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Sand, Gravel and Heavy-Mineral Resource Potential of Holocene Sediments Offshore of Florida, Cape Canaveral to the Georgia Border: Phase I

By

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ABSTRACT

Sand, gravel, and heavy-mineral types and abundances in sediments of the Atlantic inner continental shelf offshore of Florida were determined to assess their resource potential. A total of 70 sediment samples, averaging about 7 kg each, derived from 49 vibracores collected from the region between Cape Canaveral and the Florida-Georgia state line were analyzed. The data show high variability both laterally and vertically (as probable functions of sample density and large-scale sediment facies changes) and preclude definitive statements about resources.

Deposits of sand and gravel with mud content under 2 weight percent are located offshore of St. Augustine and Fernandina Beach and, if laterally and vertically persistent, they may be locally suitable for beach replenishment projects. Other areas within the region of study have higher mud percentages.

The heavy-mineral assemblage (Specific gravity >2.96) in the study region is comprised (in decreasing order of abundance) of epidote, ilmenite (including altered ilmenite), aluminosilicates (sillimanite, kyanite, and andalusite), zircon, staurolite, rutile, garnet, pyroboles (undifferentiated pyroxenes and amphiboles), tourmaline, and monazite, and others (phosphorite, sulfides, unidentified opaques/nonopaques, quartz, spinel, etc). The average total heavy mineral value is .49 weight %. The economic heavy mineral suite consisting of ilmenite, rutile, zircon, monazite, and aluminosilicates comprises about 50 percent of the heavy-mineral assemblage; on a bulk sample basis the average is about 0.2 percent by weight. Although there is a general regional trend of

increasing heavy-mineral content to the north, high variability is characteristic of the study area. The concentrations of economic heavy minerals are, on the average, an order of magnitude lower than those found in commercial deposits onshore in Florida, and thus the potential for offshore placer resources appears to be limited.

INTRODUCTION

Beach erosion is a chronic problem in Florida and ongoing programs of beach replenishment require abundant sources of suitable sediment. Offshore sediment bodies are becoming increasingly common sources of sediment for such programs (Clark, 1989; Tait, 1990). With continued coastal development in Florida there will be an increasing demand for beach replenishment sand. Onshore heavy-mineral deposits are commercially mined in Florida, there is a likelihood that commercially significant concentrations of heavy minerals may occur in the offshore area as well. The objectives of this study are to provide information that will enable an assessment of potential offshore sediment borrow sites and to provide reconnaissance information on heavy mineral types and abundances. This study area is an extention of the geographic coverage of mineral resource assessments conducted in the vicinity of Cape Canaveral (Grosz et al., 1989; Nocita et al., 1989, 1990), thus providing baseline information on the hard mineral resource potential of Atlantic shelf sediments offshore of Florida.

STUDY AREA

The area covered in this investigation is the Atlantic inner continental shelf offshore of northeastern Florida extending from the vicinity of Cape Canaveral to the Florida-Georgia state line and east to a maximum of about 22 kilometers (km) offshore (Figure 1). Water depths of the core locations range from 4.5 to 22 meters (m); the sea floor in the study area is generally smooth with a gentle seaward gradient. Well-developed linear shoals such as those near Cape Canaveral and Ft. Pierce are not present in this study area. The northern portion of the study area has poorly developed shoals which have subtle bathymetric expression.

For ease of presentation and discussion the study area is divided into three smaller regions (Map Areas 1, 2 and 3, Figure 1) whose boundaries are approximately coincident with those of NOAA navigation charts. Figures 2, 3 and 4 represent the areas of NOAA charts 11488, 11486 and 11484 respectively, although Figure 2 also contains the southernmost portion of chart 11502.

PREVIOUS WORK

Studies of the inner continental shelf region offshore of Florida's east coast have been based primarily on data derived from surface samples collected on small-scale grids (on the order of 20 km between sample points). Milliman (1972), in a study of the Atlantic Continental Shelf (ACS) and slope from northern New Jersey to southern Florida, reported general sediment texture information for the entire Atlantic continental shelf of Florida; however, only about 20 of his samples fall into the area of this

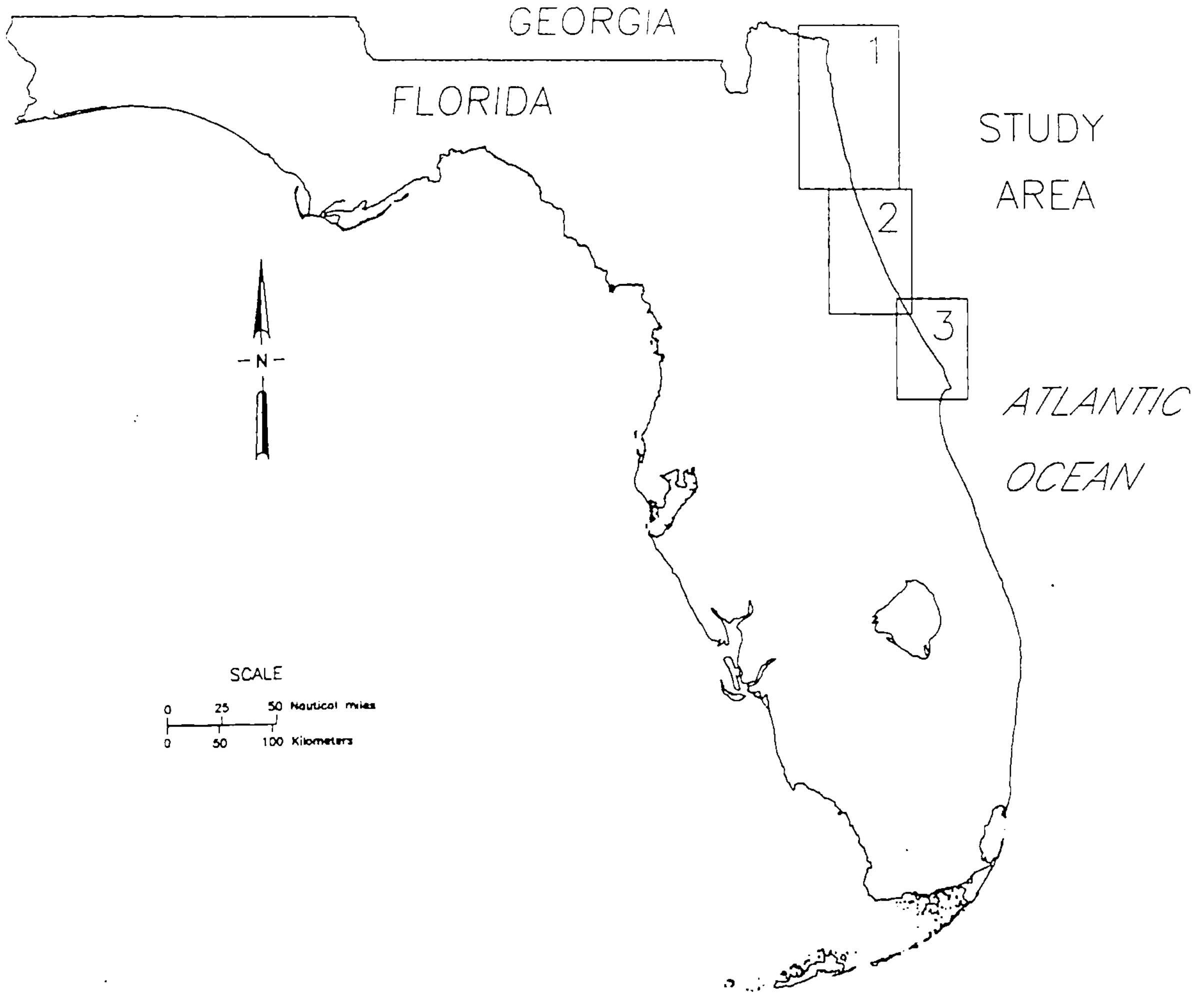

Fig. 1. Location map of study area. The entire study area has been subdivided into three map areas. These are labeled Map 1, 2 and 3 in text.

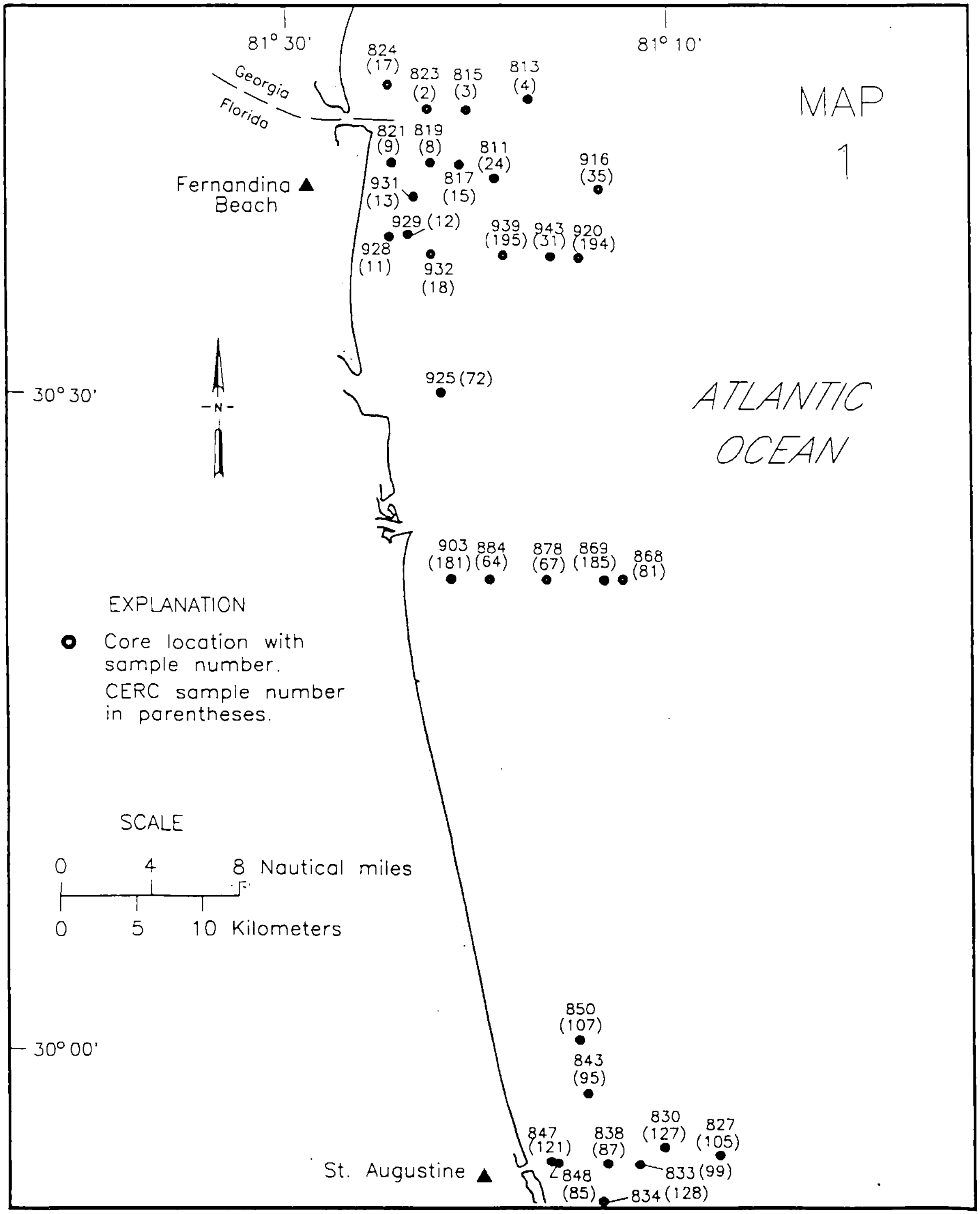

Fig. 2. Vibracore sample locations for Map 1. Top of map is just north of the Florida-Georgia border.

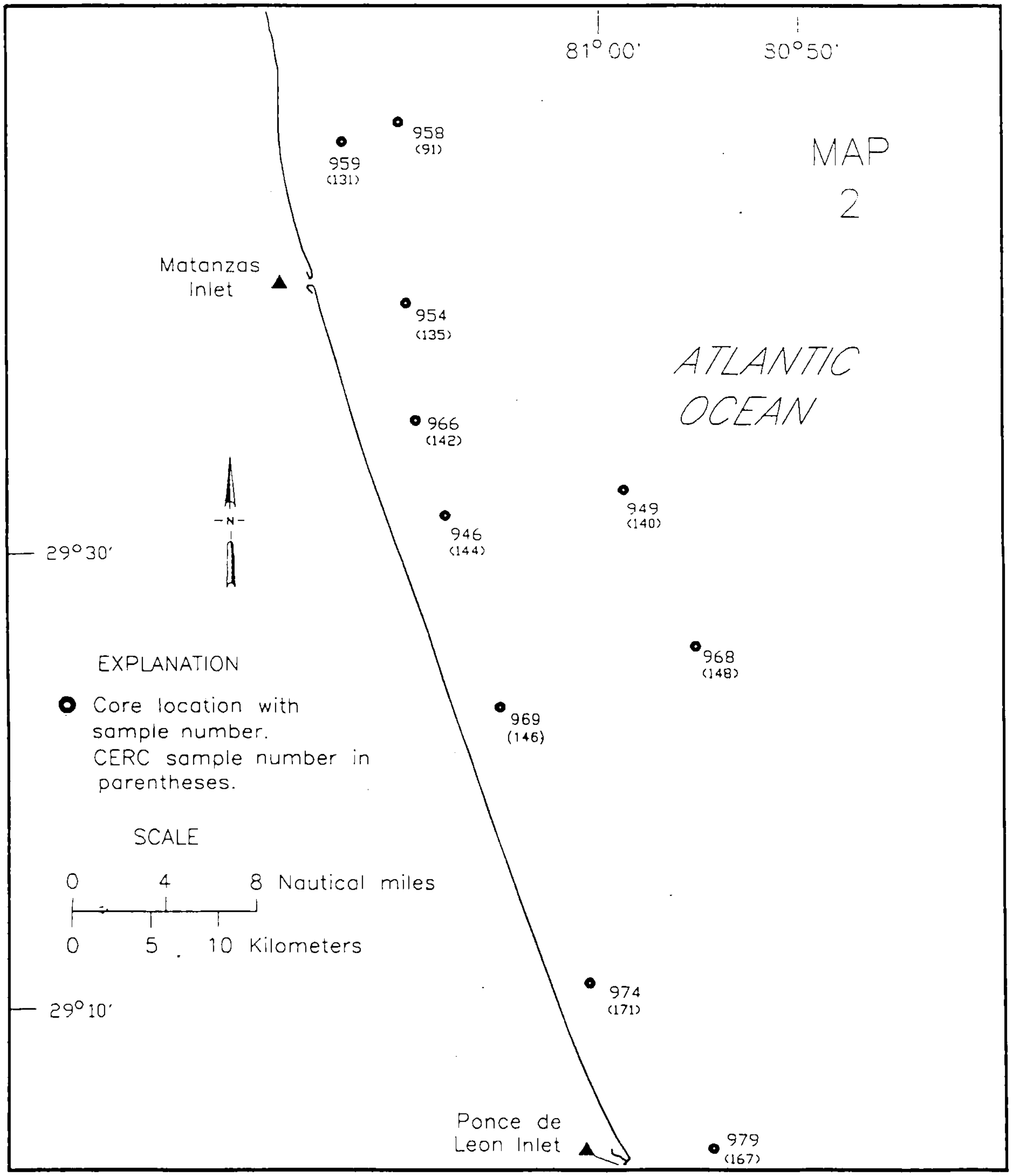

Fig. 3. Vibracore sample locations for Map 2.

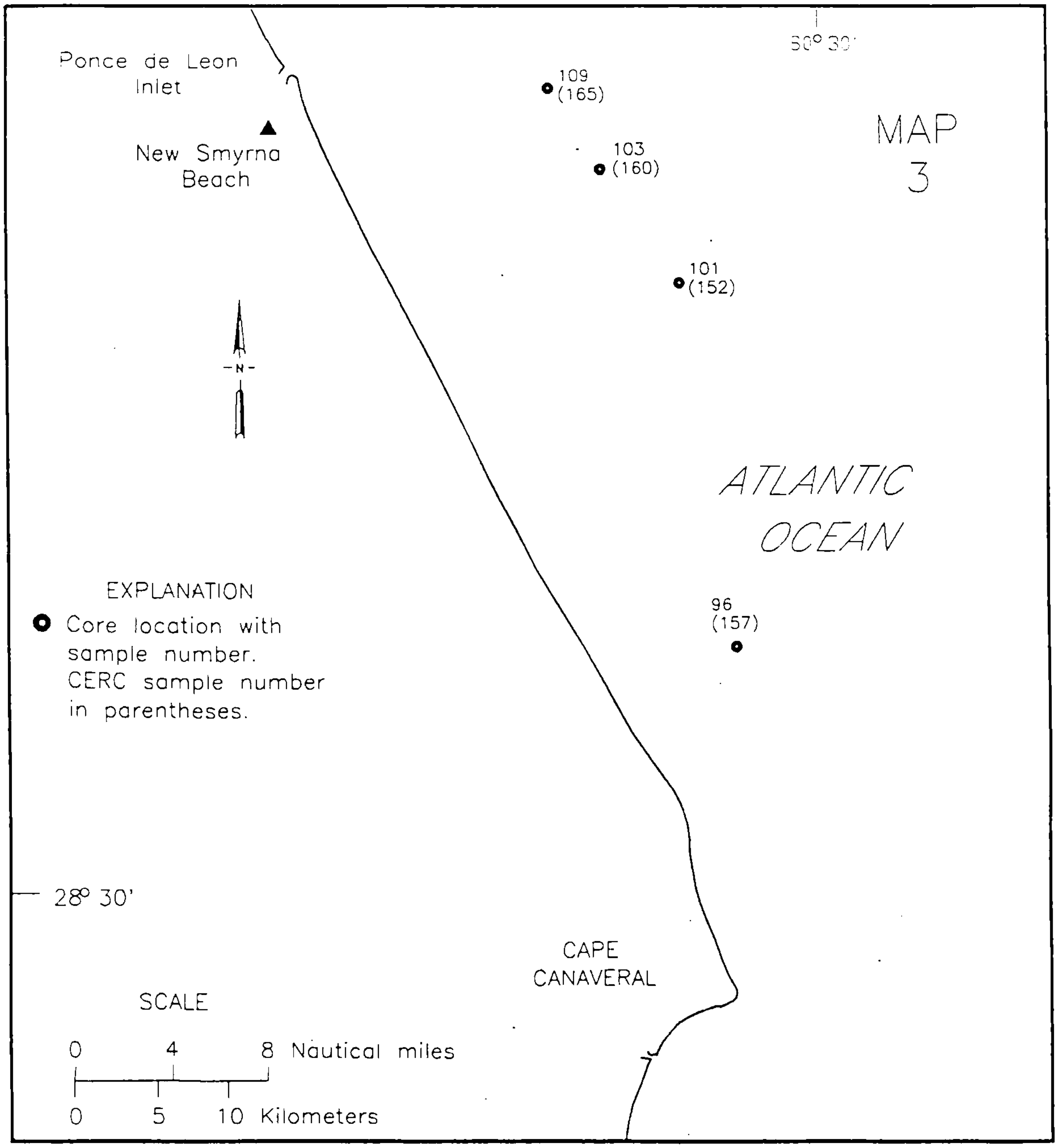

Fig. 4. Vibracore sample locations for Map 3.

study. Milliman's study shows small-scale generalized information for nearshore (within approximately 15 km of the shoreline) shelf sediments such as modal size classes (at 1.5 phi intervals for sand) and distribution of sand-sized calcium carbonate.

Duane and others (1972) discussed linear shoals on the Atlantic inner continental shelf, including those offshore of Florida, and hypothesized on the genesis of different types of shoals. They define three different shoal types: 1) linear, 2) inlet-associated, and 3) cape-associated. Extensive, but poorly developed shoals are found only in the area of Figure 2 and are of the linear type which they interpret as relict interfluves of a late Wisconsin sea-level lowstand. Geomorphology and sediment characteristics in the area were examined by Meisburger and Field (1975). Their study was part of the Inner Continental shelf Sediment and Structure Program (ICONS) of the U.S. Army Corps of Engineers Coastal Engineering Research Center (CERC), which was a reconnaissance program to find sand deposits suitable for beach restoration. The ICONS project collected vibracore samples after high resolution seismic profiling suggested potential sediment bodies. Such an approach provides better information for sediment resource assessments than studies using surface grab samples. Because of the reconnaissance nature of the ICONS studies, vibracores were only cursorily sampled and examined: textural analyses, were performed on small plug samples taken at approximately 1 foot intervals through the core tube. Heavy-minerals were not examined. The sample numbering scheme used in the present report is keyed in to their numbering scheme in Figures 2-4 and the analytical tables given later to provide the reader with an opportunity to cross-reference the two studies.

METHODS

The samples utilized for this project consist of vibracores collected by CERC and reported on by Meisburger and Field (1975), and now archived at the Florida Institute of Technology in Melbourne, Florida. Seventy samples derived from 49 vibracores were used for this study (Figures 2, 3 & 4).

The methods and rationale used for sample preparation and analysis are the same as those used in studies of the Cape Canaveral region and elsewhere on the ACS (Grosz and others, 1990). Data were generated for grain-size, composition, heavy-mineral abundance, and mineralogy of the heavy-mineral assemblage. A brief description of methods is given here for completeness. Cores were split lengthwise, described, photographed, and divided into approximately 1.5 m sections on the basis of lithology and/or section length if the lithology was consistent throughout. This division produced "upper" and "lower" core sections, each being approximately 1.5 m in length. Repository samples of approximately 300-500 grams were also collected from each section. Samples were weighed on a dry-weight basis and ranged from about 2 to 15 kilograms (kg), averaging approximately 7 kg.

Textural Analyses

The gravel-sized fraction was removed from each of the 70 bulk samples by wet sieving thru a 10 mesh (2.00mm) U.S. Standard stainless steel sieve. Gravel portions were dried, weighed and described. Textural analysis of the sand fraction (with carbonate) was done by use of a Rapid Sediment Analyzer (RSA or settling tube) at the University of South Florida. A computer program interfaced with the settling tube computed the first four moment measures (mean, standard deviation, skewness and kurtosis) for each sample. Raw data were processed by another program which produced cumulative grain-size curves (Appendix I). Mud percentages were derived by wet-sieving from a split of the repository samples.

Heavy Minerals

Two different processes were used to produce heavy-mineral concentrates for mineralogic analyses. Initially, the bulk sand samples were processed through a Humphrey's three-turn spiral to produce a 500 to 1,000 g heavy-mineral concentrate. The second step utilized high-density liquids to remove any remaining light minerals from the heavy-mineral concentrate. Because spiral concentration does not completely recover heavy minerals from bulk samples an aliquot of the material rejected by the spiral was collected and also processed in heavy liquid in order to estimate the total heavy-mineral (THM) content of the sediments. The recovered heavy-mineral (RHM) content of the sediments is based upon the heavy-minerals recovered by the spiral. Subsequent magnetic fractionation by use of a Frantz Magnetic Barrier Mineral Separator produced subsamples that were examined with binocular and petrographic microscopes to estimate mineral abundances. Comparison charts for visual estimation of percentage composition (Terry and Chillingar, 1955) were used for this purpose along with point-counting. The identification of zircon and monazite was aided by the use of long- and short-wave (respectively) ultraviolet illumination.

RESULTS

Sand, Gravel and Mud

Because of the relatively low density of samples (an average distance between samples of 9 to 15 km), it is not reasonable to produce contour maps of sediment distribution. Data are presented, therefore, as weight percent values next to the sample site. Weight percentages of shell-gravel, sand and mud are plotted in order to show the distribution of sediment (in both upper and lower sections) which might be useful for beach renourishment. Shell-gravel, sand & mud and grain size analysis data are presented in Tables 1 and 2.

Each map area will be discussed in terms of sediment distribution. It was found that, for the most part, there was little difference in sediment characteristics between the upper and lower 1.5 m core sections. It should also be noted that not all sample sites had both an upper and lower core section. There were 49 upper and 21 lower sections.

Map Area 1

The distribution of shell-gravel for both upper and lower core sections is shown in Figure 5. Most of the values are less than 5 weight percent, with only 3 samples having values greater than 15 percent. Overall, the shell content of samples in Map

Table 1. Sand, shell-gravel and mud weight percent for vibracore samples

Sample No.	CERC Sample No.	Shell-gravel	Sand	Mud
96-1	157	5.1	55.9	38.9
96-2	157	24.4	72.3	3.3
101	152	1.8	98.2	0.00
103	160	5.2	91.3	3.5
109	165	10.7	64.6	24.7
811-1	24	2.0	96.1	1.9
811-2	24	0.8	79.2	20.0
813	4	0.2	97.9	1.9
815	3	2.3	85.4	12.3
817-1	15	6.9	58.7	7.4
817-2	15	4.5	91.8	3.7
819	8	0.9	91.8	7.3
821-1	9	8.5	87.0	4.5
821-2	9	2.2	87.5	10.3
823	2	0.00	99.3	.7
824	17	14.2	79.4	6.4
827	105	5.5	92.3	2.2
830-1	127	1.6	96.8	1.6
830-2	127	0.6	99.3	.1
833	99A	4.9	92.2	2.9
834-1	128	15.4	67.4	17.2
834-2	128	2.8	77.6	19.6
835-1	98	9.0	61.4	29.6
838	88	35.4	54.8	9.8
838A	88A	20.9	65.2	13.9
843-1	95	8.7	81.1	10.2
843-2	95	27.0	58.8	14.2
847	121	0.8	97.0	2.2
847A-1	121A	0.2	98.1	1.7
847A-2	121A	0.4	97.3	2.3
848-1	85	1.0	92.2	6.8
848-2	85	0.8	98.6	0.6
850-1	107	1.2	98.0	0.8
850-2	107	4.7	91.6	3.7
868	81	0.00	99.4	0.6
869	185	1.6	97.7	0.7
878	67	1.9	97.3	0.8
884	64	0.4	92.7	6.9
903	181	2.9	75.2	21.9
916	35	1.2	91.9	6.9
920-1	194	6.5	93.2	0.3
920-2	194	1.7	95.5	2.8
925	72	5.1	40.3	54.6
928	10	8.5	56.2	35.2
929A-1	12A	2.3	62.3	35.4
929A-2	12A	8.3	39.7	52.0
929-1	12	0.2	63.4	36.4
931	13	3.6	26.5	69.9
932-1	18	3.1	93.5	3.4

Sample No.	CERC Sample No.	Shell-gravel	Sand	Mud
932-2	18	3.1	77.2	19.7
939	195	0.3	65.2	34.5
943	31	*13.7	85.7	0.6
946-1	144	1.9	88.1	10.0
946-2	144	23.7	67.9	8.4
946-3	144	5.5	91.3	3.2
949-1	140	2.0	97.5	0.5
949-2	140	3.9	95.7	0.4
954-1	135	7.9	54.0	38.1
954-2	135	10.1	63.7	26.2
958	91	26.6	53.9	19.5
959-1	131	6.9	85.7	7.4
959-2	131	30.4	46.4	23.2
966-1	142	17.5	63.3	19.2
966-2	142	9.1	74.8	16.1
968-1	148	24.8	73.0	2.2
968-2	148	12.3	77.8	9.9
969-1	146	19.0	70.9	10.1
969-2	146	14.9	72.9	13.2
974	171	5.0	53.1	41.9
979	151	27.7	65.2	7.1

* gravel portion of this sample is mostly quartz pebbles

Table 2. Granulometric data (RSA) for
Vibracore samples (carbonate included).

Sample No.	CERC Sample No.	Mean grain size (phi)	Standard deviation	Skewness	Kurtosis
96-1	157	2.48	1.21	0.44	1.81
96-2	157	2.36	0.84	-0.68	3.87
101	152	2.02	0.62	-0.14	2.83
103	160	2.05	0.78	0.10	4.62
109	165	2.56	1.07	0.12	2.36
811-1	24	2.73	0.44	-0.53	10.84
811-2	24	2.96	0.69	0.49	3.31
813	4	2.81	0.41	-0.31	12.11
815	3	2.51	0.98	-0.24	3.03
817-1	15	2.00	0.94	0.45	3.27
817-2	15	2.25	0.70	0.54	3.73
819	8	2.53	0.75	-0.05	4.70
821-1	9	2.47	0.81	-0.26	3.21
821-2	9	3.32	0.52	-1.59	11.33
823	2	2.46	0.43	-1.28	14.95
824	17	2.20	0.95	0.14	2.87
827	105	2.31	0.73	-0.64	4.69
830-1	127	2.60	0.66	-0.31	3.36
830-2	127	2.14	0.57	-0.38	3.94
833	99A	2.54	0.63	-0.87	7.52
834-1	128	2.55	0.89	0.53	2.88
834-2	128	2.47	1.05	0.29	2.46
835-1	98	2.73	1.10	-0.15	2.29
838	88	2.13	1.05	0.21	2.71
838A	88A	2.34	1.03	0.22	2.67
843-1	95	2.60	0.78	0.25	3.54
843-2	95	2.29	1.04	0.4	2.44
847	121	2.82	0.47	-1.26	12.33
847A-1	121A	2.86	0.63	-2.46	13.02
847A-2	121A	2.88	0.50	-2.09	16.47
848-1	85	2.92	0.55	-0.37	8.18
848-2	85	2.75	0.47	-2.61	16.71
850-1	107	2.21	0.48	-0.12	6.54
850-2	107	2.28	0.61	0.75	5.82
868	81	2.38	0.49	-0.21	4.75
869	185	1.98	0.69	-0.29	3.65
878	67	2.14	0.66	-0.17	3.32
884	64	2.75	0.82	-0.86	4.35
903	181	2.66	1.14	-0.15	1.91
916	35	2.60	0.70	-0.19	4.89
920-1	194	2.03	0.65	-1.33	5.78
920-2	194	2.43	0.71	-0.32	3.88
925	72	2.86	1.21	-0.28	2.22
928	10	2.73	1.18	-0.35	2.37
929A-1	12A	2.65	1.19	-0.20	2.42
929A-2	12A	3.29	0.87	-0.60	2.93
929-1	12	3.23	0.67	0.55	1.87
931	13	3.13	1.05	-0.32	1.97

Sample No.	CERC Sample No.	Mean grain size (phi)	Standard deviation	Skewness	Kurtosis
932-1	18	2.64	0.64	-0.08	3.67
932-2	18	2.91	0.94	-0.50	2.98
939	195	2.90	0.89	0.41	2.21
943	31	1.34	0.70	1.17	5.99
946-1	144	2.60	0.75	0.23	4.58
946-2	144	2.35	0.95	-0.06	2.97
946-3	144	2.27	0.70	0.01	4.56
949-1	140	1.90	0.57	-0.68	4.72
949-2	140	2.08	0.59	0.25	4.57
954-1	135	2.59	1.27	-0.01	1.77
954-2	135	2.13	1.35	0.44	1.85
958	91	2.03	1.21	0.62	2.44
959-1	131	2.68	0.65	0.43	4.18
959-2	131	2.63	1.00	0.20	2.41
966-1	142	2.37	1.02	0.54	2.71
966-2	142	2.44	1.02	0.32	2.72
968-1	148	1.72	0.82	0.45	4.06
968-2	148	2.18	0.92	0.88	3.65
969-1	146	3.03	0.68	-0.80	4.96
969-2	146	2.71	0.17	0.02	4.17
974	171	2.98	0.99	-0.12	2.32
979	151	2.62	0.77	-0.16	3.49

Area 1 generally is low and relatively homogeneous between upper and lower core sections.

Sand content in the northern part of Map Area 1 with one exception, ranges from 56 to 99 weight percent, with one sample having a very low sand value of about 26 percent (Figure 6). Overall, the lower core sections have a higher average sand content. The St. Augustine area has the highest percentage of both upper and lower core sections with greater than 90% sand.

Many of the samples, both upper and lower core sections, in Map Area 1 have mud contents greater than 5 percent; five samples are over 20% mud; and one sample is almost 70% mud (Figure 7). The only samples close together that have mud values less than 1% are in the center of Figure 7.

Map Area 2

Shell-gravel is variable in this area, with values ranging from 2 to 30 weight percent (Figure 8). There do not seem to be any trends, either along shore or inshore-offshore. Differences between upper and lower core sections are not systematic.

As with the shell-gravel percentages, there are no apparent trends in the distribution of sand. Overall values are low, with only 2 samples having greater than 90% sand, and only 5 of 17 samples having greater than 80% sand (Figure 9). As in the case of gravel, sand content variability is high between the upper and lower core sections.

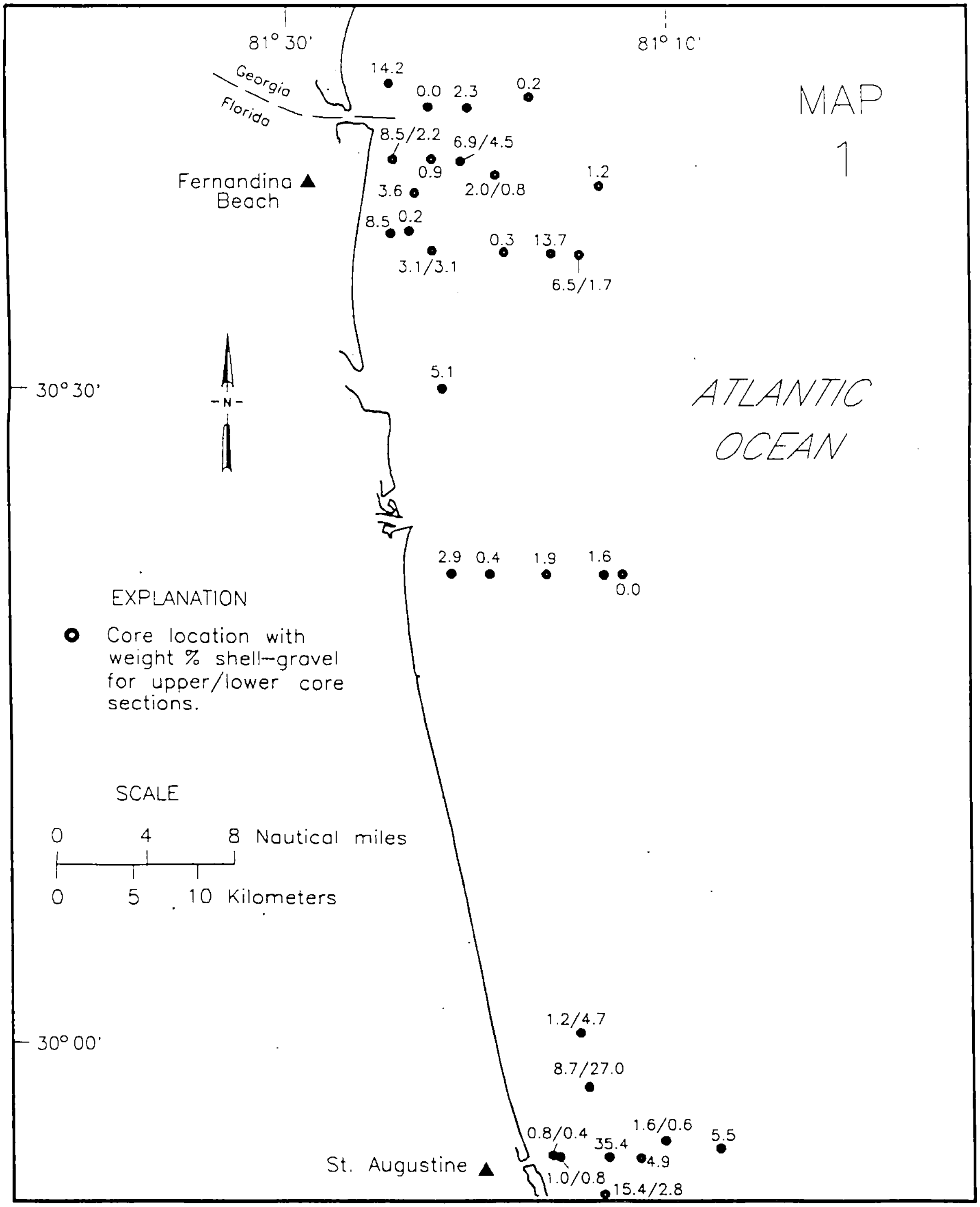

Fig. 5. Distribution of shell-gravel, given in weight percent, for upper/lower core sections in Map 1.

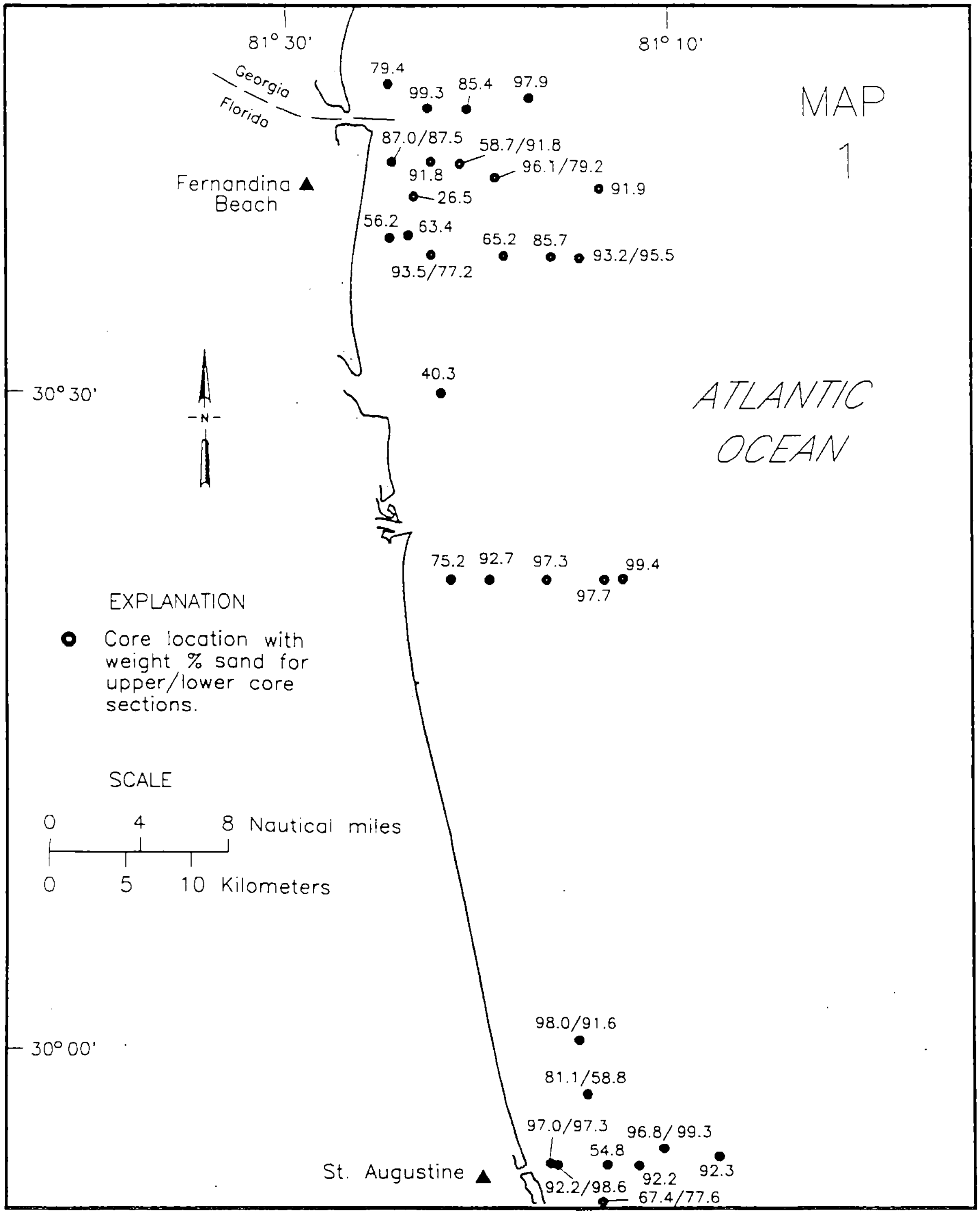

Fig. 6. Distribution of sand, given in weight percent, for upper/lower core sections in Map 1.

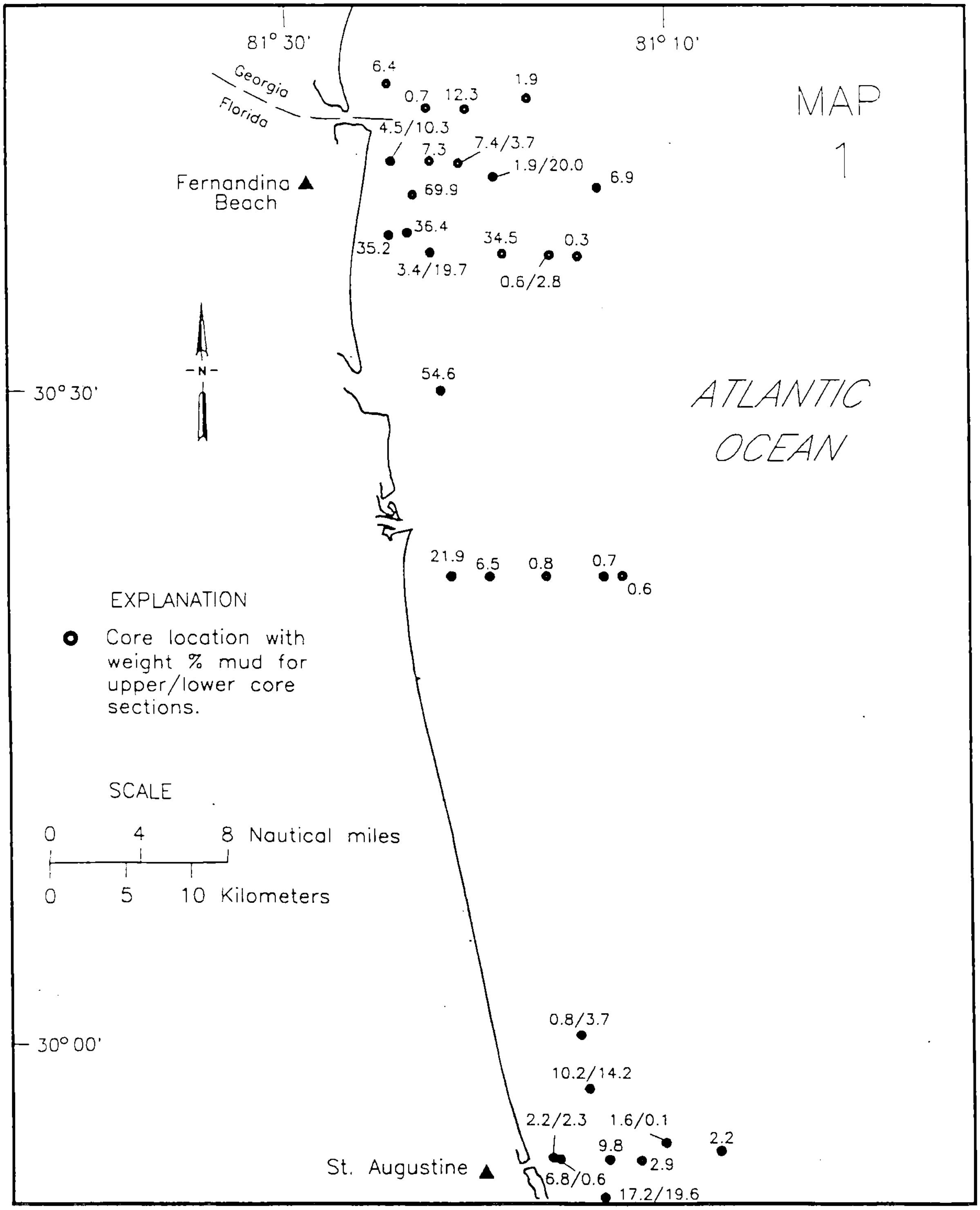

Fig. 7. Distribution of mud, given in weight percent, for upper/lower core sections in Map 1.

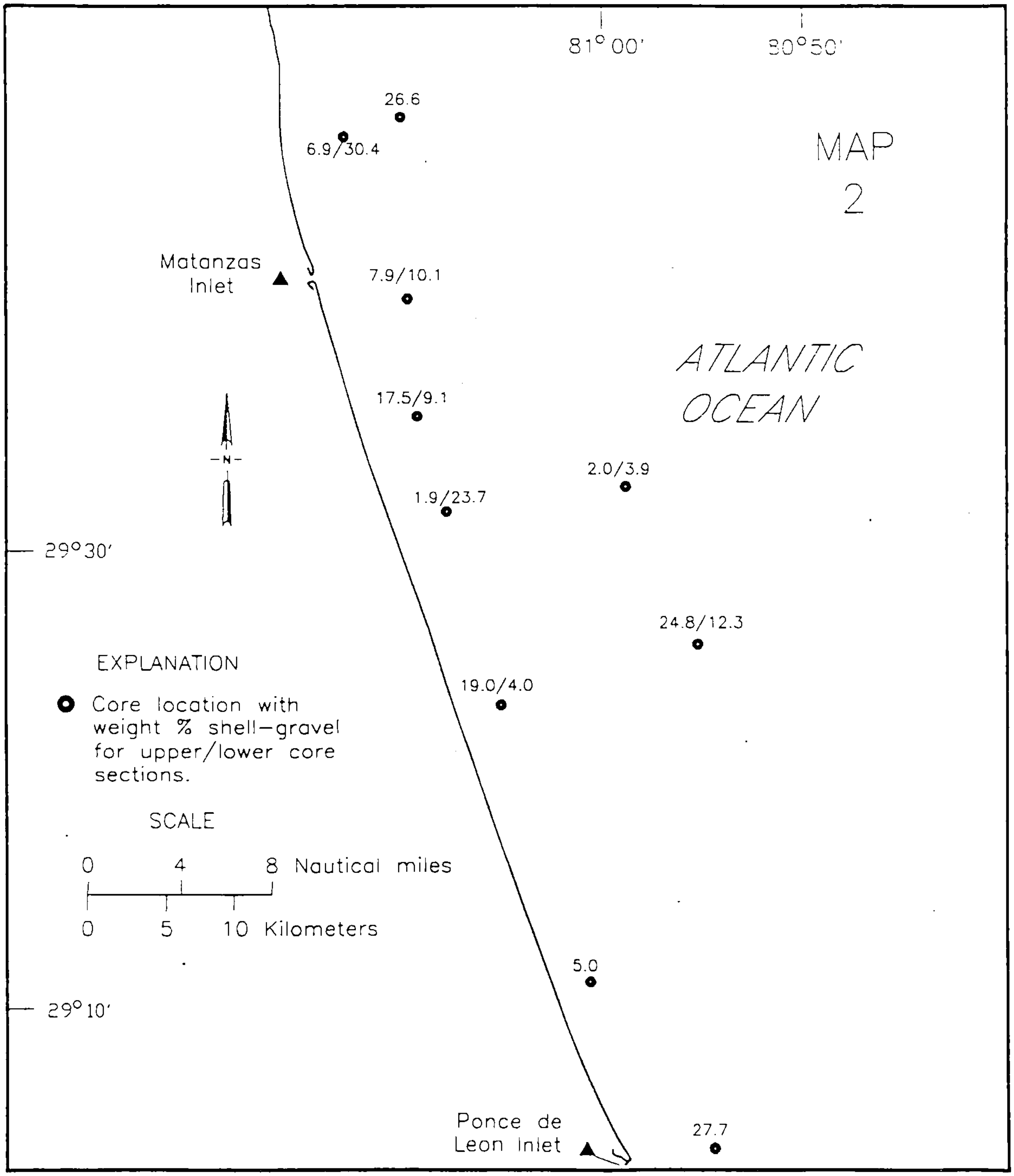

Fig. 8. Distribution of shell-gravel, given in weight percent, for upper/lower core sections in Map 2.

