International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Depositional Environment and Geochemical Classification of Ilaro Sandstone, Dahomey Basin, Southwestern Nigeria

Olusola Christopher Oduneye[a*], Adegoke Olukayode Afolabi[b]

[a,b]*Department of Earth Sciences, Ladoke Akintola University of Technology Ogbomoso, 210214. Nigeria*
[a]*Email: christodus01@yahoo.com*
[b]*Email : aoafolabi@lautech.edu.ng*

Abstract

Sandstones are sedimentary rocks formed from cemented sand-sized clasts. The cement that binds the clasts can vary from clay minerals to ca, silica or iron oxides. Sandstone can be further divided according to: Clast size – fine (0.06-0.2mm), medium (0.2-0.6mm), coarse (0.6-2mm); Sorting - poorly sorted, moderately well sorted and well sorted. Sandstones could also be discussed in terms of little or significant amount of silt and / or clay as arenaceous or argillaceous (wacke). Nine (9) samples were collected from the Ilaro sandstone and subjected to granulometric, petrographic and geochemical analysis precisely ICP-MS (Inductively coupled plasma mass spectrometry) for the major elements and their oxides. Granulometric analysis reveals that the texture of the sediments ranged from medium to coarse through to very coarse, they are symmetrically skewed and dominantly mesokurtic. Bivariate plot however depicts the Ilaro sandstone to be fluviatile in their depo-setting. All the samples also showed strong inclination towards sub-greywacke in terms of their geochemical classification.

Keyword: granulometric; mesokurtic; fluviatile; sub-greywacke; sandstone.

1. Introduction

The Ilaro sandstone conformably overlies the Oshosun Formation and it consists of massive, yellowish, poorly consolidated, fine to coarse, cross-bedded sandstones with thin clays and shales.

----

* Corresponding author.

It is part of the Dahomey basin and of Eocene age. Sandstone, sometimes known as arenite, is a clastic sedimentary rock comprised of sand- sized minerals or rock grains. Most sandstone is composed of quartz and/or feldspar because these are the most common minerals in the earth’s crust. Like sand, sandstone can be any color but the most common colors are tan, brown, yellow, red, grey, pink, white and black. Rock formations that are primarily composed of sandstone usually allow percolation of water and other fluids and are porous enough to store large quantities, making them valuable aquifers and petroleum reservoirs. Sandstones are clastic in origin (as opposed to either organic, like chalk and coal or chemical like gypsum and jasper). They are formed from cemented grains that may either be fragments of a pre-existing rock of be mono-mineralic crystals. The cement binding these grains together is typically calcite, clays and silica. The formation of sandstone involves two principal stages: Firs, a layer or layers of sand accumulate as a result of sedimentation, either from water (stream, lake and sea) or from air (as in a desert). The environment where the sandstone is deposited is crucial in determining the characteristics of the resulting sandstone, which, in finer detail, include its grain size, sorting, and composition and, in more general detail, include the rock geometry and sedimentary structures. Principal environments of deposition may be split between terrestrial and marine as illustrated by the following broad groupings**:**

1.1 Terrestrial Environment

- Rivers (levees, point bars, channel sands), Alluvial fans, Glacial outwash, Lakes, Deserts (sand dunes and ergs)

1.2 Marine Environments

– Deltas, Beach and shoreface sand, Tidal flats, Offshore bars and sand waves, Storm deposits (tempestites). Turbidites (submarine channels and fans). Generally, the study area is on a relief of 200m above sea level and lies between latitude $6^0 50^'$ and $6^0 57$’N and longitude$2^0 58$’ and $3^0 05$’E. The formation falls around Kajola Abalabi in Ilaro south western part of Nigeria. Fig.2 The study area is accessible through Papalanto-Ifo road towards Ilaro town. It is also accessible by a major road, minor roads and several footpaths. The formation is exposed as a massive road cut.

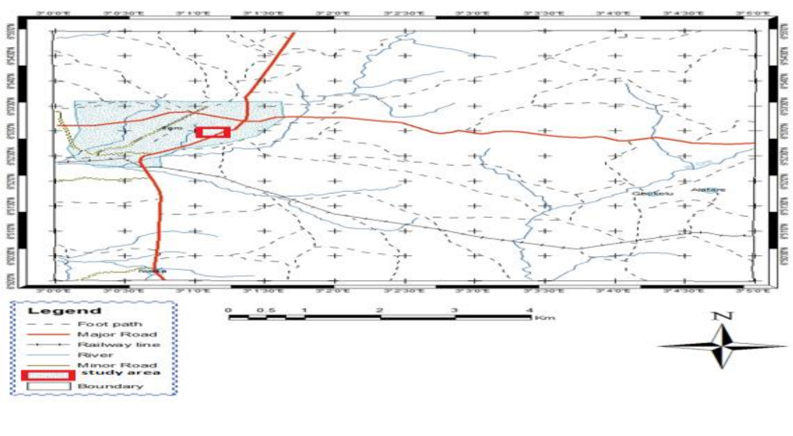

Figure 1: Drainage and accessibility map of the study area

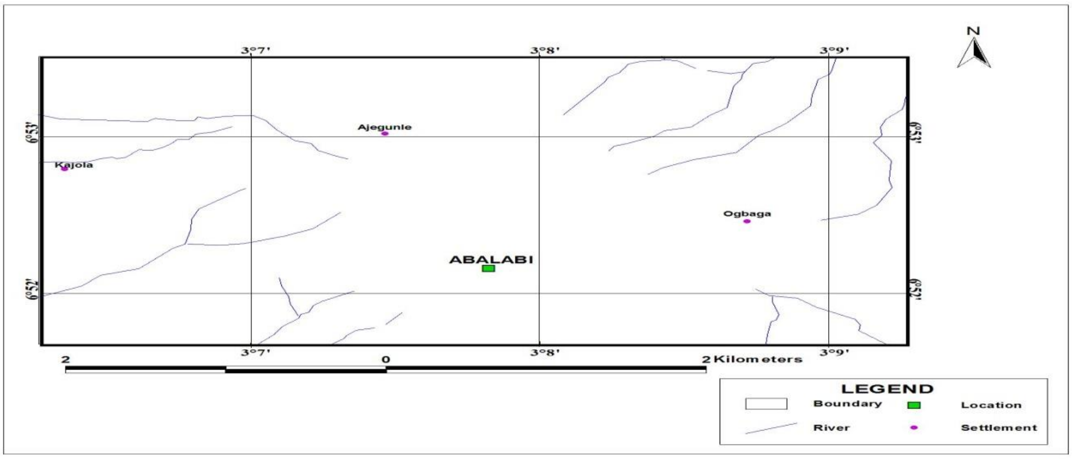

Figure 2: Location of the study Area.

This research paper aims at unraveling the depositional setting using granulometric analysis as well as further classifying the Ilaro sandstone based on result of geochemical analysis.

