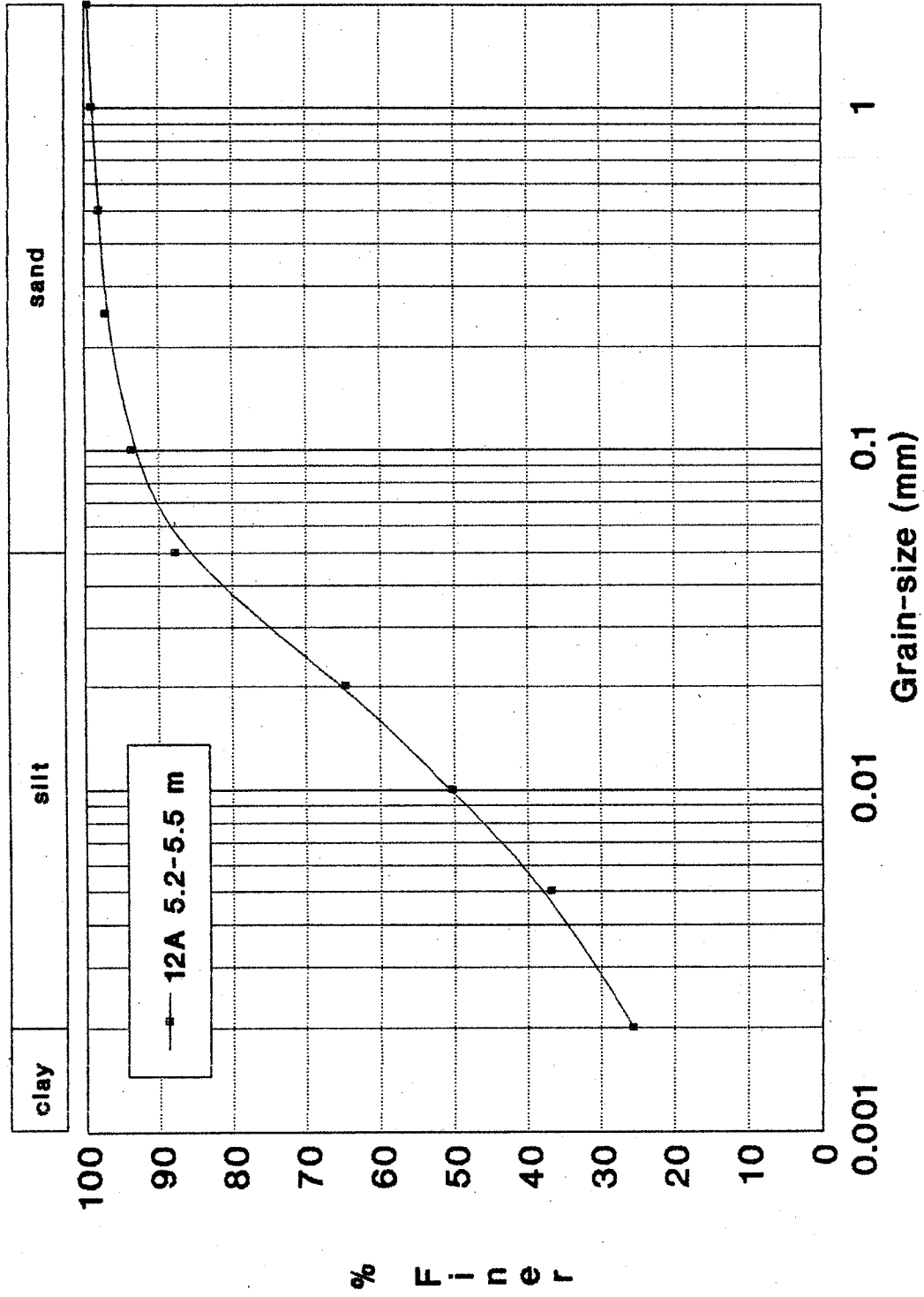
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