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Full Length Research

HEAVY MINERAL CHARACTERISTICS AND GRAIN-SIZE DISTRIBUTION OF THE SILICICLASTIC SEDIMENTS IN IJEBU-OMU, ILOTI, ITELE AND IJEBU-IFE STUDYAREAS OF EASTERN DAHOMEY BASIN, SOUTHWESTERN NIGERIA

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The knowledge of particle size distribution and the assemblages of heavy minerals in sedimentary rocks particularly in the earth crust make it possible to effectively locate and use essential minerals to predict their dispersal pattern when they re-enter the natural environment. Particle size distribution of sedimentary outcrop samples exposed around Ijebu-Omu, Iloti, Itele and Ijebu-Ife located within the eastern Dahomey basin were used to study the provenance and to deduce the transportation history, environment of deposition of the sediment.

Twenty four (24) surface samples collected from the study area were subjected to granulometric analysis in order to determine their grain size distribution using the sieve method. The sediment samples were passed through a set of mechanical sieves of 4.75mm diameter screen opening. Thin sections of finer particles from twelve (12) selected samples were also done to describe the heavy mineral make-up.

Results showed that sediments with 0.212mm grain size dominate in all the samples. The average statistical mean (textural maturity), standard deviation (sorting) and kurtosis determined from the grain size data are 0.65, 0.66, and 1.35 respectively. The heavy mineral assemblage shows the presence of opaque and non opaque minerals such as zircon, tourmaline, rutile, staurolite, garnet, apatite and epidote. The calculated zircon, tourmaline, rutile index in percentage (ZTR) varied between 33-56%, average apatite- tourmaline index(ATI), garnet-zircon index(GZI), rutile-zircon index(RuZI) and staurolite-zircon index(SZI) values in all the locations are 27.7%, 30.6%, 46%, and 50% respectively.
The textural study indicates that the sediments are leptokurtic, moderately well sorted coarse sands. The high value of SZI indicates sediments with a fairly short transportation history and the low ATI value is a characteristic of the unstable nature of apatite and tourmaline that has been affected by weathering. The presence of staurolite, garnet and rutile occuring in fairly large quantities is an indication of metamorphic and igneous rock source and the maximum ZTR index of 56% indicates that the sediments are mineralogically immature.

Key words: Sediments, Tourmaline, Kurtosis, Garnet, Zircon.

INTRODUCTION

Studies of composition and properties of sedimentary rocks are vital in interpreting stratigraphy. Some of the major work of a sedimentary petrologist is to determine location, lithology and tectonic activity of the source area, to deduce the character of the environment of deposition, establish the cause of changes in thickness or lithology and to correlate beds in a precise form. The Dahomey basin is a marginal pull-apart basin (Klemme, 1975) or margin sag basin (Kingston *et al.,* 1983), which was initiated during the early Cretaceous separation of Africa and South American lithospheric plates. Geology and stratigraphy of the Dahomey basin has been described by various workers, (Jones and Hockey, 1964; Omatsola and Adegoke, 1981; Agagu, 1985; Elueze and Nton, 2004; Akinmosin *et al.,* 2005). In most part of the basin, the stratigraphy is dominated by sand and shale alternations with minor proportion of limestone, (Agagu, 1985). In all, eight lithostratigraphic units have been identified and described by these workers. A variety of tools including facies analysis, sequence stratigraphy, uplift studies, and detrital-mineral geochronology are commonly used to analyze the sedimentary response to tectonism, in particular the timing, rates, and provenance of deposition. Applying these principles to the sedimentary succession spanning the late Cretaceous rocks of the Abeokuta group is potentially a powerful way to access fundamental changes that occurred during the critical period in the earth history.

The purpose of this study is to use sedimentological analysis to infer the provenance of the Abeokuta group. The Abeokuta group is the oldest unit of the Dahomey basin and it lies unconformably on the basement complex rock throughout the entire Dahomey basin

(Jones and Hockey, 1964). The Group, being the thickest single sedimentary unit, and consisting of interbeds of organic rich shale, siltstone, with porous and permeable detrital sandstone together with its depth of burial makes it a prime target for petroleum exploration in the Dahomey basin.

GEOMORPHOLOGY AND GEOLOGY

The study area is located within the eastern part of the Dahomey basin and lie between latitude N06^{0}44^{1} and N06^{0}47^{1}, and longitude E03^{0}52^{1} and E04^{0}02^{1} as shown in figure 1. The outcrops sampled are road-cuts around Ijebu Omu (E03^{0}52^{1} 22.2^{11}, N06^{0} 44^{1} 01.4^{11}), Iloti (E03^{0} 58^{1} 43.8^{11}, N06^{0}44^{1} 44.1^{11}), Itele (E04^{0}02^{1} 00.8^{11}, N06^{0}46^{1} 18.2^{11}) and Ijebu Ife (E03^{0}59^{1} 59.4^{11}, N06^{0} 47^{1} 00.0^{11}), Southwestern Nigeria as illustrated in figure 1. The climatic condition of the area is tropical and is expressed as an alternation between wet and dry seasons. The two regimes of tropical climate show a fairly wide seasonal and diurnal variation in temperature which ranges between 35^{o}C during dry season and 25^{o}C during wet season. There are two peak of period of rainfall from June to July with a slight break in August referred to as “August break” (Onakomaya, 1992). These periods of wet and dry season have remarkable effects on the vegetation. The vegetation is characterized by trees and plant growth controlled by these systematic seasonal changes. Plants exhibit fresh looking green leaves during wet season with all types of plant showing luxurious growth and these disappear during dry season as many trees shed their leaves. The area have low to moderate relief and the drainage pattern is somewhat integrated having a network of streams that is sub-dendritic in nature.

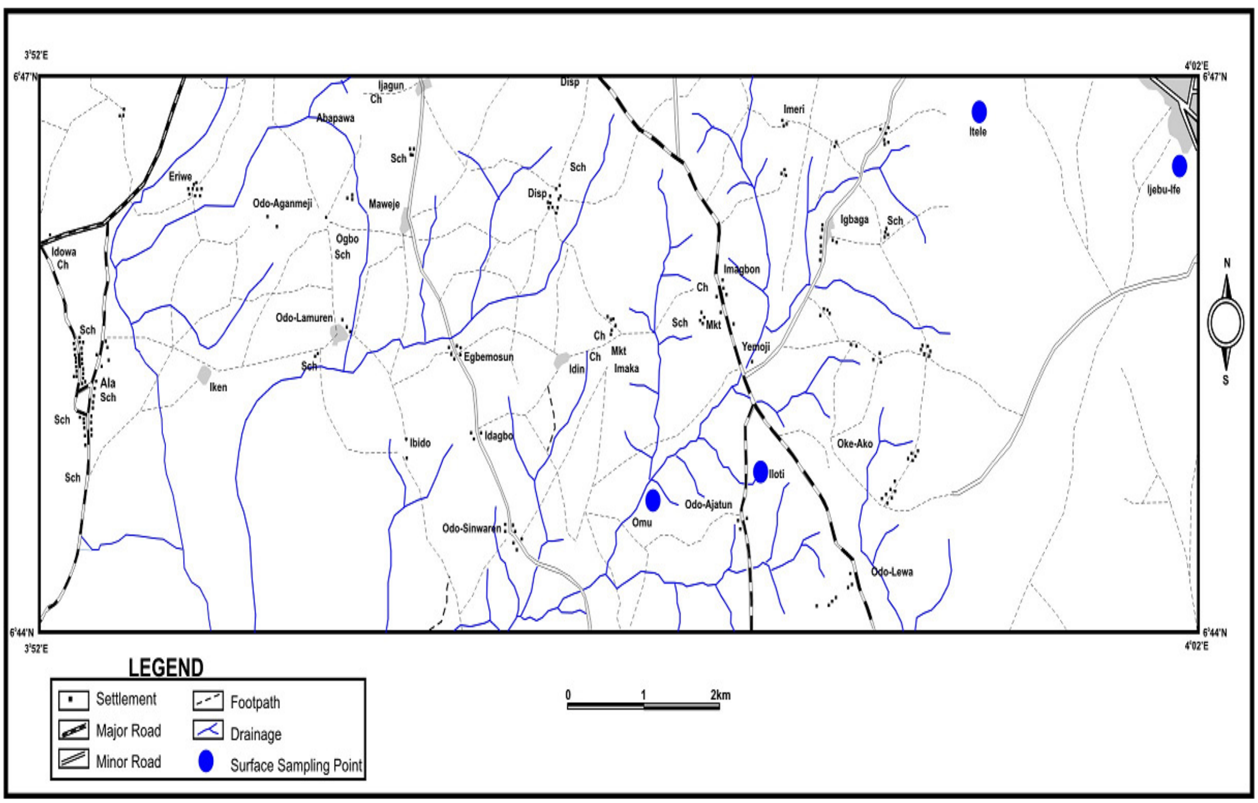


Figure1: Map of the study area showing location and sampling points.

The stratigraphy and stratigraphic architecture (Table 1a) have been well established by various workers (Jones and Hockey 1964; Omatsola and Adegoke 1981; Agagu 1985; Enu (1990), Nton *et al.,* (2006). However, Agagu (1985) placed together the stratigraphy of eastern Dahomey basin from surface as well as subsurface data, deciphering that in most part of the basin, the stratigraphy is dominated by monotony of sand and shale alternations with minor proportion of limestone and clay. The stratigraphy of the Cretaceous to Tertiary sedimentary pile which unconformably overlies the basement complex includes the following lithostratigraphic units and is summarized in Table 1a.

Table 1a: Stratigraphy of the Eastern Dahomey Basin as coupled by various authors

JONES AND HOCKEY (1964)		REYMENT (1965)		ADEGOKE (1969)		FAYOSE (1970)		BILLMAN (1976)		OMATSOLA (1981)		AGAGU (1985)	
AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION	AGE	FORMATION
RECENT	ALLUVIUM	RECENT	ALLUVIUM	RECENT TO POST-EOCENE	BENIN	EARLY MIOCENE	BENIN	LATE MIOCENE	BENIN; IJEBU	PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS	RECENT	ALLUVIUM
PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS	PLEISTOCENE PLIOCENE; NEOCENE	BENIN; IJEBU		OGWASHI ASABA	EARLY MIOCENE & LATE OLIGOCENE	OGWASHI ASABA	MIDDLE & EARLY MIOCENE	AFOWO BEDS			PLEISTOCENE TO OLIGOCENE	COASTAL PLAIN SANDS
LATE MIDDLE AND EARLY EOCENE	ILARO	MIDDLE EOCENE; EARLY EOCENE	AMEKI; OSHOSUN	EOCENE	AMEKI; OSHOSUN	EARLY OLIGOCENE TO MIDDLE EOCENE	AMEKI	MIDDLE EOCENE	OSHOSUN	EOCENE	ILARO / OSHOSUN	EOCENE	ILARO / OSHOSUN
PALEOCENE	EWEKORO	PALEOCENE	IMO / EWEKORO / SHALE	PALEOCENE	IMO SHALE; EWEKORO	EARLY EOCENE & PALEOCENE	IMO	EARLY EOCENE & PALEOCENE	IMO SHALE	PALEOCENE	EWEKORO	PALEOCENE	EWEKORO
LATE SANTONIIAN	ABEOKUTA	DANIAN; LATE CRETACEOUS	NKPORO SHALE	NOT DISCUSSED	ABEOKUTA	LATE CRETACEOUS	ABEOKUTA	EARLY PALEOCENE DANIAN MAASTRIC-HTIAN	NKPORO SHALE	MAAST-RICHTIAN TO NECOMIAN	ARAROMI FORMATION	MAAST-RICHTIAN TO NECOMIAN	ARAROMI MEMBER
PRE-CAMBRIAN	CRYSTALLINE BASEMENT		ABEOKUTA WHERE SANDY			UPPER MAAST-RICHTIAN		SENONIAN TURONIAN; ALBIAN	AWGU; ABEOKUTA RESTRICTED; UNNAMED ALBIAN SANDS		AFOWO FORMATION; ISE FORMATION		AFOWO MEMBER; ISE MEMBER
		PRE-CAMBRIAN	CRYSTALLINE BASEMENT				CRYSTALLINE BASEMENT	PRE-ALBIAN	UNNAMED OLDER FOLDED SEDIMENTS				

METHODS

The field approach entailed a detailed geological mapping carried out at different exposures found in the study area, positioning was taken with the aid of a global positioning system (GPS) as shown in (Tables 1b-1d) below. A total of four outcrops were located around Ijebu-Omu, Iloti, Itele, and Ijebu-Ife. On each sampling point, reasonably fresh samples were systematically taken at an interval of 30m and 50m laterally with vertical distance of 2m. The samples from each outcrop were labeled for subsequent granulometric and heavy mineral analyses. Equipments used in the field includes ; GPS, hand trowel, measuring tape, chisel, sample bag, hammer, masking tape, digital camera, field note.