2. Materials and Method

The study area was traversed by foot and detailed geological mapping of thel exposed sandstone was carried out. The co-ordinate and elevation of the outcrop above sea level were first recorded with the aid of a G.P.S (Global positioning System). Visually observable features were carefully mapped and recoded accordingly. These include color, texture, lithological unit, bedding pattern, presence of ichno fossils, visible minerals as well as intensity of weathering. strikes and dips readings were taken along the bedding planes of each litho-unit with the aid of compass clinometers to determine the trending pattern of the road-cut exposure, The entire road-cut exposure was logged and the thickness of each litho-unit was recorded. Nine samples were later collected from different litho-unit into sample bags and labeled with the use of a masking tape accordingly as L1 to L9 for ease of identification. The samples were then subjected to granulometric, petrographic and geochemical analysis. For granulometric analysis, initial weight of 50g of slightly pulverized sample was used, which was run through sieve openings of graded diameter (µm). Thin sections were also made for samples L1 to L9 and then viewed under petrologic microscope in both plane polarized light and under crossed nicol for mineral identification and modal composition of the inherent minerals in the Ilaro Sandstone.. Photomicrographs of all the slides were then shot in both plane polarized light and under crossed nicol. Geochemical analysis was resolved using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) about 25g of each sample were pulverized into powdery form and major, trace and rare earth elements were analysed for, although the major elemental oxides were employed for geochemical calculations. Criteria for the classification of sandstones were further employed in classifying the Ilaro sandstone [1].

3. Literature Review

Authors in [2] Worked on the geochemistry and mineralogy of the Imobi sandstones. The study was aimed at inferring the provenance and possible depositional environment for these sandstones. Eight rock samples from the study area were subjected to geochemical analysis using X-ray fluorescence in order to determine the chemical composition. Parts of the samples were also used for mineralogical analysis to determine mineralogical compositions and to estimate the modal percentages of minerals in the Imobi sandstone samples. Geochemical analysis revealed sixteen elements and their oxides which includes SiO_2, Al_2O_3, Fe_2O_3, CaO, V_2O_5, ZrO_2, SO_3, K_2O, Br, P_2O_5, CuO, TiO_2, MnO, Rb_2O, As_2O3, Cr_2O_3. However mineralogical study shows the presence of three minerals along with accessory minerals, they include quartz, iron oxide, microcline and some accessory minerals. The presence of element and elemental oxides such as Br, V_2O_5, ZrO_2, Cu_2O, Rb_2O, As_2O_3 and MnO (especially Br which occurred in a recognizable quantity of about 12%-27%) suggests the depositional environment of the Imobi sandstone to be a shallow marine or near marine environment. However the abundance of Fe_2O_3 infers the derivation of the sediments from a metamorphic source.

4. Geology and Stratigraphy of the Basin

The Dahomey Basin, which is also referred to as, Benin Basin, or West Nigerian Basin, extends from south-eastern Ghana in the West, through Southern Togo and southern Benin Republic (formerly Dahomey) to Southwest Nigeria. The western flank of the Niger delta to be precise Fig 4. The axis of the basin and the thickest sediments occur slightly west of the border between Nigeria and Benin Republic. The basin is bounded on the west by faults and other tectonic structures. Its eastern limit is marked by the Benin Hinge line, a major fault structure marking the western limit of the Niger delta basin. To the west of the Benin Hinge line is the Okitipupa Ridge [4]. The tertiary sediments of the Dahomey basin thin out and are partially cut off from the sediments of the Niger delta basin against this ridge of basement rocks. The basin's offshore limit is similarly marked by the Hinge line, a major bounded in the north by the Precambrian fault structure marking the western limit of Niger Delta [5]. It is also basement rock and the Bight of Benin in the south. The stratigraphy of Dahomey basin to which the Ilaro sandstone belongs had been resolved by several workers including; [4]

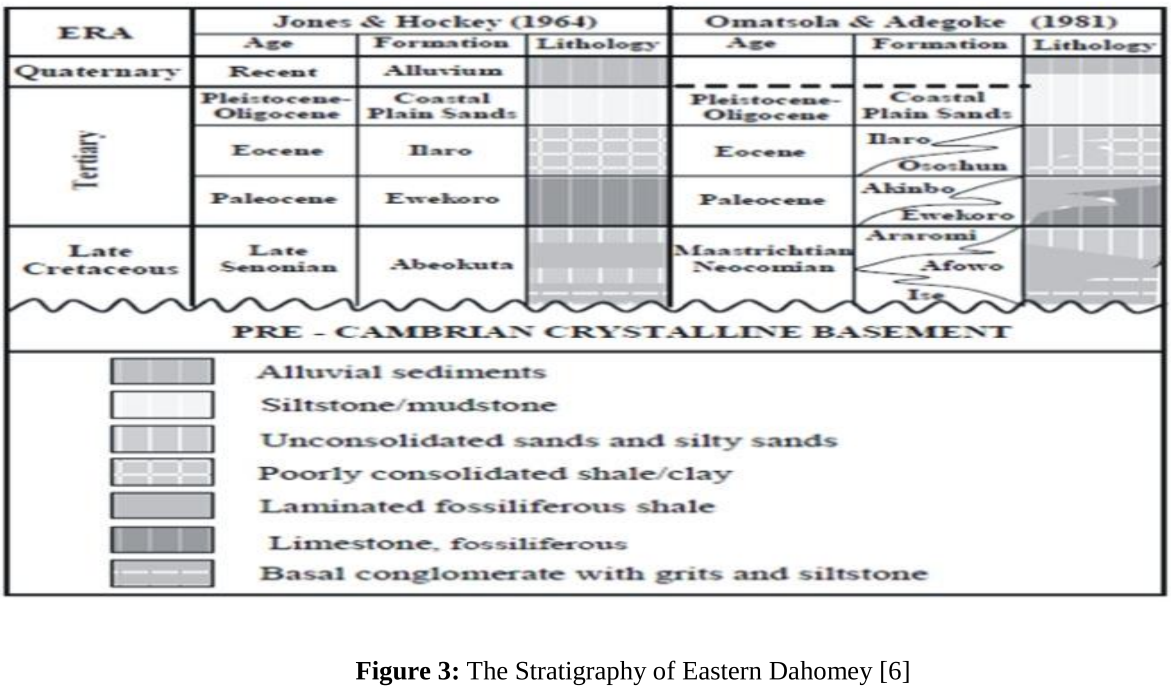

Figure 3: The Stratigraphy of Eastern Dahomey [6]

The general sequence for the rock unit from the top are the Coastal plain sands, Ilaro formation, Oshosun formation, Akinbo formation, Ewekoro formation, and Abeokuta formation lying on the South western Basement Complex of Nigeria. The Dahomey basin is an extensive sedimentary basin in the Gulf of Guinea. It extends from south-eastern Ghana through Togo and Benin Republic on the west side to the Okitipupa ridge/Benin Hinge line on the west of Niger Delta

