Grain size analysis and soil stratigraphy across Suffolk County: Proxy for classification of sediment as a diamict

Katherine Dominguez
Stony Brook University, Stony Brook, NY

Abstract

Field observations and previous studies of the sediment across Suffolk County have puzzled many, due to its fine-grained, silty nature but consistent and abundant presence of pebbles. Dr. Gil Hanson of Stony Brook University has called this sediment "pebbly loess". However, the presence of pebbles in wind-blown silt has eluded explanation by many. Grain size analysis of undisturbed sediments across four locations in Suffolk County (Stony Brook University, Suffolk County Farm, North Street, and Dwarf Pine Plains) reveal the poorly to very poorly sorted nature of the sediment, with consistent and abundant clasts ranging from 1-4cm or greater. Due to the poorly sorted nature of the sediments at all four sites, a better descriptor for the sediment, diamict, is proposed. This term also better accounts for and explains the presence of pebbles in the sediment. A diamict is defined as non-sorted, or poorly sorted, unconsolidated sediment containing a wide range of particle sizes, where quantitatively, poorly sorted is defined as a geometric standard deviation σ_G between 2-4 (poorly sorted), 4-16 (very poorly sorted) and >16 (extremely poorly sorted). Furthermore, diamicts are often deposited and characterized by a variety of sedimentary processes. While it is most probable that glacial processes may have contributed to the nature of the sediment on Long Island, other processes including landslides, mudflows, solidfluction, flowtill activity, slumping and sliding, and deformation by floating ice are capable of forming diamict deposits. Formation methods may also have been a result of an impact event associated with the Younger Dryas cooling period. Statistical results point to multiple processes responsible for the deposition of these diamicts.

Introduction

The purpose of this study is to characterize and describe the nature of the sediment across Long Island, specifically in Suffolk County, in an attempt to explain the existence of 'pebbly loess' found on Stony Brook Campus and other sites across the county. The presence of pebbly loess and the characteristics of the sediment at various sites could provide insight into the processes associated with their existence. Furthermore, this study looks into the naming scheme for the sediment called, "pebbly loess" (Hanson, 2014). Loess, otherwise known as wind blown silt, does not typically contain pebbles, as they are too large to be carried by wind. Their presence, therefore, suggests another process may be involved. Grain Size analysis statistics and potentially correlating stratigraphic sections at each of the four sample sites can provide a better understanding of the nature of the sediment described as pebbly loess, to perhaps provide another, more accurate descriptor. Moreover, based on the findings, this research has further implications for the impact theory associated with the onset of the Younger Dryas cooling period. The original impact model explaining the onset of the Younger Dryas period was proposed by Firestone et al. (2007). It suggests one or several low-density extraterrestrial objects exploded over northern North America, and in doing so, partially destabilized the Laurentide Ice Sheet, contributing to the Younger Dryas cooling period (Firestone et al., 2007). The results of this study may help explain the presence of pebbles in the loess in relation to an impact event, in which material was thrown upward, and as it came back down, settled in a poorly sorted manner.

Methods

Samples were collected over four sites across Suffolk County, at various depths, specifically where there appeared to be a change in the nature of the sediment. The Stony Brook (SBU) site has an exposed sample of loess along a streambed where samples were taken, and a small hole was dug at each of the other three sites, Suffolk County Farm (SCF), North Street (NS) and the Dwarf Pine Plains (DPP) (fig. 1a-d). The research team sought to dig in an area at each site where the sediment was undisturbed, as to not influence the data upon analysis. Samples at each site were bagged and labeled according to the depth and sample location using the following scheme:

Samples:

Site 1: Stony Brook University Stream (SBU) (40° 54'51.78"N 73° 7'44.64"W (fig. 1a.)
Depth: 124 cm
Sample Names: SBU A (top of section)
SBU B
SBU C
SBU D (bottom of section)

Site 2: Suffolk County Farm (SCF) (40°49'40.02"N 72°55'31.44"W) (fig. 1b.)
Depth: 40.64 cm
Sample Names: SCF A (top of section)
SCF B
SCF C (bottom of section)

Site 3: North Street (NS) (40°52'15.96"N 72°50'17.58"W) (fig. 1c.)
Depth: 60.96 cm
Sample Names: NS A (top of section)
NS B
NS C (bottom of section)

Site 4: Dwarf Pine Plains (DPP) (40°52'18.12"N 72°39'17.40"W) (fig. 1d.)
Depth: 68.58 cm
Sample Names: DPP A2 (top of section)
DPP B2
DPP C2
DPP D2
DPP E2 (bottom of section)

*****Note: DPP sites A2-E2 indicate data used is from a second run through the mastersizer, due to inherent limitations associated with the machine's accuracy.

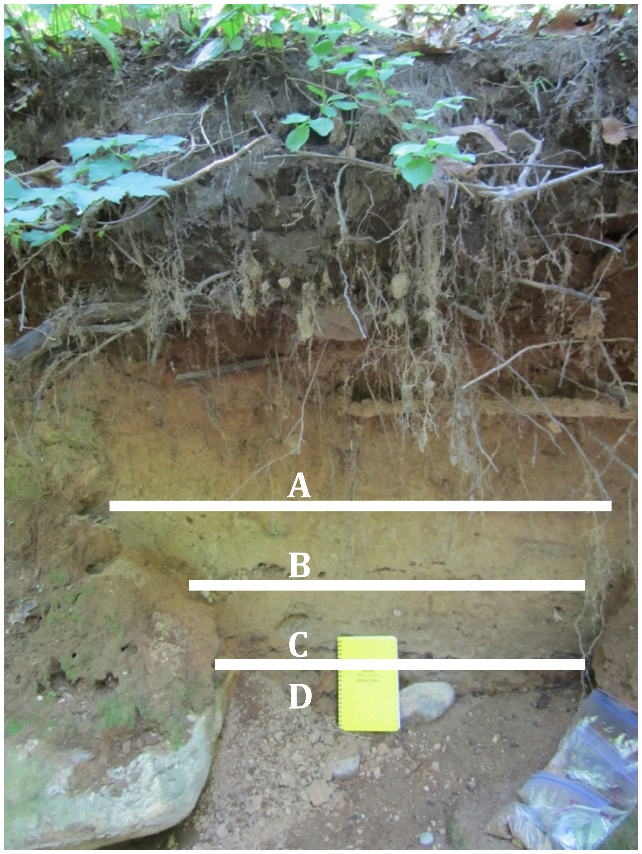


Fig. 1a: Stony Brook University (SBU) section and sample site. SBU layers A-D shown. Section is 124 cm deep.

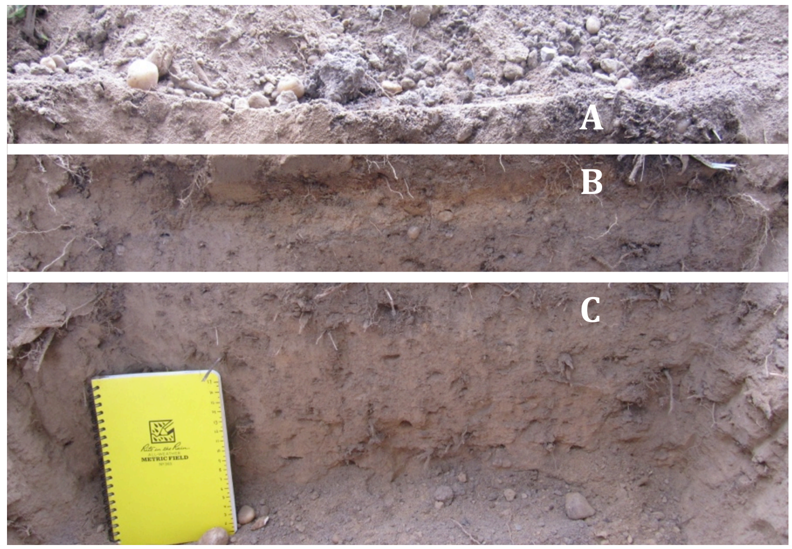


Fig. 1b: Suffolk County Farm (SCF) section and sample site. SCF layers A-C shown. Section is 40.64 cm deep.

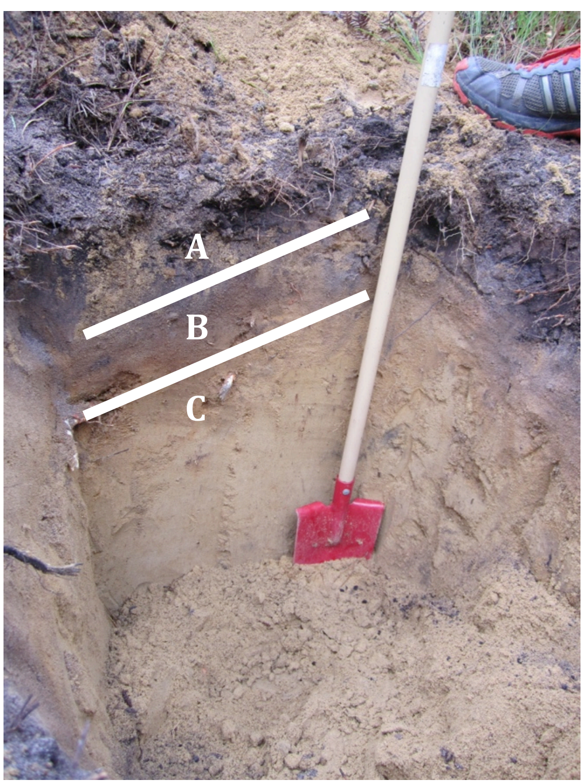


Fig. 1c: North Street (NS) section and sample site. NS layers A-C shown. Section is 60.96 cm deep.

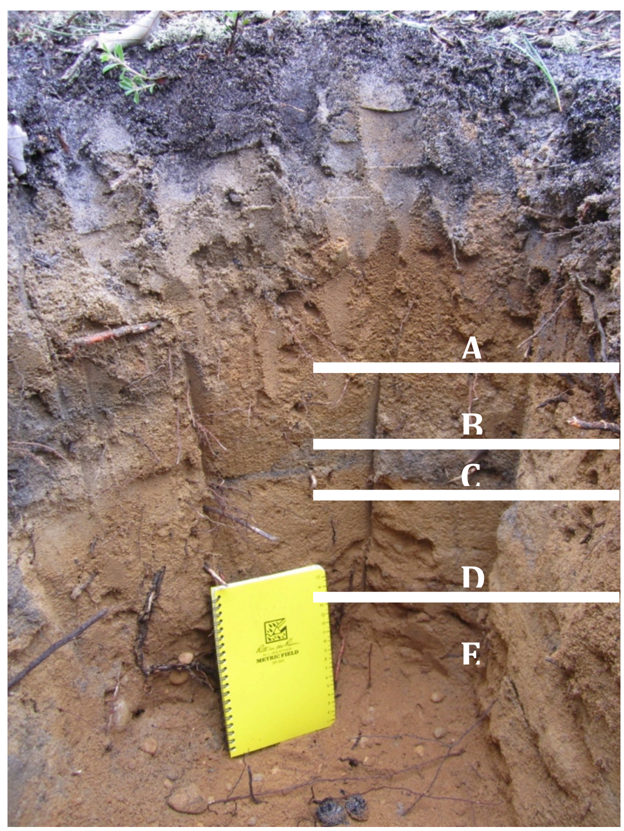


Fig. 1d: Dwarf Pine Plains (DPP) section and sample site. DPP layers A-E shown. Section is 68.58 cm deep.