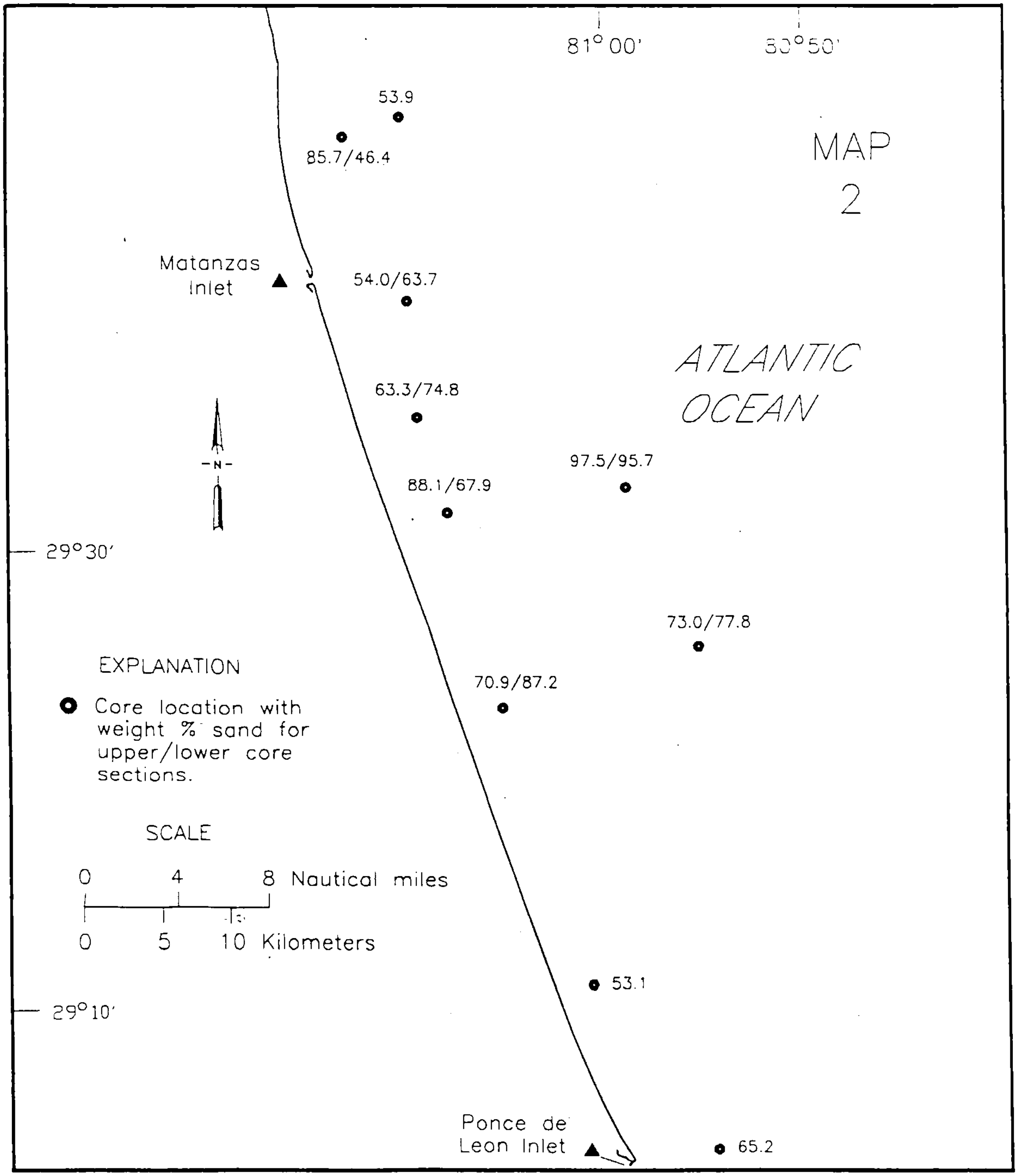

Fig. 9. Distribution of sand, given in weight percent, for upper/lower core sections in Map 2.

Only one sample site (949) has a mud value under 1% for both upper and lower core sections (Figure 10). All other samples, either upper or lower, have mud values of at least 2 %.

Map Area 3

This area is represented by only 4 sites (4 upper and 1 lower core section). All samples are relatively far offshore, between about 9 and 18.5 km. The upper sections have shell-gravel values less than 11 weight percent while the lower core section contains about 25% shell-gravel (Figure 11). The northernmost and southernmost samples in Map Area 3 have low sand contents, 65 and 56/72 (upper/lower) percent respectively (Figure 12). The two samples in between have over 90% sand. Low mud values are found in the two samples that have the highest sand values and also in the lower section of the southernmost core (Figure 13).

Heavy Minerals

The suite of heavy minerals found in Holocene sediments of the study area is identical in composition to that of the Cape Canaveral region (Grosz et al., 1989; Nocita et al., 1989, 1990). Minerals present include ilmenite, rutile, tourmaline, zircon, garnet, epidote, staurolite, aluminosilicates (sillimanite/kyanite/andalusite), pyroboles, pryoxenes and amphiboles, phosphate and trace amounts of monazite. The results of the heavy-mineral analysis are given in Table 3.

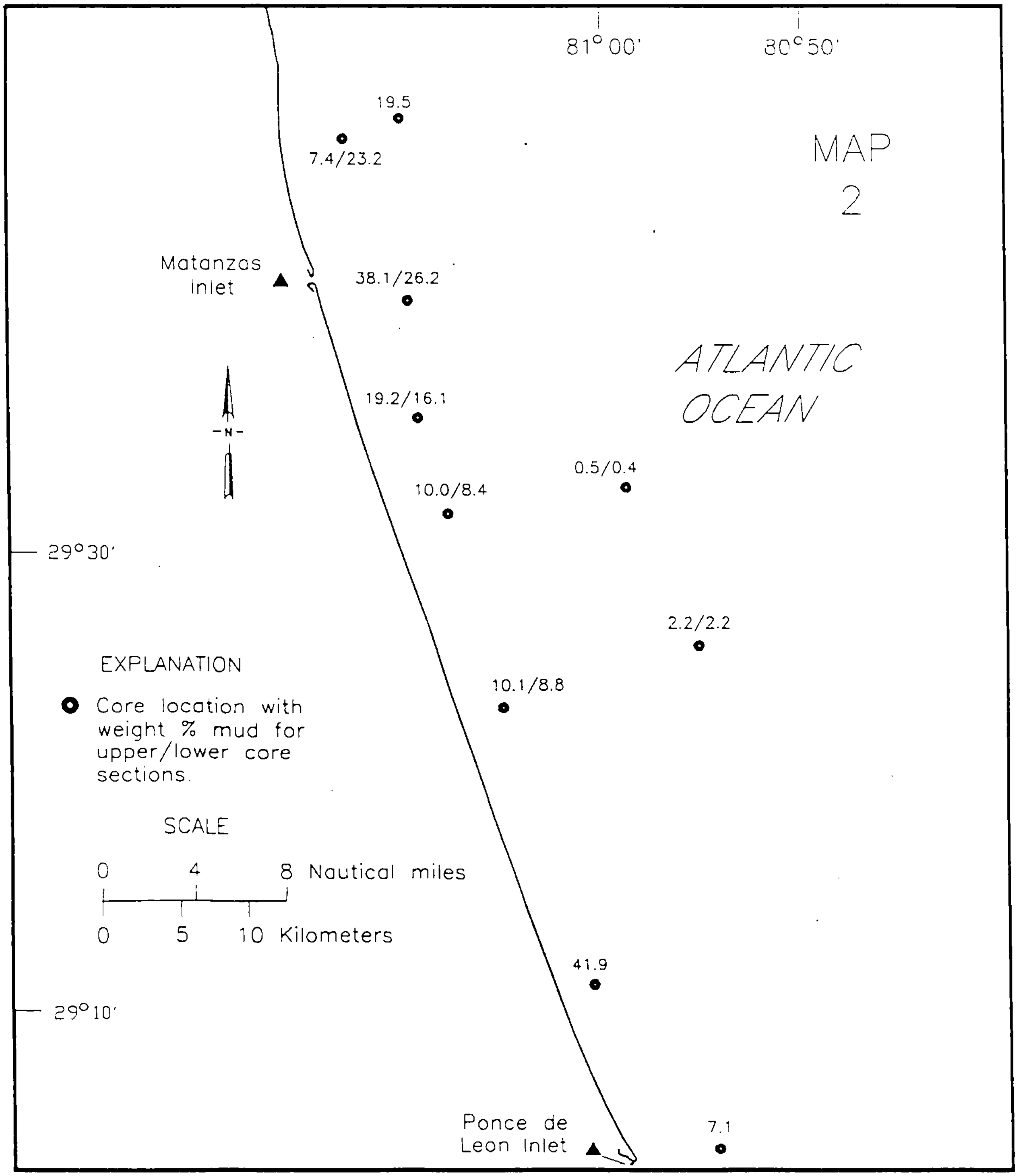

Fig. 10. Distribution of mud, given in weight percent, for upper/lower core sections in Map 2.

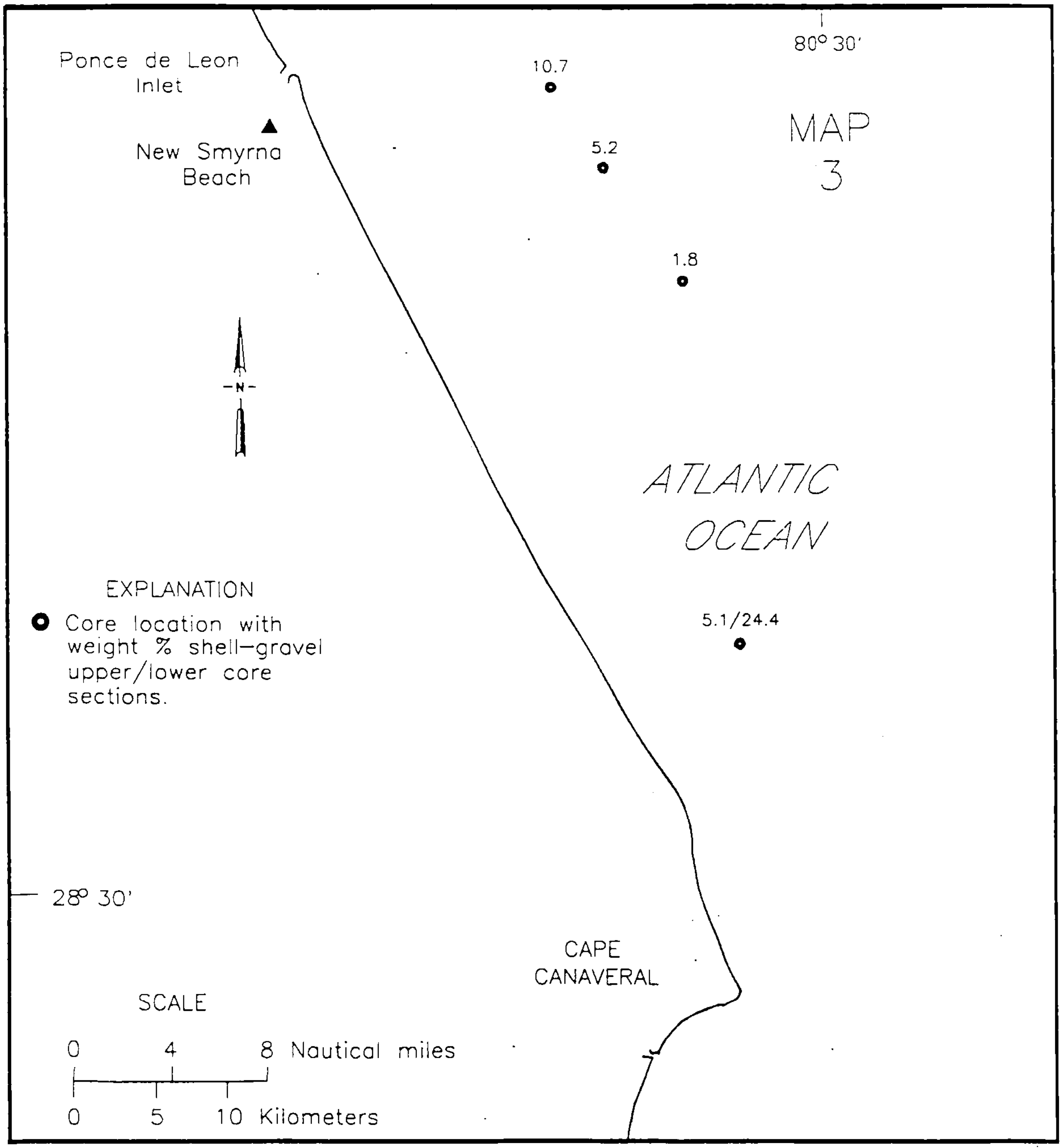

Fig. 11. Distribution of shell-gravel, given in weight percent, for upper/lower core sections in Map 3.

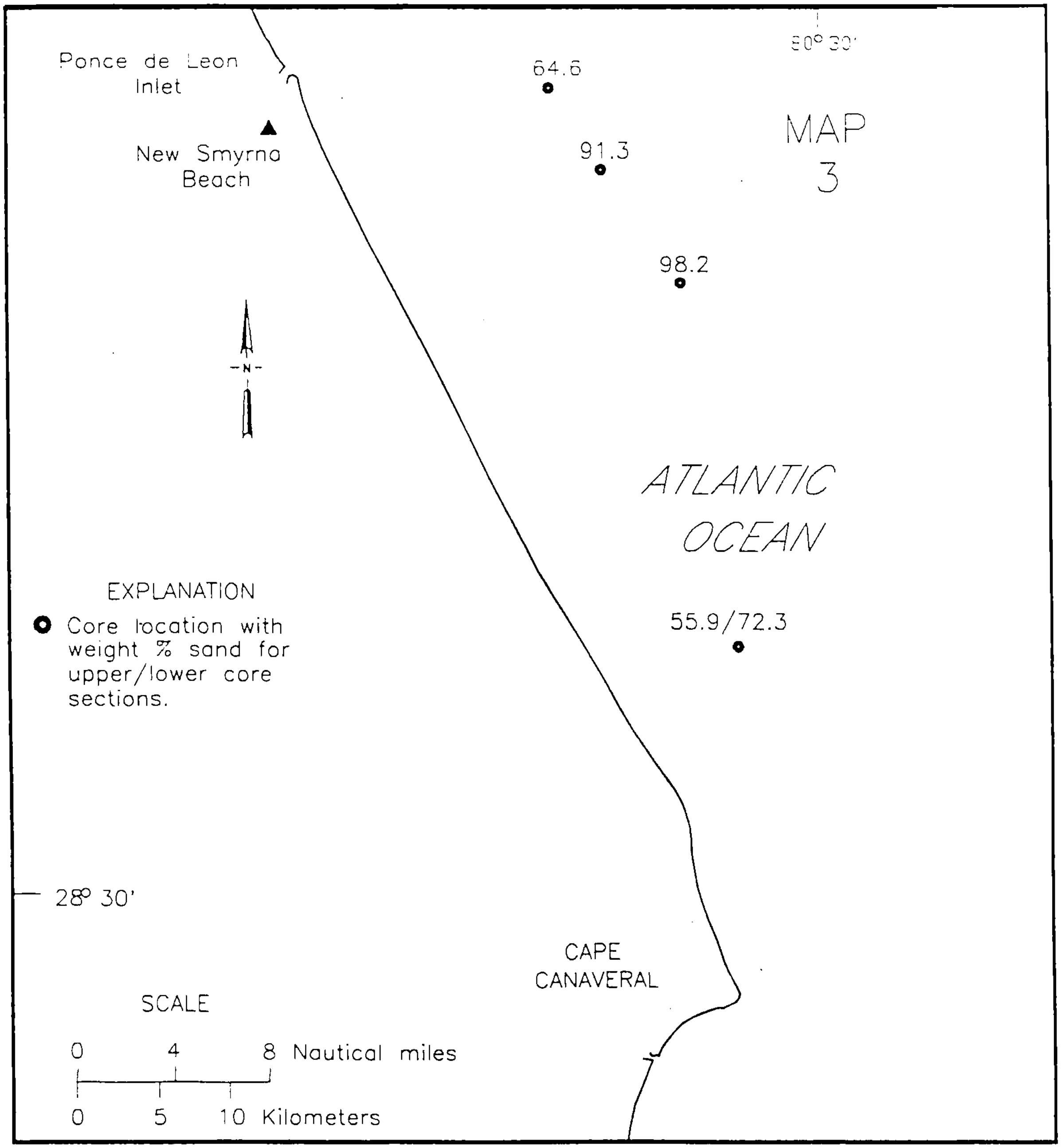

Fig. 12. Distribution of sand, given in weight percent, for upper/lower core sections in Map 3.

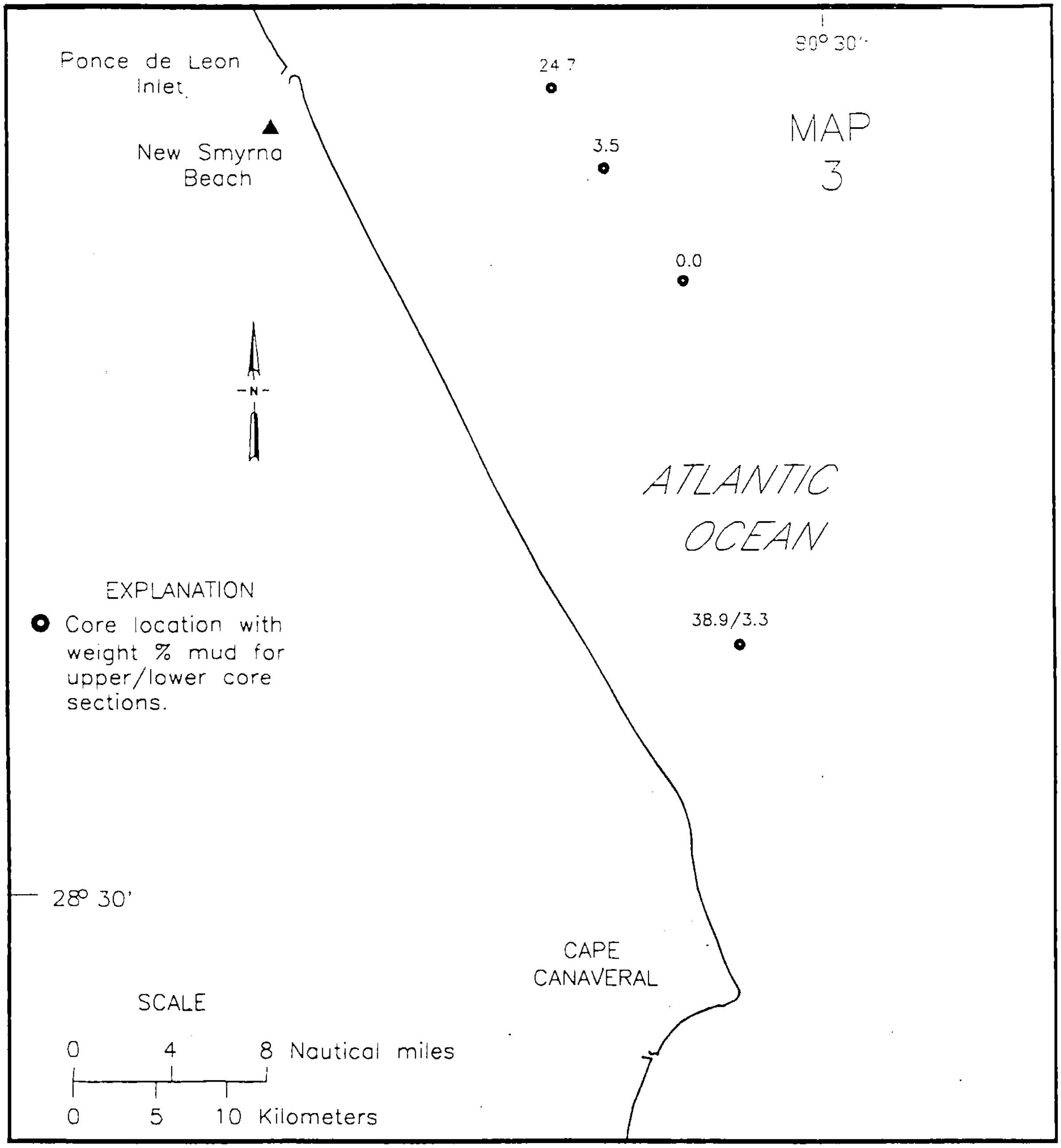

Fig. 13. Distribution of mud, given in weight percent, for upper/lower core sections in Map 3.

Table 3. Heavy Mineral (>2.96 specific gravity) content of core samples from offshore of Florida, Cape Canaveral to the Georgia border (P, present but less than .01% of heavy mineral concentrate).

Footnotes:

1. Sample numbers with postscript: 1/indicates upper portion of core, 2/indicates lower portion of core.

2. Undifferentiated sillimanite, kyanite and andalucite.

3. Undifferentiated pyroxenes and amphiboles.

4. May include sulfides, unidentified opaques/non opaques, quartz and coated grains.

5. Economic heavy minerals expressed as a percentage of the heavy mineral concentrate.

6. Economic heavy minerals expressed as a percentage of the bulk sample.

SAMPLE[1] NUMBER	CERC NO	LATITUDE	LONGITUDE	LENGTH (CM)	BULK WT (g)	WT% GRAVEL	WT% RHM	WT% THM	ILMENITE RHM	ILMENITE THM	RUTILE RHM	RUTILE THM	ZIRCON RHM	ZIRCON THM	MONAZITE RHM	MONAZITE THM	ALUMINO-[2] SILICATES RHM	ALUMINO-[2] SILICATES THM	EPIDOT RHM
96-1	157	28.69900	80.53910	145	2951	2.4	0.19	0.19	33.9	33.7	3.5	3.4	9.0	8.9	0.0	0.0	11.7	12.0	30.8
96-2	157	28.69900	80.53910	190	4086	27.4	0.10	0.14	30.2	24.2	3.7	2.6	10.1	8.6	0.0	0.0	7.7	9.9	36.2
101	152	28.94795	80.59970	174	13009	2.2	0.22	0.26	21.6	18.4	4.7	4.0	6.4	6.2	0.0	0.0	13.0	12.4	36.4
103	160	29.02218	80.66670	162	10519	5.4	0.25	0.27	28.7	26.7	2.7	2.4	4.0	3.8	P	P	19.0	19.4	31.1
109	165	29.07549	80.71190	172	8756	6.5	0.23	0.36	31.1	19.8	4.1	2.5	5.3	5.2	0.0	0.0	17.4	18.4	28.4
811-1	24	30.67107	81.30900	90	3065	1.9	0.82	1.09	36.3	24.8	3.7	4.1	10.2	7.0	0.0	0.0	8.2	12.0	25.5
811-2	24	30.67107	81.30900	137	4540	0.9	0.19	0.20	32.1	31.4	2.7	2.6	10.2	9.8	0.0	0.0	10.3	11.4	34.2
813	4	30.73629	81.28160	90	5081	1.0	0.63	0.89	34.1	23.1	3.6	3.4	1.9	1.2	0.0	0.0	16.0	15.7	34.0
815	3	30.72353	81.33950	78	3568	4.7	0.42	0.45	31.3	29.0	4.0	3.8	3.7	3.4	P	P	17.2	17.0	31.5
817-1	15	30.67940	81.34270	120	3973	7.0	0.01	0.01	33.6	22.7	5.9	4.0	11.7	7.9	P	P	7.5	7.6	27.8
817-2	15	30.67940	81.34270	49	3519	8.8	0.02	0.03	28.2	26.1	4.7	3.9	11.7	10.3	0.0	0.0	6.2	10.2	32.8
819	8	30.68202	81.37580	93	2951	1.8	0.61	0.64	28.3	29.2	3.1	2.9	8.0	8.0	0.0	0.0	11.5	11.2	29.3
821-1	9	30.68128	81.41060	170	5675	12.5	0.60	0.79	35.2	27.8	1.5	1.6	7.5	5.6	0.0	0.0	10.5	13.3	30.0
821-2	9	30.68128	81.41060	178	3973	1.7	0.50	0.80	31.1	17.1	2.2	8.0	13.4	7.4	0.0	0.0	8.0	7.6	31.8
823	2	30.72183	81.37650	161	10469	.0	0.37	0.40	29.0	26.3	3.1	2.9	3.4	3.0	0.0	0.0	15.0	15.2	32.6
824	17	30.73960	81.41560	245	13877	17.3	0.24	0.30	31.3	24.4	4.6	4.0	10.0	8.6	P	P	4.4	7.0	30.9
827	105	29.92160	81.11920	150	10134	2.3	0.24	0.32	26.8	22.0	4.0	2.9	4.1	4.9	P	P	18.4	17.4	32.5
830-1	127	29.92744	81.16730	175	7311	1.3	0.34	0.42	28.4	21.9	2.3	1.7	3.6	4.5	0.0	0.0	18.3	17.5	33.8
830-2	127	29.92744	81.16730	178	6581	1.0	0.29	0.32	26.6	24.6	2.9	2.6	3.5	3.7	0.0	0.0	15.4	15.3	36.2
833	99A	29.91349	81.18900	89	4991	3.4	0.65	0.69	32.3	29.6	4.5	4.1	3.6	3.8	0.0	0.0	18.7	18.8	30.2
834-1	128	29.88528	81.21750	202	4631	15.7	0.38	0.43	29.0	27.9	3.2	2.8	7.5	8.4	0.0	0.0	12.4	11.4	33.8
834-2	128	29.88528	81.21750	191	4767	6.0	0.08	0.10	21.9	16.3	2.4	1.8	9.6	7.1	0.0	0.0	6.7	5.2	32.1
835-1	98	29.90838	81.21600	137	3405	12.1	0.31	0.01	29.7	29.8	2.4	2.3	4.3	4.3	0.0	0.0	17.4	17.6	33.6
838	88	29.91414	81.21680	234	13724	35.9	0.05	0.10	31.0	22.1	6.0	5.4	3.8	7.3	P	P	13.7	9.9	31.0
838A	88A	29.91414	81.21680	231	14802	20.9	0.17	0.18	30.1	27.2	5.0	4.4	4.7	5.1	0.0	0.0	11.5	11.3	30.1
843-1	95	29.96872	81.23410	165	3859	10.2	0.67	0.92	28.8	30.5	2.7	1.8	12.0	9.7	0.0	0.0	9.1	8.7	32.7
843-2	95	29.96872	81.23410	155	4313	25.3	0.18	0.20	25.0	25.2	1.6	1.5	10.1	10.1	0.0	0.0	8.8	8.6	24.9
847	121	29.91534	81.26610	148	9466	0.4	1.05	1.32	33.7	25.9	4.9	4.4	3.7	3.8	0.0	0.0	19.2	18.1	28.8
847A-1	121A	29.91534	81.26610	140	9151	0.7	0.95	1.11	35.6	29.8	3.6	3.0	3.8	4.9	0.0	0.0	15.1	15.1	32.5
847A-2	121A	29.91534	81.26610	145	10419	0.3	0.52	0.70	33.1	23.2	2.9	2.6	2.9	4.8	0.0	0.0	19.0	19.3	33.1
848-1	85	29.91432	81.26050	155	9471	1.5	0.94	1.02	33.4	29.9	3.0	2.9	3.1	3.4	0.0	0.0	17.9	17.0	31.7
848-2	85	29.91432	81.26050	91	6011	1.2	1.06	1.28	41.2	31.7	1.1	2.5	0.5	2.2	P	P	5.4	7.6	38.7
850-1	107	30.00966	81.24190	170	3496	1.2	0.66	0.77	26.0	25.5	4.4	3.6	10.6	11.9	0.0	0.0	9.1	9.3	24.3
850-2	107	30.00966	81.24190	149	6129	2.8	0.53	0.69	33.4	29.1	3.9	2.8	9.4	9.0	0.0	0.0	11.9	14.2	29.5
868	81	30.36219	81.20560	115	7621	0.1	0.55	0.59	23.9	21.9	2.6	2.5	3.7	3.6	P	P	17.9	17.6	29.0
869	185	30.36141	81.22200	159	11129	2.9	0.17	0.19	24.1	21.6	3.0	2.6	4.7	4.2	0.0	0.0	14.3	14.4	34.5
878	67	30.36196	81.27230	156	10879	1.8	0.37	0.48	30.2	25.7	2.8	1.9	3.8	4.2	P	P	16.4	16.0	33.2
884	64	30.36147	81.32230	103	5786	1.8	0.69	0.84	26.6	20.9	2.7	2.6	1.6	1.9	0.0	0.0	19.4	19.5	33.0
903	181	30.36141	81.35620	252	12664	3.8	0.09	0.23	26.0	12.3	3.4	1.2	8.9	9.0	P	P	10.8	13.6	33.9
916	35	30.66231	81.22530	136	4313	3.5	0.56	0.59	24.1	22.9	1.6	1.5	6.3	6.0	0.0	0.0	9.9	11.0	32.9
920-1	194	30.60514	81.24440	168	9393	5.2	0.43	0.52	24.5	21.4	3.1	2.4	9.7	8.5	P	P	9.8	13.0	35.9
920-2	194	30.60514	81.24440	172	10494	3.6	0.67	0.83	31.0	24.1	2.1	3.9	4.5	4.4	0.0	0.0	18.0	18.4	34.3
925	72	30.50714	81.36600	84	1816	3.4	0.10	0.11	28.3	28.6	3.1	2.7	7.4	6.9	0.0	0.0	11.4	14.3	34.6
928	10	30.62070	81.40990	139	3632	7.8	0.65	0.67	21.0	21.0	4.3	4.2	9.9	9.6	0.0	0.0	7.7	8.4	28.3
929A-1	12A	30.62250	81.39370	147	2270	4.9	0.35	0.36	27.6	27.6	2.2	2.1	6.8	6.6	0.0	0.0	11.6	11.5	31.1
929A-2	12A	30.62250	81.39370	152	4200	5.4	0.51	0.51	30.4	30.2	1.8	1.8	7.6	7.6	0.0	0.0	10.0	10.0	33.8
929-1	12	30.62250	81.39370	149	1702	0.2	0.58	0.58	27.7	27.7	2.3	2.3	5.5	5.5	P	P	13.7	13.9	31.3
931	13	30.65120	81.38900	221	3405	6.9	0.09	0.09	29.3	28.8	3.7	3.5	9.8	9.3	0.0	0.0	10.2	12.7	32.1
932-1	18	30.60768	81.37330	147	9759	2.2	0.55	1.03	33.3	16.5	2.6	1.2	4.9	7.6	0.0	0.0	18.7	14.1	28.4
932-2	18	30.60768	81.37330	147	7761	3.9	0.47	0.52	34.0	29.5	1.7	1.5	2.0	2.7	0.0	0.0	16.7	17.1	33.4
939	195	30.60686	81.31050	154	8171	0.8	0.37	0.44	29.7	24.4	3.6	4.3	3.8	3.9	0.0	0.0	14.6	15.8	33.4
943	31	30.60571	81.26890	105	5846	13.7	0.68	0.85	69.9	59.4	2.4	2.1	3.5	3.6	P	P	9.0	8.5	1.8
946-1	144	29.54143	81.10550	127	6671	3.3	0.44	0.49	33.3	29.3	4.0	3.5	6.8	7.0	0.0	0.0	16.2	16.0	25.9
946-2	144	29.54143	81.10550	122	6601	23.7	0.38	0.40	32.7	30.8	3.5	3.3	5.5	5.6	0.0	0.0	15.3	15.3	31.6
946-3	144	29.54143	81.10550	169	10209	6.7	0.31	0.38	26.9	20.8	2.8	2.2	6.6	6.9	0.0	0.0	12.3	11.8	34.0
949-1	140	29.56917	80.95880	145	7396	2.6	0.44	0.46	18.6	18.1	3.4	3.3	4.8	4.6	P	P	15.9	15.7	35.6
949-2	140	29.56917	80.95880	153	5646	4.1	0.35	0.37	21.4	20.6	3.2	3.1	3.5	3.4	0.0	0.0	16.8	16.9	35.7
954-1	135	29.69561	81.14860	190	9954	12.4	0.37	0.48	31.1	23.9	2.9	2.1	5.0	5.0	P	P	9.4	9.5	34.0
954-2	135	29.69561	81.14860	218	9799	9.0	0.07	0.65	27.3	7.2	2.6	0.3	4.0	9.4	P	P	15.3	10.5	33.2
958	91	29.82624	81.16380	112	5701	26.6	0.17	0.19	31.3	28.0	5.2	4.6	5.8	5.8	0.2	P	15.5	15.4	27.9
959-1	131	29.80924	81.20930	135	3723	4.5	0.47	0.54	26.5	25.5	2.9	2.4	6.2	6.0	0.0	0.0	13.6	14.9	32.4
959-2	131	29.80924	81.20930	125	3746	39.5	0.30	0.38	30.3	28.1	3.9	3.1	7.6	7.5	P	P	13.2	17.5	35.5
966-1	142	29.61004	81.13450	130	3973	17.2	0.50	0.51	22.8	22.3	5.1	4.9	8.9	8.7	0.0	0.0	10.4	10.5	28.5
966-2	142	29.61004	81.13450	185	3519	13.8	0.14	0.16	23.7	20.3	5.1	4.3	8.2	7.7	0.0	0.0	7.6	9.2	32.3
968-1	148	29.45753	80.89080	136	6696	28.2	0.23	0.24	25.9	24.4	3.8	3.6	7.7	7.5	P	P	16.6	16.5	29.9
968-2	148	29.45753	80.89080	160	7491	11.0	0.28	0.31	23.8	21.0	4.5	4.0	6.5	6.4	0.0	0.0	19.1	19.2	25.5
969-1	146	29.40394	81.05090	166	4994	17.1	0.31	0.45	35.5	27.2	3.1	2.0	8.9	6.5	0.0	0.0	10.5	18.1	29.6
969-2	146	29.40394	81.05090	178	5902	15.5	0.49	0.52	27.0	26.2	2.9	2.7	8.8	8.3	0.0	0.0	9.8	10.7	35.1
974	171	29.20466	80.96220	233	12414	3.6	0.35	0.43	33.6	26.3	3.6	5.1	7.4	6.8	P	P	20.0	18.8	25.1
979	151	29.08967	80.84920	210	6243	24.7	0.39	0.42	27.5	24.6	1.9	5.3	7.9	7.4	0.0	0.0	11.3	13.6	32.0
			COUNT	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
			MINIMUM	49	1702	.0	0.01	0.01	18.6	7.2	1.1	0.3	0.5	1.2	0.0	0.0	4.4	5.2	1.8
			AVERAGE	154	6774	8.3	0.40	0.49	29.8	25.2	3.3	3.0	6.5	6.3	.0	0.0	13.1	13.6	31.3
			MAXIMUM	252	14802	39.5	1.06	1.32	69.9	59.4	6.0	8.0	13.4	11.9	0.2	0.0	20.0	19.5	38.7
			STD. DEV.	41	3255	9.1	0.24	0.30	6.4	6.2	1.0	1.2	2.9	2.3	.0	0.0	4.1	3.7	4.7

TE HM	ALUMINO-[2] SILICATES RHM	THM	EPIDOTE RHM	THM	GARNET RHM	THM	PYROBOLES[3] RHM	THM	TOURMALINE RHM	THM	STAUROLITE RHM	THM	PHOSPHATE RHM	THM	OTHERS[4] RHM	THM	EHM/C[5] RHM	THM	EHM/T[6] RHM	THM
0.0	11.7	12.0	30.8	30.8	2.2	2.2	1.7	1.7	1.6	1.6	5.6	5.5	0.0	0.0	P	P	58.1	58.1	0.11	0.11
0.0	7.7	9.9	36.2	35.9	1.1	0.8	2.6	3.9	3.0	5.1	3.5	5.4	1.2	0.8	0.6	2.8	51.8	45.3	0.05	0.06
0.0	13.0	12.4	36.4	33.7	2.0	1.7	1.7	2.2	5.4	6.2	5.5	5.0	1.8	1.8	1.5	8.5	45.7	40.9	0.10	0.11
P	19.0	19.4	31.1	31.3	2.5	2.3	2.2	3.2	2.5	2.8	3.2	3.4	2.4	2.2	1.7	2.4	54.4	52.3	0.14	0.14
0.0	17.4	18.4	28.4	31.0	2.7	1.6	1.9	5.1	2.9	5.7	2.9	3.8	1.1	0.7	2.2	6.2	57.9	45.9	0.13	0.16
0.0	8.2	12.0	25.5	30.1	2.0	1.4	9.8	16.2	0.4	0.3	3.8	3.9	0.0	0.0	P	0.3	58.6	47.9	0.48	0.52
0.0	10.3	11.4	34.2	34.4	0.7	0.7	4.4	4.5	1.0	1.0	4.2	4.2	0.0	0.0	0.1	0.1	55.4	55.2	0.11	0.11
0.0	16.0	15.7	34.0	32.6	2.3	1.5	3.8	14.8	0.5	2.5	2.0	2.3	P	P	1.7	2.9	55.6	43.4	0.35	0.38
P	17.2	17.0	31.5	33.1	1.9	1.8	1.7	2.4	4.0	4.2	2.9	2.7	0.2	0.2	1.7	2.4	56.2	53.2	0.23	0.24
P	7.5	7.6	27.8	19.8	2.1	1.4	1.6	1.1	2.2	1.5	6.9	4.6	P	P	0.7	29.3	58.7	42.3	0.01	0.01
0.0	6.2	10.2	32.8	32.8	2.6	2.2	2.0	1.7	3.4	4.5	5.7	5.6	P	0.5	2.8	2.3	50.7	50.5	0.01	0.01
0.0	11.5	11.2	29.3	29.3	2.4	2.2	6.3	6.1	4.3	4.1	6.2	6.4	0.7	0.6	P	P	50.9	51.3	0.31	0.33
0.0	10.5	13.3	30.0	34.4	2.1	1.5	3.2	5.2	2.7	2.5	5.2	6.6	1.2	0.8	0.9	0.7	54.7	48.4	0.33	0.38
0.0	8.0	7.6	31.8	44.5	5.5	3.0	3.7	8.8	1.3	1.2	2.2	1.7	0.2	0.1	0.5	0.7	54.8	40.0	0.27	0.32
0.0	15.0	15.2	32.6	34.3	2.5	2.3	3.4	4.0	2.9	3.3	4.1	4.2	2.3	2.1	1.7	2.4	50.5	47.5	0.18	0.19
P	4.4	7.0	30.9	31.9	8.1	7.3	1.9	3.9	2.5	3.6	1.6	2.4	2.3	2.2	2.4	4.8	50.4	43.9	0.12	0.13
P	18.4	17.4	32.5	33.2	2.4	2.0	2.1	4.3	3.5	5.4	3.4	3.0	0.5	0.4	2.3	4.5	53.3	47.2	0.13	0.15
0.0	18.3	17.5	33.8	35.4	2.5	1.8	2.9	6.0	2.3	3.0	3.1	3.1	1.0	0.7	1.8	4.4	52.7	45.7	0.18	0.19
0.0	15.4	15.3	36.2	36.1	3.4	3.2	1.6	3.0	3.4	3.8	2.9	3.1	2.1	1.9	2.0	2.8	48.4	46.3	0.14	0.15
0.0	18.7	18.8	30.2	31.0	2.1	1.9	2.3	3.4	2.1	2.6	1.8	2.3	0.5	0.4	1.9	2.2	59.1	56.3	0.38	0.39
0.0	12.4	11.4	33.8	31.1	1.8	1.6	2.8	2.8	2.0	1.8	3.5	3.1	1.4	1.2	2.7	7.9	52.1	50.5	0.20	0.22
0.0	6.7	5.2	32.1	23.9	3.9	2.9	1.2	0.9	10.4	8.2	6.2	4.6	5.5	4.9	0.1	24.2	40.6	30.4	0.03	0.03
0.0	17.4	17.6	33.6	33.5	3.3	3.3	P	0.1	3.3	3.3	3.3	3.3	.0	.0	2.6	2.5	53.8	53.9	0.17	.00
P	13.7	9.9	31.0	19.3	4.9	3.8	2.1	6.5	1.9	6.4	3.4	3.2	0.1	1.2	2.1	14.9	54.5	44.7	0.03	0.04
0.0	11.5	11.3	30.1	28.2	4.6	4.6	2.6	3.5	2.6	2.9	3.0	3.5	1.8	1.9	5.8	5.6	51.2	48.0	0.08	0.09
0.0	9.1	8.7	32.7	31.8	4.4	3.0	4.8	9.7	0.7	0.5	3.6	3.4	0.9	0.6	0.2	0.1	52.6	50.8	0.35	0.47
0.0	8.8	8.6	24.9	25.3	11.7	10.4	5.6	5.5	3.4	3.5	6.2	6.6	2.4	2.2	0.4	1.0	45.5	45.4	0.08	0.09
0.0	19.2	18.1	28.8	34.1	2.8	2.1	2.2	4.1	1.9	2.7	1.7	2.5	P	P	1.3	2.2	61.4	52.2	0.65	0.69
0.0	15.1	15.1	32.5	34.7	3.8	3.1	2.5	3.8	1.1	1.8	1.1	1.8	P	P	1.1	2.1	58.0	52.7	0.55	0.58
0.0	19.0	19.3	33.1	36.8	2.5	1.8	2.1	4.5	1.1	2.9	1.4	1.9	0.0	0.0	1.8	2.2	58.0	50.0	0.30	0.35
0.0	17.9	17.0	31.7	32.5	3.7	3.3	2.5	4.9	1.3	1.7	1.6	2.0	0.2	0.1	1.8	2.4	57.2	53.1	0.54	0.54
P	5.4	7.6	38.7	39.0	2.8	2.1	3.5	6.1	2.3	2.9	2.1	2.8	0.2	0.2	2.2	2.8	48.3	44.1	0.51	0.57
0.0	9.1	9.3	24.3	24.8	2.3	1.9	4.8	3.9	7.7	8.5	7.9	8.3	2.8	2.3	P	P	50.1	50.3	0.33	0.39
0.0	11.9	14.2	29.5	31.0	2.2	1.6	2.3	3.6	1.7	2.6	4.5	5.2	1.2	0.9	P	P	58.7	55.1	0.31	0.38
P	17.9	17.6	29.0	29.6	2.1	1.9	3.4	5.3	6.4	6.5	6.6	6.4	2.5	2.4	1.9	2.1	48.1	45.7	0.26	0.27
0.0	14.3	14.4	34.5	32.6	3.5	3.1	2.7	3.6	4.1	4.8	3.9	3.8	2.9	2.7	2.2	6.4	46.2	42.9	0.08	0.08
P	16.4	16.0	33.2	32.2	3.3	2.4	2.8	6.4	2.3	4.6	2.6	3.3	0.8	0.6	1.8	2.7	53.1	47.8	0.19	0.23
0.0	19.4	19.5	33.0	33.4	2.5	2.4	9.2	11.6	1.4	3.3	1.2	1.4	P	P	2.3	2.9	50.4	44.9	0.35	0.38
P	10.8	13.6	33.9	31.3	3.9	2.0	3.0	7.6	2.9	4.3	2.9	1.7	2.3	0.8	2.0	16.4	49.1	35.9	0.05	0.08
0.0	9.9	11.0	32.9	32.6	4.4	4.0	13.3	14.6	1.8	1.6	3.9	4.0	1.5	1.4	0.4	0.4	41.9	41.4	0.23	0.25
P	9.8	13.0	35.9	33.5	2.1	1.6	3.0	5.6	5.0	6.0	3.6	3.5	2.3	1.8	1.2	2.6	47.1	45.3	0.20	0.23
0.0	18.0	18.4	34.3	33.3	2.0	1.6	2.8	6.8	1.6	2.9	1.6	1.2	0.6	0.5	1.6	2.9	55.5	50.9	0.37	0.42
0.0	11.4	14.3	34.6	33.9	1.3	1.3	3.1	2.7	3.1	2.7	5.2	4.9	P	0.1	2.4	2.0	50.3	52.4	0.05	0.06
0.0	7.7	8.4	28.3	27.9	7.9	7.7	9.2	8.9	4.7	4.9	6.2	6.2	0.8	1.0	0.1	0.2	43.0	43.3	0.28	0.29
0.0	11.6	11.5	31.1	31.5	2.3	2.3	11.6	11.4	2.4	2.3	3.3	3.3	P	P	1.1	1.3	48.3	47.8	0.17	0.17
0.0	10.0	10.0	33.8	33.6	2.8	2.9	5.0	5.0	1.3	1.4	4.9	5.0	1.9	1.9	0.5	0.6	49.9	49.6	0.25	0.25
P	13.7	13.9	31.3	31.1	3.8	3.8	9.2	9.2	1.8	1.8	3.7	3.7	0.0	0.0	1.0	1.0	49.2	49.4	0.29	0.29
0.0	10.2	12.7	32.1	30.7	3.4	3.2	2.8	2.7	1.1	1.0	4.0	3.9	.0	.0	3.8	3.9	53.1	54.3	0.05	0.05
0.0	18.7	14.1	28.4	34.6	3.0	1.4	2.8	14.7	1.1	3.2	1.4	2.2	1.6	1.8	2.4	2.7	59.5	39.4	0.33	0.41
0.0	16.7	17.1	33.4	33.0	2.3	2.1	2.9	5.9	1.4	1.9	0.8	1.3	1.3	1.2	3.5	3.7	54.4	50.8	0.25	0.26
0.0	14.6	15.8	33.4	32.7	2.7	2.1	3.4	7.0	2.4	3.4	3.4	2.7	1.2	0.9	1.7	2.8	51.7	48.4	0.19	0.21
P	9.0	8.5	1.8	7.8	5.9	5.2	1.4	1.8	1.3	3.6	2.1	3.4	P	P	2.7	4.6	84.9	73.7	0.58	0.63
0.0	16.2	16.0	25.9	27.6	1.7	1.5	3.6	5.0	2.3	2.7	2.6	2.5	1.6	1.4	2.1	3.6	60.3	55.7	0.27	0.27
0.0	15.3	15.3	31.6	31.2	1.9	1.8	1.9	2.7	3.9	4.0	1.5	1.4	0.7	0.6	1.5	3.3	57.1	55.1	0.22	0.22
0.0	12.3	11.8	34.0	32.0	2.4	2.3	2.9	5.6	3.5	3.8	4.4	4.1	2.7	2.5	1.6	8.0	48.5	41.7	0.15	0.16
P	15.9	15.7	35.6	35.6	1.8	1.7	2.8	3.3	6.0	6.1	5.0	4.9	4.0	3.9	2.1	2.7	42.7	41.7	0.19	0.19
0.0	16.8	16.9	35.7	35.6	2.3	2.2	2.9	3.4	5.3	5.3	3.5	3.4	3.7	3.6	1.7	2.4	44.9	44.0	0.16	0.16
P	9.4	9.5	34.0	34.3	3.2	2.5	1.7	4.2	3.0	4.2	2.8	2.6	0.7	0.5	9.0	8.5	48.4	40.5	0.18	0.20
P	15.3	10.5	33.2	43.8	3.3	1.2	3.2	5.7	2.4	6.5	3.7	1.3	2.7	0.3	2.2	13.7	49.3	27.4	0.04	0.18
P	15.5	15.4	27.9	29.2	4.4	4.4	2.1	3.5	1.7	2.3	2.8	3.1	0.8	0.7	2.3	3.0	57.9	53.8	0.10	0.10
0.0	13.6	14.9	32.4	33.6	4.7	4.0	6.0	6.3	1.8	1.5	5.9	5.7	P	P	P	P	49.1	48.8	0.23	0.27
P	13.2	17.5	35.5	35.4	1.5	1.2	0.8	1.2	3.2	2.5	3.8	3.4	0.2	0.1	P	P	55.0	56.1	0.17	0.21
0.0	10.4	10.5	28.5	29.0	4.1	4.0	4.8	5.1	5.4	5.4	9.3	9.4	0.5	0.4	0.3	0.3	47.2	46.4	0.24	0.24
0.0	7.6	9.2	32.3	31.1	4.3	3.6	2.8	4.0	6.1	9.2	7.8	8.2	1.8	1.5	0.3	1.1	44.6	41.4	0.06	0.07
P	16.6	16.5	29.9	29.0	3.8	3.7	2.1	2.6	1.8	2.0	2.6	2.7	3.9	3.8	1.9	4.3	54.0	52.0	0.12	0.12
0.0	19.1	19.2	25.5	25.4	2.1	1.8	2.6	3.5	6.1	5.7	5.9	5.3	2.0	1.8	2.0	5.8	53.9	50.7	0.15	0.16
0.0	10.5	18.1	29.6	29.7	3.2	2.1	4.4	9.2	1.3	0.8	2.1	2.4	1.0	0.6	0.4	1.3	58.0	53.8	0.18	0.24
0.0	9.8	10.7	35.1	33.9	3.8	3.6	5.5	6.0	1.7	2.2	2.9	2.8	2.0	1.9	0.6	1.7	48.4	47.9	0.24	0.25
P	20.0	18.8	25.1	28.5	3.1	2.4	2.1	3.9	1.7	2.4	2.4	2.5	0.1	.0	1.1	3.2	64.5	57.0	0.23	0.24
0.0	11.3	13.6	32.0	31.0	6.2	5.6	5.8	5.2	1.8	1.8	3.0	3.0	1.3	1.1	1.4	1.1	48.7	50.9	0.19	0.22
70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
.0	4.4	5.2	1.8	7.8	0.7	0.7	P	0.1	0.4	0.3	0.8	1.2	0.0	0.0	P	P	40.6	27.4	0.01	P
.0	13.1	13.6	31.3	31.6	3.2	2.7	3.6	5.3	2.8	3.5	3.7	3.7	1.2	1.0	1.6	3.9	52.7	48.2	0.22	0.24
.0	20.0	19.5	38.7	44.5	11.7	10.4	13.3	16.2	10.4	9.2	9.3	9.4	5.5	4.9	9.0	29.3	84.9	73.7	0.65	0.69
.0	4.1	3.7	4.7	5.0	1.7	1.6	2.5	3.3	1.8	1.9	1.8	1.7	1.2	1.1	1.4	5.1	6.3	6.6	0.14	0.15

DISCUSSION

Sand and Gravel

Usefulness of offshore sediment for beach nourishment purposes depends on several criteria. Desirable textural characteristics include very low mud contents (rarely higher than 1 or 2 weight percent) and an overall textural and mineralogic similarity to the "native" beach sediment. The latter characteristic makes each project site specific. In addition, the type and amount of gravel are considered. In Florida, virtually all gravel-sized sediment is shell material. Natural beach sediment may contain from 0 to virtually 100 percent shell. The west-central Florida (Pinellas County) coastline averages around 25 percent shell but in some cases is being nourished with sediment containing up to 50 percent shell (R. Hogue, Univ. S. Florida, pers. comm., 1991). Thus, shell-gravel content can vary considerably depending on what is available and what the nature of the "native" beach material.

