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Mound Study Project
Cape Fear, North Carolina
Sediment Entrainment Devices
June 2001 – November 2002
EHI Project No. 6000.21

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Prepared for Evans-Hamilton, Inc
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1. SUMMARY

This work was conducted in support of an ongoing investigation of sediment dispersal and evolution of a mixed-sediment disposal mound off Cape Fear, NC, by the US Army Corps of Engineers (USACE) and Evans-Hamilton, Inc. (EHI), project number 6000.21. Sediment Entrainment Devices (SEDs), fabricated by Virginia Institute of Marine Science (VIMS) and College of William and Mary personnel, were deployed on USACE bipods. Each SED collected suspended sediment at a specific height over a period of weeks in an effort to provide a representative sample of the suspended sediment for that height at a specific site over the deployment time period. After retrieval, the sediment samples were analyzed for grain-size distribution by weight, for grain-size distribution by volume concentration for the mud and sand fractions, and for the associated D50 grain-size for each fraction. Analyses of the sediment collected in the SEDs were performed by VIMS, under the direction of Grace Battisto. Results of the sediment analyzes are to be used by EHI in the analyses of optical backscatter (OBS) data collected at the same site and during the same period as each SED.

Figure 1. Sediment Entrainment Device (SED) fabricated to collect in-situ suspended sediment from a distinct height, usually the same height as an Obstacle Backscatter Sensor.

Table 1. Sediment Entrainment Devices Sample Log

Sample ID	Date Rec'd	Sample Location	Date In	Date Out	Picture #	Description	Height of SED from bottom (ft)
1T	20-Aug-01	Top basin on West Mound Crest bipod	29-Jun-01	28-Aug-01		1.75" sediment	1.85/2.05
1B	20-Aug-01	Bottom basin on West mound Crest bipod	29-Jun-01	28-Aug-01		3.25" sediment	0.2/0.4
2T	4-Sep-01	Top basin on West Mound Crest bipod	28-Aug-01	15-Aug-01		1.63" sediment	2.05
2B	4-Sep-01	Bottom basin on West Mound Crest bipod	28-Aug-01	15-Aug-01	2674	4" sediment	0.4
3T	Oct-01	Top basin on West Mound Crest bipod	16-Aug-01	5-Sep-01	3338	1.25" well mixed black sediment	2.05
3B	Oct-01	Bottom Grab on West Mound Crest	16-Aug-01	5-Sep-01		Sandy sediment in bag (bottom grab)	SED gone
4T	Oct-01	Top basin on West Mound Crest bipod	5-Sep-01	27-Sep-01	3341	1.25" black sediment with black floc on top	2.15
4B	Oct-01	Bottom basin on West Mound Crest bipod	5-Sep-01	27-Sep-01	3340	0.25" fine gray sediment on top 4" sand mixed with black sediment 1" black material on bottom	0.5
CF01	26-Mar-02	Bottom basin on West Mound Crest bipod	27-Sep-01	31-Oct-01	p3261167-68	4" sediment	0.5
CF02	26-Mar-02	Bottom basin on West Mound Crest bipod	31-Oct-01	29-Nov-01	p3261169-71	13.25" sediment (SED bottom buried)	1.5 to SED top
CF03	26-Mar-02	Top basin on West Mound Crest bipod	31-Oct-01	29-Nov-01	p3261172	2" sediment	2.6
CF04	26-Mar-02	Bottom basin on East Mound Crest bipod	28-Sep-01	29-Nov-01	p3261173-74	4.5" sediment	0.6
CF05	26-Mar-02	Baldhead bipod	14-Aug-01	27-Nov-01	p3261175-1178	13" sediment	1.3
CF06	26-Mar-02	Oak Island bipod	15-Aug-01	29-Nov-01	p3261179-1180	12.25" sediment	0.45
CF07	28-May-02	Oak Island bipod	16-Jan-02	16-Apr-02	p0001866-1868	1.25" sediment	0.3
CF08	28-May-02	Eleven Mile	17-Jan-02	17-Apr-02	p0001866-1868	9" sediment	0.3
CF09	28-May-02	Bottom basin on East Mound Crest bipod	18-Apr-02	15-May-02	p0001871-1873	13" sediment	0.2
CF10	28-May-02	Mound Deep	17-Apr-02	15-May-02	p0001874-1876	6" sediment	0.2
CF11	28-May-02	Oak Island bipod	16-Apr-02	15-May-02	p0001874-1876	10.75" sediment	on bottom
CF12	28-May-02	Bald Head	17-Apr-02	16-May-02	p0001871-1873	9" sediment	on bottom
CF13	30-Jul-02	East Bipod bottom SED	15-May-02	12-Jun-02	EB061202p1-p6	5.8" sediment	on bottom
CF14	30-Jul-02	Oak Island bottom SED	17-May-02	12-Jun-02	OK061202p1-p5	7.6" sediment	on bottom
CF15	12-Aug-02	Eleven Mile	17-May-02	31-Jul-02	EL080102p1-p2	~12" sediment	on bottom
CF16	12-Aug-02	Mound Deep	15-May-02	31-Jul-02	MD073102p1-p5	~13.5" sediment	on bottom
CF17	12-Aug-02	Bald Head	16-May-02	31-Jul-02	BH073102p1-p2	~13.5" sediment	on bottom
CF18	12-Aug-02	Oak Island	12-Jun-02	1-Aug-02	OK073102p1-p4	~13" sediment	on bottom

2. METHODS

Each SED is a 48 cm long, 8.5 cm ID, clear acrylic tube tapered at each end (Figure 1). The end caps were machined with a 1 cm lip to fit snug into each end of the SED with an o-ring to complete the seal. A 2 cm diameter plastic dowel was inset into each end cap and held in place with a screw. The dowel serves a dual purpose. In addition to holding the end caps in place, the dowel slows down the velocity of the water bringing the sediment into the SED via a series of 1.4 cm holes located 13 cm from the top of the SED. This aids in the collection of the suspended sediment in the SED. The SED is designed to capture as much sediment as possible at a single height above the bed, usually corresponding to an OBS height, in an effort to provide information to be used by EHI to correct the OBS calibrations (VIMS report CHSD-2002-XX) for in-situ grain-size when they are used to convert OBS mV response to mg/L concentrations. The SEDs are not expected to collect sediment efficiently enough to provide a quantitative measure of the flux of sediment into the system. However, comparisons of relative accumulation among SEDs in time and space may provide useful qualitative information regarding sediment flux.

Table 1 shows the deployment and retrieval dates for the SEDs received by VIMS for analysis. Before deployment by USACE and EHI personnel, each SED was completely wrapped with duct tape with the exception of the holes. The duct tape allowed any barnacle growth that may have occurred to be pealed off after retrieval of the SED. Upon retrieval, the duct tape and any biological growth were removed. At first, the SEDs were transported intact to VIMS for analysis. At VIMS, the sediment heights were measured and a digital photograph was taken to document the visible layers of sediment in the SED (example Figure 2) before the SED was emptied and shipped back to be redeployed. Later into the project, it was decided that the USACE/EHI field crew would document the sediment height and photograph the SED and ship only the sediment to VIMS for analysis.

2.1 Percent grain-size distribution by weight

Wet sieve methods were used to determine the percent fractions of mud (<63 microns), fine-to-medium sand (63-500 micron), coarse sand (500 micron – 2 mm) and shell fragments etc. (> 2mm) for an aliquot of sample from each SED. Ten milliliters of a stock mesophosphate solution (0.3 g sodium carbonate and 51 g sodium mesophosphate solution /L de-ionized water) was added to each aliquot and put in a sonicator to prevent flocculation during the size separation process. Pipette analyses were used to separate the mud into clay and silt fractions. Percent by weight was determined for each fraction of the total weight of the aliquot.

2.2 Percent grain-size distribution by volume

The sand and mud fractions from the previous section were used to determine the volume grain-size distribution for each fraction. For the mud distribution, 2-15 ml of the mud fraction was brought to a total of 90 ml with a 10% solution of the stock sodium mesophosphate solution above. For the sand distribution, enough fine-to-medium sand (63 –500 micron size fraction) was added to 90 ml of the 10% sodium mesophosphate solution to give a good response. Each solution was placed in a stirring chamber within the laser path length of the LISST, and at least 100 seconds of data were collected at 1 Hz. The LISST records grain-size distribution ranging from 5 to 500 microns in 32 bins. An average LISST response for each of these bins was calculated.

For the mud distribution, the averaged responses of the first 17 bins, corresponding to the 5 to 63 microns grain-size range, were added together to get a total mud response. The response of each of the component bins was then divided by the total mud response and multiplied by 100 to give a logarithmically spaced percent volume grain-size distribution for the mud fraction. The D50 mud grain-size is the bin-size that corresponds to 50 percent of the cumulative response of these 17 bins.

For the sand distribution, the averaged response for bins 18-32, corresponding to the 63 to 500 microns range, were added together to get a total sand response. The response of each of these bins was then divided by the total sand response and multiplied by 100 to give a logarithmically spaced percent volume grain-size distribution for the sand fraction. The D50 sand grain-size is the bin-size that corresponds to 50 percent of the cumulative response of these 15 bins.

2.3 **Documentation of >500 micron sediment fraction**

Digital photographs were taken of the sediment fraction greater than 500 microns in an attempt at completeness. These photos could potentially be used at a later date to determine the size distribution of this fraction. The pictures were taken in the close-up mode with an Olympus E-10 digital camera mounted on a close-up stand with the lens 26 cm from the sample using two 75 watt bulbs for illumination.

Figure 2. Example Digital Photograph documenting visible layers of sediment captured by SED 2B. Additional photos in Figure 3.1-3.4

3. RESULTS

Figure 3 shows the digital photographs of the visible sediment layers in the SEDs. Only a portion of the first set of SEDs received by VIMS were photographed as examples of the sediment layers. The procedure was changed after this set so there was at least one photograph for each SED. Some of the SEDs shown in Figure 3 have two photos in the figure. This was done to show a difference between one side of the SED versus another side or to provide close-up detail of interesting features. Several of the SEDs have multiple photos not shown here but are available upon request (see Table 1). Distinct layers of sand separated from distinct layers of mud could be observed in several of the SEDs. It is believed the layers of sand correspond with periods of strong currents and waves large enough to suspend sand from the bed up to the inlet height.