Table1b: GPS location of samples at Ijebu-Omu

Sample label (IjebuOmu)			Horizonta l distance (m)	Vertical distance (m)	GPS location	Elevation
A	B	C	30m	2m	$N003^{0}52^{1}$ 22.1 $E06^{O}$ 44^{1} 01.4	54m
D	E	F	30m	2m		
G	-	-	-	2m		

Figure 2: Showing sampling procedure at the Ijebu-Omu outcrop.

Table 1c: GPS location of samples at Iloti

Sample label (Iloti)			Horizontal distance(m)	Vertical distance(m)	GPS location	Elevation
H	I	J	30m	2m	$N003^{0}58^{1}$ 43.8 $E06^{O}$ 44^{1} 44.1	71m
K	L	M	30m	2m		

Figure 3: Showing sampling procedure at the Iloti outcrop

Table 1d: GPS location of samples at Itele

Sample label (Itele)			Horizontal distance(m)	Vertical distance(m)	GPS location	Elevation
N	O	P	30m	2m	$N003^{0}59^{1}$ 59.4 $E06^{O}$ 47^{1} 00.0	70m
Q	R	S	30m	2m		

Figure 4: Showing sampling procedure at the Itele outcrop.

Table 1e: GPS locations of samples at Ijebu-Ife

Sample label (Ijebu-Ife)			Horizontal distance(m)	Vertical distance(m)	GPS location	Elevation
T	U	V	50m	2m	$N004^{0}$ 02^{1} 00.8 $E06^{O}$ 46^{1} 18.2	53m
W	X	-	50m	2m		

Figure 5: Showing sampling procedure at the Ijebu-Ife outcrop.

LABORATORY ANALYSIS

Granulometric analysis using the sieve method was carried out on a total of twenty four (24) samples in other to access the particle size distribution of the granular materials of the rock. Heavy mineral photomicrography was also carried out on the finest portion of the sediment to determine the heavy mineral make-up of the samples.
For the sieve analysis, air-dried samples each weighing 50g were run through a set of sieve sizes (4.75, 2.36, 1.18, 0.85, 0.425, 0.212, 0.150, 0.075 mm) arranged in downward decreasing mesh diameters using a mechanical shaker agitating for about 15 minutes for each sample, the amount retained on each sieve was then weighed using a sensitive weighing balance. The bottom of the sieve was then cleaned thoroughly but gently with a brush to dislodge the grains partially stacked in the mesh holes to avoid contamination of subsequent samples. The weight of the sample on each sieve was then divided by the total weight to give the percentage retained on each sieve. Both graphic and statistical methods of data presentation are used for the interpretation of sieve data, the percentage of each sample in each class can be shown graphically in bar charts or histograms. Cumulative arithmetic curves are also extremely useful because many sample curves can be plotted on the same graph and differences in sorting are at once apparent.

Statistical parameters of sieve analysis

Statistical parameters used in this study adopted the formula commonly used for measure of central tendency: Mean (M) = $\frac{\varphi16+\varphi50+\varphi84}{3}$

The formula for standard deviation sorting (S), kurtosis (K) and skewness (SK) is adopted from Folk and Ward (1957) and is given as: Sorting (S) = $\frac{\varphi84-\varphi16}{4}+\frac{\varphi95-\varphi5}{6.6}$; Kurtosis(K) = $\frac{\varphi95-\varphi5}{2.44(\varphi75-\varphi25)}$ and Skewness: (SK) = $\frac{\varphi16+\varphi84-2\varphi50}{2(\varphi84-\varphi16)}+\frac{\varphi5+\varphi95-2\varphi50}{2(\varphi95-\varphi5)}$

Calculations

In interpreting the results of the grain size distribution, the individual weight, cumulative weight, as well as the individual and cumulative weight percentages was determined to construct histogram, and a cumulative frequency curve for each sample on semi log graphs. The phi values Φ5, Φ16, Φ25, Φ50, Φ75, Φ84, and Φ95, were used for the calculation of statistical parameters which were obtained from the cumulative frequency curves. The Microsoft excel spreadsheet software was adopted to carry out the cumulative percentage weight calculation and also in the plot of the phi values against the cumulative weight percentage. The mean values and standard deviation of each location was also derived mathematically using this software. Many formulae have been proposed although the most widely used are those proposed by Folk and Ward (1957) and it is utilized in this work.

Table 2: Statistical formulae used in the calculation of grain size parameter and suggested descriptive terminology, modified from Folk and Ward, (1957)

Sorting	skewness	Kurtosis
Very well sorted <0.35	very fine skewed +0.3 to +1.0	very platykurtic <0.67
Well sorted 0.35-0.50	fine skewed +0.1 to +0.3	platycurtic 0.67 – 0.90
Moderately well sorted 0.50-0.70	symmetrical +0.1 to -0.1	mesokurtic 0.90 – 1.11
Moderately sorted 0.70-1.00	coarse skewed -0.1 to -0.3	leptocurtic 1.11 –1..50
Poorly sorted 1.00-2.00	very coarse skewed -0.3 to -1.0	very leptokurtic 1.50 – 3.00
Very poorly sorted 2.00-4.00		extremely leptokurtic > 3.00
Extremely poorly sorted		

RESULTS, INTERPRETATION AND DISCUSSION.

PRESENTATION OF RESULTS

Data obtained from the statistical analysis are graphically interpreted using cumulative frequency curves to illustrate the transportation history of the sediments as shown in figure 10(A-X). Results of cumulative weight percentage and sieve diameter (phi) were used to make representative plots. Results of the percentage weight retained were also graphically represented using histograms to illustrate the nature of the sediments for all the samples as shown in figure 11(A-X). Data obtained from the statistical analysis displayed in the histograms of figure 11(A-X),

From the granulometric analysis, results of the grain size distribution (raw sieve data) obtained for each sample are shown in table 3-26. From the tables, the cumulative weight percentage were calculated for each location (A-X) and the average values of 47.19, 46.57, 45.20, 41.88, 50.96, 49.39, 50.58, 48.83, 45.57, 51.08, 48.42, 51.29, 48.04, 50.47, 47.86, 52.39, 48.70, 47.04, 53.01, 48.20, 44.47, 42.94, 46.11, 42.99 , were obtained respectively. From the calculation of the percentage weight retained, an average value of 12.5 was obtained for all the samples. Results of heavy mineral separation of the finer grain portion of the samples are presented in table 27

Table 3: Grain size analysis result for sample A

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.63	0.63	1.28	1.28
2.36	-1.238	1.93	2.56	5.18	3.9
1.18	-0.238	6.35	8.91	18.08	12.9
0.85	0.231	3.18	12.09	24.56	6.47
0.425	1.234	12.16	24.25	49.25	24.7
0.212	2.237	16.69	40.94	83.15	33.9
0.15	2.736	6.45	47.39	96.27	13.12
0.075	3.736	1.71	49.18	99.75	3.48

Table 4: Grain size analysis result for sample B

Sieve size(mm)	Phi(Φ)	Weight(g)	Cumulative weight(g)	Cumulative weight (%)	Weight retained %
4.75	-2.247	0.45	0.45	0.91	0.91
2.36	-1.238	1.29	1.74	3.52	2.61
1.18	-0.238	4.22	5.96	12.02	8.5
0.85	0.231	5.89	11.85	23.93	11.91
0.425	1.234	13.87	25.72	52.01	28.08
0.212	2.237	16.6	42.32	85.57	33.56
0.15	2.736	4.45	46.77	94.57	9
0.075	3.736	2.69	49.46	100.1	5.44

Table 5: Grain size analysis result for sample C

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.45	0.45	0.9	0.9
2.36	-1.238	0.76	1.21	2.42	1.52
1.18	-0.238	3.27	4.48	8.98	6.56
0.85	0.231	5.49	9.97	19.99	11.01
0.425	1.234	14.73	24.7	49.52	29.53
0.212	2.237	17.66	42.36	84.93	35.41
0.15	2.736	4.98	47.34	94.91	9.98
0.075	3.736	2.54	49.88	100	5.09

Table 6: Grain size analysis result for sample D

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.4	0.4	0.81	0.81
2.36	-1.238	1.46	1.86	3.76	2.95
1.18	-0.238	4.21	6.07	12.26	8.5
0.85	0.231	2.46	8.53	17.23	4.97
0.425	1.234	9.98	18.51	37.39	20.16
0.212	2.237	16.74	35.25	71.2	33.81
0.15	2.736	10.5	45.75	92.41	21.21
0.075	3.736	3.76	49.51	100.01	7.6

Table 7: Grain size analysis result for sample E

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	2.45	2.45	4.9	4.9
2.36	-1.238	1.03	3.48	6.96	2.06
1.18	-0.238	6.52	10	20	13.04
0.85	0.231	5.6	15.6	31.2	11.2
0.425	1.234	13.02	28.62	57.24	26.04
0.212	2.237	16.1	44.72	89.44	32.2
0.15	2.736	4.28	49	98	8.56
0.075	3.736	1	50	100	2

Table 8: Grain size analysis result for sample F

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.81	1.81	3.62	3.62
2.36	-1.238	2.43	4.24	8.48	4.86
1.18	-0.238	6	10.24	20.48	12
0.85	0.231	9.15	19.39	38.79	18.31
0.425	1.234	3.67	23.06	46.13	7.34
0.212	2.237	17.25	40.31	80.64	34.51
0.15	2.736	8.2	48.51	97.05	16.41
0.075	3.736	1.47	49.98	99.99	2.94

Table 9: Grain size analysis result for sample G

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.14	1.14	2.28	2.28
2.36	-1.238	3.28	4.42	8.93	6.65
1.18	-0.238	6.7	11.12	22.51	13.58
0.85	0.231	6.01	17.13	34.69	12.18
0.425	1.234	11.24	28.37	54.47	22.78
0.212	2.237	14.38	42.75	86.61	29.14
0.15	2.736	4.23	46.98	95.18	8.57
0.075	3.736	2.37	49.35	99.98	4.8