Samples were brought back to the lab and prepped for grain size analysis using the following procedure outlined by Timothy D. Clare (2013) below:

After collection, the samples were taken into the lab and laid out on clean sheets of white paper to dry for 24 hours. The next day each sample was prepped for grain-size analysis using the following procedure:

1. Large pebbles and organic matter removed from sample
2. 10 minute paper folding method to remix sample, as sediments will naturally sort overnight
3. 10 grams of sample is weighed out into a small cup (cup is weighed first)
4. 10 g sample is sifted through a 1mm sieve
5. Larger particles ($\geq 1mm$) are removed, weighed and put aside
6. Particles $<1mm$ are weighed and placed into a small plastic bottle

*Steps are repeated for each sample

7. Each bottle is then filled with a $(NaPO_3)_6$ solution that acts as a dispersant
8. Bottle is shaken vigorously for 30 seconds after dispersant is added
9. Samples are left to sit for 24 hours

Once samples are prepared in the manner detailed above, they can be run through Mastersizer 2000 particle size analyzer. As detailed by the manufacturer Malvern (2014), the Mastersizer 2000 uses laser diffraction to measure the size of particles by measuring the intensity of light scattered as a laser beam passes through a dispersed particulate sample. The instrument software analyzes the data and calculates the size of the particles that created the scattering pattern.

The samples were prepared for the Mastersizer 2000 in the following manner detailed by Clare (2013):

1. $(NaPO_3)_6$ solution is run through the machine as a background for the particulate sample
2. Sample is shaken for 30 seconds using a vibration machine to complete mix the particles
3. Small amount of sample is drawn out of bottle with a pipette and dropped into solution to an obscuration of ~15% (measured by computer software)
4. Sample is passed through Mastersizer 3 times

The Mastersizer instrument software averages the three tests to yield a mean, mode, and percent of silt versus sand and clay for each of the samples. For the purposes of this study, this information was then input into a program called Gradistat to run grain size statistics for each sample. Gradistat provides rapid grain size statistics by arithmetic, geometric and logarithmic moments and methods (Blott and Pye, 2001). Gradistat assumes sieves are used to measure the amount of sediment retained in a number of size fractions, which serves as the input data for the program (Blott and Pye, 2001). Sample statistics including mean, mode(s), sorting, skewness, kurtosis, and a range of cumulative percentile values (Blott and Pye, 2001). According to Blott and Pye (2001), the following parameters are used to define a grain size distribution from gradistat: the average size of grains, sorting, skewness, and kurtosis. Sorting refers to the spread of the sizes around the average. The preferential spread of grains to one side of the average is known as the skewness. Lastly, kurtosis refers to the degree of concentration of grains relative to the average or is considered the measure of "peakedness" in a distribution curve (Blott and Pye, 2001). A normal distribution, or symmetrical curve is considered mesokurtic. An excessively peaked distribution curve, better sorted in the central portion of the graph rather than the outer tails is leptokurtic. If the opposite holds true, and sorting is better on the tail ends, the sample is platykurtic.

In addition, relative percent values of sand, silt, and clay obtained for each sample from the mastersizer were totaled and graphed on the United States Department of Agriculture soil texture calculator. Analyses of the above results were used to compose a stratigraphic section for each site, detailing the nature of the sediment. Results obtained from the above methods are detailed in the next section.

Results: Grain Size Statistics

Gradistat program statistics (geometric method of moments) yielded the following results for mean, sorting, skewness, and kurtosis as summarized in the following tables (tables 1-4).

The Stony Brook site uppermost layers A and B had a mean grain size (in microns) of 75.7 and 74.4, respectively (table 1). Sites C and D yielded a mean of 114.7 and 69.3, respectively (table 1). All samples were very poorly sorted, containing sediments ranging from fine to pebble sized. Pebbles ranging from 1mm or larger were evident throughout the section (fig. 1a). Symmetrical skewness at the site for each layer indicates there was an equal abundance or spread of fine and coarse sediment about the average. SBU B is mesokurtic, or normally distributed about the mean (fig. 2b). However, all other Stony Brook samples are platykurtic; they are sorted better in the tails of the graph rather that the center (fig. 2a, c, and d).

Suffolk County Farm samples A, B, and C had a mean of 281.0, 203.0, and 87.5 microns, respectively (table 2). All layers were considered very poorly sorted, and with the exception of SCF A (fine skewed), B and C were symmetrical (table 2, fig. 3a,b,c). Pebbles of varying grain sizes (1-5mm) were evident throughout the section, but seemingly more prevalent towards the top (fig. 1b). Distribution curves were platykurtic for SCF A and B, whereas C was very platykurtic (table 2, fig. 3a,b,c).

North Street samples A, B, and C had a mean of 41.9, 128.5, and 122.8 microns, respectively (table 3). All are were very poorly sorted, and with the exception of the uppermost section NS A which has a symmetrical distribution, NS B and C are fine skewed (fig. 4a,b,c). Pebbles were also present, but not as prevalent in the section as in SCF. Pebble abundance seemed to decrease with depth (fig. 1c).

Dwarf Pine Plains samples A, B, C, D, and E had a mean of 174.2, 347.4, 68.0, 161.6, and 118.7 microns, respectively (table 4). All layers were very poorly sorted, except DPP E2, which was extremely poorly sorted. Skewness varied from fine skewed (DPP A2, D2), very fine skewed (DPP B2) to symmetrical (DPP C2, DPP E2). All samples were platykurtic, with the exception of DPP B2 (leptokurtic) and DPP E2 (very platykurtic) (fig. 5a-e). An abundance of pebbles was evident at the base of the section (fig. 1d).

Table 1: Gradistat Grain Size Statistics: Stony Brook Campus

Sample	SBU A		SBU B	
MEAN ($\bar{x}$):	75.7		74.4	
SORTING (σ):	9.675	Very poorly sorted	5.788	Very poorly sorted
SKEWNESS (Sk):	0.144	Symmetrical	-0.126	Symmetrical
KURTOSIS (K):	2.209	Platykurtic	3.157	Mesokurtic
Sample	**SBU C**		**SBU D**	
MEAN ($\bar{x}$):	114.7		69.3	
SORTING (σ):	7.676	Very poorly sorted	7.593	Very poorly sorted
SKEWNESS (Sk):	-0.173	Symmetrical	0.227	Symmetrical
KURTOSIS (K):	2.387	Platykurtic	2.542	Platykurtic

Table 2: Gradistat Grain Size Statistics: Suffolk County Farm

Sample	SCF A		SCF B		SCF C	
MEAN ($\bar{x}$):	281.0		203.0		87.5	
SORTING (σ):	12.010	Very poorly sorted	10.006	Very poorly sorted	12.847	Very poorly sorted
SKEWNESS (Sk):	-0.722	Fine skewed	-0.371	Symmetrical	0.137	Symmetrical
KURTOSIS (K):	2.146	Platykurtic	1.926	Platykurtic	1.665	Very platykurtic

Table 3: Gradistat Grain Size Statistics: North Street

Sample	NS A		NS B		NS C	
MEAN ($\bar{x}$)	41.9		128.5		122.8	
SORTING (σ):	5.325	Very poorly sorted	5.873	Very poorly sorted	4.485	Very poorly sorted
SKEWNESS (Sk):	0.223	Symmetrical	-0.859	Fine skewed	-1.117	Fine skewed
KURTOSIS (K):	2.784	Mesokurtic	2.944	Mesokurtic	4.505	Leptokurtic

Table 4: Gradistat Grain Size Statistics: Dwarf Pine Plains

Sample	DPP A2		DPP B2			
MEAN ($\bar{x}$):	174.2		347.4			
SORTING (σ):	9.284	Very poorly sorted	5.653	Very poorly sorted		
SKEWNESS (Sk):	-0.808	Fine skewed	-1.686	Very fine skewed		
KURTOSIS (K):	2.242	Platykurtic	5.219	Leptokurtic		
Sample	**DPP C2**		**DPP D2**		**DPP E2**	
MEAN ($\bar{x}$):	68.0		161.6		118.7	
SORTING (σ):	9.391	Very poorly sorted	10.812	Very poorly sorted	19.942	Extremely poorly sorted
SKEWNESS (Sk):	-0.074	Symmetrical	-0.803	Fine skewed	-0.224	Symmetrical
KURTOSIS (K):	1.796	Platykurtic	2.361	Platykurtic	1.435	Very platykurtic

