Tracing Paleotsunami signatures on central part of east coast of TamilNadu by using granulometric analysis

N.Muthukrishnan,
Department of Civil Engineering, Shivani Institute of Technology, Trichy, TamilNadu, India.

R.Sivasamandy,
Department of Civil Engineering, OAS Engineering college, Thuraiyur, TamilNadu, India.

Abstract: The Trench samples collected at five places like Chandrapadi, Manickabangu, Pillaiperumalnallur, Chinnamedu and Vanagiri areas of east coast of Tamilnadu, India were analysed for tracing paleotsunami signatures. The importance was given because these areas were highly affected both by frequent occurrence of storm surges and tsunami. An attempt was made by making trenches at five locations next to coastal dunes on seaward side upto the depth of watertable to find the specific type of layers. The areas like Vanagiri, Chinnamedu having three evidences of tsunami event including the recent tsunami occurred on 26th of December 2004 whereas Manickabangu and Pillaiperumanallur shows two signatures but at the same time Chandrapadi location having only one at the top and the remaining two are below the hard lateritised layers. This has been suspected that the coast may have undergone a long period of exposure for weathering that is why they may not be comparable with that of other locations. The exact date may be deciphered once after OSL C^{14} dating in these regions.

Keywords: Bay of Bengal, Paleotsunami, Tsunami signature, East coast of India

1. Introduction

The west coast of India had affected by limited number of tsunami events (Rajamanickam and Prithviraj 2006). Some of the researchers made study on tsunami related deposits named as tsunamites (Shanmugam 2006) and the term was utilized by the consequent researchers done in the west coast (Rajendran et al. 2006). Once after tsunami occurred in the east coast of India on 26th Dec 2004 there were so many researches went on in that area about damage assessment, grain size analysis, heavy mineral analysis, water contamination analysis and so on among which one of the study on tsunami made between Rameswaram and Thoothukudi (Singarasubramanian, et al. 2006) observed that dunes were breached, erosional channels were created, inundation sedimentation thickness ranges from 1 to 30cm and the areal extend was up to 10 to 100m from shoreline. Fine sediments with layering were deposited over the eroded surface along the cost. The thickness of fresh dark colored sediments deposited over the coarser fragments was about 30cm revealed that thinning out towards landside and were dark gray in color enriched with heavy minerals. Tsunami deposits have multiple graded beds within the deposition by successive tsunami waves (Moore 2000).

The tsunami events were evidently proved that they occurred in four stages (i) lower layer mixed with beach and terrigenous sands, (ii) Overlain by thick coarse poorly sorted sand, (iii) Followed by angular deformed beach sand with coarse grains and (iv) finally the badly sorted coarse grained outwash deposits. Lower layer was enriched with heavy minerals derived from marine environment and other two were by tsunami run up. Final one was the backwash of tsunami from distal inundations (Barbara Keating et. al., 2004). Tsunami deposits were believed to be loosely consolidated water saturated sand and silt with poor sorting (Dzulynski 1966). The most common tsunami deposits were fine sediments that most frequently occur as sediment sheets.

Once after the tsunami deposits occur in varying dimensions it undergoes further reworking by means of consecutive wave action, mixing up of later sediments or by denudation due to natural agencies like streams, wind, rain and also biogenic activities (Srinivasalu 2009). Thinning out of the tsunami layer also observed even within short span of time like few months or years. Hence there is a possibility of complete removal or alteration. Srinivasalu (2009) made frequent visits and observed the consequences of alterations of 24th Dec 2004 tsunami of the same study area and he found that there were three different layers occurred from top to bottom. The upper layer he observed that cross laminations with wavy patterns, middle with cross laminations and the lower with lateral laminated sheets. There were minimum two layers observed at all the places of the study area having fining upwards and thinning landwards.

The lack of knowledge in differentiating a tsunami from a storm deposit led to the controversy in previous publications (Bryant et al., 1992). Goff et al. (2004) published the paper in Marine Geology that differentiate the 2002 storm deposits and 15th century tsunami deposits of New Zealand based on textural characteristics. Textural parameters of river sediments vary from the beach sediments (Rajamanickam and Muthukrishnan 1995). Fine sediments present in tsunami deposits vary from mud and fine sands of lakes and bays. Predominance of muddy sand found in the west coast of Indian lakes and bays due to ebbing of tidal waters constantly winnowed the finer particles (Reji Srinivasan and Kurian Sajan 2010). Medium sand with mesokurtic are supplied by river and reworked by marine currents when they exposed to wave action (Anfuso 1999). Further he illustrated that the grains less than 0 phi are transported by suspension and greater than that are by traction.

Prehistoric tsunami have also been identified by the sand sheets found in coastal low lands of Scotland (Dawson et.al., 1988),Pacific Northwest (Atwar and Moore, 1992, Bension et.al., 1997), New zealand (Clague-Goff and Goff, 1999), the Mediterranean (Dominey-Howes et.al. 1999), the Pacific coast of North America (Clague et.al. 2000), Hawaii (Moore, 2000), Kamchatka (Pinegina et.al., 2003), Japan (Nanayama et. al., 2003), Chile (Cisternas et. al., 2005) and Thailand (Jankaew et. al., 2008) had markers of paleotsunami especially enriched with high concentration of heavy minerals. These were observed in the trench walls of the study area also.

2. Study Area

The study area lies within the limit of Pumpuhar to Chandrapadi of east coast of central part of TamilNadu, India. The five trenches made at Manickabangu (MKB-T 79°

51.40E Long. and 11° 03.76N Lat.) , Chandrapadi (CHP-T 79° 51.38E Long. 11° 00.24N Lat.), Pillai Perumal Nallur (PPN-T 11° 04.79E Long. 79°51.47N Lat.), Vanagiri (VAG-T 79° 51.51E Long. 11° 07.18N Lat.) and Chinnamedu (CMD-T 79° 51.54E Long. 11° 05.89N Lat.) (Fig-1). The station interval was fixed based on the recent tsunami worst affected places and with the knowledge of the shoreline changes like erosion and accretion. The beach was seen with varying width from narrow to wide and rich in heavy mineral on the surface at some places and others were lighter in tone. Beach slope was very gentle and low angle ranging from 3° to 5°. The northern part comprised of deltaic plain and estuary of the Cauveri river and the southern parts also have the estuaries of distributaries of the same river. Chinnankudi near Chinnamedu region is discharged with Ambanar River.

3. Methodology

The five sample locations were marked with GPS and the sites were suitably selected near base of seaward side of beach ridges where the preservation of paleo-tsunami signatures were believed to be more without much alteration. The trench were made perpendicular to the ridges with 3ft width, 5ft length and depth upto water table. The layers were photographed (Fig -2) and the samplings were made from top to bottom with varying interval as per noticeable changes were observed.

The samples collected were washed with Distilled water, Hydrogen Ferroxide, HCL and HNO_3 with Tin chloride to remove soluble substances, Organic content, carbonates and iron coatings. During the process drying and weighing was made at every stage to compute the weight loss. After drying, sieving has been done by using ASTM sieve mesh with quarter phi interval. The weights were recorded to find various statistical parameters like Mean, Median, Mode, 1st percentile, Sorting, Skewness and Kurotsis.

4. Results and Discussion

4.1 Field observations

When the trenches were made the noticeable variation in lithology observed as in figure 2 were recorded and the dark patches seen represent the fine sediments of heavy mineral rich layer. Bottom of the layers showed the scoring that is undulated mark observed notice that the erosion occurred during tsunami wash. Dark layer itself consists of thin bands of laminations with varying thickness. At some places the lateritised layers were observed that indicates the area underwent long exposure to weathering for a long period of time without deposition.

4.2 Frequency Distribution

Frequency curves that plot grain size classes on the x-axis, and proportion of grain size class on the y-axis Fig-3 can be used to glean general information about the grain size distribution of the sediment population in the individual sediment. The most abundant class (mode) of the sample can be described from peaks whereas sorting in the sample is generally expressed by the spread of the data along x-axis, it indicates transport process. Skewness and kurtosis of a sediment population have been used as indicators of sorting. Skewness compares the sorting in the coarse and finer grained halves of a sediment sample. In normal distribution mean, median and mode of the population coincide but for skewed they do not. Kurtosis or peakedness compares the sorting in the central portion of the grain size distribution with sorting in the tails (ends) of the distribution.

Chandrapadi sediments shows higher fine populations in 25-30, 30-35 and 45-51 cm depth, whereas other samples from this core shows coarser sand as a major constituent (Fig -3a).

Manickabungu sediments that don't show many variations but the samples obtained from 0-20, 52-61 and 77-87cm are having more fine populations than that of coarse but all the other samples obtained from this core having coarser populations (Fig -3b).

Cinnamedu trench samples exhibits some distinct variations in abundance of fine populations at the depth of 0-15,28-33,46-51 and 51-54 cm(Fig -3c).

Pillaiperumanallur Trench has not shown much variation in their populations except 0-15.This 0-15 alone more fine grained than other samples (Fig -3d).

Vanagiri Trench 0-10 and 10-20 cm depth of samples are having more fine populations than that of other samples, but at the depth of 58-60cm still fine sediments present (Fig -3e).

