Grain size analysis of core samples from the Bay of Mecklenburg, Germany

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Project information	
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Project partners

Funding agencies

Grain size analysis for the SENSE project

Introduction

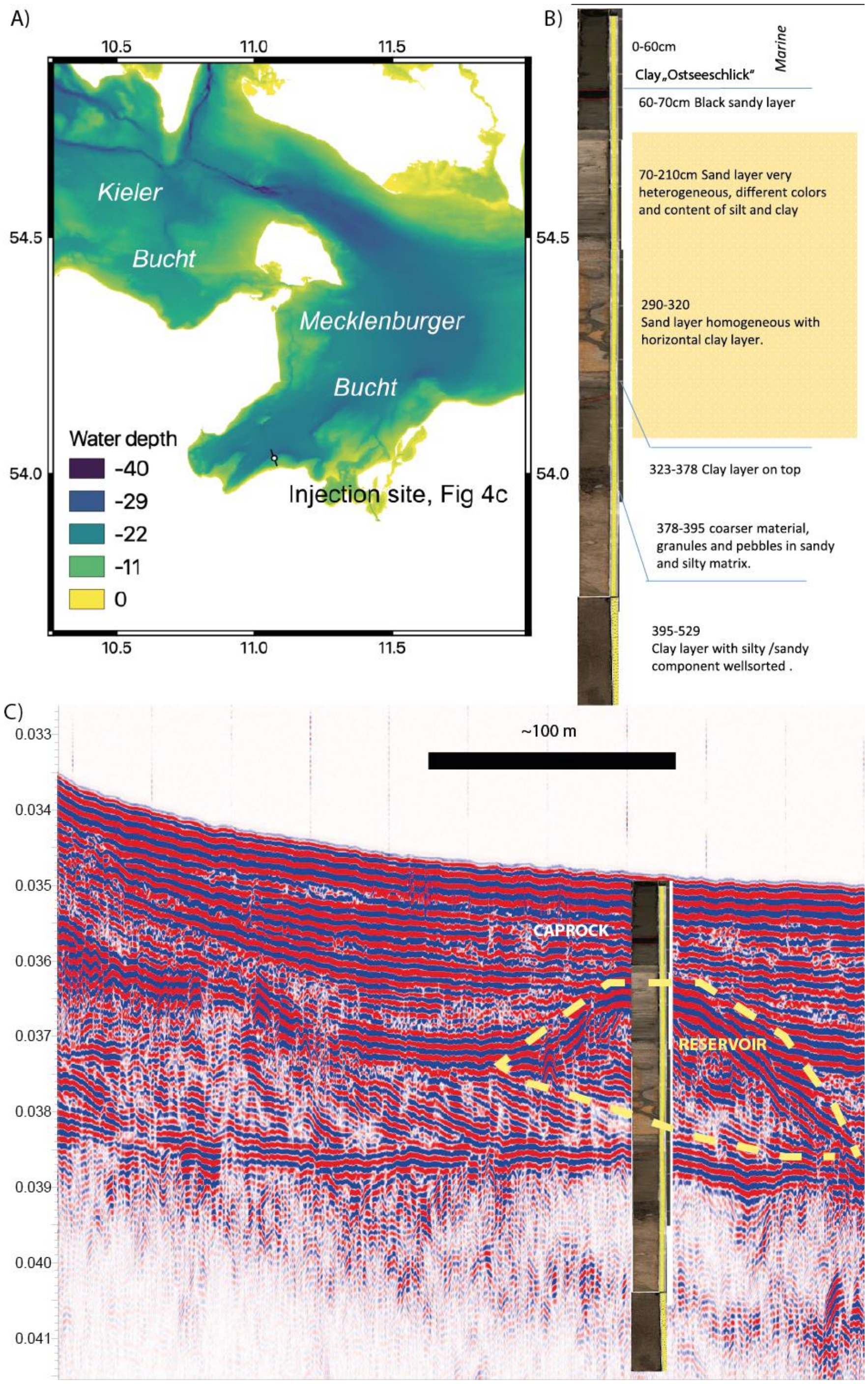
Grain size is an essential textural parameter of clastic rocks that carries the information about the dimeter of individual grains of sediment or the lithified particles in clastic rocks. Grain size analysis is a sedimentological analysis used for determining the size of grains in sedimentary rocks, deposits and soil units. The analysis provide information on the statistical distribution of size ranges in a sediment sample. Various statistical parameters and indices can be computed using such distributions. Main statistical parameters are: mean, median, standard deviation, skewness(symmetry) and kurtosis(peakedness).

Research objective

The main objective is to characterize samples according to acquired statistical distribution of grain sizes for each sample.

Data

The data that is used in this project come from core samples retrieved from Bay of Mecklenburg, Germany (Appendix 1). There are 29 core samples, obtained from wells AL527-03(samples 1-19) and AL527-07(samples 20-29). The samples vary in depth from 0.12-3.4 meters and 0.1-1.8 meters in wells AL527-03 and AL527-07, respectively.



Methods

This research is carried out using Beckman Coulter LS13320 instrument to perform grain size analysis based on laser diffraction method.

Laser diffraction method

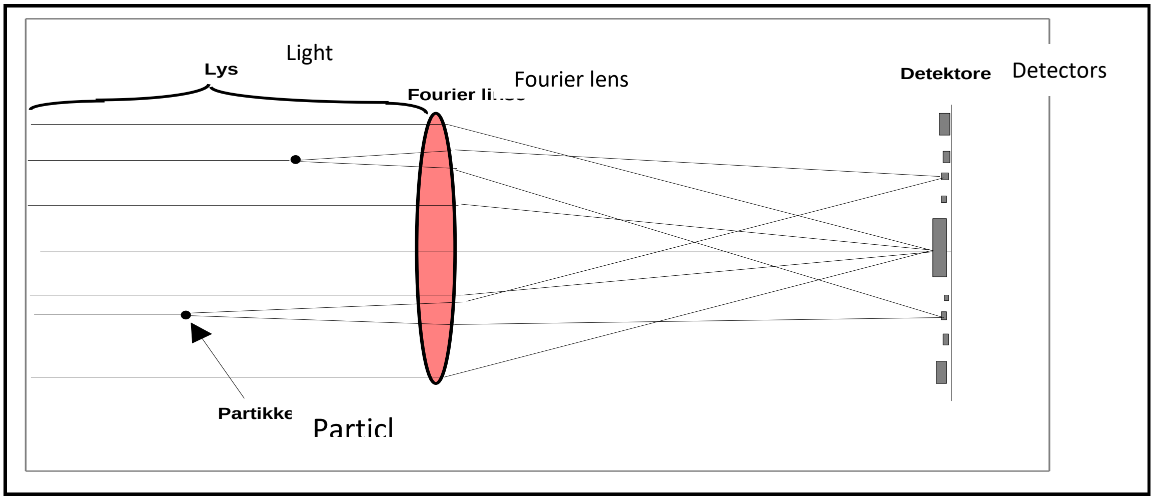
The method is based on laser diffraction and used to carry out determination of grain distribution in the area of 0.4 μ m - 2000 μ m. The results usually reported as cumulative distribution. Calculation of the results is based on normalization so that the entire measuring range equals 100% cumulative. It is important to note that the results for the 0.4 μ m always set to 0, even if the samples contain material finer than 0.4 μ m. The determination of grain size distribution by this technique is generally based on grain volume, and volume% will only be identical to mass% if the samples materiel has the same density throughout the size range. Moreover, the method is based on the assumption that all measured particles are spherical.

The method is suitable for geological material, but the analysis assumes that the samples do not have a high content of salts and organic materials. At the same time samples must be disintegrated so that all grains are free under running of the analysis. It is therefore certain requirements for sample preparation prior to analysis. The method has some errors related to flocculation under analysis, variations and deviations in particle shape, density variations, as well as transparency of the particles.

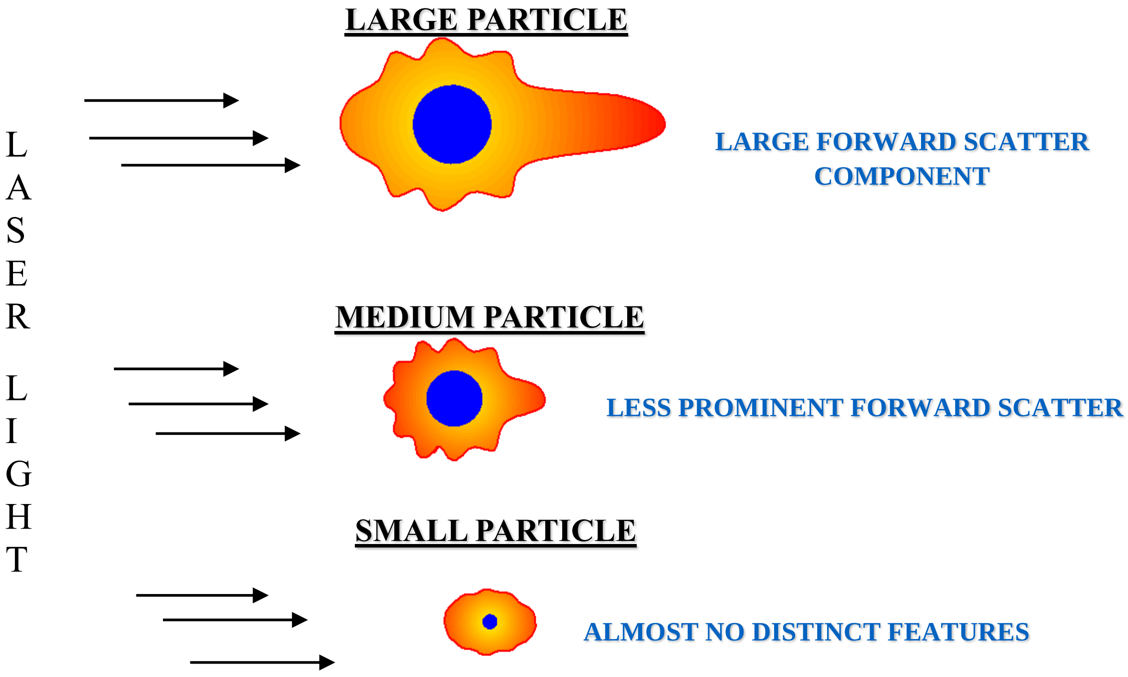
Theoretical background

The basis for the analysis is that light from a laser is broken on the surface of a particle at a certain angle depending on the size of the particle. Simply one can say that small particles have a high angle of broken light, while large particles have a low angle. Each particle size will give a specific pattern (diffractogram), and intensity depends on the number of particles in a given size interval. A brief description of the principles of laser diffraction follows.

Grain size distribution is determined by measuring the scattering pattern caused by particles in the sample. This pattern of scattered light is often called a diffraction pattern and represents the intensity of scattered light as a function of scattering angle. The measured scattering pattern is a cumulative pattern of all particles in the sample. An important component for determining these patterns is the Fourier lens, see Fig. 1 and 2



LIGHT SCATTER PATTERNS FOR SINGLE PARTICLES



Fourier lens focus all the light that hits the lens with a given angle in a single point on its focus plane. Fourier lens is sensitive only for the angel of the light and not the position or velocity of the light source. This results in forming a image of the entire diffraction pattern of each simple particle, which is centered at a fixed point in Fourier plane. This image is centered in the same area regardless of the position and velocity of the particles in the measuring cell. The overlay of diffraction patterns of all particles forms an integrated pattern which reflects all of the particles in the sample. This integrated pattern is measured by detectors placed on Fourier plane. The instrument has 126 detectors located at angles up to approx. 35 ° from the optical axis. The intensity measured by flux (light intensity per unit area). Particle sizes are determines by decomposition of the pattern in subgroups, each of them corresponds to a size category. The relative amplitude of each “sub pattern” is then used for determining the relative proportions of spherical particles with the actual size.

Calibration

No methodological calibration of the instrument required. Autoalignment and background measurement is an integral feature of the analysis and performed at each run.

Sample preparation

The following moments should be considered under sample preparation:

- If there is organic matter in the sample, or if the specimen is cemented by iron oxides or other compounds then it is useful to oxide the sample with hydrogen peroxide, and/or treat it with hydrochloric acid.
- For samples dominated by sand and coarse silt is no preparation necessary. The dry samples can be sprinkled in the machine until the appropriate concentration is achieved. Please be care when withdrawing representative sample. This is difficult to achieve by withdrawing small amounts of sample and from the dry material.
- Samples with high salt concentration (water-soluble salts) should be desalinated by soaking in water for about 1 week. The clear water is decanted or drawn off from the precipitated sample. This can be repeated if necessary. A faster method is to centrifuge after elutriation. Speed and time of the centrifuge must be adjusted so that the smallest particles also settle down before the water is decanted. In practice, desalination rarely required and even sea bottom- sediments can be analyzed without prior desalination.
- Freeze-drying and disintegration.

  Samples where the average grain size is less than 50 μm, or samples containing significant amounts of clay, has be diluted with distilled water in plastic beakers. The samples (suspensions) freezes before transferring to the freeze dryer (see separate procedure for freeze-drying). Then it will be easy to stir/mix the dry samples to extract representative weight. Weighed sample is added to 5-10 ml of 5% sodium pyrophosphate solution and 40 ml water in a 50 mL beaker. The sample suspension then is to be treated with ultrasound for 5 min before pouring directly into the sample vessel of the machine. Rinse the beaker with water so entire sample is transferred to the vessel.