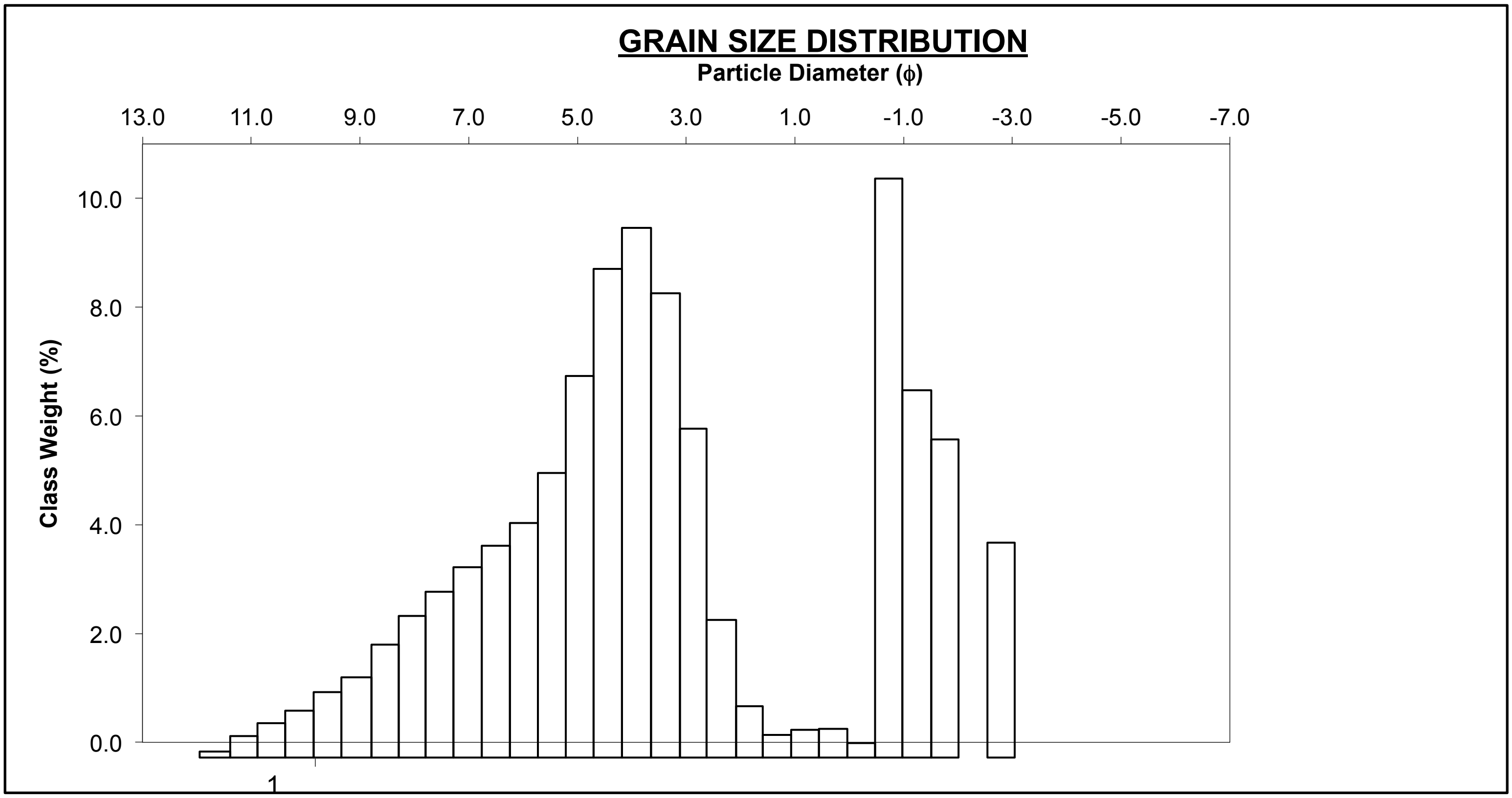


Fig. 2a: SBU A grain size distribution graph

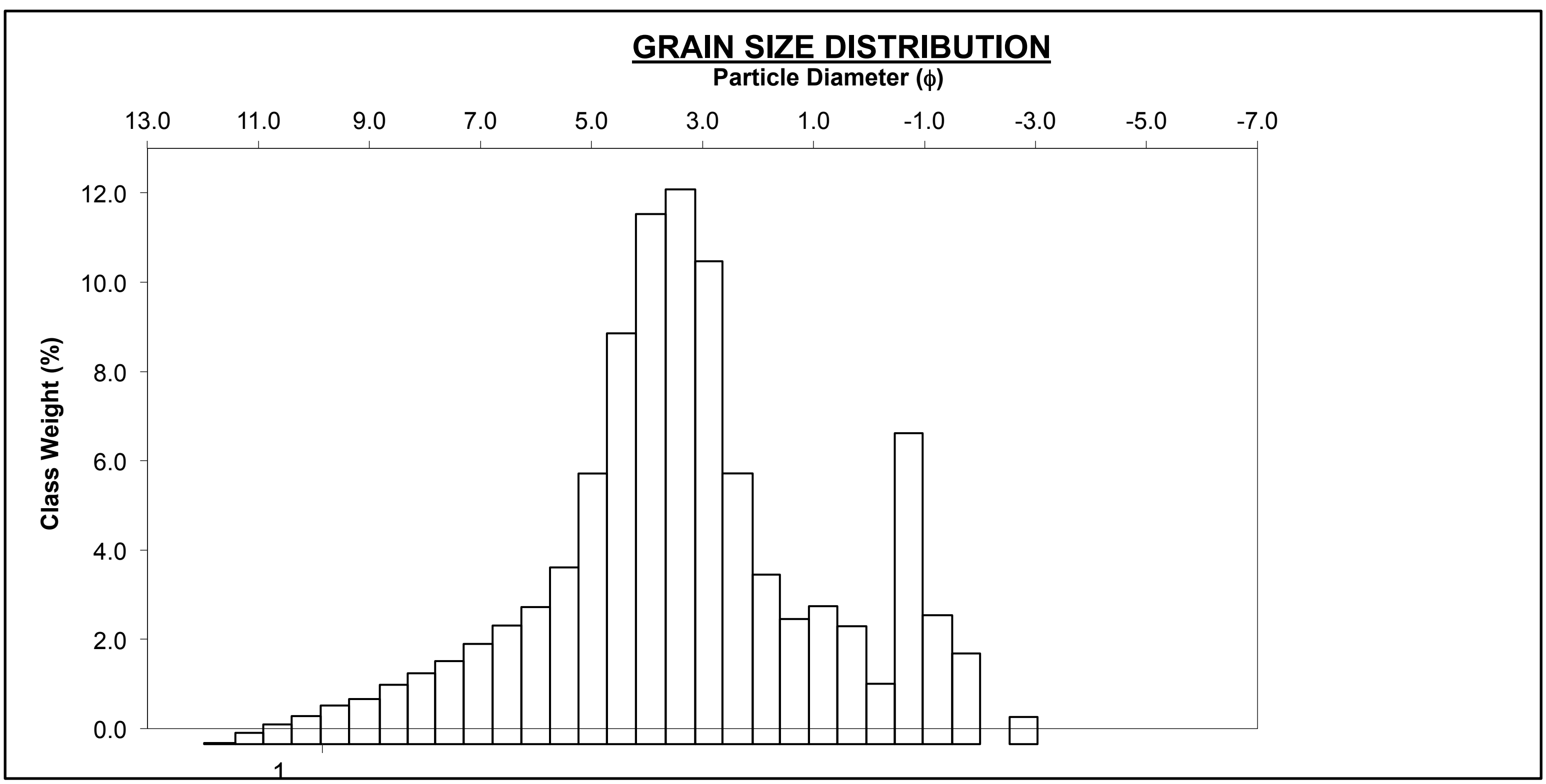


Fig. 2b: SBU B grain size distribution graph

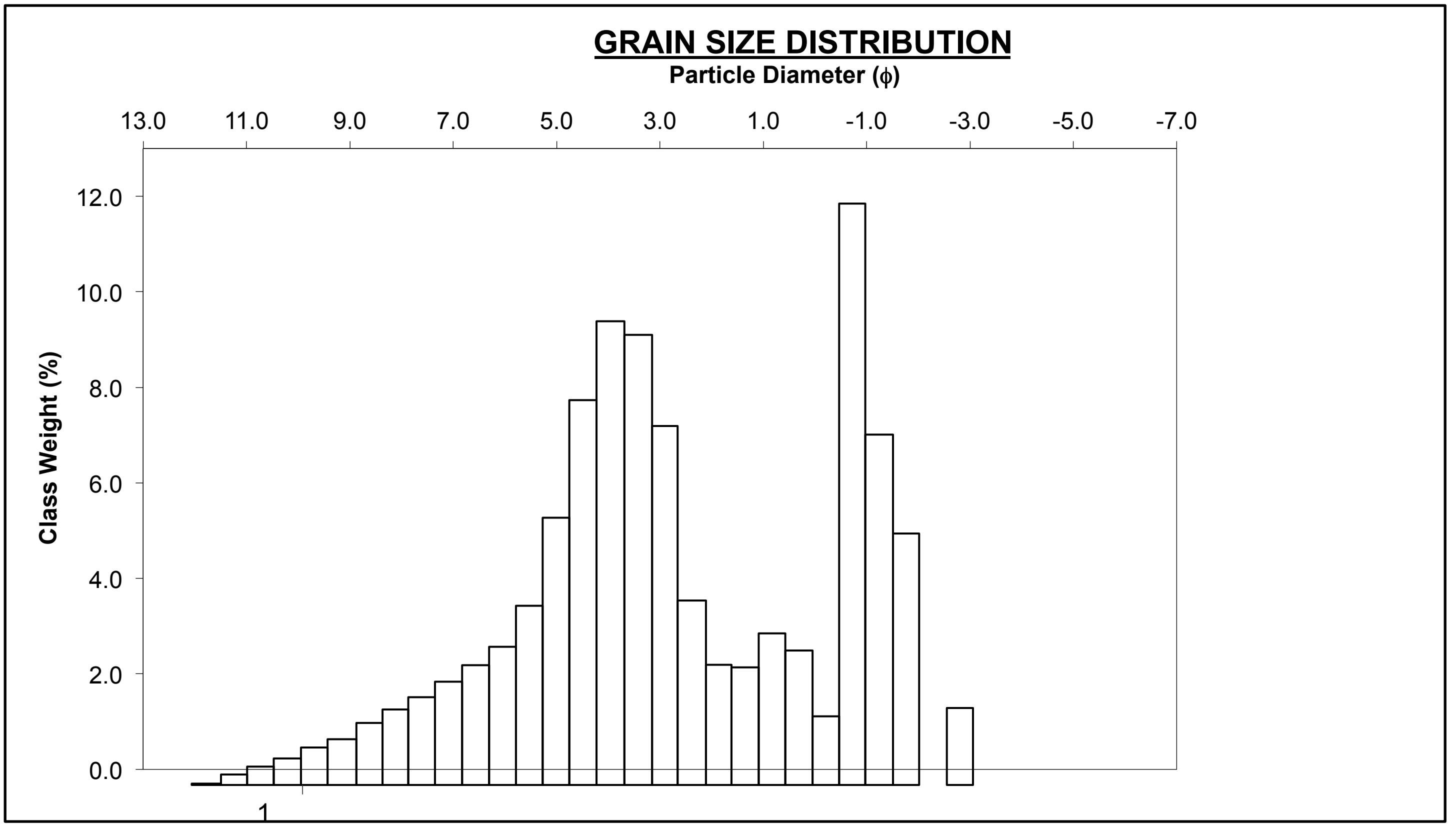


Fig. 2c: SBU C grain size distribution graph

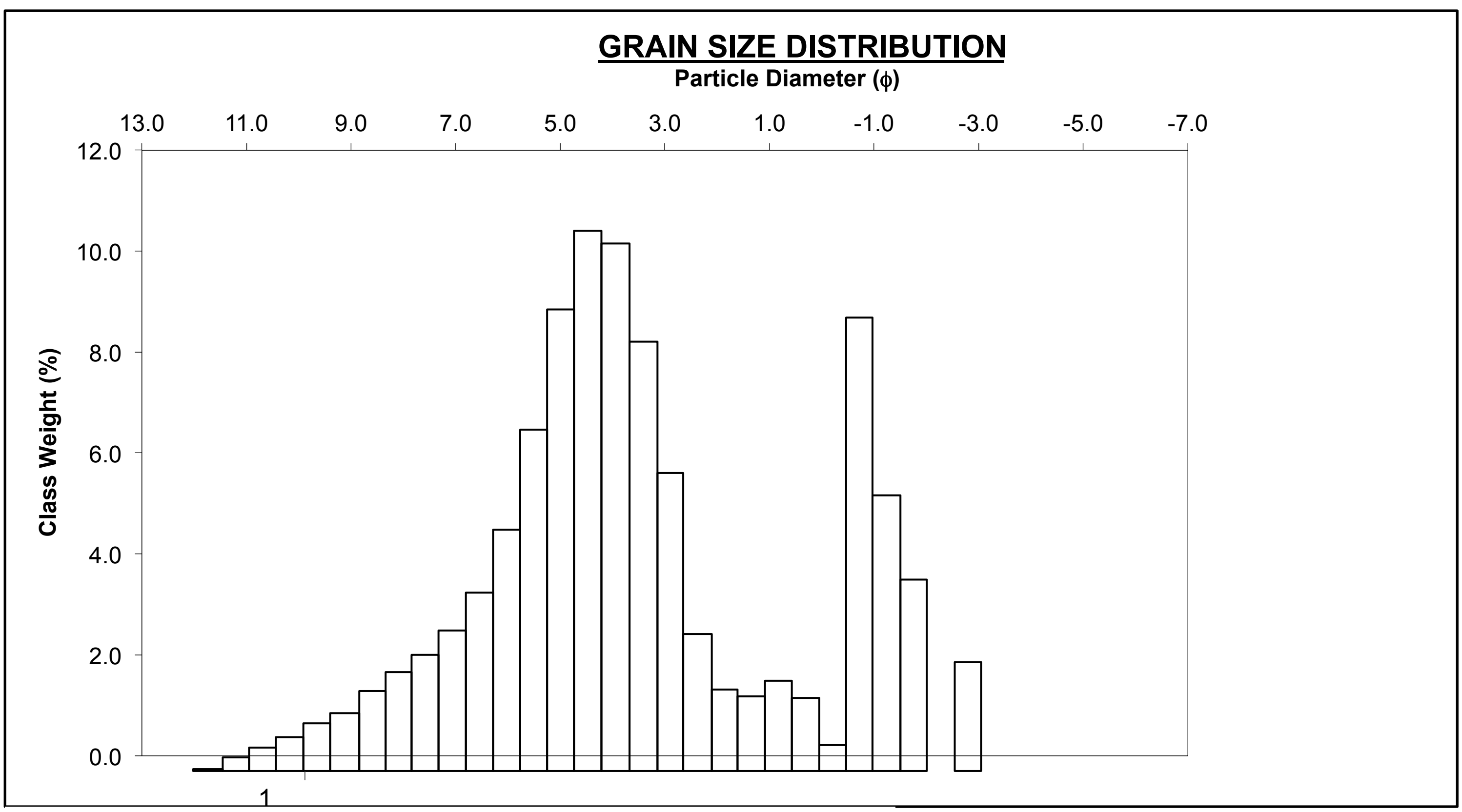


Fig. 2d: SBU D grain size distribution graph.