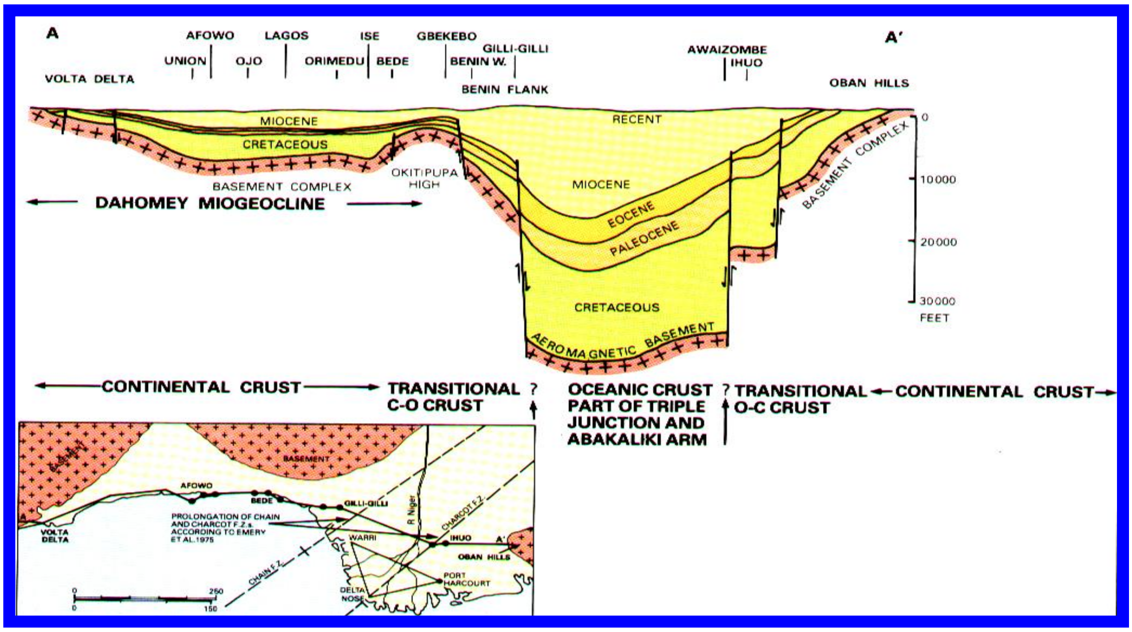

Figure 4: East-West Geological Section Showing the Dahomey (Benin) Basin and Niger Delta [7]

5. Results and Discussion

Table 1: Result of Sieve Analysis that shows Cumulative weight percent for samples L1-L9

Class(mm)	Cumm Wt% IL1	Cumm Wt% IL2	Cumm Wt% IL3	Cumm Wt% IL4	Cumm Wt% IL5	Cumm Wt% IL6	Cumm Wt% IL7	Cumm Wt% IL8	Cumm Wt% IL9
2	1.7	0.42	14.88	5.14	5.1	13.18	15.98	6.14	14.96
1	17.76	0.8	50.61	18.66	17.9	34.84	51.66	34.04	37.00
0.71	36.16	17.79	64.25	33.03	28.3	40.7	65.56	49.64	49.26
0.5	60.48	29.51	75.2	53.19	45.74	58.1	76.56	66.18	64.44
0.355	79.5	45.4	82.44	68.67	65.16	68.26	83.82	78.94	77.54
0.25	88.38	63.4	88.22	81.1	81.48	78.2	89.22	88.4	87.52
0.18	92.26	77.83	92.36	89.26	90.3	86.26	93.16	94.08	93.96
0.125	95.56	91	96.08	95.06	95.8	93.74	96.68	97,16	97.5
0.075	100	100	100	100	100	100	100	100	100

Table 2: Result of Sieve Analysis that shows weight percent for samples L1-L9

Interval Phi(φ)	Wt% IL1	Wt% IL2	Wt% IL3	Wt% IL4	Wt% IL5	Wt% IL6	Wt% IL7	Wt% IL8	Wt% IL9
-1.0	1.7	0.42	14.88	5.15	5.1	13.18	15.98	6.14	14.96
0.0	16.07	8.37	35.74	13.52	12.8	21.16	35.68	27.9	22.04
0.5	18.4	9.00	13.64	14.38	10.4	10.36	13.9	15.6	12.26
1.00	24.31	11.72	10.95	20.17	17.44	13.4	11.0	16.54	15.18
1.5	19.03	15.91	7.23	15.45	19.42	10.16	7.26	12.76	13.1
2.0	8.88	18.00	5.79	12.45	16.32	9.94	5.4	9.46	9.98
2.5	4.23	14.44	4.13	8.15	8.82	8.42	3.94	5.68	6.44
3.0	2.96	13.19	3.72	5.79	5.5	5.5	3.52	3.08	3.54
3.5	4.44	9.00	3.93	4.94	4.2	4.2	3.32	2.84	2.5

For calculating grain-size statistical parameters by graphical method, [8] mathematical expressions were adopted and Percentile values were then extrapolated.

Table 3: Percentile Values for Samples L1 - L9

Percentiles	L1	L2	L3	L4	L5	L6	L7	L8	L9
5	-0.4	-0.6	-1.5	-1.18	-1	-1.7	-1.65	-1.1	-1.7
16	-0.1	0.4	-0.8	-0.2	-0.1	-0.75	-1	-0.6	-0.8
25	0.2	0.8	-0.5	0.2	0.3	-0.3	-0.65	-0.2	-0.4
50	0.8	1.6	-0.1	0.9	1.1	0.6	0	0.5	0.5
75	1.4	2.5	1.3	1.8	2.1	1.9	1	1.3	1.4
84	1.8	2.75	2	2.5	2.3	2.2	1.5	1.7	1.8
95	3	3.3	3	3	2.8	3	2.7	2.78	2.5

Table 4: Sieve Analysis Table for samples L1 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	0.68	0.85	0.85	1.7	1.7
1	0	7.6	8.03	8.88	17.76	16.07
0.71	0.5	8.7	9.2	18.08	36.16	18.4
0.5	1	11.5	12.16	30.24	60.48	24.31
0.355	1.5	9	9.51	39.75	79.5	19.03
0.25	2	4.2	4.44	44.19	88.38	8.88
0.18	2.5	2	2.11	46.3	92.26	4.23
0.125	3	1.4	1.48	47.78	95.56	2.96
0.075	3.75	2.1	2.22	50	100	4.44
Receiving pan		2.1				
Total		47.3	50			100.02
Weight loss		2.7				

Table 5: Sieve Analysis Table for samples L2 (Initial Weight of sample = 50g)

Class MM	Interval phi ɸ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	0.2	0.21	0.21	0.42	0.42
1	0	4	4.19	4.4	0.8	8.37
0.71	0.5	4.3	4.5	8.9	17.79	9
0.5	1	5.6	5.86	14.76	29.51	11.72
0.355	1.5	7.6	7.95	22.71	45.4	15.91
0.25	2	8.6	9	31.71	63.4	18
0.18	2.5	6.9	7.22	38.93	77.83	14.44
0.125	3	6.3	6.59	45.52	91	13.19
0.075	3.75	4.3	4.5	50.02	100	9
Receiving pan		1.4				
Total		47.78	50.02			100.05
Weight loss		2.22				