Map Area 1 has several concentrated sites with low mud percentages that may be good potential borrow sites. Map Area 2, on the other hand, has relatively high mud values except for far offshore. Two of the four sites in Map Area 3 have very low mud percentages. These observations are based solely on a combination of low mud and high sand percentages. Replenishment is site-specific and would require integration of beach sediment characteristics before an assessment could be made.

Heavy Minerals

The average THM content of the 70 samples in the study area is 0.49 weight percent (with a standard deviation, STD, of 0.30); the RHM content averages 0.40 weight percent (STD of 0.24) (Table 3). Table 4 summarizes values for THM and RHM for all samples and also according to depth interval (upper and lower core sections designated as -1 and -2 respectively).

Table 4. Data for total heavy minerals (THM) and recovered heavy minerals (RHM) tabulated for all samples, in the upper 1.5m sections and the lower 1.5m sections.

	All Samples (n=70)				Upper 1.5m Samples (n=70)				Lower 1.5m Samples (n=21)			
Variable	Min	Max	Avg	Std	Min	Max	Avg	Std	Min	Max	Avg	Std
Wt % RHM	0.01	1.06	0.40	0.24	0.01	1.05	0.43	0.24	0.02	1.06	0.35	0.24
Wt % THM	0.01	1.32	0.49	0.30	0.01	1.32	0.50	0.30	0.03	1.28	0.45	0.29

The heavy-mineral species present in these samples, in decreasing order of abundance are epidote, ilmenite, alumino-silicates, zircon, staurolite, rutile, garnet, pyroboles, tourmaline, monazite and others (including phosphorite, sulfides, unidentified opaques, quartz, and coated grains).

The economic heavy minerals (EHM) in the study area consist of ilmenite (including altered ilmenite), rutile, zircon, monazite, and aluminosilicates. Monazite, however, is present in very small quantities and does not substantially affect EHM values. Ilmenite is the most abundant economic heavy mineral present comprising about 29 percent (STD of about 6) of the heavy minerals. Zircon comprises about 6 percent (STD of about 2.5), rutile about 3 percent (STD of about 1) and aluminosilicates about 13 percent (STD of about 4) of the heavy minerals (Table 3). In this study, 52.7 percent of the heavy-mineral assemblage in the concentrate consists of EHM (EHM/C, Table 3); on a bulk sample basis, however, the sediments contain only about 0.2 percent (STD of about 0.12) EHM (EHM/T, Table 3).

The distribution of THM values for upper and lower core sections is shown in Figures 14-16. Map 1 has three main areas of sample concentration (Figure 14). The northernmost region near Fernandina Beach has a total of 22 samples with an average of 0.55 weight percent heavy THM. The linear array of samples in the middle of the map averages 0.47 weight percent THM for 5 samples. The cluster of 15 samples offshore of St. Augustine at the south end of the map has the highest THM values in the entire study area, 0.61 weight percent.

Map 2 has a total of 17 samples with an average of 0.37 weight percent THM (Figure 15). The 5 samples on Map 3 continue the regional trend of southerly decreasing THM values, averaging 0.24 weight percent (Figure 16).

While the overall heavy-mineral suite is the same here as in the Cape Canaveral area, there are a number of differences. Both RHM and THM values are higher. The RHM and THM values offshore of Cape Canaveral average 0.18 and 0.27 weight percent respectively (Grosz et al., 1989; Nocita et al., 1990), while in the area of this study RHM and THM values average 0.40 and 0.49 percent. Epidote, ilmenite, and aluminosilicates are less abundant in the Cape Canaveral region than on the shelf to the north. Zircon, pyroboles, staurolite, tourmaline, rutile and

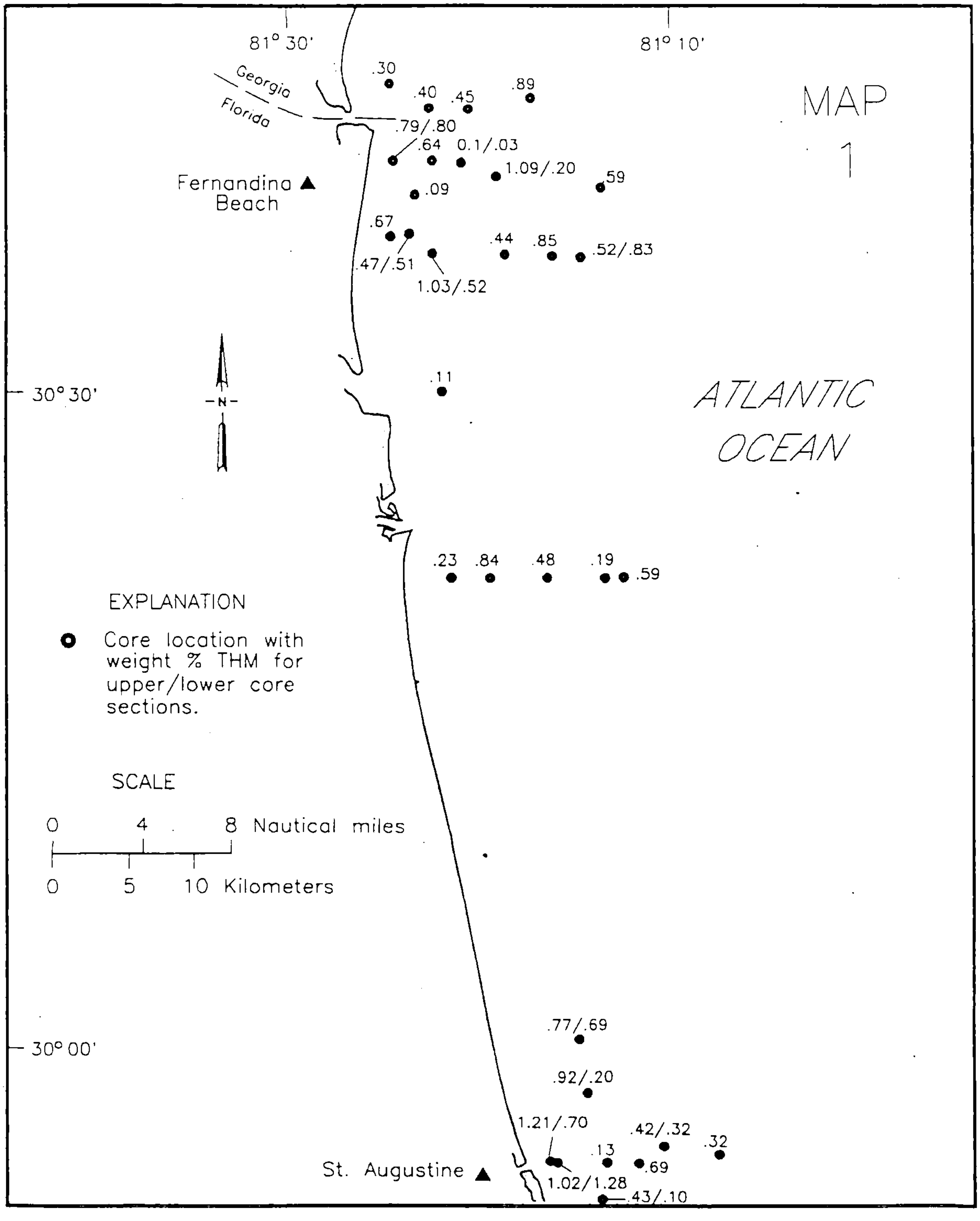

Fig. 14. Distribution of heavy minerals given as THM, for upper/lower core sections in Map area 1.

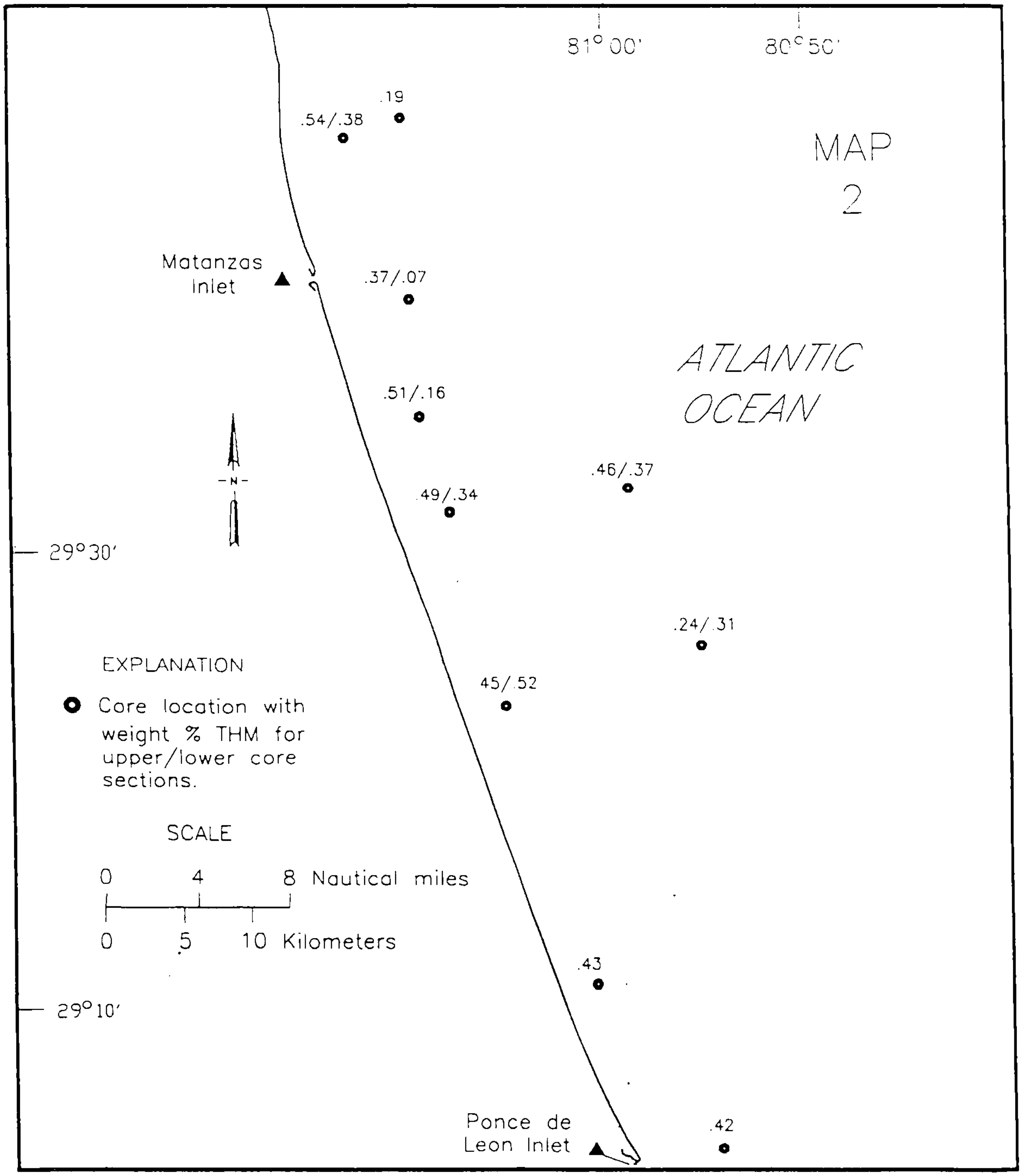

Fig. 15. Distribution of heavy minerals given as THM, for upper/lower core sections in Map area 2.

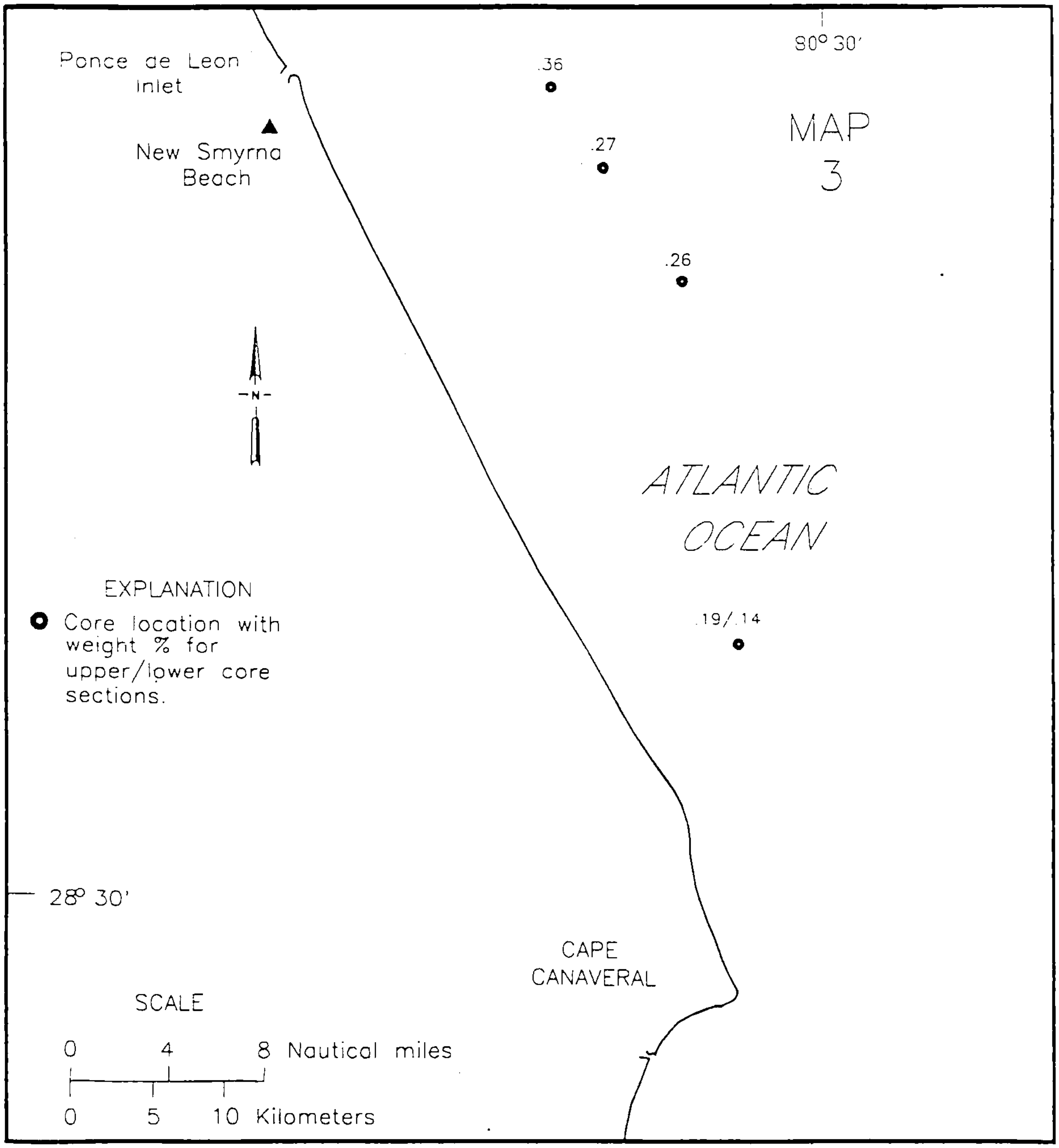

Fig. 16. Distribution of heavy minerals given as THM, for upper/lower core sections in Map area 3.

garnet are more abundant in the Cape area. The combined effects of sediment supply and reworking are complex and the widely spaced samples in this study preclude definitive explanations of these trends.

CONCLUSIONS

Sand and shell-gravel deposits may locally be suitable for beach nourishment where they have low mud contents. The best sites for borrow material are offshore of St. Augustine and Fernandina Beach. Additional studies are needed to quantify their thickness and lateral extent.

The heavy-mineral assemblage in sediments of the study area consists dominantly of epidote, ilmenite, aluminosilicates, pyroboles and zircon. The assemblage is similar to suites found offshore of Cape Canaveral (Grosz and others, 1989; Nocita and others, 1989, 1990) and offshore of Jacksonville, Florida and South Carolina, as deduced from grab sample analyses (Grosz and Escowitz, 1983).

As was found offshore of Cape Canaveral, absolute abundances of heavy minerals in sediments offshore of Florida's east coast are almost an order of magnitude lower, on the average, than in onshore economic deposits such as Trail Ridge and Green Cove Springs. The reconnaissance results show a very low potential for detrital heavy-mineral resources in sediments offshore Florida's east coast even though the trend suggests increasing abundances to the north of Cape Canaveral.

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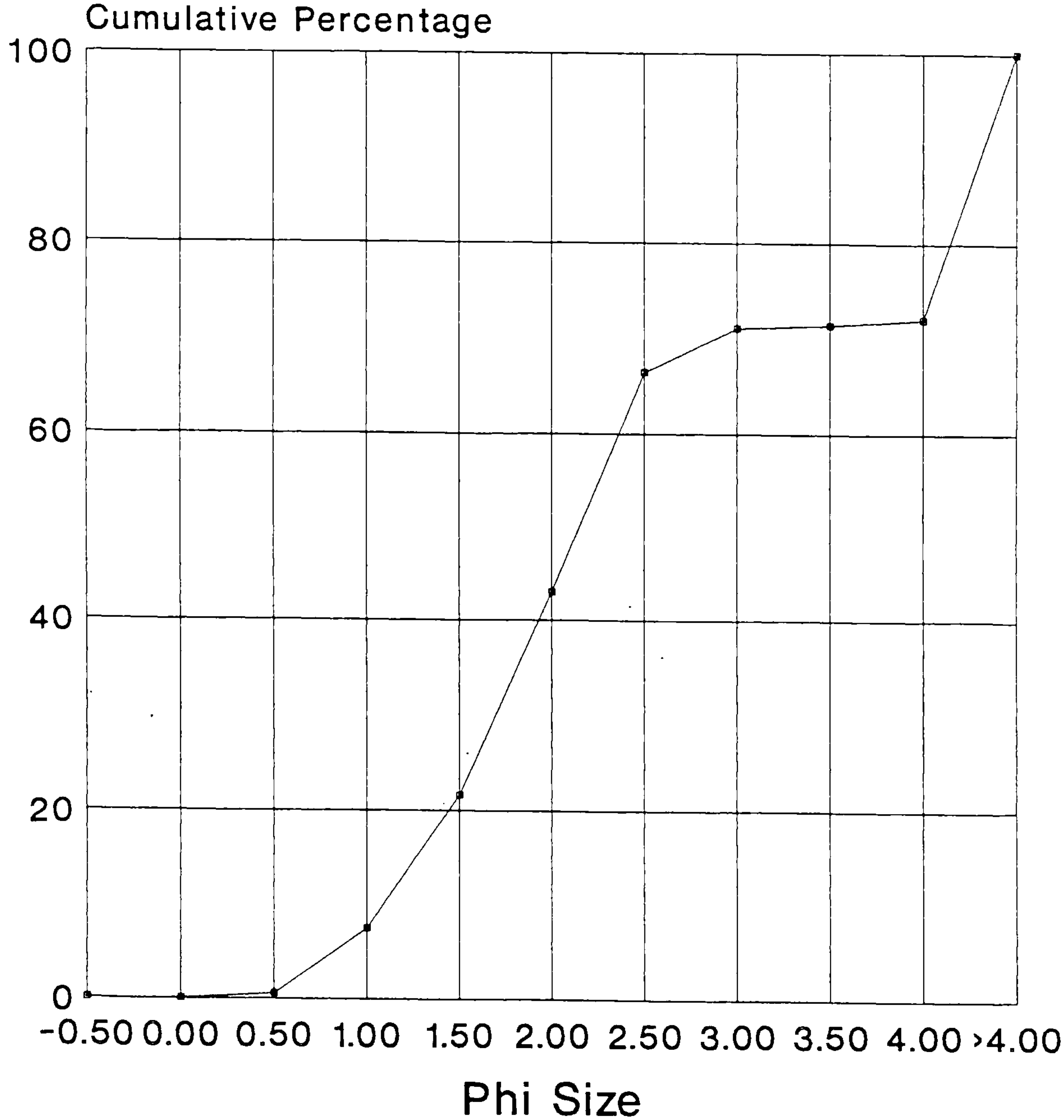
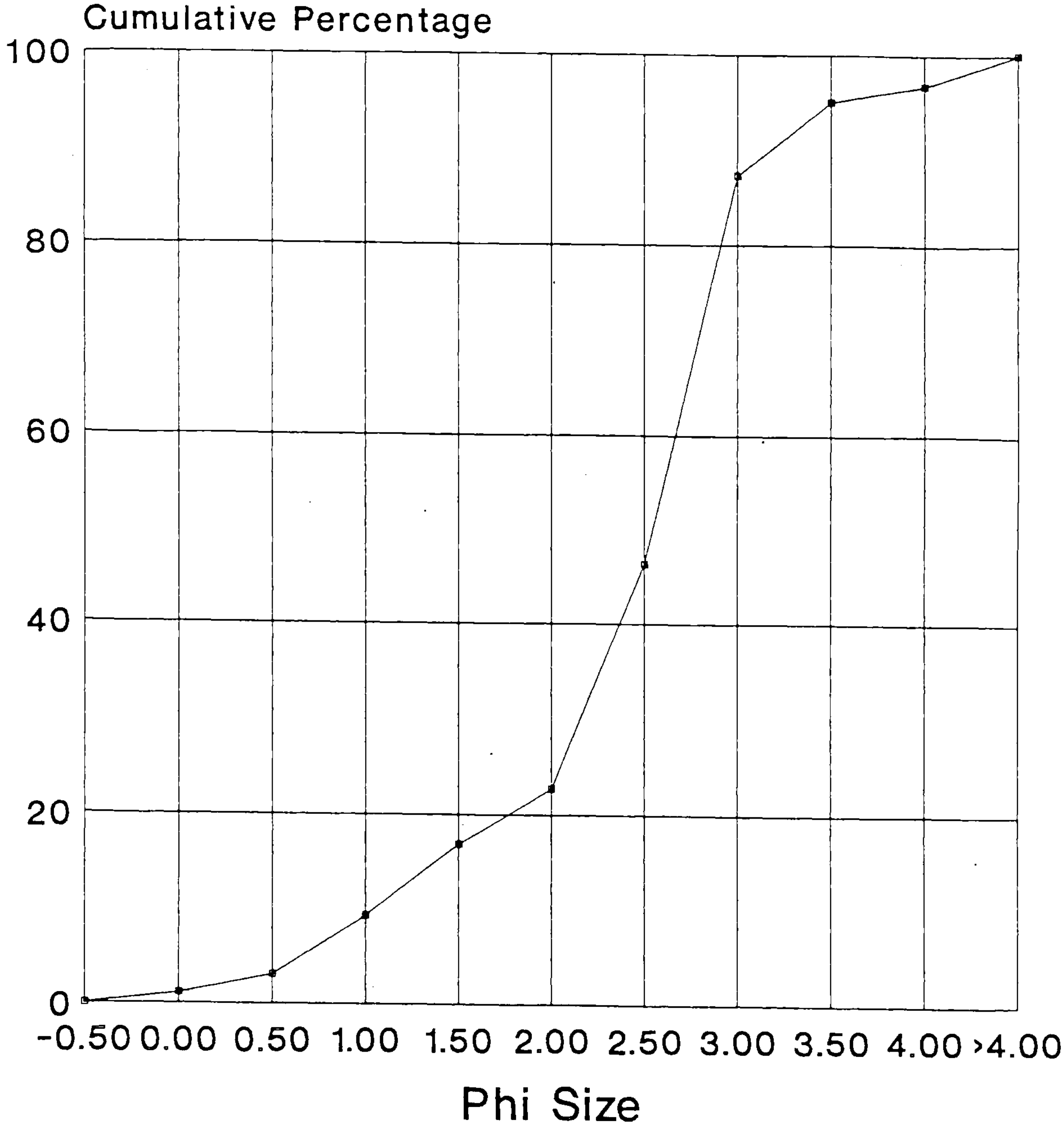
APPENDIX I

Grain Size Analysis
Sample U.S.G.S. 96-1



Grain Size Analysis

Sample U.S.G.S. 96-2



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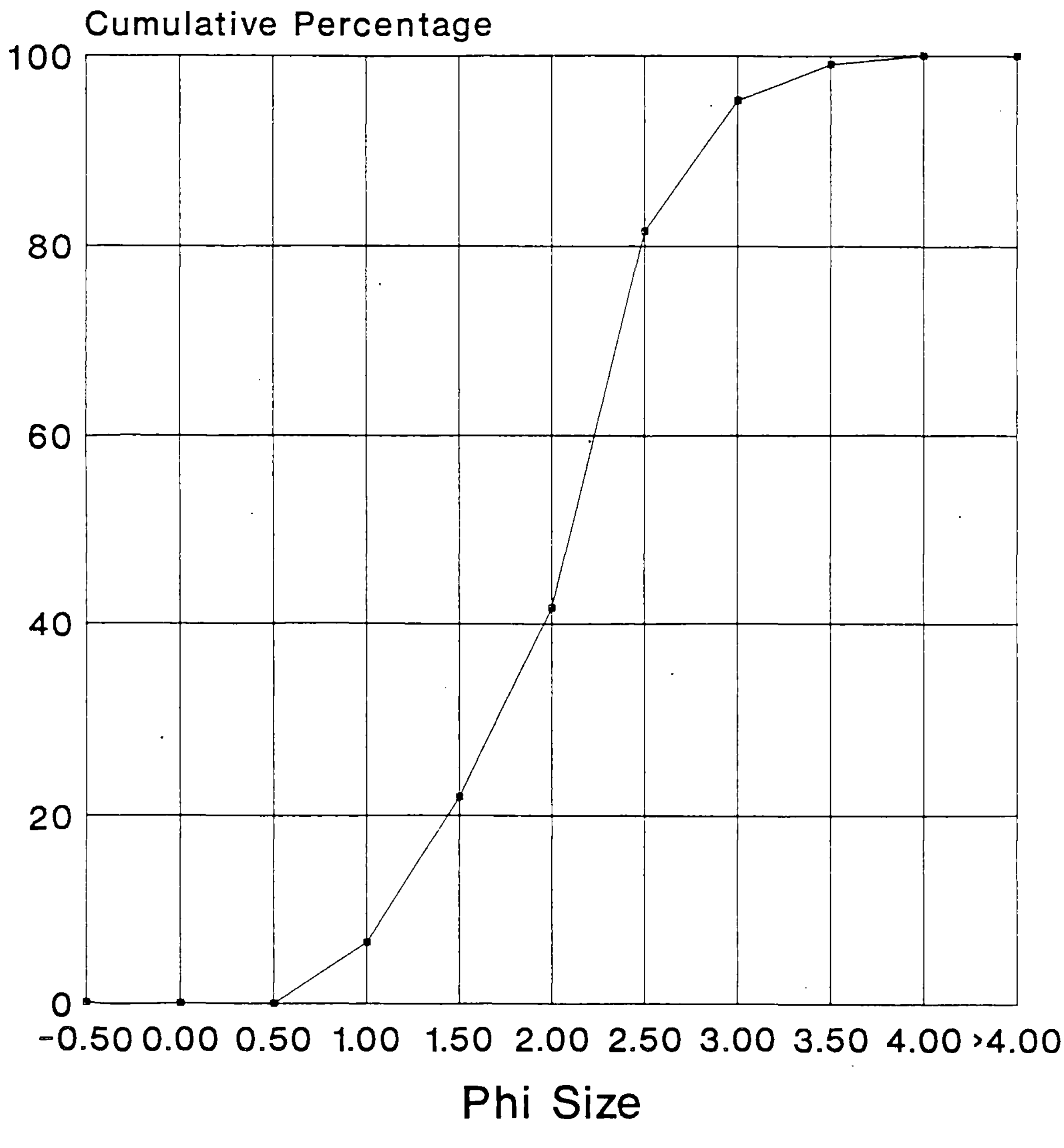

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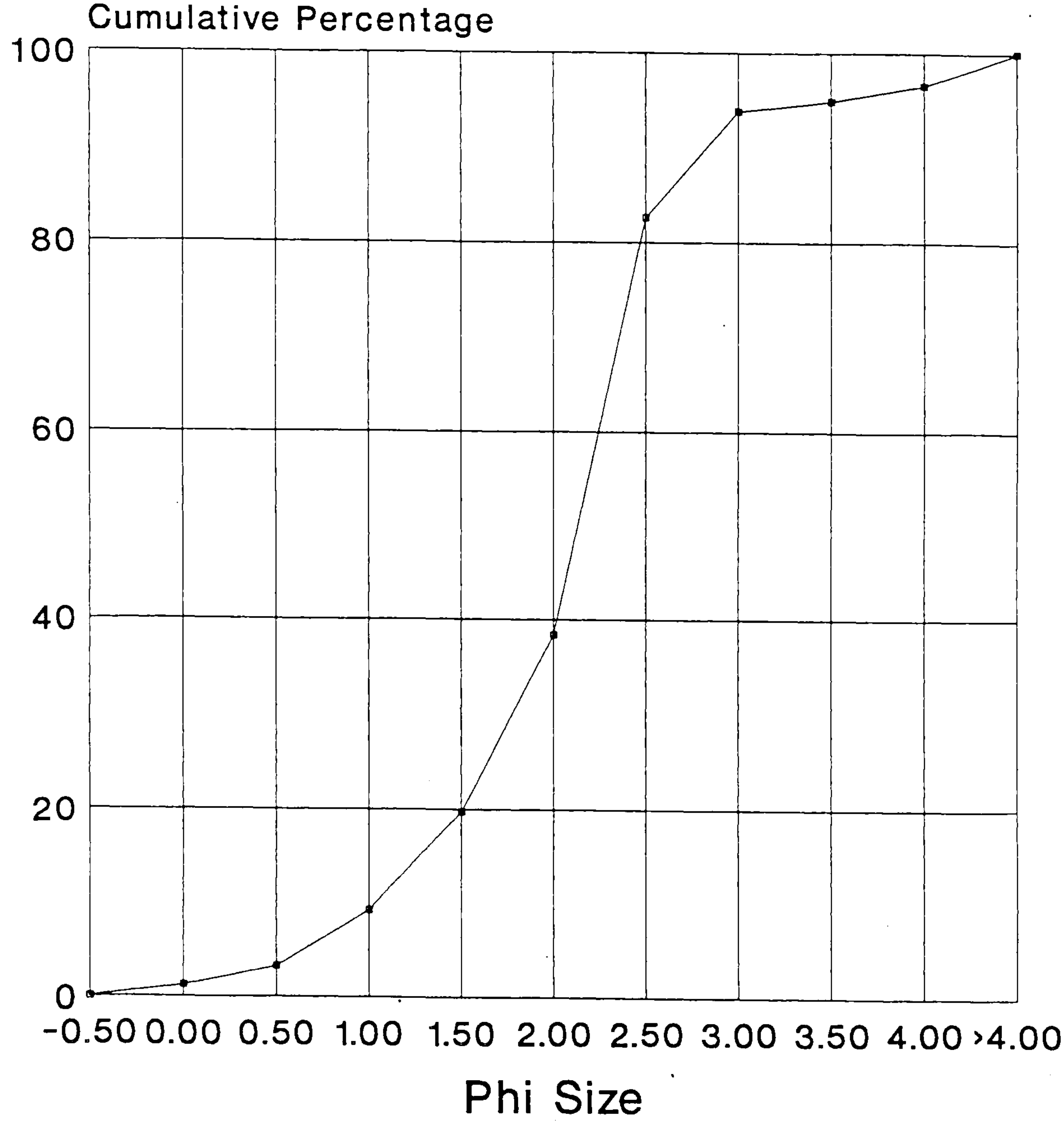

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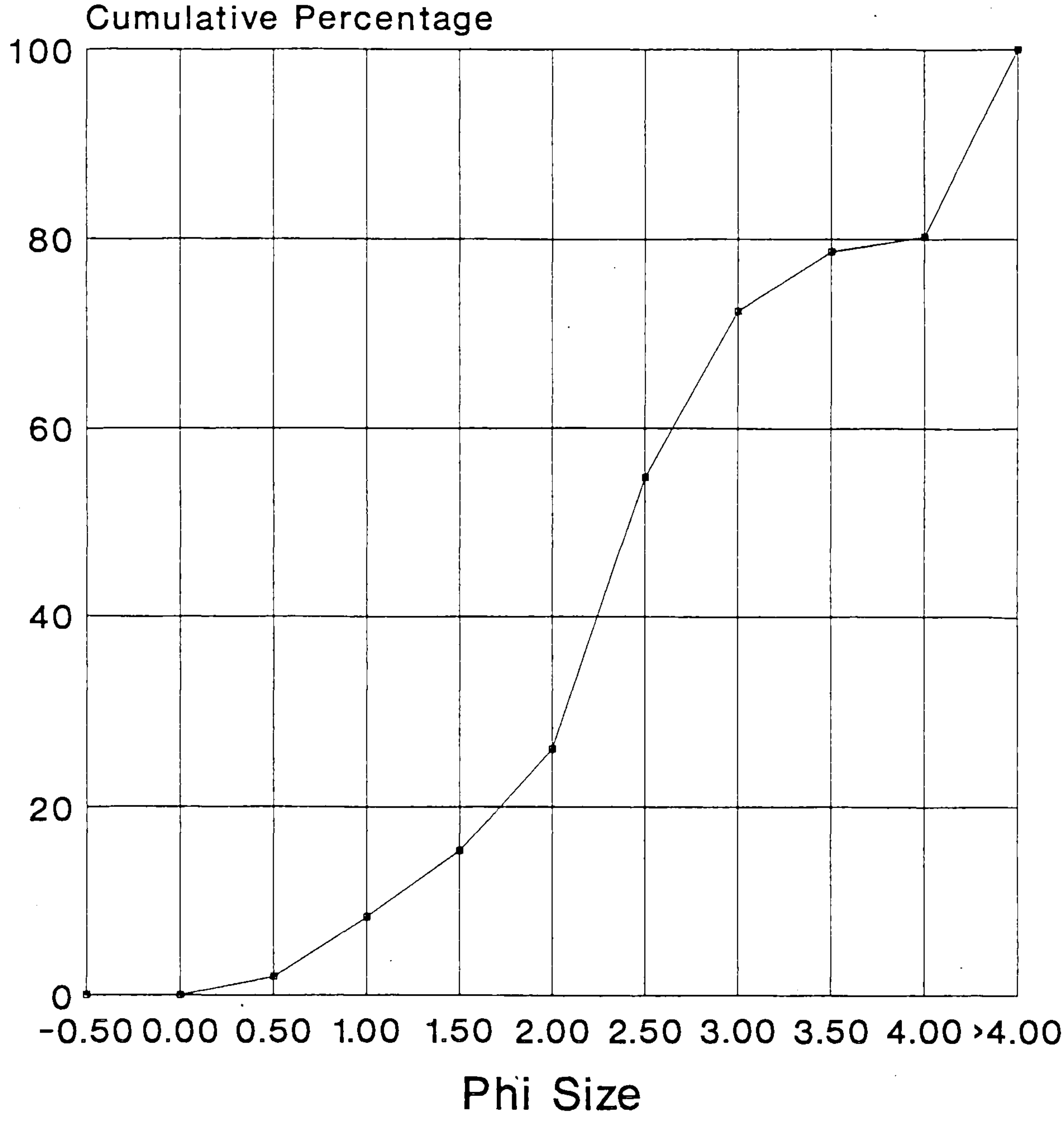
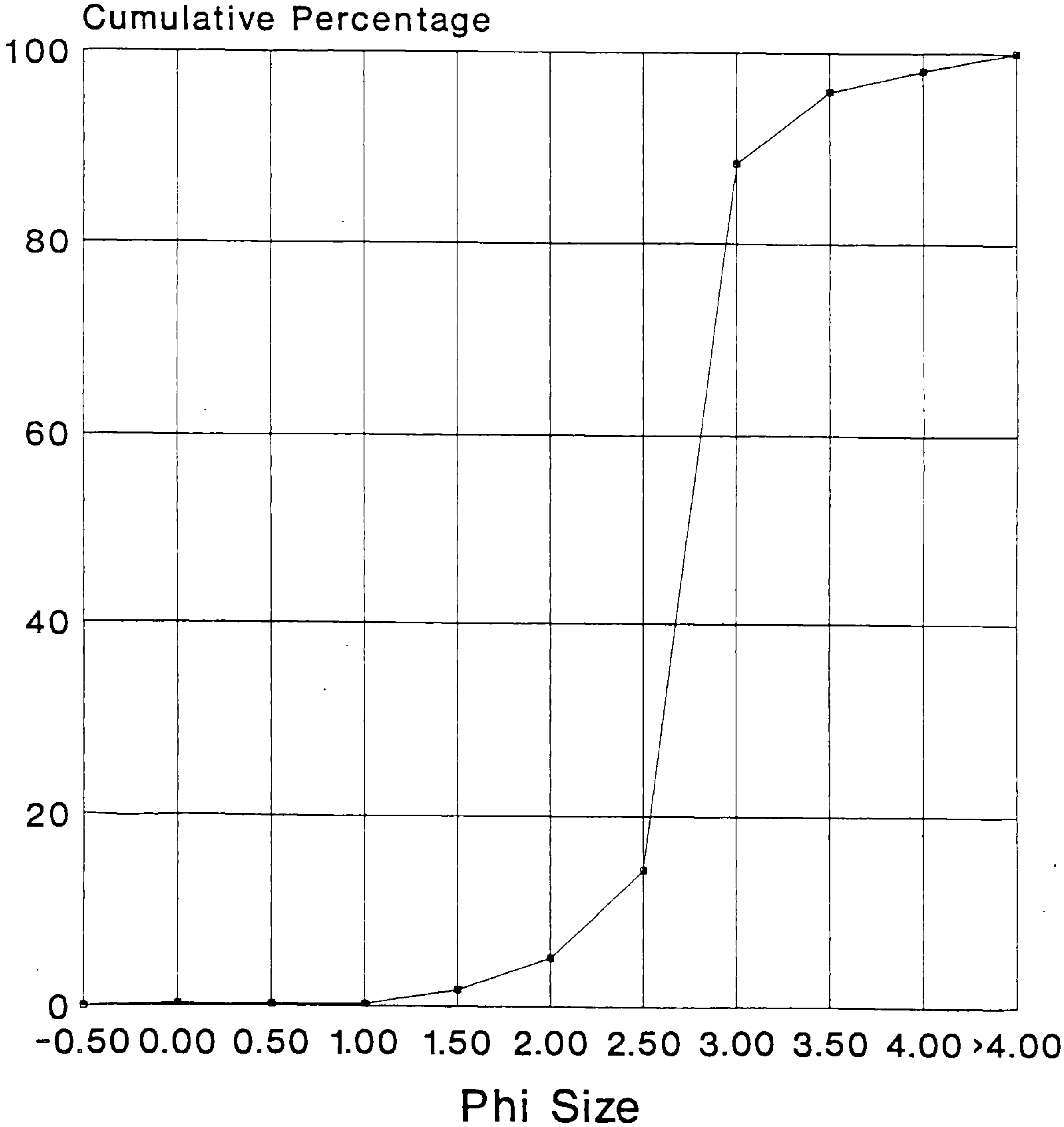
Sample U.S.G.S. 109