One interesting feature was observed in SED CF05. In this SED there was barnacle growth inside the SED. The barnacles were not included in the sediment analyses because it was obvious they must have settled in the SED as spat. At the observed size they were too big to pass through the inlet holes and would have biased the percent weight distribution toward the >500 microns fraction if they were included in the analyses.

3.1 Percent grain-size distribution by weight

Table 2 and Figure 4 show the percent grain-size distribution by weight for each SED. Figure 4 shows that the SEDs deployed on the mound (both east and west bipods) tended to have less than about 10% mud (<63 micron portion of the sediment) if the bottom of the SED was mounted less than 0.5 foot from the seafloor (1B, 2B, 3B, 4B, CF01, CF02, CF09 and CF13). The only exception is CF04, deployed September 28 to November 29, 2001 on the East Mound Crest bipod, which had over 30% mud. The sediment in SEDs mounted on top of the either bipod on the mound, with the bottom of the SED 1.85 to 2.6 feet from the seafloor, consisted of a larger portion of mud, approximately 40-60% (1T, 2T, 3T, 4T and CF03). Two deployments on the Baldhead Island bipod consisted of approximately 70-80% mud (CF05 and CF17). A third deployment on the Baldhead Island bipod, April 17 to May 16 2002, consisted of only approximately 20% mud (SED

CF12). SEDs deployed on the Oak Island bipod tended to consist of about 70 to >80% mud (CF06, CF11, CF14 and CF18) except CF07, deployed January 16 to April 16, 2002, which consisted of less than 20% mud. SEDs deployed on the Eleven Mile bipod (CF08 and CF15) had approximately 30-40% mud, and SEDs deployed on the Mound Deep bipod (CF10 and CF16) had approximately 55-75% mud.

The mud portion was split into two fractions: clay (<20 microns) and silt (20 - 63 microns). Figure 5 shows that the distribution of clay in the mud portion tended to be between 60-70%. Only four SEDs had slightly less than 60% clay in the mud portion. Two were deployed on the top mount of the West mound crest bipod (1T and 3T), and the other two were deployed on the Oak Island bipod (CF06 and CF18). All four consisted of greater than 55% clay. Four others consisted of greater than 70% clay (3B, CF02, CF07 and CF09). The first two (approximately 85% and 75% clay, respectively) were deployed on the bottom mount of the West mound crest bipod, and the fourth one, which consisted of 100% clay, was deployed on the bottom mount of the East mound crest bipod. CF07 (approximately 75% clay) was deployed on the Oak Island bipod.

The sand and larger-size portion was split into three fractions: a 63-500 micron fine-to-medium sand fraction (to be consistent with the size range distribution measured by the LISST), a 500 micron – 2mm coarse sand fraction, and a >2mm gravel-size fraction. Figure 6 shows the LISST sand-size fraction (63-500 micron) comprised approximately 65% or greater of the sand and larger-size portion except in five SEDs. 4T, mounted on the top mount of the West crest mound bipod deployed September 5 to 27, 2001, consisted of less than 40% of the LISST sand-size fraction in the sand portion. CF08, deployed on the Eleven Mile bipod consists of approximately 50% of the LISST sand-size fraction. CF14 and CF18 deployed on the Oak Island bipod consist of approximately 55 and 63%, respectively.

3.2 Percent grain-size distribution by volume

Figures 7.1-7.26 show two graphs for each station. The **A** graph of each pair is the percent grain-size distribution calculated from the LISST volume distribution of the mud

fraction. In each bar graph, the first peak represents the clay portion of the mud and the second peak is the silt portion. If the clay peak is proportionally greater than the silt peak, then the mud D50 grain-size will be in the clay region, represented by a red line and listed in Table 3 and in Figure 8. Conversely, when the silt peak is greater, the mud D50 is larger.

The **B** graph of each pair in Figures 7.1-7.26 is the percent grain-size distribution of the sand fraction from 63-500 microns. The limitation of this method is seen when this fraction is not a majority of the sediment greater than 63 microns because it gives an erroneously low sand D50 represented by the red line in the graph and listed in Table 3 and Figure 8.

3.3 Percent grain-size distribution by volume

Figures 9.1-9.4 display digital photographs of the sediment fraction >500 microns. The photographs show that the sediment greater than 500 microns consists not only of sand grains but shell hash and detritus material as well.

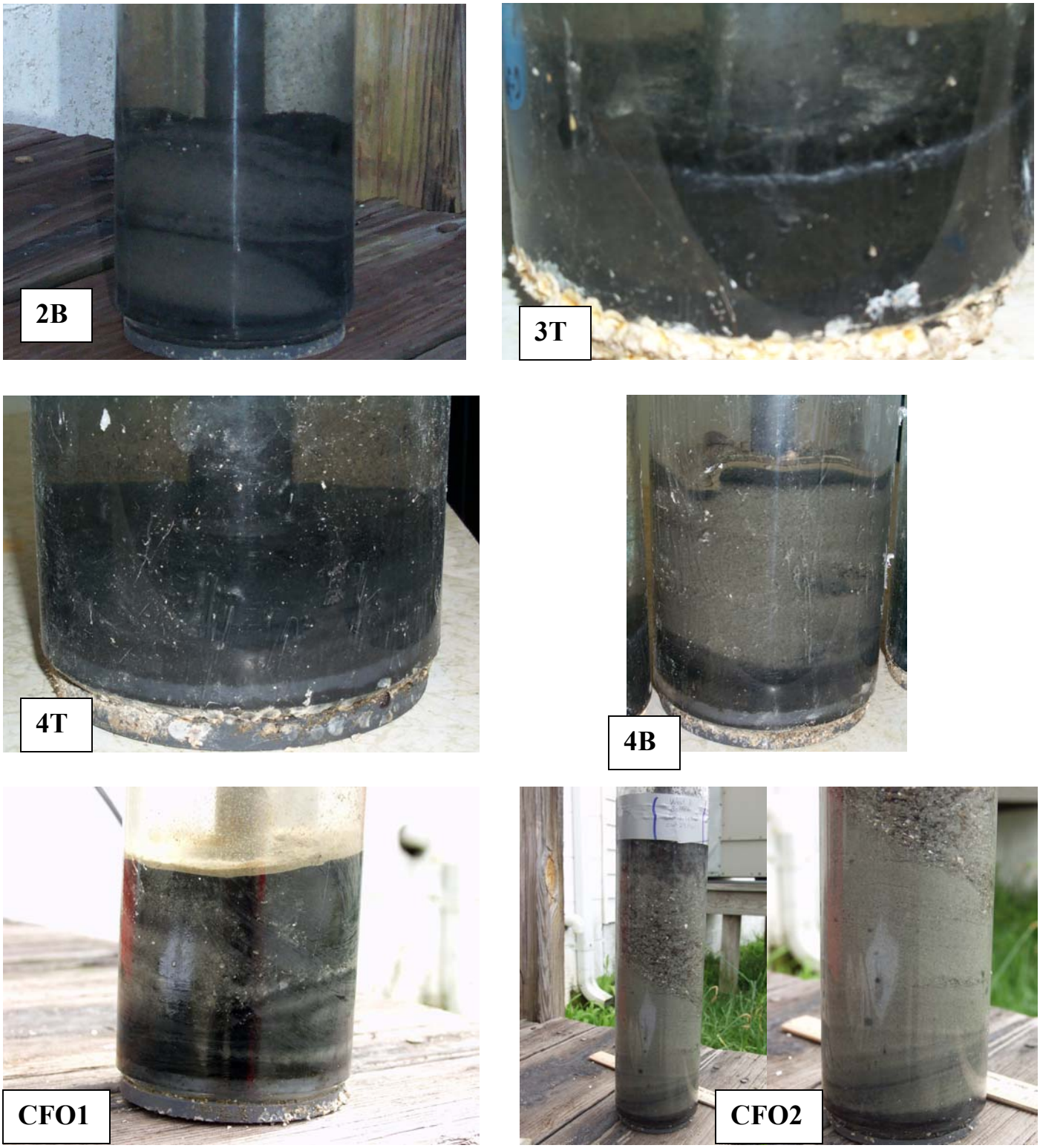


Figure 3.1 Digital photographs of sediment layers in SEDs 2B, 3T, 4T, 4B, CF01 and CF02 after retrieval.