Material larger than 2 mm in the sample must be removed by dry sieving.
If the sample contains a large fraction material larger than 2 mm, it will normally be dry sieved down to 0.5 mm, so that only the fraction <0.5 mm is analyzed on the Coulter

Extraction of representative sample

This is a very important but difficult task.
Performing first a preliminary determination to get examined the weight which is suitable for performing the analysis. This can be done practically by weighing all the samples and then transfer representative material to sample vessel in the instrument until the concentration shows 8-12% obscuration.

Minimum sample quantity is dependent on grain size. Table 1 shows the guide for weights of samples examples with different medians.

Table 1 Indicative weight values for different medians.

MEDIAN DIAM. (⍰⍰⍰	Weight (g)
10	0.2
50	0.4
70	0.6
100	0.8
300-400	1.0
600	1.5 - 2.0

These values are only indicative; the software of the instrument gives a message when sufficient amount of sample is loaded.

Analysis

Samples must be run at least 2 times (2 parallels). If the gap between the parallels is greater than the stated precision of the method, perform running of two or even more additional parallels from new extracted weights. Report from analyzing of several parallels will be given by averaged curve and results

Reference: **ISO 13320:2009** Particle size analysis -- Laser diffraction methods.

Interpretation

Definition and interpretation of the following statistical parameters: mean, median, standard deviation, skewness and kurtosis.

Mean is the average size of the entire sample.

Median is the median which is that size such that ,50 percent of the material is larger and 50 percent is smaller, i.e. the 50th percentile value (Derek W. Spencer, 1963)

Standard deviation(SD) is a precise measure of the amount of variation of grain size values. A low standard deviation indicates that the grain size values are closer to the mean, while high standard deviation indicates that the grain size values are spread out over a wider range.

Skewness is the measure of relative symmetry of the distribution. As skewness value approaches zero, the more symmetrical is the distribution, where zero indicates symmetry. The larger its absolute value, the less symmetric is the cross plot (relative frequency vs grain size). Positive values indicate that the curve tail extends to the left and negative value indicate that the curve tail extends to the right.

Kurtosis is the measure of the relative peakedness of a distribution. As the kurtosis value approaches 3, the curve has a mesokurtic type, normal “bell-shaped” distribution. If the value is less than 3 the distribution is platykurtic(flatter than a normal distribution) and if the value is greater than 3, the distribution is leptokurtic(more peaked than a normal distribution)

Results

Statistical parameters for 29 samples

Table 1: Statistical parameters for 29 samples(Arithmetic)

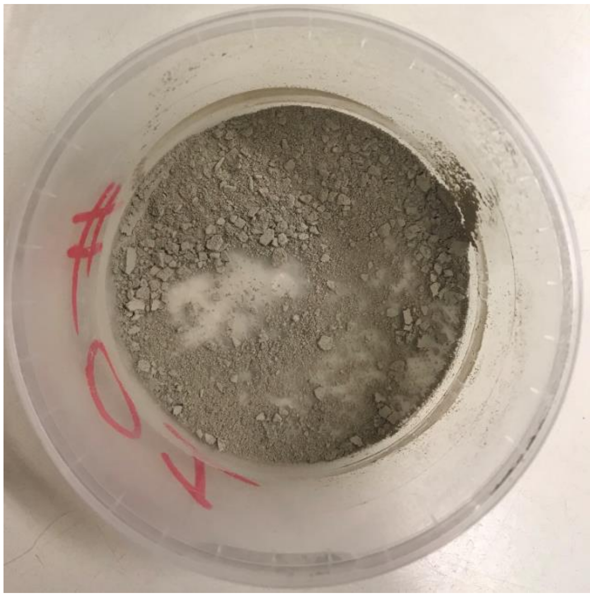
Sample number	Depth(m)	Mean (µm)	Median (µm)	Standard deviation (µm)	Skewness	Kurtosis	Lithology based on grain size (Friedman and Sanders, 1978)
1	0.12	29.66	20.49	29.52	2.214	7.019	Coarse silt
2	0.17	25.46	13.96	34.48	3.212	12.63	Coarse silt
3	0.25	17.56	9.810	24.83	3.821	18.72	Coarse silt
4	0.63	19.05	11.63	22.29	2.753	10.05	Coarse silt
5	0.68	20.83	11.79	26.58	3.065	12.23	Coarse silt
6	1.03	17.07	9.607	25.28	4.052	20.12	Coarse silt
7	1.08	15.01	9.188	20.43	4.361	26.40	Medium silt
8	1.25	17.98	11.81	22.39	3.854	19.8	Coarse silt
9	1.35	17.08	11.53	18.51	2.753	10.26	Coarse silt
10	1.45	16.00	9.644	20.29	3.212	13.49	Coarse silt
11	2.05	14.96	9.253	20.52	4.555	28.85	Medium silt
12	2.13	17.18	12.24	17.87	3.210	16.54	Coarse silt
13	2.43	16.07	10.86	18.48	3.254	14.90	Coarse silt
14	2.64	15.90	9.885	22.26	4.442	25.30	Medium silt
15	2.76	16.31	9.237	23.48	4.122	22.59	Coarse silt
16	3.05	29.05	11.6	51.67	3.267	10.72	Coarse silt
17	3.12	270.2	271.2	174.0	0.272	-0.069	Medium sand
18	3.31	136.9	140.5	101.8	0.741	1.539	Fine sand
19	3.4	250.7	177.2	287.5	2.066	5.709	Medium sand
20	0.1	17.57	8.805	26.02	3.612	16.46	Coarse silt
21	0.3	163.6	130.2	165.9	0.995	0.347	Fine sand
22	0.32	28.57	14.80	37.13	2.575	7.526	Coarse silt
23	0.57	35.23	17.52	43.76	2.169	4.999	Very coarse silt
24	0.77	21.97	11.84	30.58	3.312	12.99	Coarse silt
25	1.12	115.6	122.4	75.59	0.033	-0.974	Very fine sand
26	1.1-1.3	62.88	28.51	72.46	1.189	0.374	Very coarse silt
27	1.67	124.6	144.3	72.44	-0.537	-0.944	Very fine sand
28	1.8	231.9	228.5	103.8	0.216	1.215	Fine sand
29	0.1	21.74	9.482	33.07	2.943	9.719	Coarse silt

Table 1 shows the summary of the results acquired through grain analysis.

Detailed analysis for each sample are demonstrated below:

Sample 1

Depth(m)	0.12
Mean(µm)	29.66
Median(µm)	20.49
Standard deviation(µm)	29.52
Skewness	2.214
Kurtosis	7.019



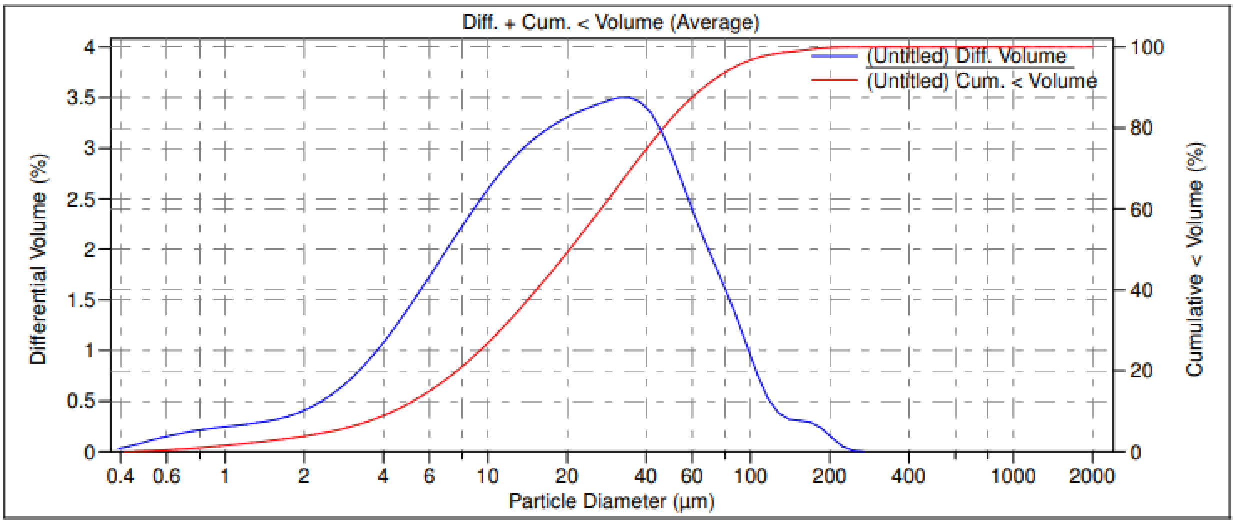
Interpretation

Lithology: Coarse silt

Sorting:

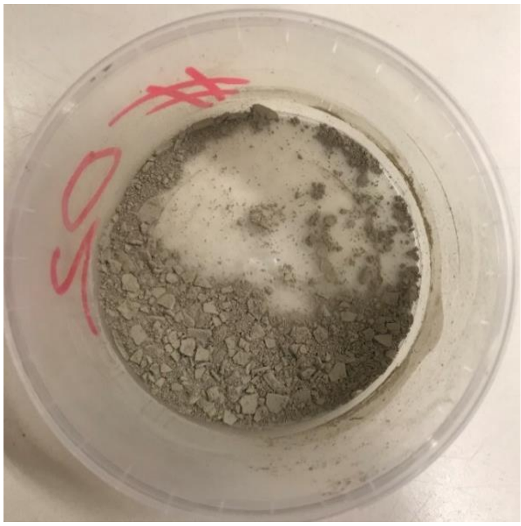
Skewness:

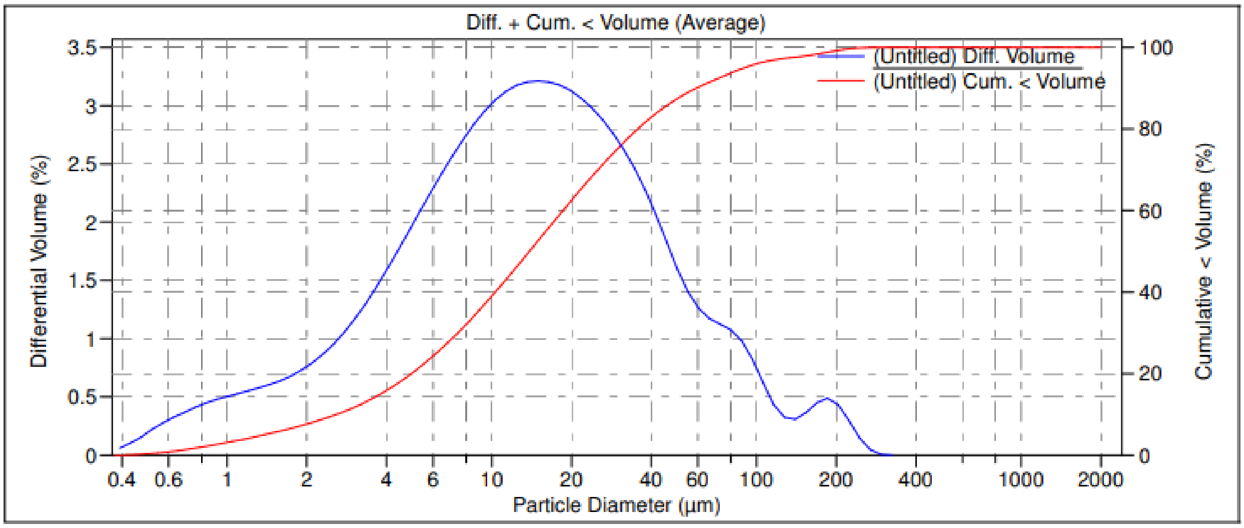
Kurtosis:



Sample 2

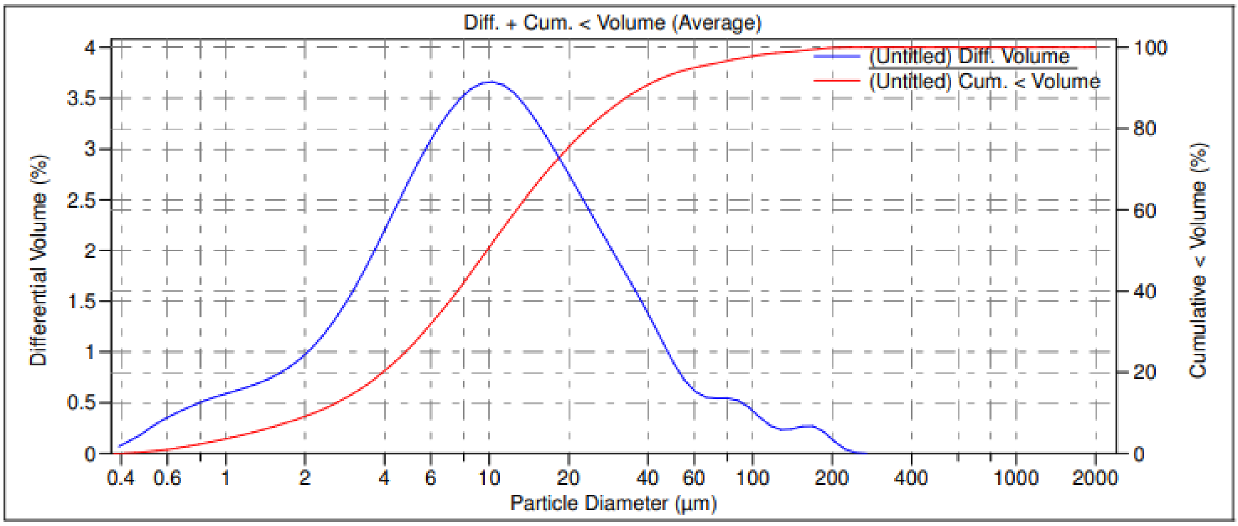
Depth(m)	0.17
Mean(µm)	25.46
Median(µm)	13.96
Standard deviation(µm)	34.48
Skewness	3.212
Kurtosis	12.63