4.3 Textural Parameters

The grainsize populations having different populations are due to the transportation by rolling, suspension and saltation (Inman, 1949). Textural parameters of sediments namely Mean, Standard deviation (Sorting), Skewness and Kurtosis were used to decipher the depositional environments of sediments (Folk and Ward, 1957; Mason and Folk, 1958; Friedman, 1961, 1967; Visher, 1969).

All the sediments obtain from all the locations exhibits only the Polymodal in nature

The mean grain size of Chandrapadi trench shows medium sand at 0-10 (1.7013ϕ), 10-20 (1.6333ϕ), 35-45 (1.7622ϕ) and 45-51cm (1.7622ϕ). All the others are fine sand (Table -1a). From the frequency curve one can ascribed that from 0-20cm, this having mixed populations of coarse as well as fine (table-1a). All the samples are showing very well sorted nature and very fine skewed. Except at 0-20 and 30-51cm almost all are mesokurtic. These two are leptokurtic in nature (Fig -4a).

0-20 (3.0261ϕ) and 77-93 cm (3.3402 to 3.2794ϕ) depth samples of Manickabungu Trench having very fine sand, but all the others fall under fine sand category.0-20, 87-90 cm depth samples showing very fine skewness, that means either addition of fine are removal of coarse played the role (Table -1b). 68-77cm sample shows symmetrical skewness others are coarse skewed that means addition of coarse particles are more at 20-35cm results platykurtic and all the remaining samples are mesokurtic except leptokurtic at 87-93cm (Fig -4b).

38-40 (1.9805ϕ) and 44-46cm (1.8027ϕ) depth samples of Cinnamedu Trench shows that they are of medium sand, all the other are fine sand (Table -1c). All are very well sorted and very fine skewed. The samples at the depth of 20-24 is coarse skewed, 33-44cm are coarse skewed. The samples obtained from 15-20, 24-28cm and 46-51cm are platykurtic and the remaining are mesokurtic in nature (Fig -4c).

At Vanagiri Trench all the samples obtain at various depth, showing very well sorted very fine skewed, fine sand but only the character forth moment kurtosis noticed at 0-10,30-35 and 45-70cm are mesokurtic whereas 10-30,35-45 and 70-85cm are platykurtic and 85-90cm alone leptokurtic in nature (Fig -4d) (Table -1d).

Samples obtained at various depth of Pillaiperumanallur Trench shows that they are all very well sorted fine sand having very fine skewed nature (Table -1e). Sample from 0-30cm depth is fine skewed 30-40 and 40-43cm are symmetrically skewed in nature. 5-10, 15-20, 30-43 and 43-50

are mesokurtic in nature whereas remaining samples are platykurtic (Fig -4e).
The phi mean size of the 24th Dec 2005 sediments varied from 0.830 to 3.153ϕ and 65% fell in the fine sand category and the rest in medium sand category. The sorting of the sediments were vary from 0.463 to 0.717ϕ that is well sorted to moderately well sorted. The symmetry of the sediments were vary from -0.159 to 1.143 that is from strongly fine skewed to coarse skewed (Singarasubramanian, et.al 2006). The fine skewed implied that the introduction fine sediments or removal of coarser sediments (Friedman, 1961). The fourth moment kurtosis of the sediments varied from 0.871 to 1.949 and 75% fell under leptokurtic nature (Singarasubramanian, et.al 2006).

4.4 Bivariate plots

A wide variety of bivariate plots using any two parameters of the grainsize analysis were applied for the interpretation (Friedman 1967, Tanner 1991).

4.4.1 Visher's Diagram

Log-Phi graphs plotted on probability paper have commonly been used in sediment grain size analysis (Sengupta et al. 1991). Many papers adopted this technique (Inman 1949, Spencer 1963) cumulating in the summary by Visher (1969). Visher (1969) described how the distribution of grains in this siliclastic rock or unconsolidated sediment sample may be related to their transport process and environment of deposition. The segments on to probability Plots have commonly been described as a coarse and fine how together with central segment (Tanner 1991) indicating different transport process and the same have been used as fingerprints for recognizing depositional environment in ancient sedimentary rocks (Visher 1969). He found that three segments - line A from 0ø to 2ø transported by Traction, line B from 2ø to 4ø transported by Saltation and line C from 4ø to 8ø transported by suspension. Beach swash and backwash have two saltation populations.
Visher diagram of Chandrapadi Trench samples shows that 0-10 and 10-20cm are transported by means of traction and also little bit extent 35-51 cm samples also (Fig 5a). The samples from 90-115cm and 125-150cm are all transported by means of suspension, all the remaining sample transported by means of saltation either by swash or backwash.
Cinnamedu Trench samples of 38-40 and 44-46cm are transported by means of traction and samples obtained from 51-60cm are transported by means of suspension and all the remaining samples shows that they were all transported by means of saltation (Fig 5b).
Manickabungu trench samples shows that most of the samples are transported by saltation except 0-20cm and above 77cm are by suspension (Fig 5c).
Pillaiperumanallur Trench samples shows that the samples obtained at the depth of 0-5, 15-20 and 20-30cm are transported by traction whereas all the remaining samples transported by means of saltation (Fig 5d).
Vanagiri Trench samples obtained at the depth of 0-10 and 71-80cm are transported by means of traction and also the saltation population is very less but the remaining samples shows that they are all transported by means of beach environment (Fig 5e).

4.4.2 CM pattern

The CM pattern (Passega 1964) is plotted by using 1st percentile Vs Median in log probability exhibits the study area sediments were transported either by graded suspension with rolling (Q-R) or by uniform suspension (R-S). Few samples exhibit bottom suspension and rolling (P-Q). Almost all fall between C=80 to 400 microns and M=80 to 200 microns. The position of the dividing line 300 microns away from the normal pattern suggests the distribution of finer sediments. Absences of sediment population in N-O segment reveals that there is no much fluvial influence but few samples fall in P-Q segment represents the little bit river contribution is there. Abundance of population fall in Q-R illustrates that almost all were transported by means of graded suspension. Very few samples only deviated towards R-S segment that they are all transported by means of uniform suspension.
Sediments obtained from Chandrapadi Trench source that the samples from 0-10, 10-20, and 35-51cm are all transported by means of graded suspension with rolling. The samples obtained at the depth of 90-150cm are transported by means of uniform suspension. Remaining samples lie in between graded and uniform suspension of P-Q segment. The samples obtained at the depth of 40-77cm are all transported by means of graded suspension with rolling, and the remaining shows that they are all transported by means of uniform suspension (Fig 6).
At the same time Manickabungu Trench samples beyond the depth of 40 cm are having coarser particles more than that of fine.
Samples obtained from Cinnamedu Trench reveals that at the depth 51-60 cm grains transported by means of uniform suspension and the others transported by graded suspension with rolling.
Vanagiri Trench samples shows that the samples from 0-10.20-35 and 85-90 are transported by means of graded suspension with rolling and all the other by means of uniform suspension.
Pillaiperumanallur Trench obtained at the depth of 5-10cm, 10-15cm are transported by means of uniform suspension and all the others transported by means of graded suspension with rolling.

4.5 Cluster Analysis

Cluster analysis is an exploratory data analysis tool which aims at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. It can be used to discover structures in data without providing an explanation/interpretation and why they exist. As a result one can link more and more objects together and aggregate larger and larger clusters of increasingly dissimilar elements. Finally, in the last step, all objects are joined together. In these plots, the horizontal axis denotes the linkage distance.
Hierarchical cluster Chandrapadi Trench reveals that there is a maximum difference between few samples with other, the samples obtained at 0-20cm as one group and 30-51cm as another group behaves distinct from all the other (Fig 7a).
The cluster analysis of Manickabungu Trench reveals that the samples of 20-35, 68-77cm and above 93cm are distinct than that of others. Another group encompasses 0-20 and 77-93 (Fig 7b).
Cinnamedu Trench cluster analysis reveals that 15-20, 24-28 and 46-51cm as different group, 28-33cm as distinct and 51-60cm as a different group. All the remaining behaves as same (Fig 7c).
The cluster analysis of Pillaiperumanallur Trench reveals that 5-10 and 48-50 cm as different group and all the remaining comes under one group (Fig 7d).
When Vanagiri Trench cluster analysis concerned 30-35 cm and 85-90cm are behaving different than that of remaining all (Fig 7e).

5. Conclusion

The areas like Vanagiri (0--20, 30-35 and 85-90), Chinnamedu (0-15, 28-34 and 51-54) having three evidences of tsunami event including the recent tsunami occurred on 26th of December 2004 whereas Manickabangu (0-20 and 52-61) and Pillaiperumanallur (0-15 and 30-43) shows two signatures but at the same time Chandrapadi (10-30) location having only one at the top and the remaining two are below the hard lateritised layers (85-90). This has been suspected that the coast might have been undergone a long period of exposure for weathering that is why they may not be comparable with that of other locations.

The area undergoes continuous erosion from 1970 to 2000 and little bit accretion upto 2008 was noticed by means of frequent survey made in these areas. When erosion compared with the deposition the amount of accretion is very meager. This may be one of the reasons for obliteration of tsunami signatures at depths or they may be reworked by means of wave action or altered by other natural agents (Srinivasalu 2009). Further investigation by using marker species of forams or heavy mineral studies will reveal the Paleo-tsunami signatures in detail. The exact time period of tsunami occurrence can be identified by means of OSL C^{14} dating.