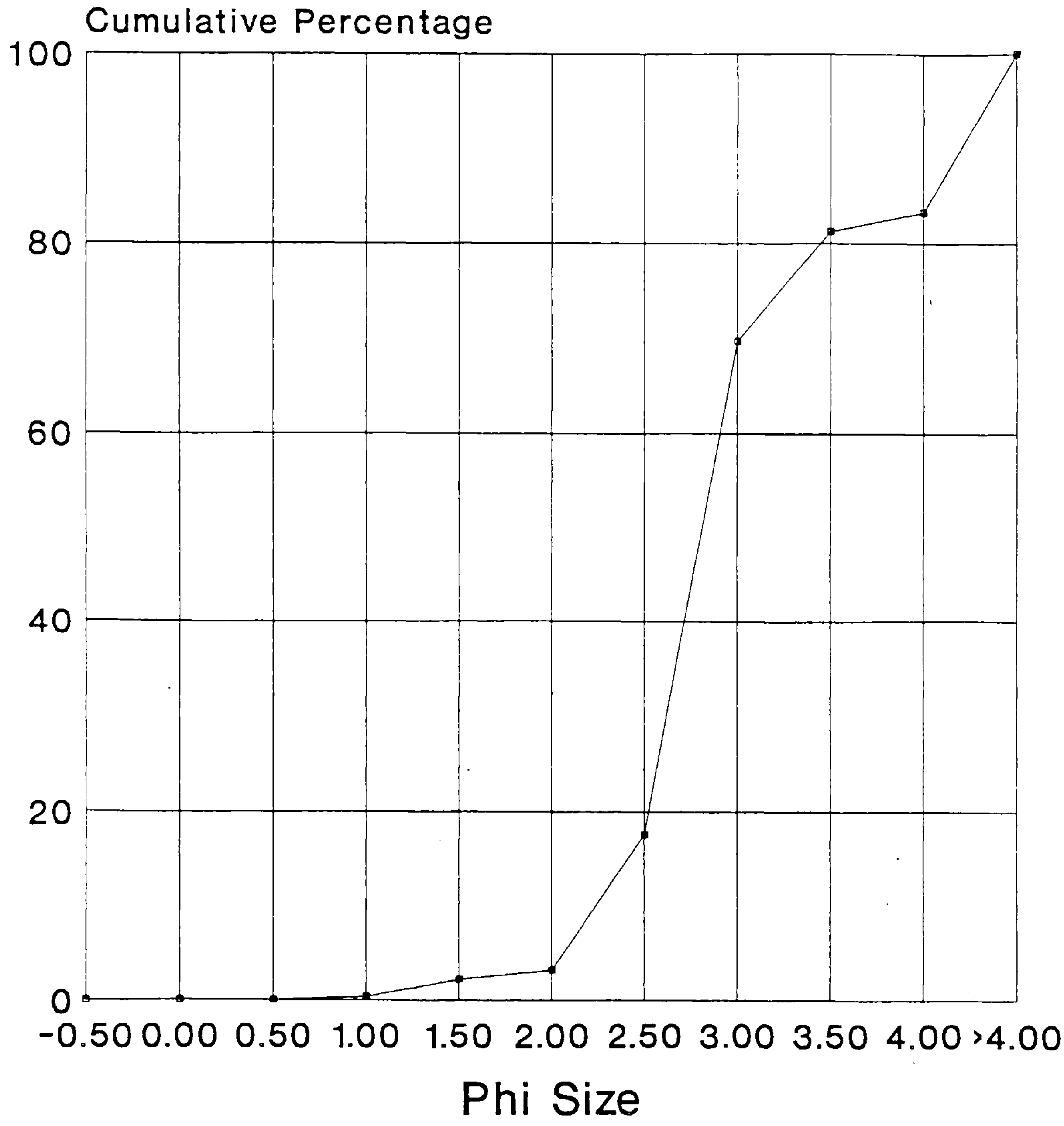


Grain Size Analysis
Sample U.S.G.S. 811-1

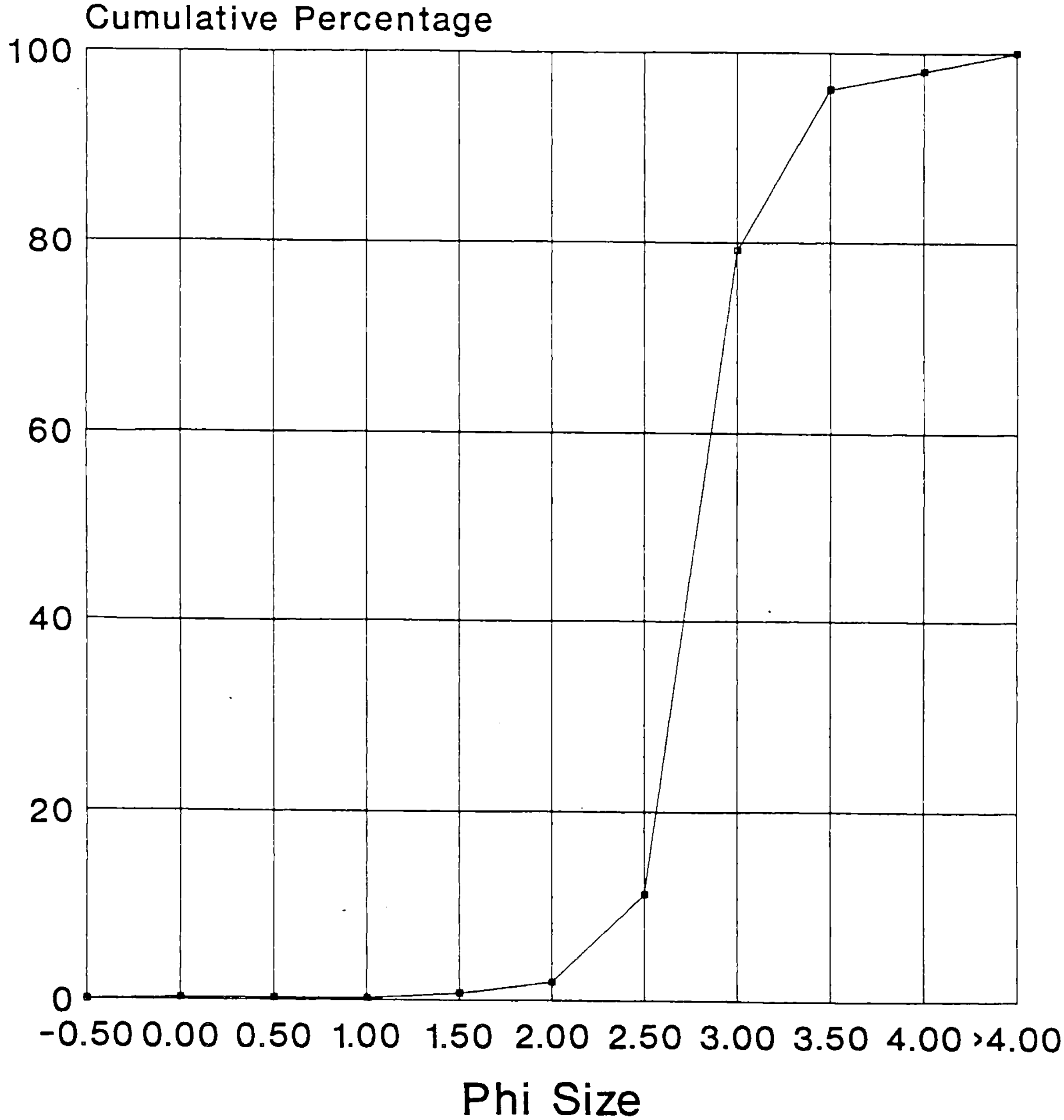


Grain Size Analysis

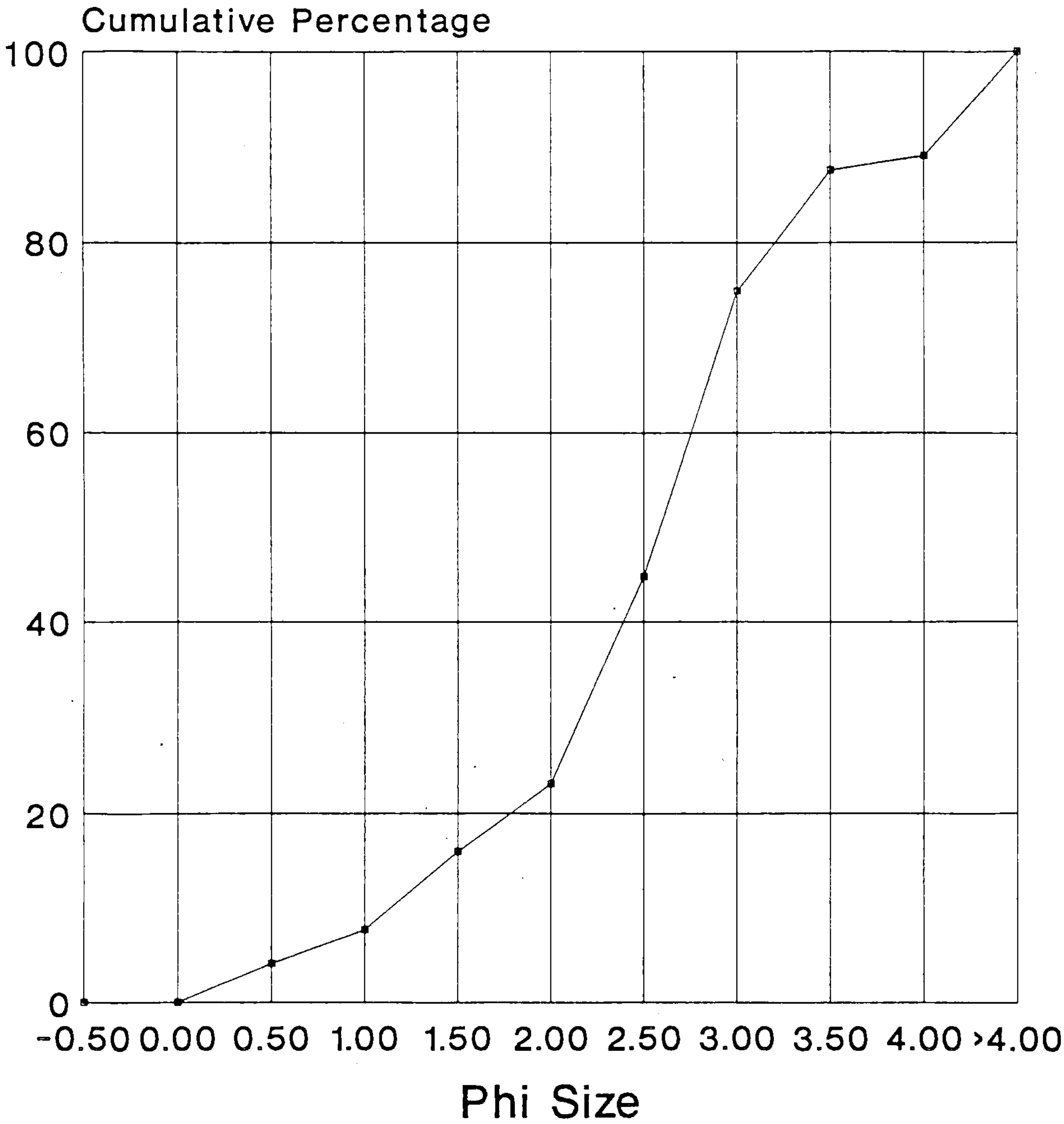
Sample U.S.G.S. 811-2



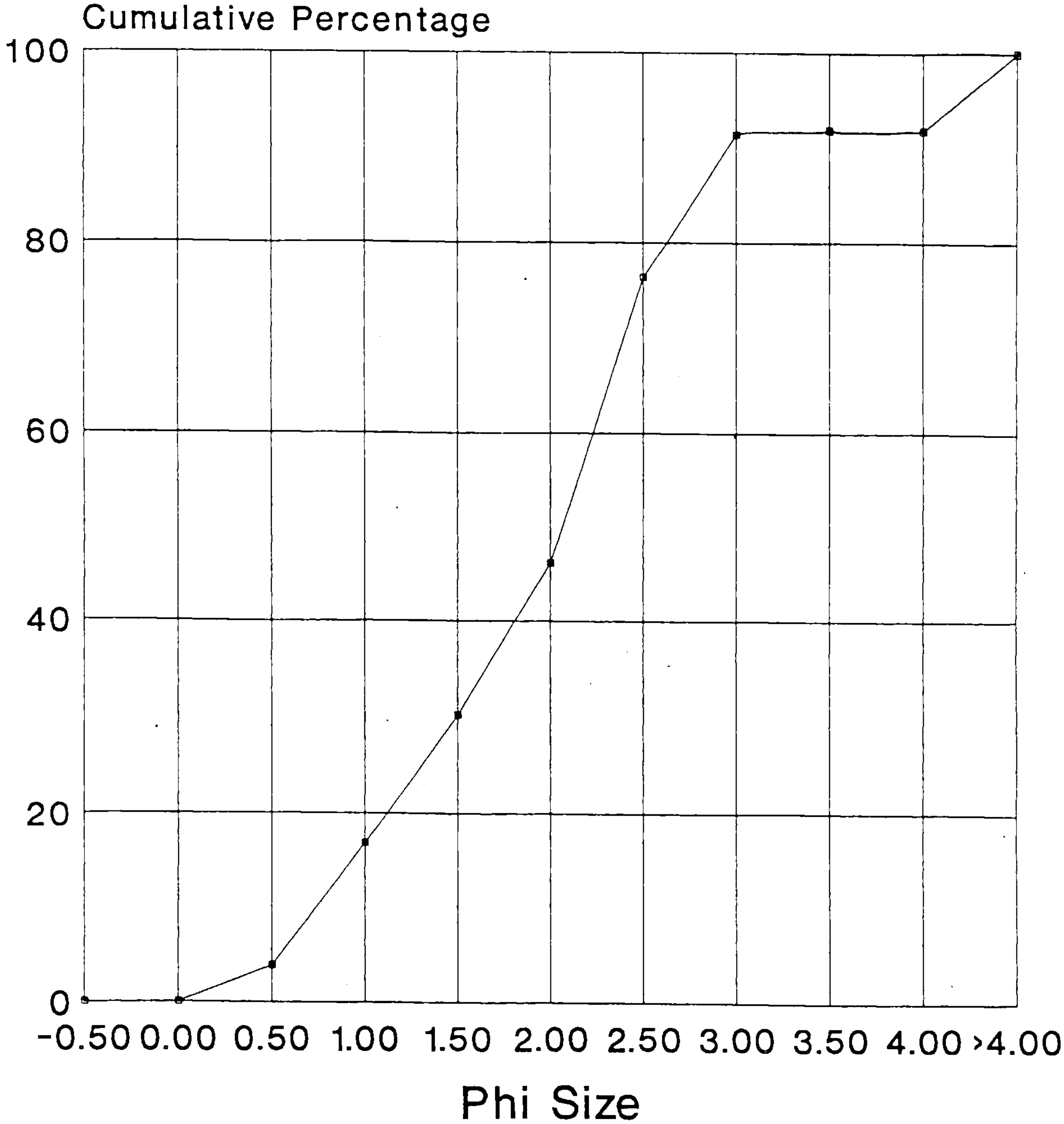
Grain Size Analysis
Sample U.S.G.S. 813



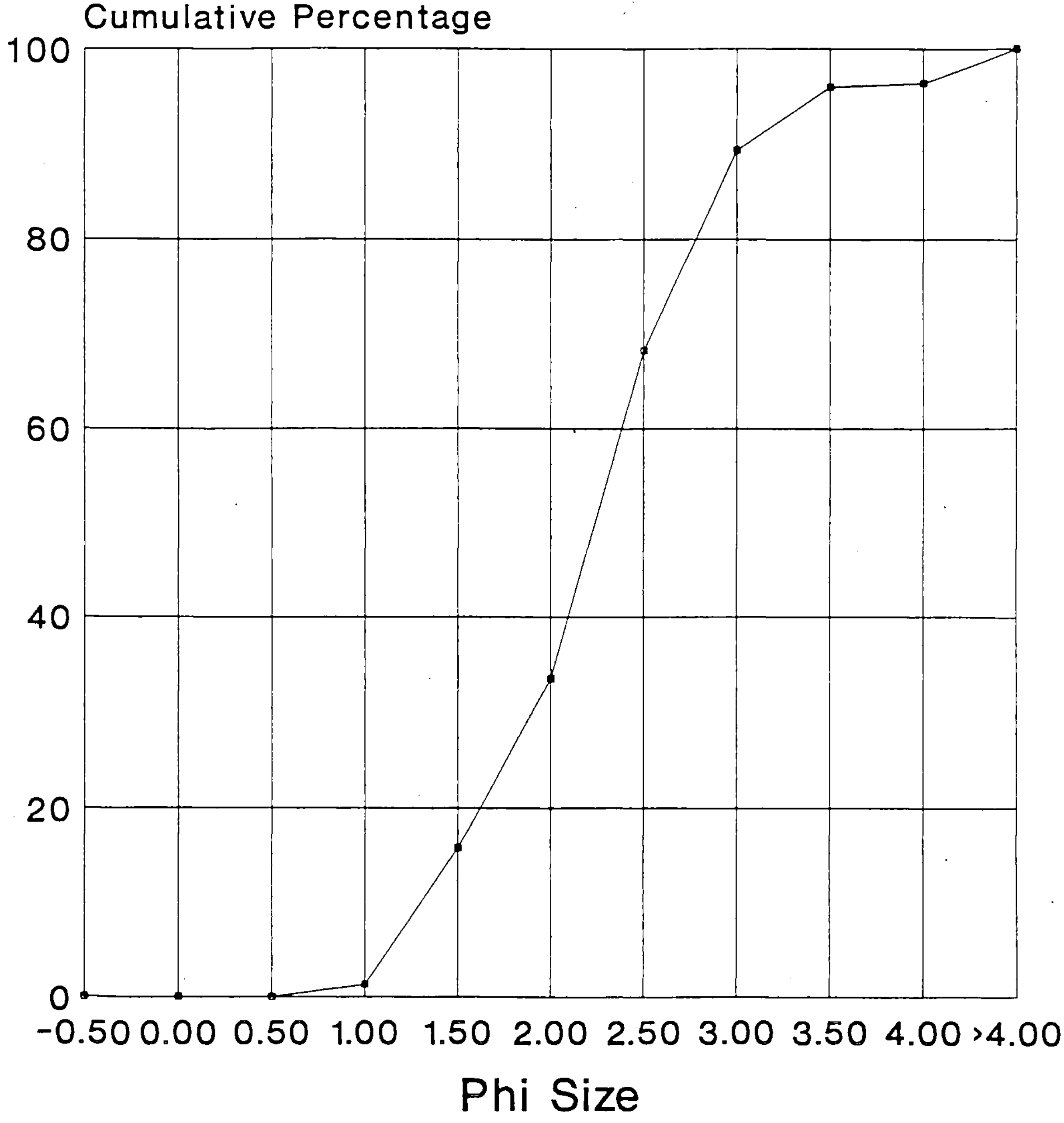
Grain Size Analysis
Sample U.S.G.S. 815



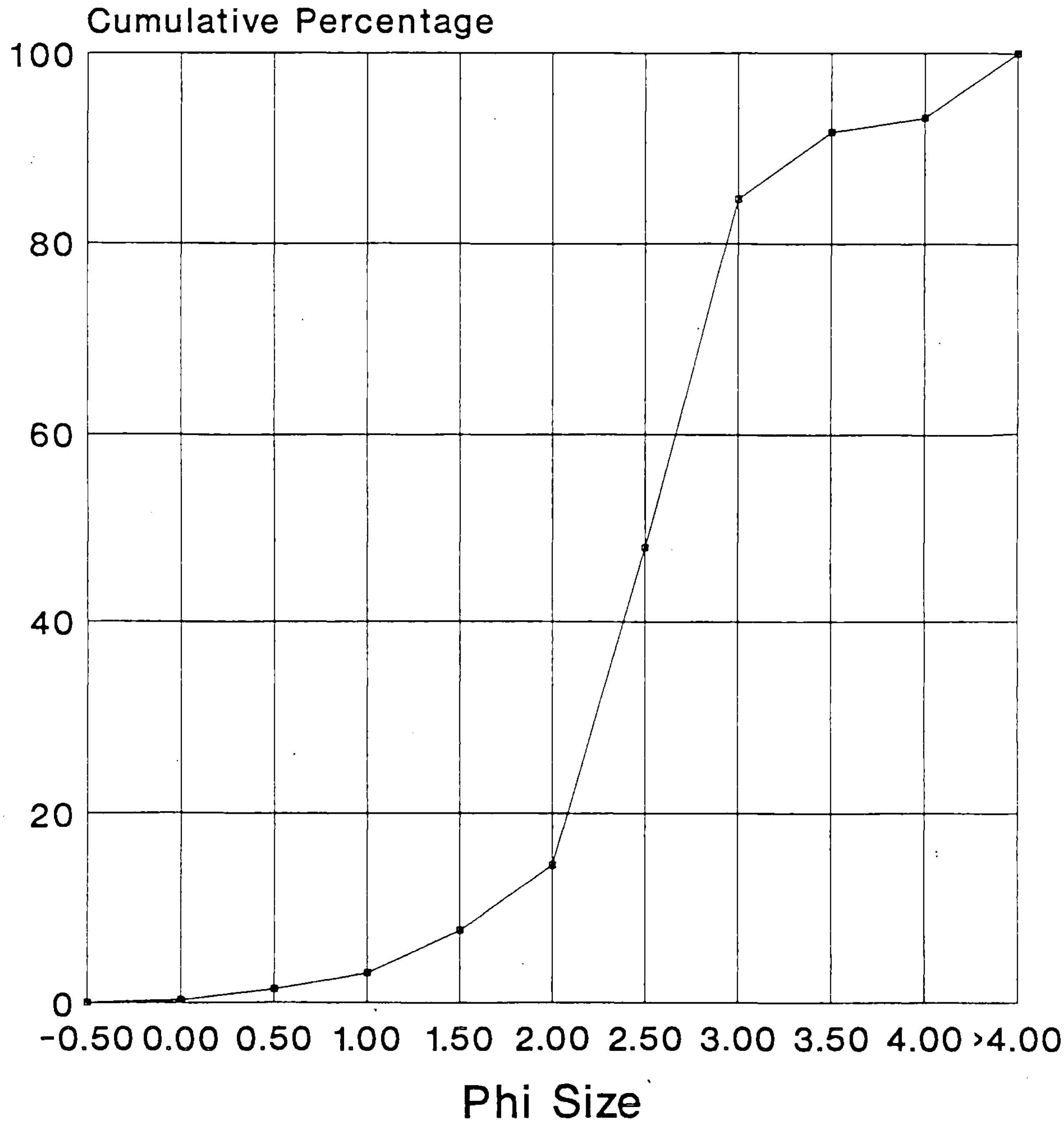
Grain Size Analysis
Sample U.S.G.S. 817-1



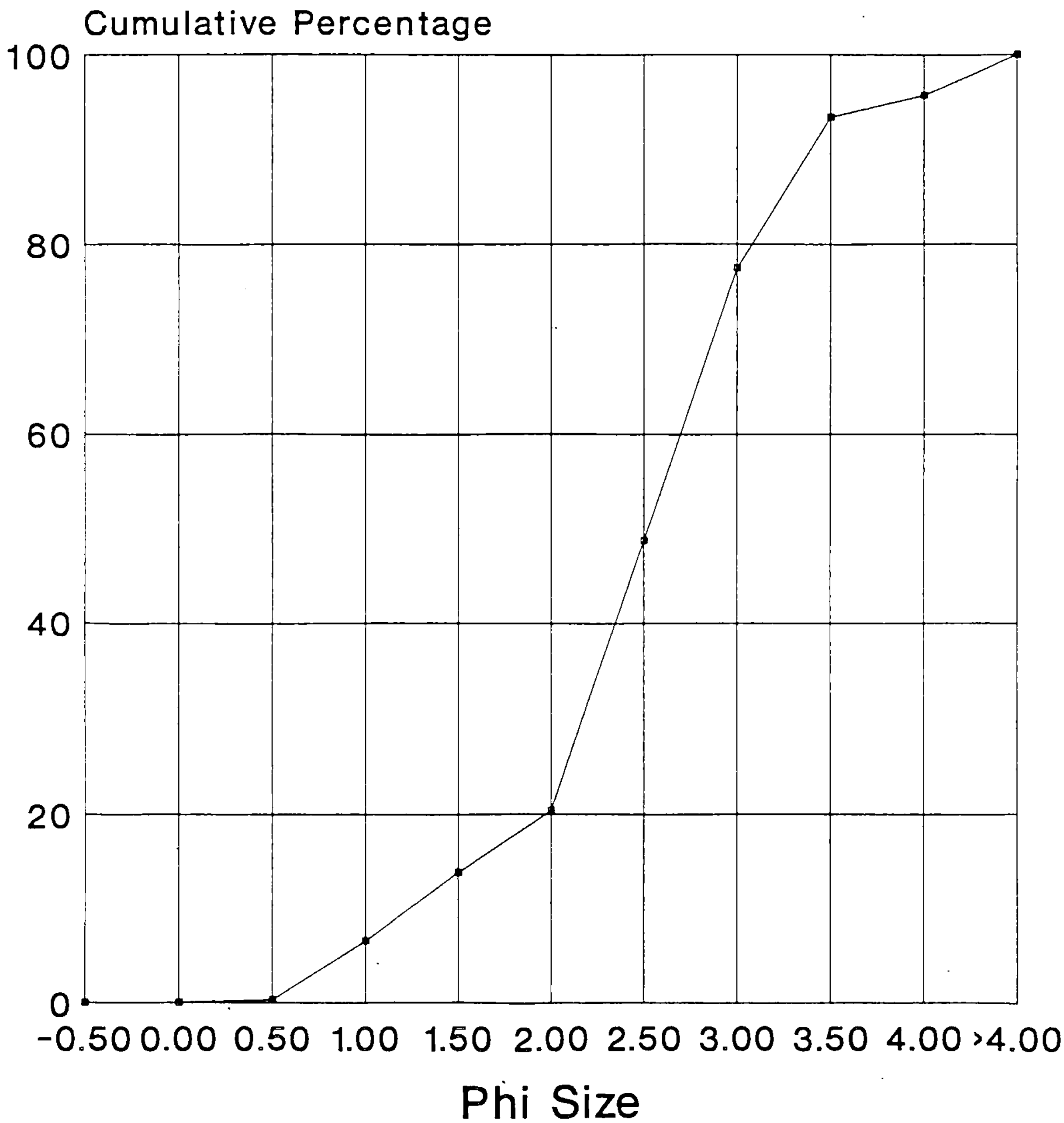
Grain Size Analysis
Sample U.S.G.S. 817-2



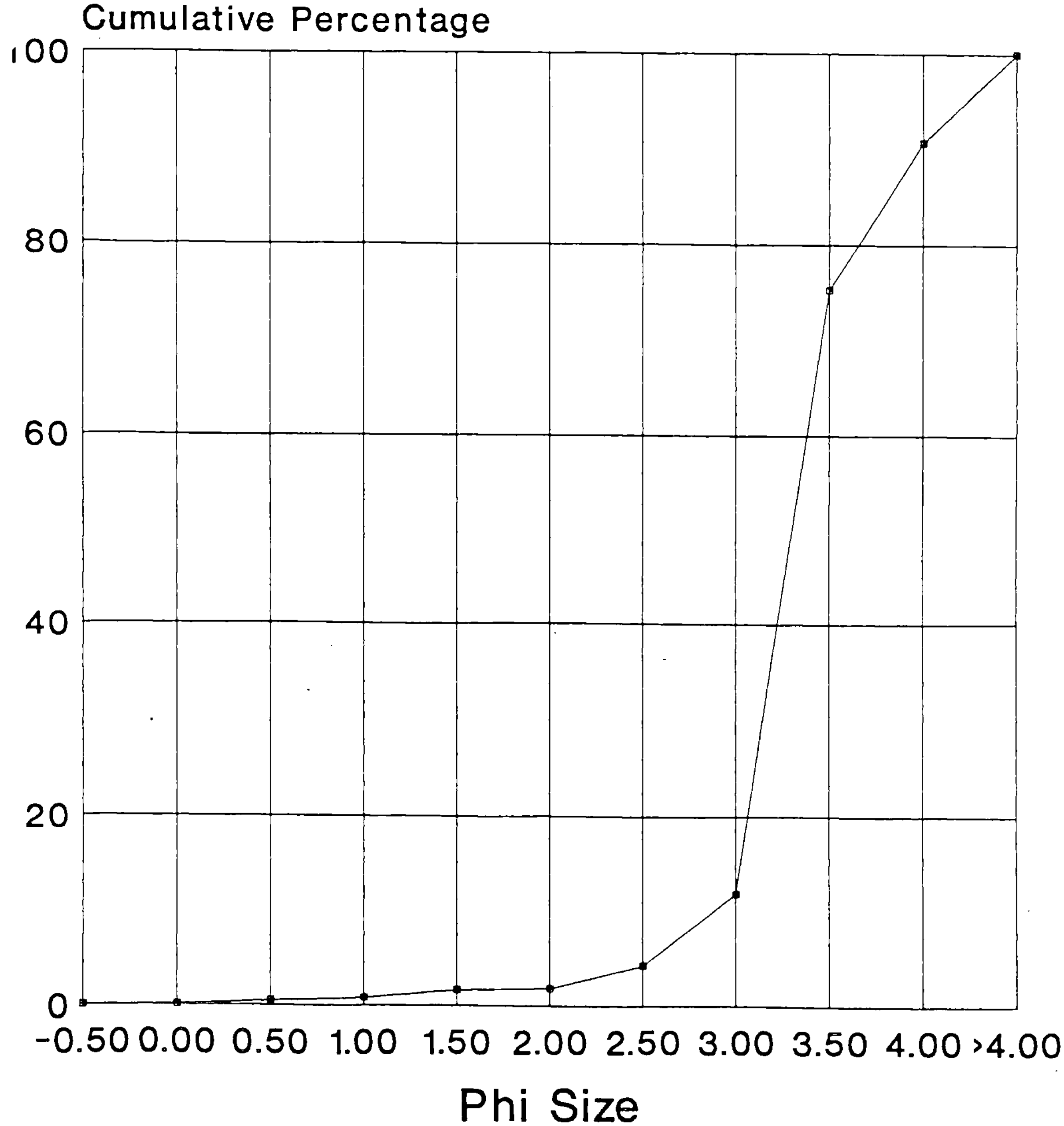
Grain Size Analysis
Sample U.S.G.S. 819



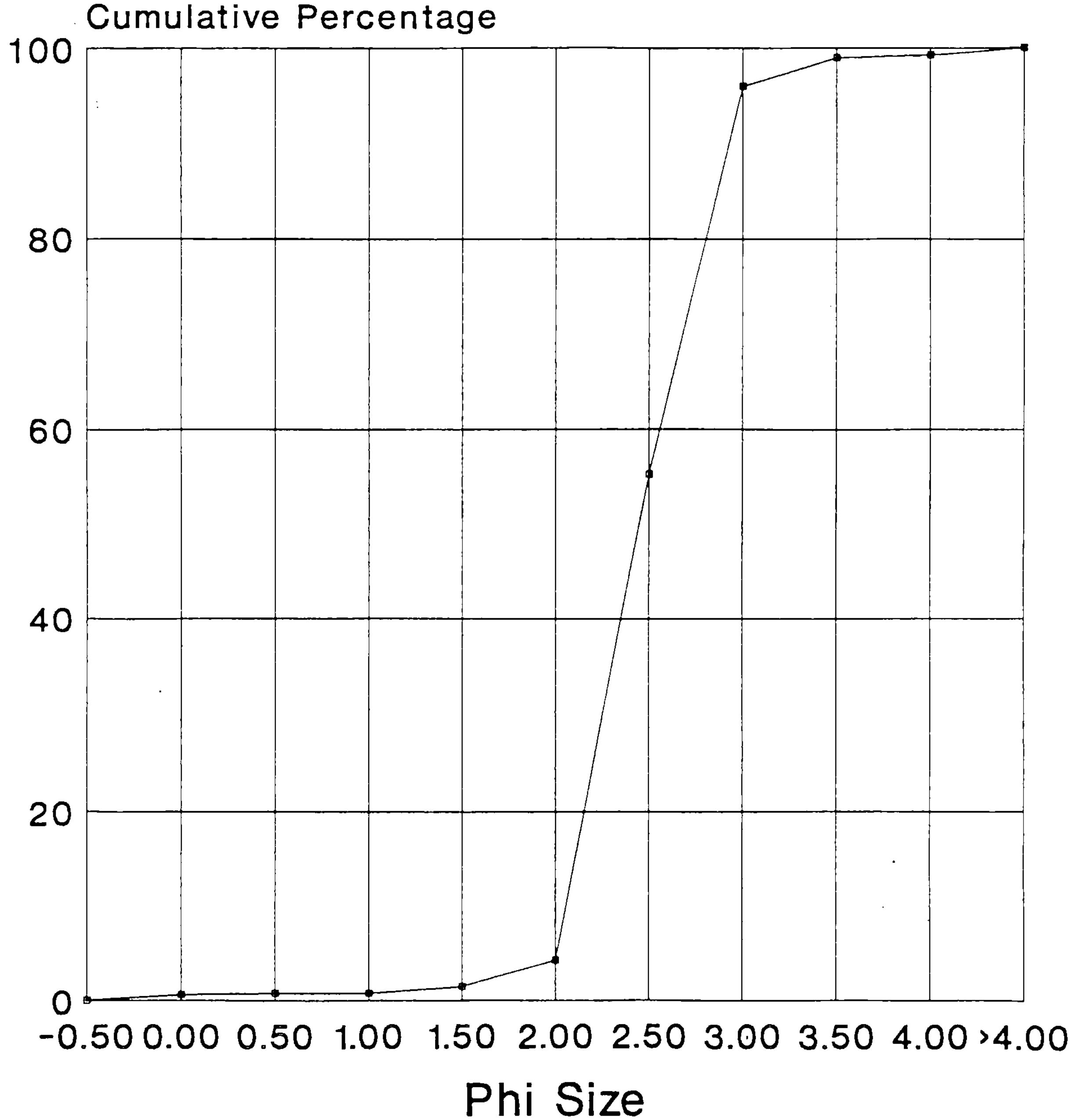
Grain Size Analysis
Sample U.S.G.S. 821-1



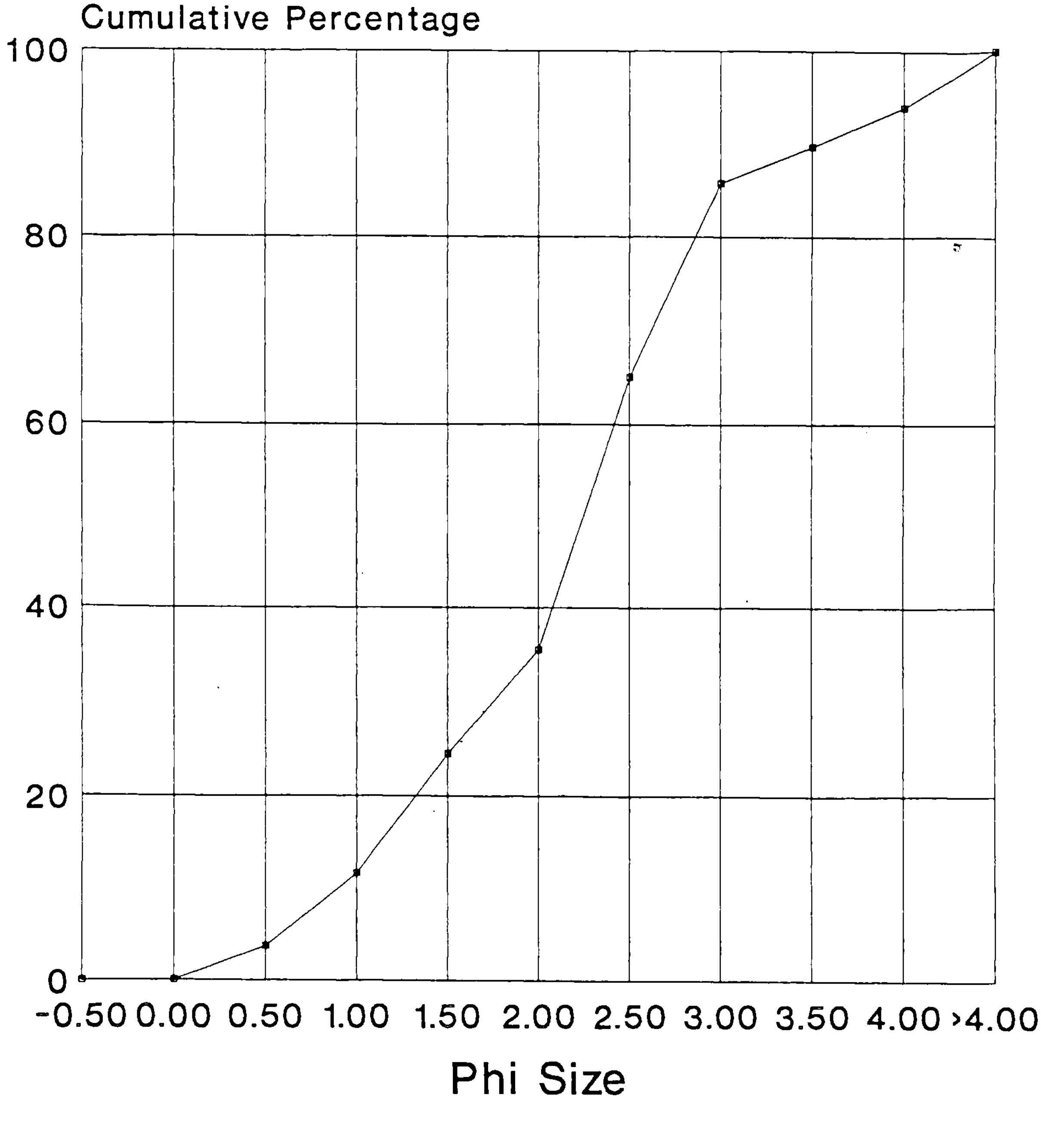
Grain Size Analysis
Sample U.S.G.S. 821-2



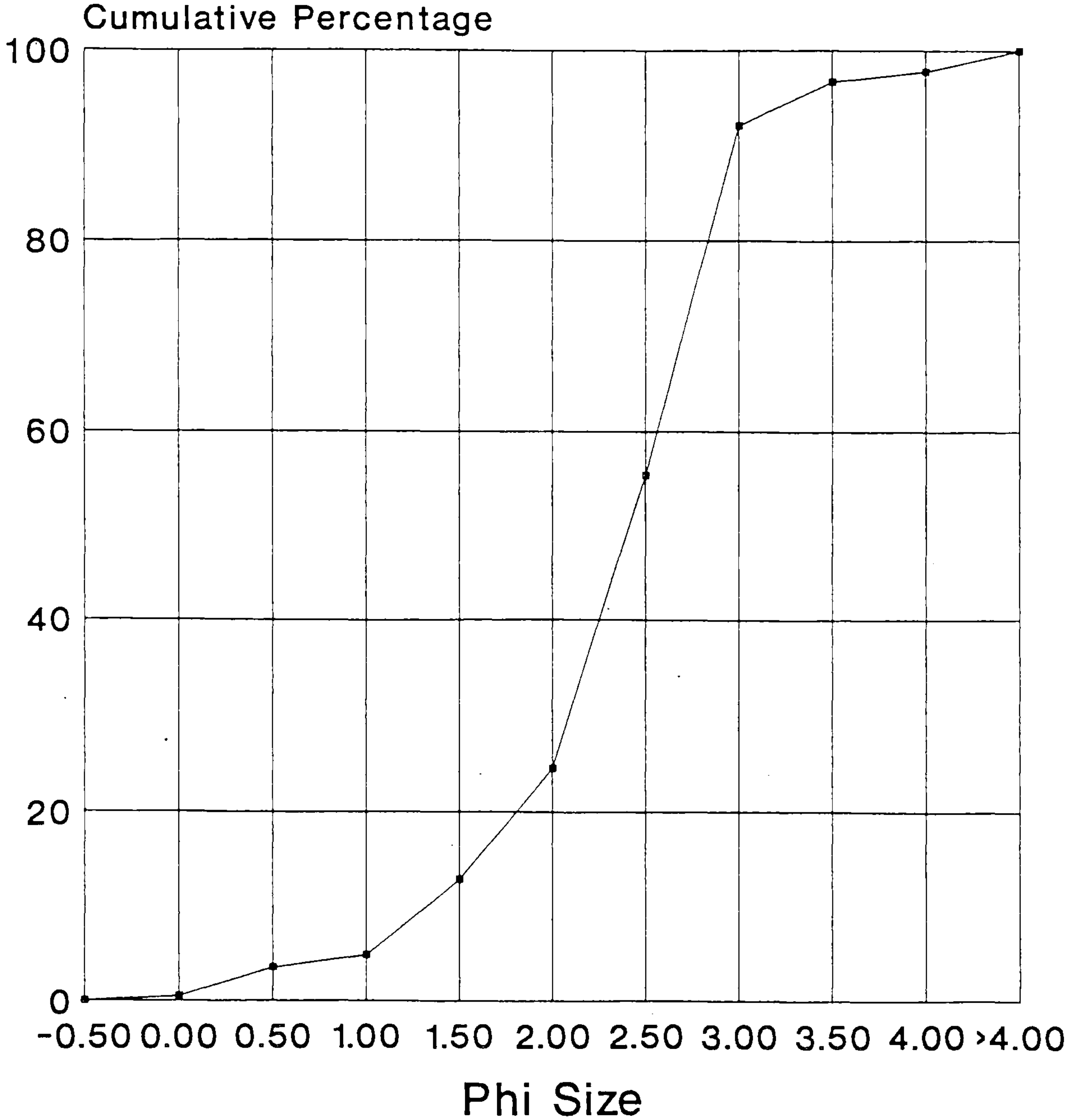
Grain Size Analysis
Sample U.S.G.S. 823



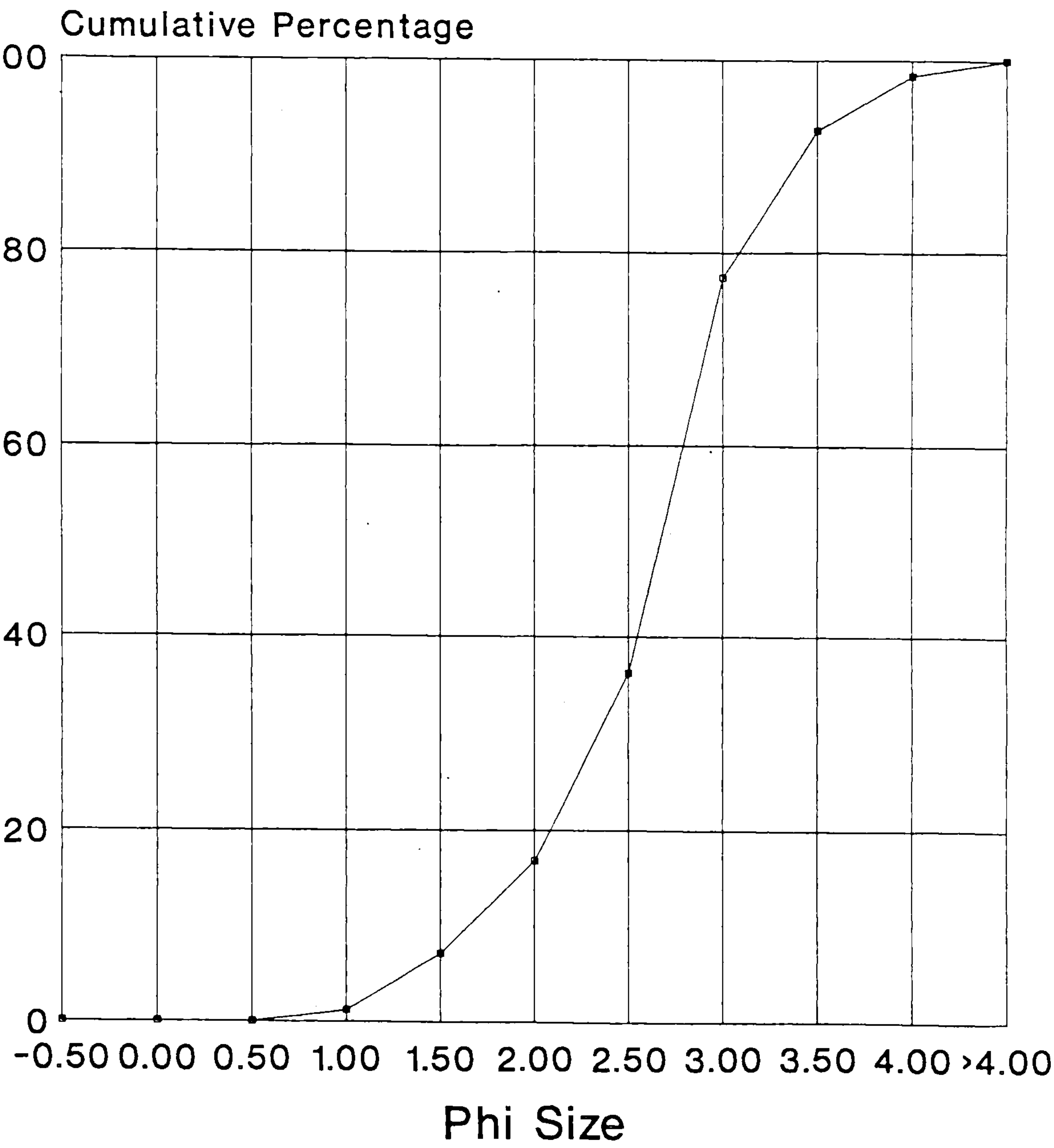
Grain Size Analysis
Sample U.S.G.S. 824



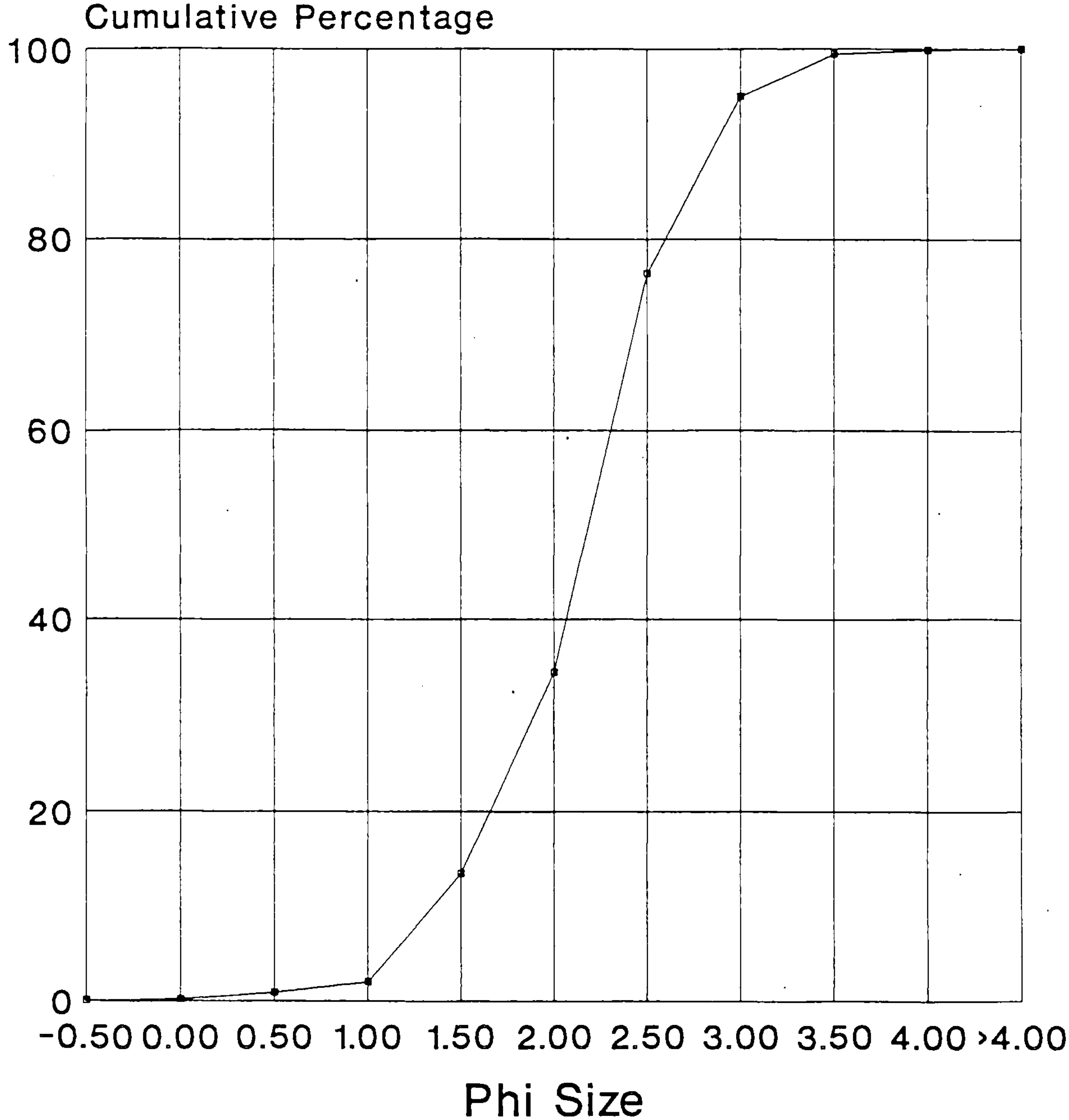
Grain Size Analysis
Sample U.S.G.S. 827



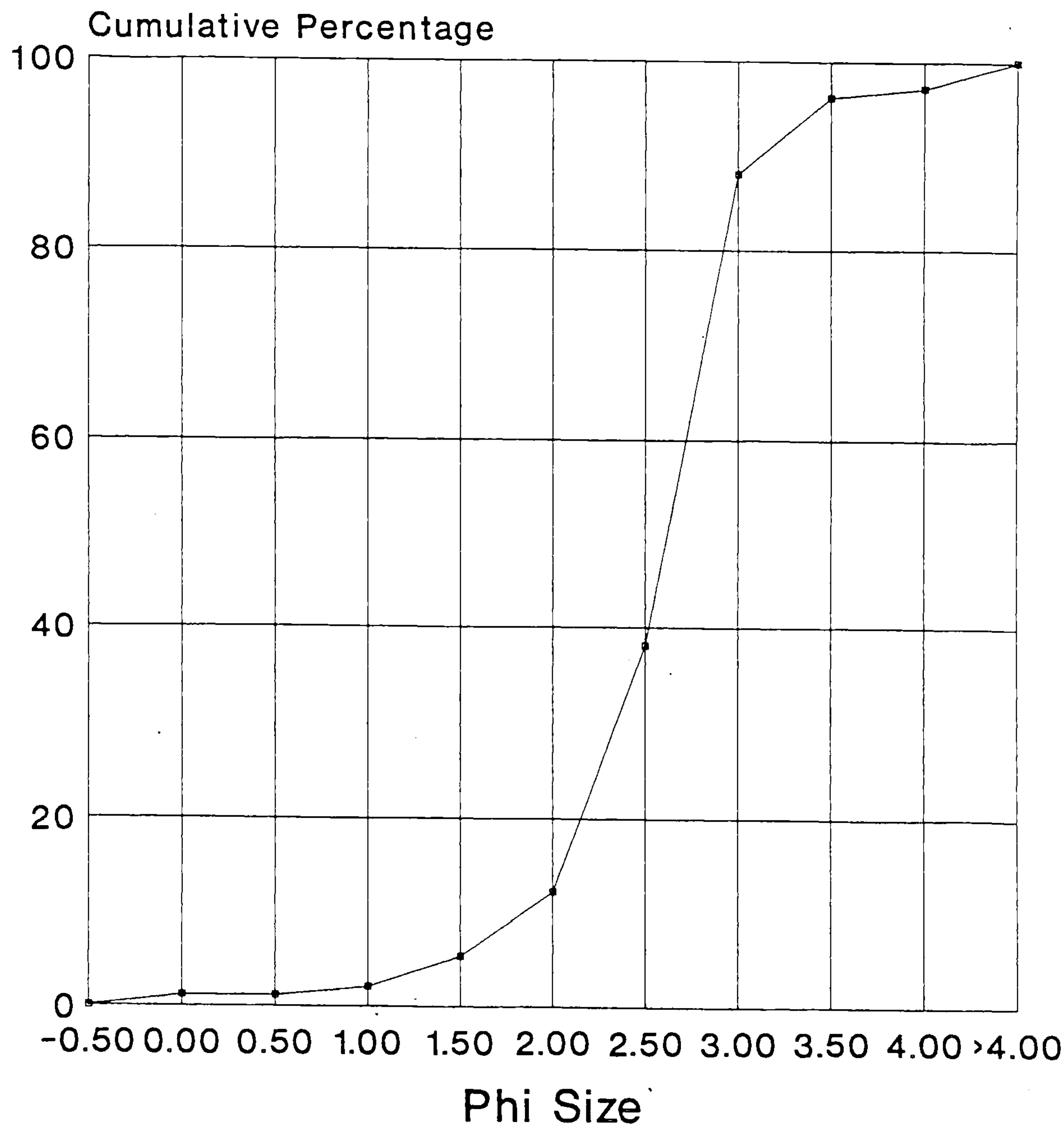
Grain Size Analysis
Sample U.S.G.S. 830-1