Rt-Retained Wt-Weight

Table 6: Sieve Analysis Table for samples L3 (Initial Weight of sample = 50g)

Class MM	Interval phi ɸ	Rt. wt. on sieve(mg)	Corrected wt. (gm)	Cumulative wt. (gm)	Cumulative wt. in %	Weight in %
2	-1	7.2	7.44	7.44	14.88	14.88
1	0	17.3	17.87	25.31	50.61	35.74
0.71	0.5	6.6	6.82	32.13	64.25	13.64
0.5	1	5.3	5.48	37.61	75.2	10.95
0.355	1.5	3.5	3.62	41.23	82.44	7.23
0.25	2	2.8	2.89	44.12	88.22	5.79
0.18	2.5	2	2.07	46.19	92.36	4.13
0.125	3	1.8	1.86	48.05	96.08	3.72
0.075	3.75	1.9	1.96	50.01	100	3.93
Receiving pan		1.3				
Total		48.4	50.01			100
Weight loss		1.6				

Table 7: Sieve Analysis Table for samples L4 (Initial Weight of sample = 50g)

Class MM	Interval phi ɸ	Wt. rt. on sieve(mg)	Corrected weight(gm)	Cumulative weight (gm)	Cumulative weight in %	Weight in %
2	-1	2.4	2.57	2.57	5.14	5.15
1	0	6.3	6.76	9.33	18.66	13.52
0.71	0.5	6.7	7.19	16.52	33.03	14.38
0.5	1	9.4	10.09	26.61	53.19	20.17
0.355	1.5	7.2	7.73	34.34	68.67	15.45
0.25	2	5.8	6.22	40.56	81.1	12.45
0.18	2.5	3.8	4.08	44.64	89.26	8.15
0.125	3	2.7	2.9	47.54	95.06	5.79
0.075	3.75	2.3	2.47	50.01	100	4.94
Receiving pan		2.5				
Total		46.6	50.01			100
Weight loss		3.4				

Rt-Retained Wt-Weight

Table 8: Sieve Analysis Table for samples L5 (Initial Weight of sample = 50g)

Class MM	Interval phi ɸ	Wt. rt. on sieve(mg)	Corrected weight(gm)	Cumulative weight (gm)	Cumulative weight in %	Weight in %
2	-1	2.4	2.57	2.57	5.14	5.15
1	0	6.3	6.76	9.33	18.66	13.52
0.71	0.5	6.7	7.19	16.52	33.03	14.38
0.5	1	9.4	10.09	26.61	53.19	20.17
0.355	1.5	7.2	7.73	34.34	68.67	15.45
0.25	2	5.8	6.22	40.56	81.1	12.45
0.18	2.5	3.8	4.08	44.64	89.26	8.15
0.125	3	2.7	2.9	47.54	95.06	5.79
0.075	3.75	2.3	2.47	50.01	100	4.94
Receiving pan		2.5				
Total		46.6	50.01			100
Weight loss		3.4				

Table 9: Sieve Analysis Table for samples L6 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	6.1	6.59	6.59	13.18	13.18
1	0	9.8	10.58	17.17	34.84	21.16
0.71	0.5	4.8	5.18	22.35	40.7	10.36
0.5	1	6.2	6.7	29.05	58.1	13.4
0.355	1.5	4.7	5.08	34.13	68.26	10.16
0.25	2	4.6	4.97	39.1	78.2	9.94
0.18	2.5	3.9	4.21	43.31	86.26	8.42
0.125	3	3.3	3.56	46.87	93.74	7.12
0.075	3.5	2.9	3.13	50	100	6.26
		Total = 46.30	Total = 50			100
Weight Retained in Pan =3.5g Weight loss = 0.2g						

Rt-Retained Wt-Weight

Table 10: Sieve Analysis Table for samples L7 (Initial Weight of sample = 50

Class MM	Interval phi ϕ	Rt. wt)	Corrected wt. (gm)	Cumm wt.(gm)	Cumulative wt. in %	Weight in %
-1		7.7		15.98	15.98	
2	0	17.2	17.84	25.83	51.66	35.68
1	0.5	6.7	6.95	32.78	65.56	13.9
0.71	1	5.3	5.5	38.28	76.56	11
0.5	1.5	3.5	3.63	41.91	83.82	7.26
0.355	2	2.6	2.7	44.61	89.22	5.4
0.25	2.5	1.9	1.97	46.58	93.16	3.94
0.18	3	1.7	1.76	48.34	96.68	3.52
0.125	0.075	3.5	1.6	1.66	50	100
Weight rt,in pan =1.8g Weight loss =0g		Total= 48.20	Total = 50			Total = 100

Table 11: Sieve Analysis Table for samples L8 (Initial Weight of sample = 50g)

Class MM	Interval phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	2.6	3.07	3.07	6.14	6.14
1	0	11.8	13.95	17.02	34.04	27.9
0.71	0.5	6.6	7.8	24.82	49.64	15.6
0.5	1	7	8.27	33.09	66.18	16.54
0.355	1.5	5.4	6.38	39.47	78.94	12.76
0.25	2	4	4.73	44.2	88.4	9.46
0.18	2.5	2.4	2.84	47.04	94.08	5.68
0.125	3	1.3	1.54	48.58	97,16	3.08
0.075	3.5	1.2	1.42	50	100	2.84
		Total = 42.30	Total = 50			Total = 100

Weight Retained in Pan =1.3g

Weight loss = 6.4g

Rt-Retained Wt-Weight

Table 12: Sieve Analysis Table for samples L9 (Initial Weight of sample = 50g)

Sieve size	Phi ϕ	Wt. rt. on sieve(mg)	Corrected weight (g)	Cumulative weight (g)	Cumulative weight %	Weight in %
2	-1	7.2	7.48	7.48	14.96	14.96
1	0	10.6	11.02	18.5	37	22.04
0.71	0.5	5.9	6.13	24.63	49.26	12.26
0.5	1	7.3	7.59	32.22	64.44	15.18
0.355	1.5	6.3	6.55	38.77	77.54	13.1
0.25	2	4.8	4.99	43.76	87.52	9.98
0.18	2.5	3.1	3.22	46.98	93.96	6.44
0.125	3	1.7	1.77	48.75	97.5	3.54
0.075	3.5	1.2	1.25	50	100	2.5
		Total = 48.10	Total = 50			Total = 100