6. Acknowledgments

Author sincerely acknowledges Prof.Dr.G.VictorRajamanickam for his valuable guidance in the Paleotsunami study. He also thanks to the co-author who provide valuable guidance through his wonderful experience in the applied geology field. And also he thanks Dr.S.K.Chaturvedi, SASTRA University cooperated in the research for providing necessary infrastructure facilities for the research. The author acknowledges the co-workers of the same study Mr.R.VijayAnand, Neelakandan, and R.Mahesh..

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Table – 1 a. Grain size parameters of Chandrapadi Trench (CHP-T)

Depth	Mean ϕ	Sorting ϕ	Skewness	Kurtosis	1st percentile mm	50th percentile mm	Remarks
0-10	1.7013	0.5992	1.3187	5.8615	151.3	306.2	Medium sand, Very well sorted, Very fine skewed, Leptokurtic.
10-20	1.633	0.6376	1.1080	5.3416	155.5	309.9	Medium sand ,Very well sorted, Very fine skewed, Leptokurtic
20-25	2.1785	0.6622	0.2897	3.4472	125.1	233.6	Fine sand, Very well sorted, Very fine skewed, Mesokurtic
25-30	2.1785	0.6622	0.2897	3.4472	112.6	212.3	Fine sand, Very well sorted, Very fine skewed, Mesokurtic
30-35	2.0004	0.5834	0.8504	4.5765	128.2	227.5	Fine sand, Very well sorted, Very fine skewed, Leptokurtic
35-45	1.7622	0.6480	0.8339	4.4728	141.6	247.3	Medium sand, Very well sorted, Very fine skewed, Leptokurtic
45-51	1.7622	0.6480	0.8339	4.4728	141.6	247.3	Medium sand, Very well sorted, Very fine skewed, Leptokurtic
51-60	2.1438	0.6775	0.3543	3.1121	111.3	217.0	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
60-70	2.2044	0.6891	0.3939	2.9720	109.2	213.7	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
70-85	2.2410	0.6428	0.2275	2.5912	108.1	175.5	Fine sand ,Very well sorted, Very fine skewed, Leptokurtic
85-90	2.5340	0.6532	0.0985	2.5905	106.1	170.7	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
90-100	2.6522	0.6499	0.0010	2.4977	85.8	158.4	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
100-110	2.6211	0.6393	0.0009	2.5246	87.6	160.2	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
110-115	2.4975	0.6835	0.0242	2.5704	89.5	174.2	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
115-125	2.4199	0.6496	0.2678	2.5796	109.2	215.1	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
125-130	2.6277	0.6884	-0.3191	2.9505	85.8	153.0	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
130-140	2.6340	0.6958	-0.2710	2.8417	85.2	157.4	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
140-150	2.6003	0.7118	-0.3033	3.0201	86.3	160.6	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
150-160	2.4987	0.6857	-0.0962	2.8884	106.7	172.2	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic
160-170	2.2234	0.6221	0.3094	2.7905	121.1	227.6	Fine sand ,Very well sorted, Very fine skewed, Mesokurtic

Table – 1 b. Grain size parameters of Manickabangu Trench (MKB-T)

Depth	Mean ϕ	Sorting ϕ	Skewness	Kurtosis	1st percentile mm	50th percentile mm	Remarks
0-20	3.0261	0.4968	-0.3802	3.5509	80.7	121.9	Very fine sand,Very well sorted, Very fine skewed, Mesokurtic
20-35	2.5314	0.6556	0.1452	2.4116	92.9	172.3	Fine sand ,Very well sorted, Fine skewed,Platykurtic
35-40	2.2816	0.5995	0.4597	2.7855	119.0	224.1	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic

40-47	2.1632	0.6299	0.6180	2.9932	121.6	235.6	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
47-52	2.1582	0.5459	0.7164	3.2643	133.6	234.8	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
52-58	2.2986	0.5978	0.5246	2.9139	118.5	223.6	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
58-61	2.4448	0.5821	0.7062	3.1019	125.5	232.7	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
61-68	2.3624	0.5920	0.6456	3.1413	132.1	238.7	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
68-77	2.6957	0.5622	0.3516	2.7234	113.2	212.0	Fine sand ,Very well sorted, Symmetrical,Mesokurtic
77-87	3.3402	0.4410	-0.5579	4.1658	80.1	118.3	Very fine sand,Very well sorted,Symmetrical,Leptokurtic
87-90	3.2794	0.4213	-0.2146	3.7822	82.3	122.7	Very fine sand ,Very well sorted, Very fine skewed, Leptokurtic
90-93	3.2875	0.4443	-0.3994	3.8604	81.5	121.4	Very fine sand ,Very well sorted, Very fine skewed, Leptokurtic
Above 93	3.1036	0.5656	-0.0696	2.7168	82.3	139.7	Very fine sand ,Very well sorted, Very fine skewed, Mesokurtic

Table – 1 c. Grain size parameters of Cinnamaedu Trench (CMD-T)

Depth	Mean ϕ	Sorting ϕ	Skewness	Kurtosis	1st percentile	50th percentile	Remarks
15-20	2.4786	0.5855	0.2648	2.5523	110.8	176.6	Fine sand,Very well sorted,Very fine skewed,Platykurtic
20-24	2.1271	0.5804	0.8457	3.3820	129.0	239.0	Fine sand,Very well sorted, coarse skewed, Mesokurtic
24-28	2.5149	0.6029	0.0690	2.3189	109.9	168.8	Fine sand,Very well sorted, Very fine skewed,Platykurtic
28-33	2.7830	0.5202	-0.4958	3.3268	106.2	139.3	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
33-38	2.1538	0.6229	0.7764	2.9810	121.0	238.2	Fine sand,Very well sorted, Coarse skewed, Mesokurtic
38-40	1.9805	0.6209	0.8164	3.1846	132.8	304.4	Medium sand,Very well sorted, Coarse skewed, Mesokurtic
40-44	2.0943	0.5769	0.6762	3.1563	132.7	240.3	Fine sand ,Very well sorted, Coarse skewed, Mesokurtic
44-46	1.8027	0.6338	0.6240	3.4576	153.7	316.0	Medium sand ,Very well sorted, Coarse skewed, Mesokurtic
46-51	2.3502	0.6979	0.0469	2.3276	110.2	216.6	Fine sand ,Very well sorted, Very fine skewed,Platykurtic
51-54	2.6450	0.7549	-0.4026	2.7042	84.1	150.6	Fine sand ,Very well sorted, fine skewed,Mesokurtic
54-56	2.6773	0.7229	-0.3642	2.8313	83.7	148.3	Fine sand ,Very well sorted, fine skewed,Mesokurtic
56-60	2.8317	0.6522	-0.3035	2.8082	81.3	137.7	Fine sand ,Very well sorted, fine skewed,Mesokurtic

Table – 1 d. Grain size parameters of Vanagiri Trench (VAG-T)

Depth	Mean ϕ	Sorting ϕ	Skewness	Kurtosis	1st percentile	50th percentile	Remarks
0-10	2.4119	0.6466	0.2486	2.6232	111.3	213.6	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
10-20	2.7184	0.6559	0.0593	2.5139	84.3	138.1	Fine sand,Very well sorted, Very fine skewed,Platykurtic
20-25	2.5438	0.7162	0.1945	2.4117	88.5	171.8	Fine sand,Very well sorted, Very fine skewed, Platykurtic
25-30	2.5861	0.7363	0.1464	2.2363	85.3	167.0	Fine sand,Very well sorted, Very fine skewed, Platykurtic
30-35	2.4851	0.5956	0.5904	3.3290	112.7	182.5	Fine sand,Very well sorted, Very fine skewed, Mesokurtic

35-45	2.6935	0.7364	-0.0743	2.4214	83.0	153.8	Fine sand,Very well sorted, Very fine skewed, Platykurtic
45-51	2.8326	0.6171	-0.2329	2.8523	83.1	137.1	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
51-60	2.7102	0.6581	0.0384	2.5673	84.9	154.1	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
60-70	2.7713	0.6121	-0.0919	2.8851	86.1	145.1	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
70-85	2.6673	0.7075	-0.2143	2.4887	84.9	150.3	Fine sand,Very well sorted, Very fine skewed, Platykurtic
85-90	2.8457	0.4609	0.0281	3.9795	106.4	140.1	Fine sand,Very well sorted, Very fine skewed, Leptokurtic

Table – 1 e. Grain size parameters of Pillaiperumanallur Trench (PPN-T)

Depth	Mean ϕ	Sorting ϕ	Skewness	Kurtosis	1^{st} percentile	50^{th} percentile	Remarks
0-5	2.5454	0.6032	0.2323	2.4601	106.9	170.2	Fine sand, Very well sorted, Very fine skewed,Platykurtic
5-10	2.8202	0.6295	-0.3562	2.7553	82.2	136.2	Fine sand, Very well sorted, Very fine skewed,Mesokurtic
10-15	2.6254	0.7048	-0.1068	2.4664	85.1	158.4	Fine sand, Very well sorted, Very fine skewed, Platykurtic
15-20	2.5071	0.6507	0.0538	2.6807	107.4	170.1	Fine sand, Very well sorted, Very fine skewed, Mesokurtic
20-30	2.5157	0.6074	0.3577	2.5451	107.1	175.8	Fine sand, Very well sorted, Fine skewed,, Platykurtic
30-40	2.6210	0.6603	0.1796	2.4262	86.0	163.6	Fine sand, Very well sorted, Symmmetrical, Platykurtic
40-43	2.5913	0.6581	0.1157	2.3657	87.4	164.9	Finesand,Very well sorted,Symmmetrical,Platykurtic
43-48	2.8097	0.5909	-0.0679	2.6435	83.3	142.8	Fine sand,Very well sorted, Very fine skewed, Mesokurtic
48-50	2.9279	0.5815	-0.2611	2.8581	80.7	130.2	Fine sand,Very well sorted, Very fine skewed, Mesokurtic