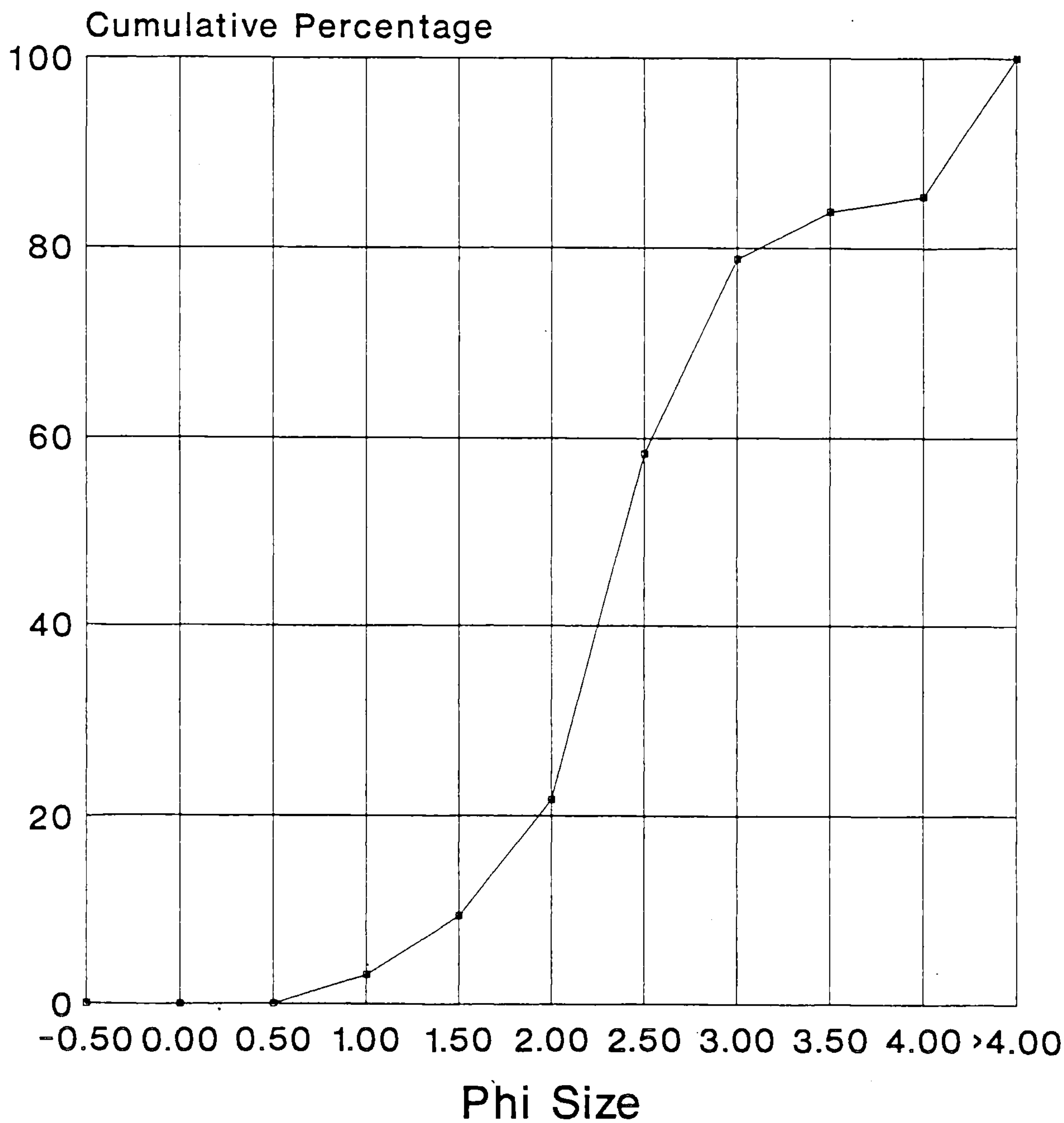
Grain Size Analysis
Sample U.S.G.S. 830-2



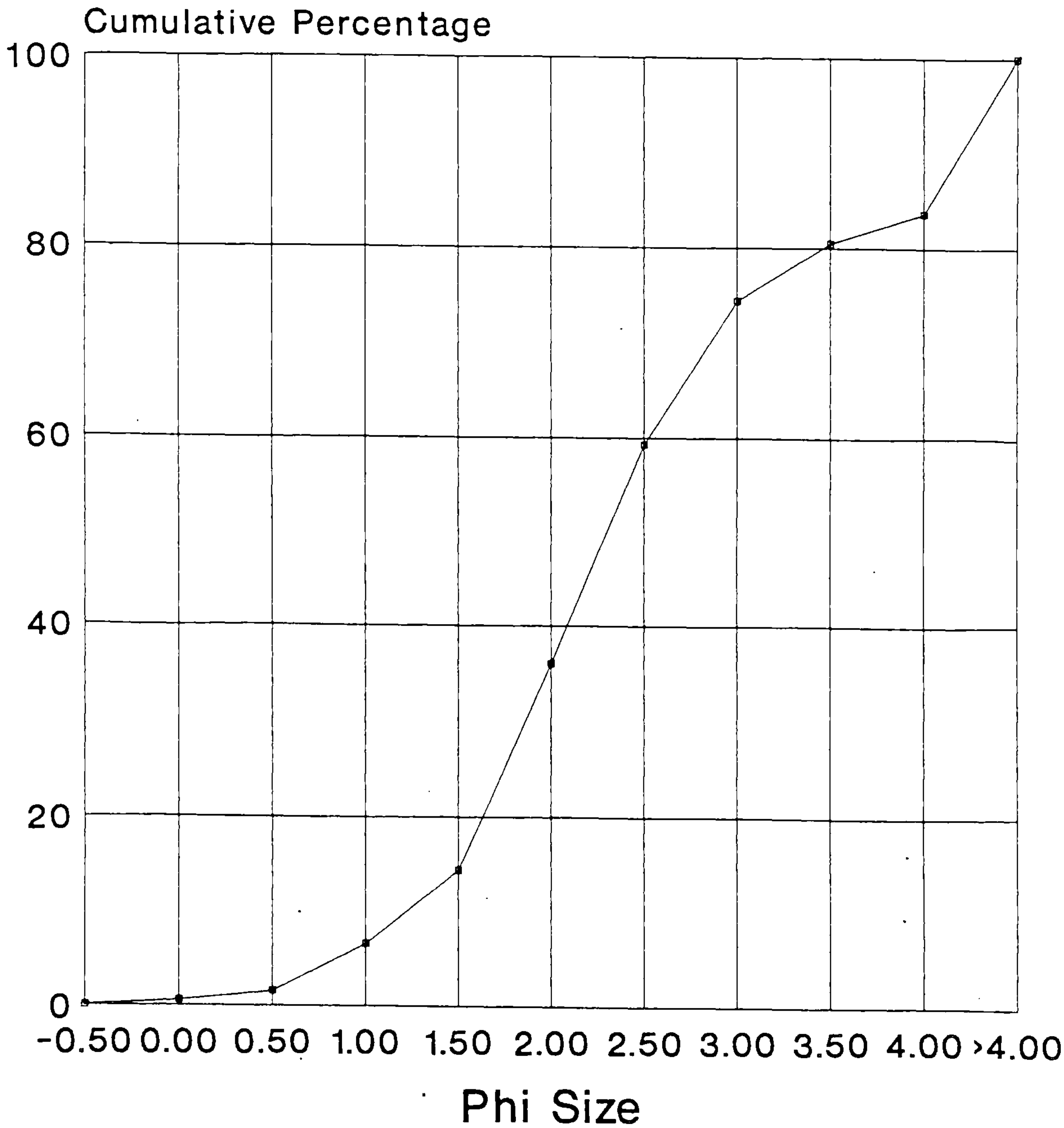
Grain Size Analysis
Sample U.S.G.S. 833



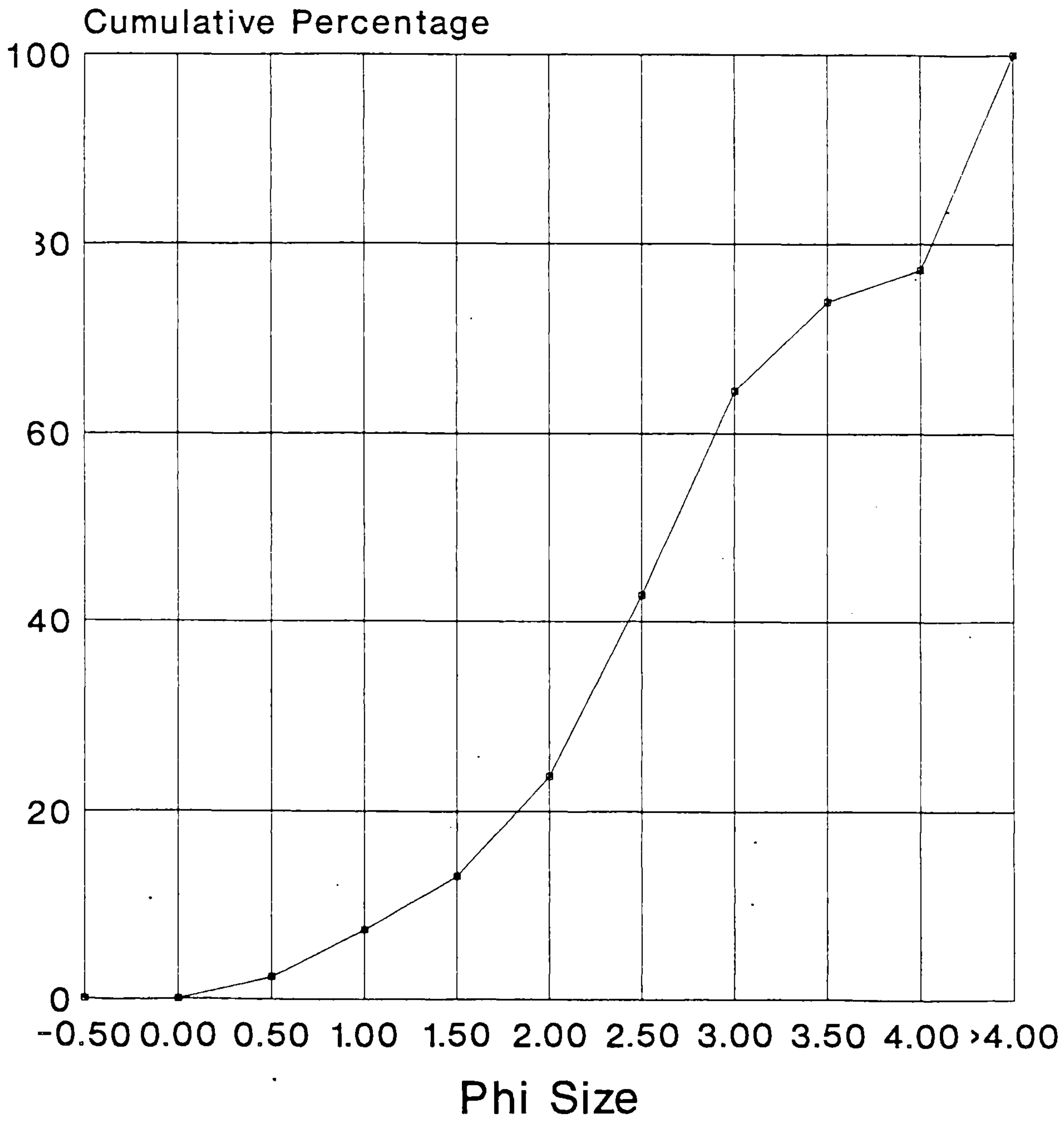
Grain Size Analysis
Sample U.S.G.S. 834-1



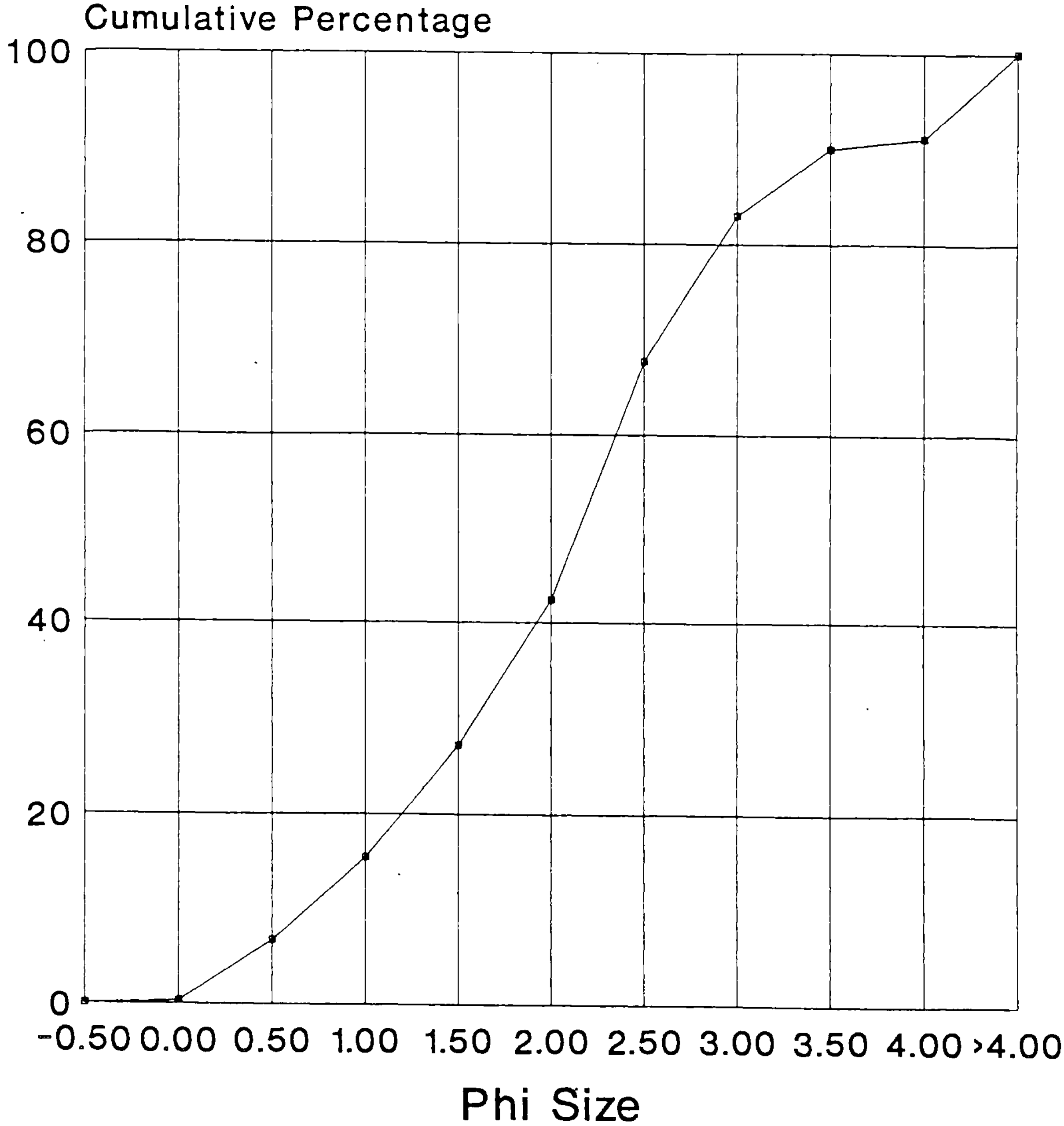
Grain Size Analysis
Sample U.S.G.S. 834-2



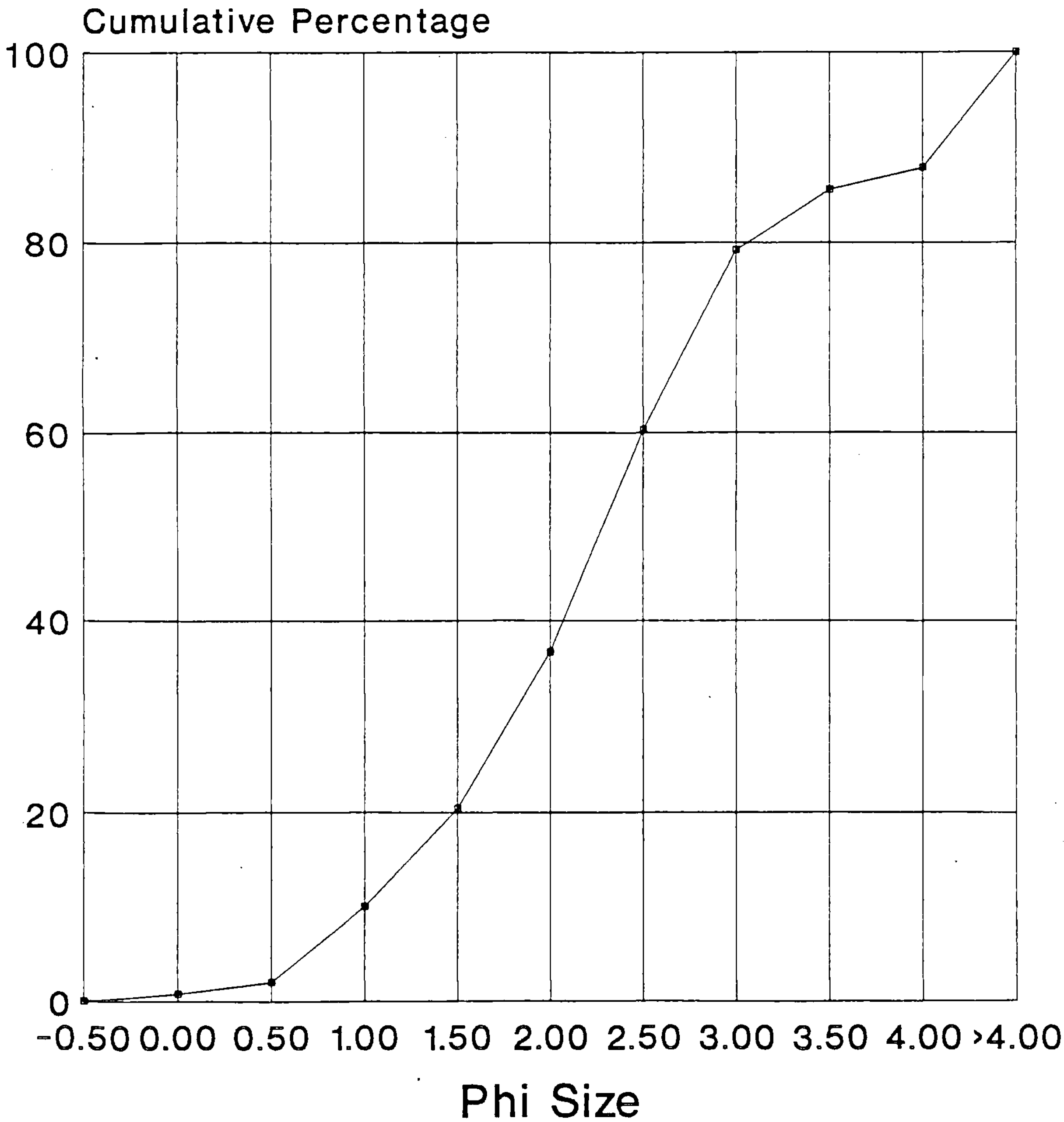
Grain Size Analysis
Sample U.S.G.S. 835-1



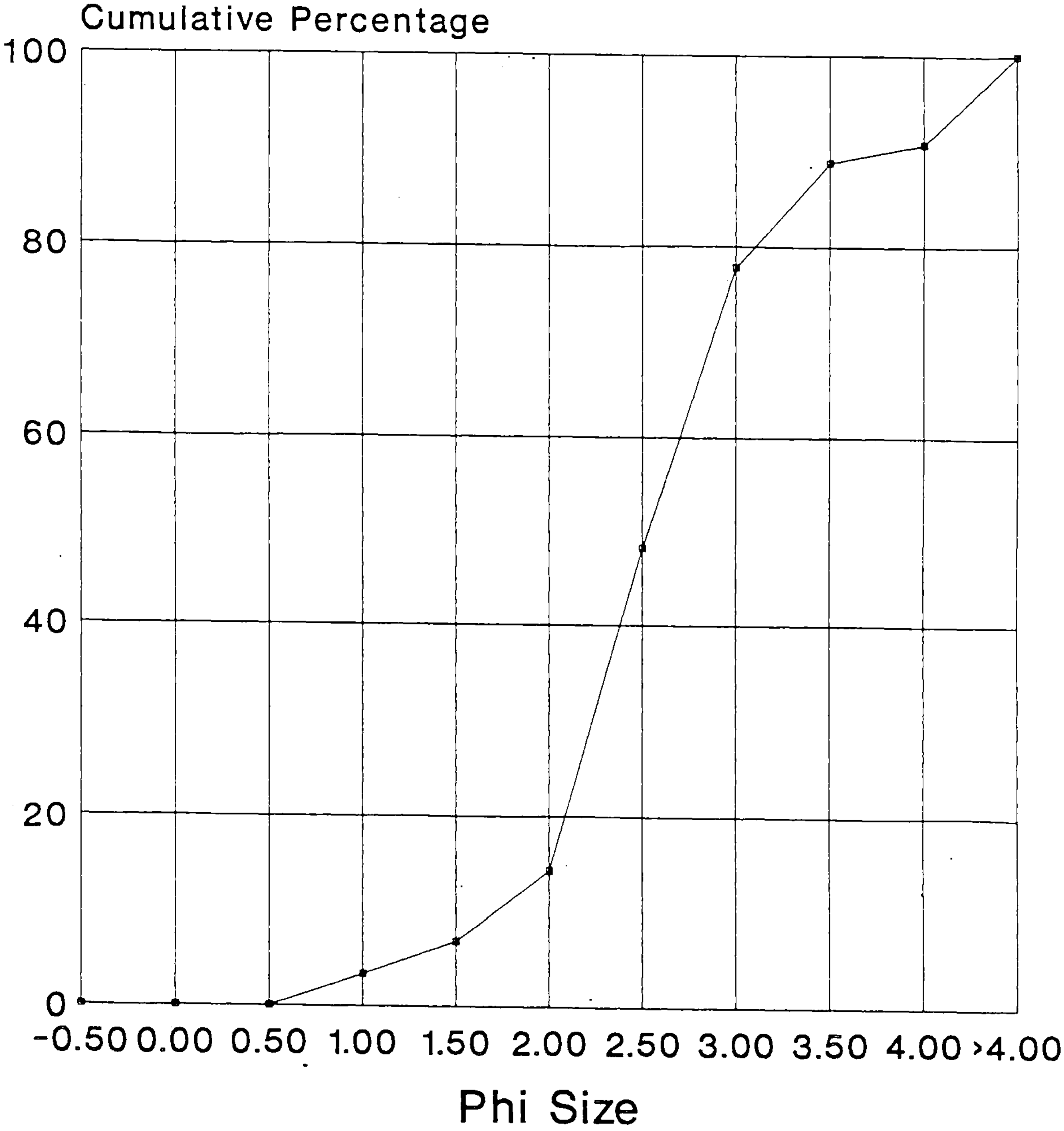
Grain Size Analysis
Sample U.S.G.S. 838



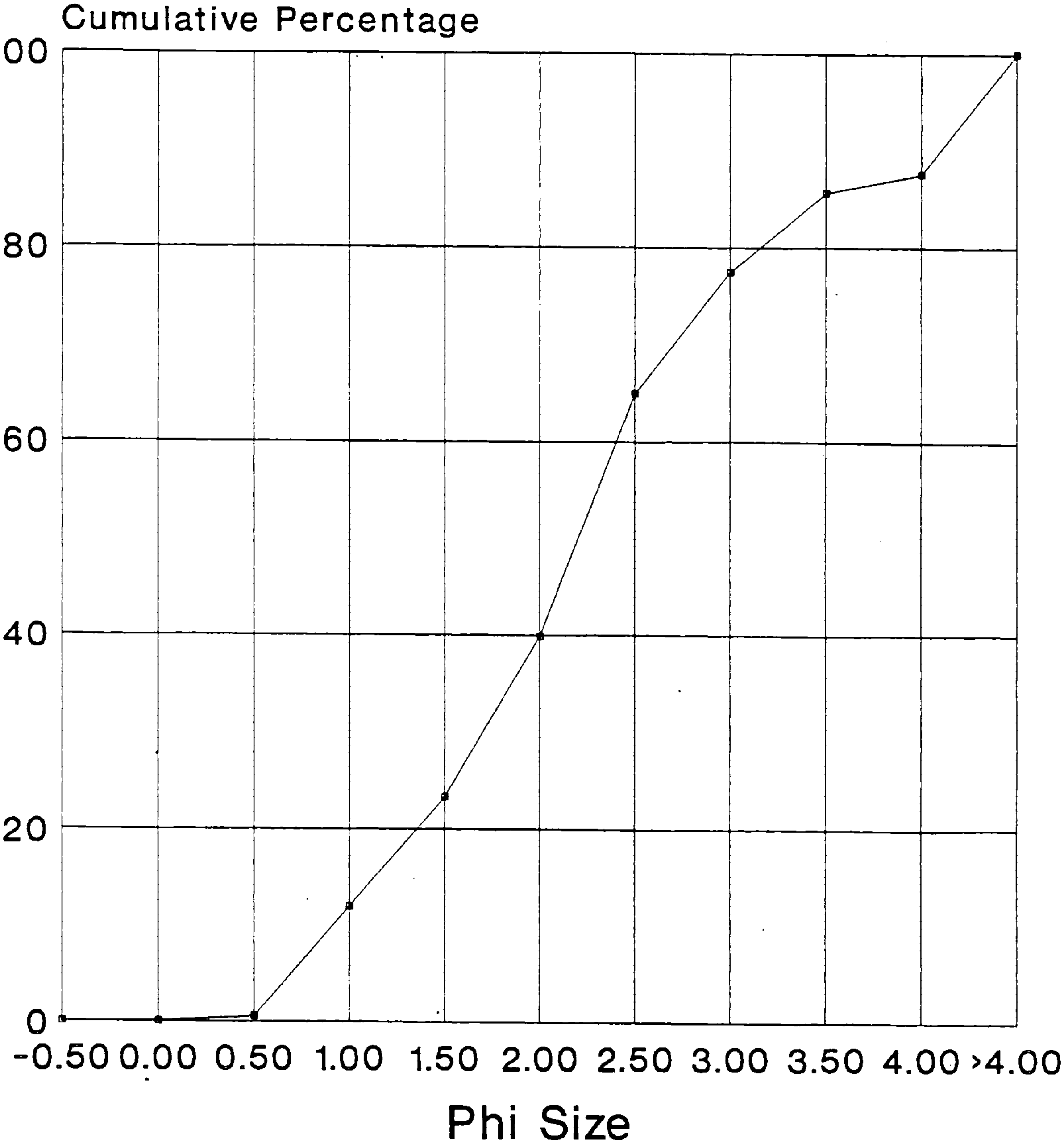
Grain Size Analysis
Sample U.S.G.S. 838A



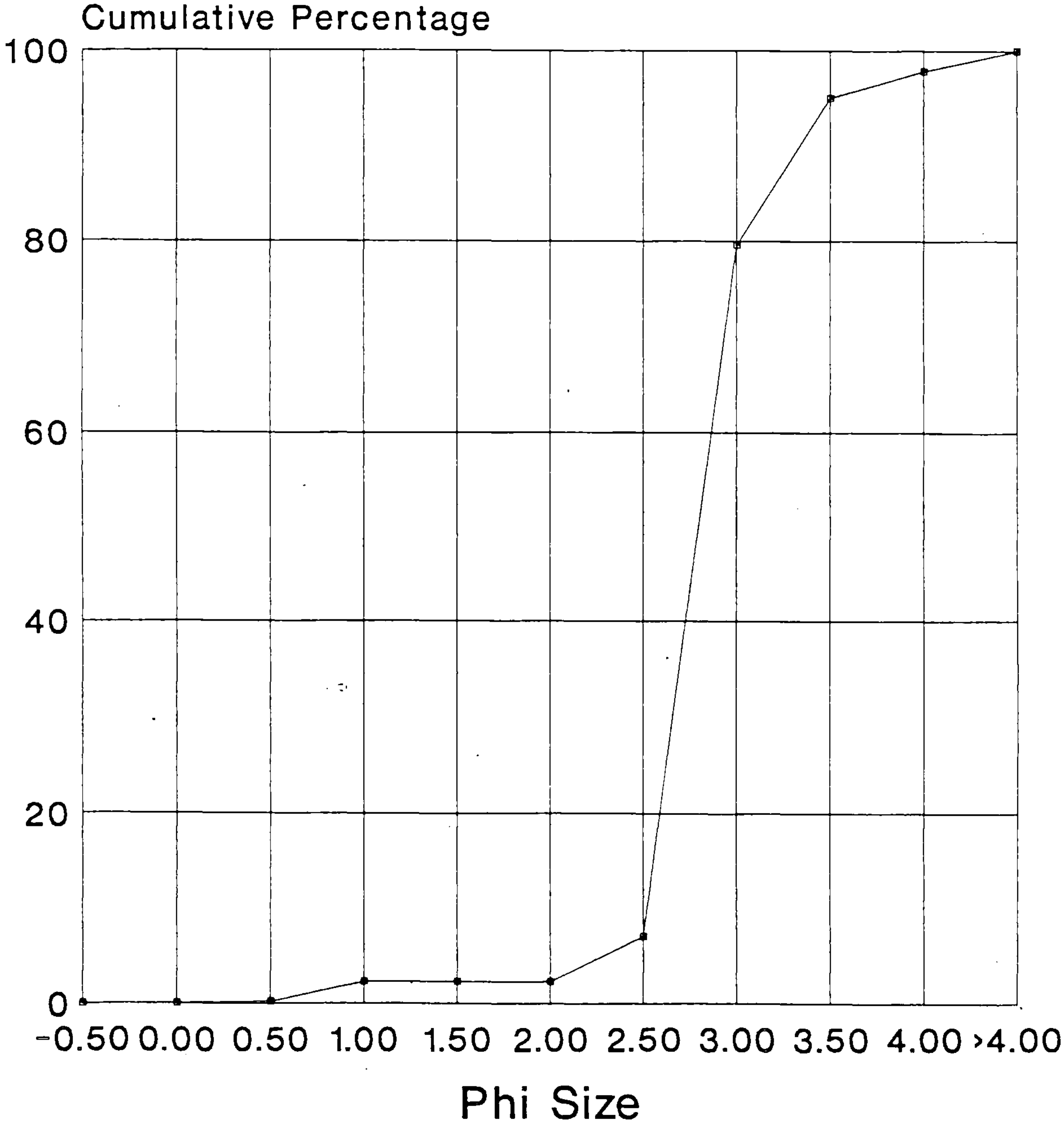
Grain Size Analysis
Sample U.S.G.S. 843-1



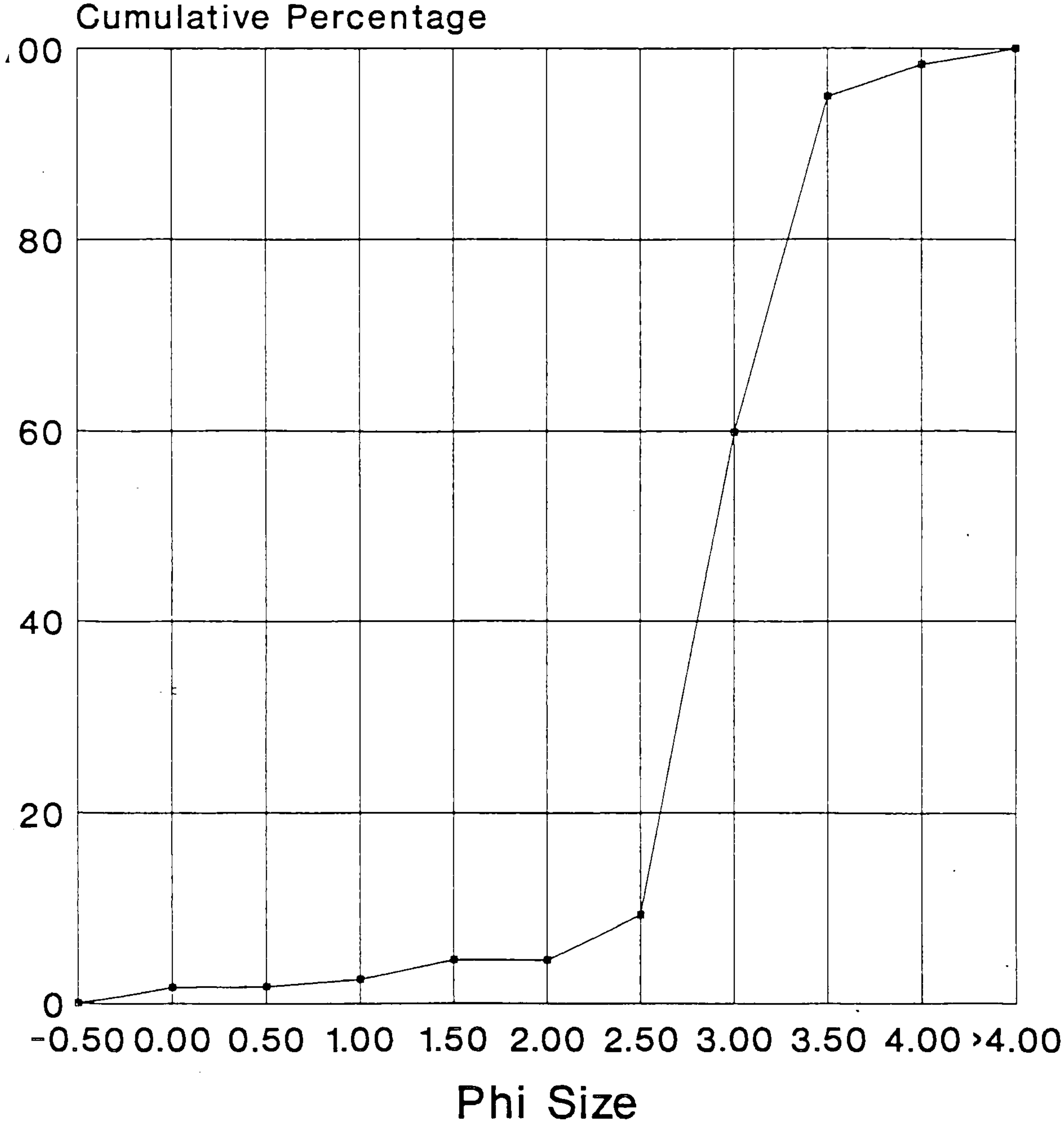
Grain Size Analysis
Sample U.S.G.S. 843-2



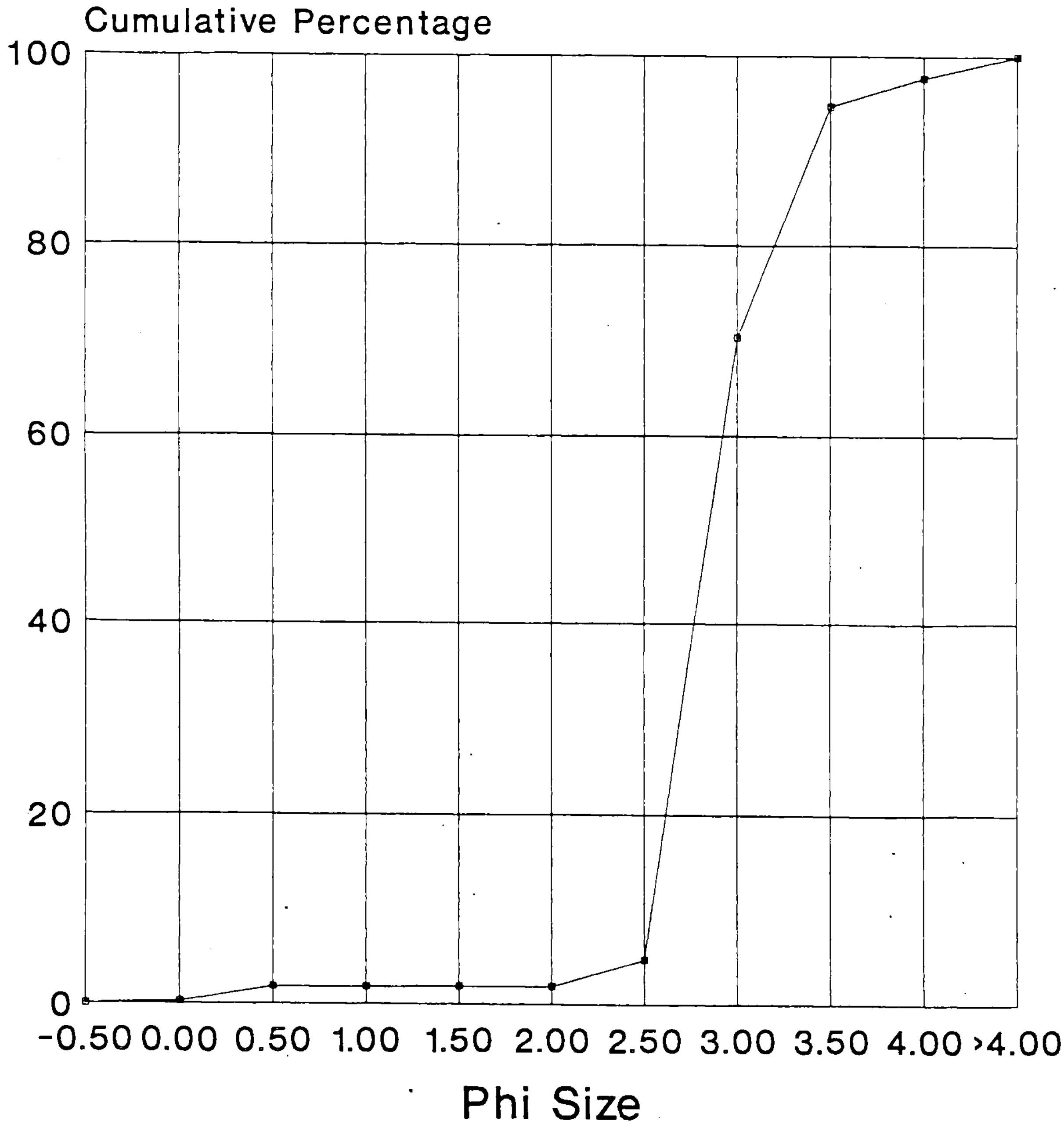
Grain Size Analysis
Sample U.S.G.S. 847



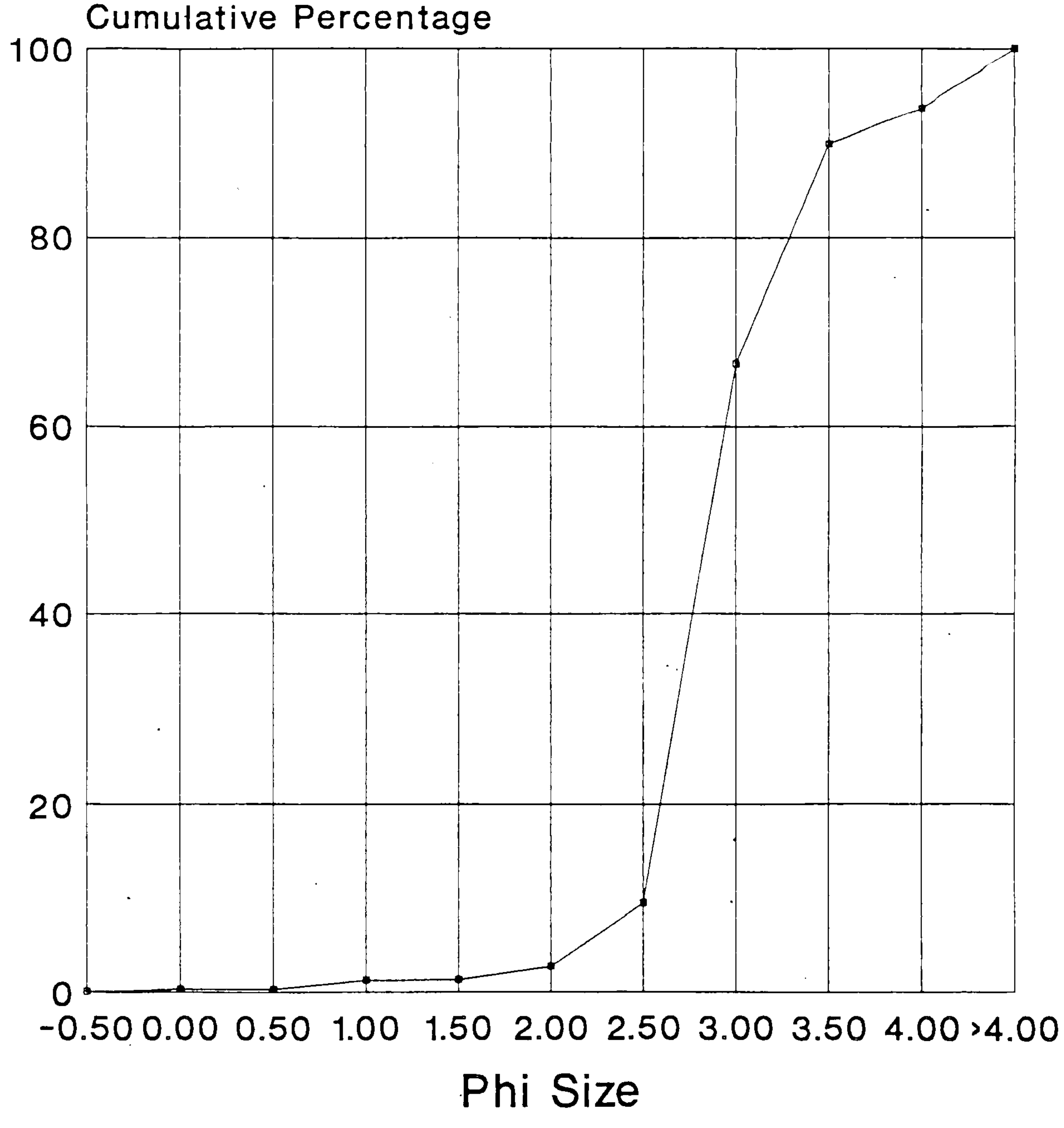
Grain Size Analysis
Sample U.S.G.S. 847A-1