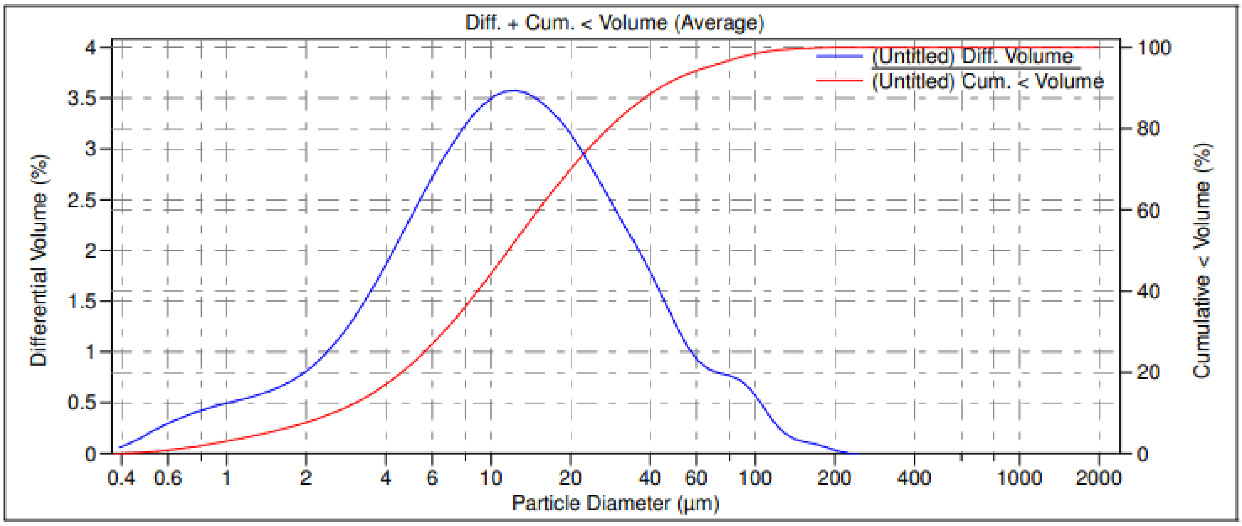
Sample 3

Depth(m)	0.25
Mean(µm)	17.56
Median(µm)	9.81
Standard deviation(µm)	24.83
Skewness	3.821
Kurtosis	18.72



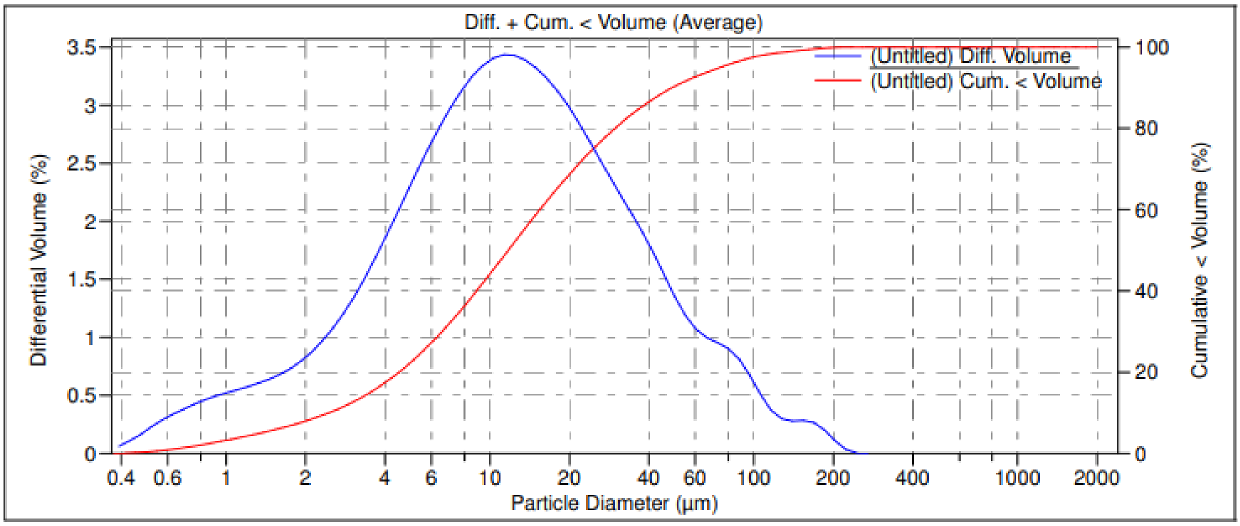
Sample 4

Depth(m)	0.63
Mean(μm)	19.05
Median(μm)	11.63
Standard deviation(μm)	22.29
Skewness	2.753
Kurtosis	10.05



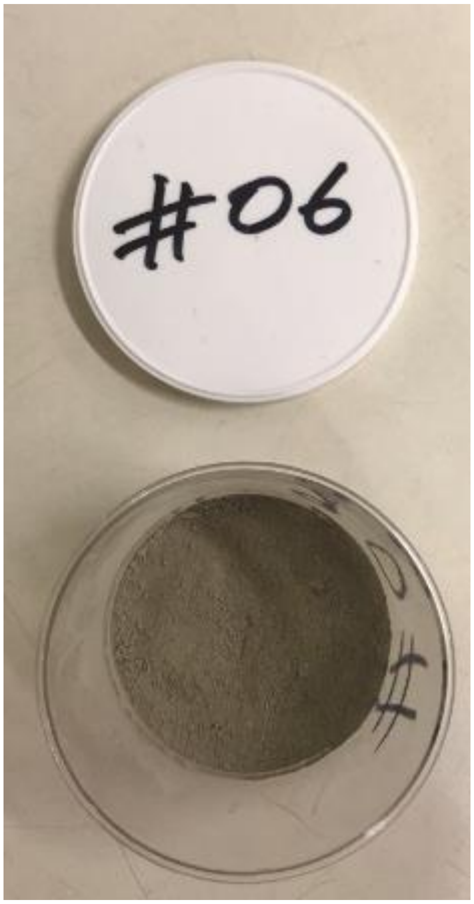
Sample 5

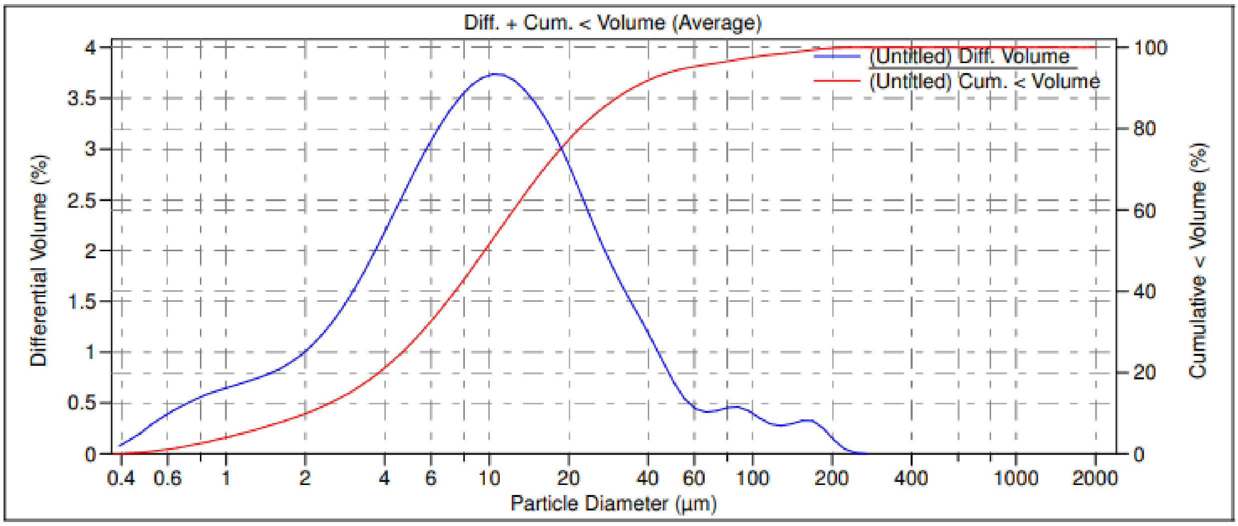
Depth(m)	0.68
Mean(µm)	20.83
Median(µm)	11.79
Standard deviation(µm)	26.58
Skewness	3.065
Kurtosis	12.23



Sample 6

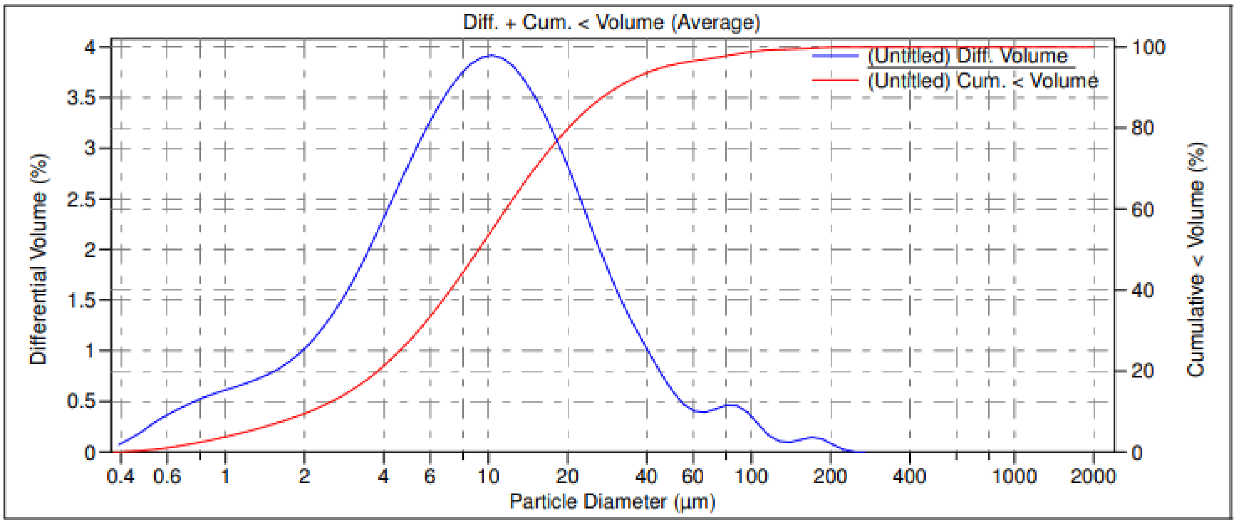
Depth(m)	1.03
Mean(µm)	17.07
Median(µm)	9.607
Standard deviation(µm)	25.28
Skewness	4.052
Kurtosis	20.12





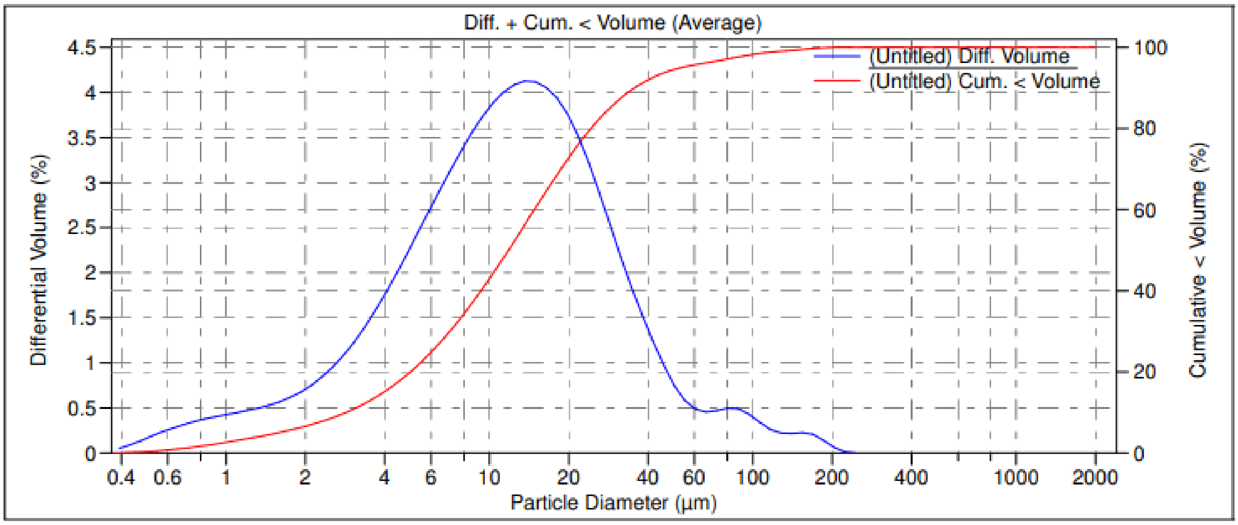
Sample 7

Depth(m)	1.08
Mean(µm)	15.01
Median(µm)	9.188
Standard deviation(µm)	20.43
Skewness	4.361
Kurtosis	26.4