Table 10: Grain size analysis result for sample H

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.04	1.04	2.13	2.13
2.36	-1.238	2.41	3.45	7.06	4.93
1.18	-0.238	7.14	10.59	21.66	14.6
0.85	0.231	4.43	15.02	30.72	9.06
0.425	1.234	9.63	24.65	50.42	19.7
0.212	2.237	15.58	40.23	82.29	31.87
0.15	2.736	6.8	47.03	96.22	13.93
0.075	3.736	1.86	48.89	100.2	3.8

Table 11: Grain size analysis result for sample I

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.24	0.24	0.48	0.48
2.36	-1.238	0.95	1.19	2.4	1.92
1.18	-0.238	3.96	5.15	10.38	7.98
0.85	0.231	5.32	10.47	21.12	10.74
0.425	1.234	14.48	24.95	50.31	29.19
0.212	2.237	17.2	42.15	84.99	34.68
0.15	2.736	4.91	47.06	94.89	9.9
0.075	3.736	2.54	49.6	100.01	5.12

Table 12: Grain size analysis result for sample J

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	2.31	2.31	4.63	4.63
2.36	-1.238	3.81	6.12	12.27	7.64
1.18	-0.238	5.12	11.24	22.53	10.26
0.85	0.231	9.82	21.06	42.21	19.68
0.425	1.234	3.54	24.6	49.31	7.1
0.212	2.237	17.21	41.81	83.81	34.5
0.15	2.736	5.03	46.82	93.89	10.08
0.075	3.736	3.07	49.89	100.04	6.15

Table 13: Grain size analysis result for sample K

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.85	0.85	1.73	1.73
2.36	-1.238	1.74	2.59	5.27	3.54
1.18	-0.238	6.41	9	18.32	13.05
0.85	0.231	5.24	14.24	28.99	10.67
0.425	1.234	12.18	26.42	53.79	24.8
0.212	2.237	15.43	41.85	85.21	31.42
0.15	2.736	4.35	46.2	94.07	8.86
0.075	3.736	2.92	49.12	100.02	5.95

Table 14: Grain size analysis result for sample L

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	2.25	2.25	4.56	4.56
2.36	-1.238	2.77	5.02	10.17	5.61
1.18	-0.238	6.82	11.84	23.98	13.81
0.85	0.231	9.49	21.33	43.19	19.21
0.425	1.234	4.42	25.75	52.14	8.95
0.212	2.237	12.93	36.68	78.32	26.18
0.15	2.736	9.73	48.41	98.02	19.7
0.075	3.736	0.98	49.39	100	1.98

Table 15: Grain size analysis result for sample M

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.44	1.04	2.1	2.1
2.36	-1.238	2.41	3.45	6.97	4.87
1.18	-0.238	7.14	10.59	21.4	14.43
0.85	0.231	4.43	15.02	30.35	8.95
0.425	1.234	9.63	24.65	49.82	19.47
0.212	2.237	15.58	40.23	81.31	31.49
0.15	2.736	6.88	47.03	95.21	13.9
0.075	3.736	1.96	49.47	97.23	2.02

Table 16: Grain size analysis result for sample N

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.95	1.95	3.93	3.93
2.36	-1.238	2.43	4.38	8.83	4.9
1.18	-0.238	6.54	10.93	22.02	13.19
0.85	0.231	10.02	20.95	42.23	20.21
0.425	1.234	3.89	24.84	50.08	7.85
0.212	2.237	14.46	39.3	79.25	29.17
0.15	2.736	9.03	48.33	97.46	18.21
0.075	3.736	1.25	49.58	99.98	2.52

Table 17: Grain size analysis result for sample O

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.39	0.39	0.78	0.78
2.36	-1.238	1.08	1.47	2.95	2.17
1.18	-0.238	6.95	8.42	16.91	13.96
0.85	0.231	5.84	14.26	28.64	11.73
0.425	1.234	12.26	26.52	53.26	24.62
0.212	2.237	16.34	42.86	86.07	32.81
0.15	2.736	4.12	46.98	94.34	8.27
0.075	3.736	2.82	49.8	100	5.66

Table 18: Grain size analysis result for sample P

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.54	1.54	3.19	3.19
2.36	-1.238	3	4.54	9.4	6.21
1.18	-0.238	5.95	10.49	21.71	12.31
0.85	0.231	10.9	21.39	44.26	22.55
0.425	1.234	4.68	26.07	53.94	9.68
0.212	2.237	16.94	43.01	88.99	35.05
0.15	2.736	4.2	47.21	97.68	8.69
0.075	3.736	1.12	48.33	100	2.32

Table 19: Grain size analysis result for sample Q

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.55	0.55	1.1	1.1
2.36	-1.238	2.62	3.17	6.34	5.24
1.18	-0.238	6	9.17	18.34	12
0.85	0.231	5.83	15	30.01	11.67
0.425	1.234	11.61	26.61	53.25	23.24
0.212	2.237	16.55	43.16	86.38	33.13
0.15	2.736	3.93	47.09	94.25	7.87
0.075	3.736	2.87	49.96	99.95	5.7

Table 20: Grain size analysis result for sample R

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.3	0.3	0.6	0.6
2.36	-1.238	2.07	2.37	4.74	4.14
1.18	-0.238	5.28	7.65	15.3	10.56
0.85	0.231	5.55	13.2	26.4	11.1
0.425	1.234	11.11	24.31	48.62	22.22
0.212	2.237	18.49	43.3	85.6	36.98
0.15	2.736	4.73	48.03	95.06	9.46
0.075	3.736	2.5	50	100.06	5

Table 21: Grain size analysis result for sample S

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	1.97	1.97	4.02	4.02
2.36	-1.238	3.26	5.23	10.67	6.65
1.18	-0.238	5.95	11.18	22.81	12.14
0.85	0.231	10.9	22.08	45.05	22.24
0.425	1.234	4.68	26.76	54.6	9.55
0.212	2.237	16.94	43.7	89.16	34.56
0.15	2.736	4.2	47.9	97.73	8.57
0.075	3.736	1.12	49.02	100.02	2.29

Table 22: Grain size analysis result for sample T

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0	0	0	0
2.36	-1.238	1.27	1.27	2.58	2.58
1.18	-0.238	6.63	7.9	16.05	13.49
0.85	0.231	9.96	17.86	36.31	20.26
0.425	1.234	8.92	26.78	54.46	18.15
0.212	2.237	14.01	40.79	82.96	28.5
0.15	2.736	5.1	45.89	93.34	10.38
0.075	3.736	3.26	49.15	99.97	6.63

Table 23: Grain size analysis result for sample U

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0	0	0	0
2.36	-1.238	0.74	0.74	1.5	1.5
1.18	-0.238	3.98	4.72	9.55	8.05
0.85	0.231	4.86	9.58	19.38	9.83
0.425	1.234	14.43	24.01	48.56	29.18
0.212	2.237	16.96	40.97	82.85	34.29
0.15	2.736	5.47	46.44	93.91	11.06
0.075	3.736	3.02	49.46	100.02	6.11

Table 24: Grain size analysis result for sample V

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0	0	0	0
2.36	-1.238	0.31	0.31	0.63	0.63
1.18	-0.238	3.03	3.34	6.75	6.12
0.85	0.231	7.86	11.2	22.7	15.95
0.425	1.234	9.95	21.15	42.89	20.19
0.212	2.237	15.59	36.74	74.52	31.63
0.15	2.736	10.64	47.38	96.11	21.59
0.075	3.736	1.91	49.29	99.99	3.88

Table 25: Grain size analysis result for sample W

Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0.33	0.33	0.67	0.67
2.36	-1.238	1.08	1.41	2.86	2.19
1.18	-0.238	4.21	5.62	11.4	8.54
0.85	0.231	5.42	11.04	22.39	10.99
0.425	1.234	14.82	25.86	52.44	30.05
0.212	2.237	16.05	41.91	84.99	32.55
0.15	2.736	4.54	46.45	94.19	9.2
0.075	3.736	2.86	49.31	99.99	5.8

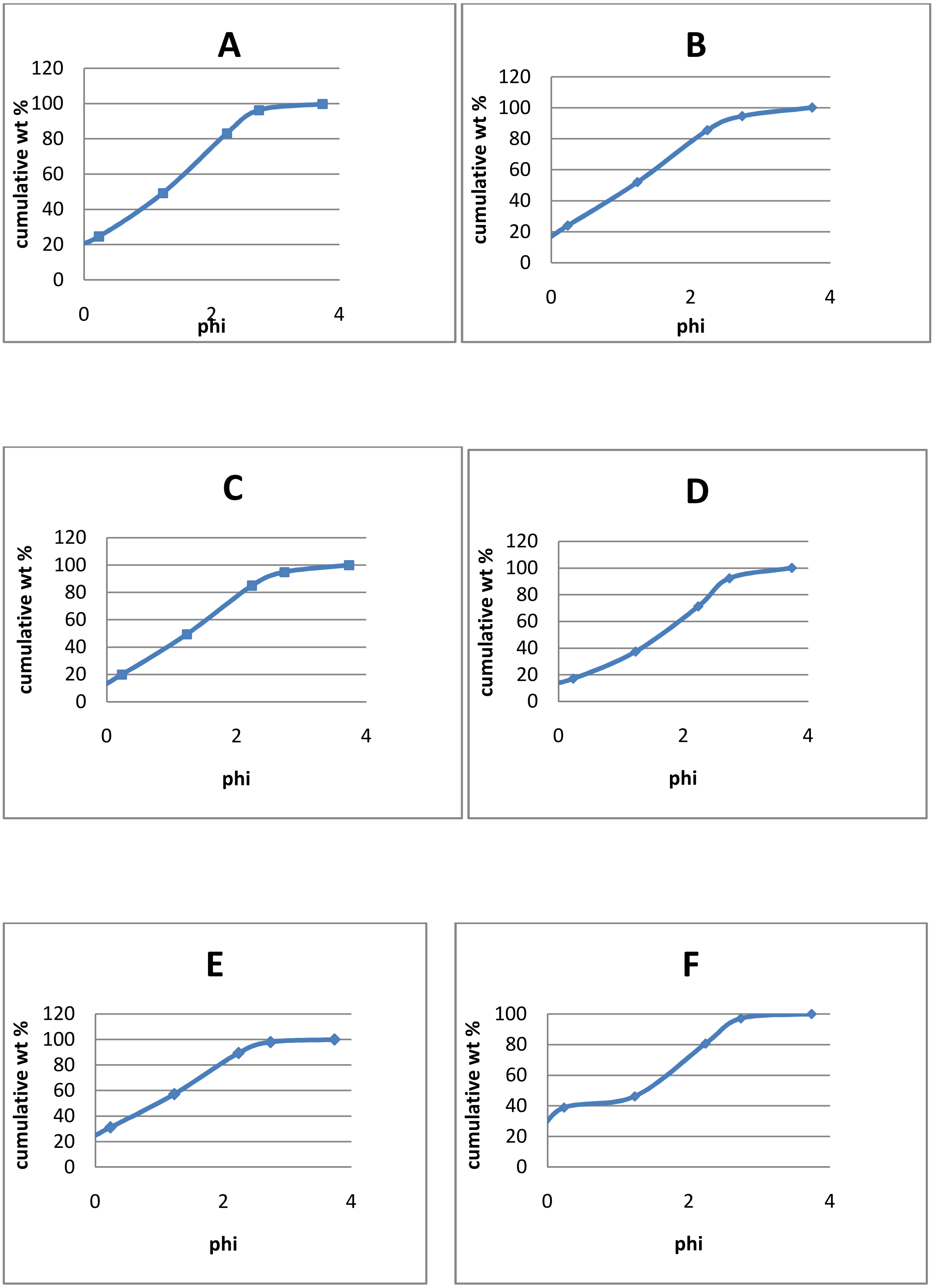
Table 26: Grain size analysis result for sample X