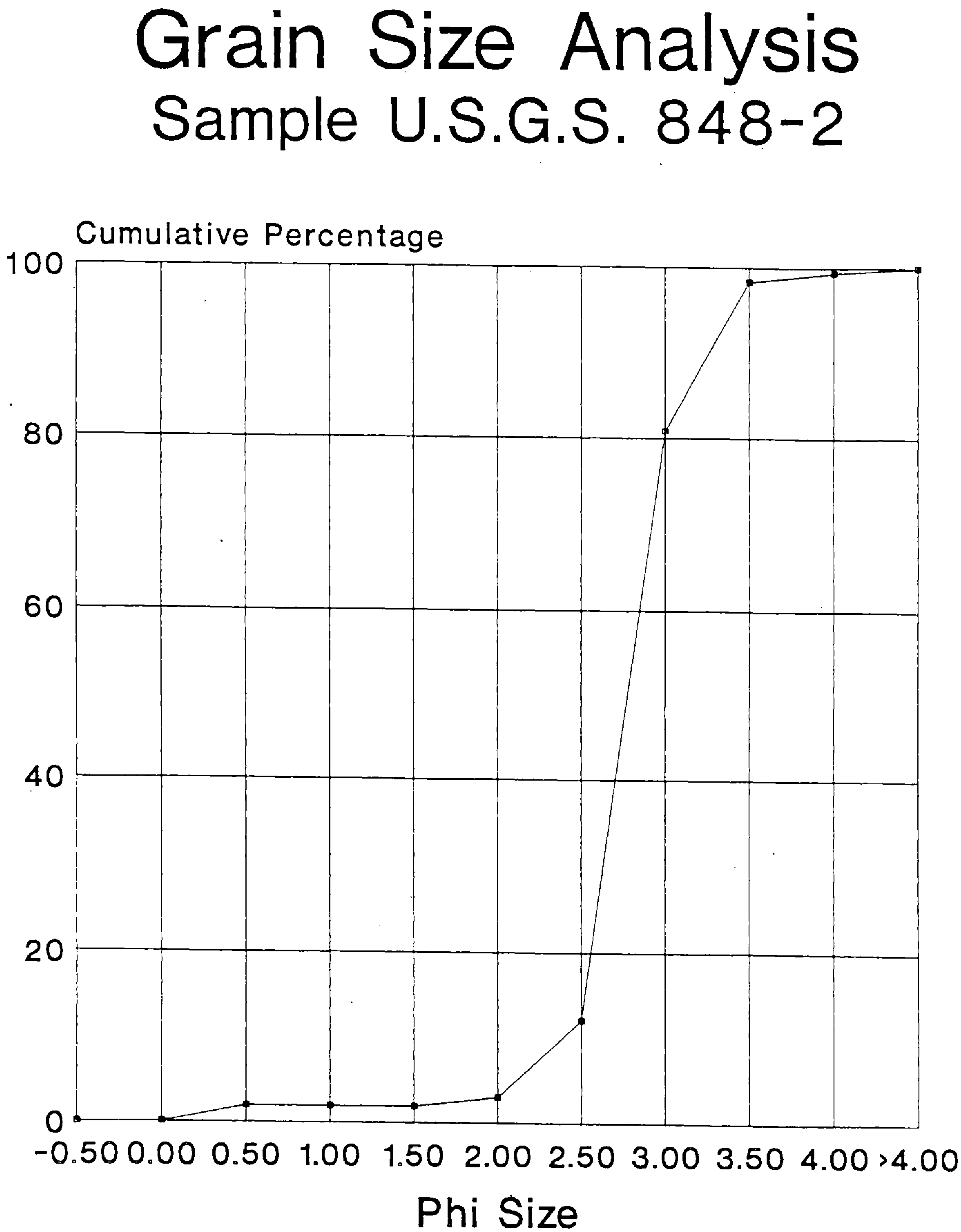


Grain Size Analysis
Sample U.S.G.S. 847A-2



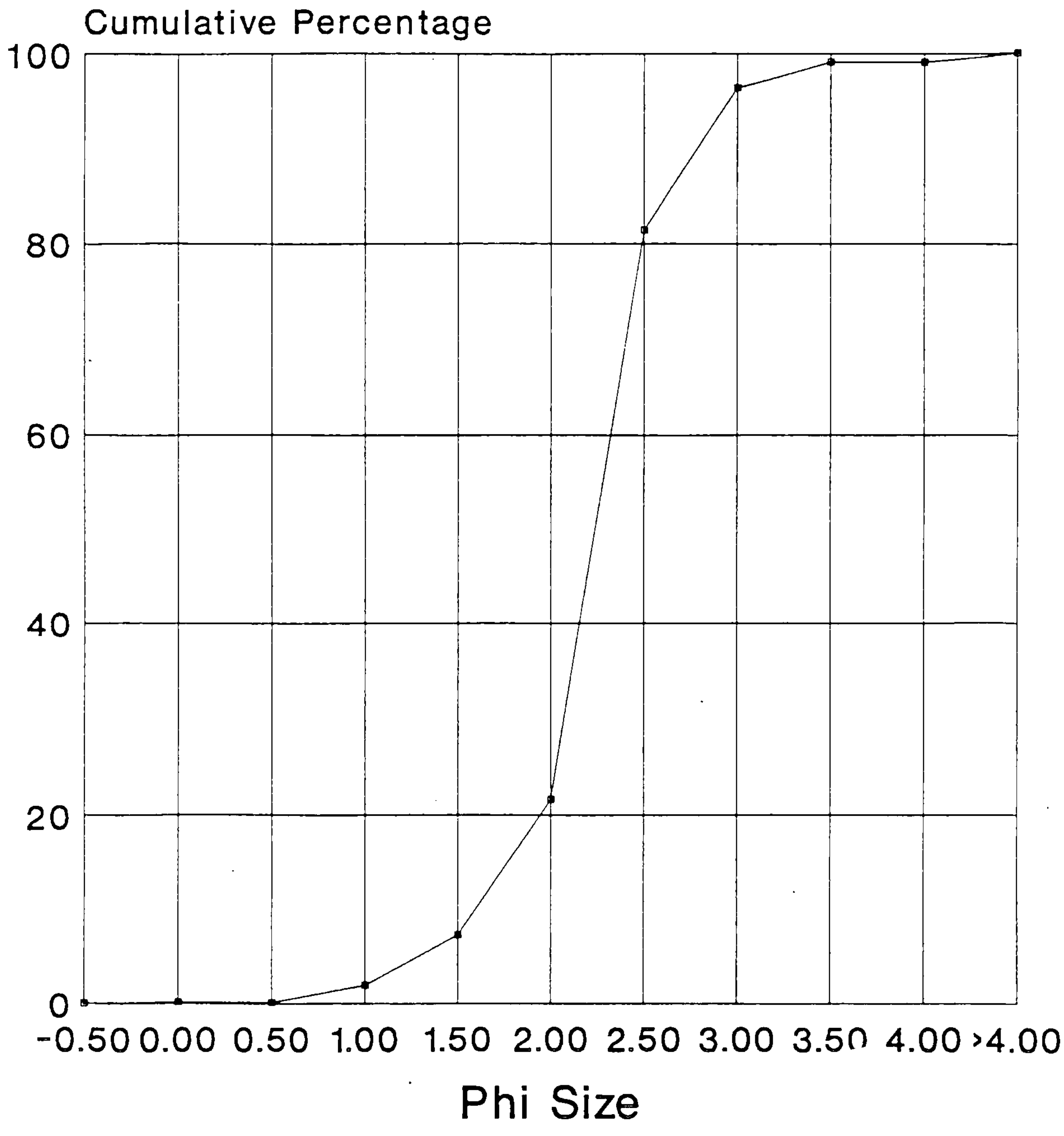
Grain Size Analysis
Sample U.S.G.S. 848-1



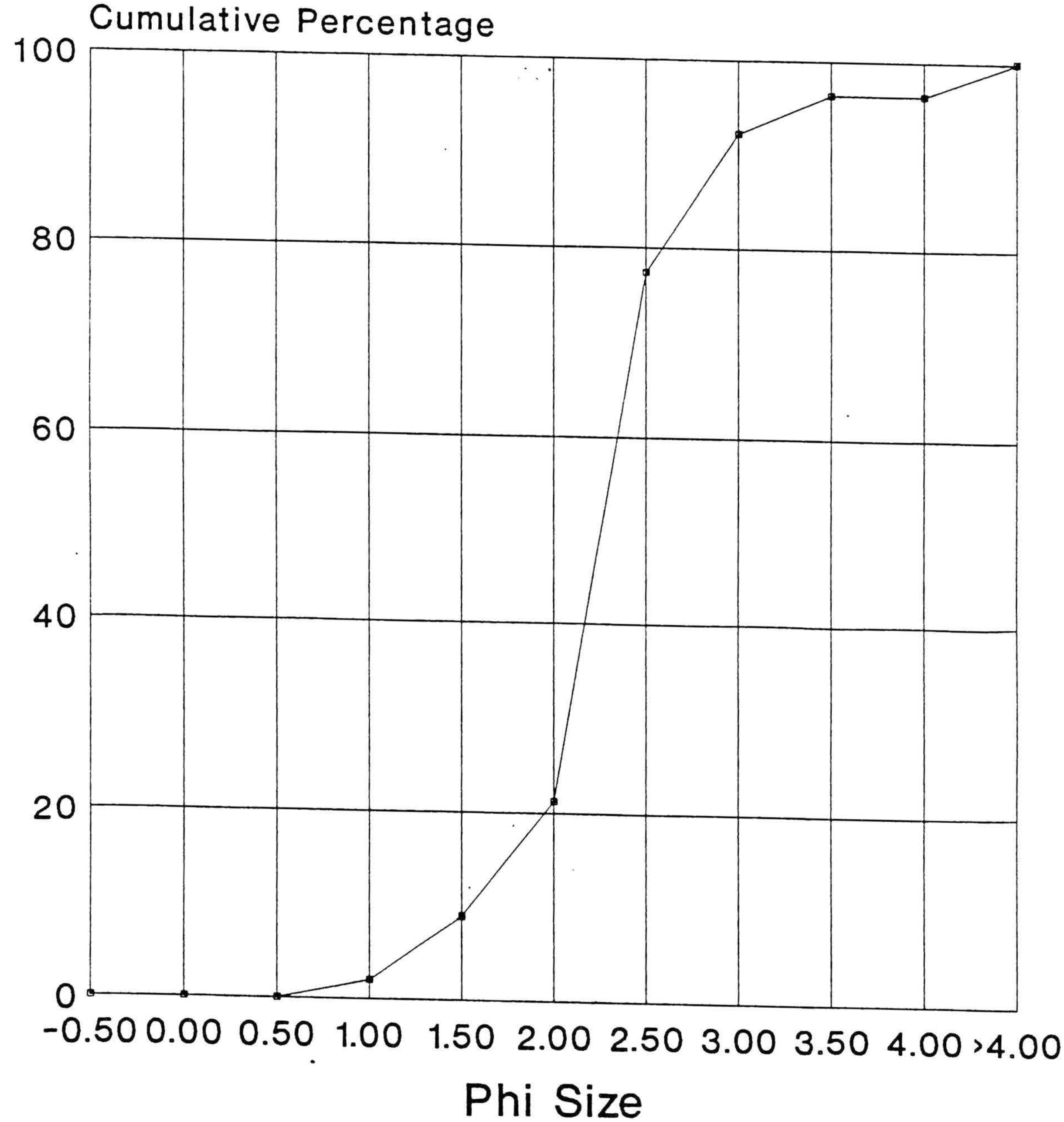


Grain Size Analysis
Sample U.S.G.S. 848-2
Cumulative Percentage
100
80
60
40
20
0
-0.50 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 >4.00
Phi Size

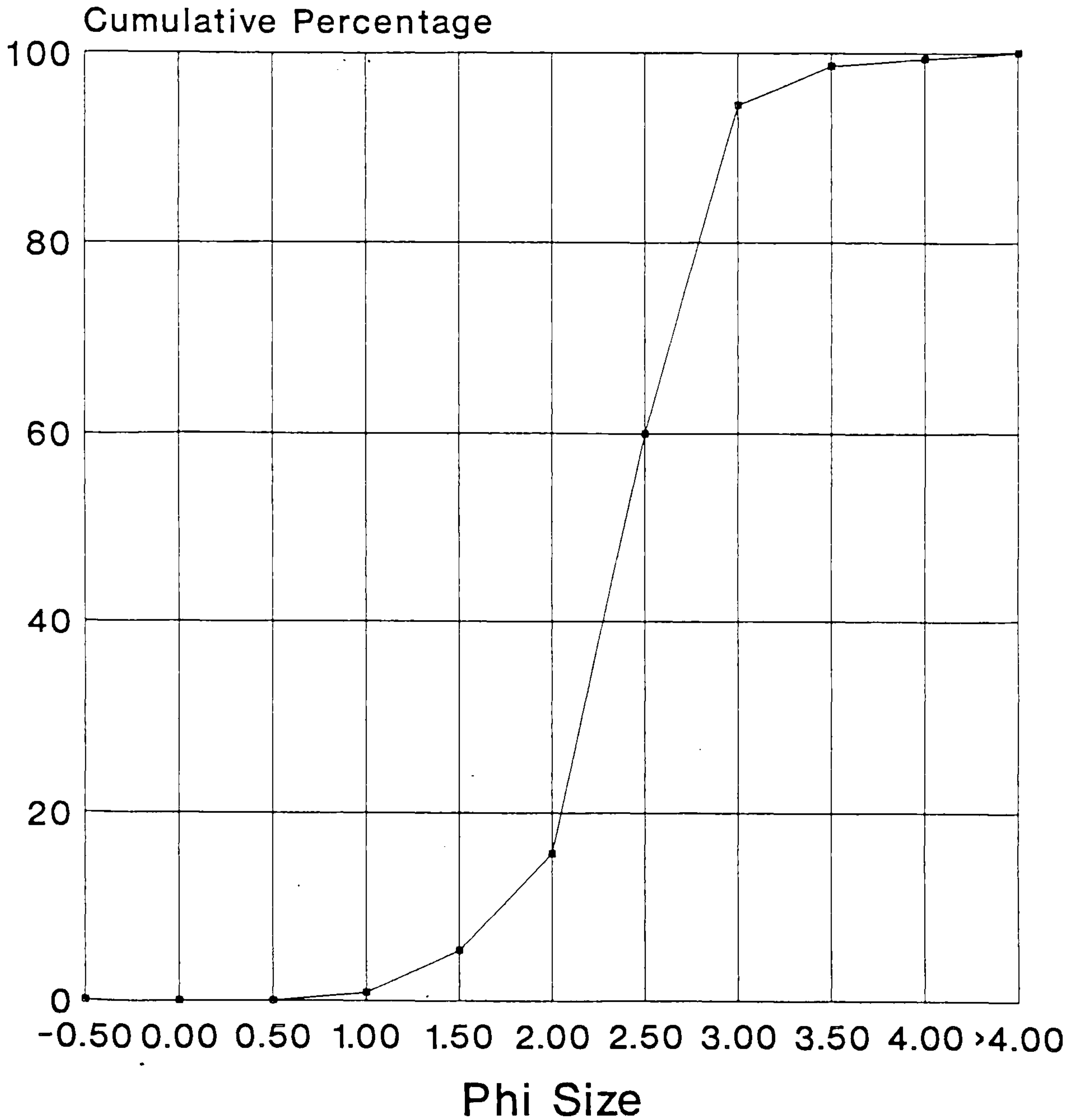
Grain Size Analysis
Sample U.S.G.S. 850-1



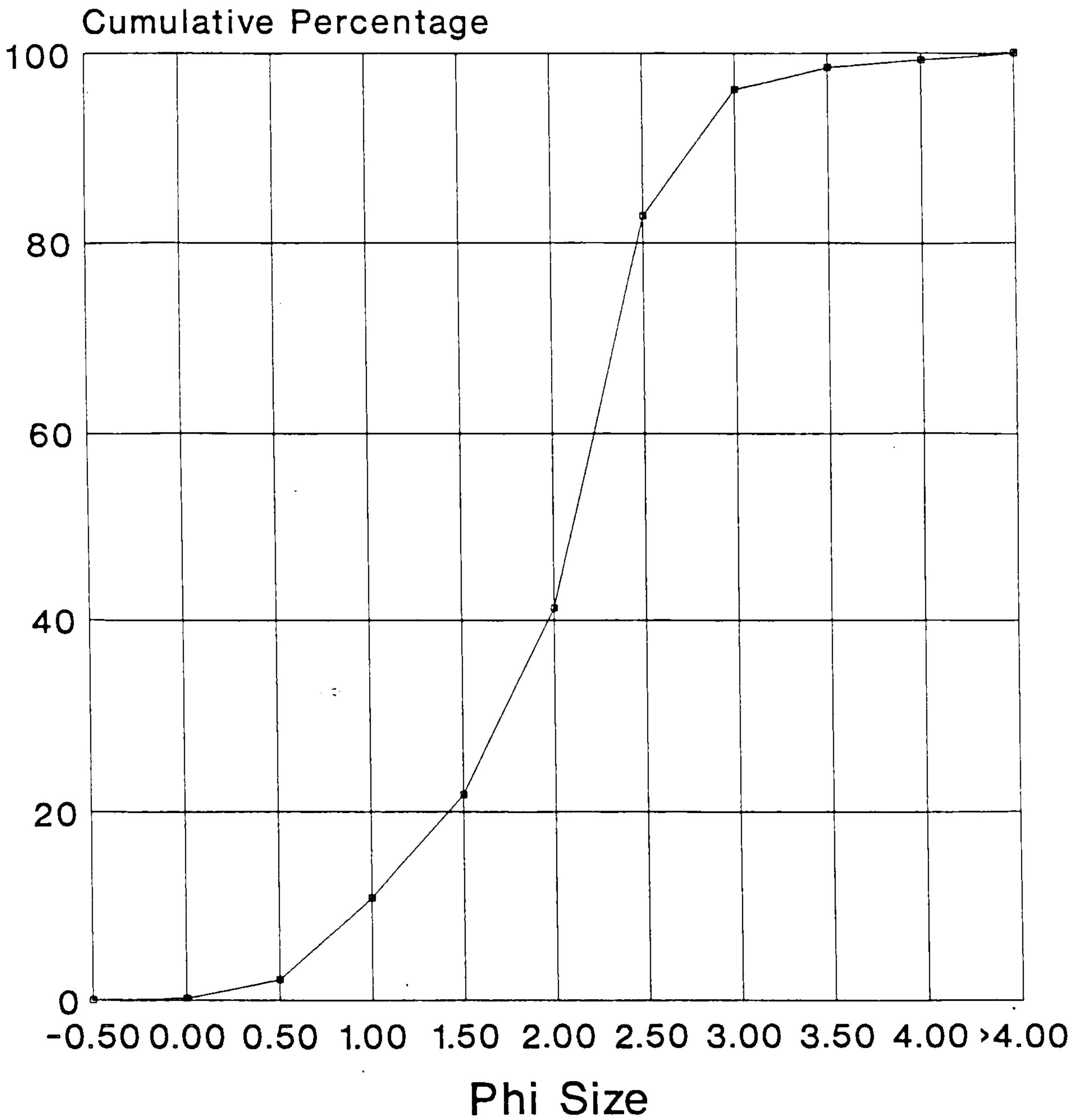
Grain Size Analysis
Sample U.S.G.S. 850-2

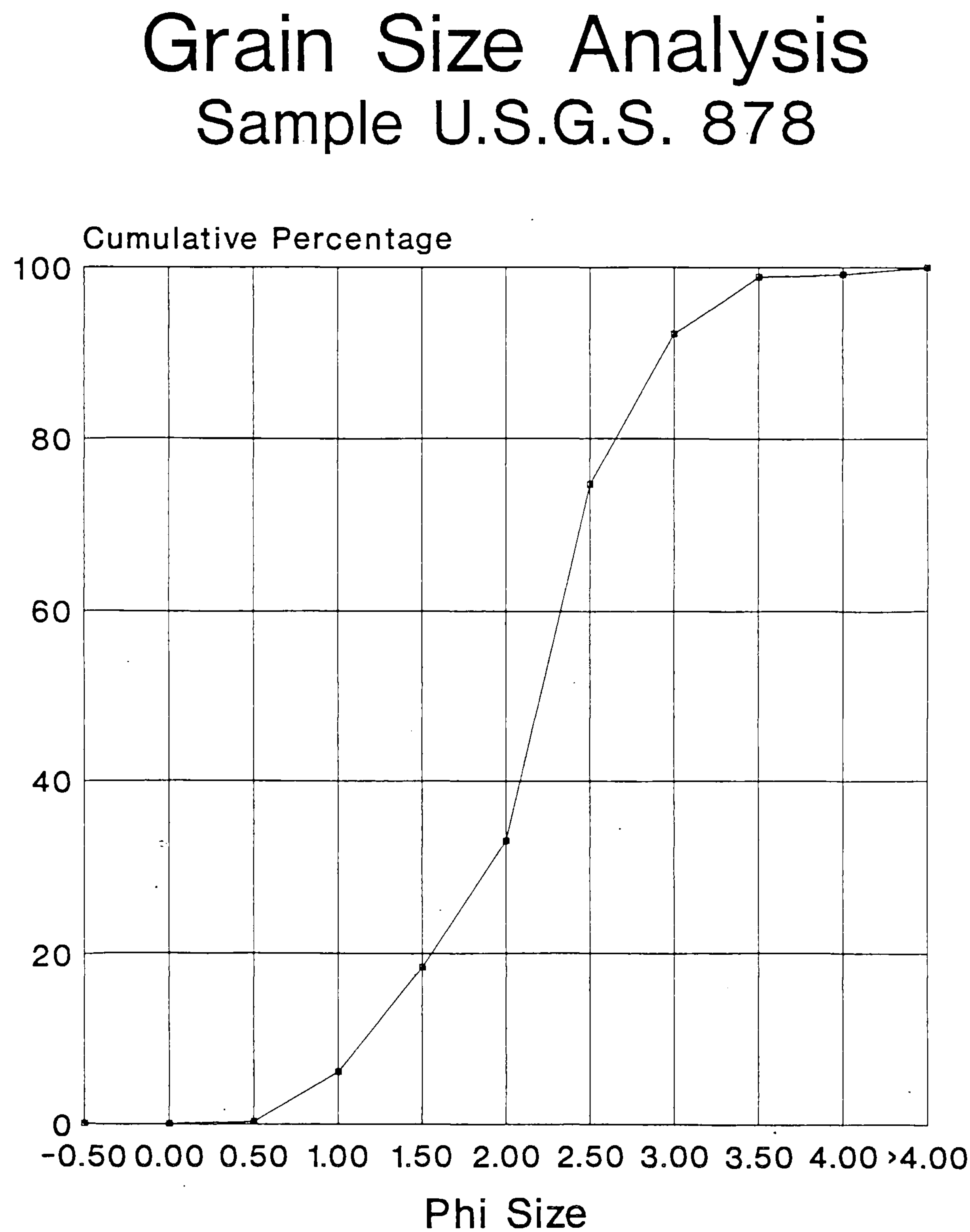


Grain Size Analysis
Sample U.S.G.S. 868

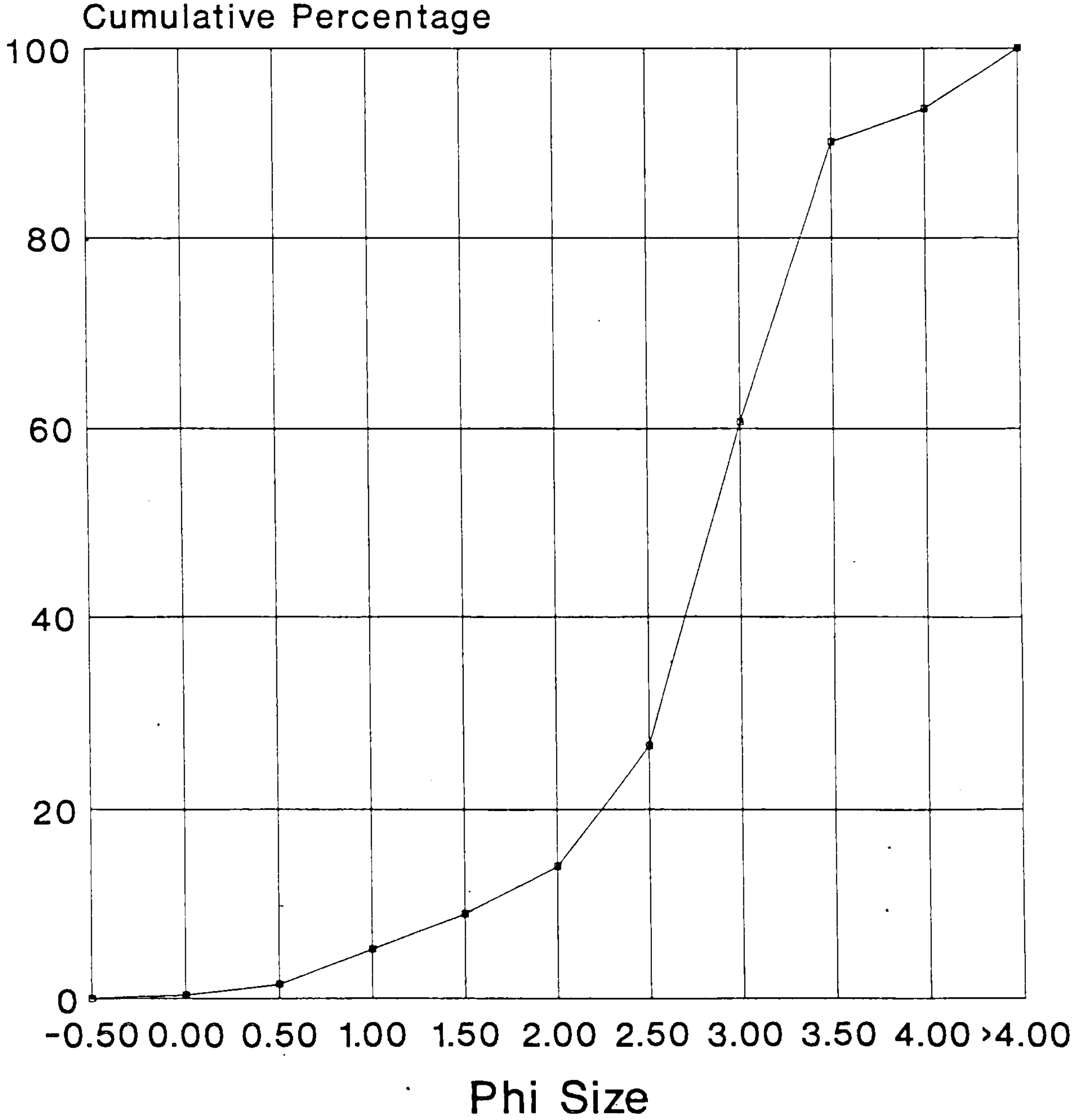


Grain Size Analysis
Sample U.S.G.S. 869

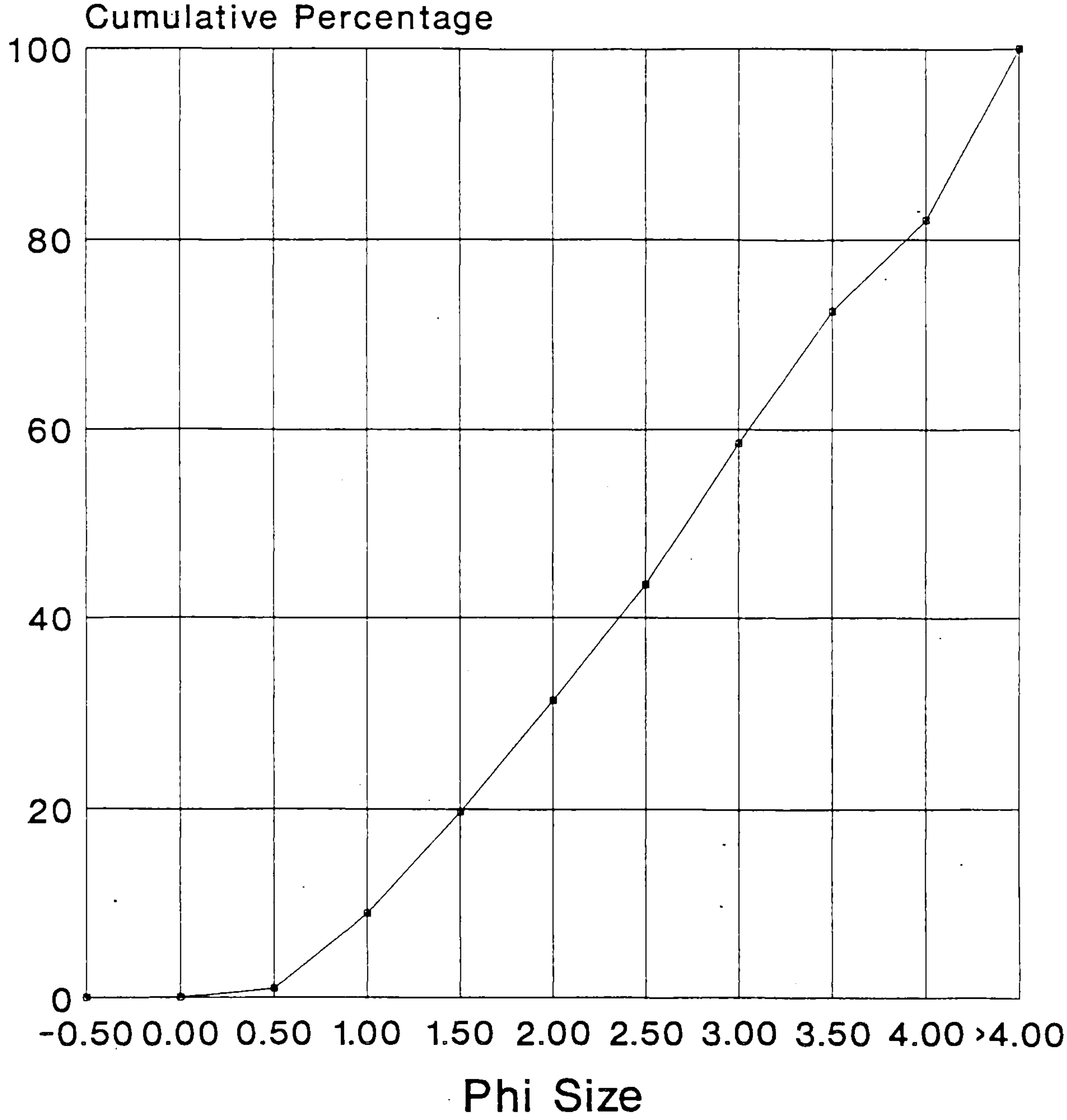



Grain Size Analysis
Sample U.S.G.S. 878
Cumulative Percentage
100
80
60
40
20
0
-0.50 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 >4.00
Phi Size

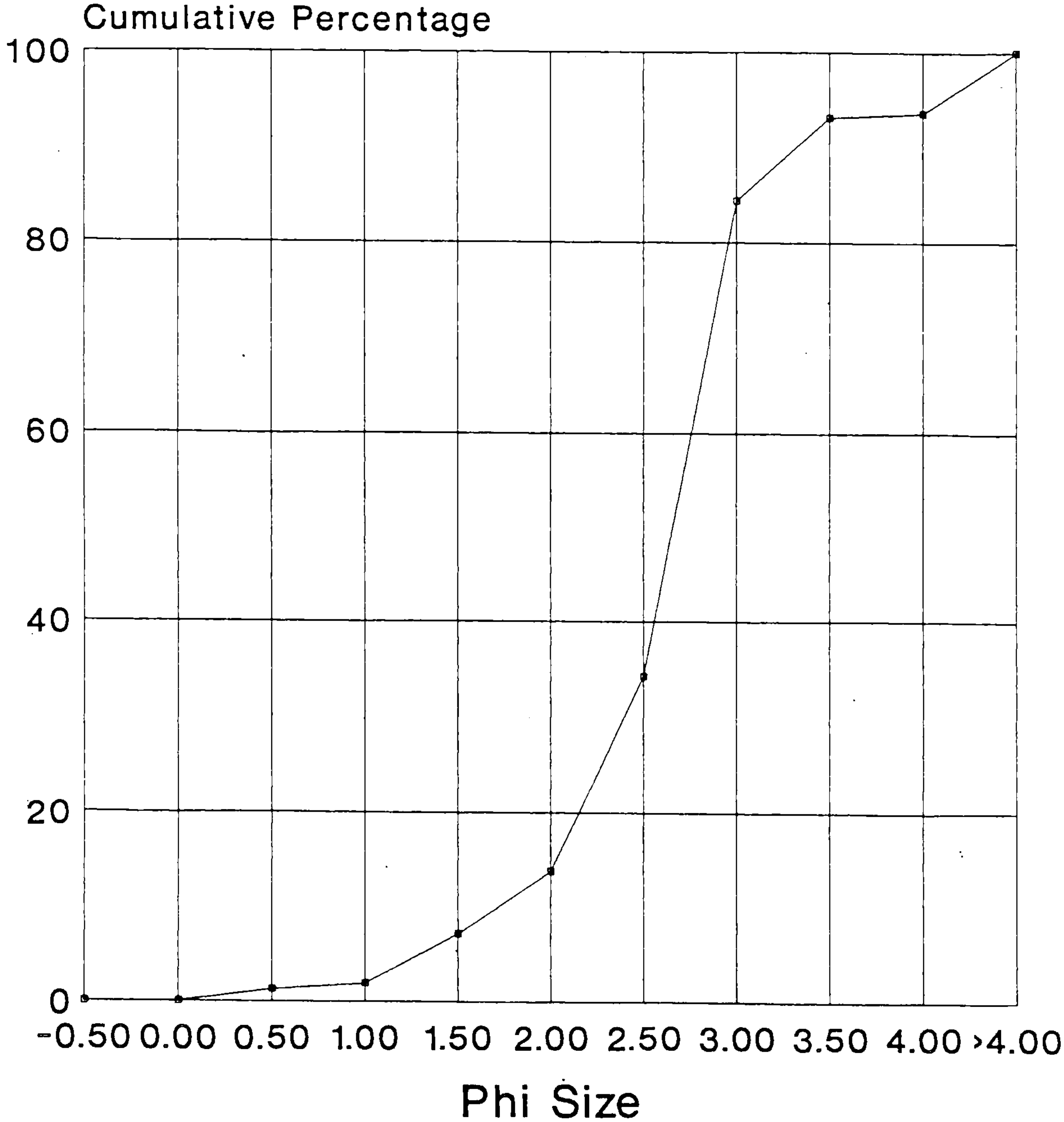
Grain Size Analysis
Sample U.S.G.S. 884



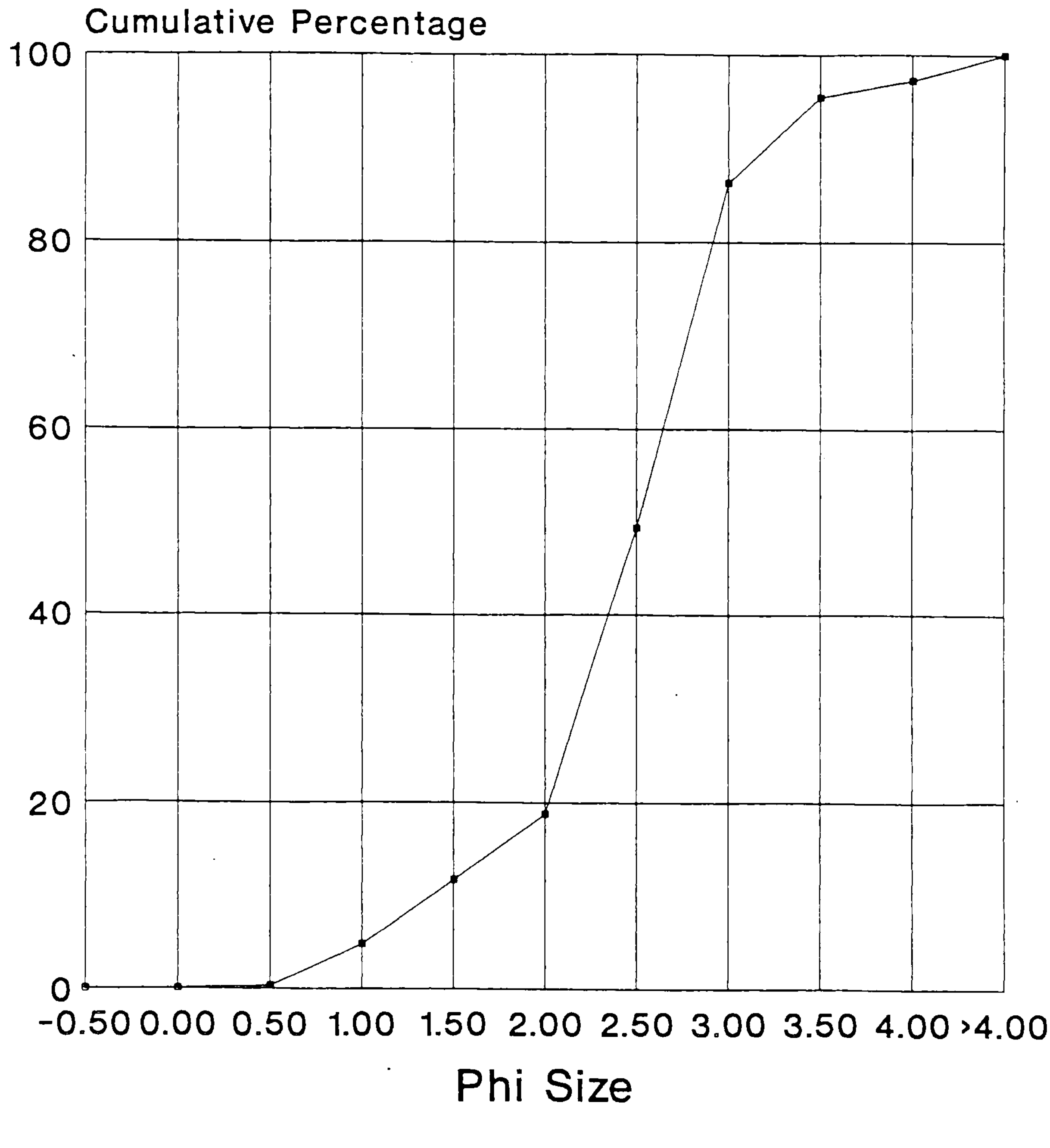
Grain Size Analysis
Sample U.S.G.S. 903



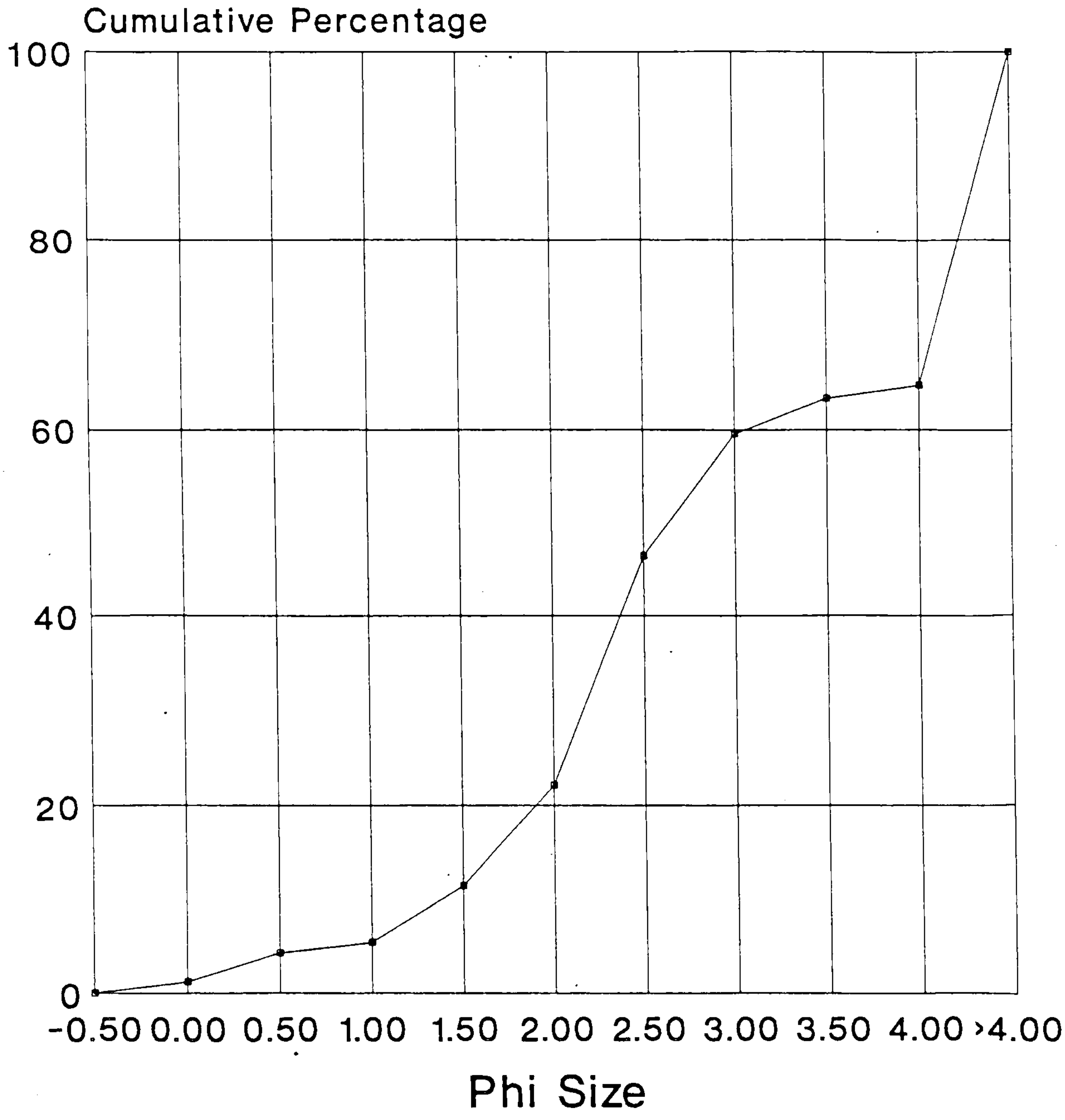
Grain Size Analysis
Sample U.S.G.S. 916



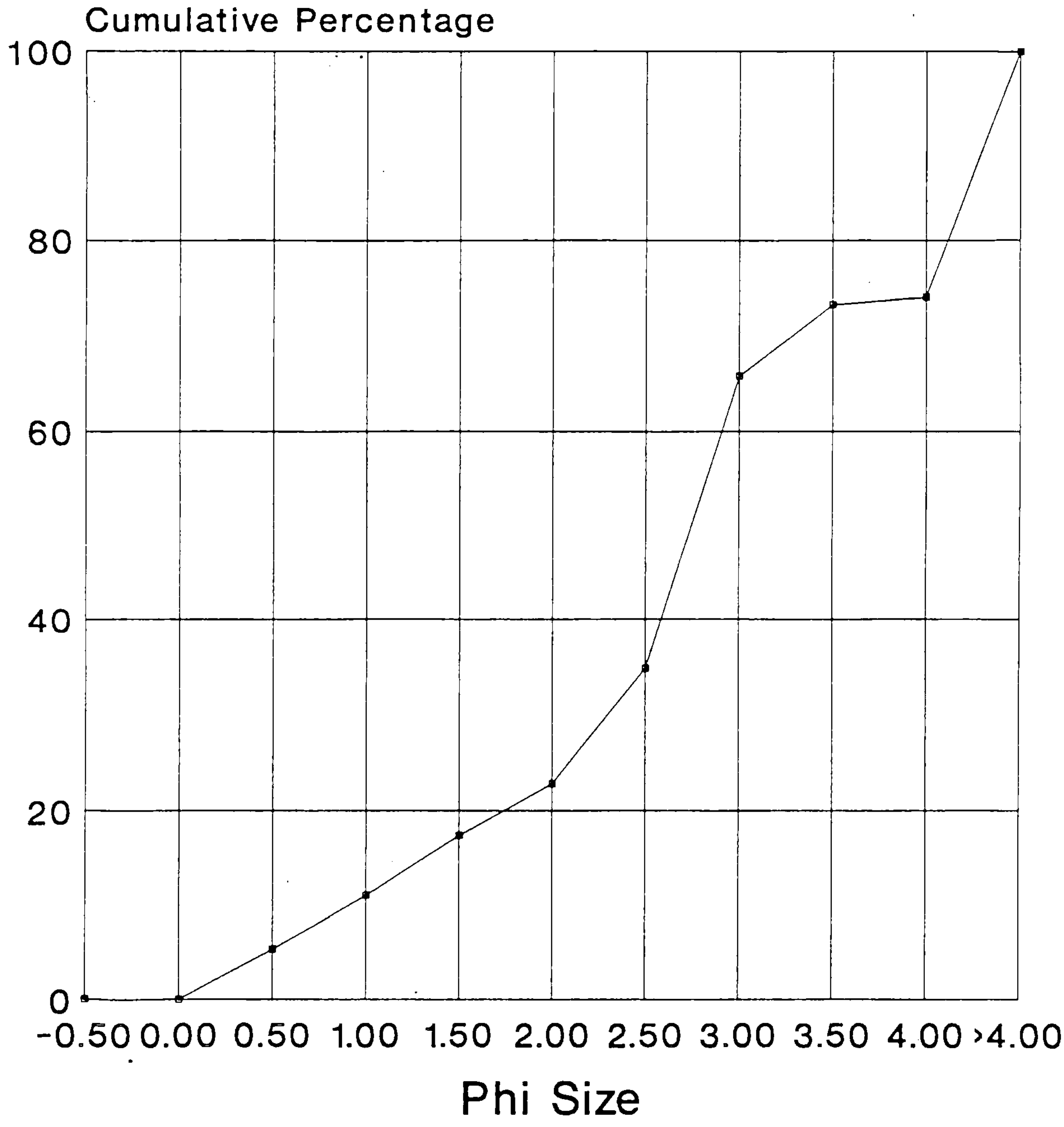
Grain Size Analysis
Sample U.S.G.S. 920-2