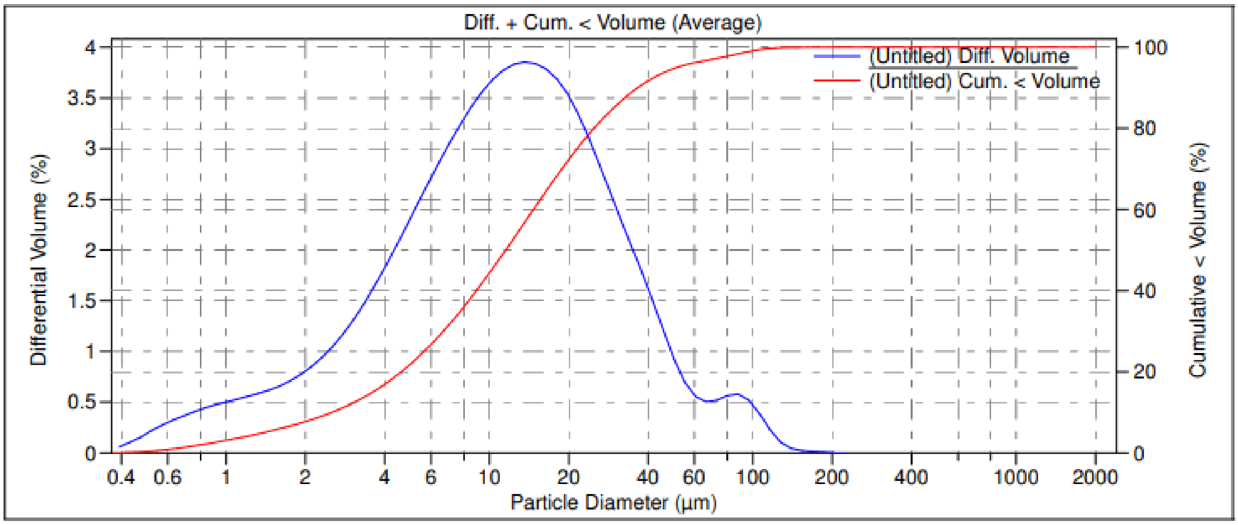
Sample 8

Depth(m)	1.25
Mean(µm)	17.98
Median(µm)	11.81
Standard deviation(µm)	22.39
Skewness	3.854
Kurtosis	19.8



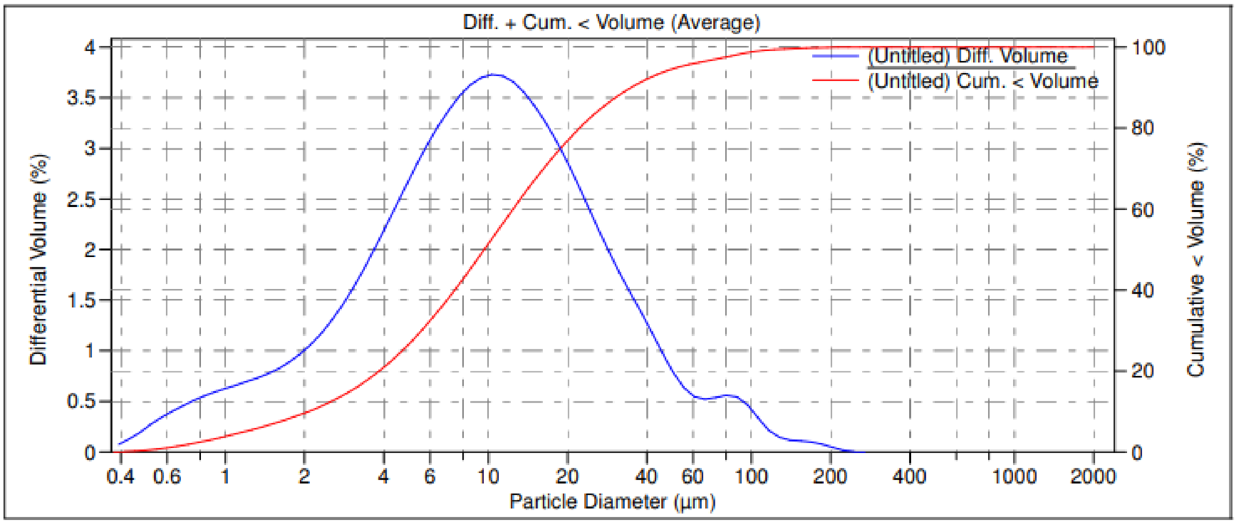
Sample 9

Depth(m)	1.35
Mean(µm)	17.08
Median(µm)	11.53
Standard deviation(µm)	18.51
Skewness	2.753
Kurtosis	10.26



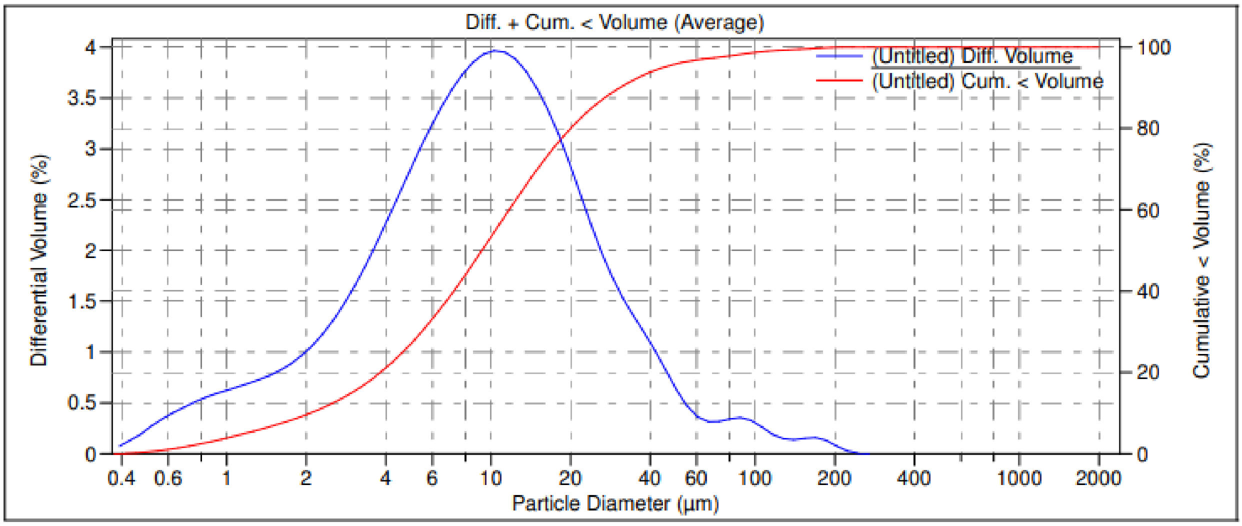
Sample 10

Depth(m)	1.45
Mean(µm)	16
Median(µm)	9.644
Standard deviation(µm)	20.29
Skewness	3.212
Kurtosis	13.49



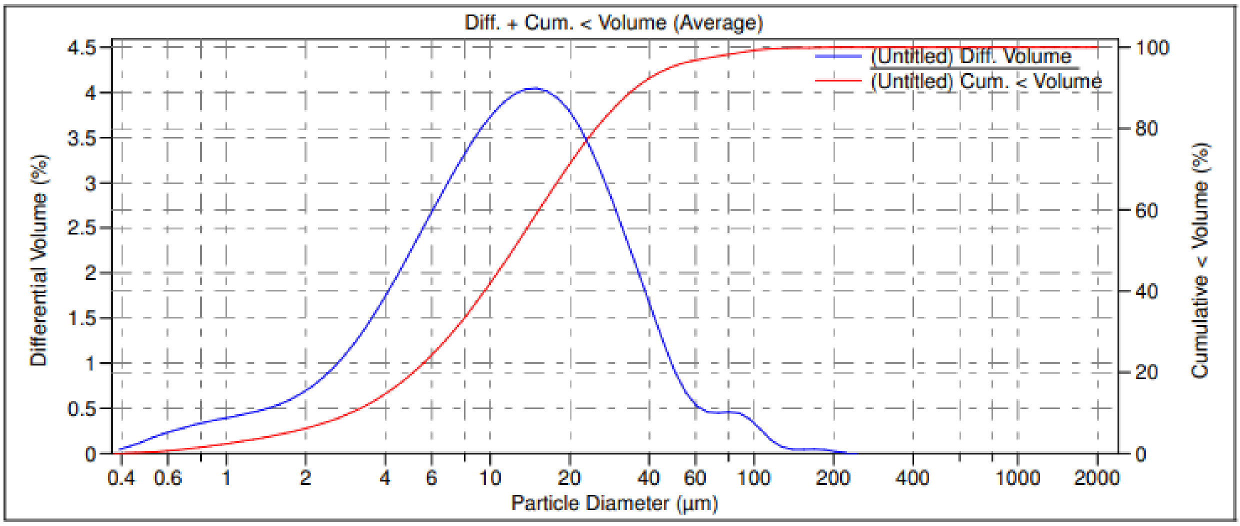
Sample 11

Depth(m)	2.05
Mean(µm)	14.96
Median(µm)	9.253
Standard deviation(µm)	20.52
Skewness	4.555
Kurtosis	28.85



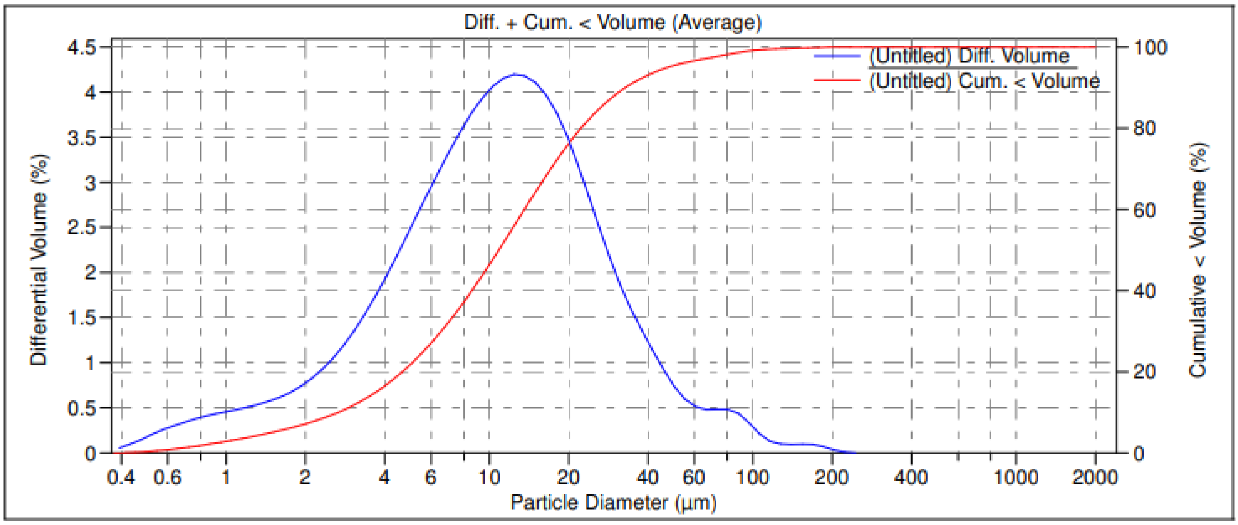
Sample 12

Depth(m)	2.13
Mean(µm)	17.18
Median(µm)	12.24
Standard deviation(µm)	17.87
Skewness	3.21
Kurtosis	16.54



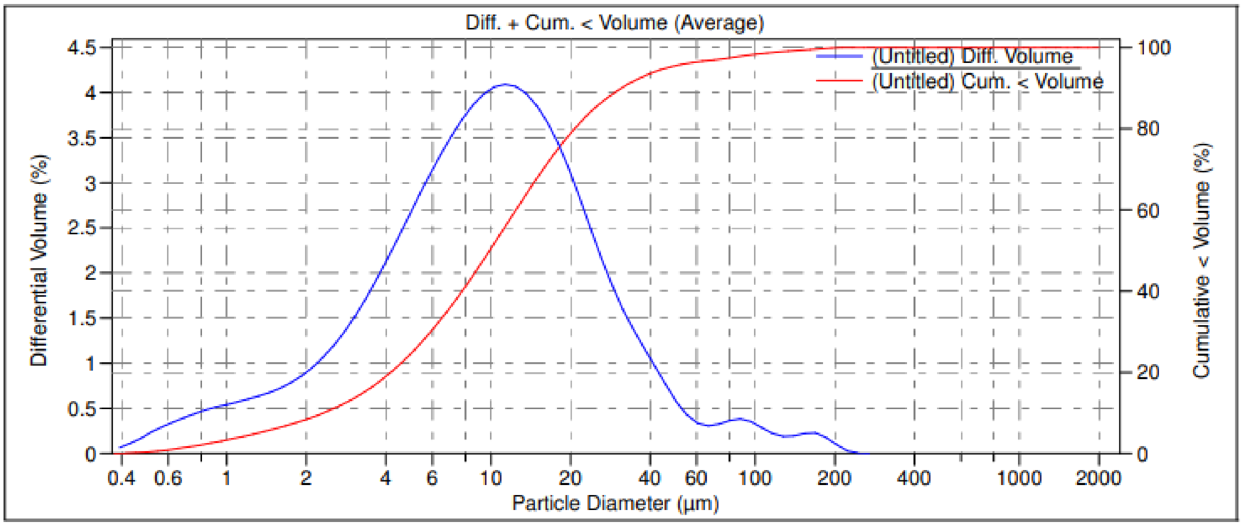
Sample 13

Depth(m)	2.43
Mean(µm)	16.07
Median(µm)	10.86
Standard deviation(µm)	18.48
Skewness	3.254
Kurtosis	14.9