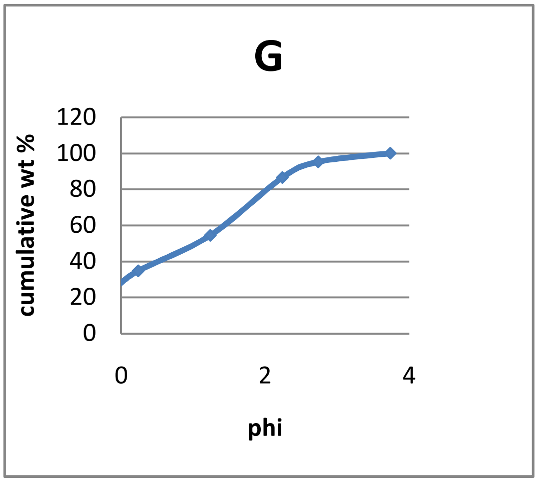
Sieve size(mm)	Phi(Φ)	weight(g)	Cumulative weight(g)	Cumulative weight(%)	Weight retained %
4.75	-2.247	0	0	0	0
2.36	-1.238	0.33	0.33	0.66	0.66
1.18	-0.238	3.28	3.61	7.26	6.6
0.85	0.231	7.68	11.29	22.72	15.46
0.425	1.234	10.18	21.47	43.21	20.49
0.212	2.237	15.62	37.09	74.65	31.44
0.15	2.736	10.35	47.44	95.48	20.83
0.075	3.736	2.24	49.68	99.99	4.51

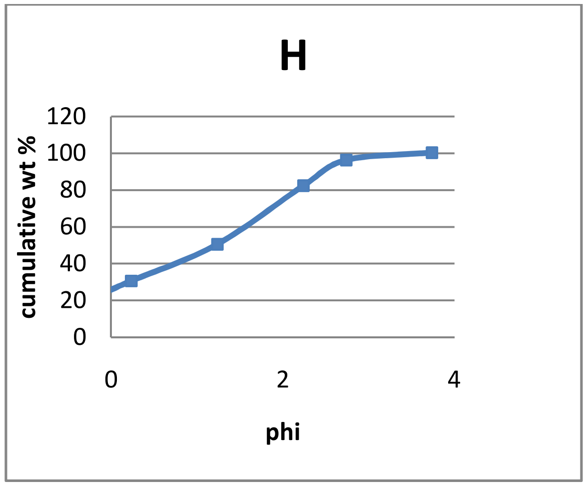
Table 27: RESULT OF HEAVY MINERAL SEPARATION

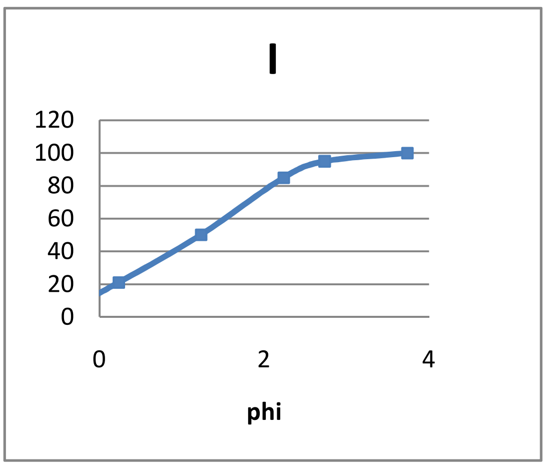
Sample	Z	T	R	E	A	G	S	OP
B	14	6	11	4	3	5	14	73
C	16	10	8	5	4	7	16	79
F	14	8	12	2	2	9	12	77
I	11	9	10	3	3	4	14	76
K	10	8	14	3	3	6	13	78
M	12	9	9	3	3	8	12	75
O	12	10	8	4	4	3	11	78
Q	11	6	10	2	2	8	14	79
R	16	9	14	4	3	4	10	70
U	19	7	12	4	2	3	14	78
W	11	9	14	3	4	5	12	78
X	9	7	9	5	3	6	10	76

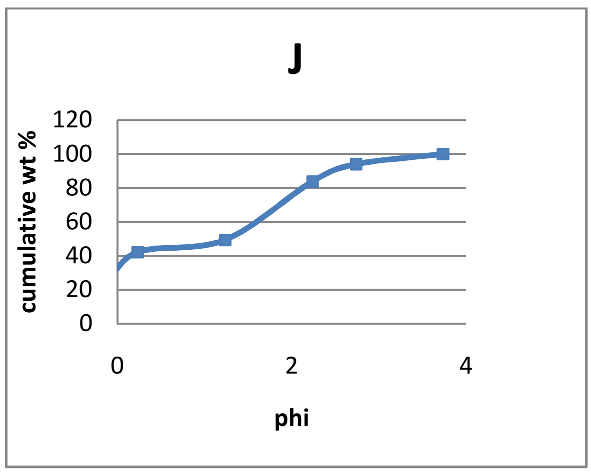
Note: Z-zircon, T-tourmaline, R-rutile, E-epidote, A-apatite, G-garnet, S-staurolite, Op- opaque mineral

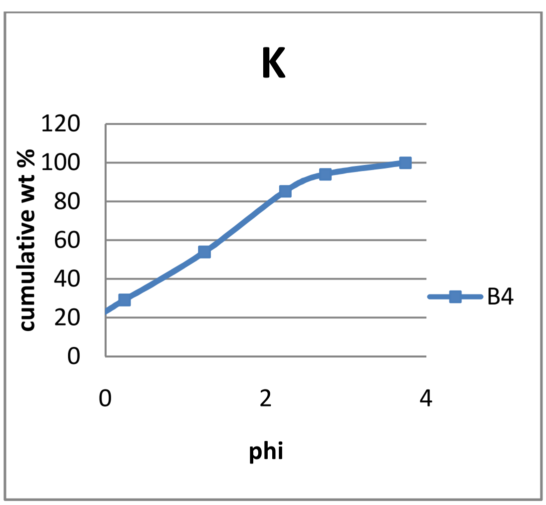

A
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
B
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
C
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
D
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
E
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
F
cumulative wt %
100
80
60
40
20
0
0
2
4
phi