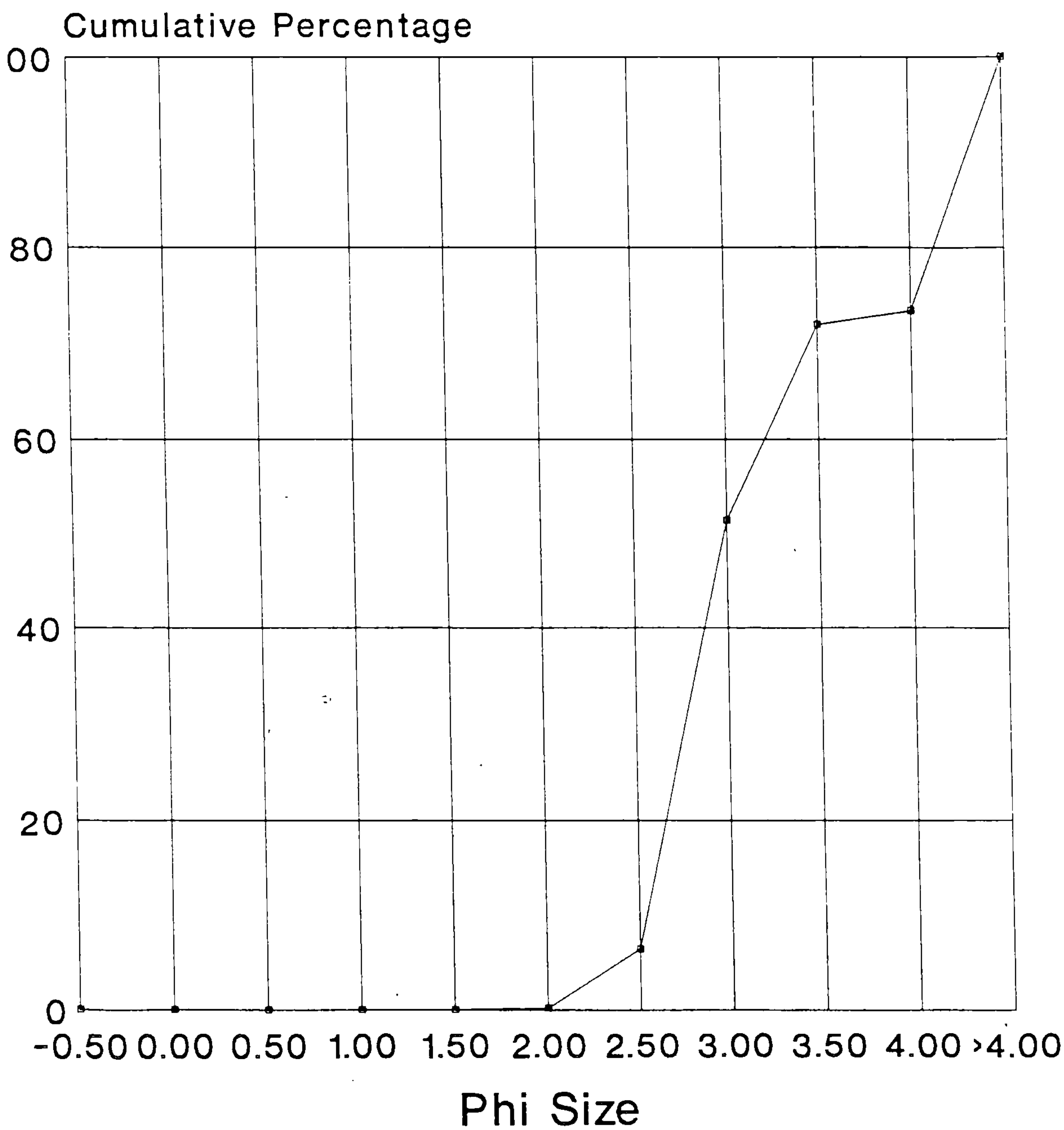
Grain Size Analysis
Sample U.S.G.S. 925



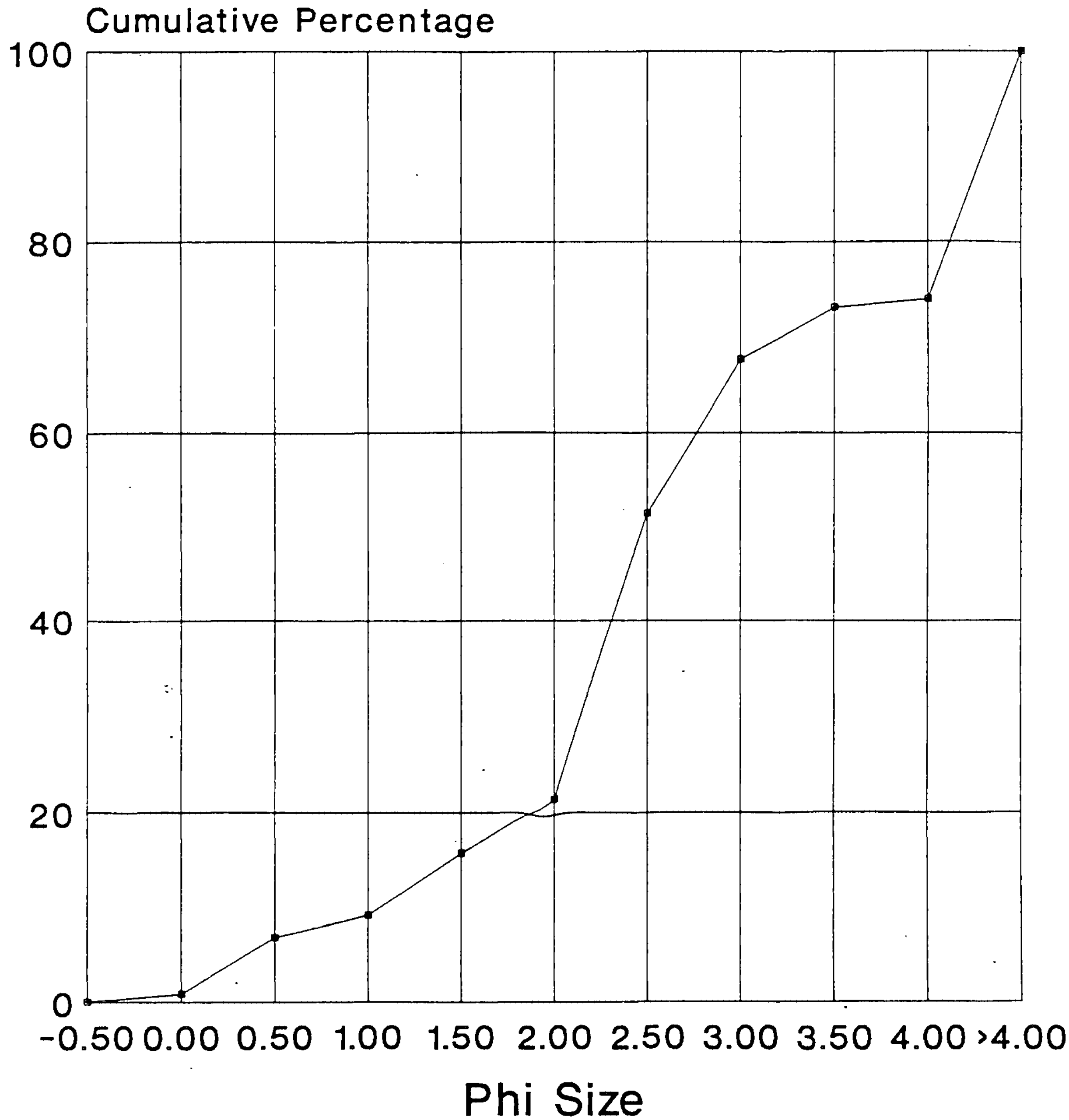
Grain Size Analysis
Sample U.S.G.S. 928



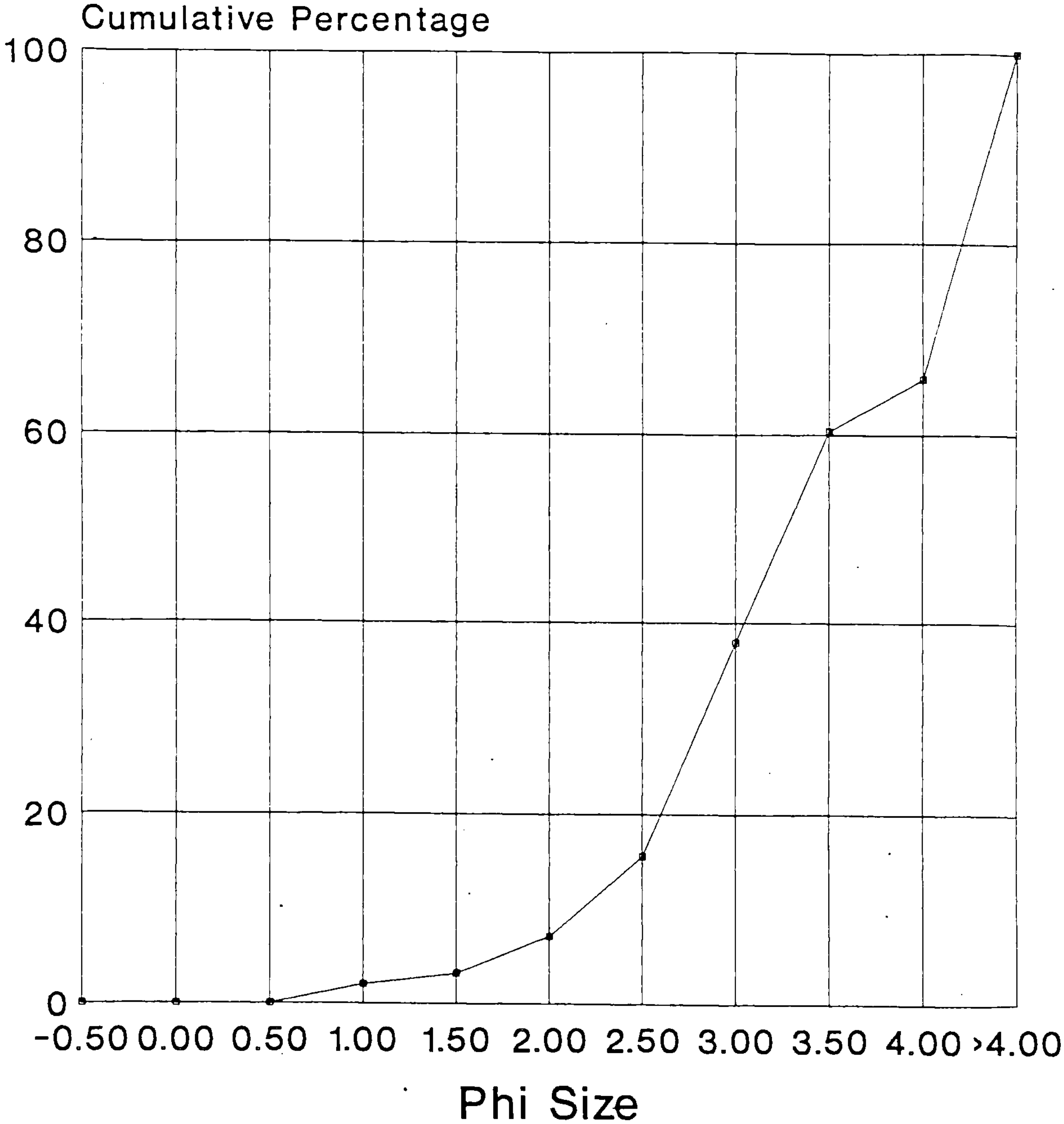
Grain Size Analysis
Sample U.S.G.S. 929-1



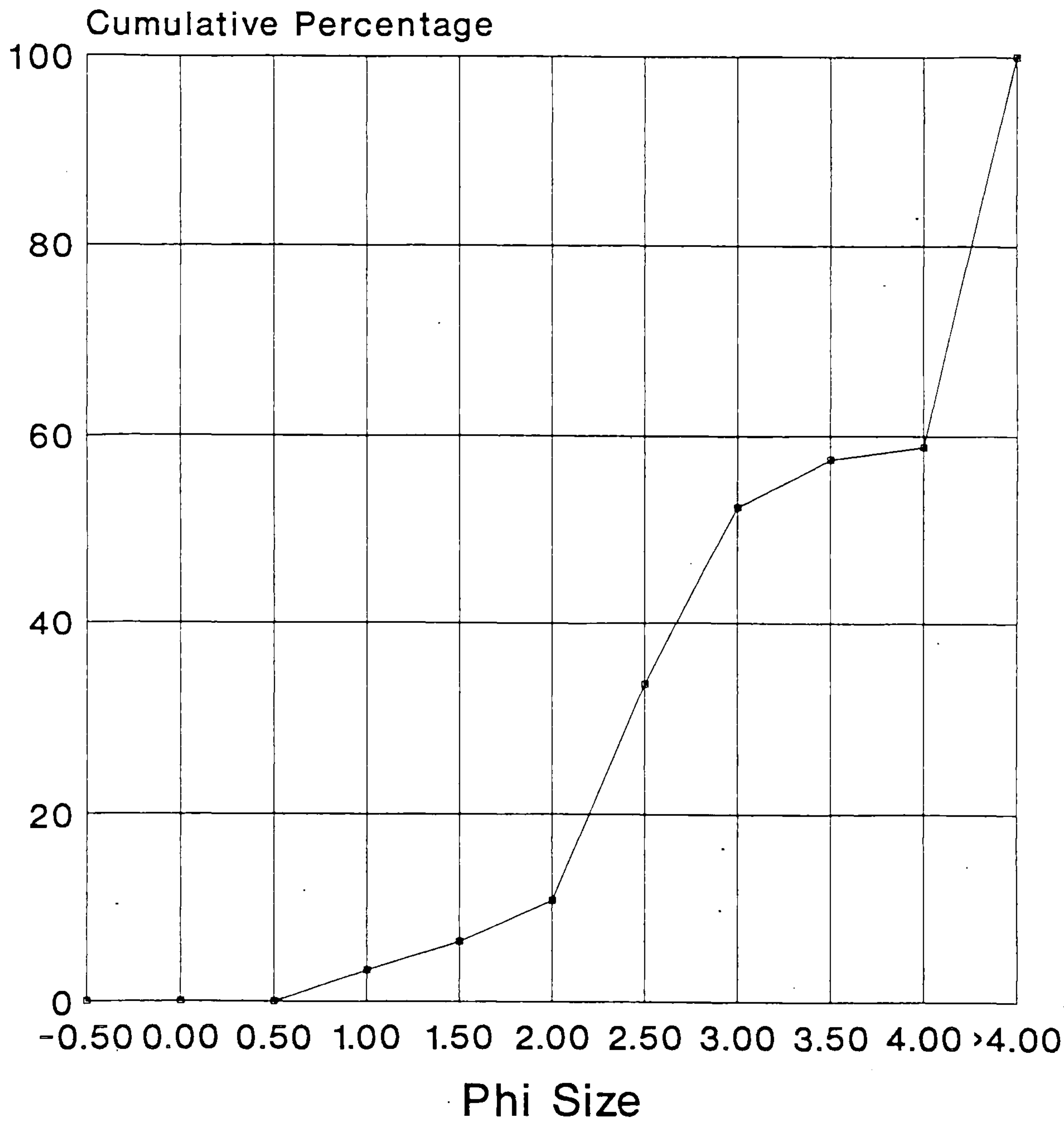
Grain Size Analysis
Sample U.S.G.S. 929A-1



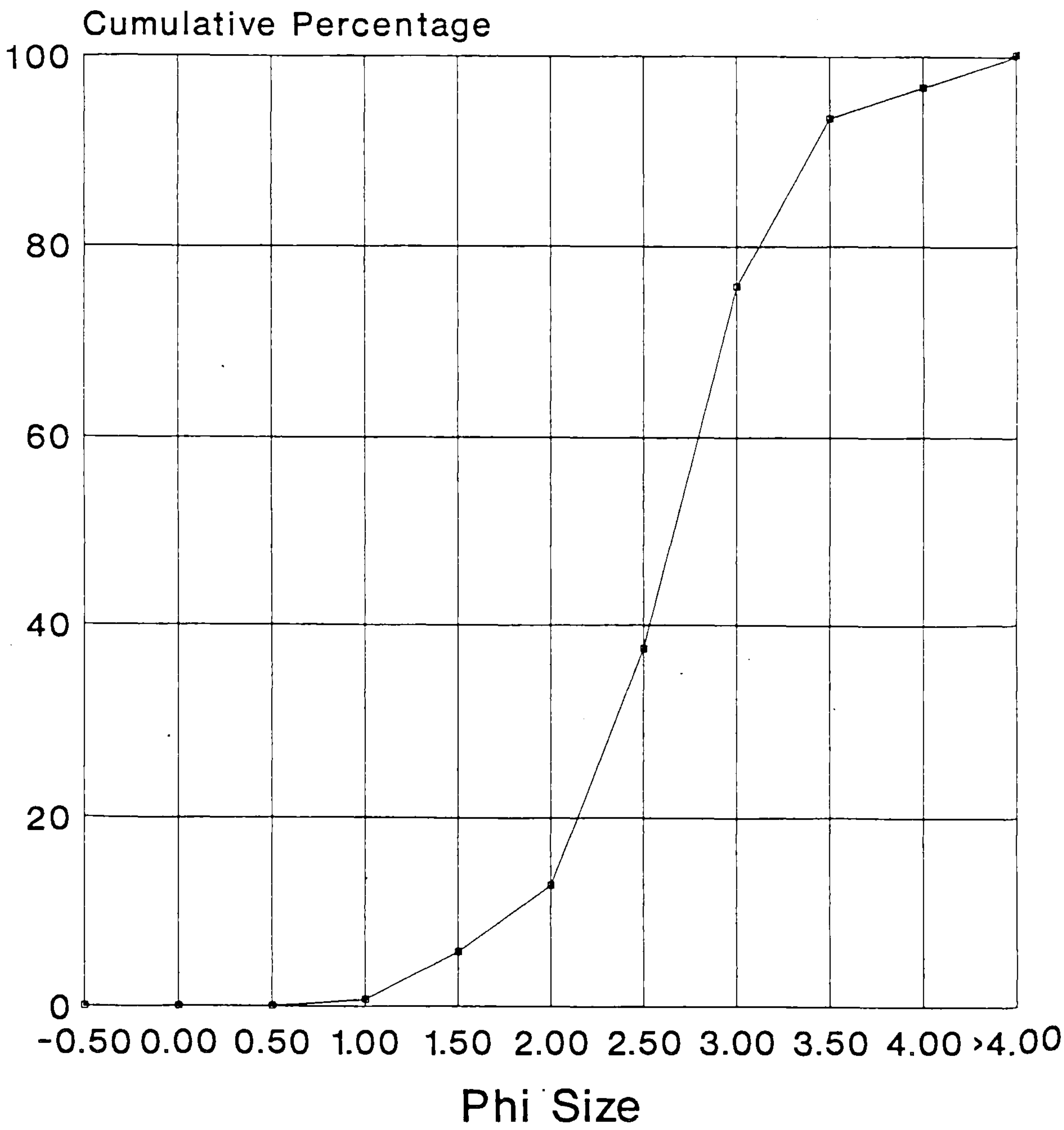
Grain Size Analysis
Sample U.S.G.S. 929A-2



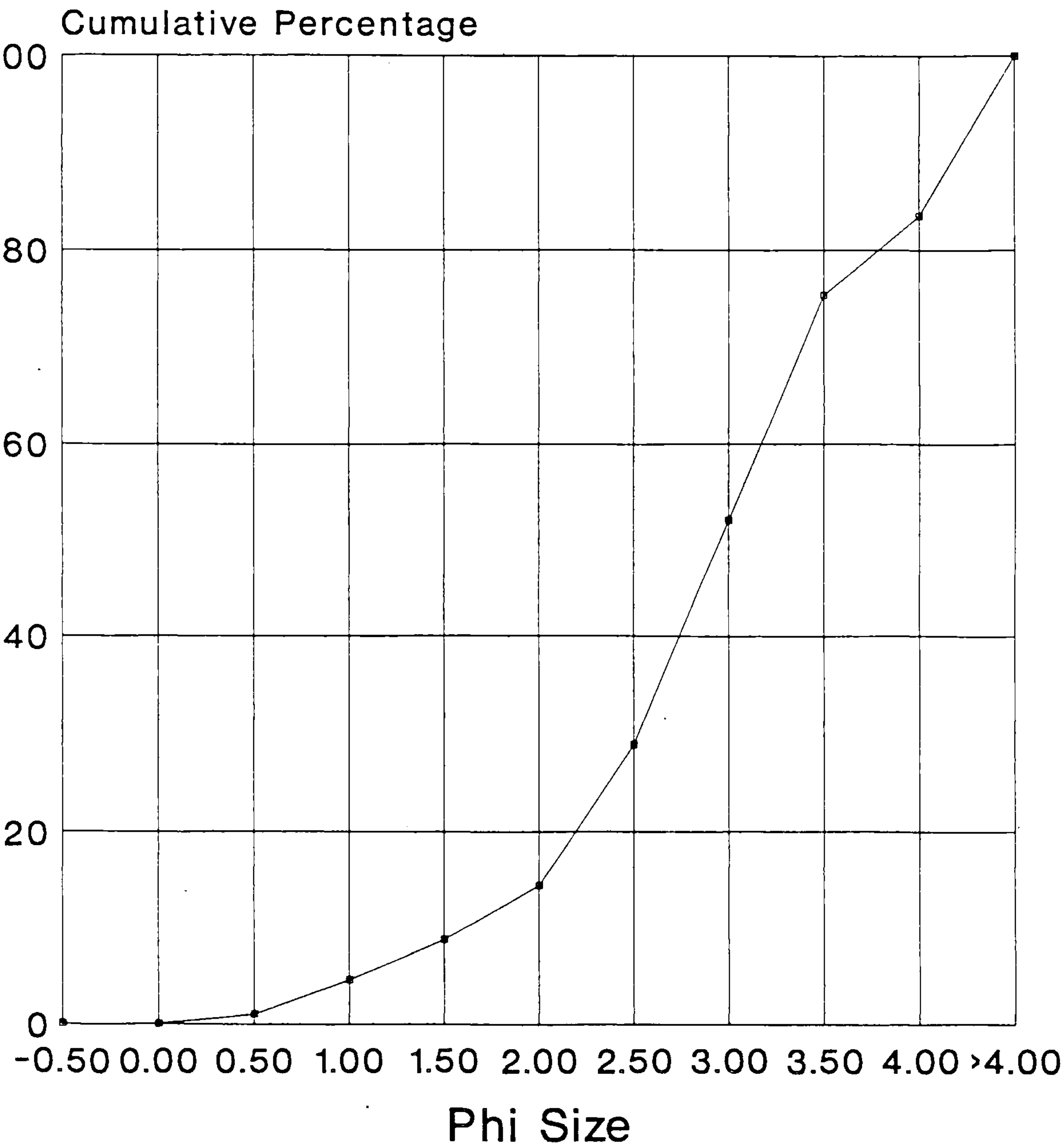
Grain Size Analysis
Sample U.S.G.S. 931



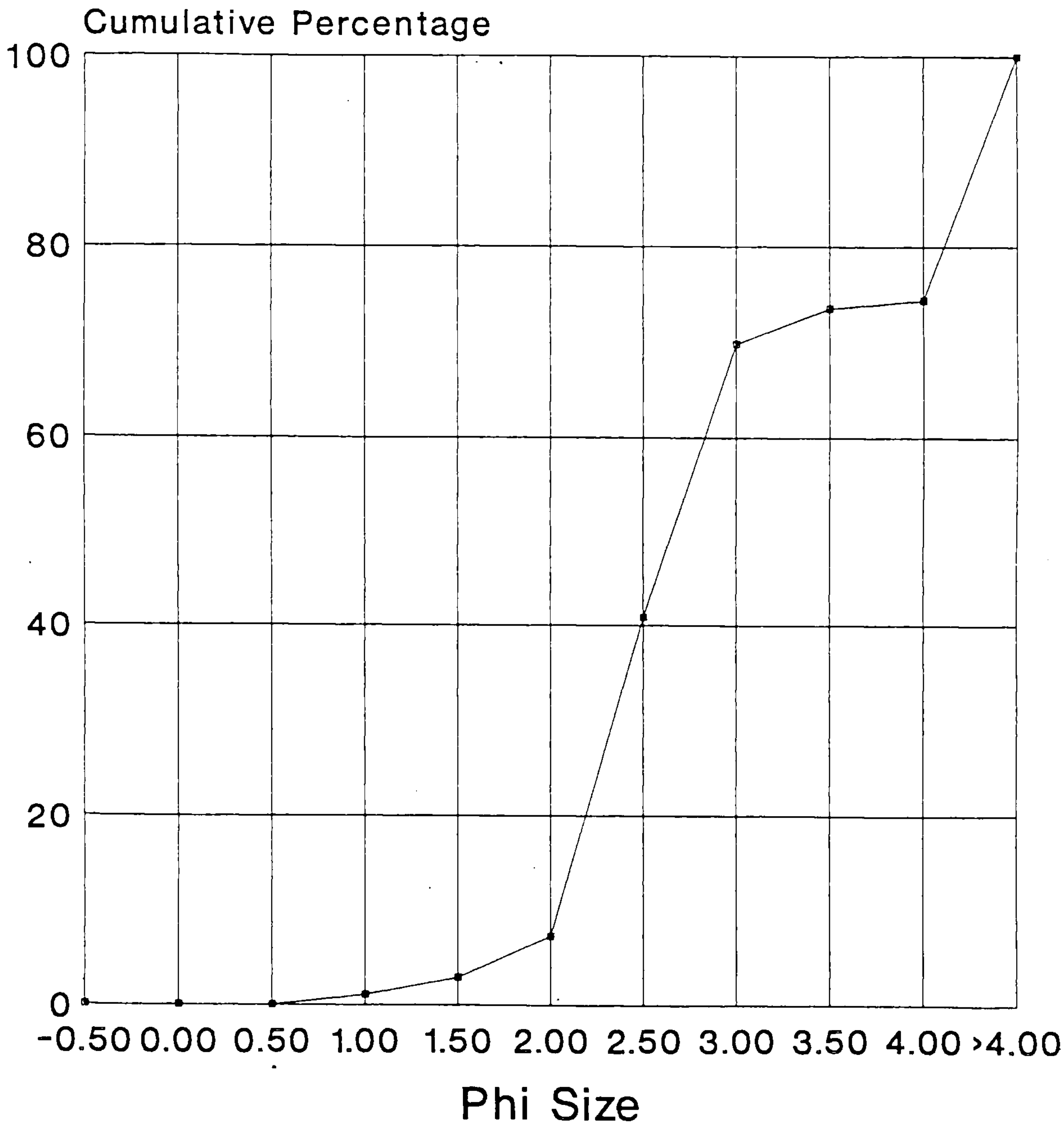
Grain Size Analysis
Sample U.S.G.S. 932-1



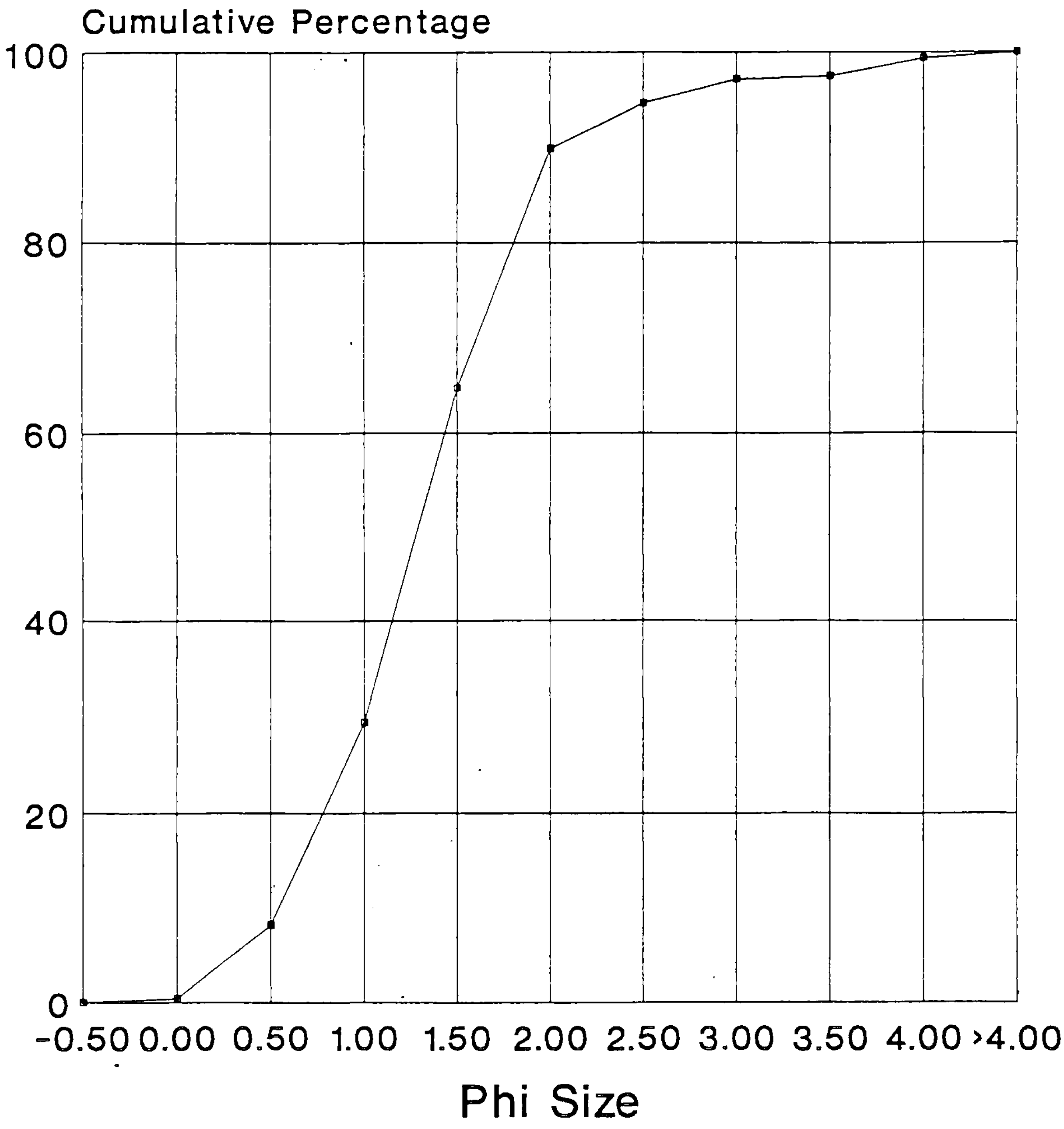
Grain Size Analysis
Sample U.S.G.S. 932-2



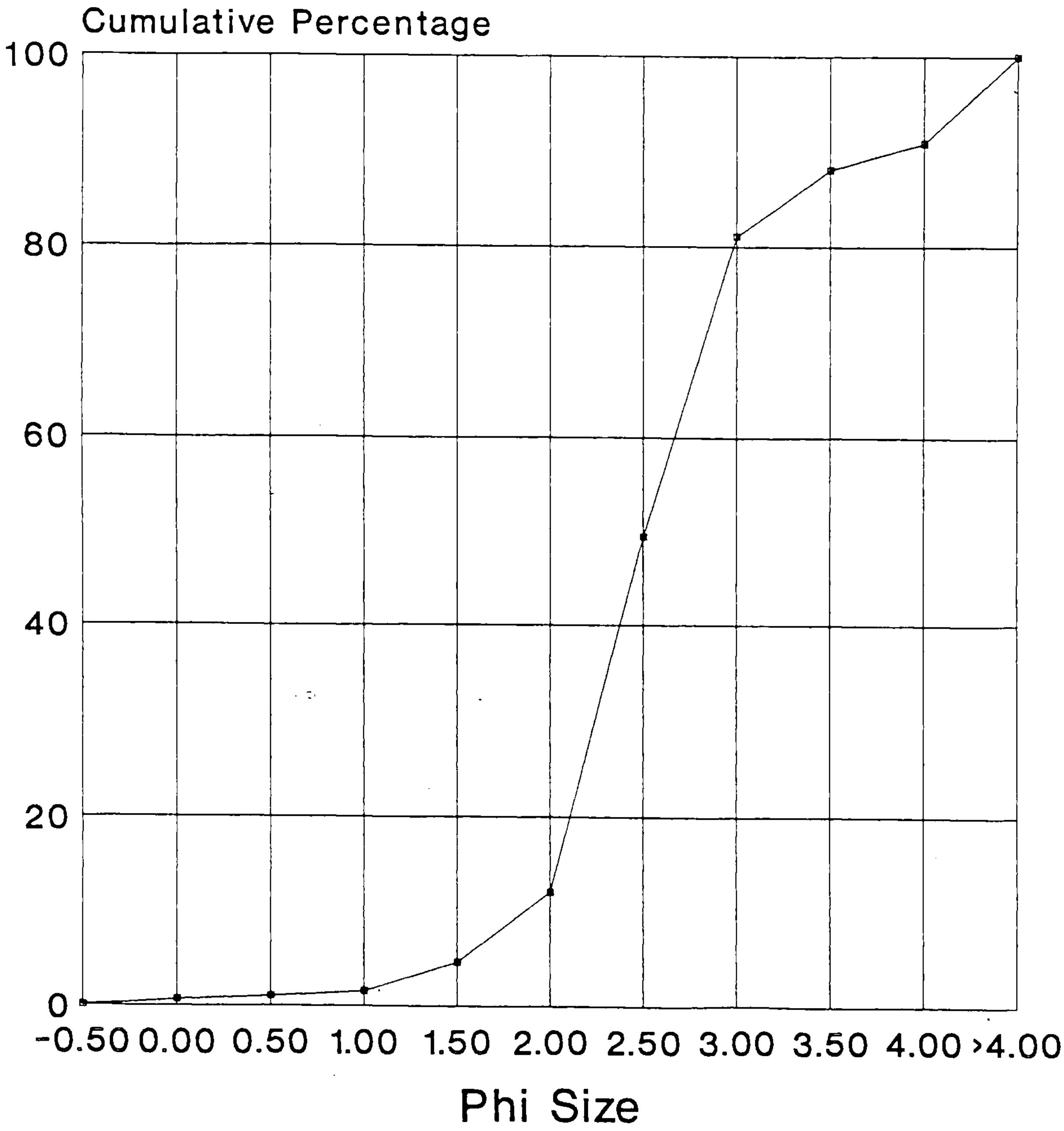
Grain Size Analysis
Sample U.S.G.S. 939



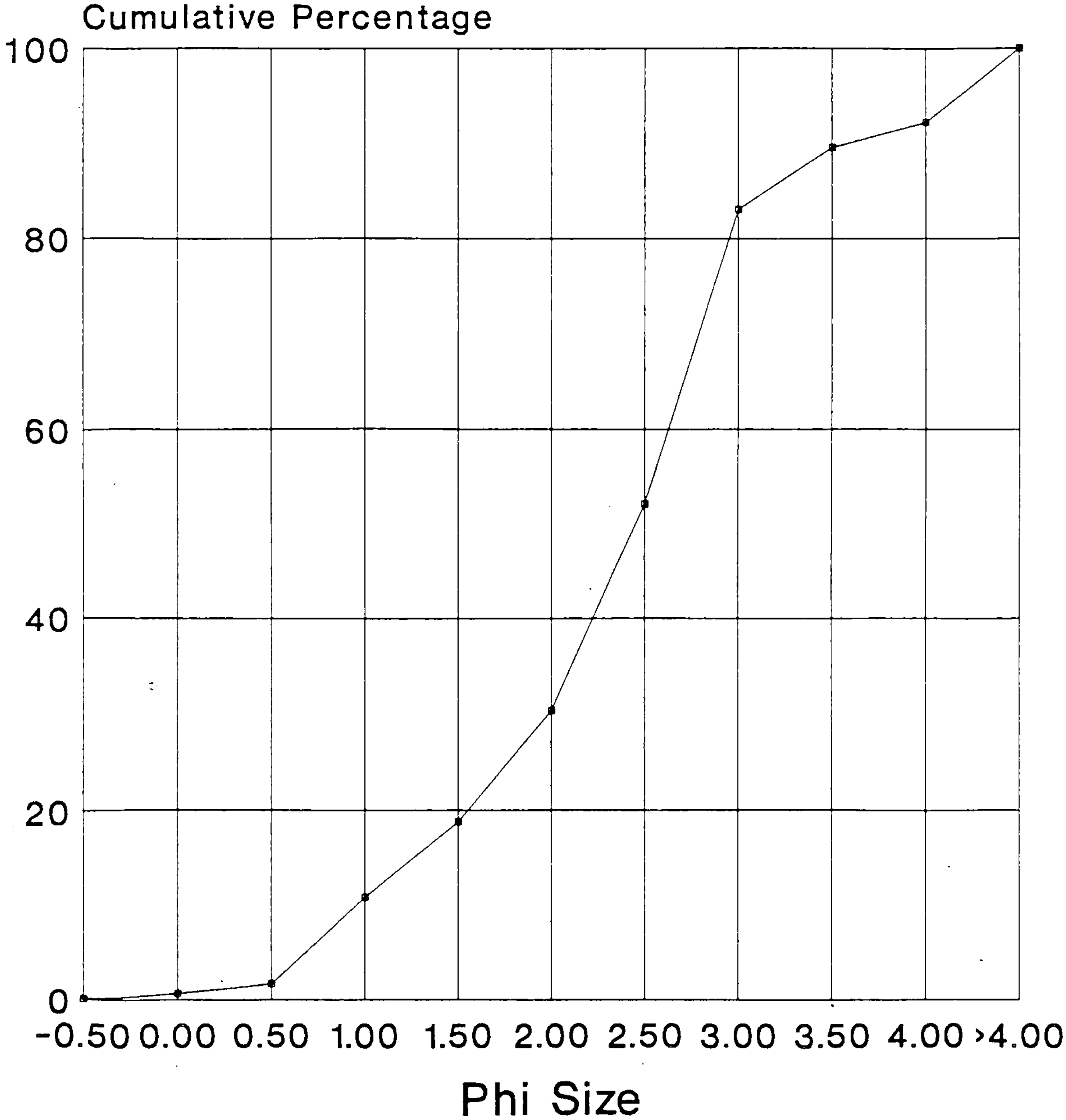
Grain Size Analysis
Sample U.S.G.S. 943



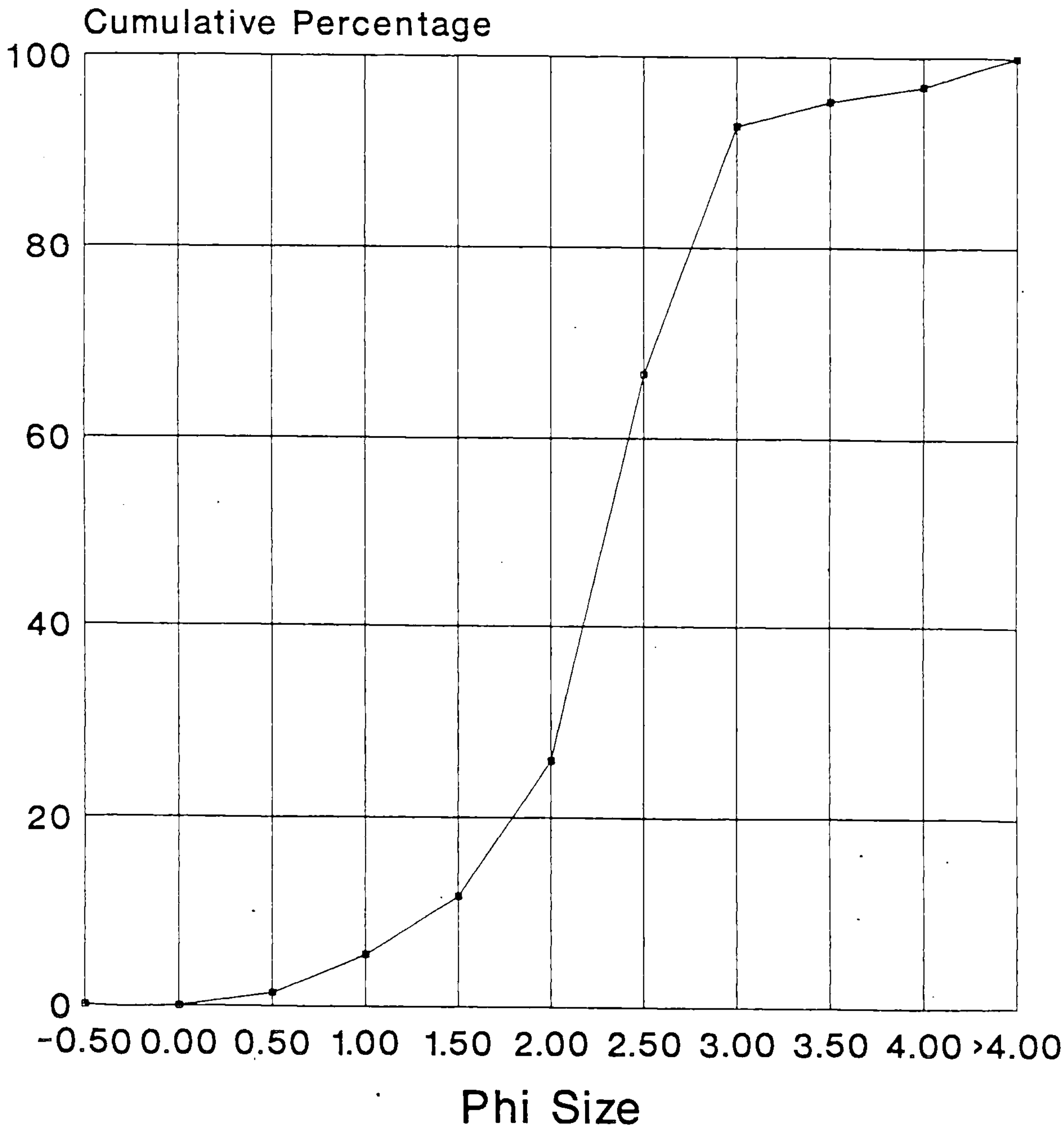
Grain Size Analysis
Sample U.S.G.S. 946-1



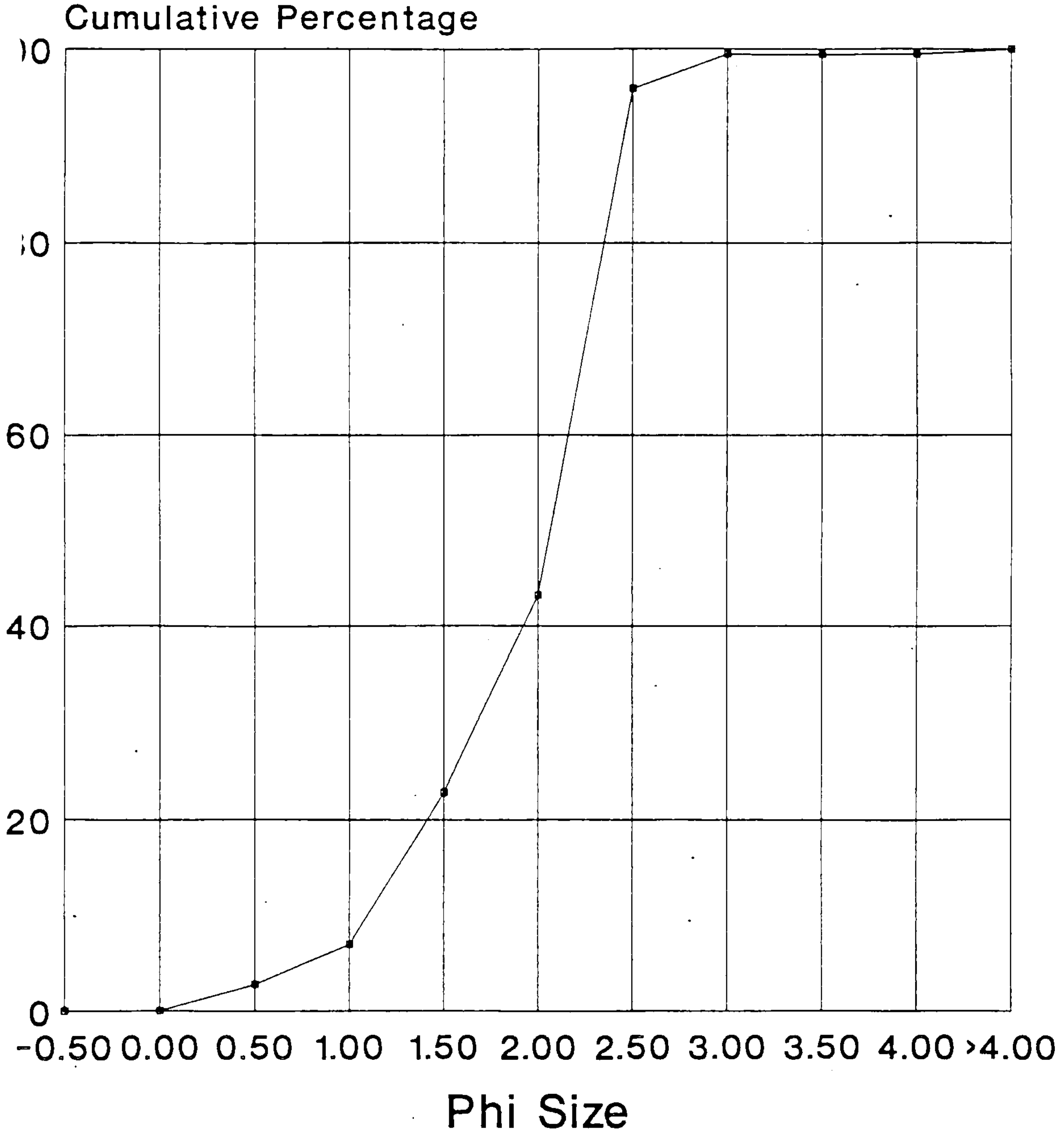
Grain Size Analysis
Sample U.S.G.S. 946-2



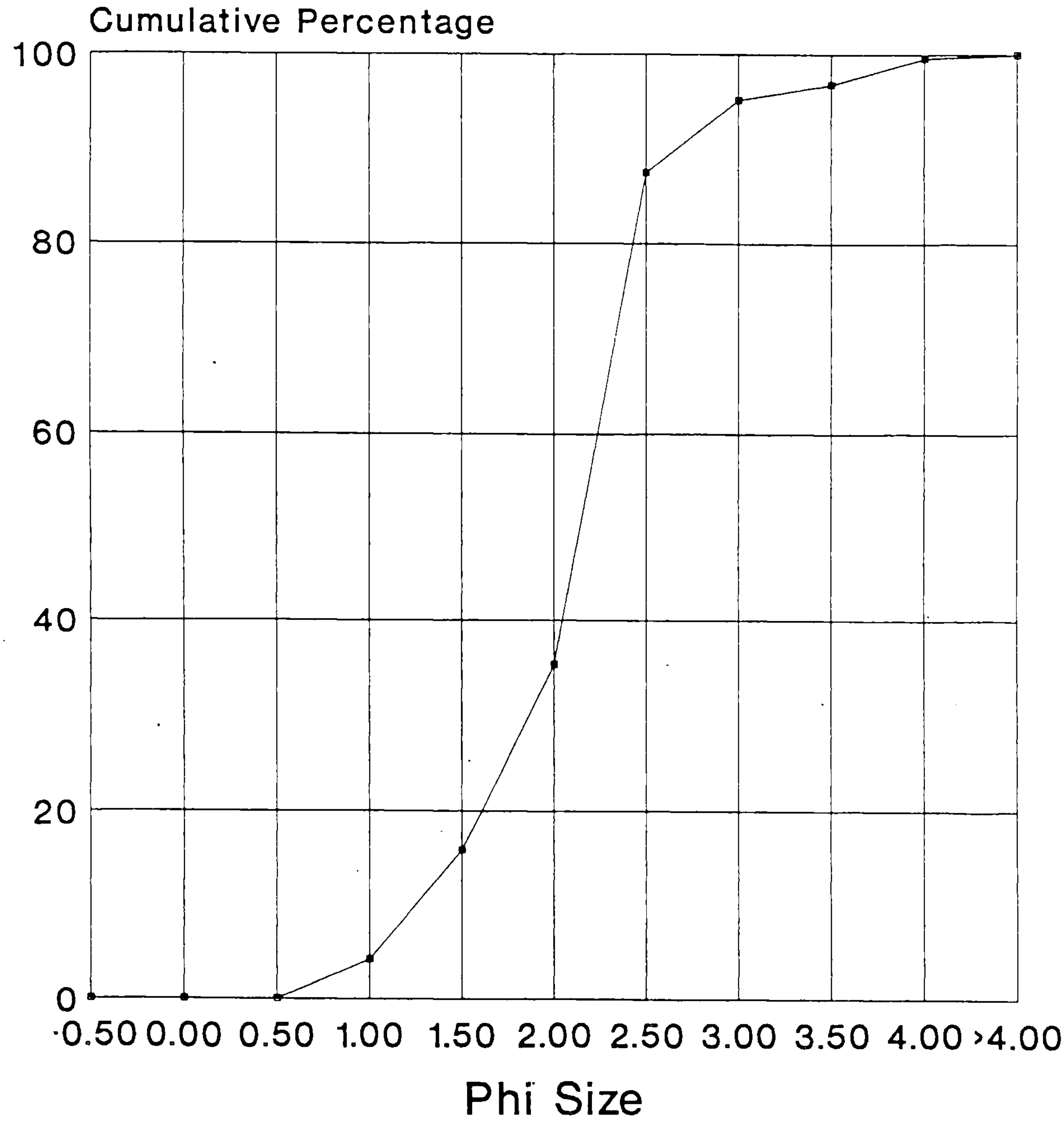
Grain Size Analysis
Sample U.S.G.S. 946-3