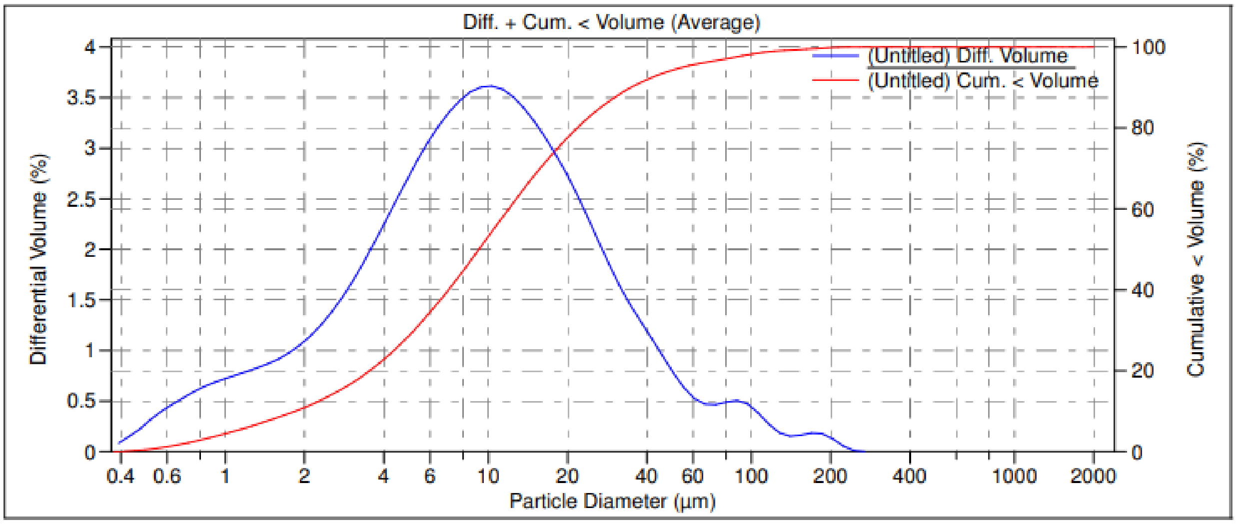
Sample 14

Depth(m)	2.64
Mean(µm)	15.9
Median(µm)	9.885
Standard deviation(µm)	22.26
Skewness	4.442
Kurtosis	25.3



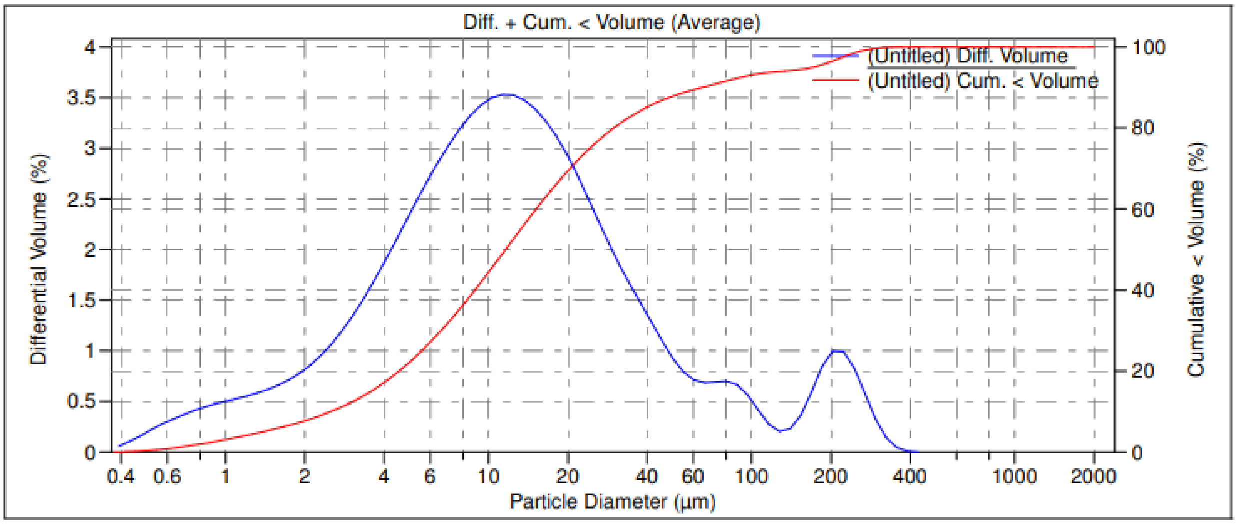
Sample 15

Depth(m)	2.76
Mean(µm)	16.31
Median(µm)	9.237
Standard deviation(µm)	23.48
Skewness	4.122
Kurtosis	22.59



Sample 16

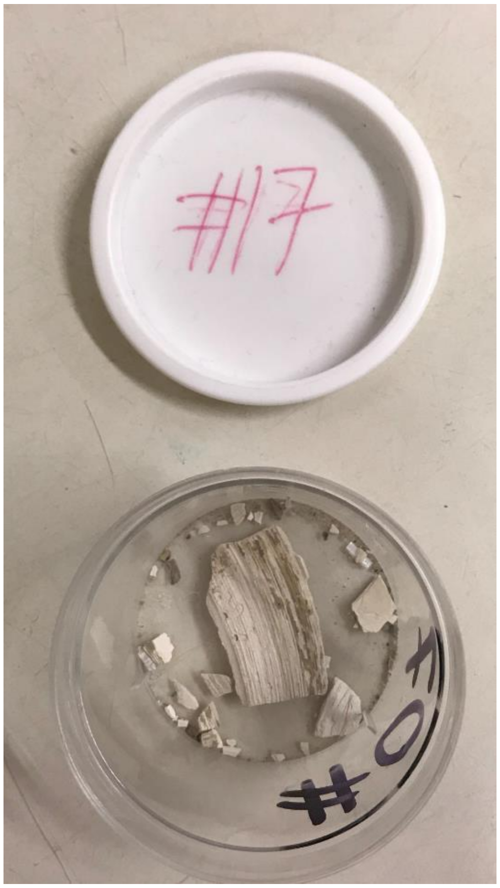
Depth(m)	3.05
Mean(µm)	29.05
Median(µm)	11.6
Standard deviation(µm)	51.67
Skewness	3.267
Kurtosis	10.72

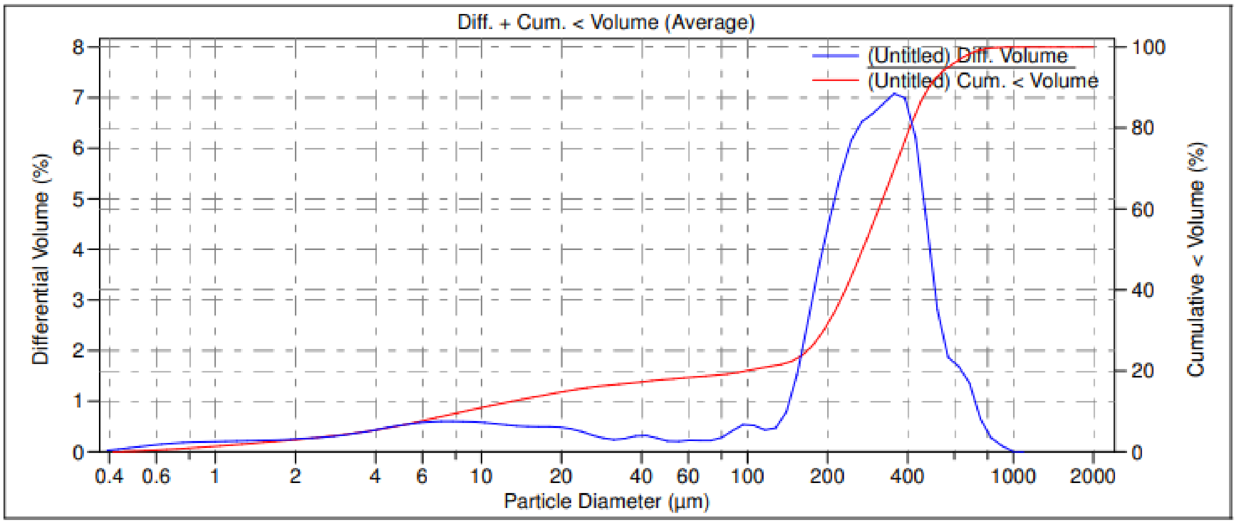


Sample 17

Depth(m)	3.12
Mean(µm)	270.2
Median(µm)	271.2
Standard deviation(µm)	174
Skewness	0.272
Kurtosis	-0.069

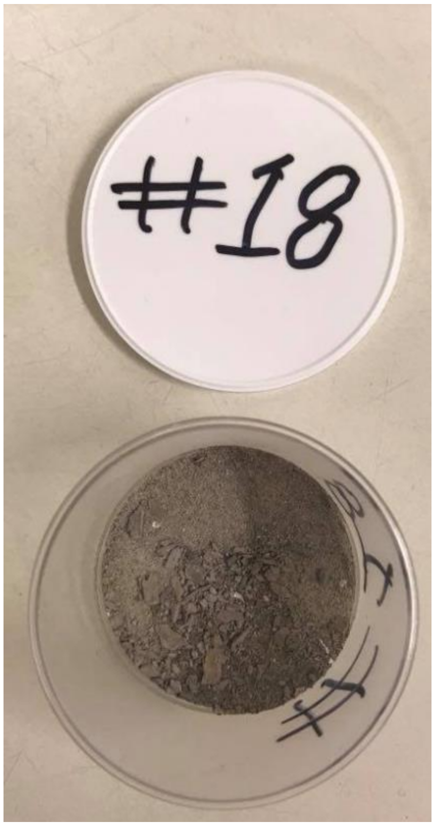
Additional observation: The sample is rich in calcium carbonate (big chunks of shells)



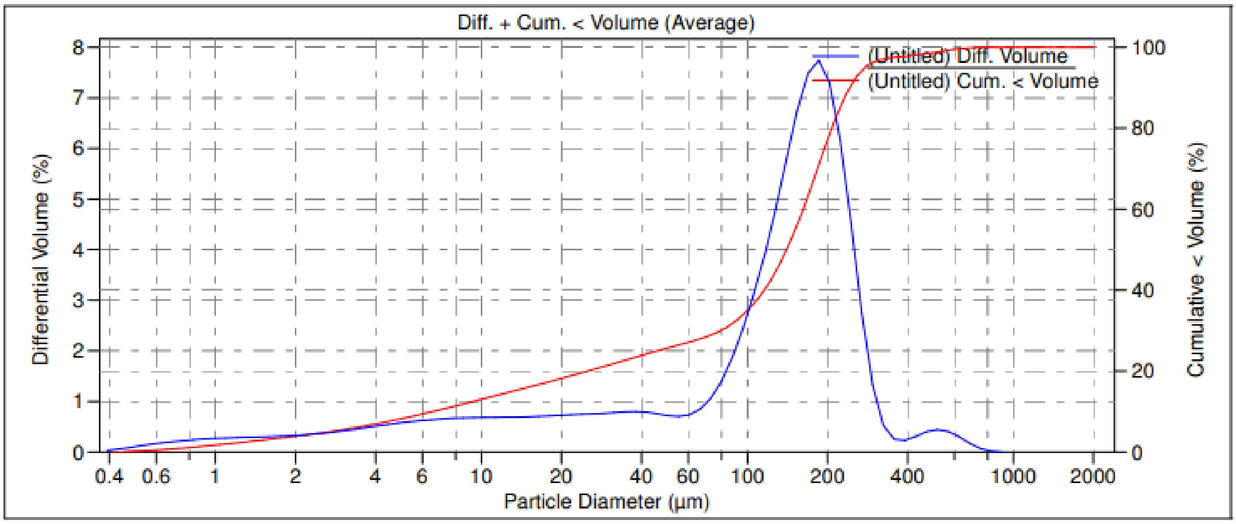


Sample 18

Depth(m)	3.31
Mean(μm)	136.9
Median(μm)	140.5
Standard deviation(μm)	101.8
Skewness	0.741
Kurtosis	1.539



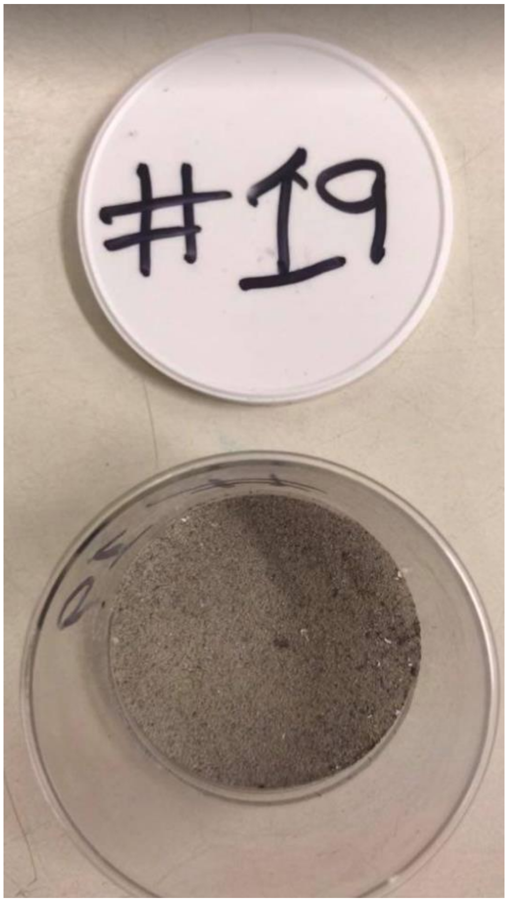
Additional observation: The sample consists organic matter in form of plants.