Weight Retained in Pan =1.5g

Weight loss = 0.4g

Rt-Retained Wt-Weight

Figure 5: picture showing logging of a sandstone litho-unit

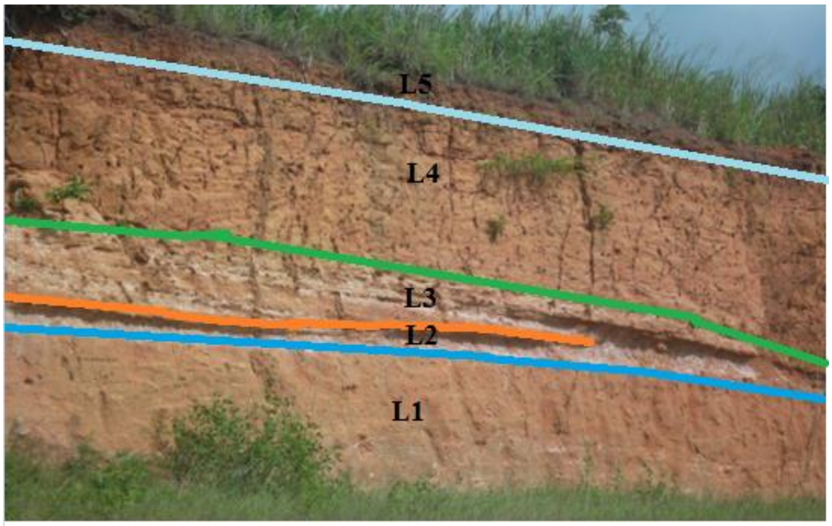

Figure 6: Delineation of the Ilaro Sandstone into different Lithology

Table 13: Derived Values of Grain Size Statistical Parameters for Samples L1-L9

Sample no	Graphic mean(M_z)	Dispersion sorting(σ)	Graphic skewness(SK_t)	Graphic kurtosis(K_G)
L1	0.83	1	0.17	1.17
L2	1.58	1.2	-0.08	0.94
L3	0.37	1.38	0.52	1.03
L4	1.07	1.31	0.11	1.07
L5	1.1	1.7	-0.053	0.87
L6	2.05	1.45	0.0529	0.8
L7	0.17	1.28	0.22	1.08
L8	0.53	1.16	0.11	1.06
L9	0.5	1.29	-0.22	0.96