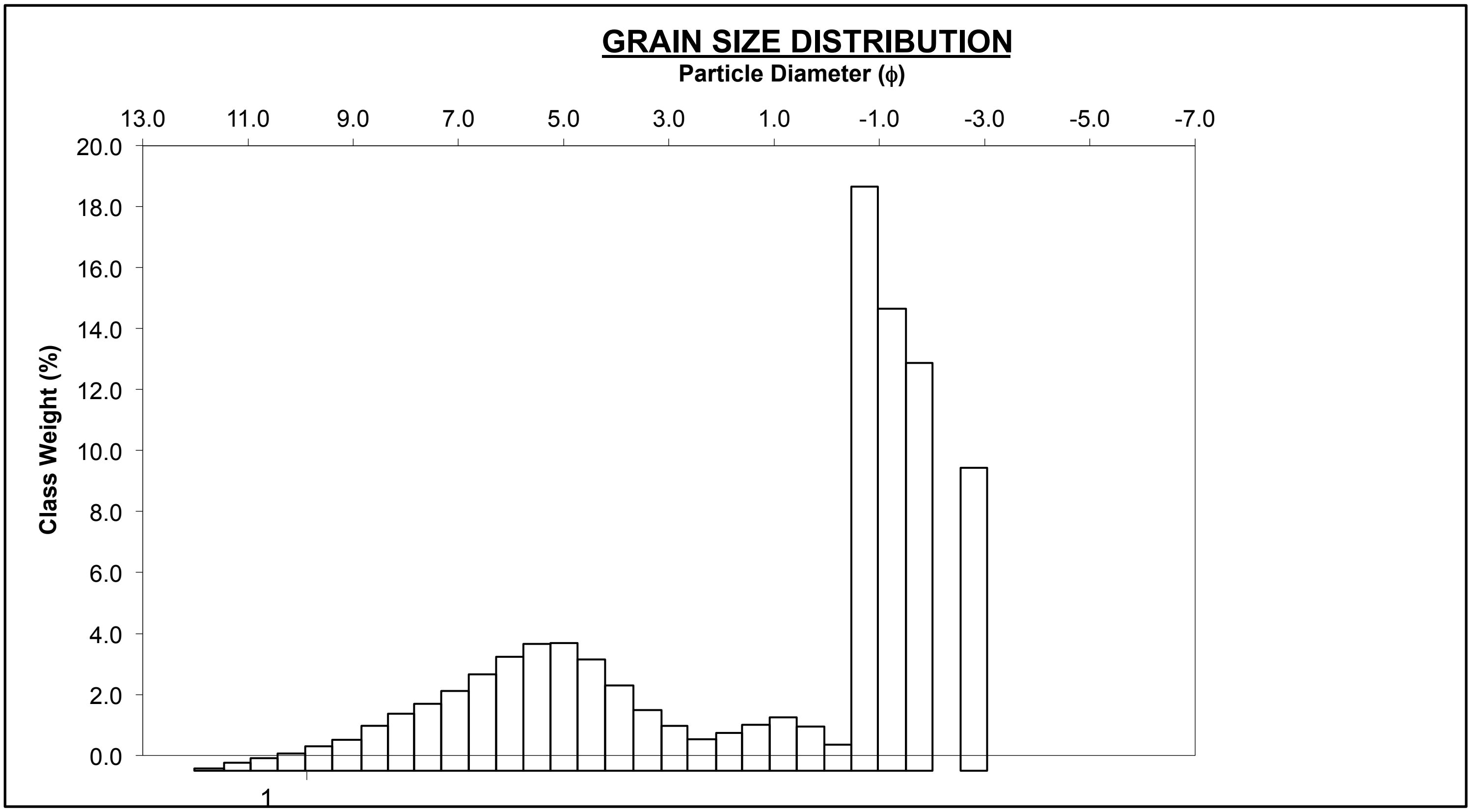


Fig. 3a: SCF A grain size distribution graph.

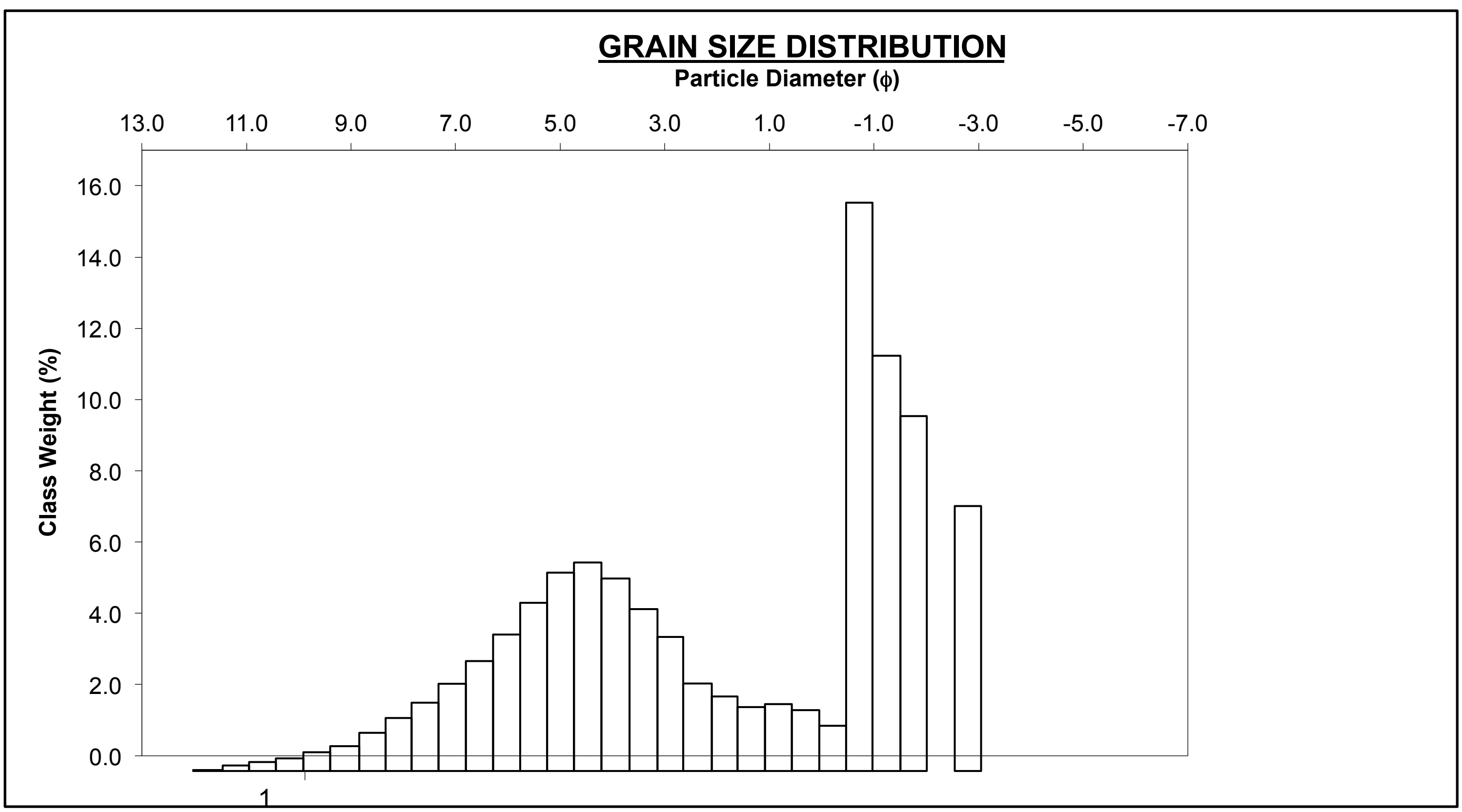


Fig. 3b: SCF B grain size distribution graph.

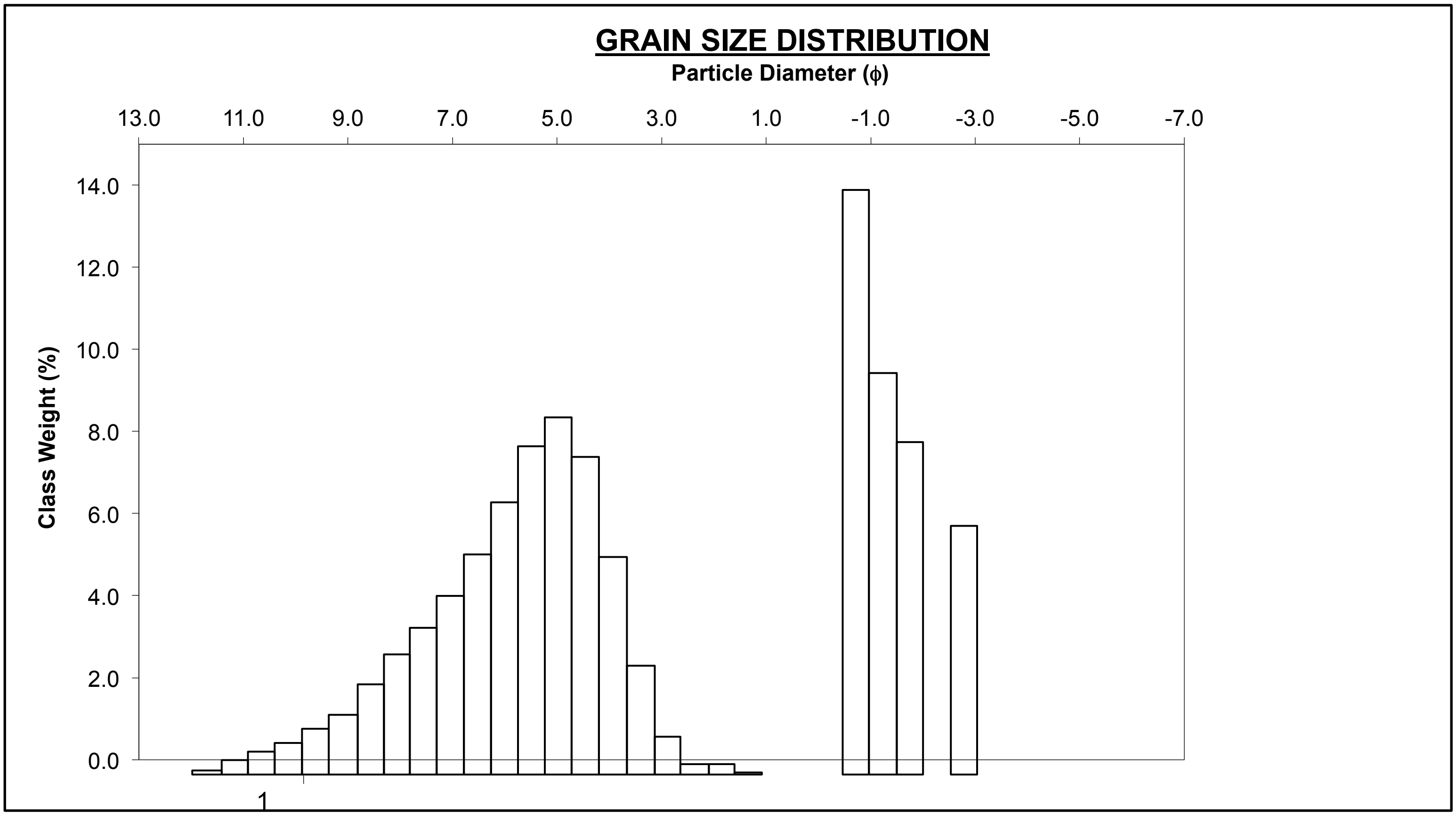


Fig. 3c: SCF C grain size distribution graph.