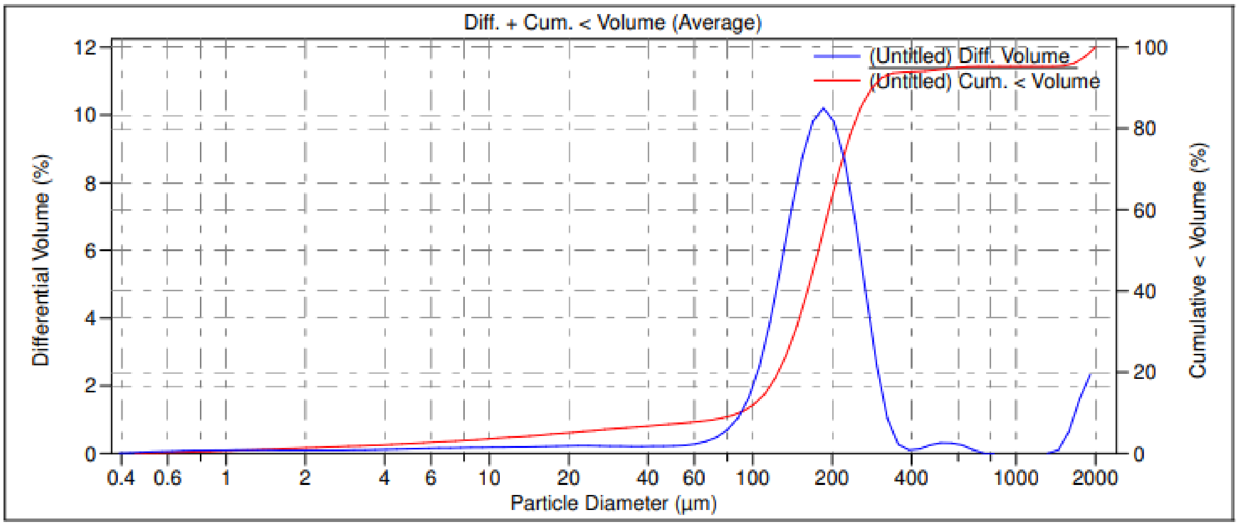


Sample 19

Depth(m)	3.4
Mean(μm)	250.7
Median(μm)	177.2
Standard deviation(μm)	287.5
Skewness	2.066
Kurtosis	5.709

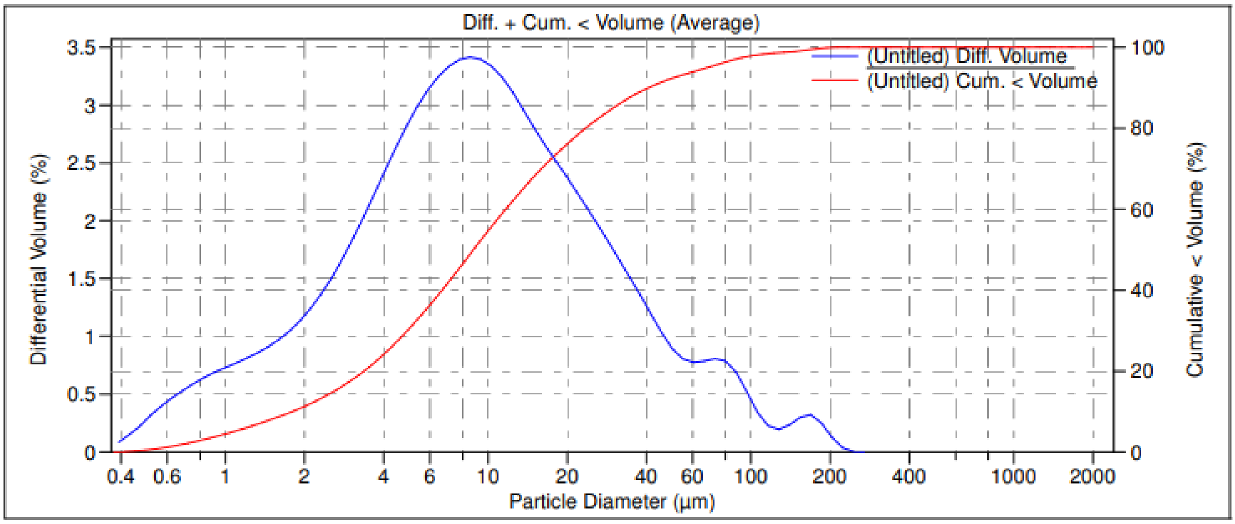
Additional observation: The sample consists calcium carbonates (in form of fine shell fragments)





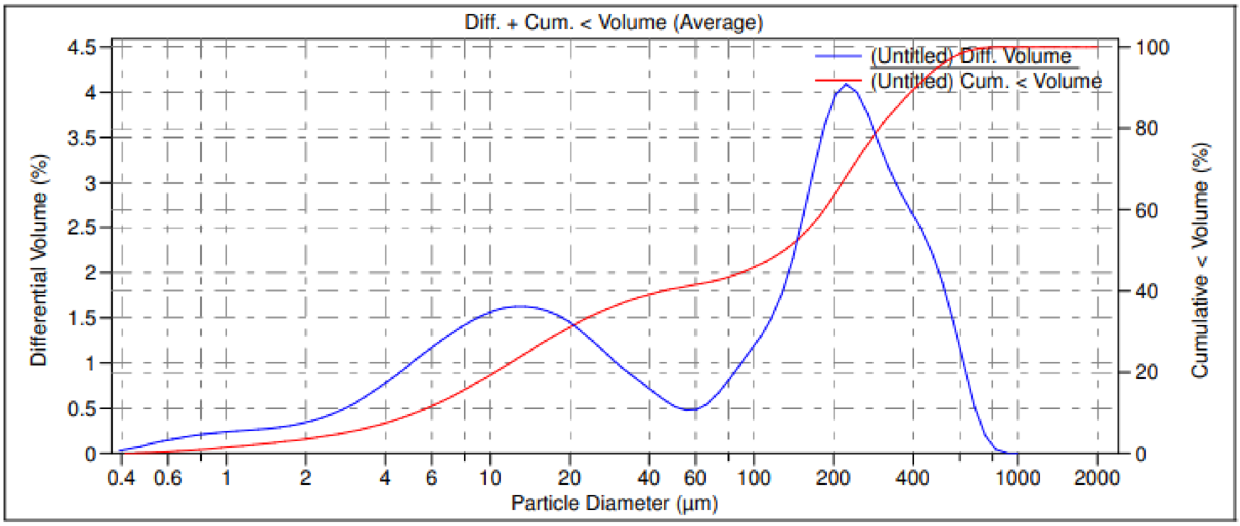
Sample 20

Depth(m)	0.1
Mean(μm)	17.57
Median(μm)	8.805
Standard deviation(μm)	26.02
Skewness	3.612
Kurtosis	16.46



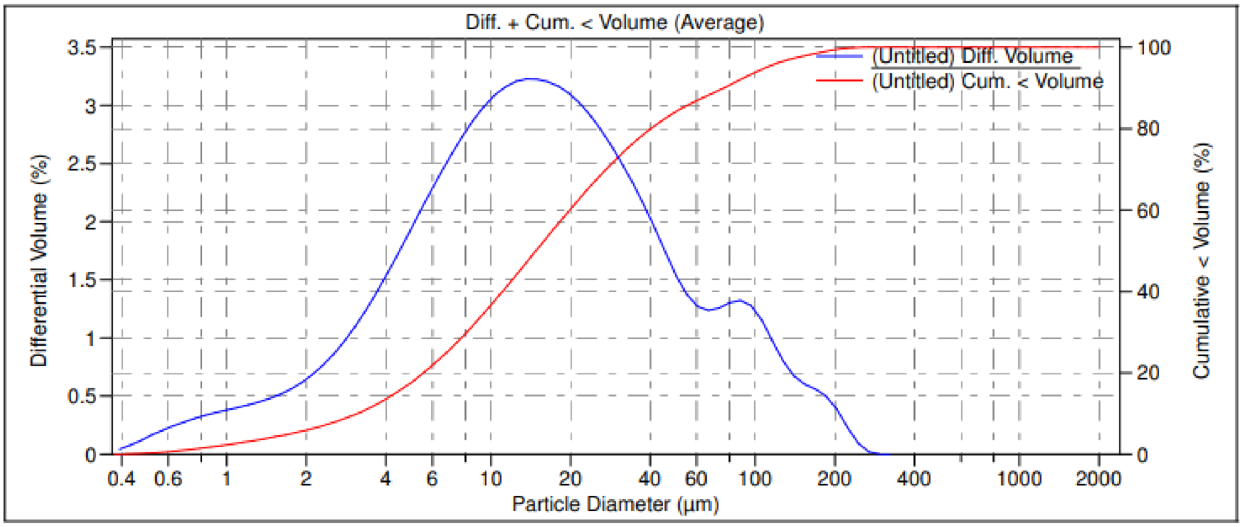
Sample 21

Depth(m)	0.3
Mean(µm)	163.6
Median(µm)	130.2
Standard deviation(µm)	165.9
Skewness	0.995
Kurtosis	0.347



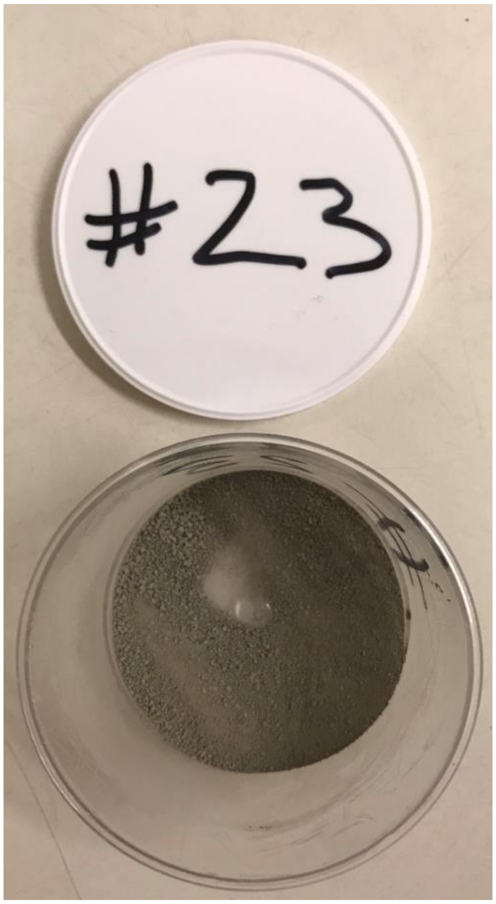
Sample 22

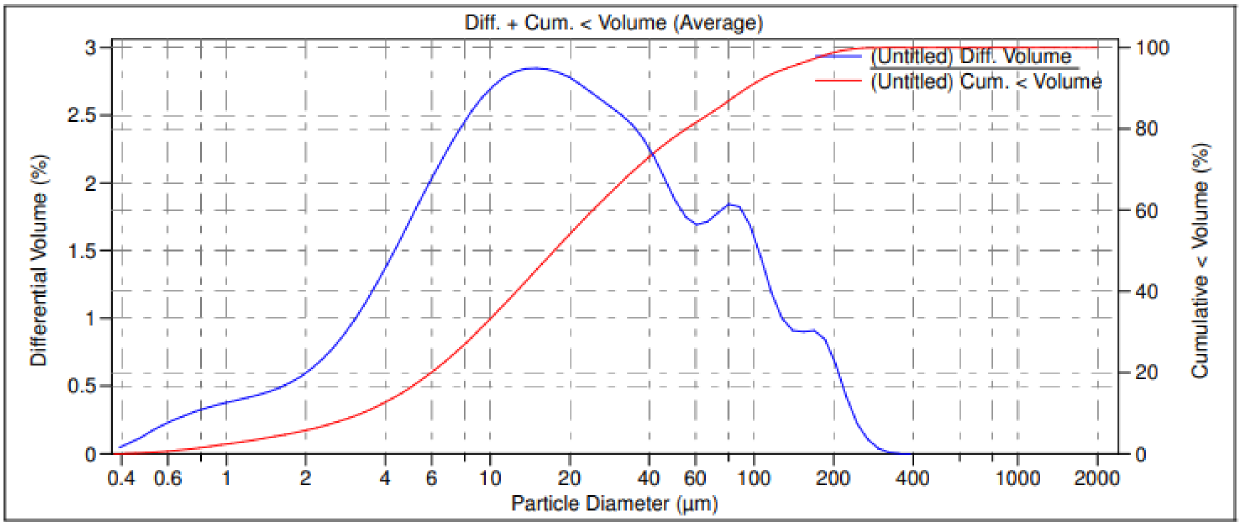
Depth(m)	0.32
Mean(μm)	28.57
Median(μm)	14.8
Standard deviation(μm)	37.13
Skewness	2.575
Kurtosis	7.526