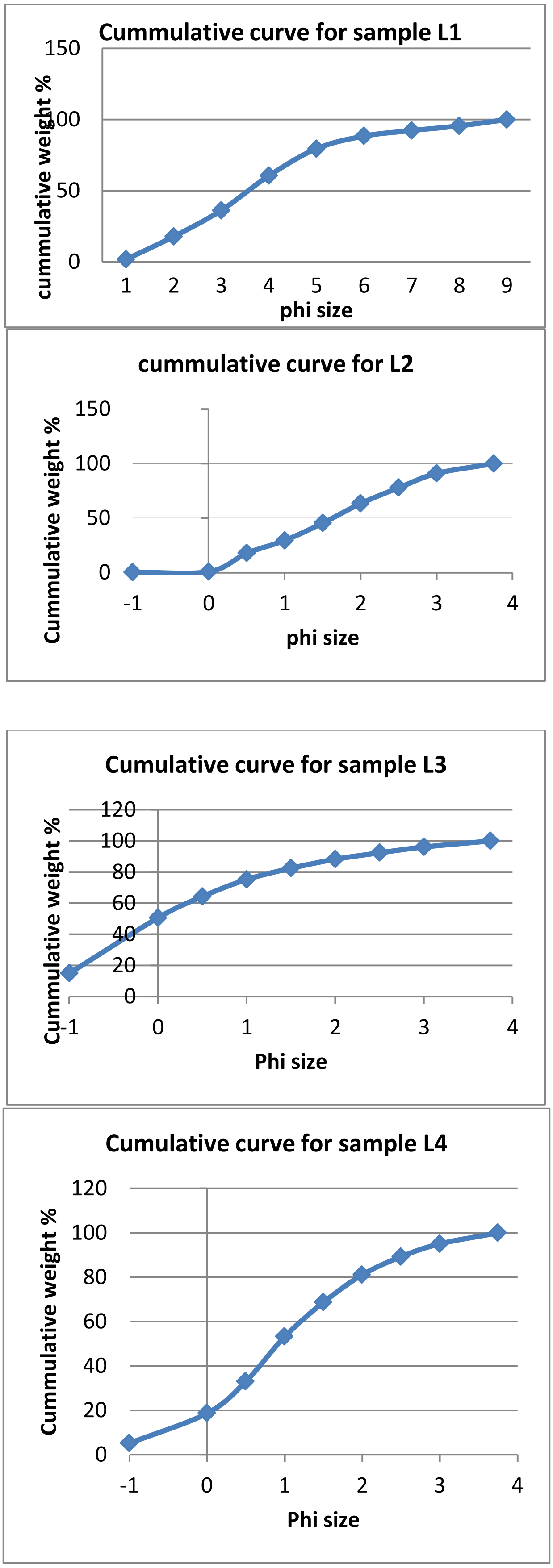

Figure 7: Plot of Cumulative frequency against phi size for samples L1-L4

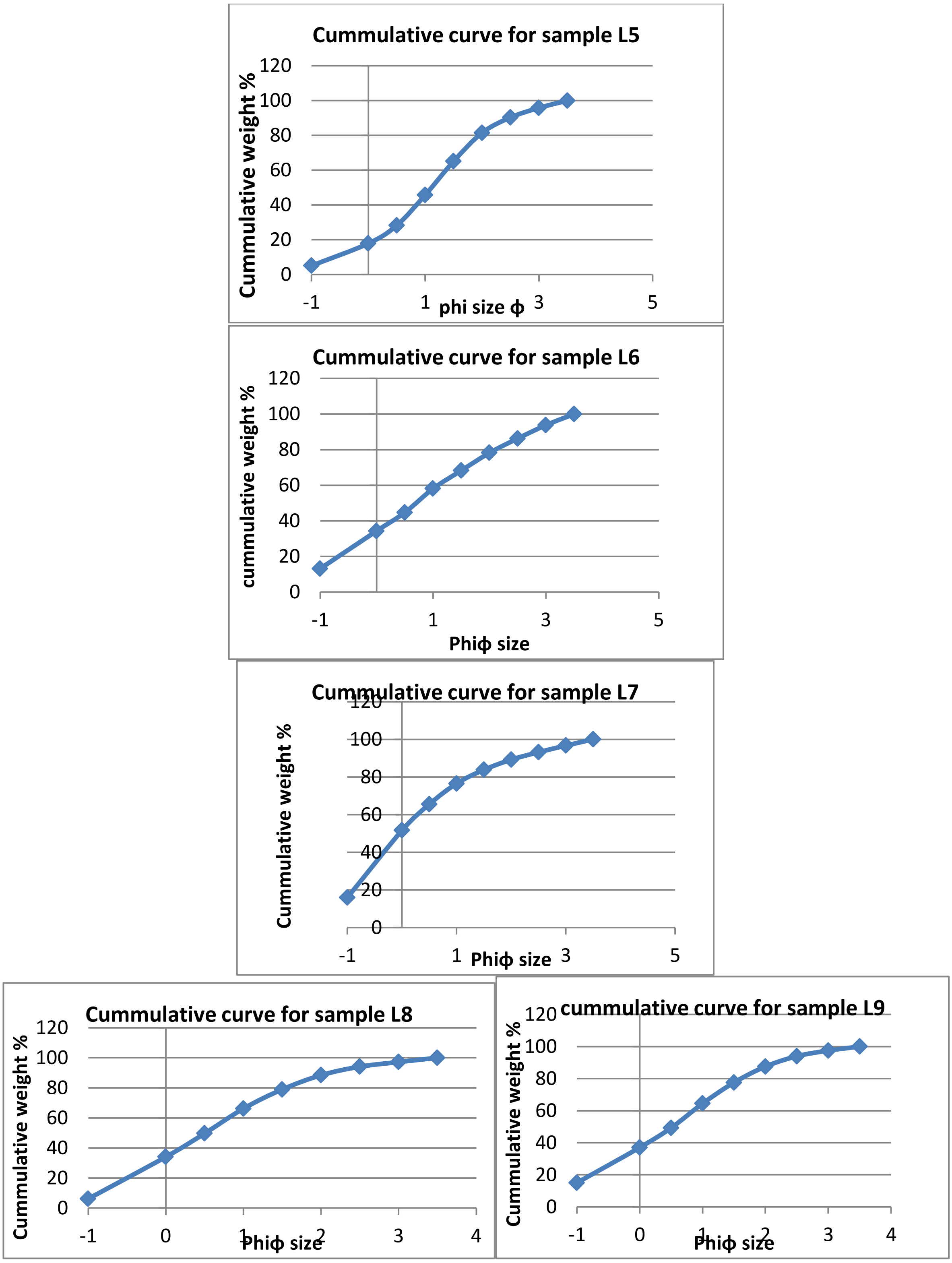

Figure 8: Plot of Cumulative frequency against phi size for samples L5-L9

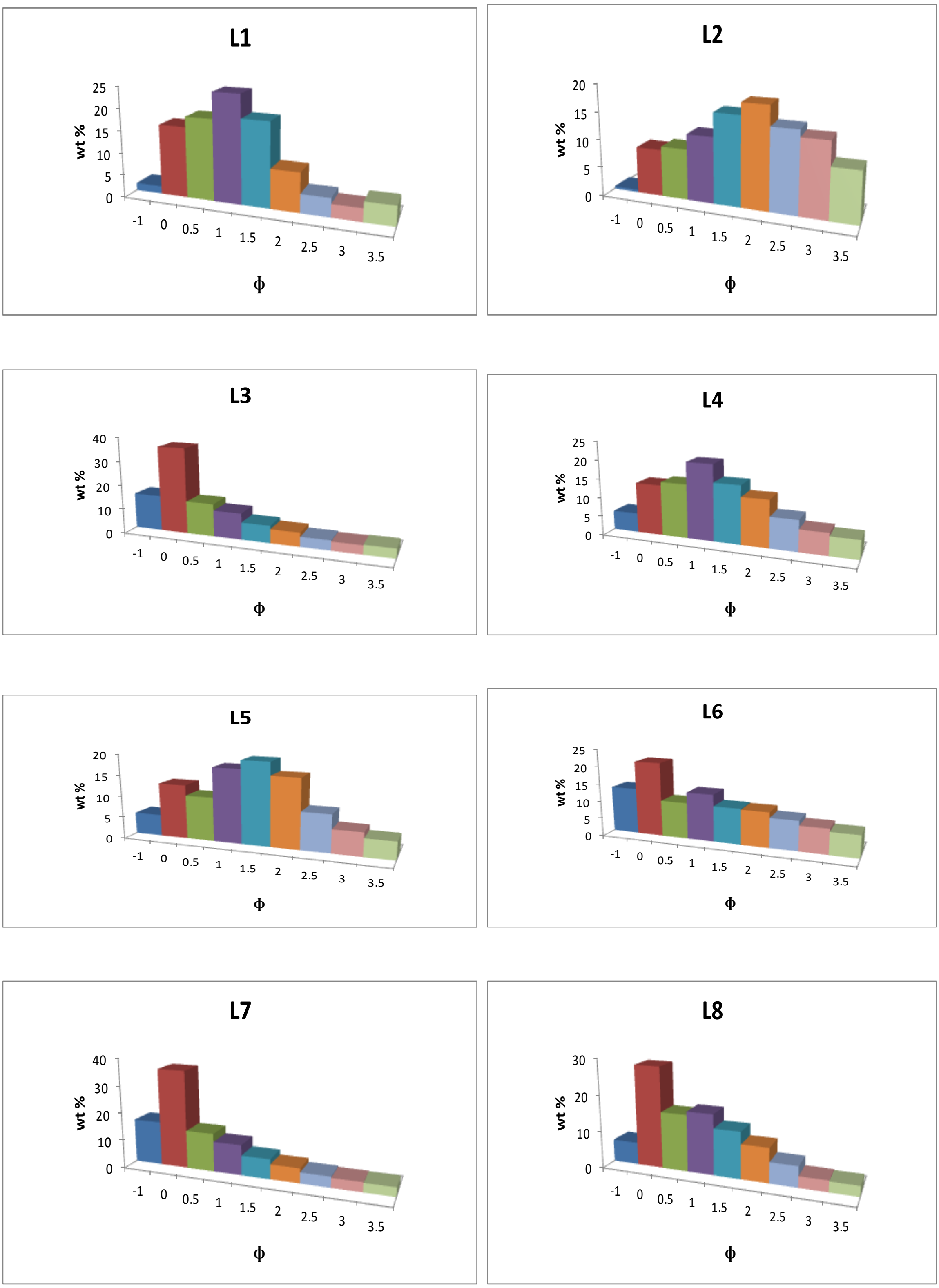

Figure 9a: Histogram showing modal variations