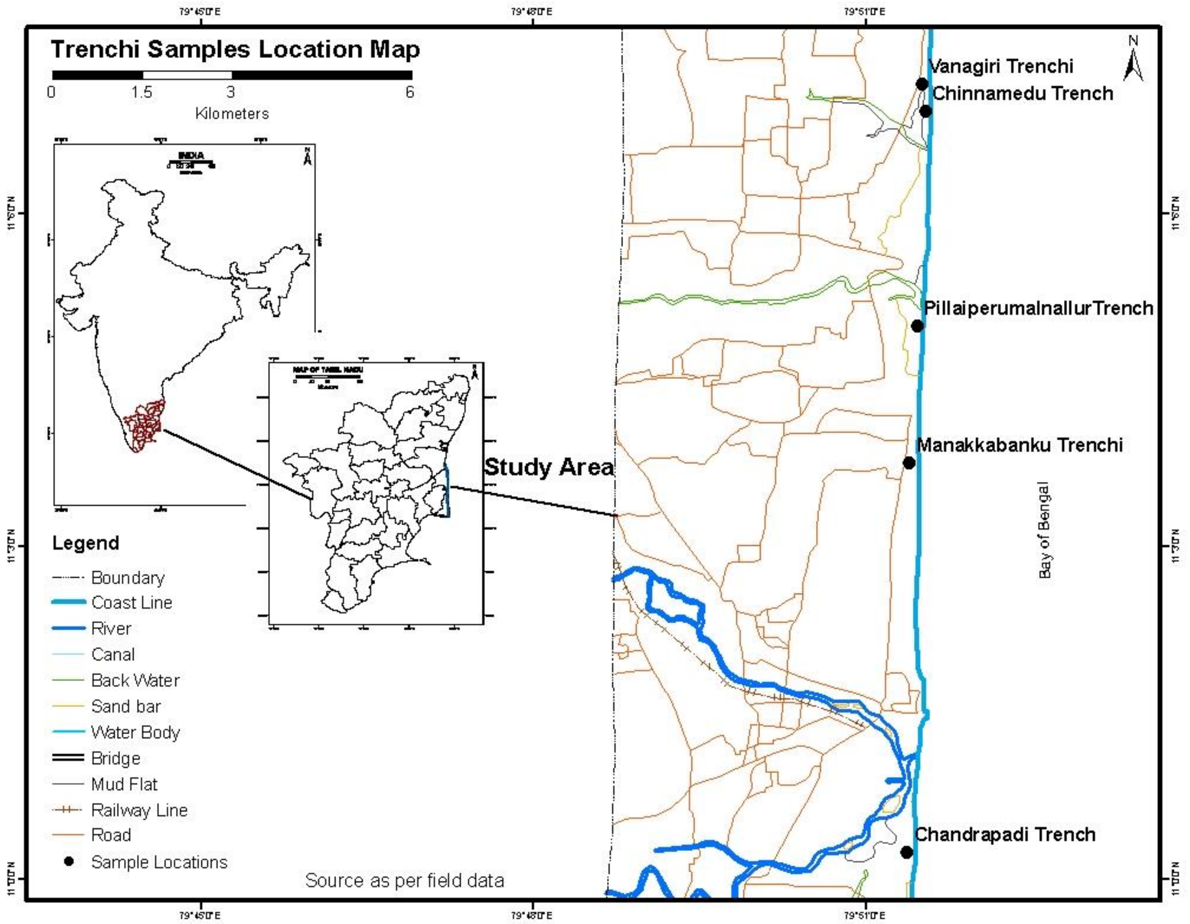
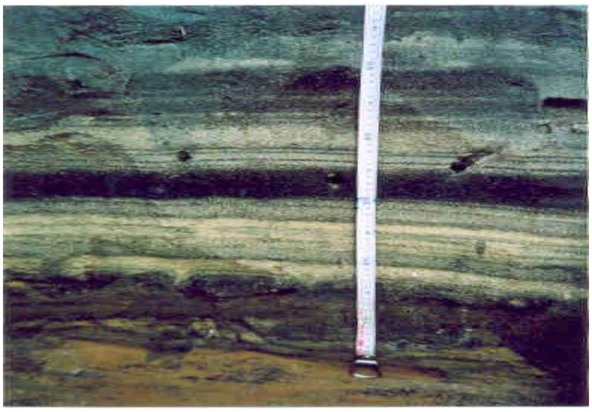


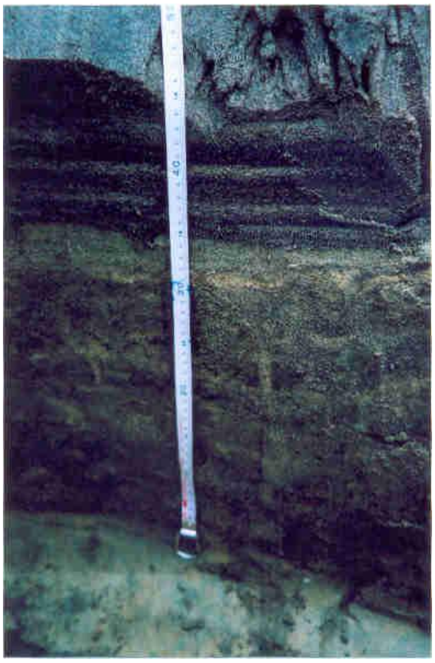
Fig -1 Map showing Study Area

a.Chandrapadi Trench

b.Vanagiri Trench

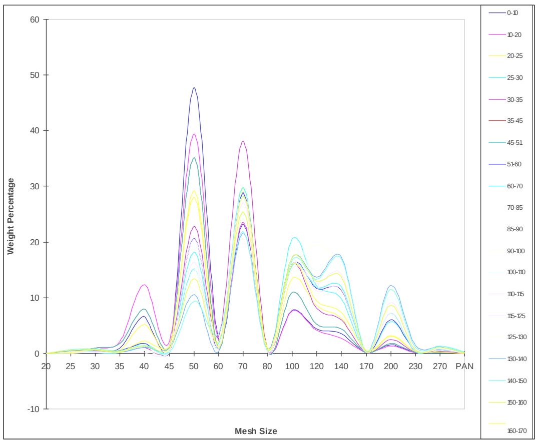


c.Chinnamedu Trench

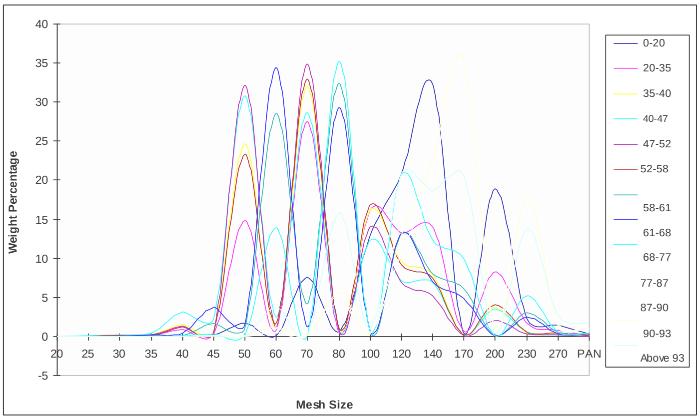


b.Pillaiperumanallur Trench

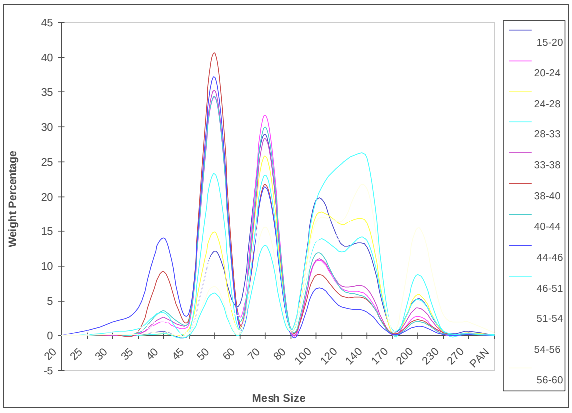
Fig-2 Trench photographs a Chandrapadi, b Vanagiri, c Chinnamedu, d Pillaiperumanallur