Sample 23

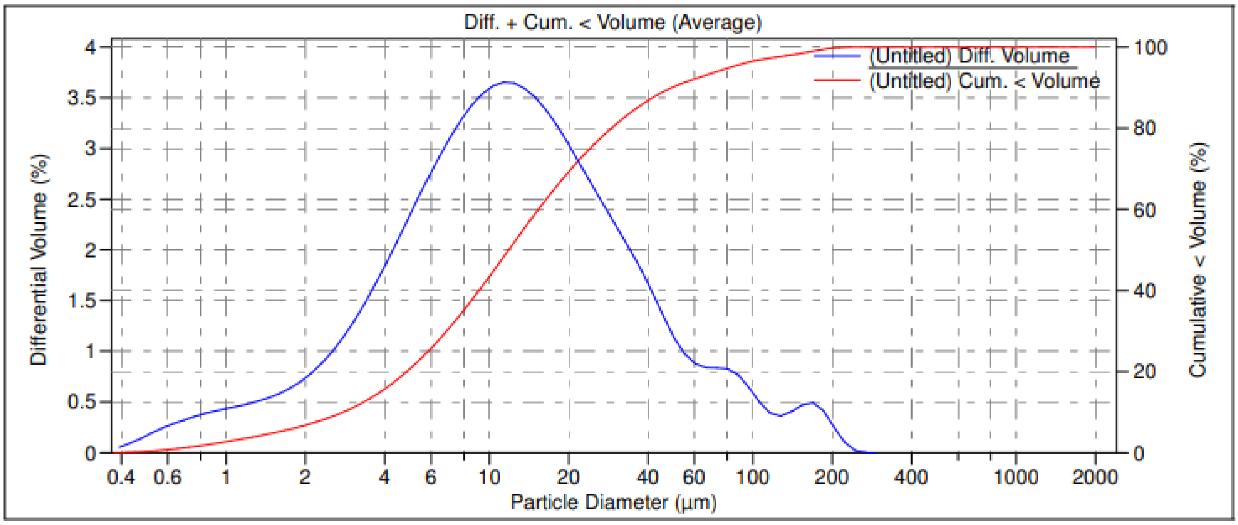
Depth(m)	0.57
Mean(µm)	35.23
Median(µm)	17.52
Standard deviation(µm)	43.76
Skewness	2.169
Kurtosis	4.999





Sample 24

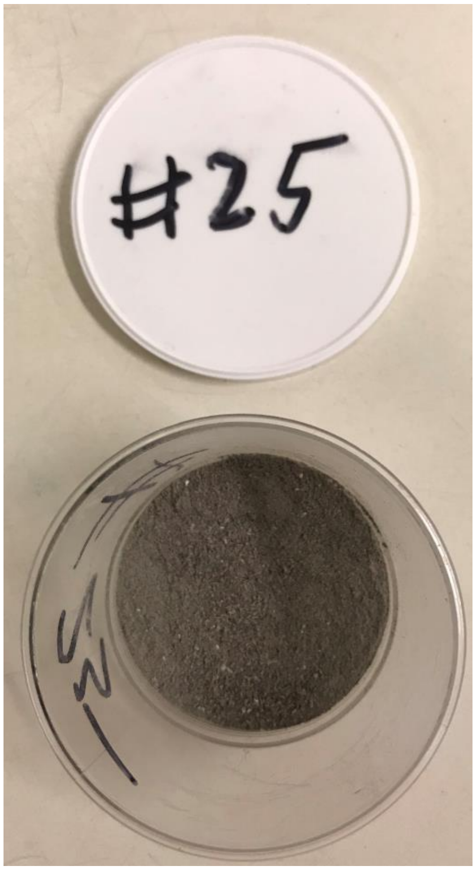
Depth(m)	0.77
Mean(μm)	21.97
Median(μm)	11.84
Standard deviation(μm)	30.58
Skewness	3.312
Kurtosis	12.99

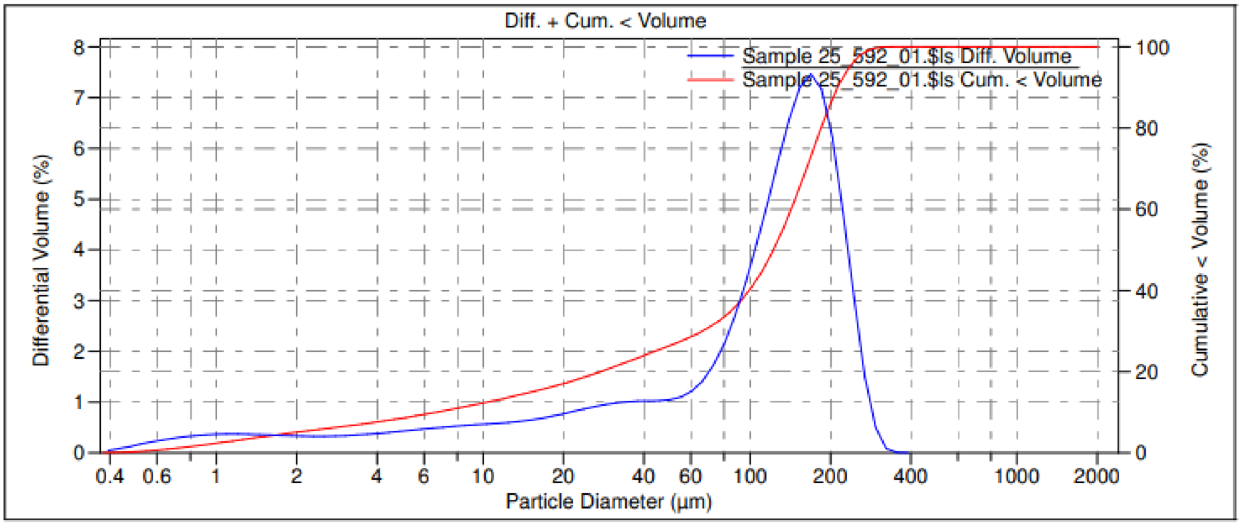


Sample 25

Depth(m)	1.12
Mean(µm)	115.6
Median(µm)	122.4
Standard deviation(µm)	75.59
Skewness	0.033
Kurtosis	-0.974

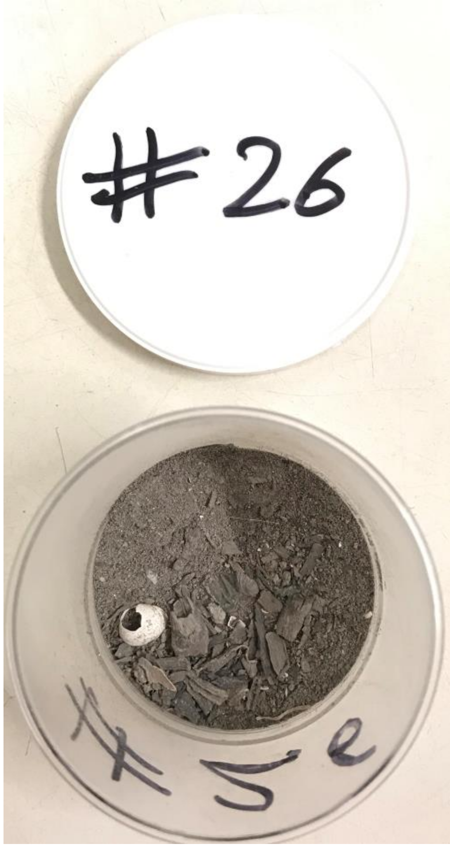
Additional observation: The sample consists calcium carbonate (in form of fine shell fragments). The sample was treated with hydrogen peroxide prior grain size analysis in order to oxide organic matter.



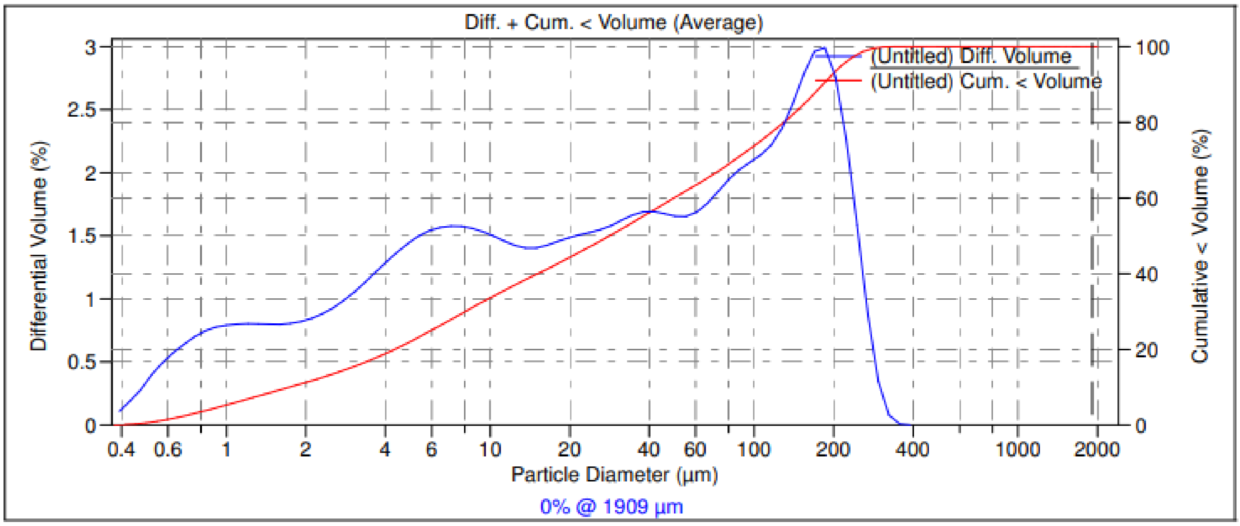


Sample 26

Depth(m)	1.1-1.3
Mean(µm)	62.88
Median(µm)	28.51
Standard deviation(µm)	72.46
Skewness	1.189
Kurtosis	0.374

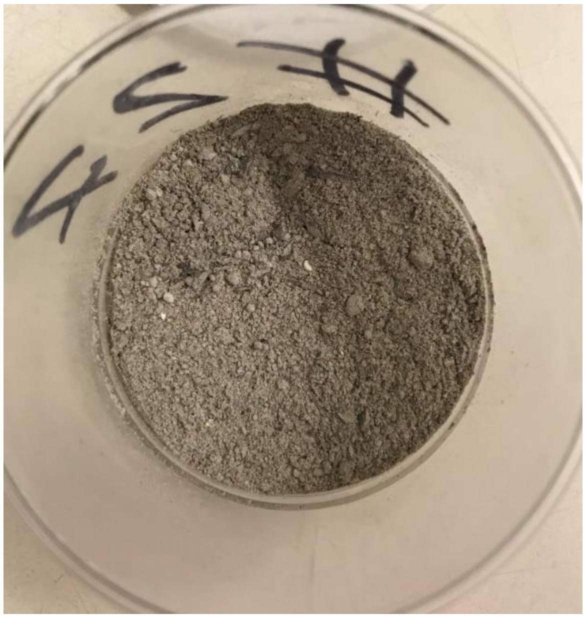


Observation: The sample is rich in organic matter. Abundance of shell fragments and plant debris. The sample was treated with hydrogen peroxide prior grain size analysis in order to oxide organic matter.