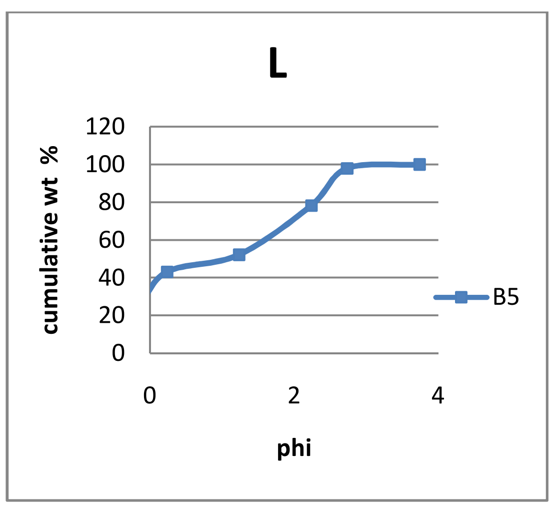

G
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi

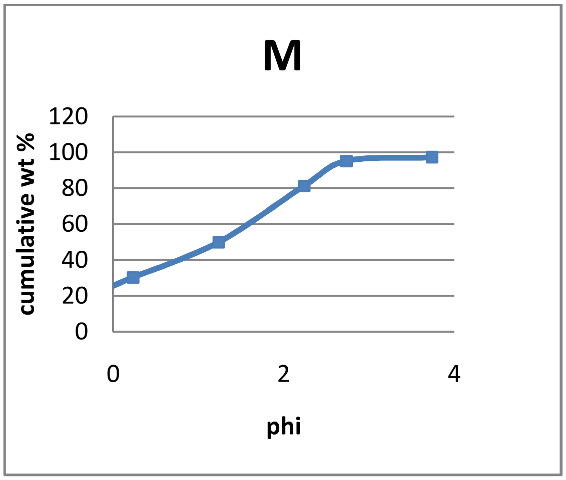

H
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi

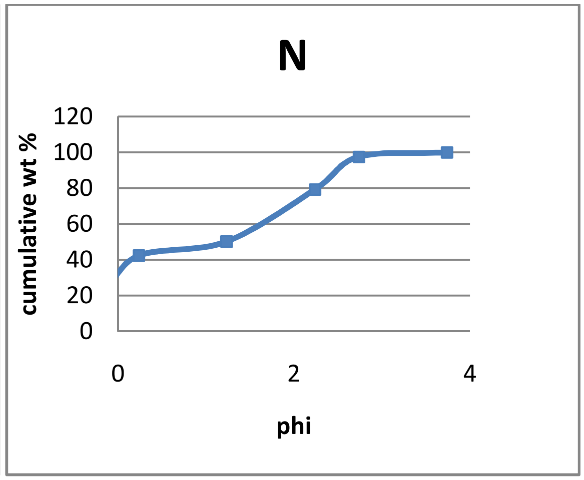

I
120
100
80
60
40
20
0
0
2
4
phi

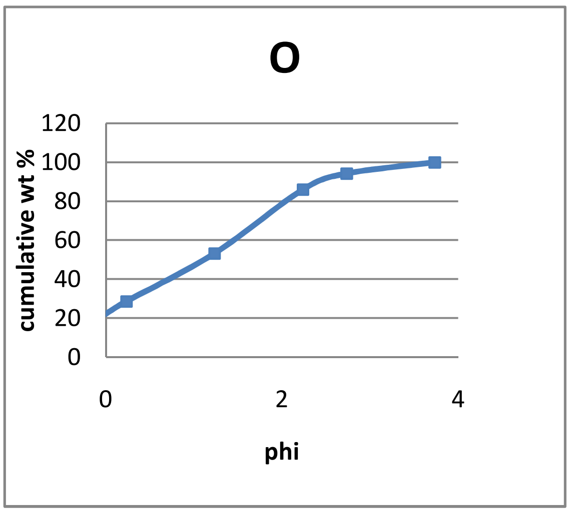

J
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi

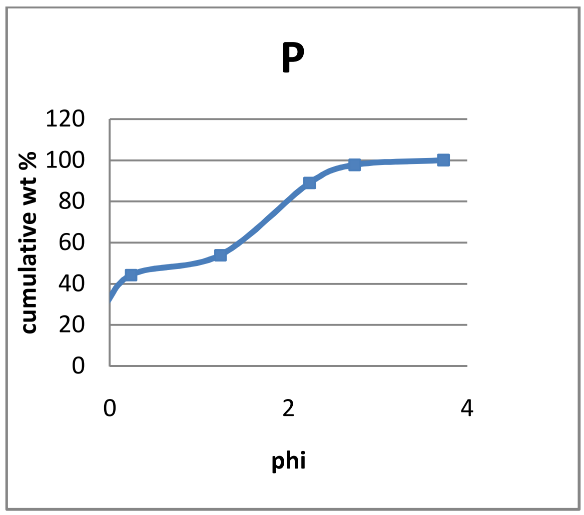

K
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
B4

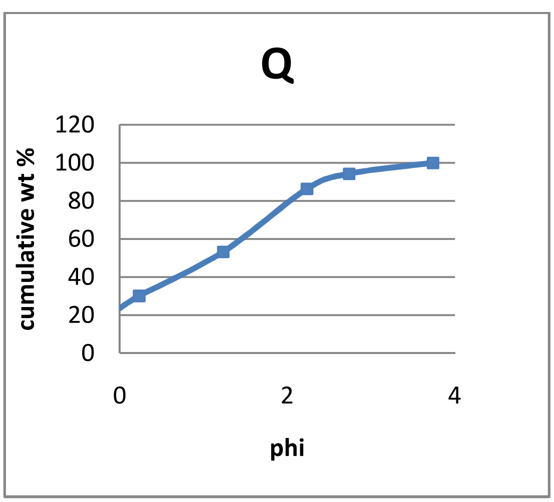

L
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi
B5

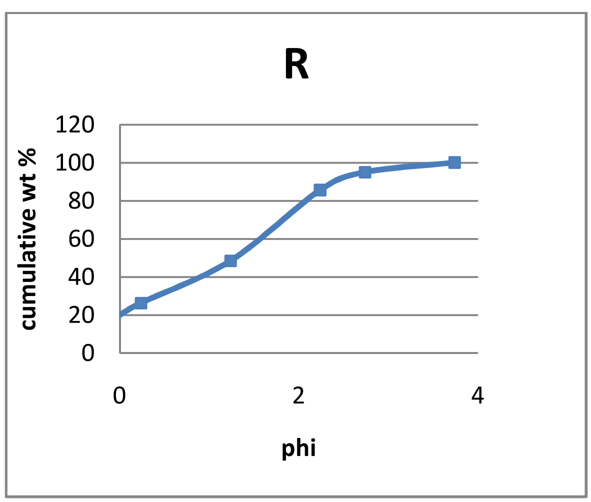

M
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi


N
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi


O
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi


P
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi


Q
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi


R
cumulative wt %
120
100
80
60
40
20
0
0
2
4
phi

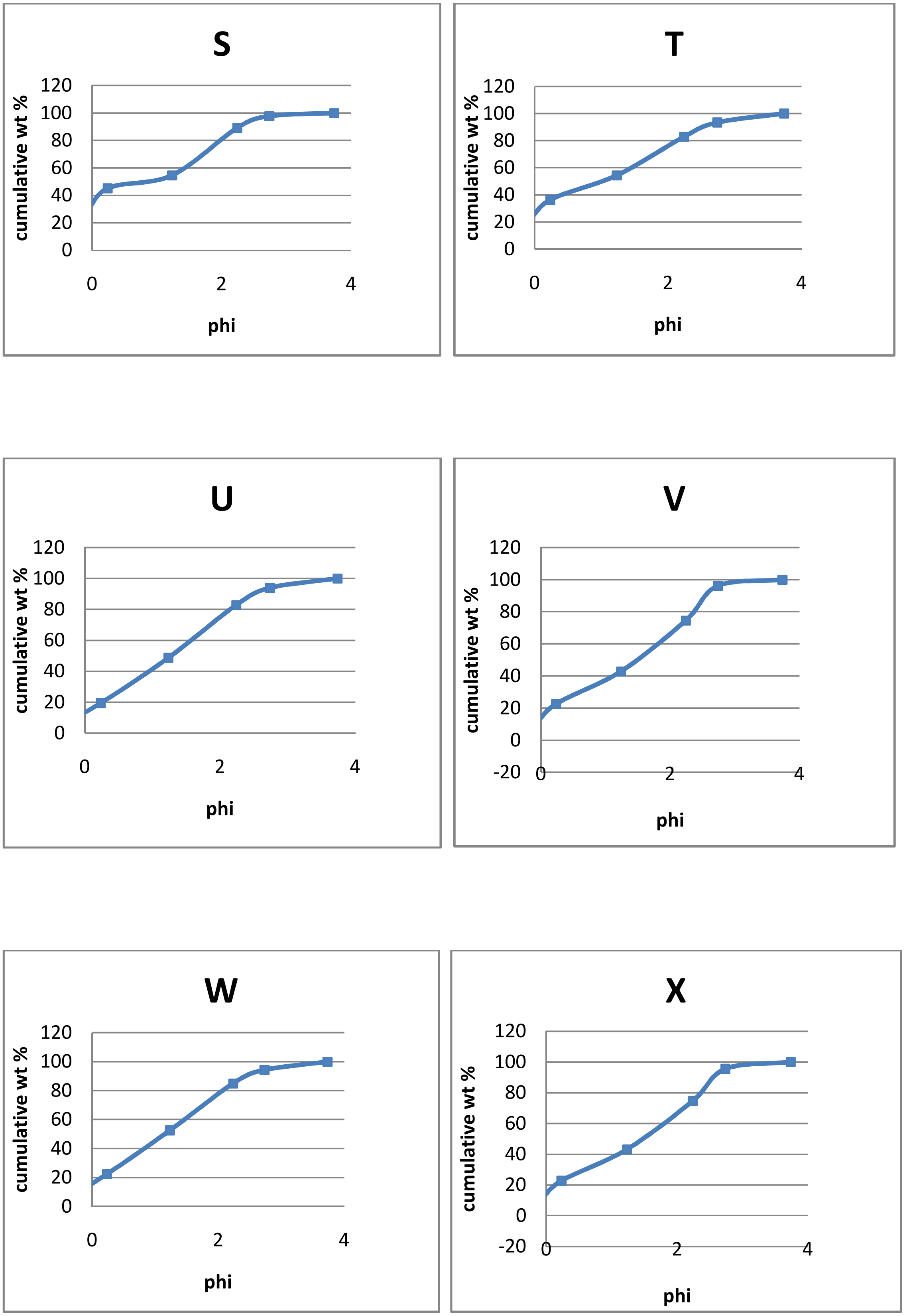
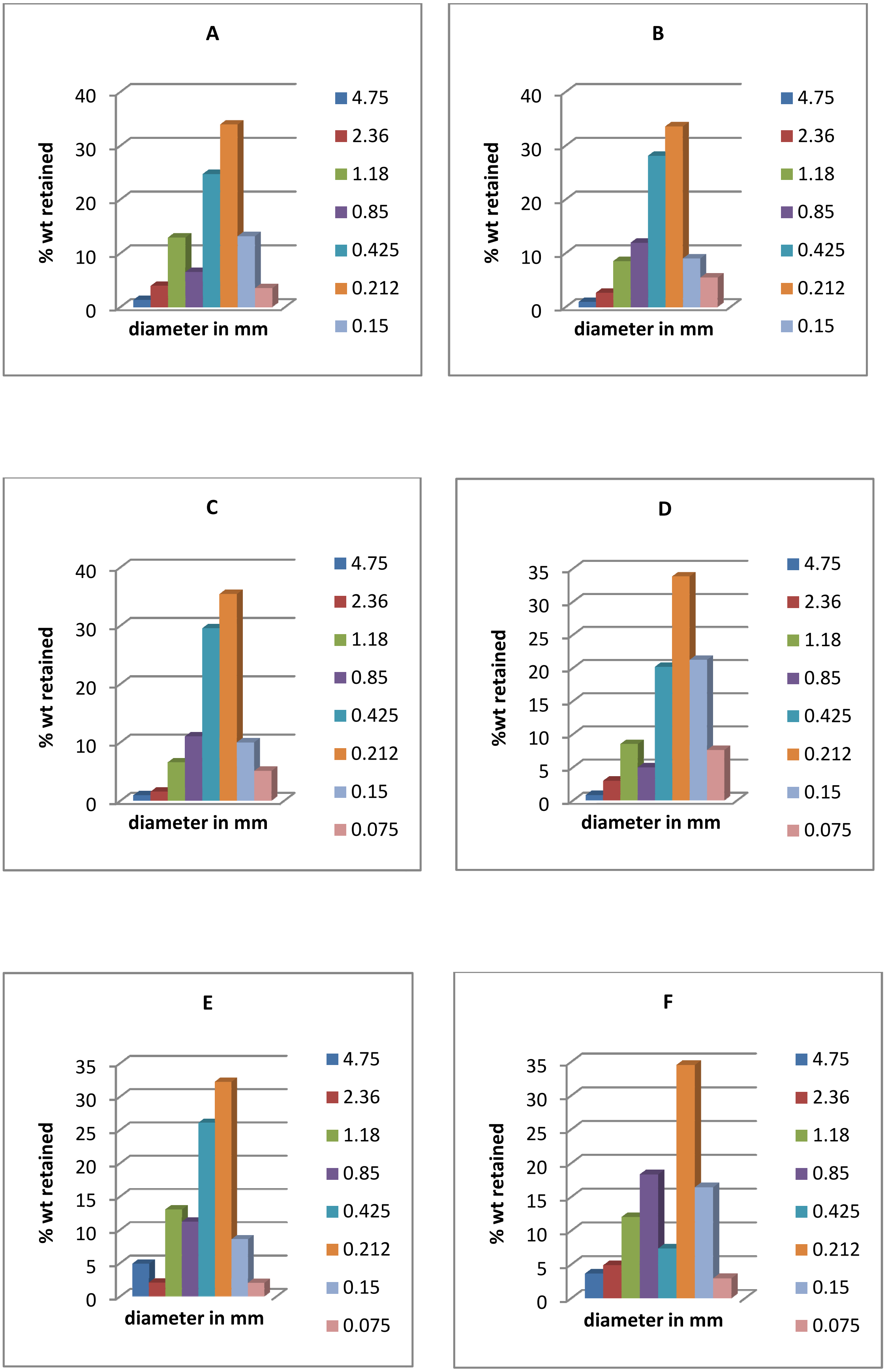
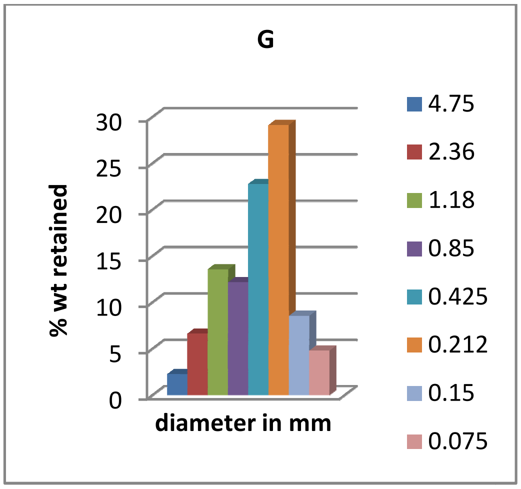
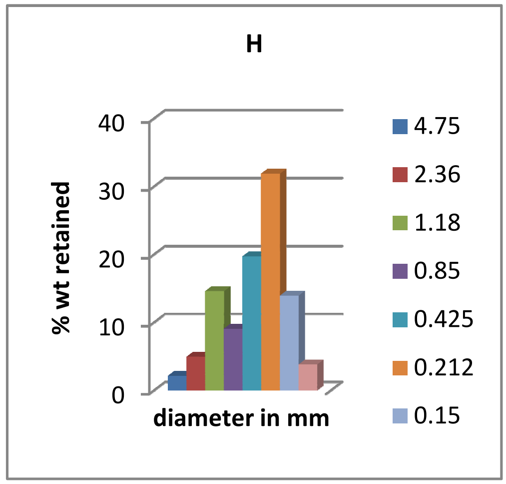
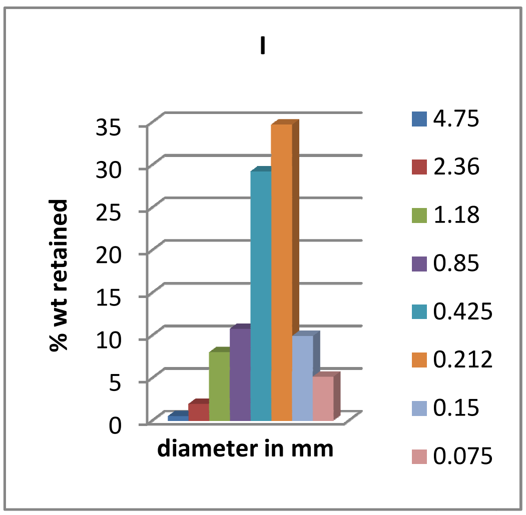