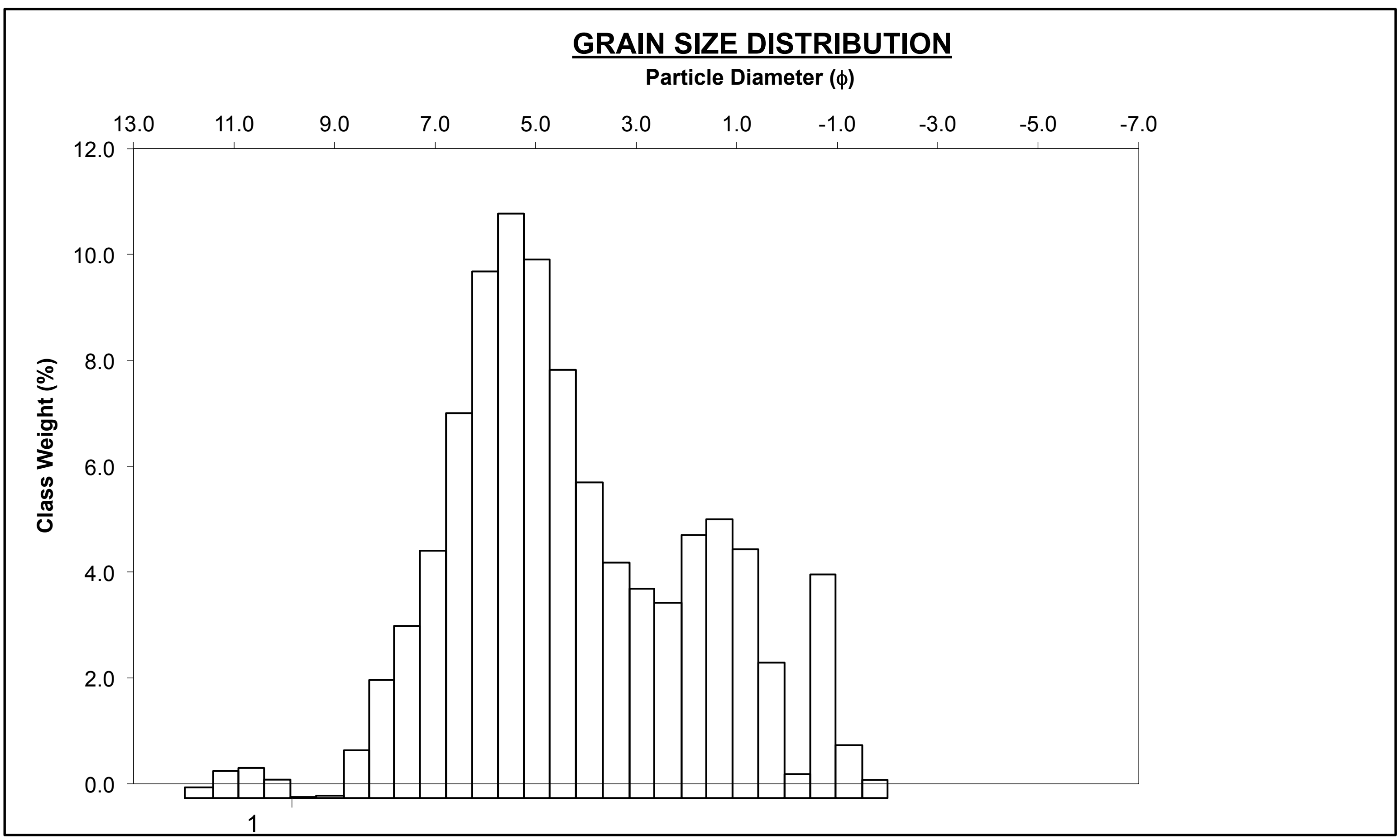


Fig. 4a: NS A grain size distribution graph.

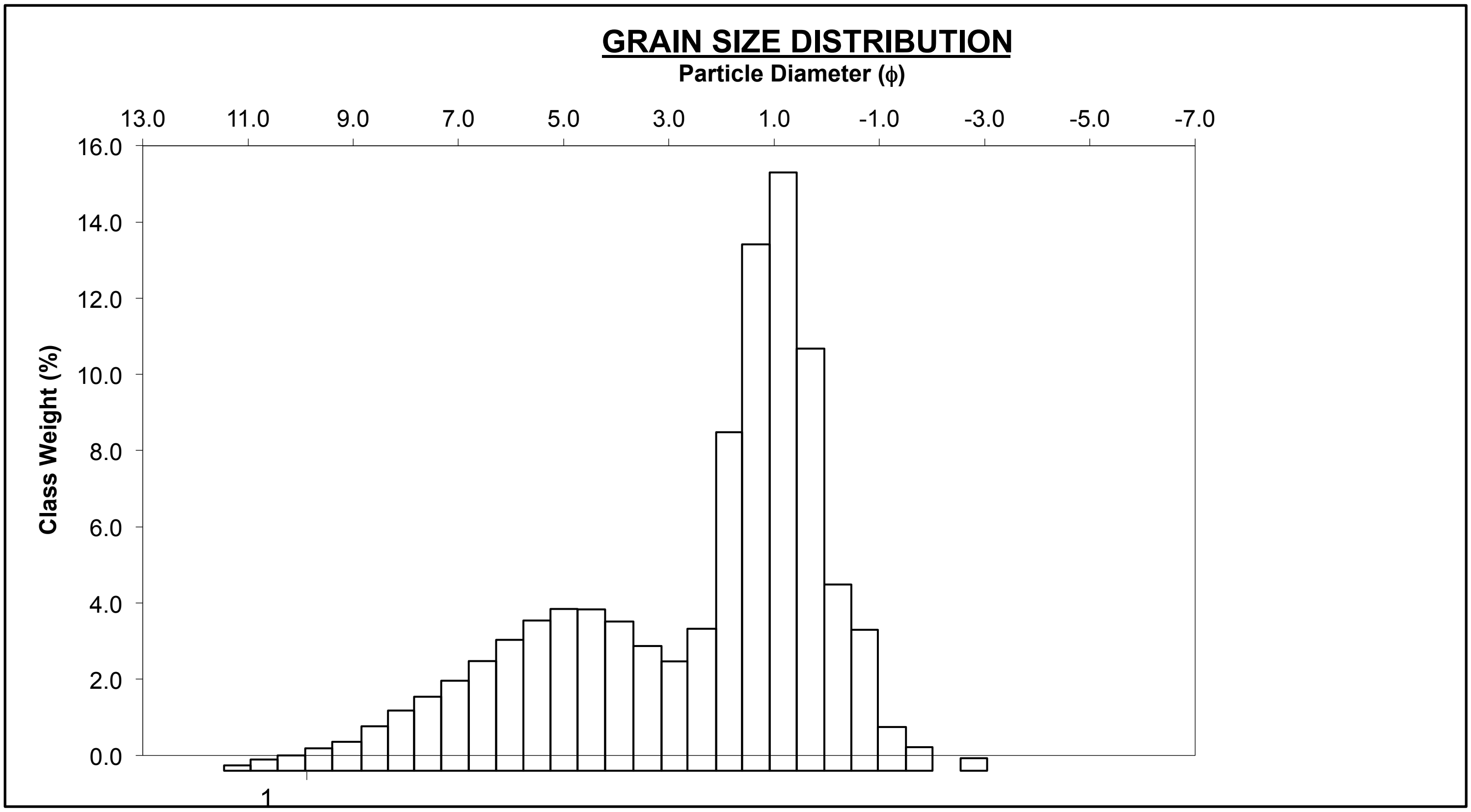


Fig. 4b: NS B grain size distribution graph.

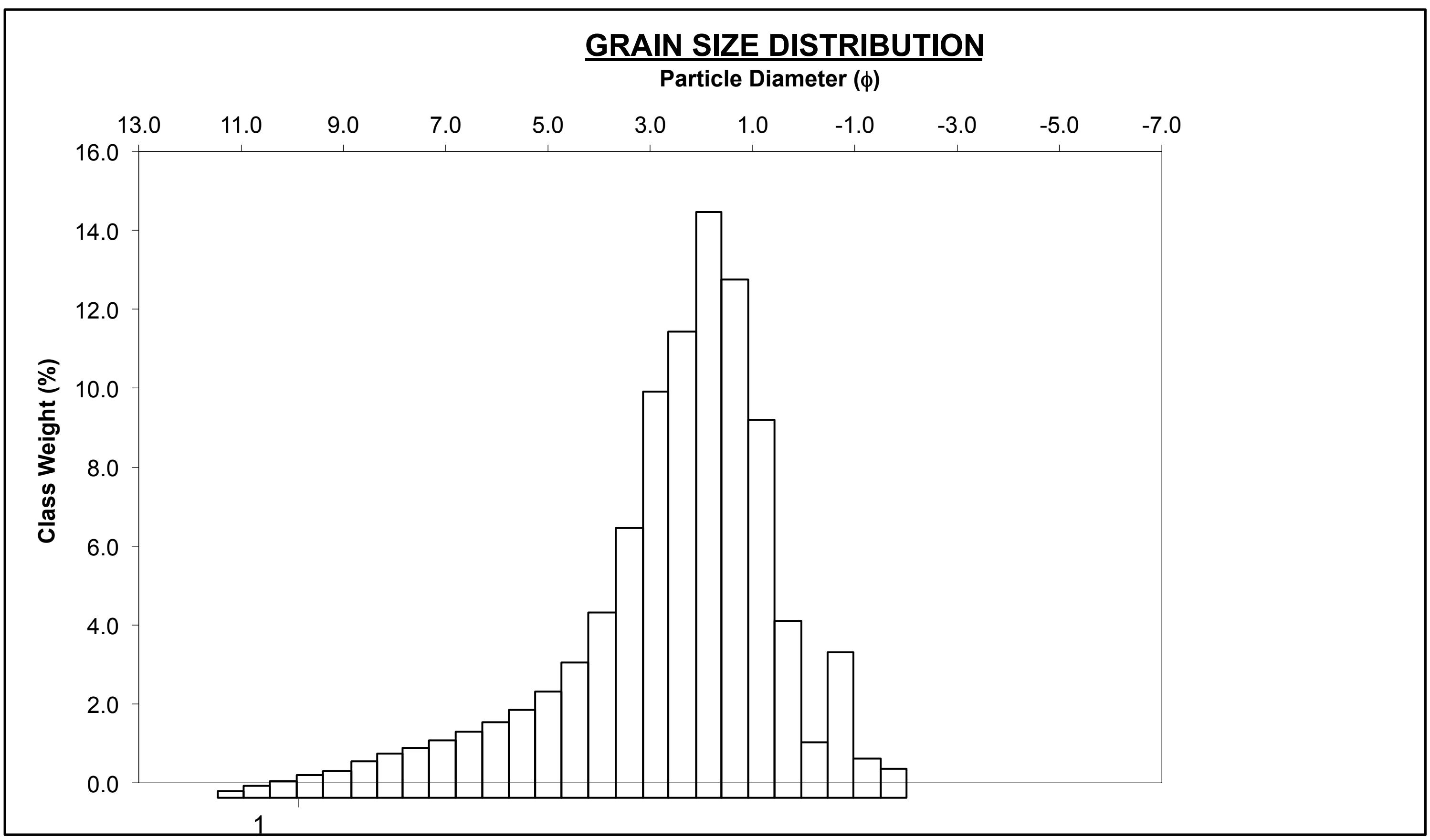


Fig. 4c: NS C grain size distribution graph.