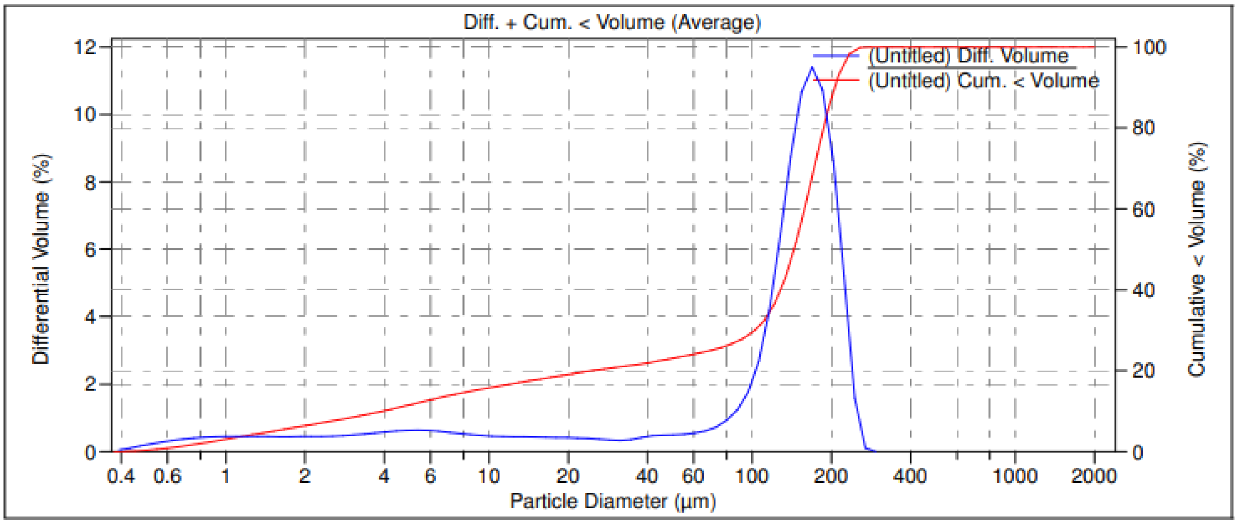


Sample 27

Depth(m)	1.67
Mean(μm)	124.6
Median(μm)	144.3
Standard deviation(μm)	72.44
Skewness	-0.537
Kurtosis	-0.944

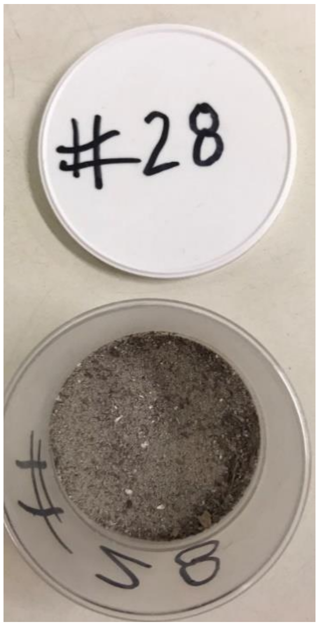


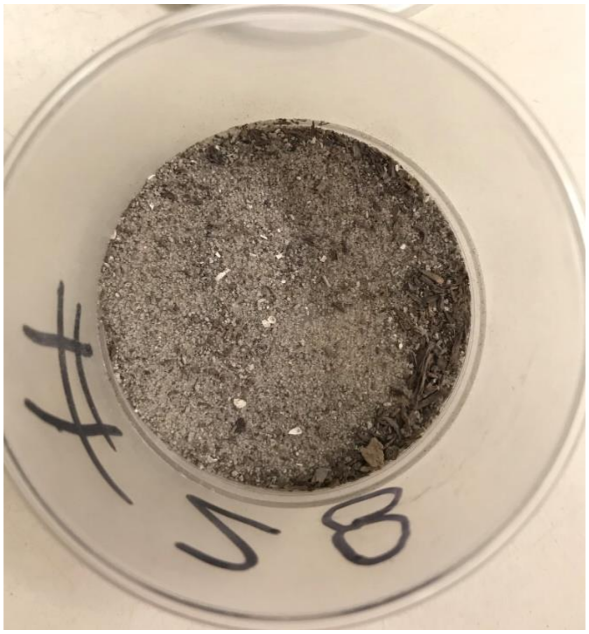
Additional observation: The sample consists calcium carbonate (in form of fine shell fragments). The sample was treated with hydrogen peroxide prior grain size analysis in order to oxide organic matter.



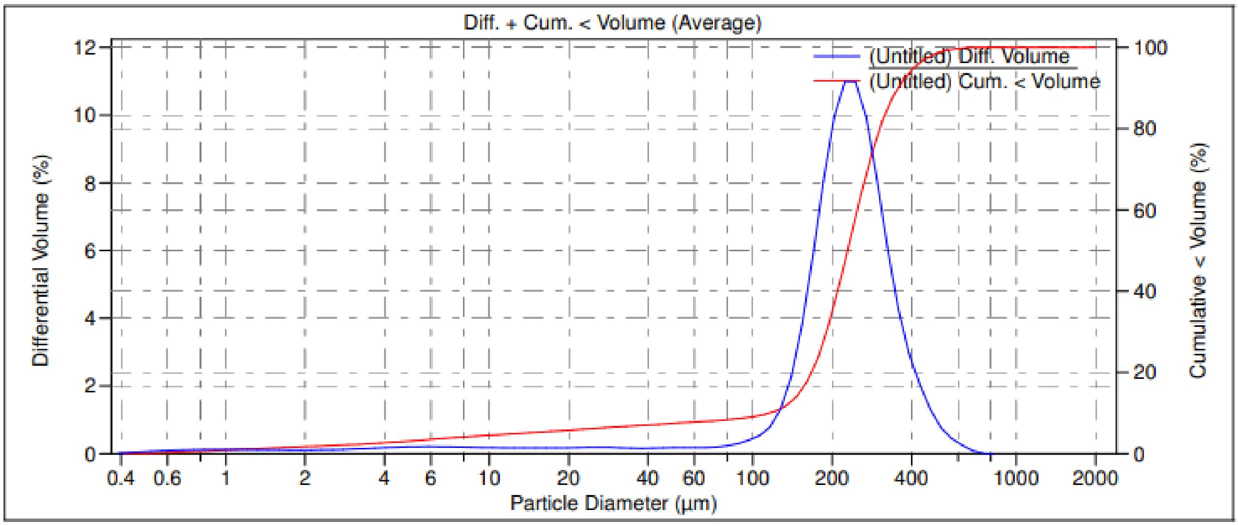
Sample 28

Depth(m)	1.8
Mean(µm)	231.9
Median(µm)	228.5
Standard deviation(µm)	103.8
Skewness	0.216
Kurtosis	1.215



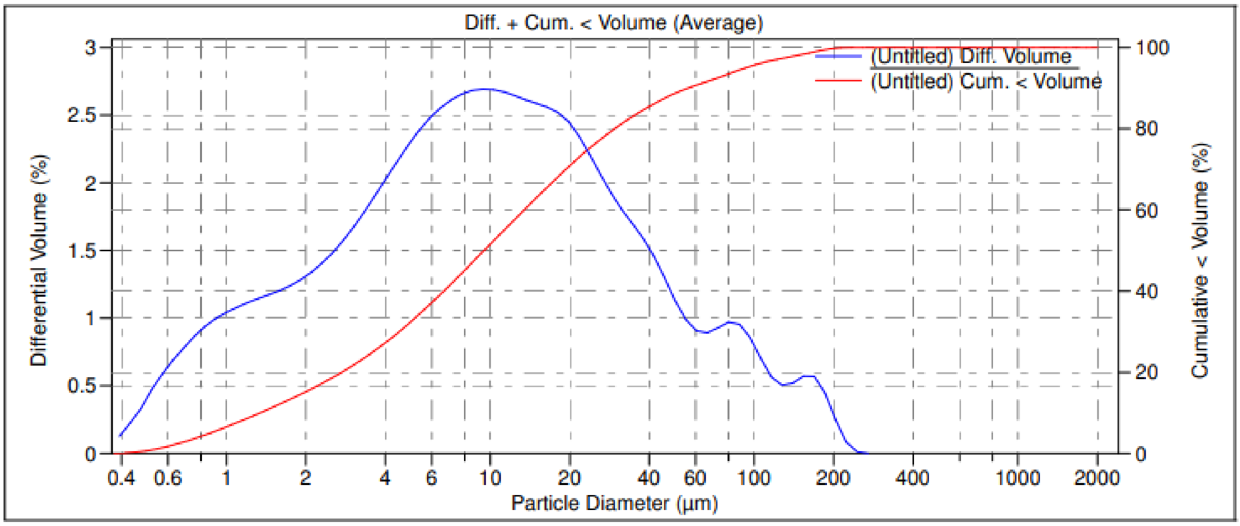


Additional observation: The sample is rich in organic matter. Shell fragments and plants are abundant. The sample was treated with hydrogen peroxide prior grain size analysis in order to oxide organic matter.



Sample 29

Depth(m)	0.1
Mean(µm)	21.74
Median(µm)	9.482
Standard deviation(µm)	33.07
Skewness	2.943
Kurtosis	9.719



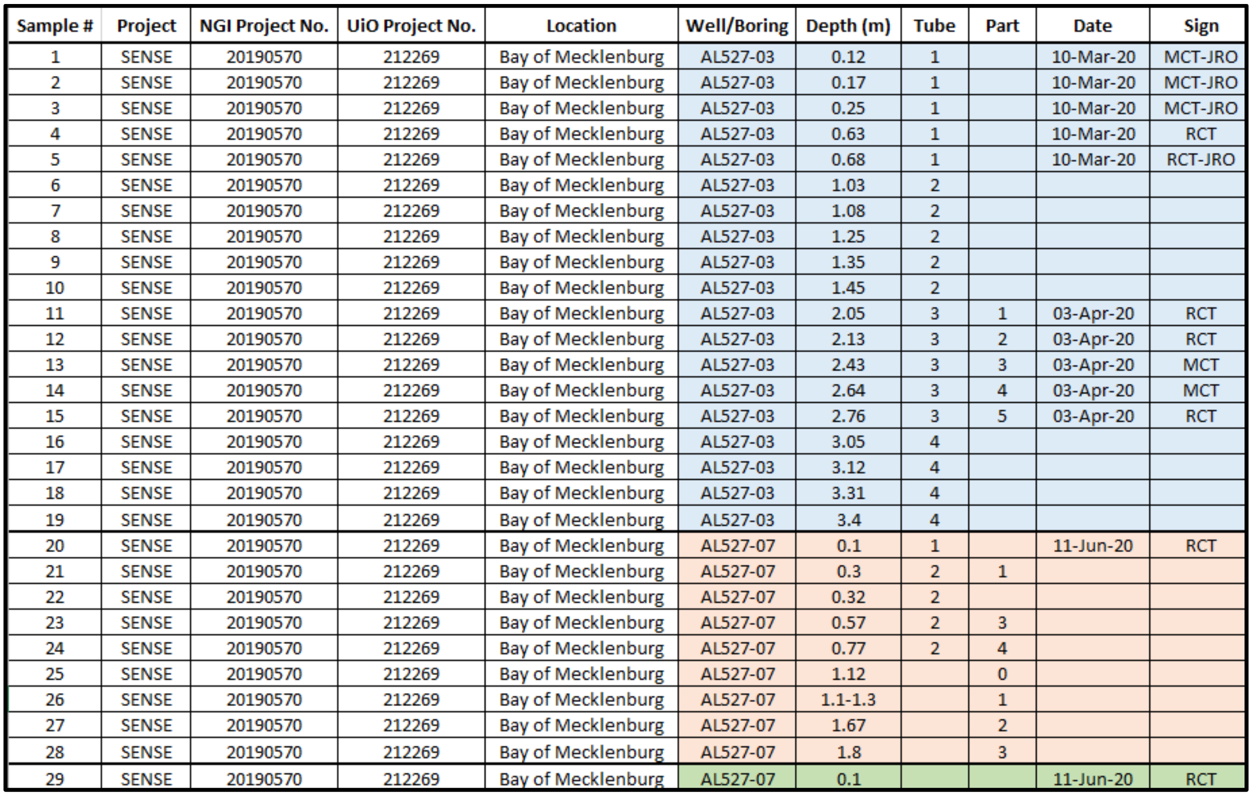
Summary

Based on grain size analysis, the descriptive terminology for grains by Friedman and Sanders (1978) were assigned to each sample.

To describe the degree of sorting, SD values should be evaluated.

Skewness and kurtosis values can be interpreted using values obtained from geometric method (FOLK & WARD Statistics)

Appendix



Sample #	Project	NGI Project No.	UiO Project No.	Location	Well/Boring	Depth (m)	Tube	Part	Date	Sign
1	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	0.12	1		10-Mar-20	MCT-JRO
2	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	0.17	1		10-Mar-20	MCT-JRO
3	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	0.25	1		10-Mar-20	MCT-JRO
4	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	0.63	1		10-Mar-20	RCT
5	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	0.68	1		10-Mar-20	RCT-JRO
6	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	1.03	2			
7	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	1.08	2			
8	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	1.25	2			
9	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	1.35	2			
10	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	1.45	2			
11	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	2.05	3	1	03-Apr-20	RCT
12	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	2.13	3	2	03-Apr-20	RCT
13	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	2.43	3	3	03-Apr-20	MCT
14	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	2.64	3	4	03-Apr-20	MCT
15	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	2.76	3	5	03-Apr-20	RCT
16	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	3.05	4			
17	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	3.12	4			
18	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	3.31	4			
19	SENSE	20190570	212269	Bay of Mecklenburg	AL527-03	3.4	4			
20	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.1	1		11-Jun-20	RCT
21	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.3	2	1		
22	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.32	2			
23	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.57	2	3		
24	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.77	2	4		
25	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	1.12		0		
26	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	1.1-1.3		1		
27	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	1.67		2		
28	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	1.8		3		
29	SENSE	20190570	212269	Bay of Mecklenburg	AL527-07	0.1			11-Jun-20	RCT

References

Beckman Coulter, Inc 2011. LS 13 320 Laser Diffraction Particle Size Analyzer

Blott, S.J. and Pye, K. (2001), GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf. Process. Landforms, 26: 1237-1248. https://doi.org/10.1002/esp.261

Derek W. Spencer, 1963. The Interpretation of Grain Size Distribution Curves of Clastic Sediments. *SEPM Journal of Sedimentary Research*, Vol. 33.

ISO 13320:2009 Particle size analysis -- Laser diffraction methods. (Mufak)