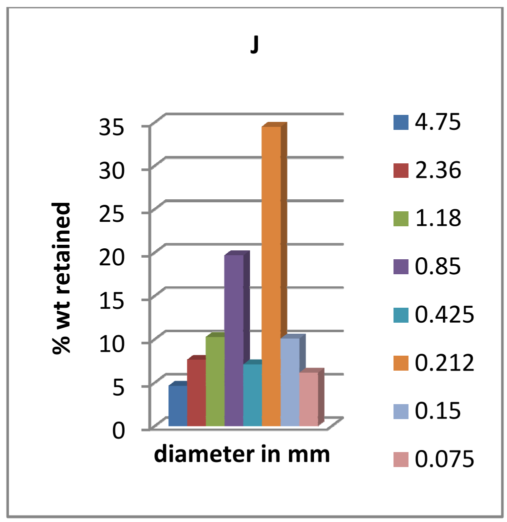
Fig.10: Cumulative percentage plots of the sediment samples A-X

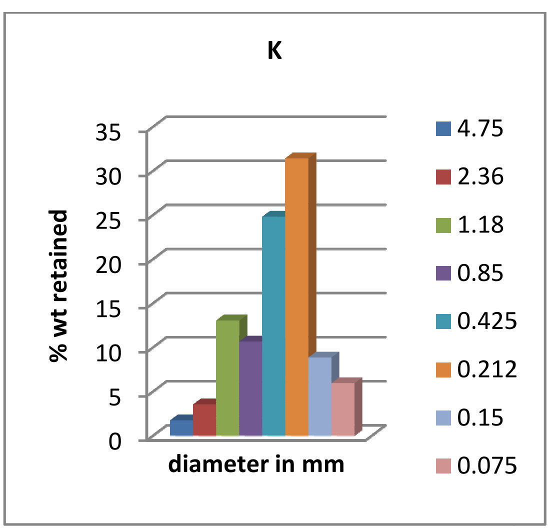

A
B
C
D
E
F
% wt retained
%wt retained
diameter in mm
0
5
10
15
20
25
30
35
40
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

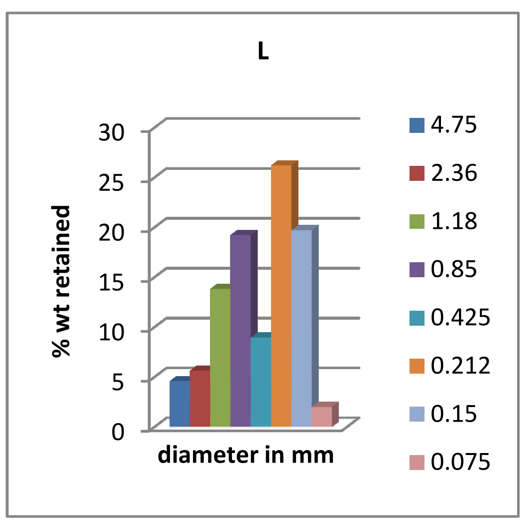

G
% wt retained
30
25
20
15
10
5
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

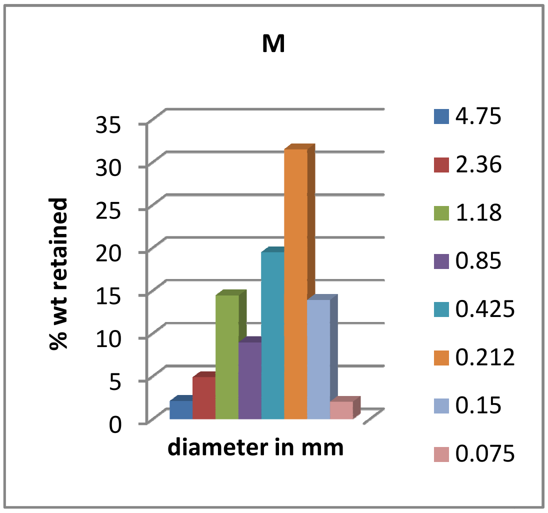

H
% wt retained
40
30
20
10
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15

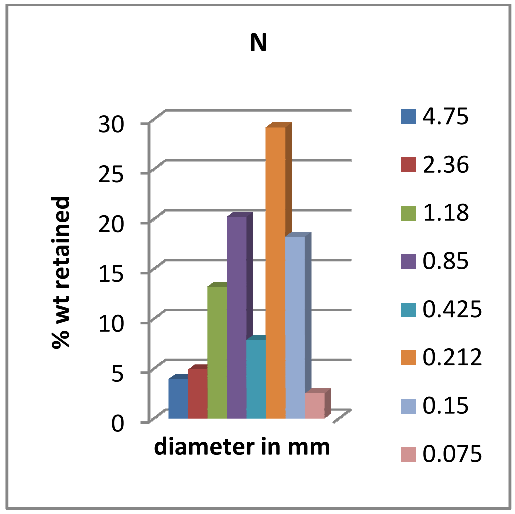

I
% wt retained
35
30
25
20
15
10
5
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

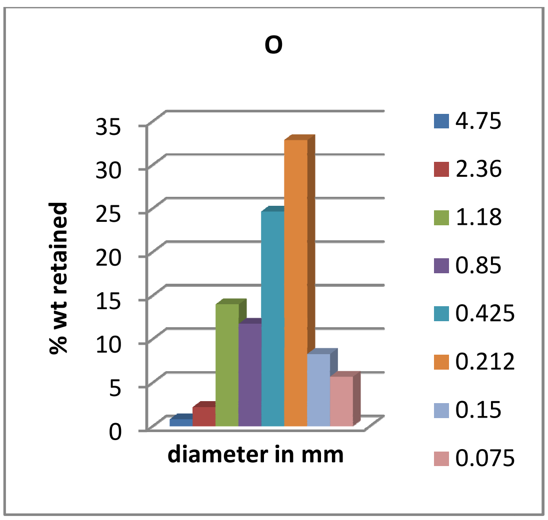

J
% wt retained
35
30
25
20
15
10
5
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

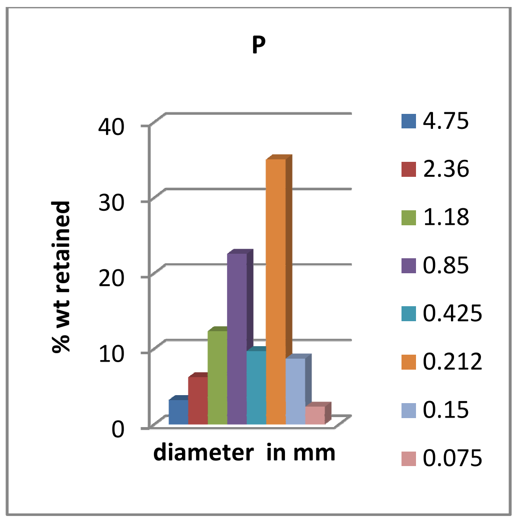

K
% wt retained
35
30
25
20
15
10
5
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

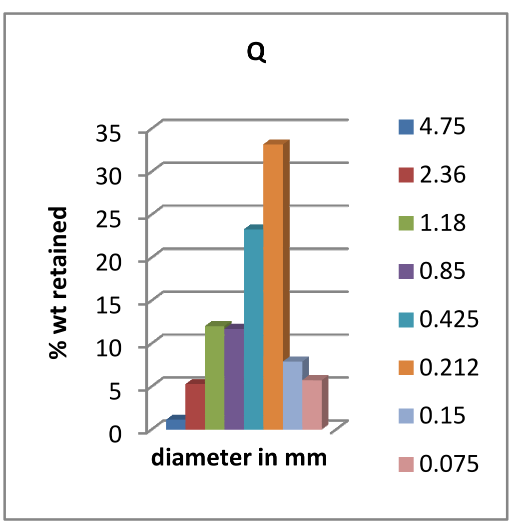

L
% wt retained
30
25
20
15
10
5
0
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

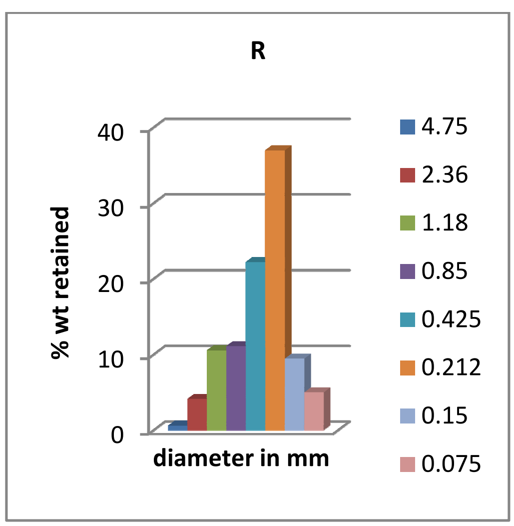

M
35
30
25
20
15
10
5
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075


N
30
25
20
15
10
5
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075


O
35
30
25
20
15
10
5
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075


P
40
30
20
10
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075


Q
35
30
25
20
15
10
5
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075


R
40
30
20
10
0
% wt retained
diameter in mm
4.75
2.36
1.18
0.85
0.425
0.212
0.15
0.075