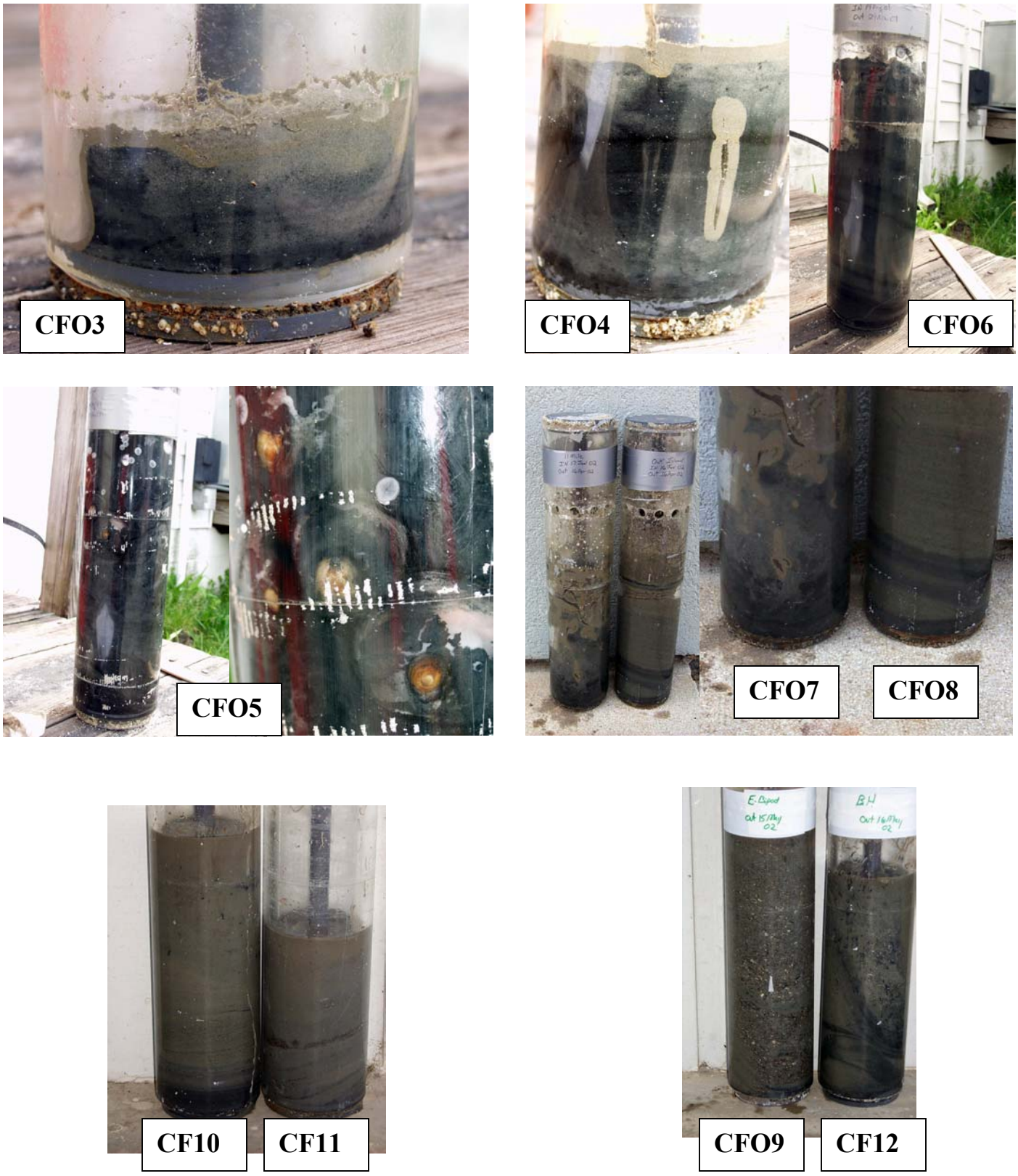


Figure 3.2 Digital photographs of sediment layers in SEDs CF03, CF04, CF05, CF06, CF07, CF08, CF09, CF10, CF11 and CF12 after retrieval.

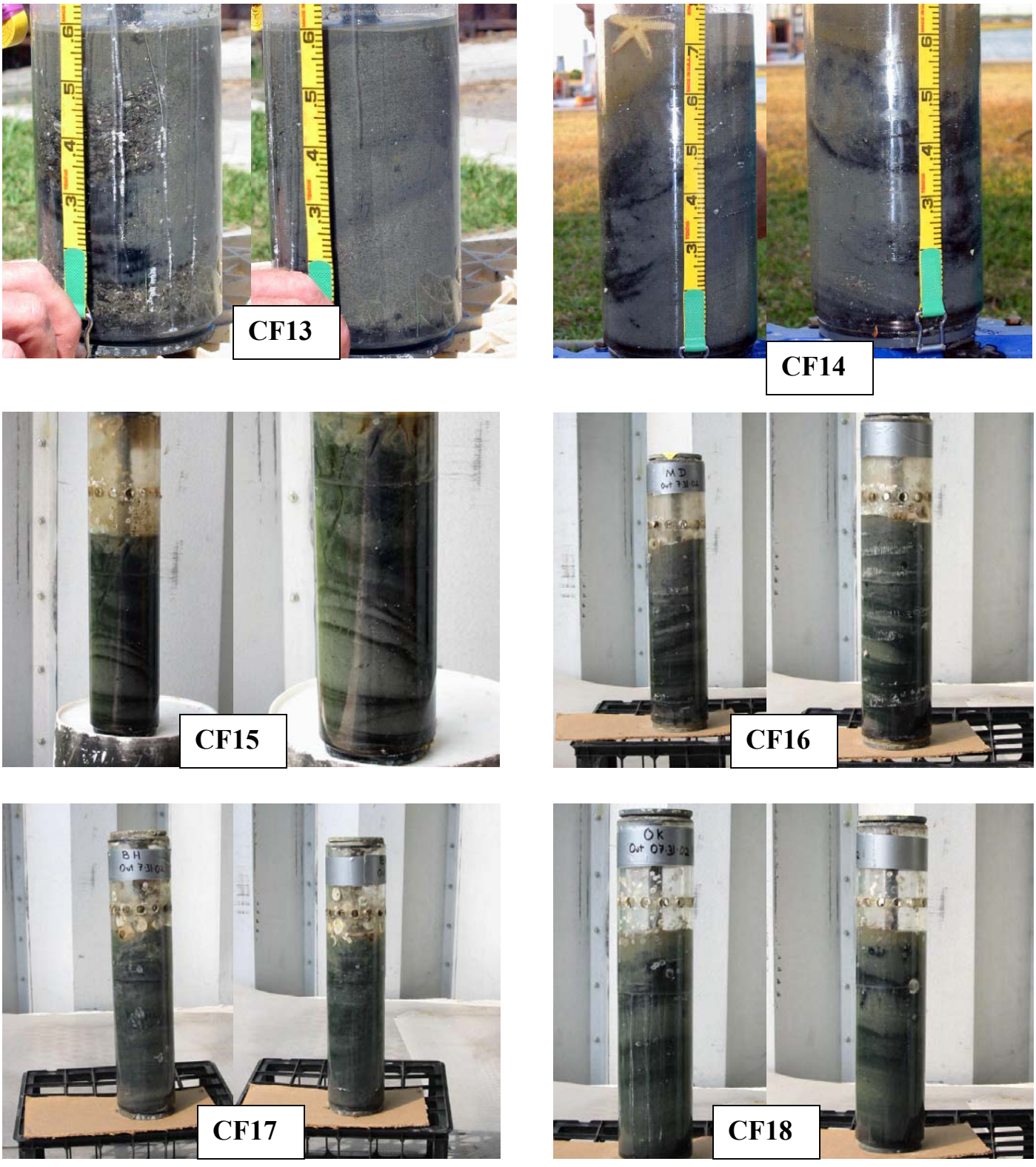


Figure 3.3 Digital photographs of sediment layers in SEDs CF13, CF14, CG15, CF16, CF17 and CF18 after retrieval.

Table 2. Grain Size Distributions by Percent Weight

Sample ID	% Clay	% Silt	% Sand		% >2 mm
			60-500 microns	500 microns - 2mm	
1T	24.11	18.42	57.47	0.00	0
1B	3.53	1.4	93.29	1.46	0.32
2T	33.49	15.68	50.83	0.00	0
2B	5.07	2.61	92.32	0.00	0
3T	25.61	18.71	43.45	12.23	0
3B	0.9	0.15	38.33	54.95	5.67
4T	40.26	19.22	30.54	9.98	0
4B	5.59	2.77	64.48	26.30	0.86
CF01	9.3	5.2	64.42	20.18	0.9
CF02	3.8	1.2	65.23	27.57	2.2
CF03	33.4	17	48.39	1.21	0
CF04	22.6	14.8	54.98	7.62	0
CF05	52.5	33.2	12.36	1.94	0
CF06	50.6	34.8	10.57	4.03	0
CF07	13.45	4.49	43.79	36.23	2.04
CF08	25.94	16.54	56.65	0.87	0
CF09	3.52	0	67.84	25.34	3.3
CF10	35.01	19.35	44.21	1.43	0
CF11	43.27	27.4	18.66	10.67	0
CF12	13.3	7.51	75.63	3.56	0
CF13	6.35	2.94	50.39	39.66	0.66
CF14	57.69	28.05	11.02	3.24	0
CF15	16.99	10.83	69.72	2.46	0
CF16	53.99	22.96	21.85	1.20	0
CF17	34.18	19.86	42.80	3.16	0
CF18	41.24	32.47	16.71	7.83	1.75