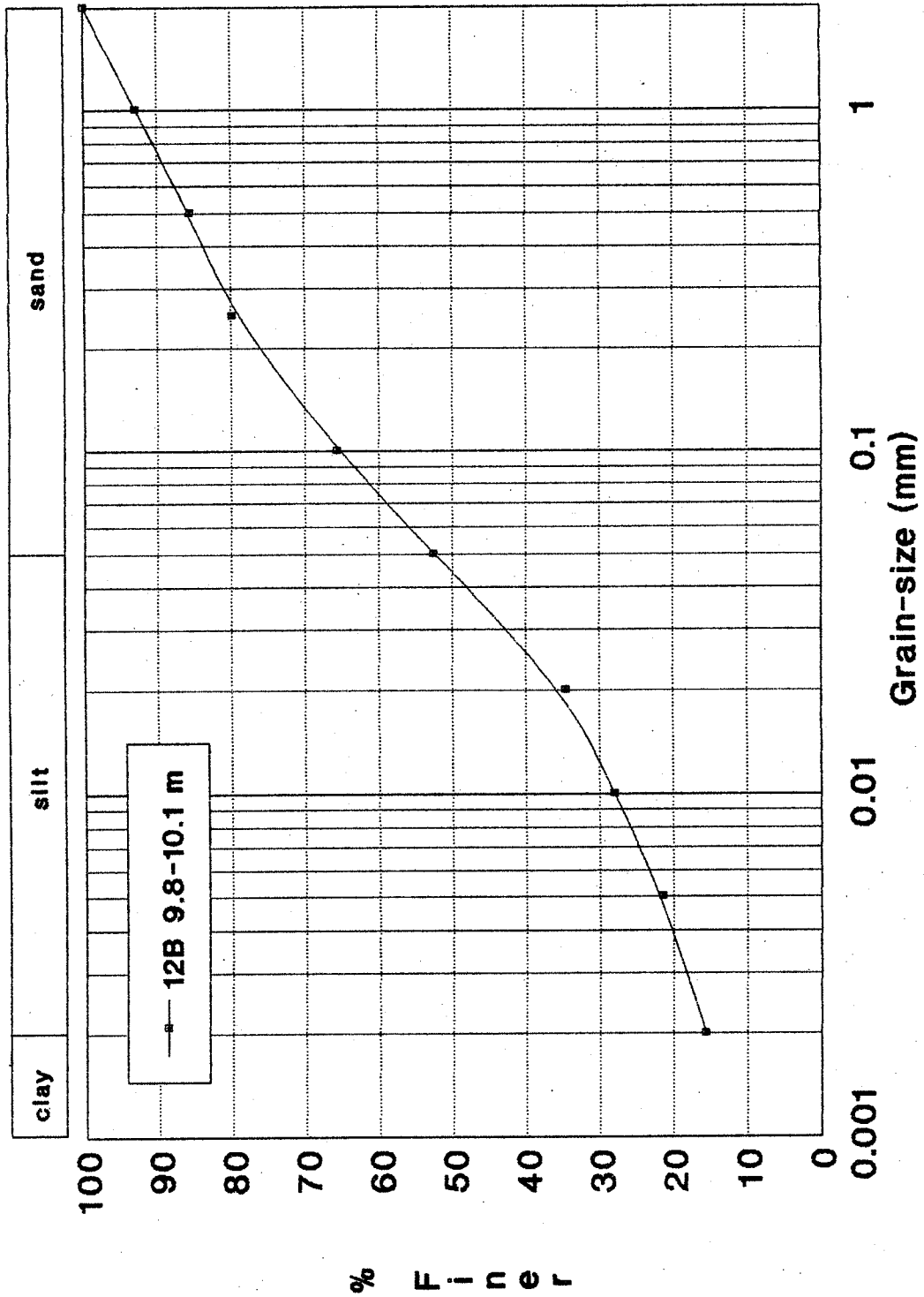
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