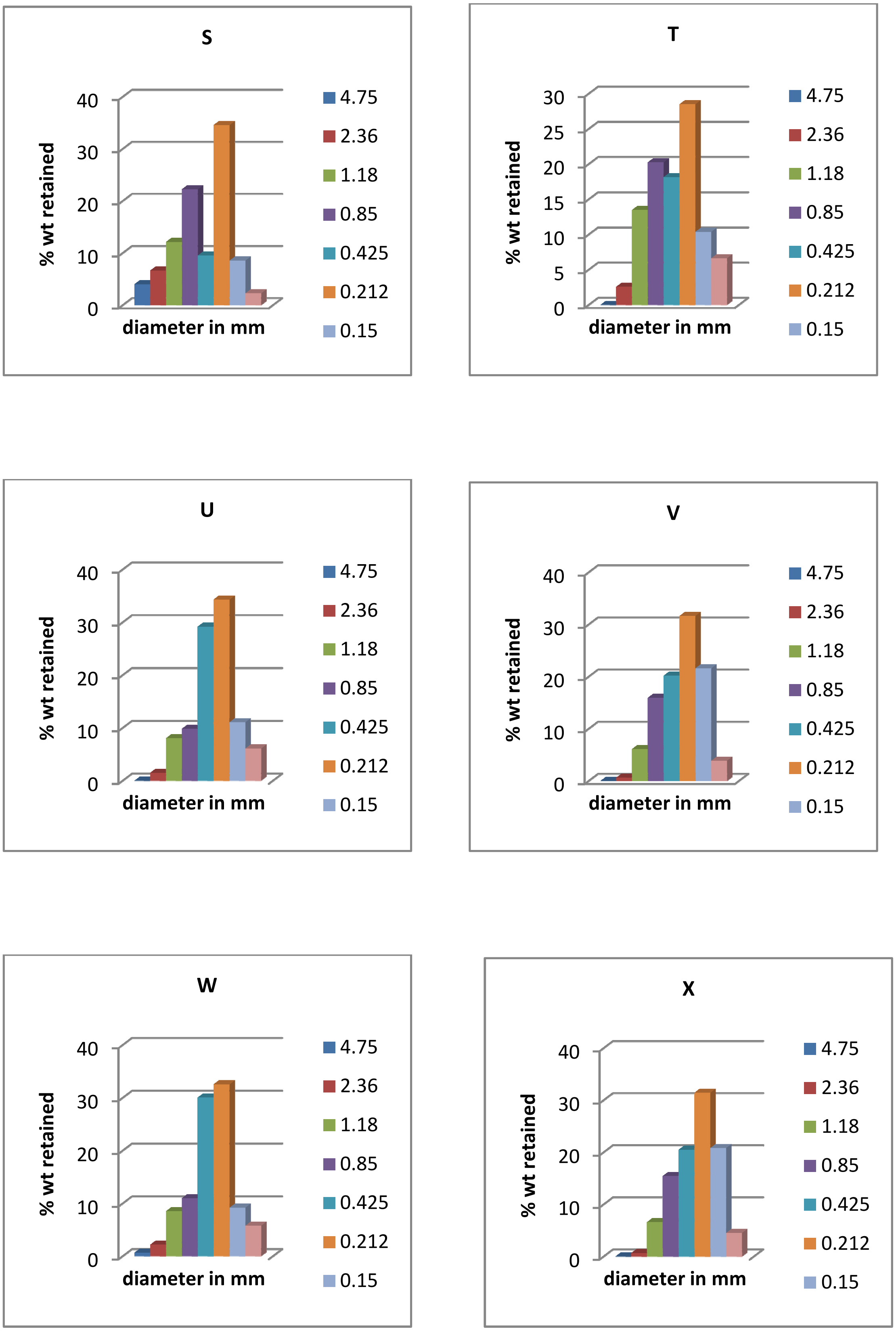


Fig.11: Histograms showing percentage proportion of grain size in each sediment samples A-X

Table 28: SUMMARY OF THE GRAIN SIZE ANALYSIS OF THE SAMPLES

Sample no.	GRAINSIZE (mean)		Standard Deviation/Sorting		KURTOSIS	
	Result	Remark	Result	Remark	Result	Remark
A	0.6	Coarse sand	0.60	Moderately well sorted	8.61	Extremely Leptokurtic
B	0.63	Coarse sand	0.43	Well sorted	1.31	Leptokurtic
C	0.53	Coarse sand	0.38	Well sorted	1.32	Leptokurtic
D	0.52	Coarse sand	0.52	Moderately well sorted	1.72	Very Leptokurtic
E	0.75	Coarse sand	0.77	Moderately sorted	4.3	Extremely Leptokurtic
F	0.73	Coarse sand	0.83	Moderately sorted	1.74	Very leptokurtic
G	0.78	Coarse sand	0.82	Moderately sorted	1.56	Very leptokurtic
H	0.68	Coarse sand	0.70	Moderately well sorted	1.18	Leptokurtic
I	0.5	Medium grained	0.86	Moderately sorted	1.35	Leptokurtic
J	0.78	Coarse sand	1.0	Moderately sorted	1.98	Very leptokurtic
K	0.68	Coarse sand	0.59	Moderately well sorted	1.26	Leptokurtic
L	0.78	Coarse sand	0.95	Moderately sorted	1.68	Very Leptokurtic
M	0.72	Coarse sand	0.77	Moderately Sorted	1.46	Leptokurtic
N	0.72	Coarse sand	0.89	Moderately sorted	1.47	Leptokurtic

Table 28 continues

O	0.62	Coarse sand	0.53	Moderately well sorted	1.10	Mesokurtic
P	0.87	Coarse sand	0.86	Moderately sorted	2.13	Very Leptokurtic
Q	0.67	Coarse sand	0.61	Moderately well sorted	2.19	Very Leptokurtic
R	0.62	Coarse sand	0.53	Moderately well sorted	0.96	Mesokurtic
S	0.77	Coarse sand	0.95	Moderately sorted	1.81	Very Leptokurtic
T	0.62	Coarse sand	0.51	Moderately well sorted	3.47	Extremely Leptokurtic
U	0.53	Coarse sand	0.42	Well sorted	1.30	Leptokurtic
V	0.34	Medium grained	0.36	Well sorted	1.02	Mesokurtic
W	0.62	Coarse sand	0.47	Well sorted	1.12	Leptokurtic
X	0.43	Medium grained	0.32	Very well sorted	1.35	Leptokurtic

PHOTOMICROGRAPH OF THE HEAVY MINERAL SLIDES

Photographs of heavy minerals are presented in plates 1 and 2. Heavy mineral assemblages identified are zircon, tourmaline, rutile, epidote, apatite, garnet, staurolite and opaque mineral.

From the computed indices in terms of percentage zircon-tourmaline-rutile index (ZTR) vary between 33% - 56%, apatite-tourmaline index (ATI) vary between 22.22% - 40%, garnet-zircon index (GZI) vary between 13.64% - 42.10%, rutile-zircon index (RuZI) vary between 33.33% - 58.33%, staurolite-zircon index (SZI) vary between 38.46% - 56.52% as shown in table 29. The average overall ZTR index is 46.2%, consequently the sands are mineralogically immature to submature

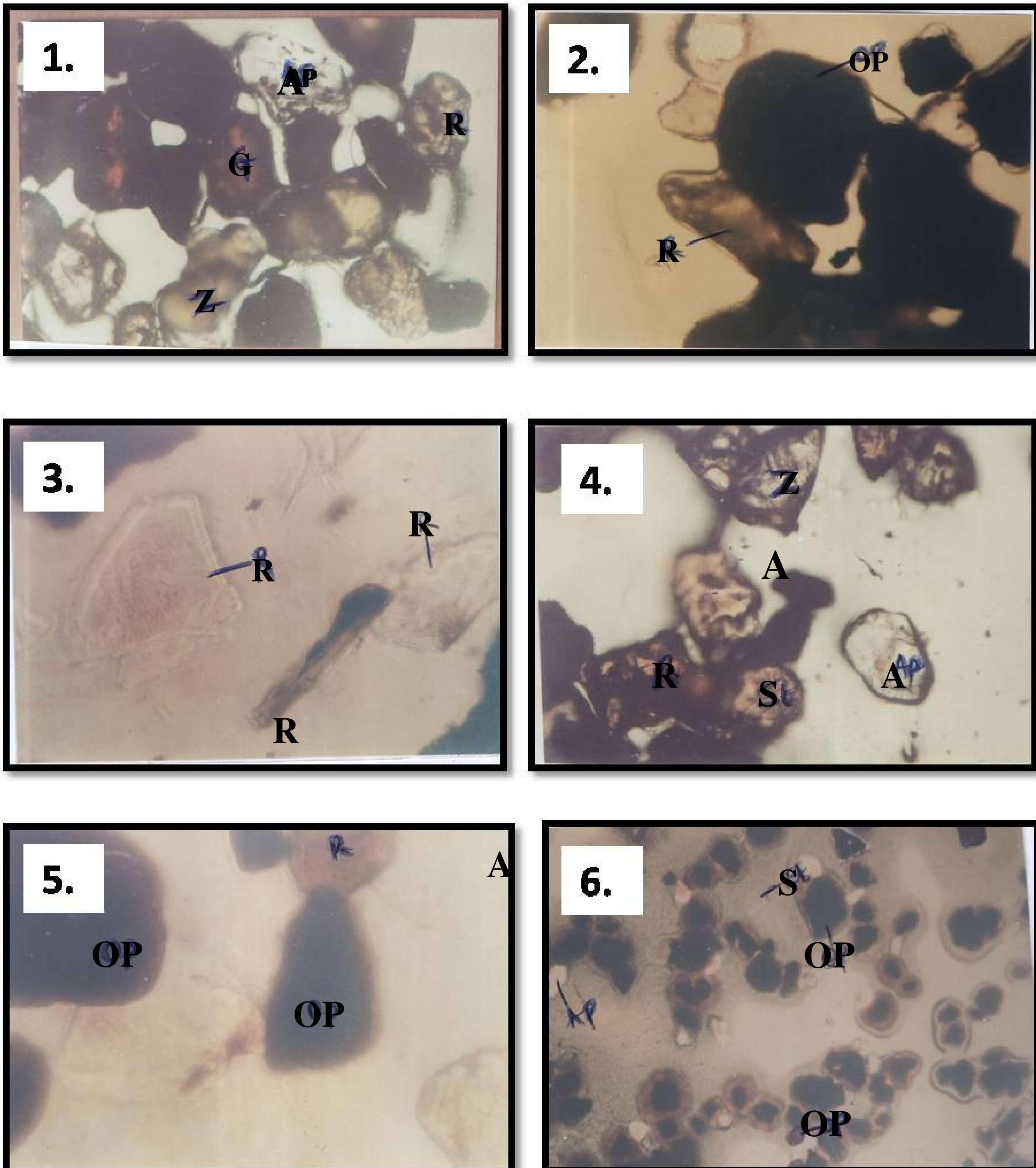


Plate 1: Photomicrograph of sediment samples (B,C, F, I, K, M)
Note; Z-zircon, G-garnet, R- rutile, A- apatite, T- tourmaline , S- staurolite, Op- opaque mineral