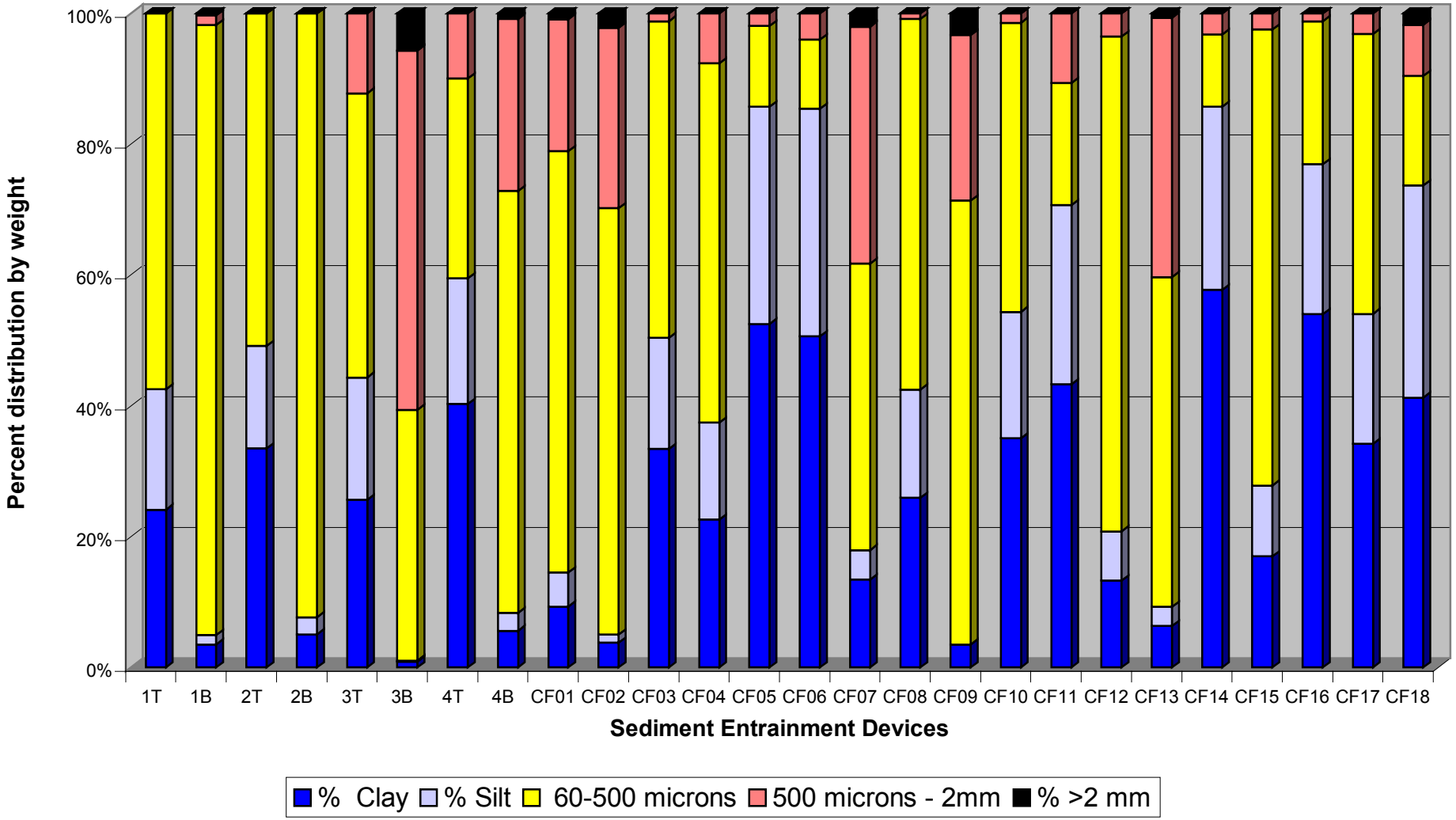


Figure 4. Percent distribution by weight of each fraction from clay to >2mm of the SED sediment samples.

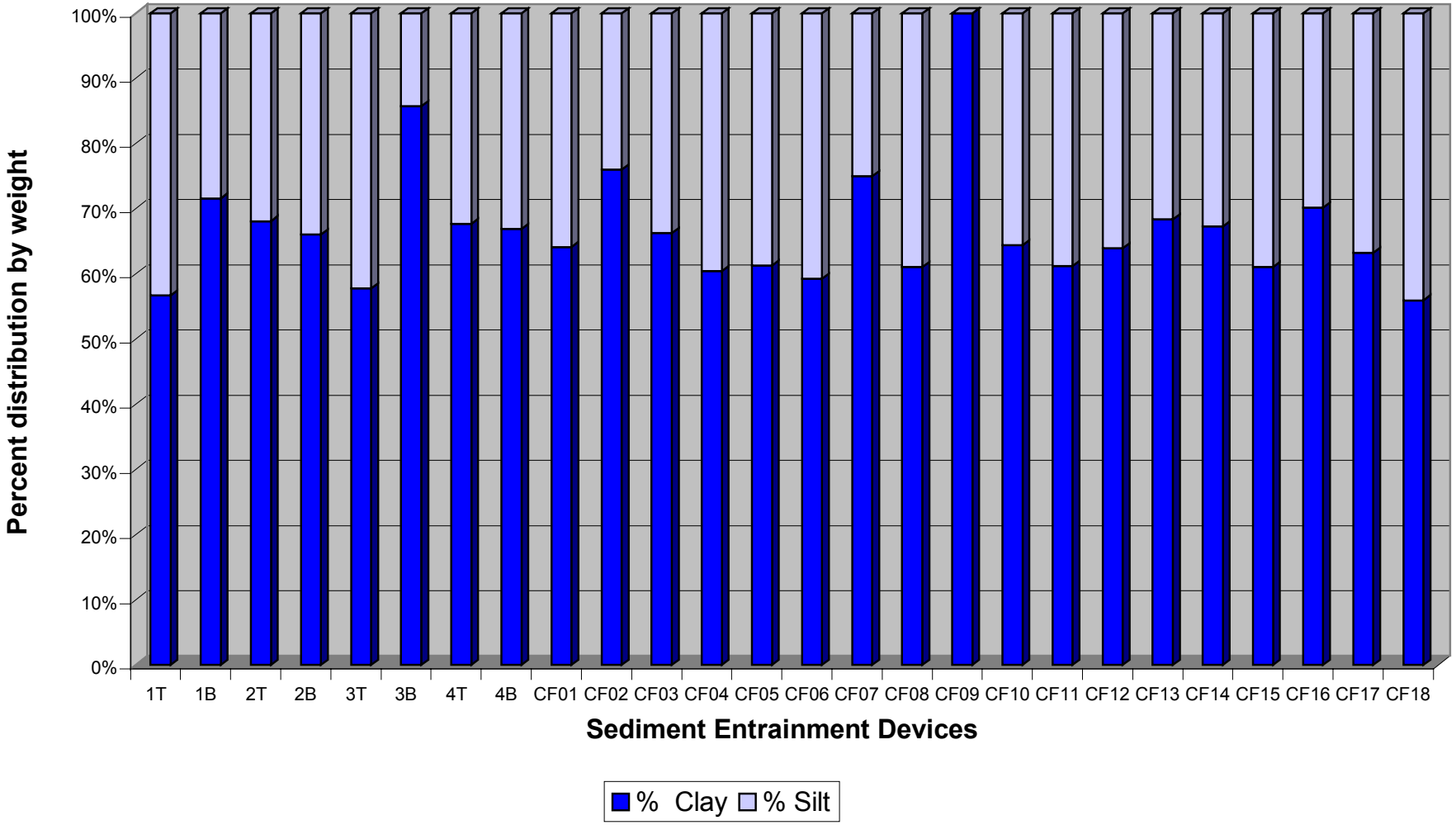


Figure 5. Percent distribution by weight of the clay and silt fractions in the mud portion (<60 microns) of the SED sediment samples.