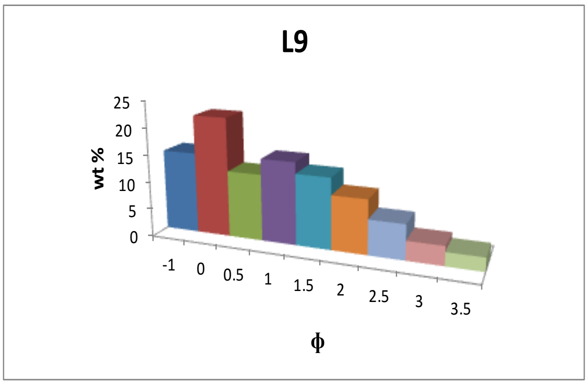

Figure 9b: Histogram showing modal variations

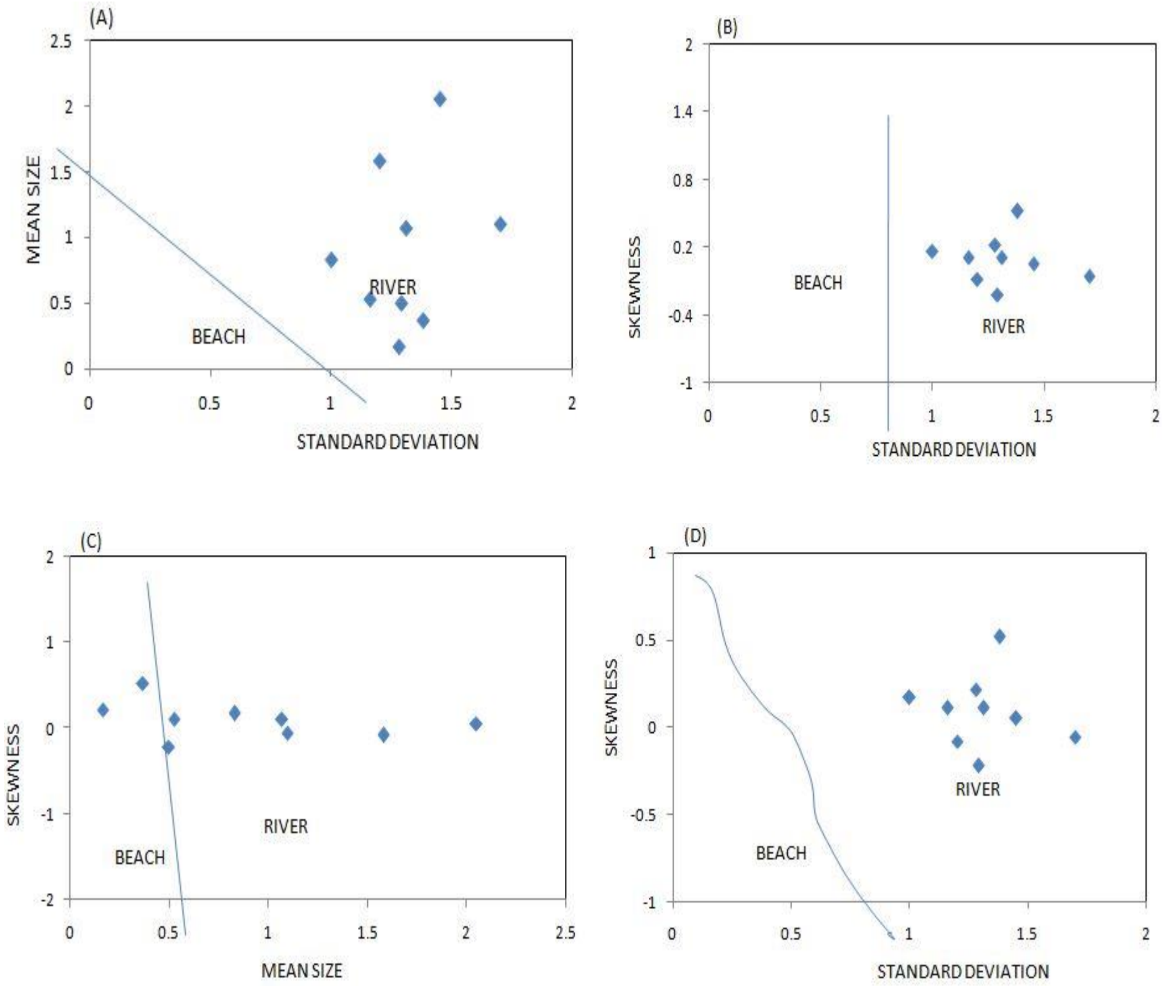

Figure 10: Bivariate plots depicting depositional setting

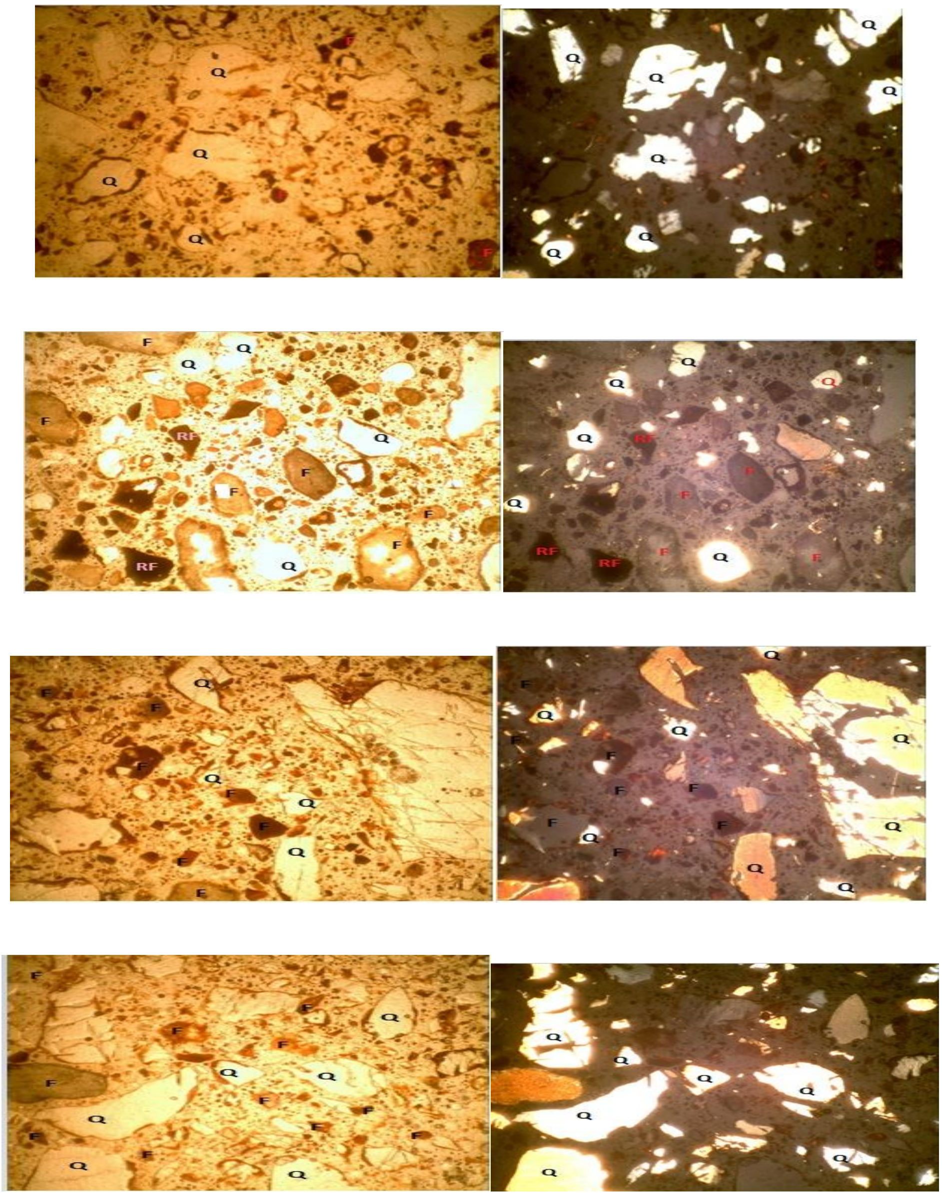

Figure 11: Photomicrographs of the Ilaro sandstone in plane polarized light and under crossed nicols.