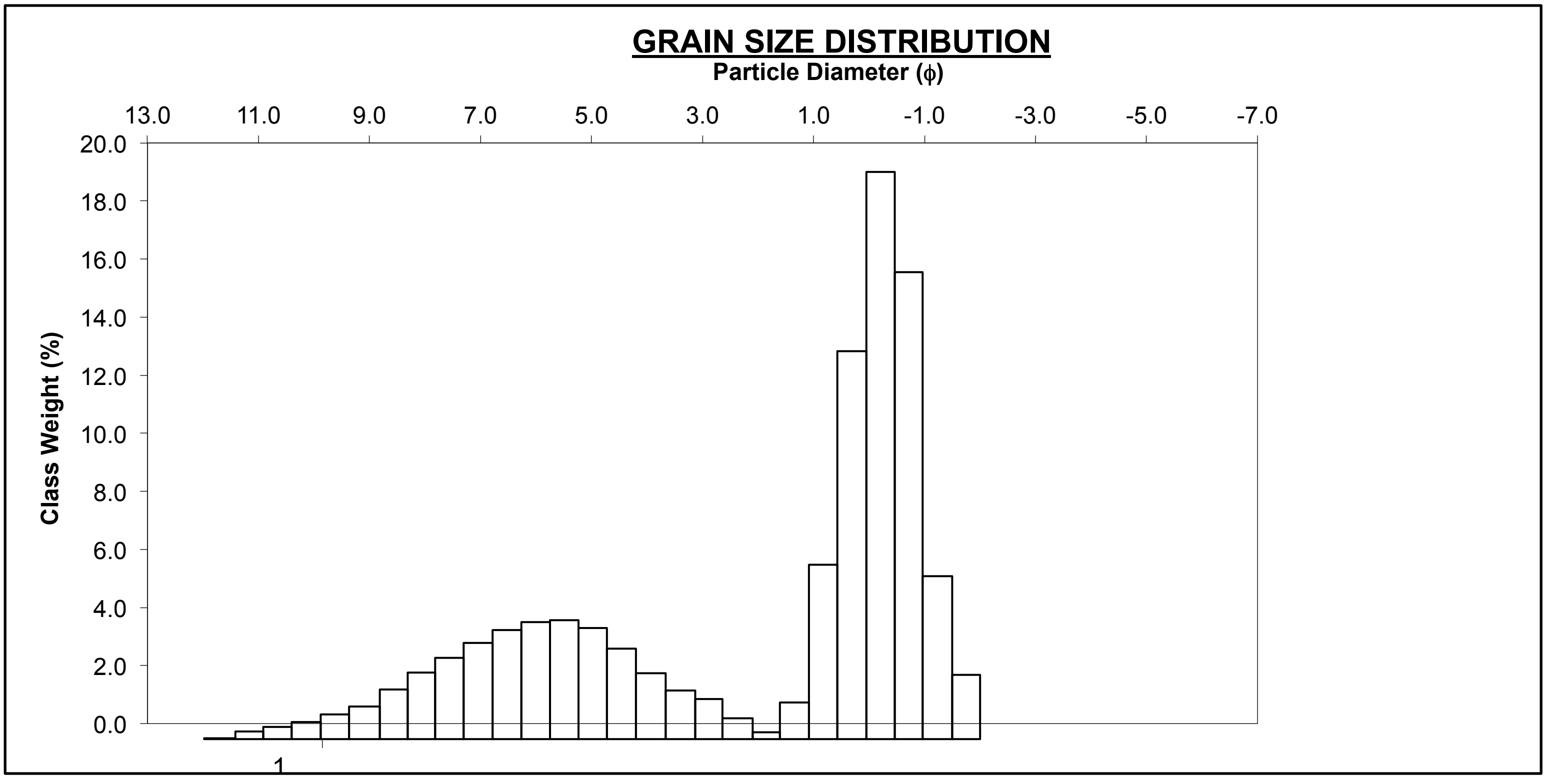


Fig. 5a: DPP A2 grain size distribution graph.

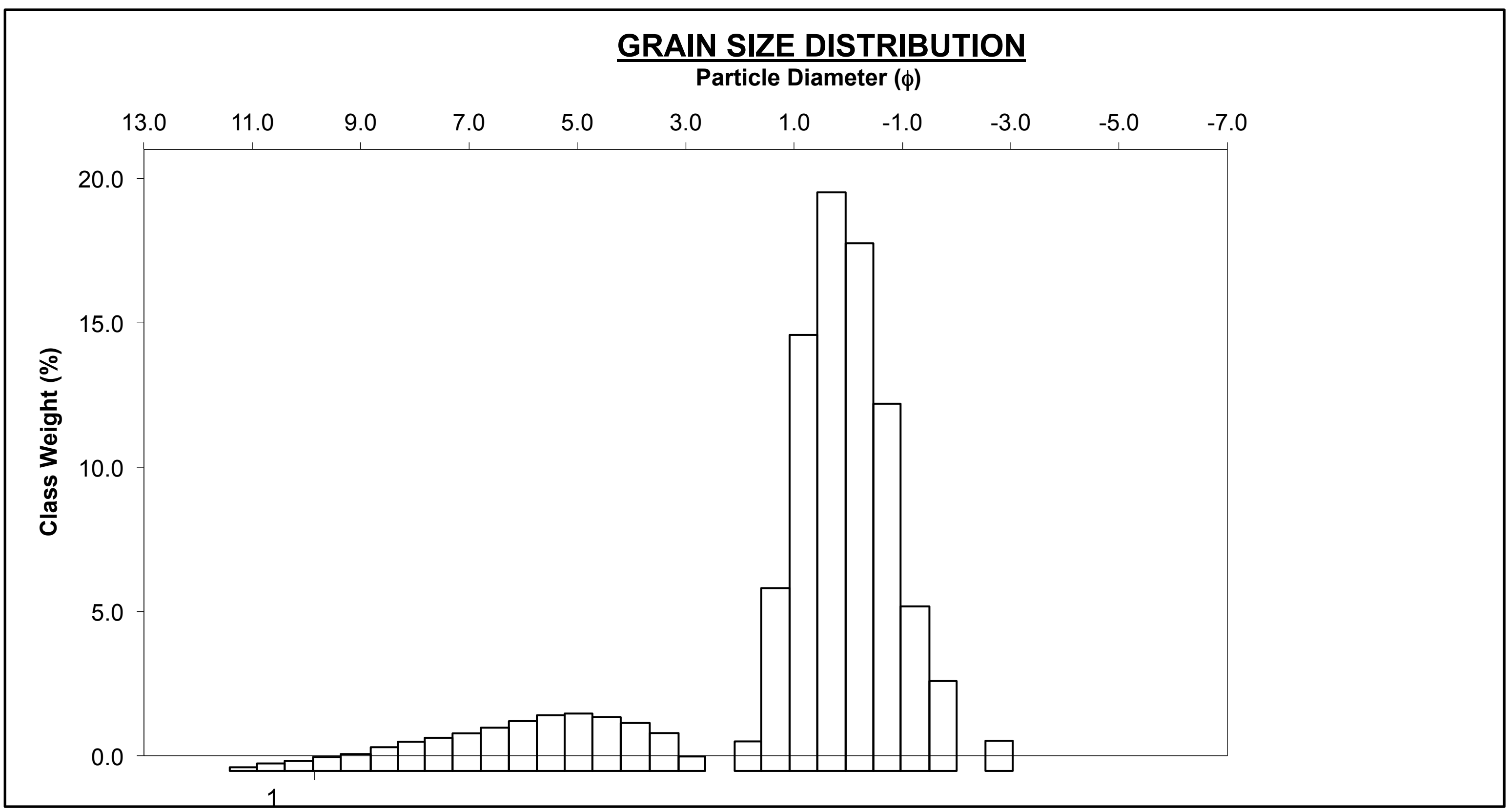


Fig. 5b: DPP B2 grain size distribution graph.

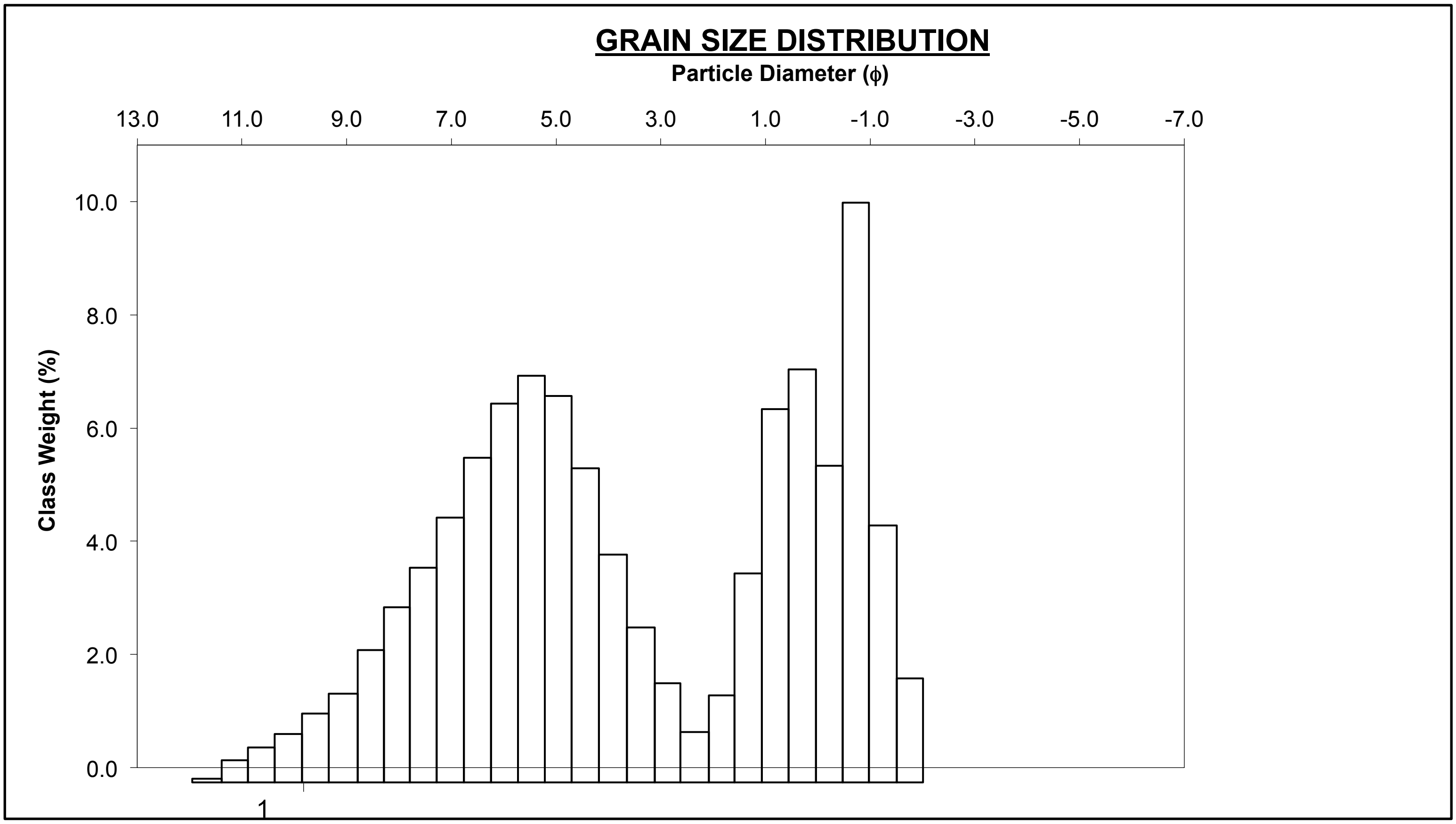


Fig. 5c: DPP C2 grain size distribution graph.

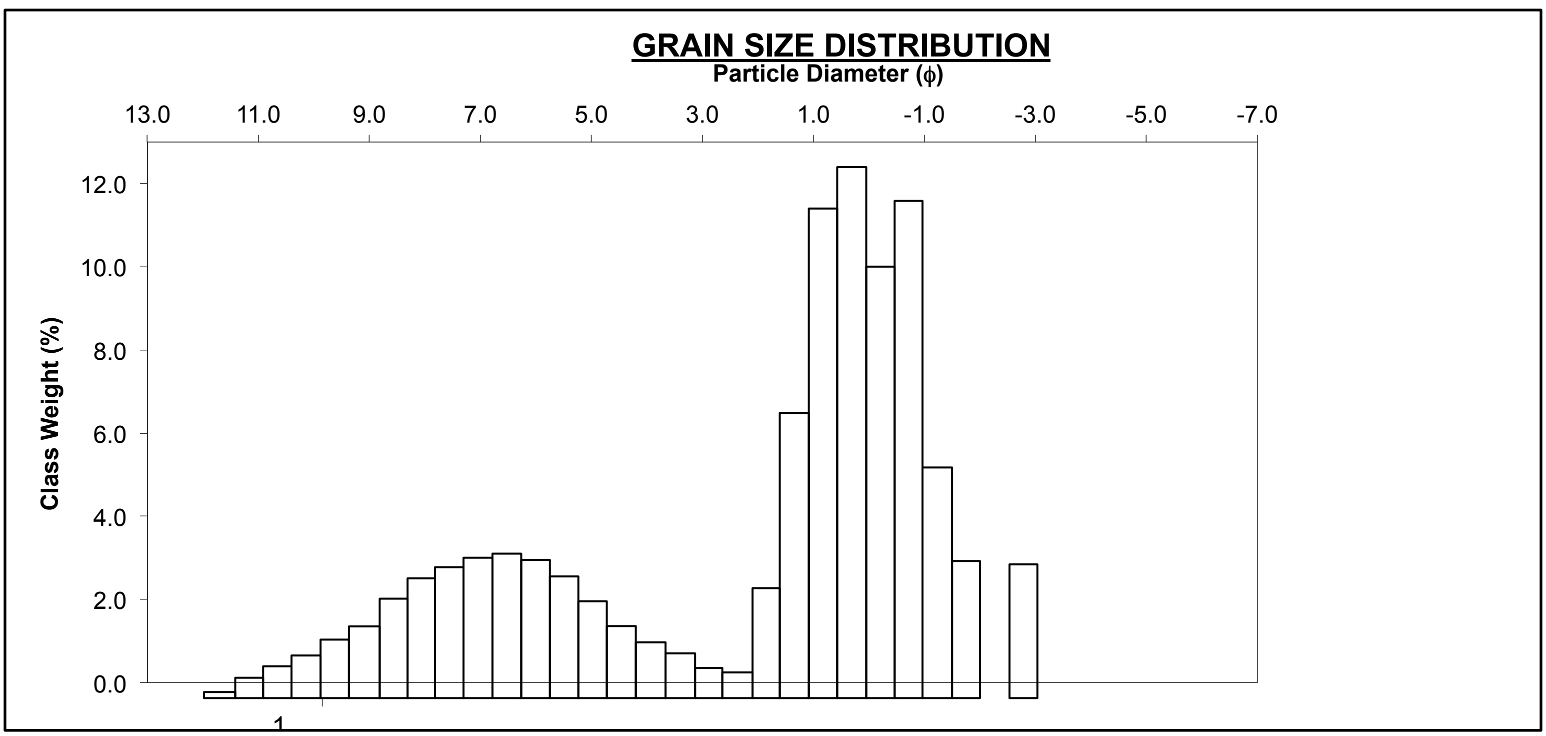


Fig. 5d: DPP D2 grain size distribution graph.