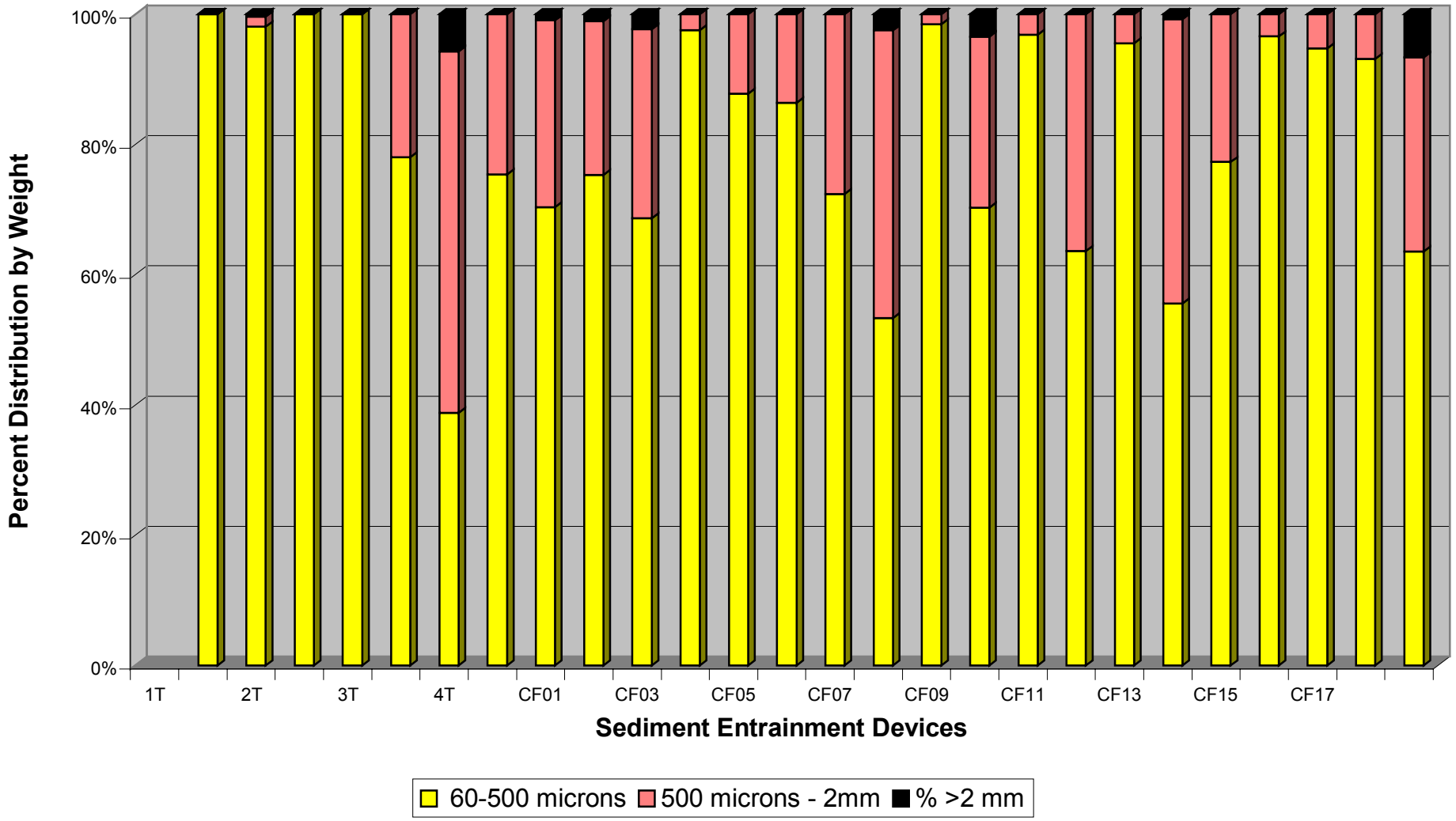
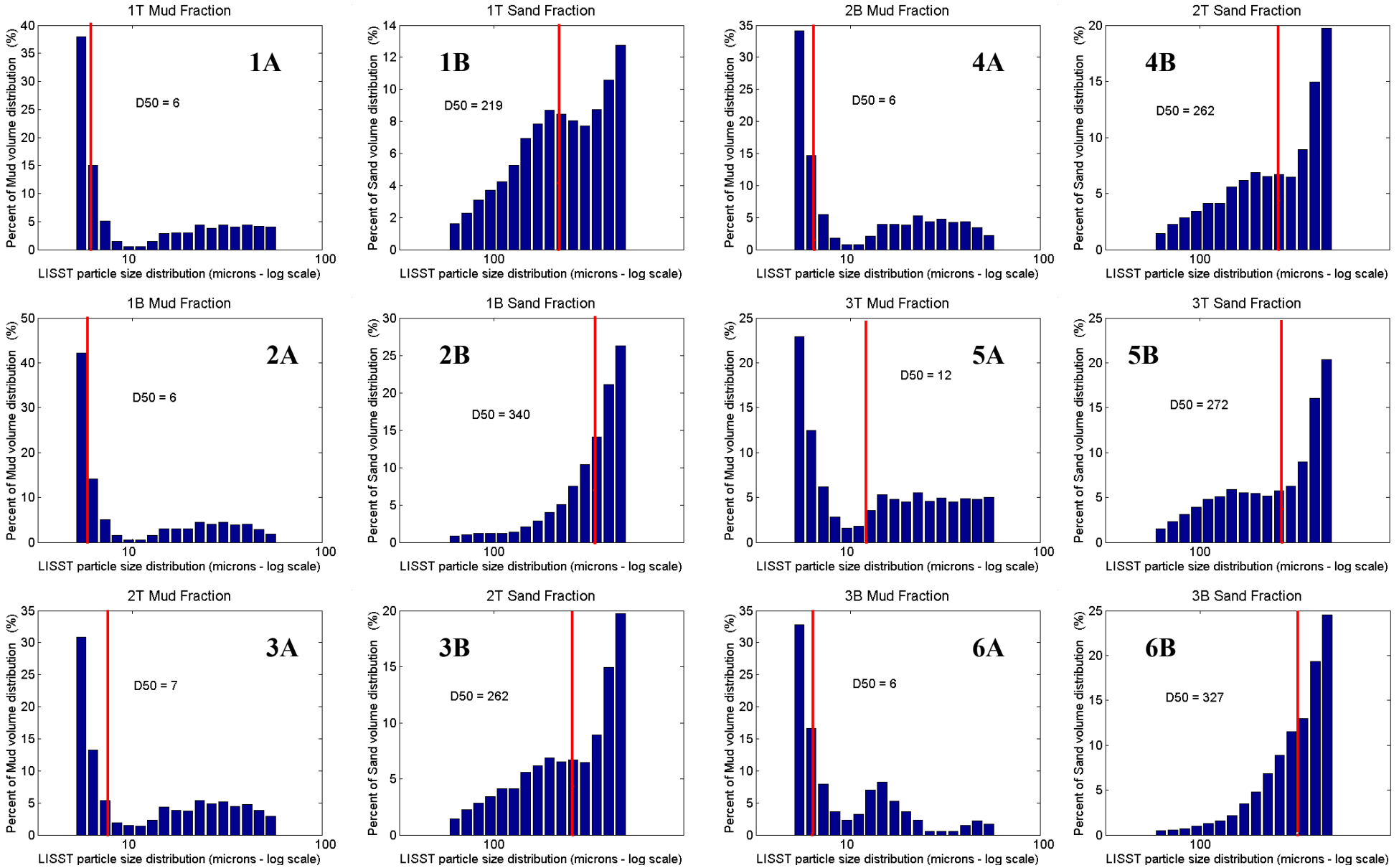
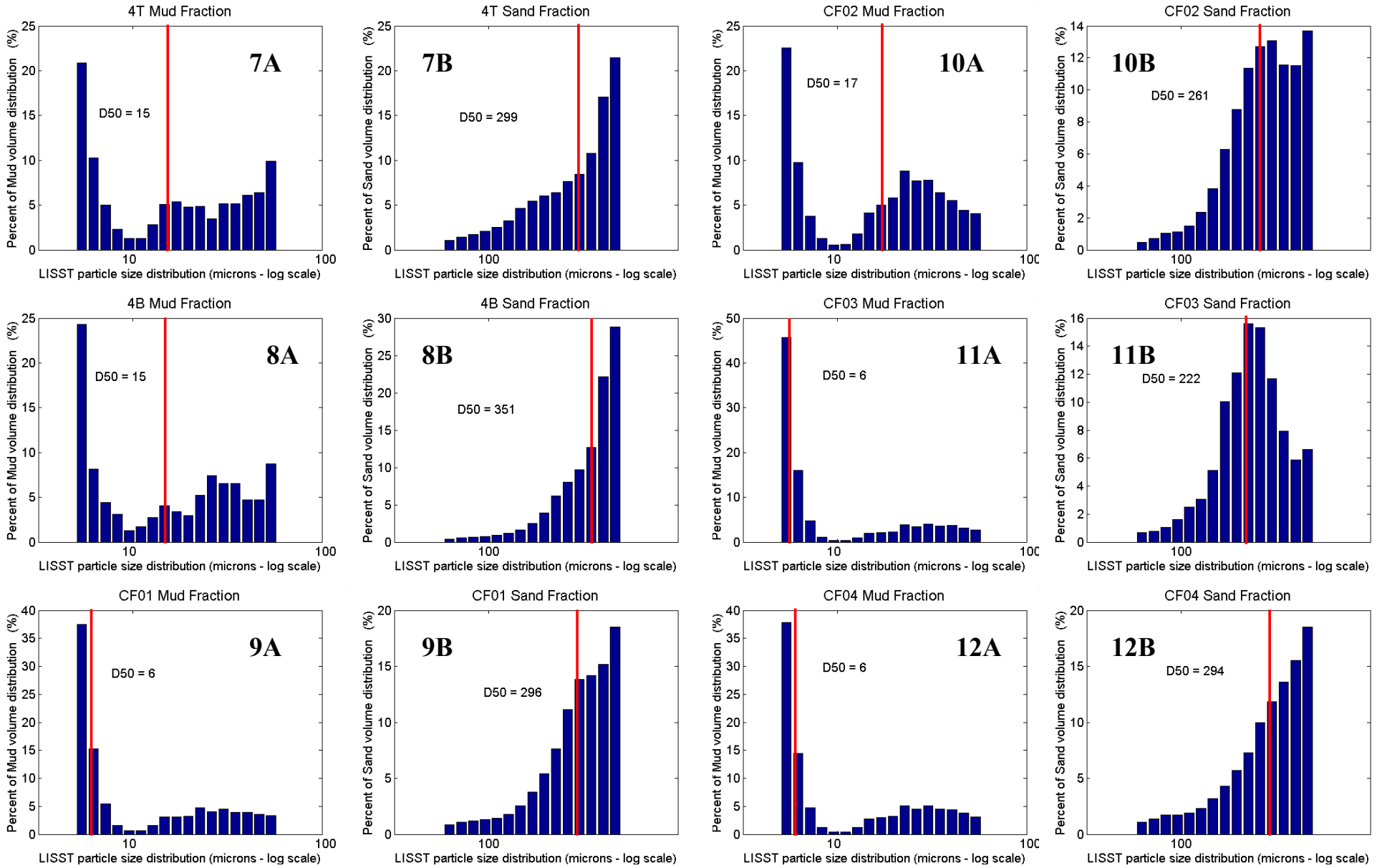


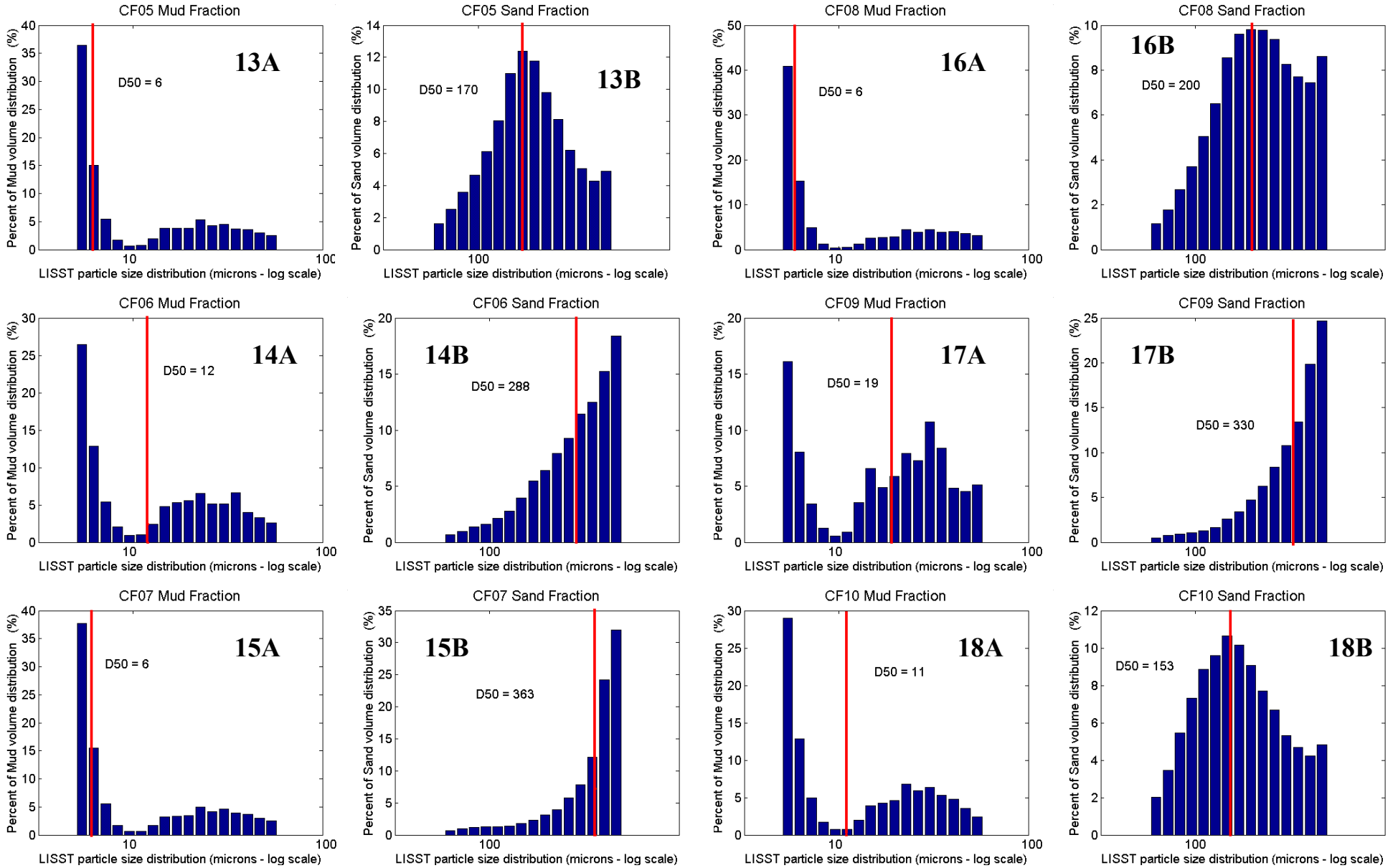
Figure 6. Percent distribution by weight of the three fractions in the sand and gravel portion (>60 microns) of the SED sediment samples.