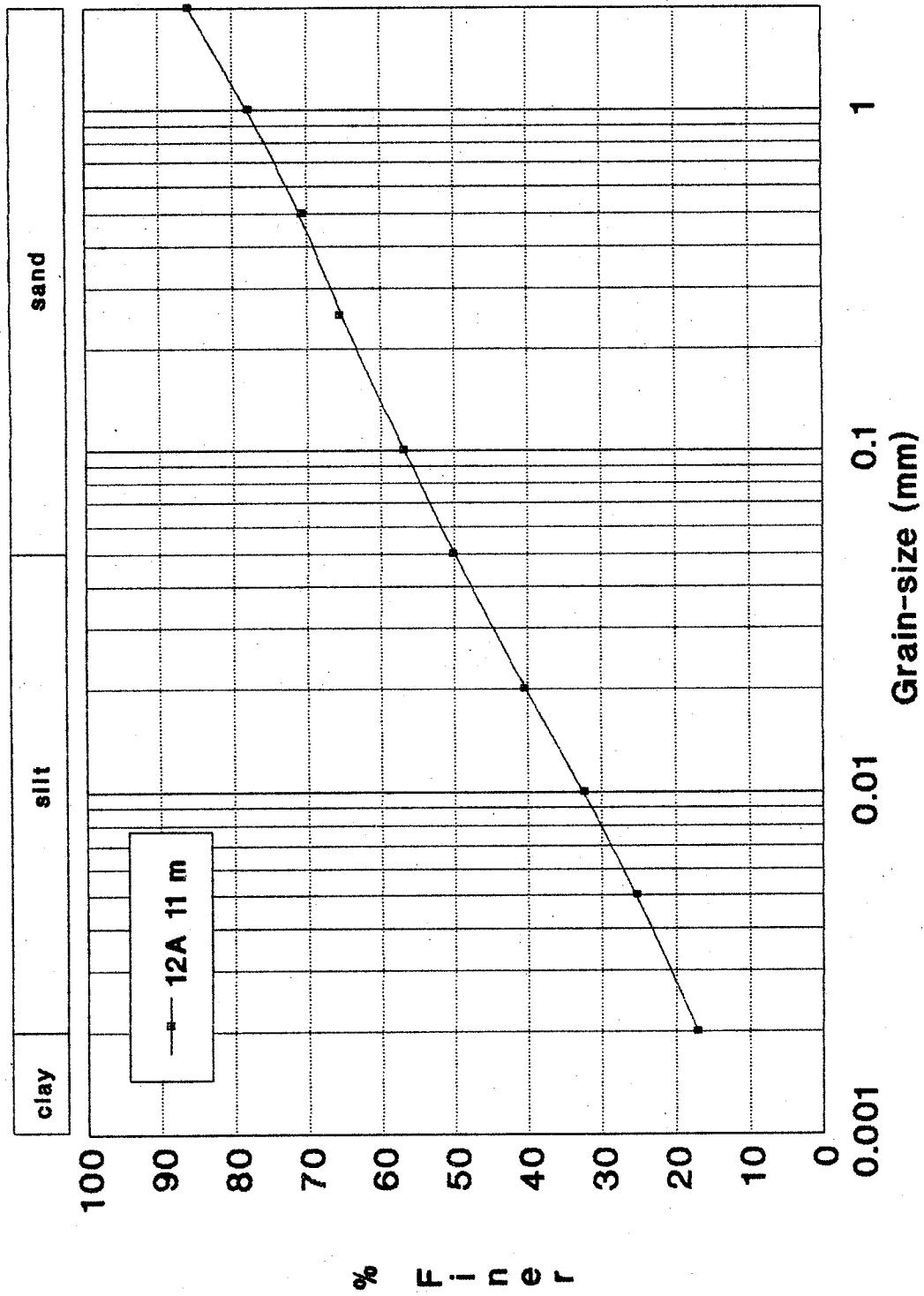


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