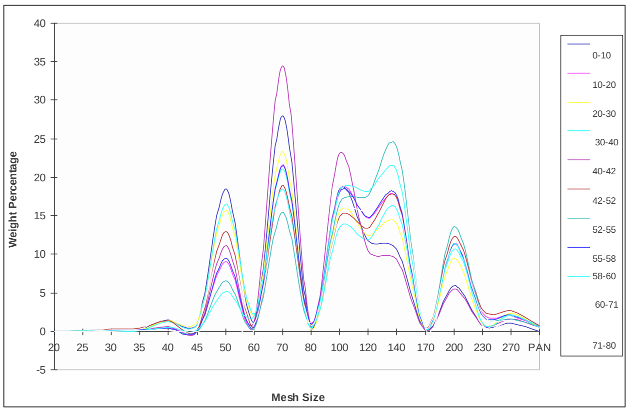
a.Chandrapadi-Trench



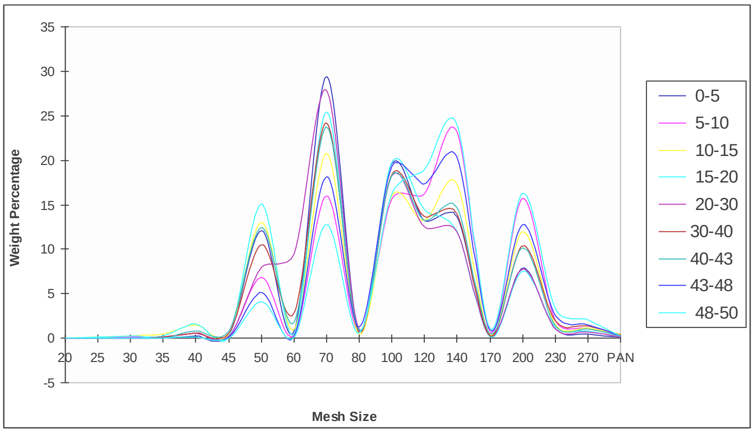
b.Manickapangu Trench



c.Cinnamaedu Trench

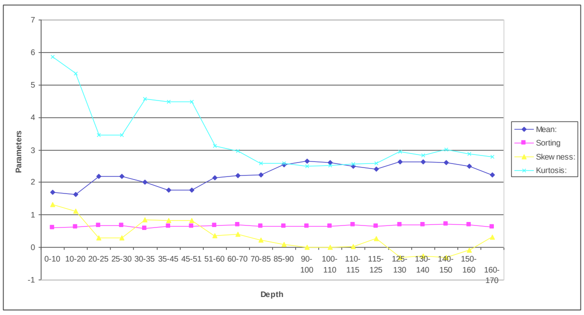


d.Vanagiri Trench

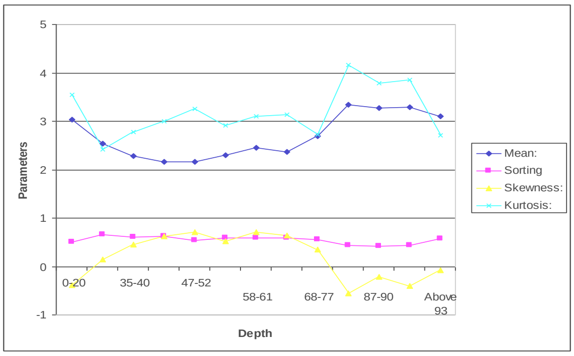


e.Pillaiperumanallur Trench

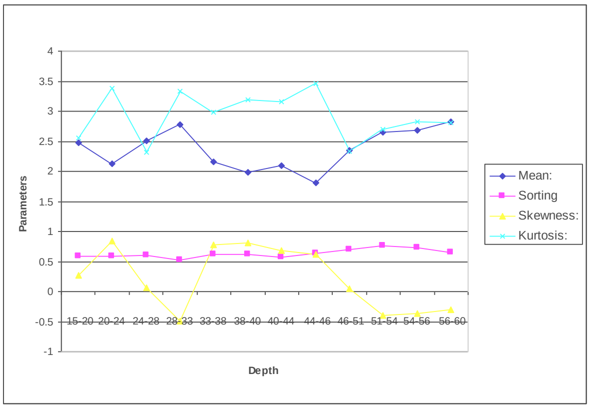
Fig – 3 Frequency curves a Chandrapadi, b Manickabangu, c Chinnamedu, d Vanagiri, e Pillaiperumanallur