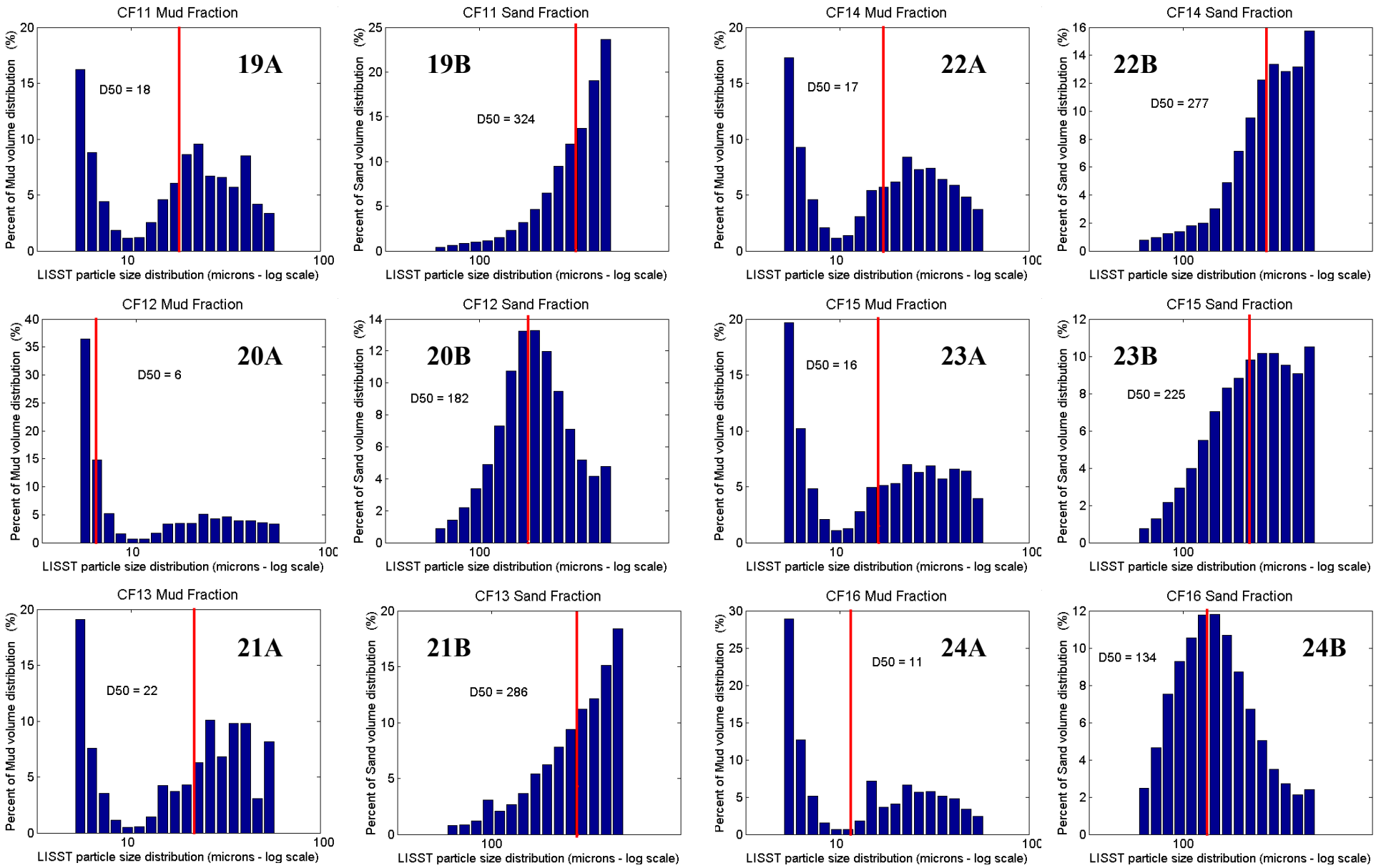
Figures 7.1 – 7.6 LISST percent grain-size distributions by volume for stations 1T, 1B, 2T, 2B, 3T and 3B. Each station has two graphs. The A graph is the distribution of the mud fraction and the B graph is the distribution for the sand fraction. The red line on each graph is the D50 grain size for that fraction.



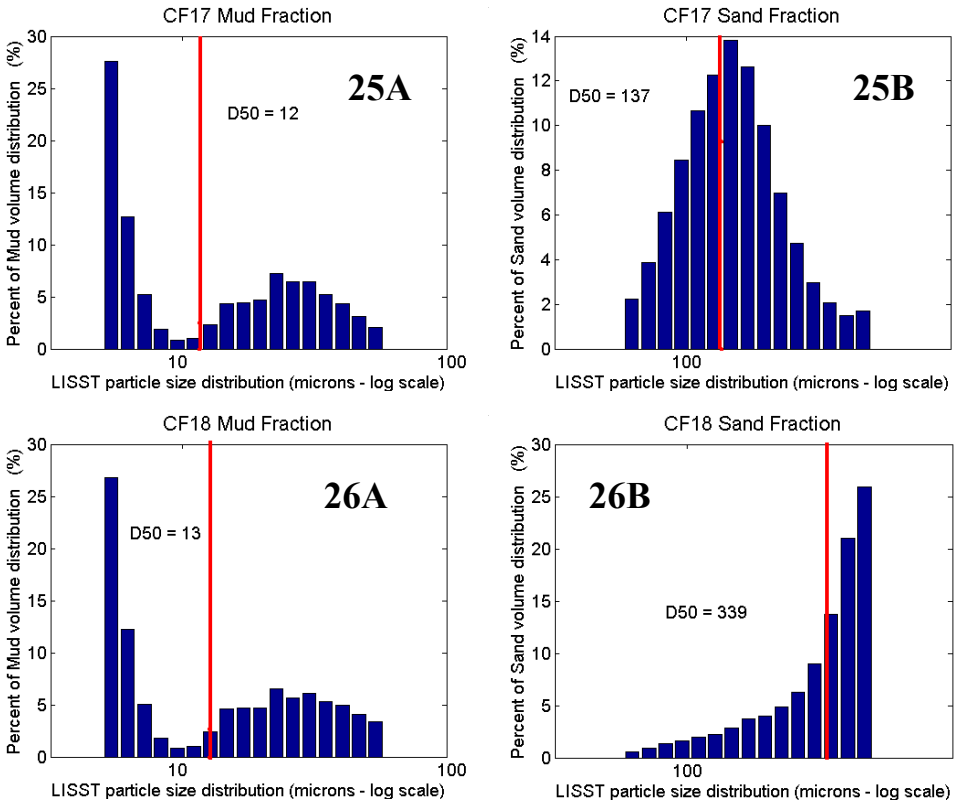
Figures 7.7 – 7.12 LISST percent grain-size distributions by volume for stations 4T, 4B, CF01, CF02, CF03 and CF04. Each station has two graphs. The A graph is the distribution of the mud fraction and the B graph is the distribution for the sand fraction. The red line on each graph is the D50 grain size for that fraction.



Figures 7.13 – 7.18 LISST percent grain-size distributions by volume for stations CF05, CF06, CF07, CF08, CF09 and CF010. Each station has two graphs. The A graph is the distribution of the mud fraction and the B graph is the distribution for the sand fraction. The red line on each graph is the D50 grain size for that fraction.



Figures 7.19 – 7.24 LISST percent grain-size distributions by volume for stations CF11, CF12, CF13, CF14, CF15 and CF16. Each station has two graphs. The A graph is the distribution of the mud fraction and the B graph is the distribution for the sand fraction. The red line on each graph is the D50 grain size for that fraction.



Figures 7.25 – 7.26 LISST percent grain-size distributions by volume for stations CF17 and CF18. Each station has two graphs. The A graph is the distribution of the mud fraction and the B graph is the distribution for the sand fraction. The red line on each graph is the D50 grain size for that fraction.