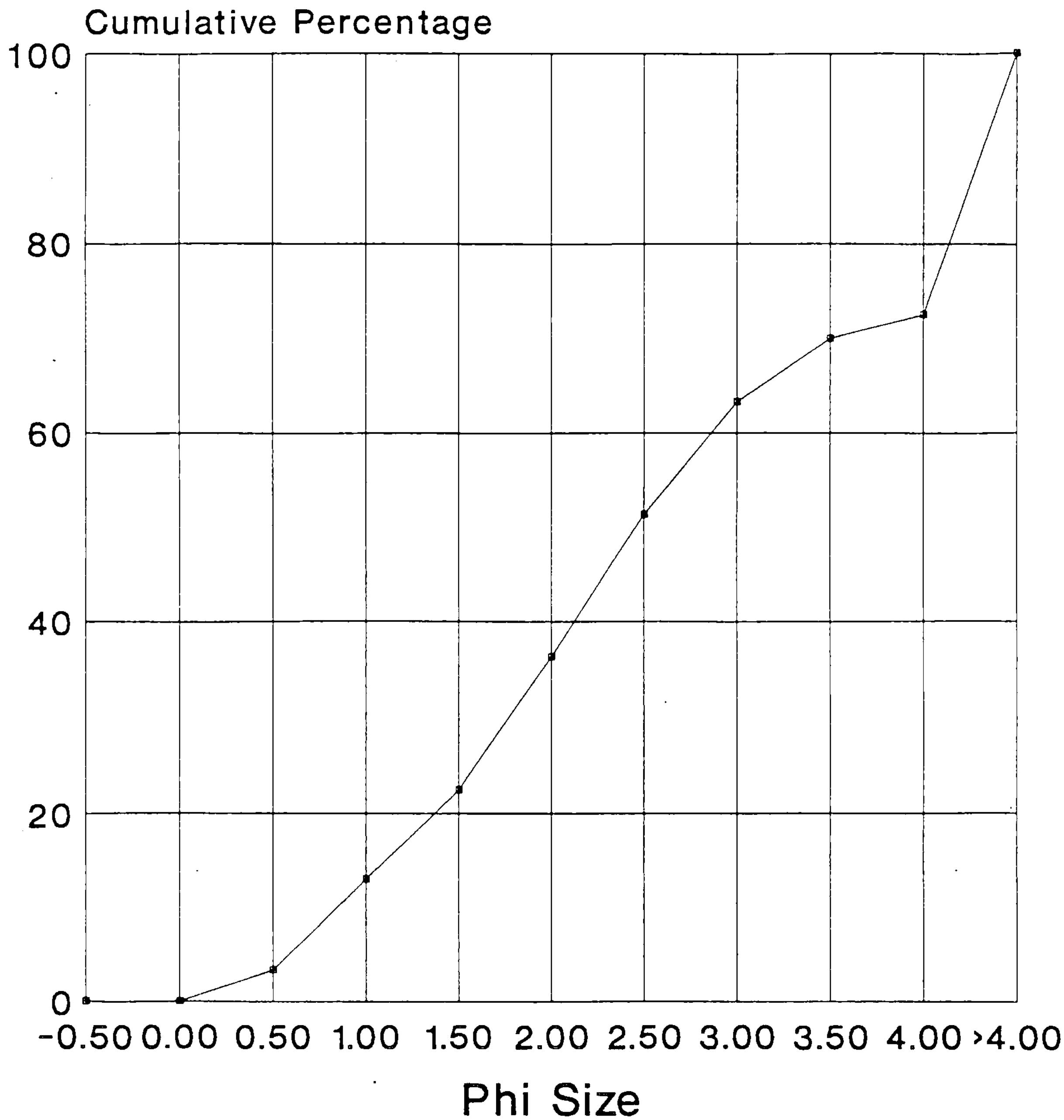
Grain Size Analysis
Sample U.S.G.S. 949-1



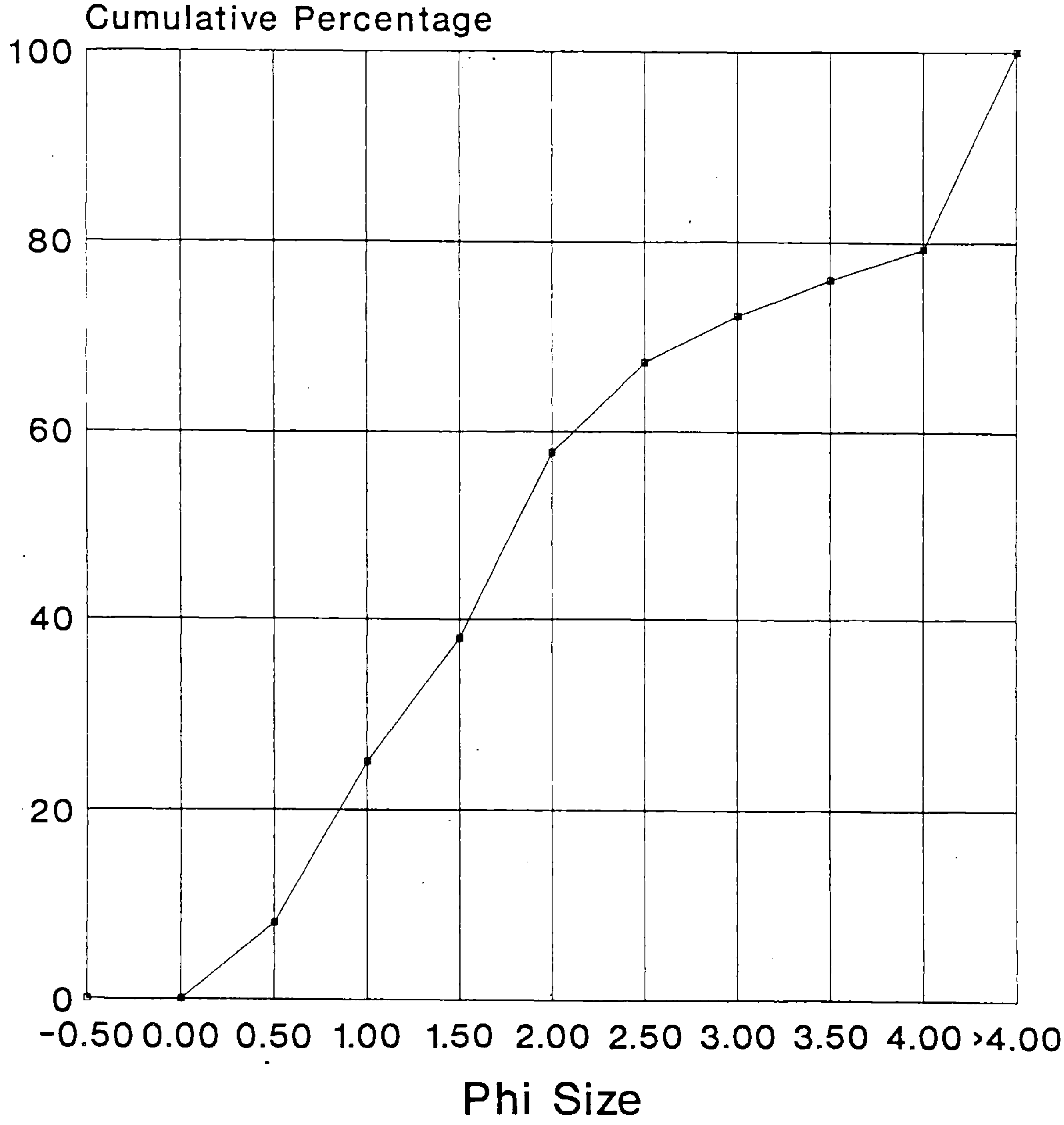
Grain Size Analysis
Sample U.S.G.S. 949-2



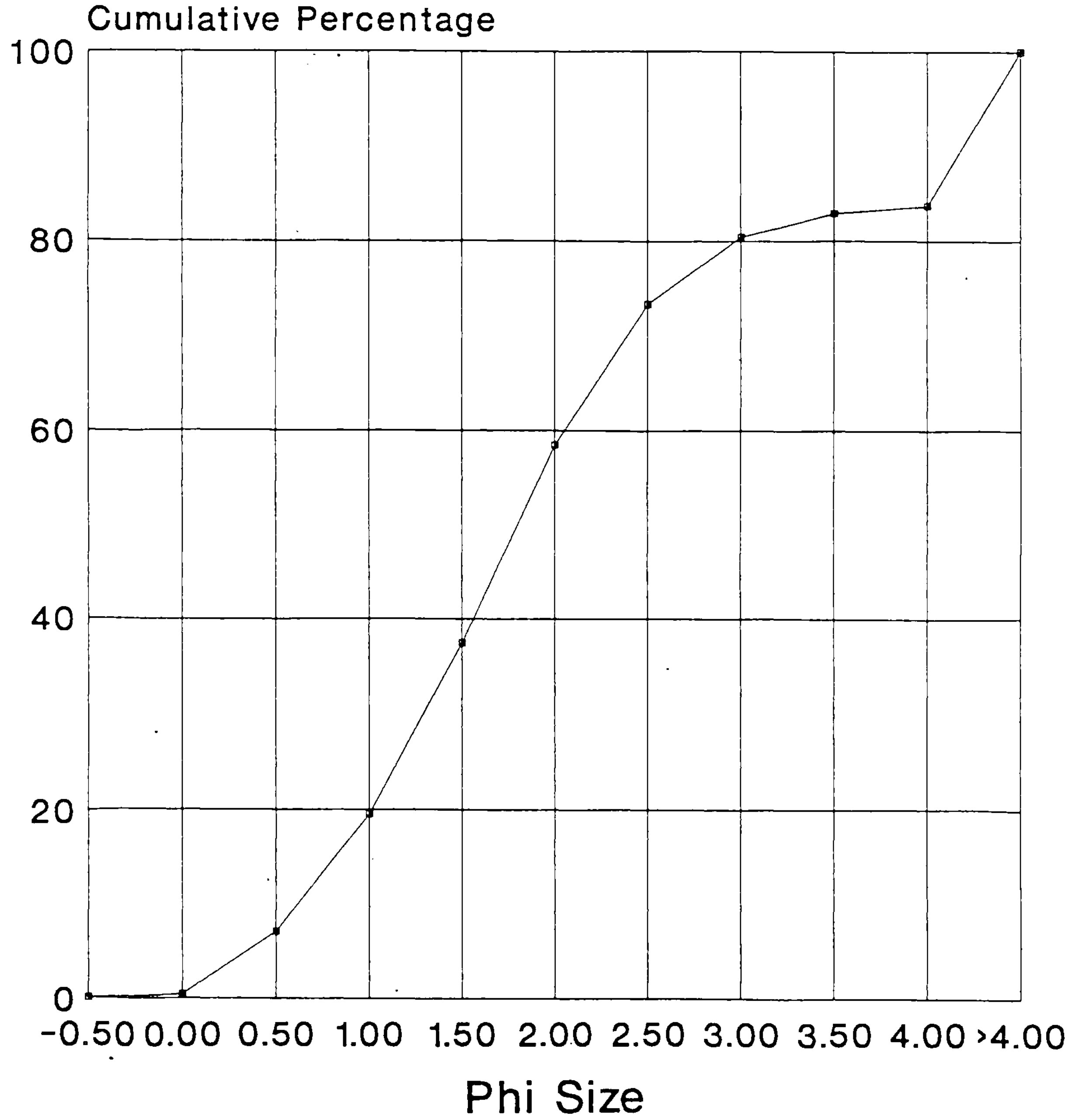
Grain Size Analysis
Sample U.S.G.S. 954-1



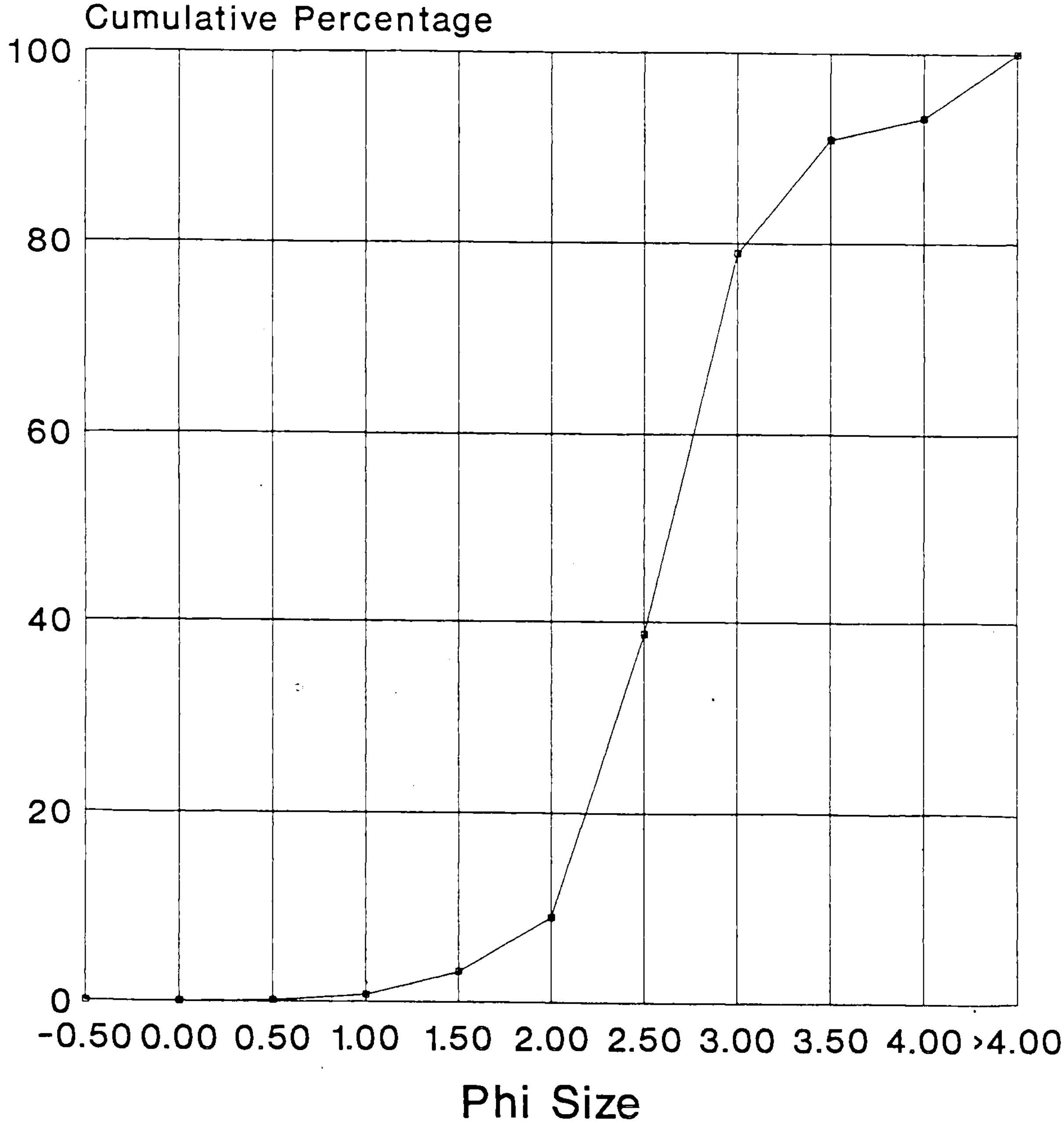
Grain Size Analysis
Sample U.S.G.S. 954-2



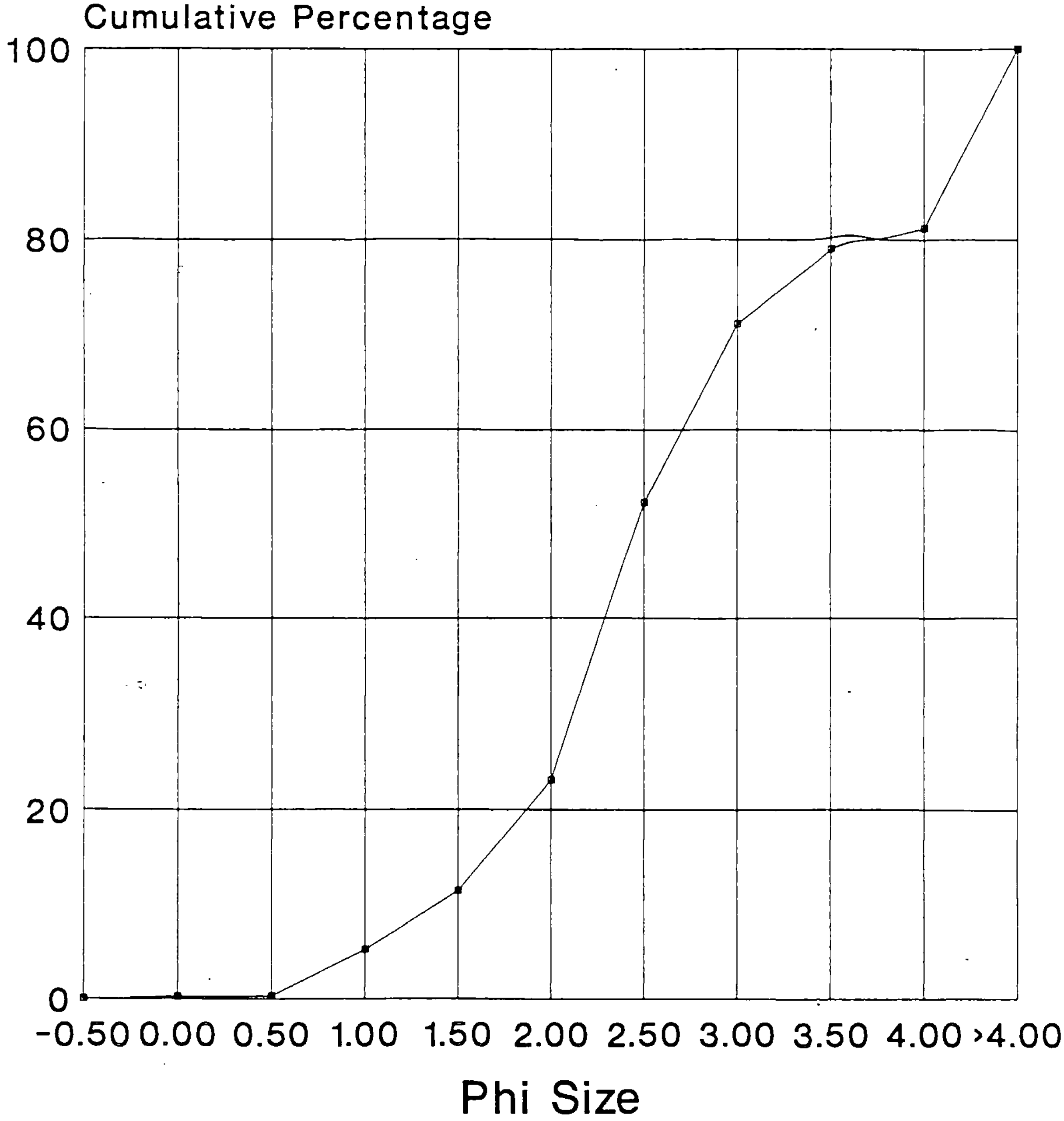
Grain Size Analysis
Sample U.S.G.S. 958



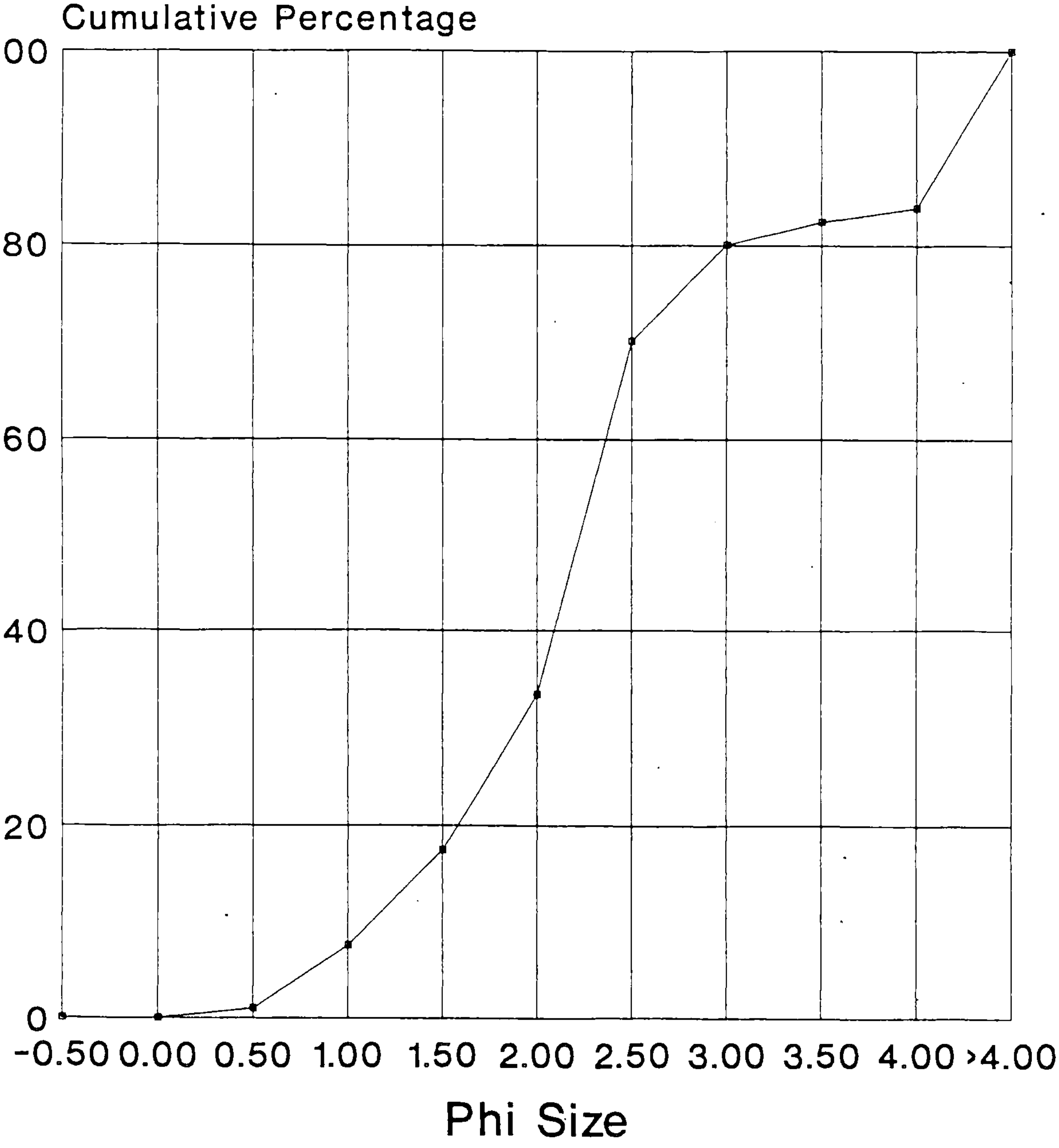
Grain Size Analysis
Sample U.S.G.S. 959-1



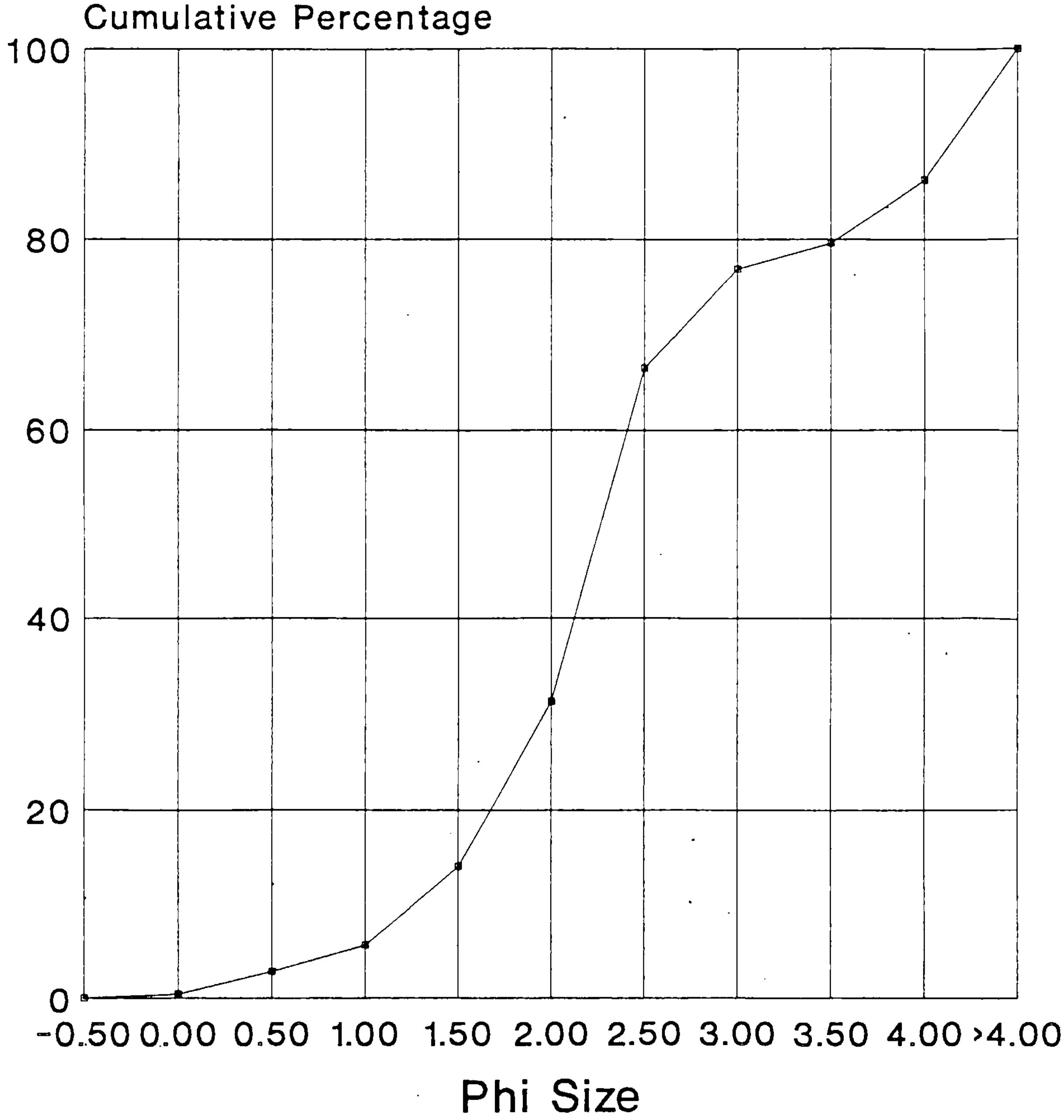
Grain Size Analysis
Sample U.S.G.S. 959-2



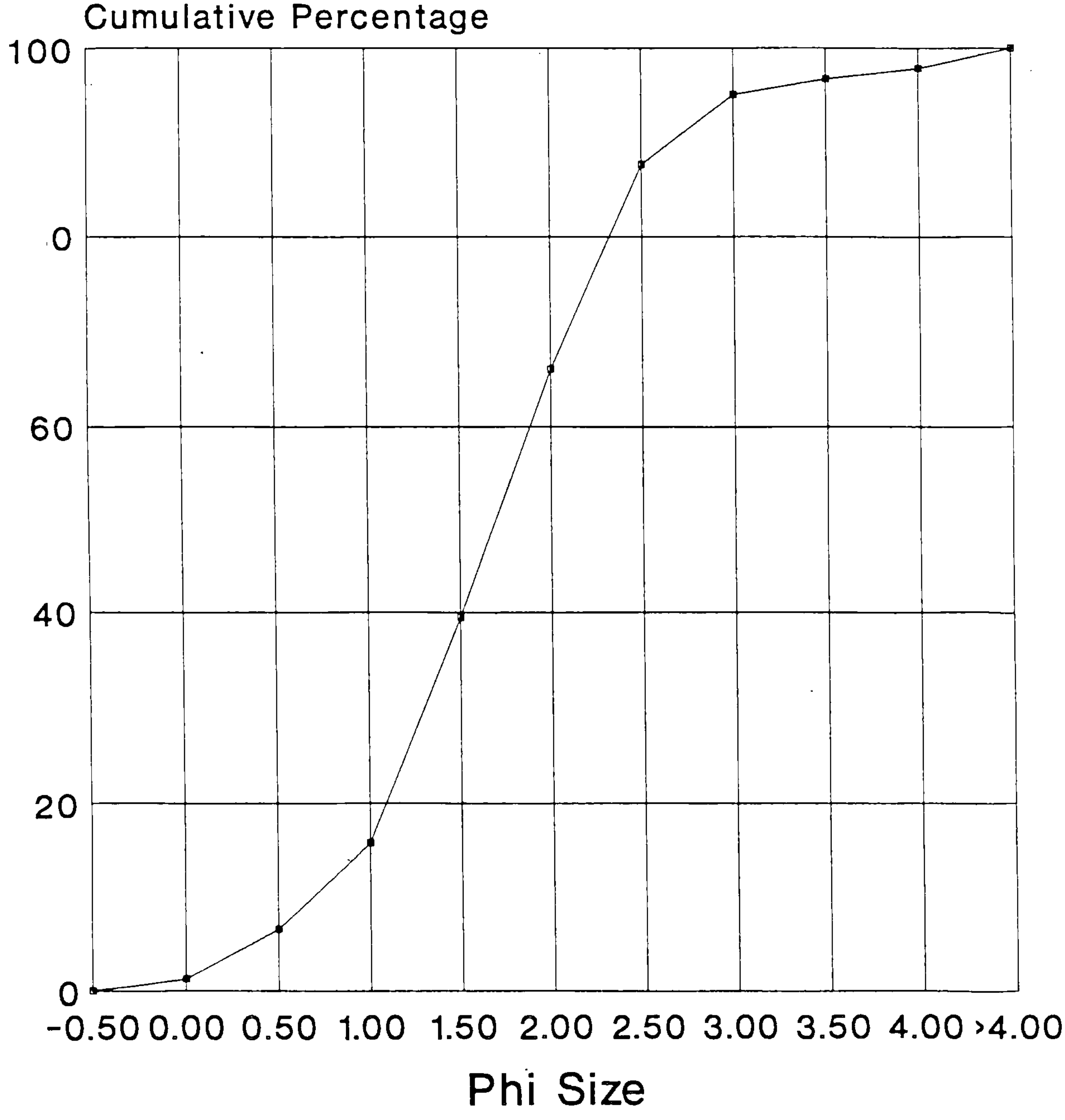
Grain Size Analysis
Sample U.S.G.S. 966-1



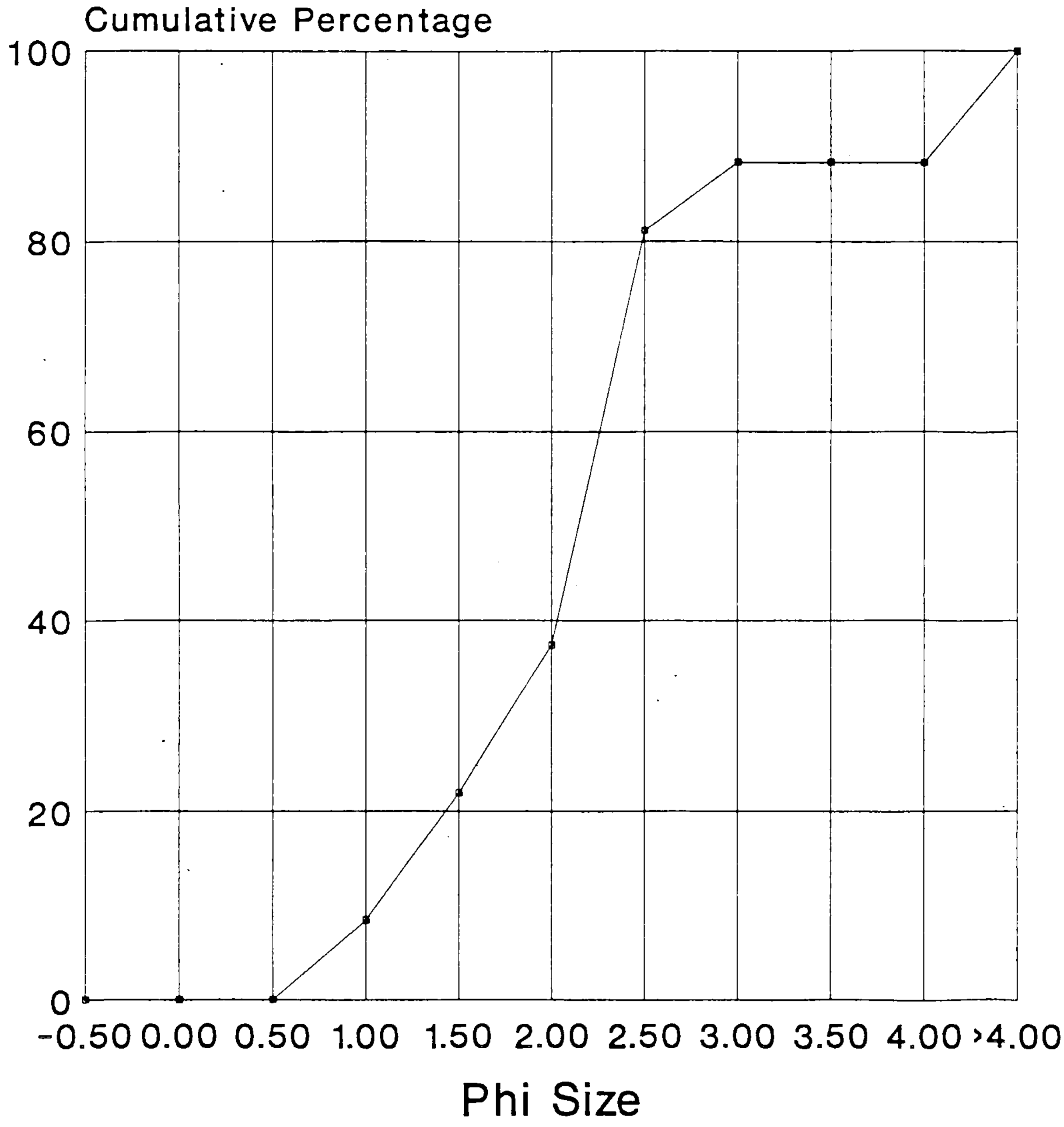
Grain Size Analysis
Sample U.S.G.S. 966-2



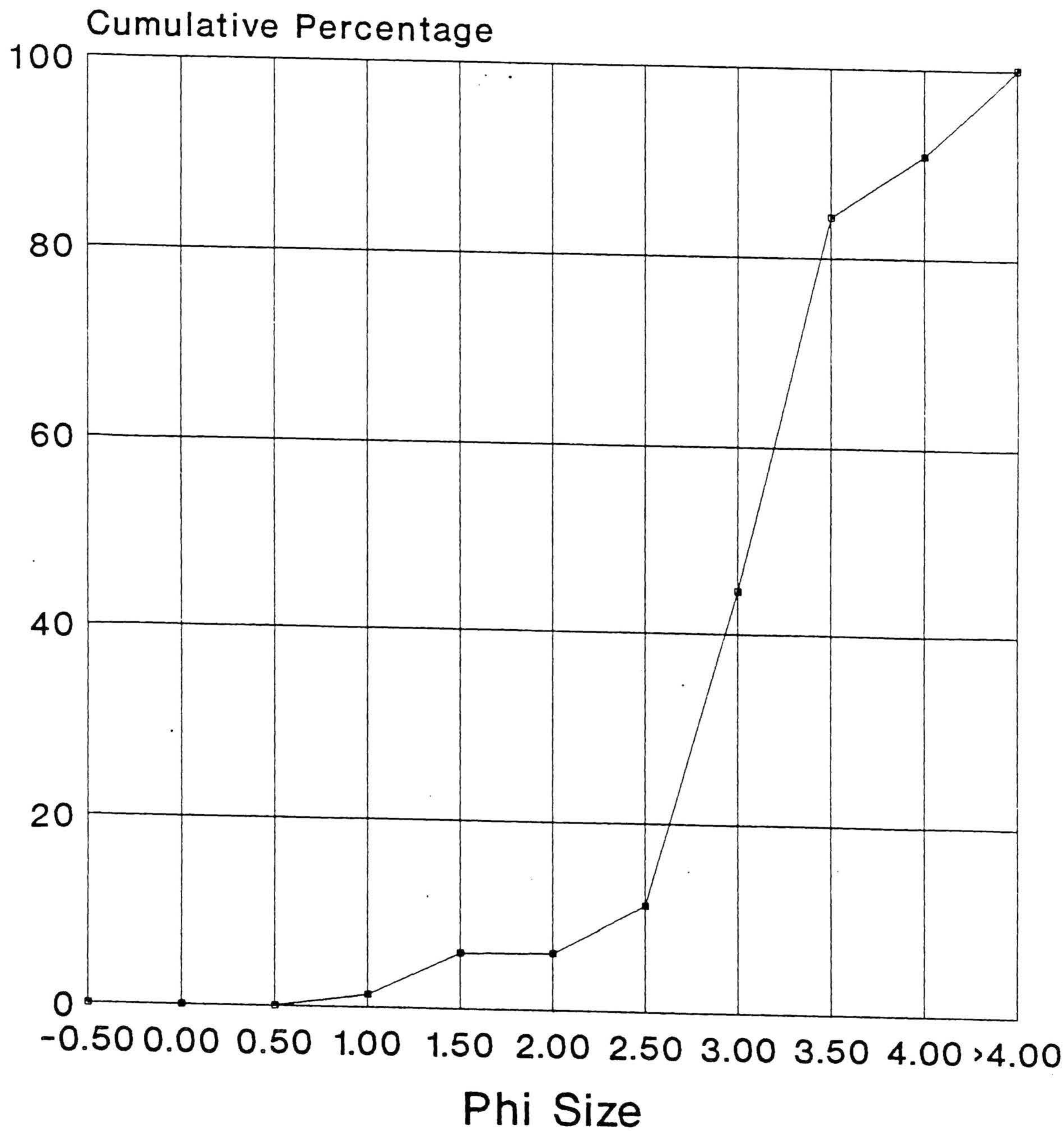
Grain Size Analysis
Sample U.S.G.S. 968-1



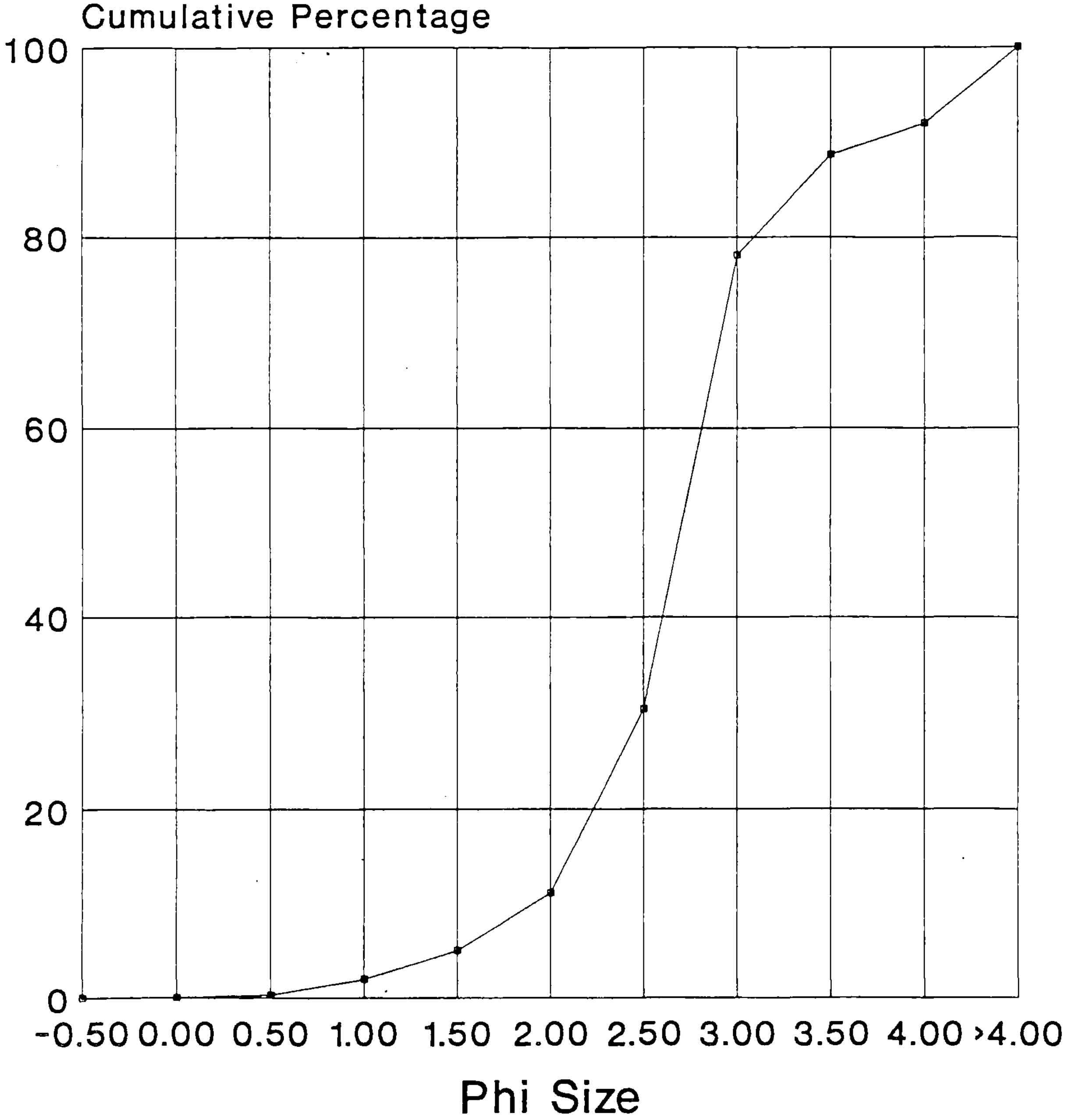
Grain Size Analysis
Sample U.S.G.S. 968-2

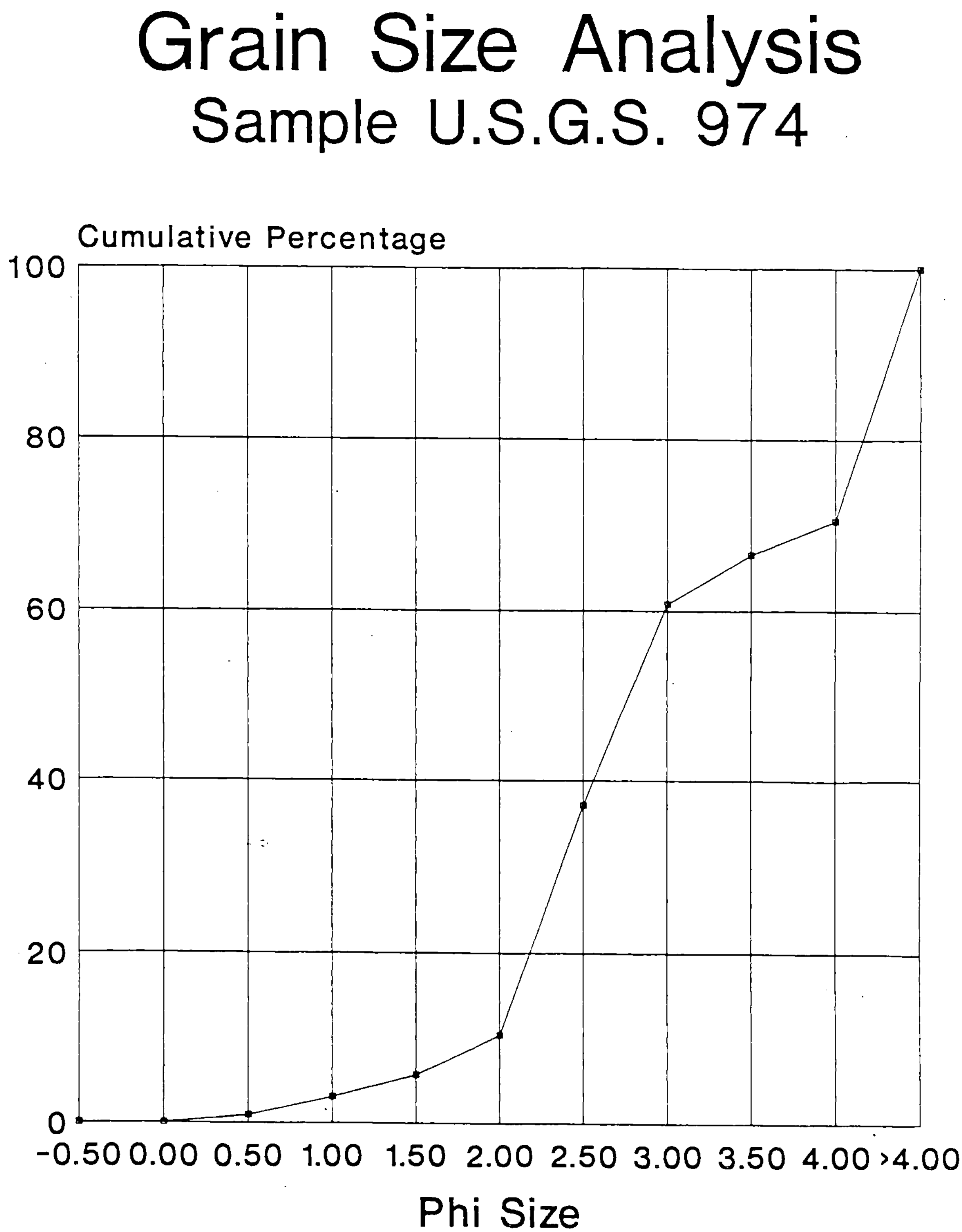


Grain Size Analysis
Sample U.S.G.S. 969-1



Grain Size Analysis
Sample U.S.G.S. 969-2




Grain Size Analysis
Sample U.S.G.S. 974
Cumulative Percentage
100
80
60
40
20
0
-0.50 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 >4.00
Phi Size

Grain Size Analysis
Sample U.S.G.S. 979