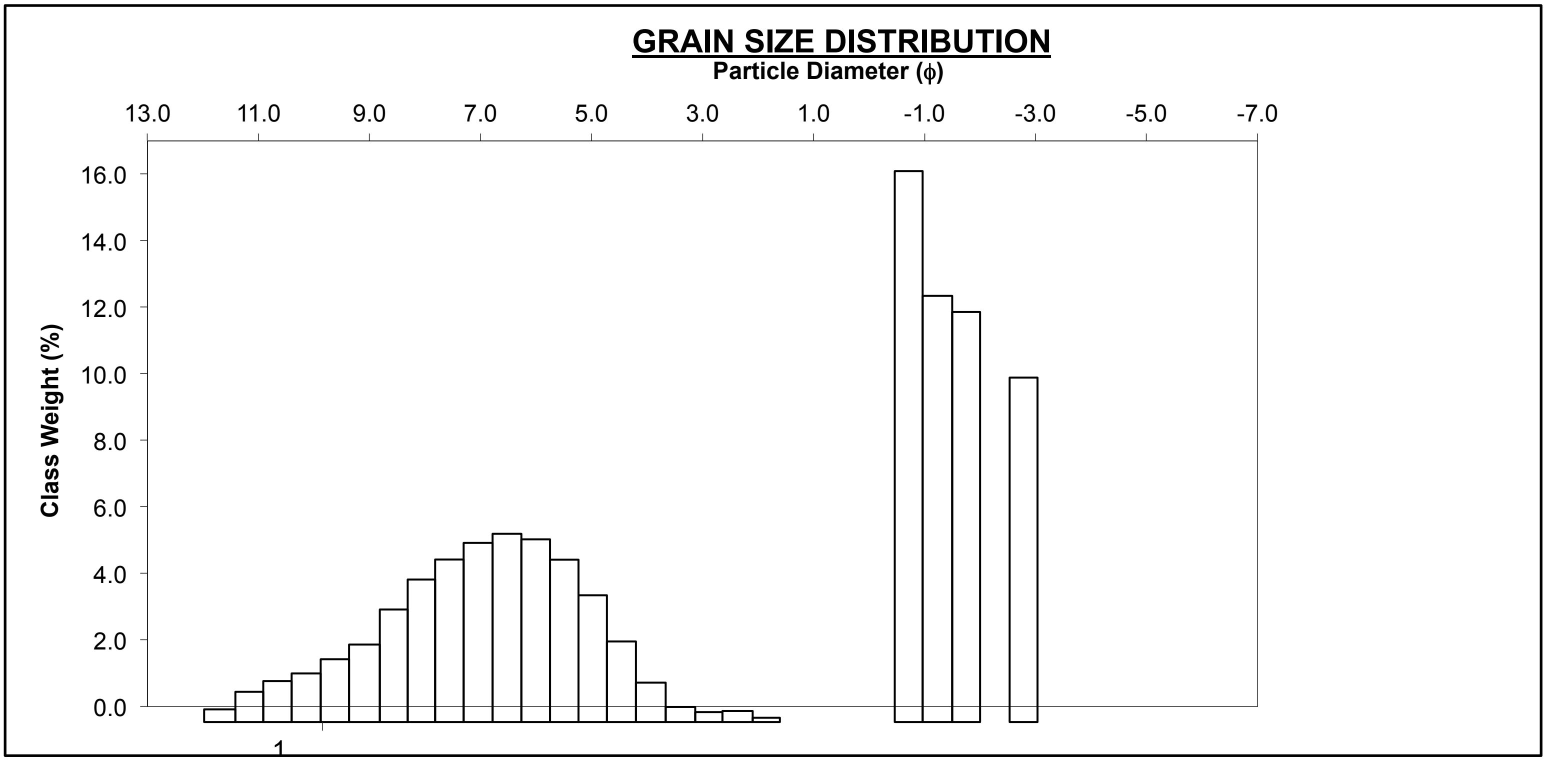
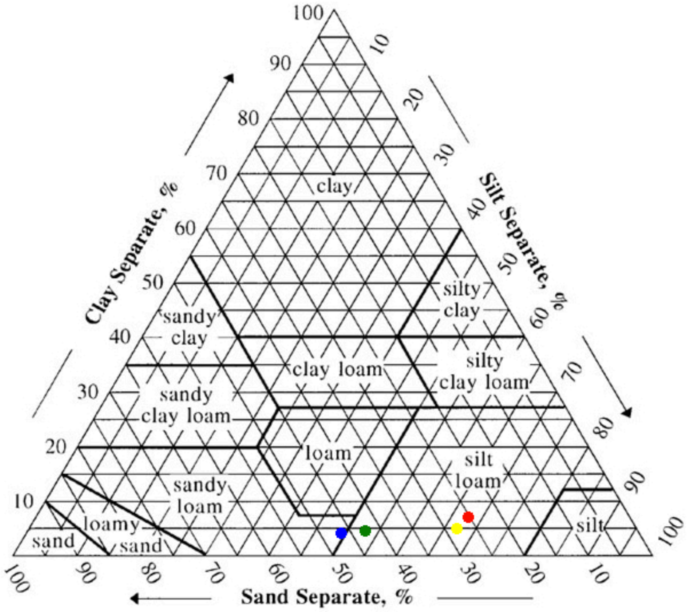


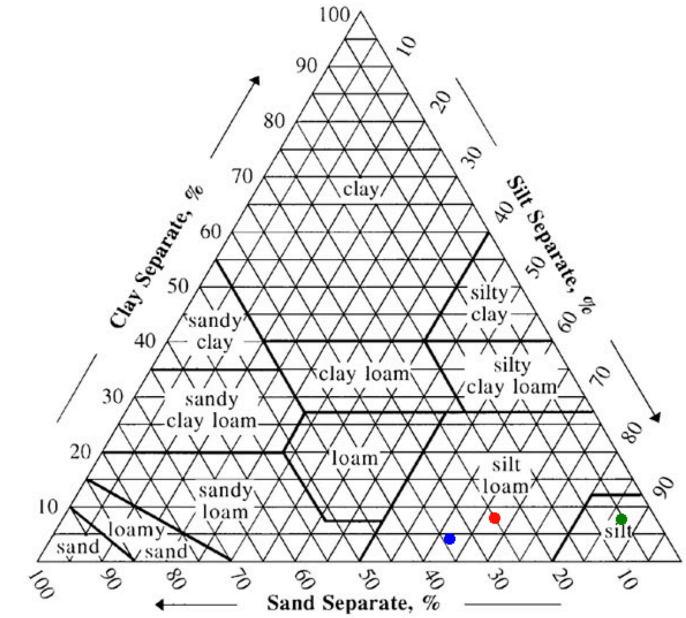
Fig. 5E: DPP E2 grain size distribution graph.

Results: Soil Texture

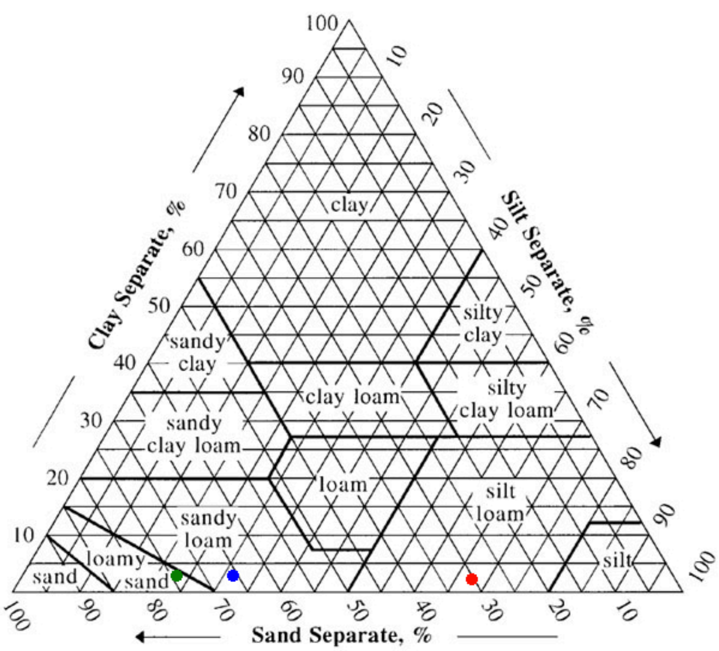
Mastersizer output data included the percent of sand, silt, and clay for each sample at all four sites. To characterize the soil based on the relative abundance of sand, silt, and clay per sample at each site, mastersizer weight percent data was plotted on the United States Department of Agriculture Soil Texture Diagram (usda.gov). The results of these plots are shown below (fig. 6).



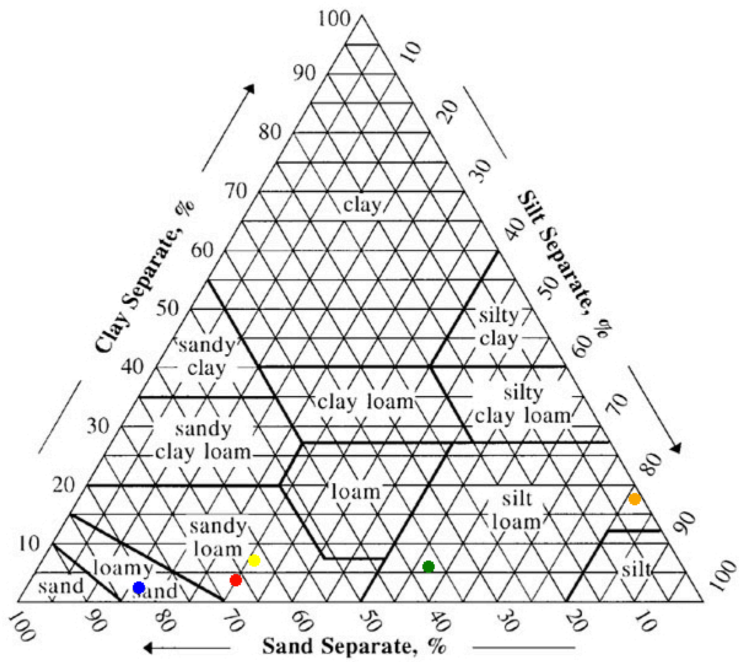
Key:
SBU A: red- silt loam
SBU B: blue- sandy loam
SBU C: green- silt loam
SBU D: yellow- silt loam



Key:
SCF A: red- silt loam
SCF B: blue-silt loam
SCF C: green- silt



Key:
NS A: red- silt loam
NS B: blue- sandy loam
NS C: green- loamy sand



Key:
DPP A2: red- coarse sandy loam
DPP B2: blue- loamy coarse sand
DPP C2: green- silt loam
DPP D2: yellow- coarse sandy loam
DPP E2: orange- silt loam

Fig. 6: Soil texture diagrams for Stony Brook site, (top left) Suffolk County Farm, (top right) North Street, (bottom left) and Dwarf Pine Plains (bottom right).