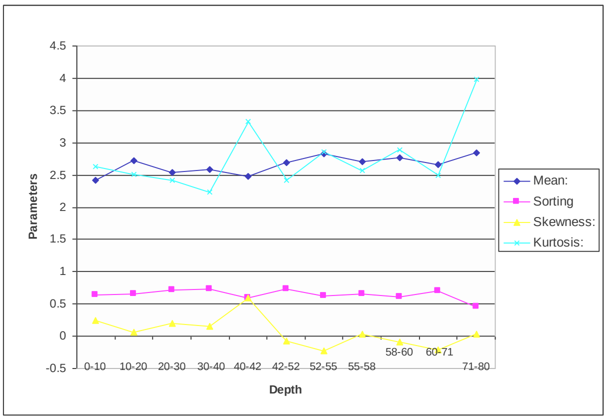
a.Chandrapadi-Trench



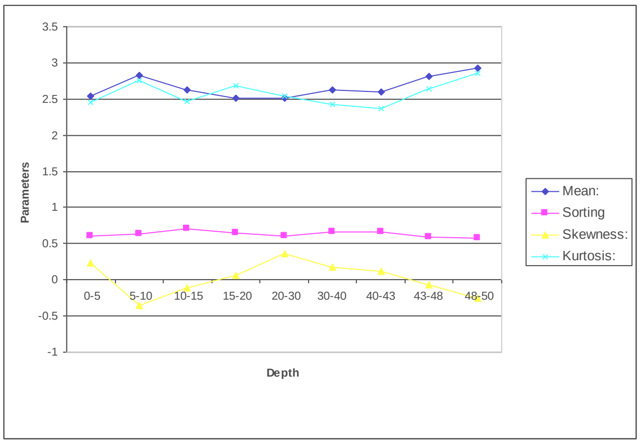
b.Manickapangu Trench



c.Cinnamaedu Trench

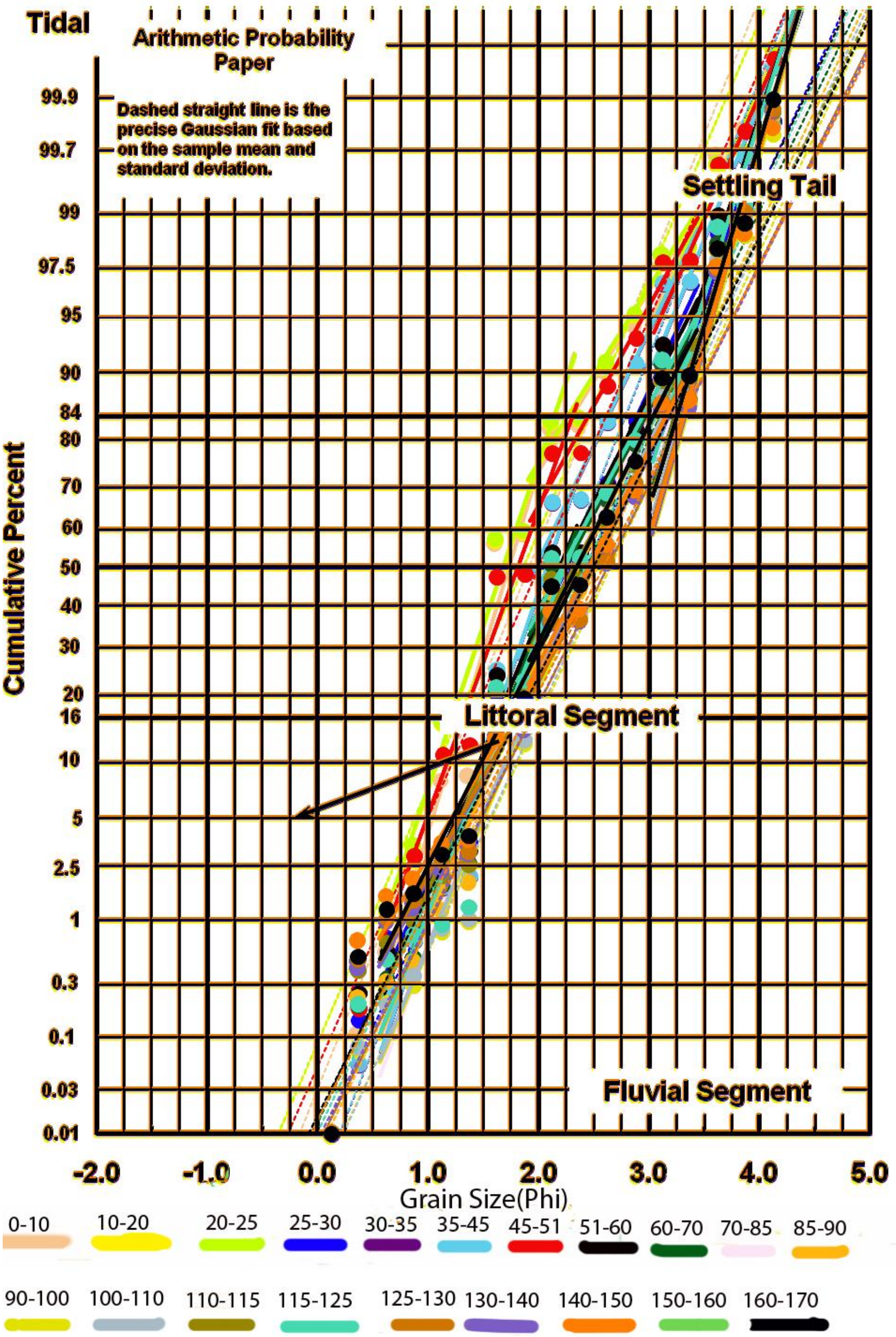


d.Vanagiri Trench

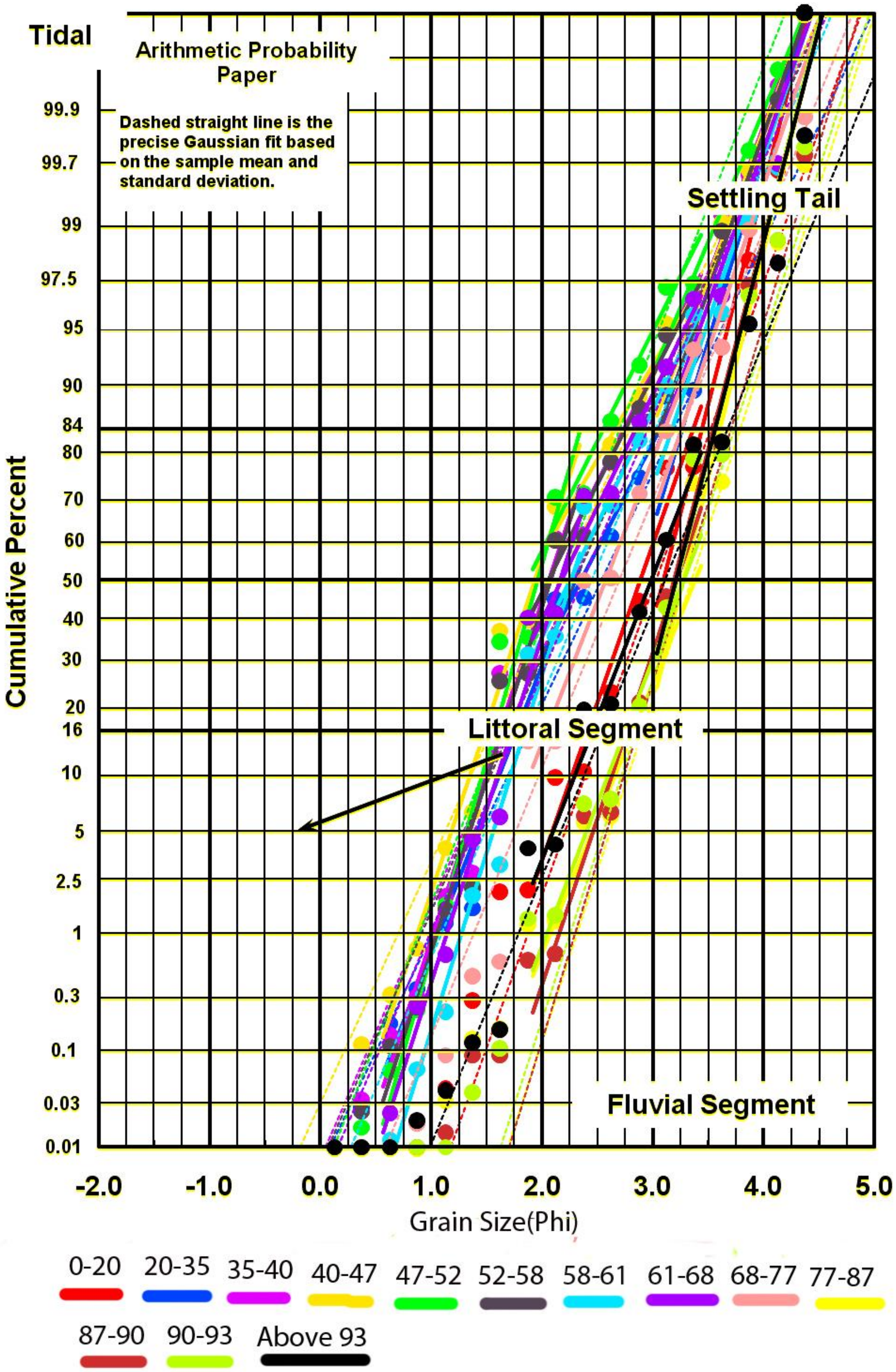


e.Pillaiperumanallur Trench

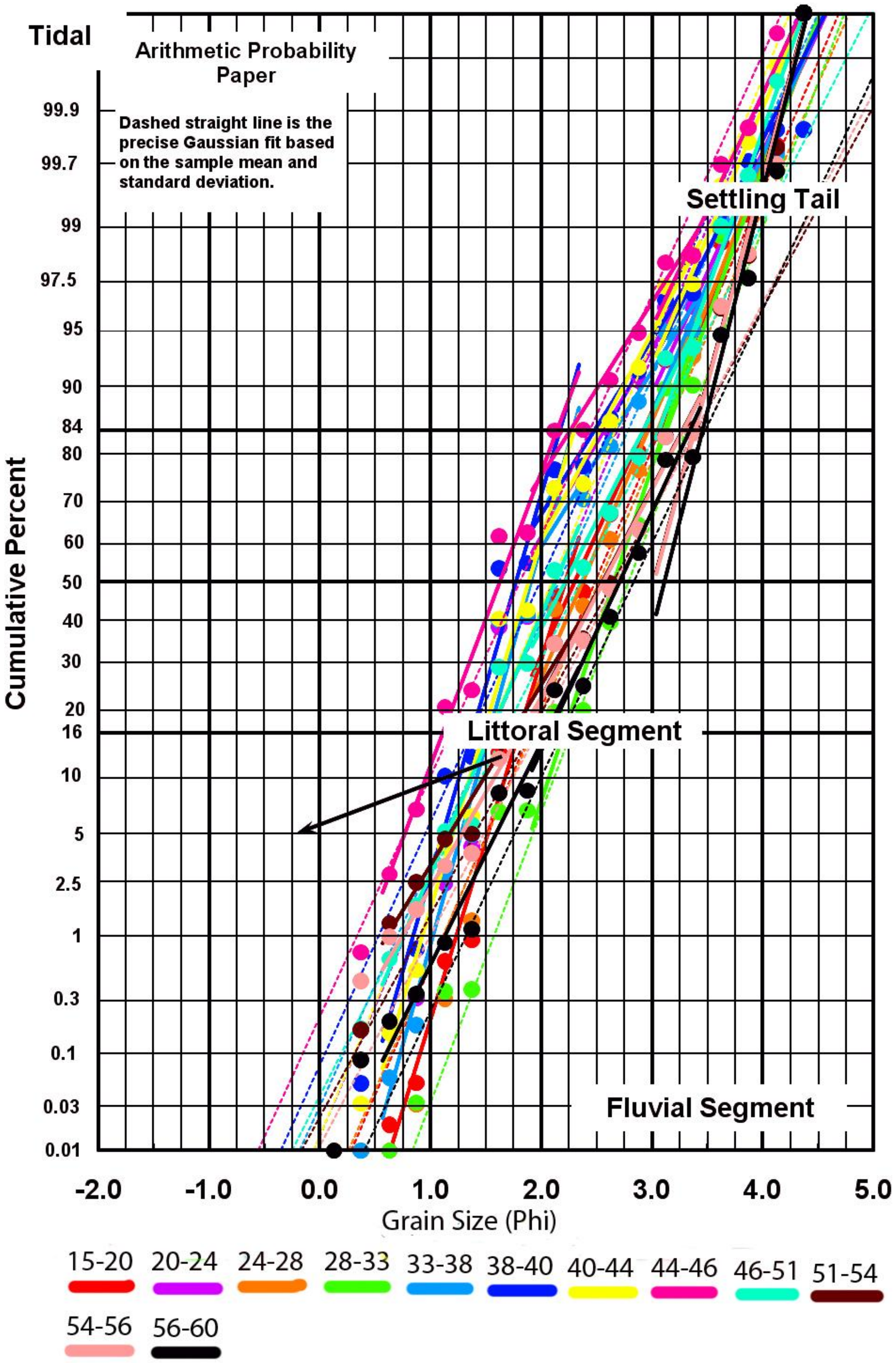
Fig – 4 Distribution pattern shown by Statistical parameters a Chandrapadi, b Manickabangu, c Chinnamedu, d Vanagiri, e Pillaiperumanallur