Table 3. LISST D50 Grain-sizes

Sample ID	MUD D50	SAND D50
1T	6	219
1B	6	340
2T	7	262
2B	6	262
3T	12	272
3B	6	327
4T	15	299
4B	15	351
CF01	6	296
CF02	17	261
CF03	6	222
CF04	6	294
CF05	6	170
CF06	12	288
CF07	6	363
CF08	6	200
CF09	19	330
CF10	11	153
CF11	18	324
CF12	6	182
CF13	22	286
CF14	17	277
CF15	16	225
CF16	11	134
CF17	12	137
CF18	13	339

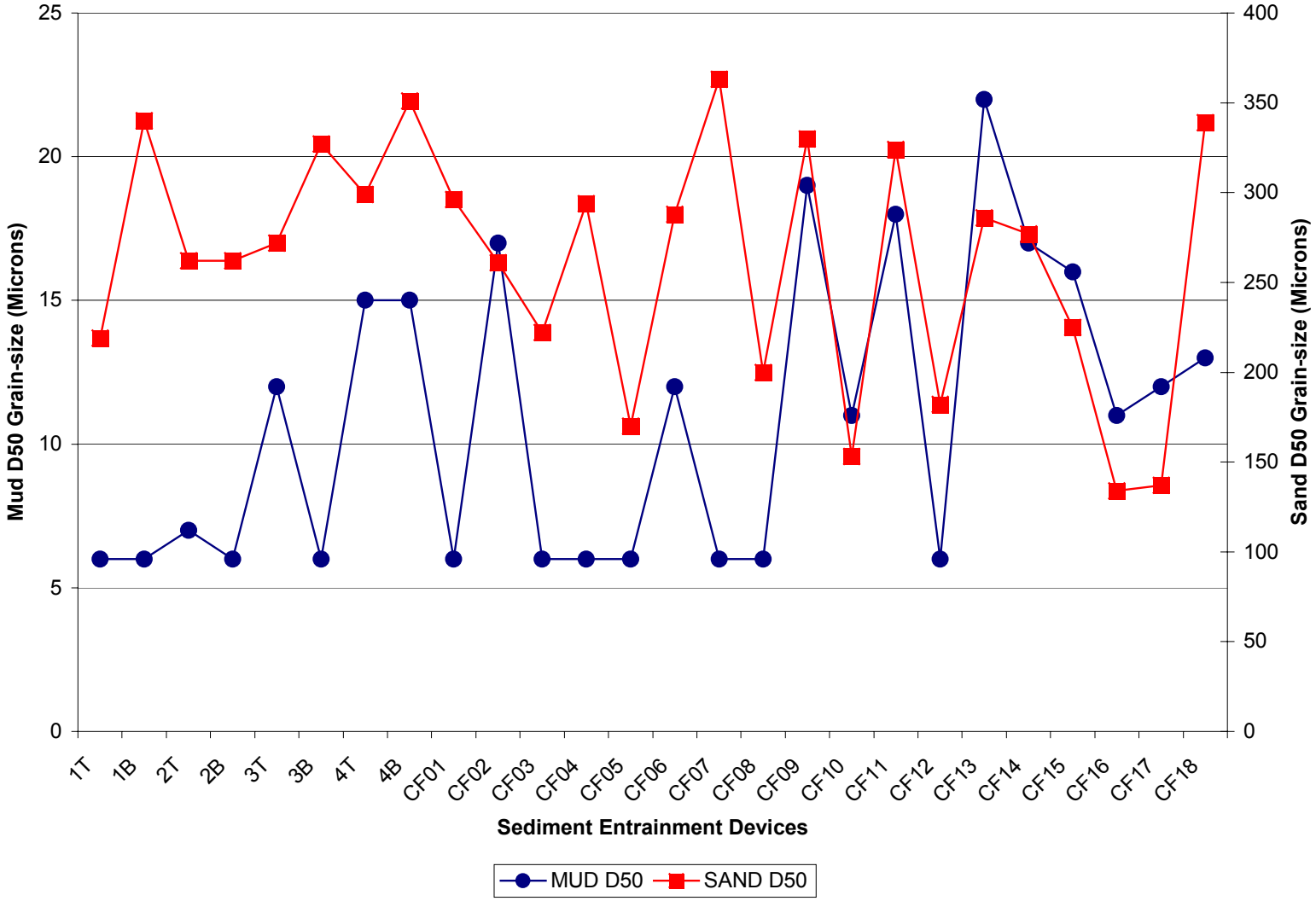


Figure 8. LISST D50 grain-sizes for mud and sand fractions from all SEDs.

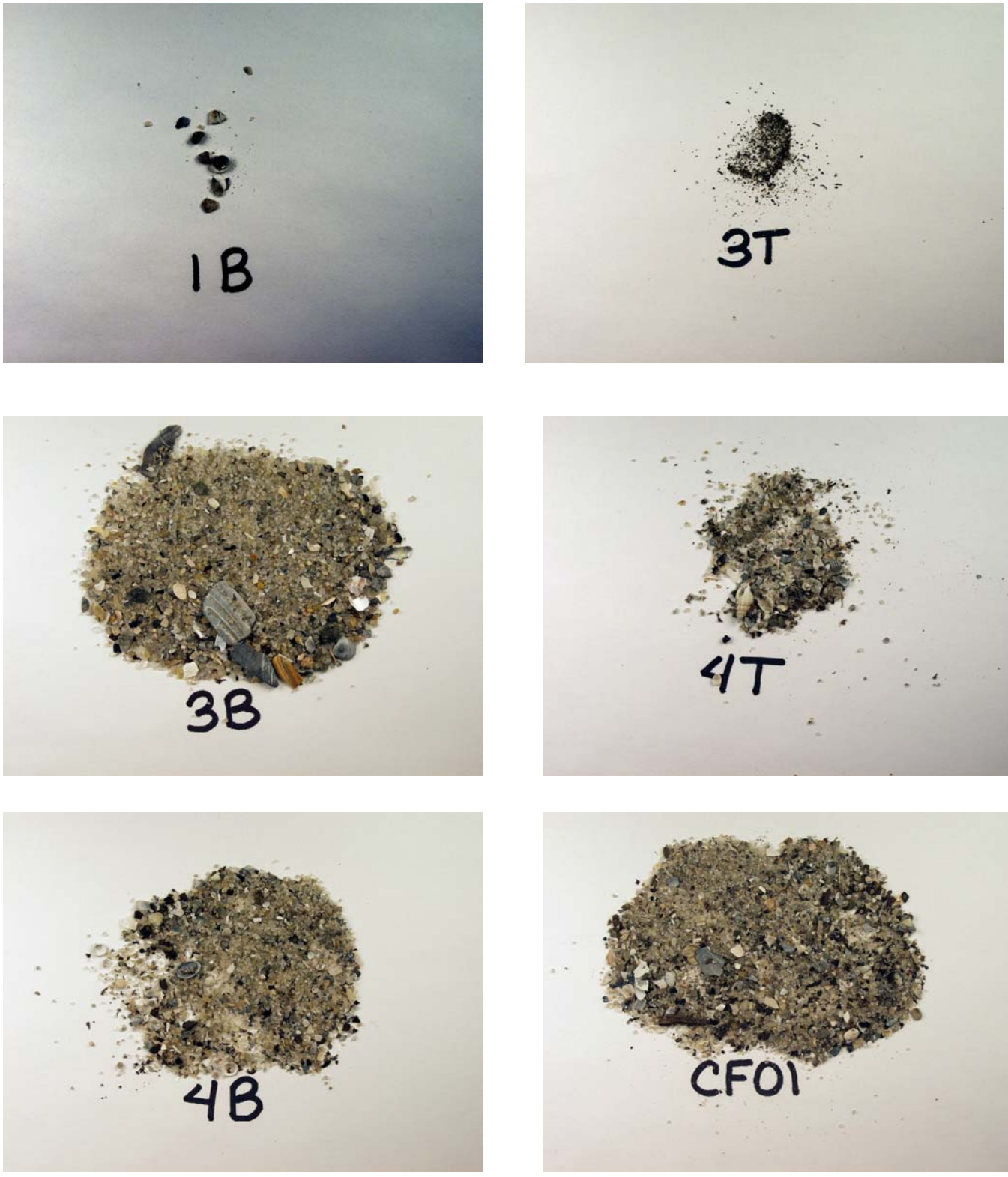


Figure 9.1 Digital pictures for SEDs 1B, 3T, 3B, 4T, 4B and CF01 of sediment fraction >500 microns.