Results: Stratigraphy: The results from this study are summarized in a stratigraphic section for each site.

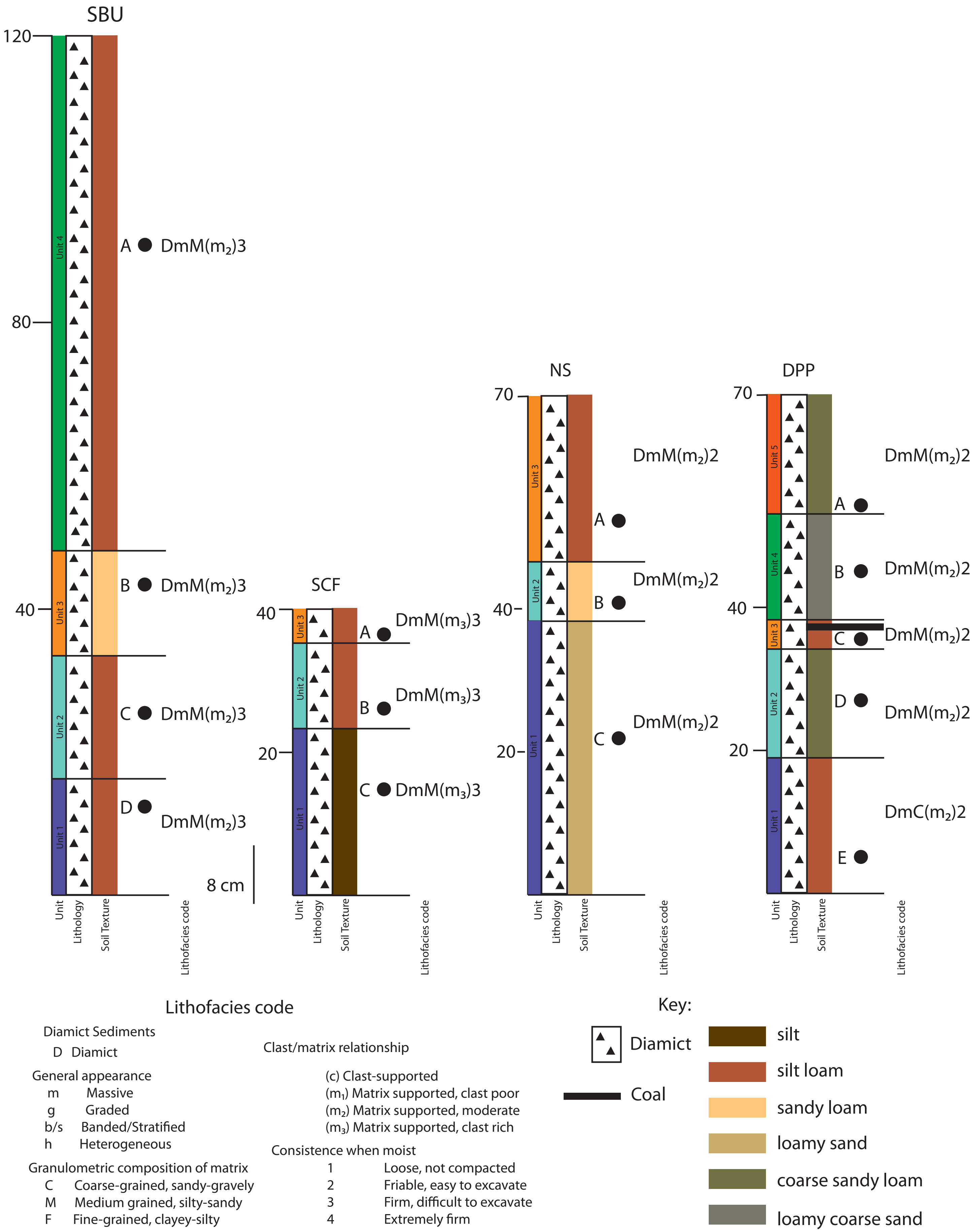


Fig. 7: Modified stratigraphic scheme and lithofacies code data chart for field description of glacial diamicts and associated sediments from Krüger and Kjaer (1999). A black circle indicates sample location within each layer of each section. The actual depths of SCF, NS, and DPP are uncertain, as this study only concerned itself with sediment associated with/considered loess, however till was located, but not dug into at the base of DPP. Columns are shown geographically from West (left) to East (right).

Based on the stratigraphy, it is evident that the sediment across all four sites is best characterized as a diamict (fig. 7). Each diamict layer however, can be further characterized by soil texture and lithologic code, the latter derived from Krüger and Kjaer (1999) data chart for field descriptions of diamicts. The lithofacies code details the nature of diamict sediments based on a four-character system (Krüger and Kjaer, 1999) summarized below:

The first character, D, indicates the appearance of the diamict unit in the field. Immediately following the first character is a modifier, distinguishing between a diamict that is massive (m), graded (g), banded/stratified (b/s), or heterogeneous (h). All stratigraphic sections are characterized as massive diamicts. The second character speaks to the nature of the granulometric composition: capital letters C, M, or F signify coarse, medium, or fine-grained diamict, respectively (Krüger and Kjaer, 1999). A coarse-grained diamict is sandy-gravely. A medium grained diamict is defined as being dominated by sand and silt, and containing <15% clay, whereas a fine-grained diamict contains >15% clay. The third character describes the relative proportions between clast and matrix, regarding whether the diamict is clast (c) or matrix (m) supported. Clast content variation is designated as a subscript m_1 being poor, m_2 being moderate, and m_3 being clast-rich. The fourth character describes the packing and the diamict's consistency when moist. Loose (1) diamicts are non-coherent, friable (2) diamicts crumble easily in your fingers and are easy to dig, firm or dense (3) diamicts crush with difficulty between your fingers and are difficult to dig, and lastly, and extremely firm (4) diamict cannot be crushed in your fingers.

For example, the lithologic code for all SBU layers is DmM(m_2)3. This implies that the units are massive, medium-grained, matrix supported with moderate clasts, and firm. The SCF diamict is massive, medium-grained, matrix supported, rich in clasts, and firm. The NS diamict is massive, medium-grained, matrix supported with moderate clasts, and friable. The DPP diamict section has the same lithologic code as NS, with the exception of DPP E, which is coarse-grained.

Discussion

Based on grain size analysis and statistics, it is evident that all sample sites are characterized by poorly sorted to very poorly sorted sediments (tables 1-4). Given the glacial history of Long Island, one can assume a variety of processes, including postglacial processes, should have sorted the sediments accordingly. However, at each sample site, even at depth, fine silt and sand sized sediments were found in conjunction with pebble-sized grains, ranging from 1-4mm or greater at times. The grain size distribution for samples at each site speaks to the poorly sorted nature of the sediment. Even so, some patterns can be drawn based on the above results. It is evident that the Stony Brook site has the most similar soil texture and grain size characteristics between distinct layers (table 1, fig. 6). Despite the poorly sorted nature of the sediment throughout the section, sorting is best on the fine and coarse ends of the grain size distribution graphs (platykurtic) (fig. 2a-d). The same overall trend holds true for the Suffolk County Farm sample sites as well (table 2, fig. 3a-c, fig. 6). Statistical variance within the samples at a given site is evident at North Street and Dwarf Pine Plains. Based on statistics, (table 3 and 4) grain size distribution graphs, (fig. 4a-c, 5a-e) and the soil texture diagrams (fig.

6) there is less consistency among soil texture and grain distribution. Given the proximity of SBU and SCF compared to NS and DPP, perhaps the same process determined the nature of the sediments in those locations, while another (or several) other processes were responsible for sediment deposition at NS and DPP. Despite the potential difference in processes, all sites consisted of poorly sorted to very poorly sorted sediment, with pebbles ranging from 1-4mm or greater at times. Due to the difficulties associated with explaining the presence of pebbles in loess, perhaps another descriptor is appropriate.

The sediment across Long Island has been known thus far as “pebbly loess” (Hanson, 2014). Given the results of this study, it seems a more accurate term can better account for the presence of pebbles in the loess. It is apparent that the sediment across the 4 sampled sites in Suffolk County is better described as a diamict. A diamict is defined as non-sorted, or poorly sorted, unconsolidated sediment containing a wide range of particle sizes (Flint, 1971: Frakes, 1978; Eyles et al., 1983). They are typically characteristic of depositional environments, like Long Island, that received poorly sorted glacial sediments. Given the results of this study, the phrase, “poorly sorted” can be quantified based on the geometric method of moments outlined by Blott and Pye (2001); sediment may be characterized as a diamict if the geometric standard deviation σ_G is between 2-4 (poorly sorted), 4-16 (very poorly sorted) and >16 (extremely poorly sorted). As outlined in tables 1-4, all samples fall under one of the above ranges, supporting their characterization as a diamict. Futhermore, a massive diamict facies describes an environment in which there is little to no organization or structure within the sediments, often characterized by a variety of sedimentary processes. While glacial processes may have contributed to the nature of the sediment, other processes including landslides, mudflows, solidfluction, flowtill activity, slumping and sliding, and deformation by floating ice are capable of forming diamict deposits, closely resembling till (Flint et al., 1960). Moreover, some of these processes could have been triggered by an impact associated with the onset of the Younger Dryas cooling period. Perhaps the presence and deposition of this diamict is evidence supporting the impact theory. Based on the results of this study, one can speculate as to the number of processes involved with the deposition of these diamicts. Given the similarities of the statistics across SBU and SCF, perhaps a single process was responsible for their deposition, while another (or several) processes proposed above may have deposited the sediment at NS and DPP due to the evident differences in statistics.

Conclusion

It is evident that the term diamict better characterizes the sediment across Suffolk County. A diamict by definition is poorly sorted, and can form by a variety of processes. Grain size statistics and soil texture as summarized in stratigraphic section support the poorly sorted nature of the sediment, and therefore its classification as a diamict. In addition, this classification better explains the presence of pebbles in what used to be considered “pebbly loess.” Though it is uncertain what specific processes led to its deposition, one can assume some processes related to diamict deposition may be glacially related, or induced by an impact. It is also evident that multiple processes may have been responsible for deposition of the diamict across Suffolk County.

References

Blott, S.J., and Pye, K., 2001, Gradistat: A grain distribution and statistics package for the analysis of unconsolidated sediments: Earth Surface Processes and Landforms, vol. 26, 1237-1248.

Clare, T.D., 2013, Grain Size Analysis of Loess and Glacial Sediments at Stony Brook University, Stony Brook University, 9p.

Eyles, N., Eyles, C.H., and Miall, A.D., 1983, Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictite sequences: Sedimentology, v. 30, 395-410.

Firestone, R.B., et al., 2007, Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling: Proceedings of the National Academy of Sciences in the United States of America, vol. 104, no. 41, 16016-16021.

Flint, R.F., 1971, Glacial and Quaternary Geology. 892 pp. Wiley & Sons, New York.

Flint, R.F., Sanders, J.E., and Rodgers, J., 1960, Symmictite: a name for nonsorted terrigenous sedimentary rocks that contain a wide range of particle sizes: Geological Society of America Bulletin, vol. 71, 507-509.

Frakes, L.A., 1978, Diamictite *In* Fairbridge, R.W, & Bourgeois, J. (eds.): The Encyclopedia of Sedimentology, 262-263. Dowden, Hutchinson and Ross, Stroudsburg.

Hanson, G., 2014, Stony Brook University, oral communication.