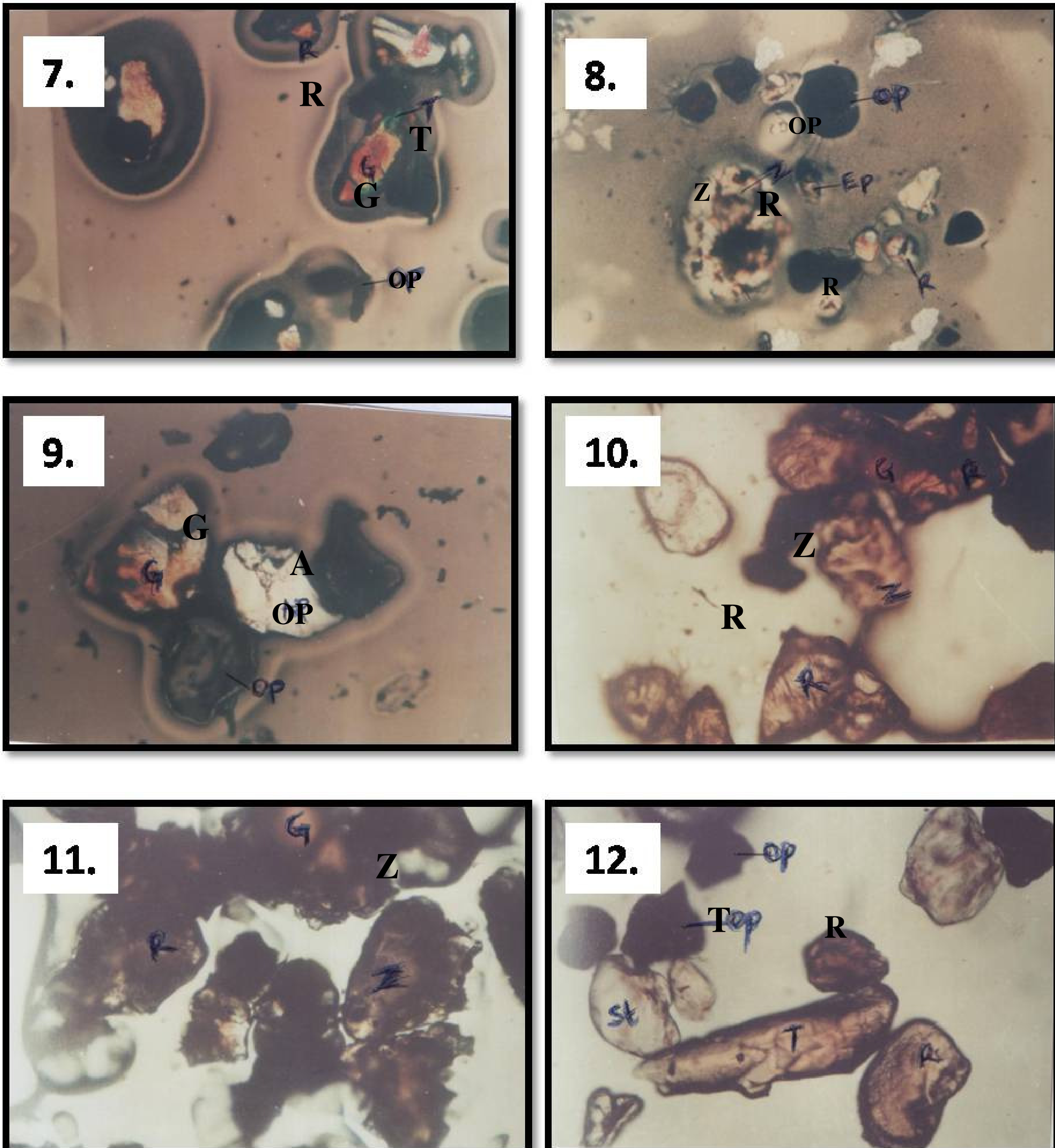


Plate 2: photomicrograph of sediment samples (O, Q, R, U, W, X)
Note; Z-zircon, G-garnet, R- rutile, A- apatite, T- tourmaline, S- staurolite, Op- opaque mineral

Table 29: SUMMARY OF HEAVY MINERAL INDEX

Sample.	ATI % apatite in total of apatite plus tourmaline	GZI % garnet in total of garnet plus zircon	RuZI % rutile in total of rutile plus zircon	SZI % staurolite in total of staurolite plus zircon	ZTR INDEX (%)
B	33.3	26.32	44	50	42
C	40	30.43	33.33	44.44	43
F	20	39.13	46.15	46.15	44
I	25	26.67	47.62	56	40
K	27.27	37.5	58.33	56.52	41
M	25	40	42.86	50	40
O	28.57	20	40	47.83	38
Q	25	42.10	47.61	56	34
R	25	20	46.67	38.46	56
U	22.22	13.64	38.71	42.42	49
W	30.77	31.25	56	52.17	44
X	30	40	50	52.63	33

Note: ATI(apatite,tourmaline index),GZI(garnet,zircon index), RuZI(rutile,zircon index), SZI(staurolite,zircon index), ZTR(zircon,tourmaline,rutile index)

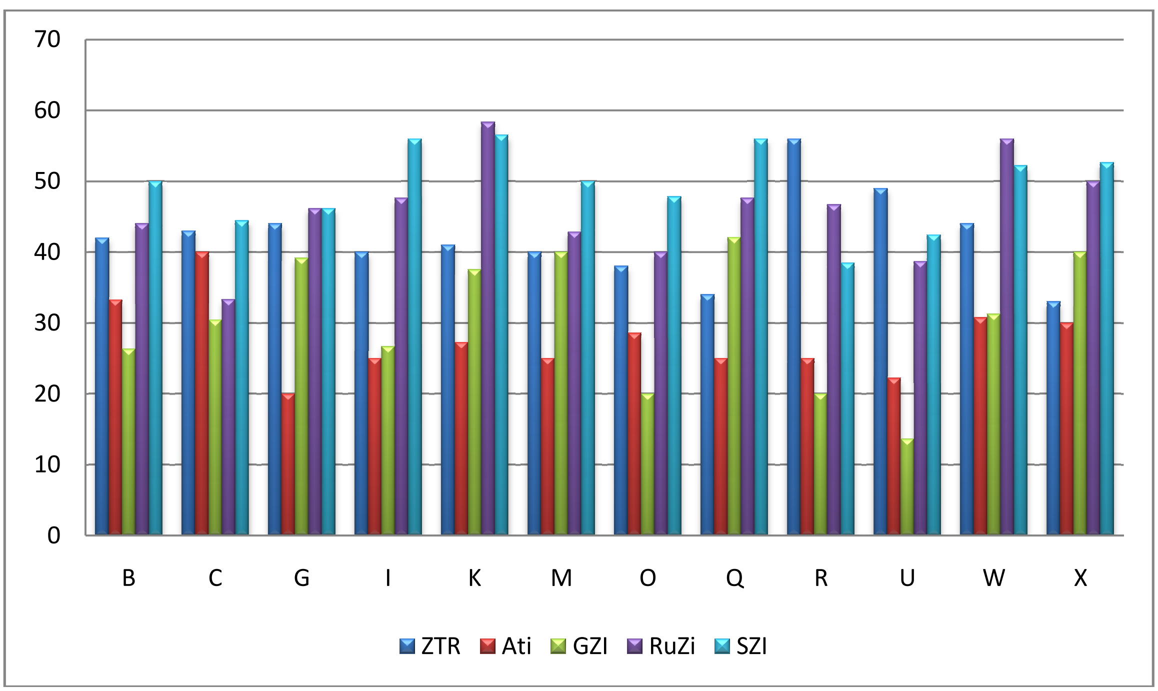


Fig.12: Bar chart showing overall proportion of the heavy mineral index

DISCUSSION

TRANSPORTATION HISTORY OF THE SEDIMENTS

From the summary of the grain size analysis in table 28, four (4) main categories of classification were established these are Very well sorted, well sorted, moderately well sorted and moderately sorted. Results of grain size statistical analysis indicate average mean of 0.65 which corresponds to the coarse grained sands. An average (standard deviation) sorting of 0.66 which shows that the sediments are moderately well sorted .

In the cumulative curves F, G, J, L, N, P, S express a somewhat similar curve which is a reflection of the distance of transportation energy and environment of deposition and are categorized under the moderately sorted sediments. The Ijebu-Ife sediments were mainly within the very well sorted and well sorted based on the statistical calculation and on the probability curve exhibit two (2) segments of mechanical transportation mechanisms which is the bedload and saltation. This could be attributed to consistent high energy system that was capable of removing the fine grain particles that were initially present. However, some parts of the Ijebu-Omu (A and B) samples show similar features.

The locations A, D, H, K, O, Q, R, and T are associated with moderately well sorted phenomenon and this laterally implies that there is gradual maturity of sediments.

Generally, there are locations with two and three segments on the probability curves, apart from Ijebu Ife sediments that are characterized with two arm segments, all other samples are represented with three arm segments (bedload, saltation and suspension).

Therefore, the sediments with the two arm segment were affected by higher energy responsible for washing away of the fine grains from the coarser grained materials due to consistent supply of water that are not in flashes. They were probably deposited in marine environment associated with multi-directional current.

SOURCE AREA OF THE SEDIMENTS

The origin and transportation history of sediments can be inferred from the heavy mineral suites. Heavy mineral separation carried out on twelve (12) representative sediment samples show that the heavy mineral assemblage includes non-opaque minerals of zircon, tourmaline, rutile (ultra-stable), garnet, apatite, staurolite (stable), epidote and opaque mineral as shown in Table 27. The results show the presence of zircon, tourmaline, rutile, epidote, apatite, garnet, staurolite and opaque minerals which have values ranging from Z(9-19), T(6-10), R(8-14), E(2-5), A(2-4), G(3-9), S(10-16), OP(70-79) .

The weathering history of the sediments, calculated in terms of percentage zircon, tourmaline, rutile index(ZTR) varied between 33-56%, average apatite-tormaline index(ATI), garnet-zircon index (GZI), rutile-zircon index(RuZI) and staurolite-zircon index (SZI) values in all the locations are 27.7%, 30.6%, 46% and 50% respectively as shown in Table 29. .

Rutile has among the highest refractive indices of any known mineral and also exhibits high dispersion, the index result is highest in sediment sample K (Iloti) with 58.33%. Rutile is found as an accessory mineral in altered igneous rocks and in certain gneisses and schists. Staurolite has the second highest SZI index of 56.52% in the same location and is one of the index mineral and its importance is to estimate the temperature, pressure and depth of which rock undergoes metamorphism. Locations G, K, M, Q, X, have moderately low ATI and increased GZI, RuZI and SZI respectively .This is a diagnostic of a first order provenance. Since the humid tropical depositional environment is likely, the low ATI value present may be as a result of loss of these minerals through weathering and their unstable nature. However, staurolite and rutile are stable under such circumstances and thus the mineralogical changes are at least partly due to a change in provenance. Staurolite is a regional metamorphic mineral of intermediate to high grade.

The calculated ZTR index varied in each location, 42-44% (Ijebu-Omu), 40-41% (Iloti), 34-56% (Itele), 33-49% (Ijebu-Ife) as shown in table 29. The average overall ZTR index is 46.2% which implies that the sediments are mineralogically immature to submature. According to Hubert (1962) scheme, ZTR < 75% are mineralogically immature to sub mature; ZTR> 75% are mineralogically mature. Zircon is a common and widespread accessory mineral in all types of igneous rocks and detrital deposits derived from these rocks. Transparent non-micaceous heavy mineral assemblage of quartz are predominantly zircon, tourmaline and rutile and this grains are ultimately concentrated in sandstone by prolong abrasion.

CONCLUSION AND RECOMMENDATION

The average statistical mean (textural maturity), standard deviation (sorting) and kurtosis determined from the grainsize data are 0.65, 0.66, and 1.35 respectively. Textural study indicates that the sediments are leptokurtic, moderately well sorted coarse sands. The sediments were probably deposited in a marine environment associated with multi-directional current. Sediments with grain size diameter 0.212mm dominate in all the samples. This shows that the sediments are composed of sand with clay content

The presence of staurolite, garnet and rutile occuring in fairly large quantities is an indication of metamorphic and igneous rock source and an avarage ZTR index of 46.2% indicates that the sediments are mineralogically immature. The high value of SZI indicates sediments with a fairly short transportation history and the low ATI value is a characteristic of the unstable nature of apatite and tourmaline that has been affected by weathering. According to modification of heavy mineral association and provenance by Feo-codecido (1956) the presence of zircon, rutile and tourmaline indicates an acid igneous rock source of the sediments. Relatively, the presence of staurolite, rutile and garnet occur in fairly large quantities with respect to apatite and tourmaline, which are indicative of metamorphic rock source. The highest value of ZTR (56.0%) is recorded in Itele outcrop while the lowest value (33%) is recorded in Ijebu-Ife.

The knowledge of particle size distribution and the assemblages of heavy minerals make it possible to locate and use essential minerals; however, further geophysical investigation should be carried out in the area using electrical resistivity tomography to correlate the stratigraphic equivalent of the basin.

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