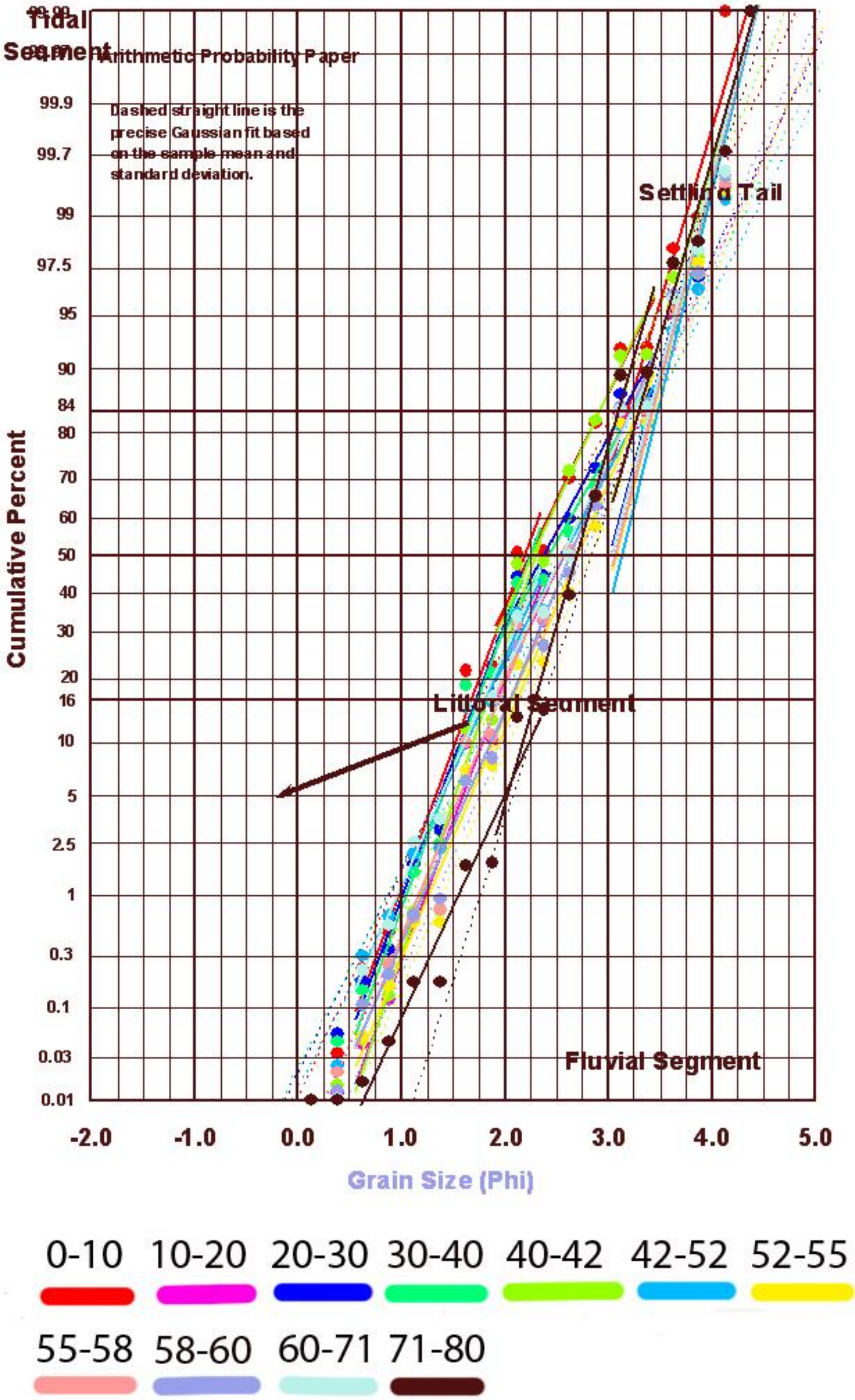
a.Chandrapadi-Trench



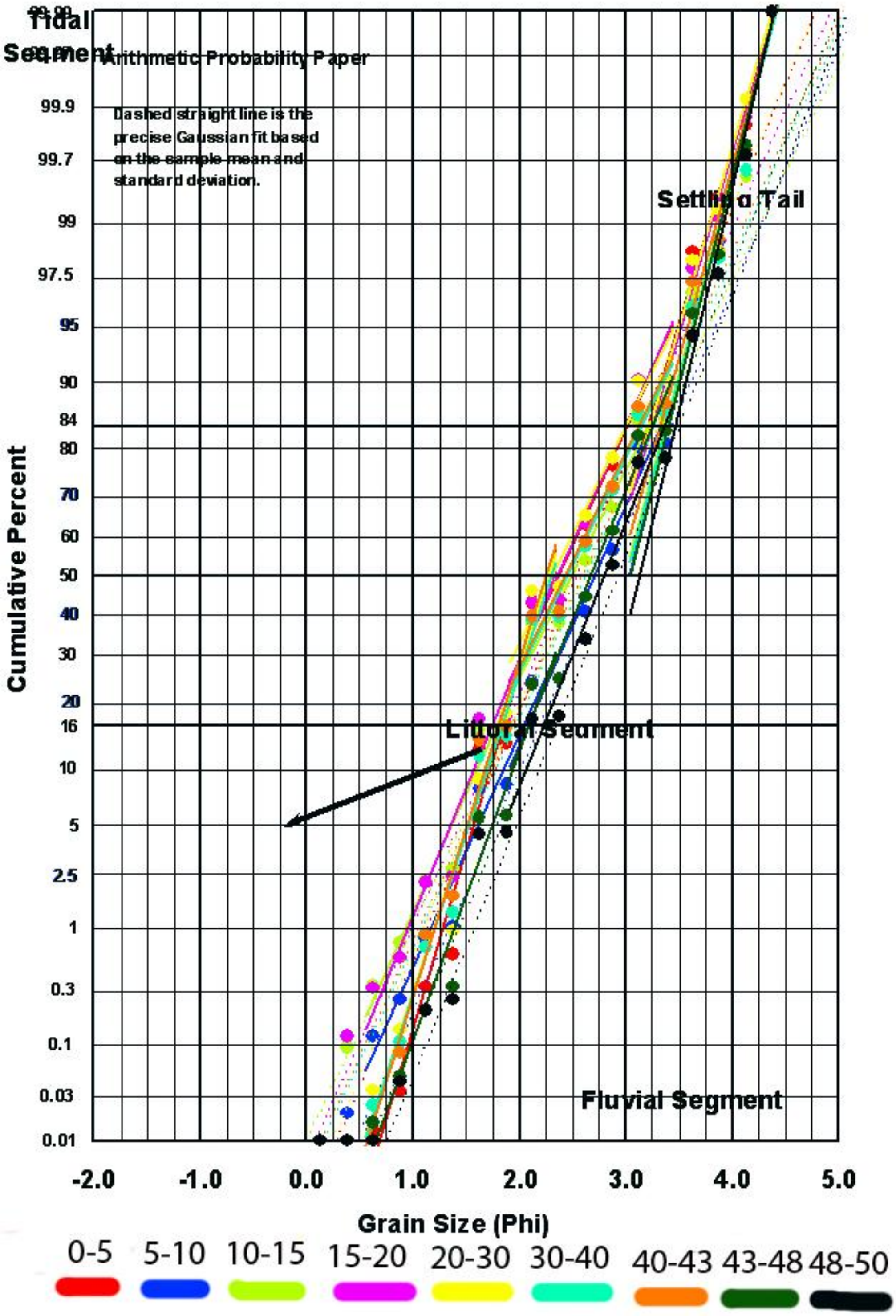
b.Manickapangu Trench



c.Cinnamaedu Trench

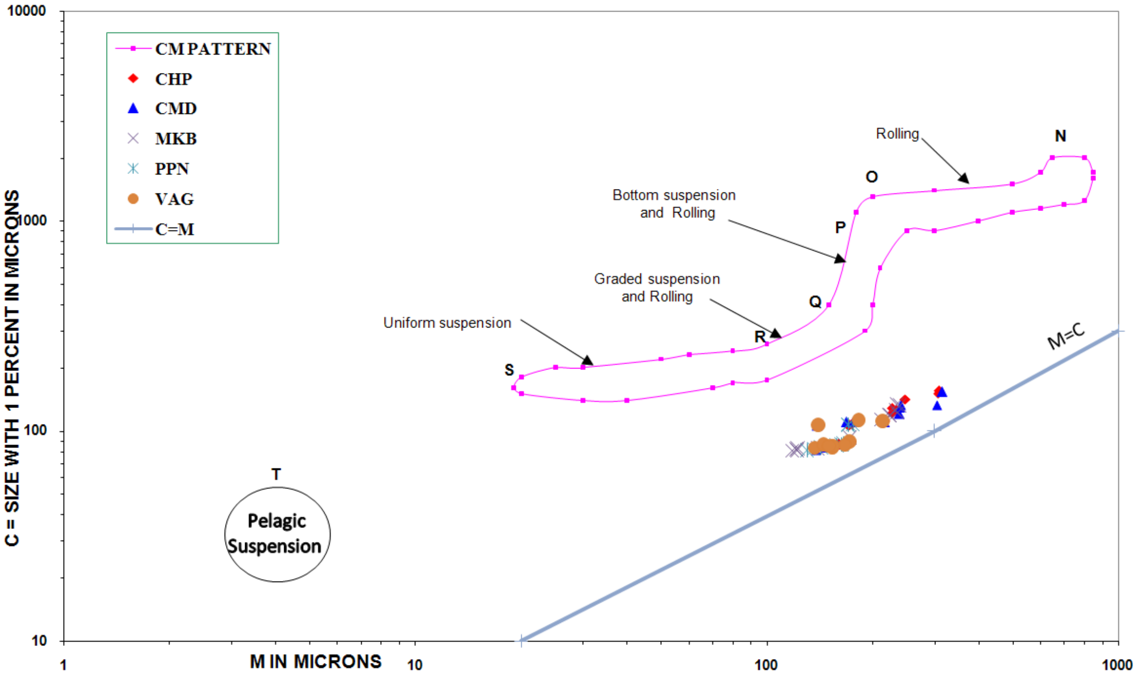


d.Vanagiri Trench



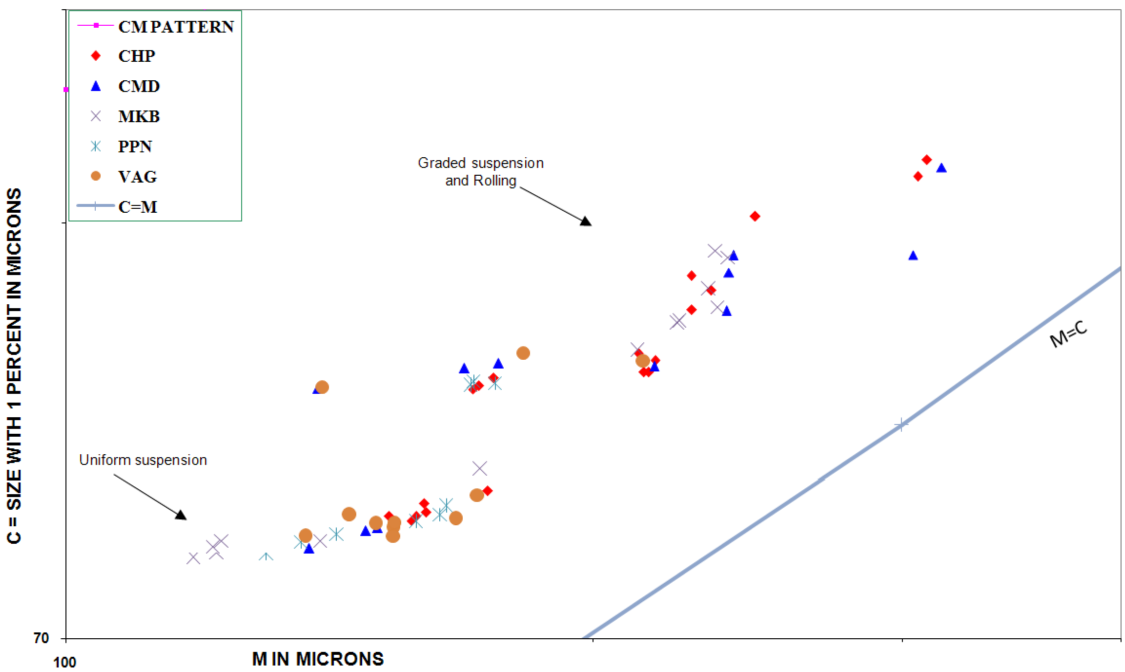
e.Pillaiperumanallur Trench

Fig – 5 Visher's diagram a Chandrapadi, b Manickabangu, c Chinnamedu, d Vanagiri, e Pillaiperumanallur



CM PATTERN

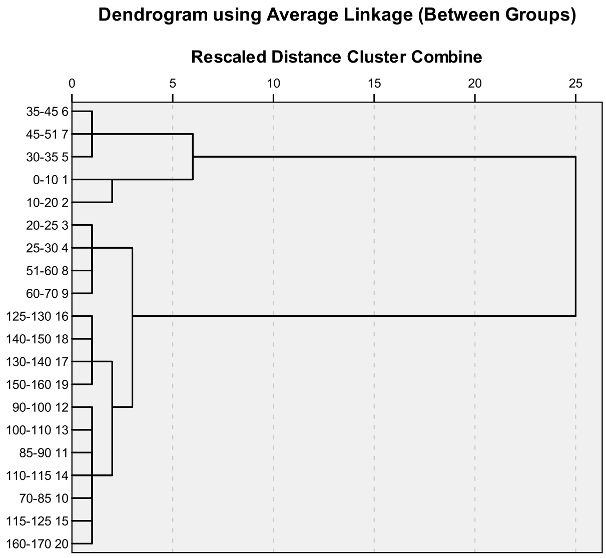
a. CM Pattern with full view



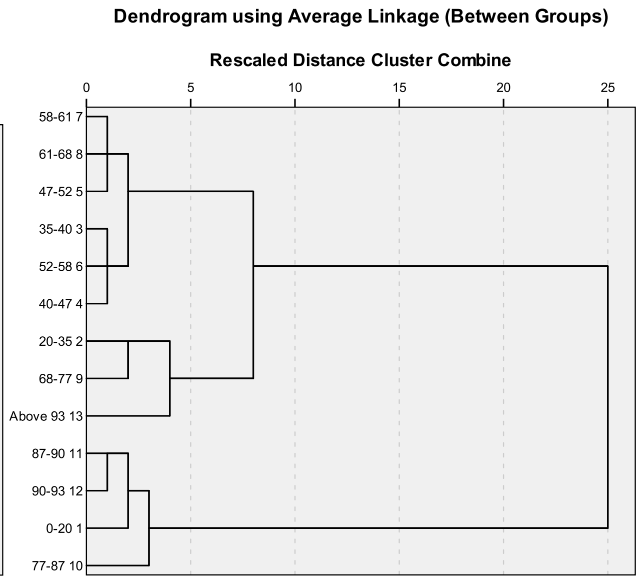