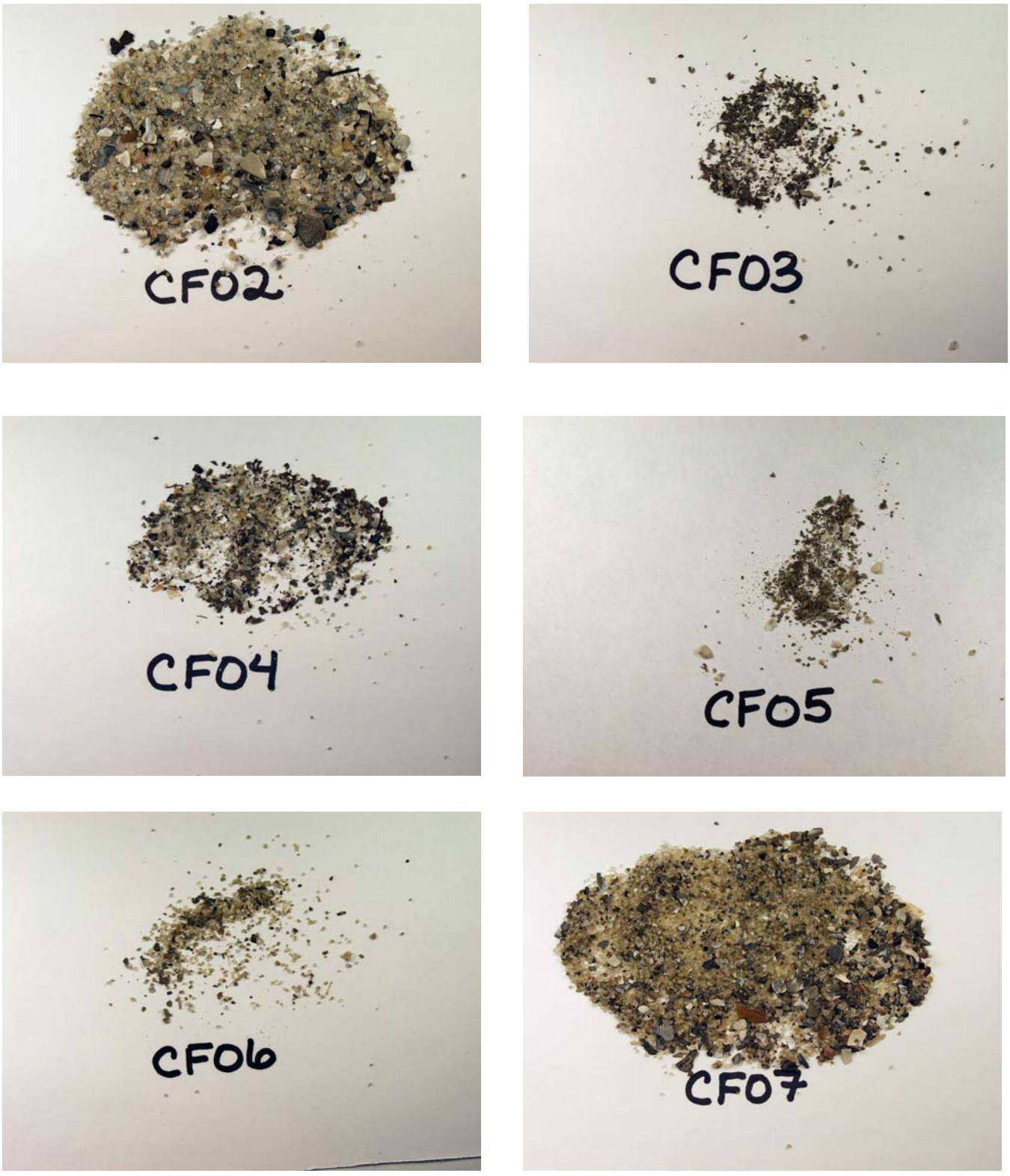


Figure 9.2 Digital pictures for SEDs CF02 - CF07 of sediment fraction >500 microns.

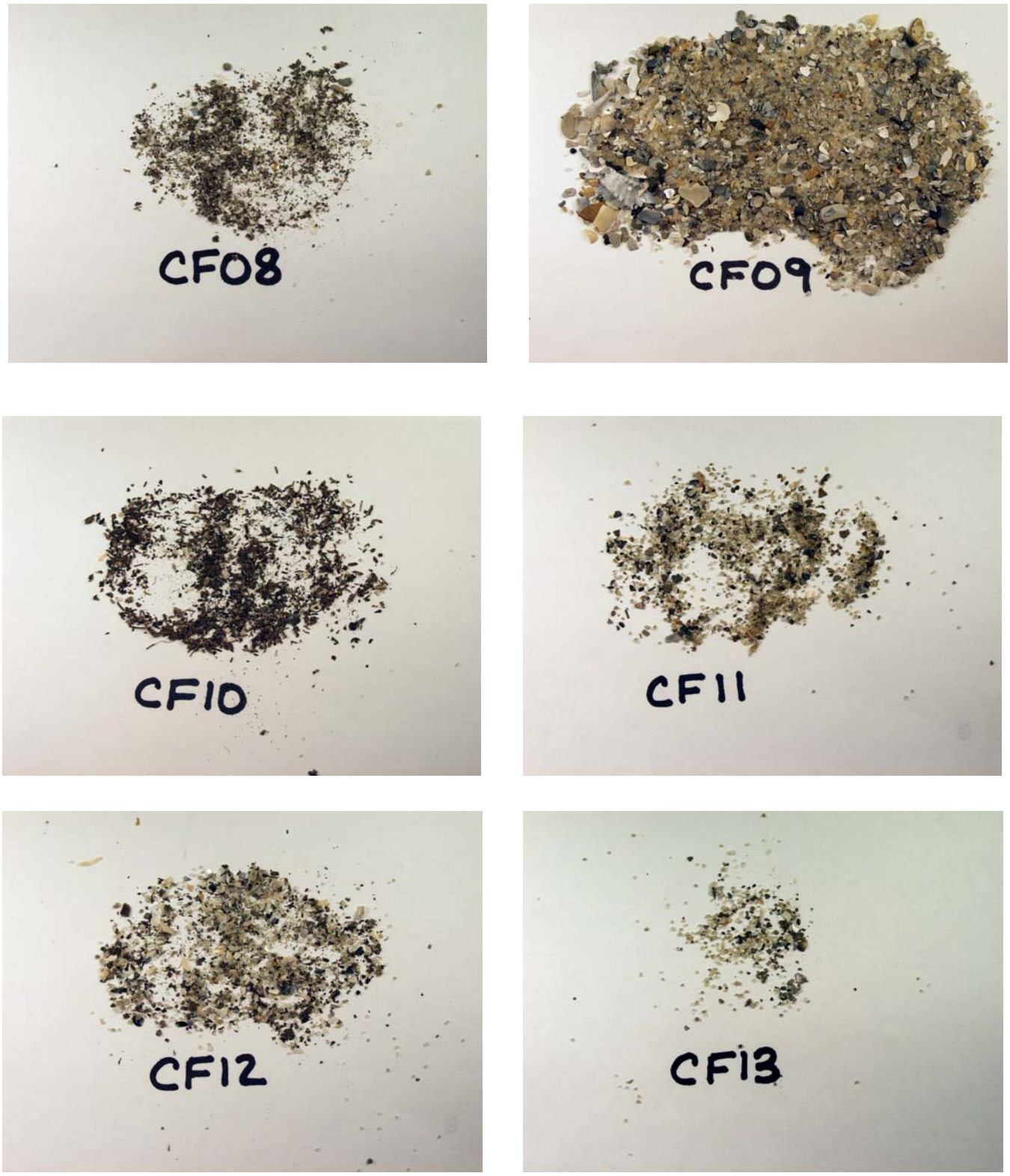


Figure 9.3 Digital pictures for SEDs CF08 – CF13 of sediment fraction >500 microns.

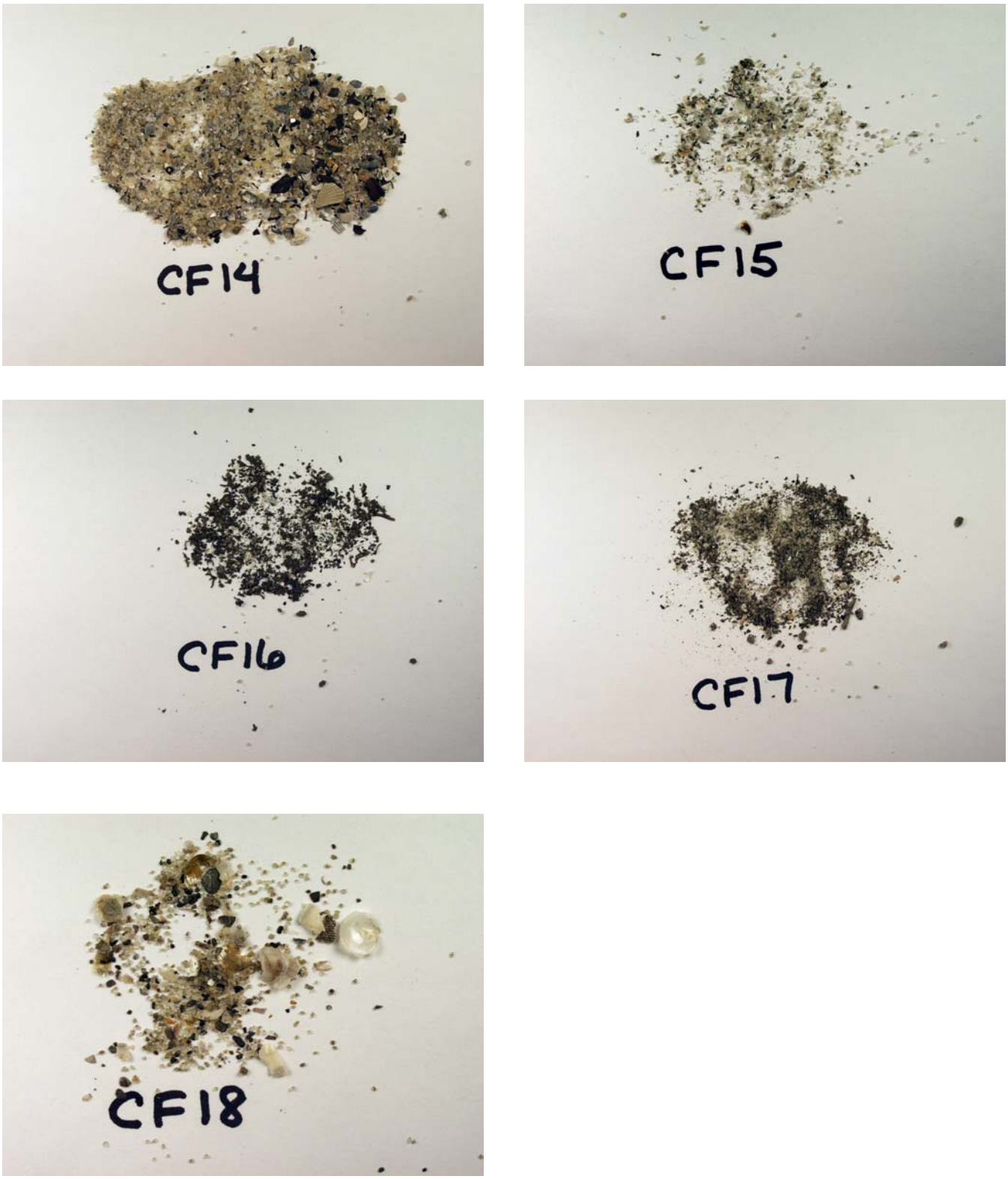


Figure 9.4 Digital pictures for SEDs CF14 – CF18 of sediment fraction >500 microns.