CM PATTERN

b. CM Pattern with enlarged view

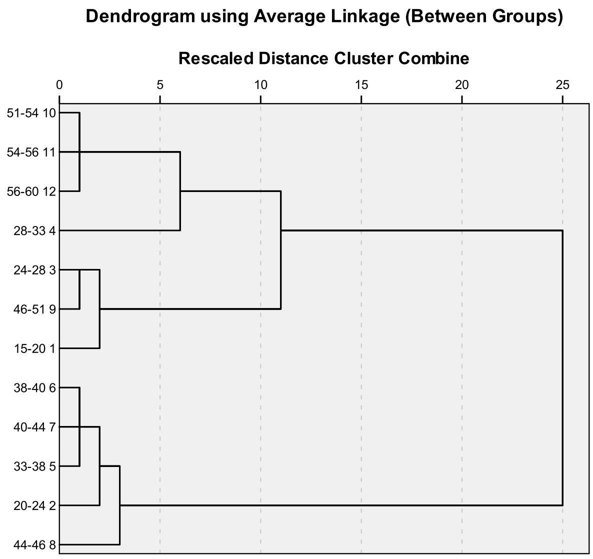
Fig – 6 a. Log probability plot of 1st Percentile µm 'C' vs Median µm 'M' after Passega 1964 b. Enlarged view.



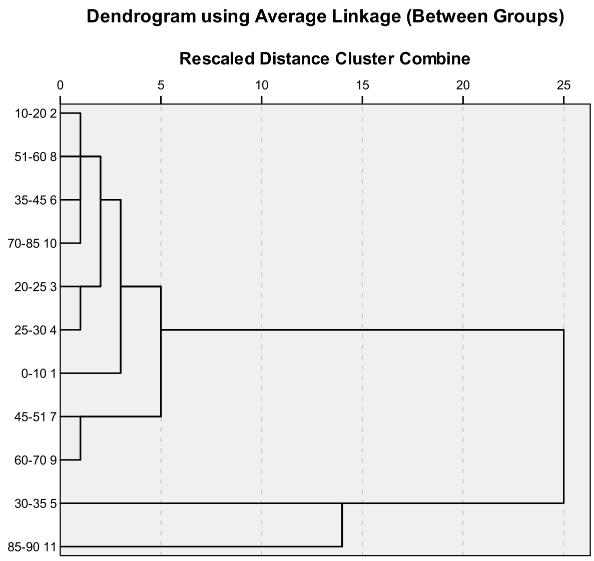
a.Chandrapadi-Trench



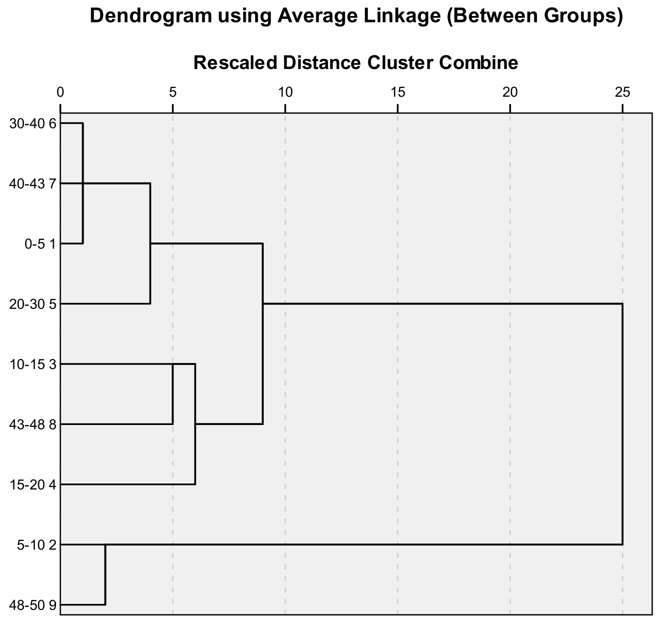
b.Manickapangu Trench



c.Cinnamaedu Trench



d.Vanagiri Trench



e.Pillaiperumanallur Trench

Fig – 7 Hierarchial Cluster diagram a Chandrapadi, b Manickabangu, c Chinnamedu, d Vanagiri, e Pillaiperumanallur