--------------- Bar Scale = 20mm Magnification: X40 Resolution: (1.50 dpi)

Figure 12: Photomicrographs of the Ilaro sandstone in plane polarized light and under crossed nicols.

Table 14: Average modal analysis of the Sandstone Samples

SAMPLE NO	QUARTZ	FELDSPAR	RUTILE	GARNET	TOURMALINE	ROCK FRAGMENT
2L1	80	10	2	1	2	3
2L2	70	25	2	-	-	3
2L3	70	25	2	1	-	2
2L4	92	1	2	1	2	2
2L5	80	4	2	2	2	10

Table 15: Geochemical result for samples L1 - L9

	Sample location 1	Sample location 2	Sample location 3	Sample location 4	Sample location 5	Sample location 6	Sample location 7	Sample location 8	Sample location 9
SiO_2	86.8	56.64	87.41	80.94	83.15	53.9	81.66	86.85	80.57
Al_2O_3	7.38	27.67	7.31	10.68	9.63	28.46	11.76	7.93	7
Fe_2O_3	1.56	2.43	1.22	2.71	2.27	3.71	1.03	1.24	6.79
MgO	0.02	0.05	0.02	0.04	0.03	0.05	0.02	0.02	0.05
CaO	0.009	0.01	0.01	0.04	0.009	0.009	0.009	0.009	0.08
Na_2O	0.008	0.02	0.006	0.007	0.009	0.02	0.009	0.009	0.01
K_2O	0.02	0.16	0.03	0.03	0.03	0.18	0.05	0.02	0.03
TiO_2	0.4	1.37	0.33	0.57	0.72	1.57	0.45	0.35	0.54
P_2O_5	0.02	0.03	0.22	0.03	0.02	0.05	0.01	0.01	0.05
MnO	0.005	0.01	0.04	0.003	0.009	0.01	0.009	0.009	0.04
Cr_2O_3	0.004	0.0015	0.09	0.009	0.005	0.016	0.004	0.004	0.016
Sum	96.29	88.39	96.57	95.059	95.93	87.98	95.01	96.45	95.18

The following are the parameter for the classification of sandstones based on chemical approach. They are used according to [9]

1) Quartz arenite: log (SiO2/Al2O3) ≥1.5

2) Greywacke: log (SiO2/Al2O3) < 1 and log (K2O/Na2O) < 0

3) Arkose (includes subarkose): log (SiO2/Al2O3) < 1.5 and log (K2O/Na2O) ≥ 0 and log ((Fe2O3+MgO)/(K2O+Na2O)) < 0

4) Lithic arenite (subgraywacke, includes protoquartzite): log (SiO2/Al2O3) < 1.5 and either log (K2O/Na20) < 0 or log ((Fe2O3+MgO)/(K2O+Na2O)) ≥0. If log (K2O/Na2O) < 0, lithic arenite can be confused with graywacke. The coastal plain sediments fall within the requirements of the third condition and thus classified as an arkose (includes subarkose).

Table 17

Sample L_1	**Sample L_2**
SiO_2 = 86.86	Si O_2 = 56.64
Al_2O_3 =7.38	Al_2O_3 = 27.67
Log SiO_2 / Al_2O_3 = log (86.86 / 7.38) Log 11.77 = 1.07	Log SiO_2 / Al_2O_3 = log (56.64 / 27.67) Log (2.05) = 0.31
K_2O = 0.02	K_2O = 0.16
Na_2O = 0.008	Na_2O = 0.02
Log (K_2O/Na_2O) = log (0.02) – Log (0.008)	Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)	= log (0.16) – log (0.02)
Fe_2O_3 = 1.56 MgO = 0.02	= -0.8 – (-1.7) = 0.9
Na_2O = 0.008	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)
K_2O = 0.02	Fe_2O_3 = 2.43
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (1.56+ 0.02) / (0.008 + 0.02)	MgO = 0.05
Log (1.58) / (0.028) = log (56.42) = 1.75	Na_2O = 0.02
	K_2O = 0.16
	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) =
	log (2.43+ 0.05) / (0.02 + 0.16)
	= log (2.48) / (0.18)
Log (1.24) / (0.036) = log (34.44) = 1.54	= log (13.78) = 1.14

Table 18

Sample L_3	**Sample L_4**
SiO_2 = 87.41	Log SiO_2 / Al_2O_3
Al_2O_3 = 7.31	SiO_2 = 80.94
Log SiO_2 / Al_2O_3 = log (87.41 / 7.31)	Al_2O_3 = 10.68
Log (11.96) = 1.08	Log SiO_2 / Al_2O_3 = log (80.94 / 10.68)
Log (K_2O/Na_2O)	Log (7.58) = 0.9
K_2O = 0.03	Log (K_2O/Na_2O)
Na_2O = 0.006	K_2O = 0.03
Log (K_2O/Na_2O) = log (0.03) – log (0.006)	Na_2O = 0.007

= -1.52 – (- 2.22)	Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)
= -1.52 + 2.22	Log (0.03) – log (0.007) = - 1.52 – (- 2.15)
0.7	0.63
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)	0.63
Fe_2O_3 = 1.22	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)
	Fe_2O_3 = 2.71
MgO = 0.02	MgO = 0.04
K_2O = 0.03	Na_2O = 0.007
	K_2O = 0.03
Na_2O = 0.006	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (2.71 + 0.04) / (0.007 + 0.03)
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (1.22 + 0.02) / (0.03 + 0.006)	Log (2.75 / 0.037) = log (74.52) = 1.87

Table 19

Sample L_5	**Sample L_6**
Log SiO_2 / Al_2O_3	Log SiO_2 / Al_2O_3
SiO_2 = 83.15	SiO_2 = 53.90
Al_2O_3 = 9.63	Al_2O_3 = 28.46
Log SiO_2 / Al_2O_3 = log (83.15 / 9.63)	Log SiO_2 / Al_2O_3 = log (53.90 / 28.46)
Log (8.63) = 0.93	Log (1.89) = 0.28
Log (K_2O/Na_2O)	Log (K_2O/Na_2O)
K_2O = 0.03	K_2O = 0.18
Na_2O = 0.009	Na_2O = 0.02
Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)	Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)
Log (0.03) – log (0.009) = - 1.52 – (- 2.05)	Log (0.18) – log (0.02) = - 0.74 – (-1.70)
0.53	0.96
0.53	0.96
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)
Fe_2O_3 = 2.27	Fe_2O_3 = 3.71
MgO = 0.003	MgO = 0.05
Na_2O = 0.009	Na_2O = 0.02
K_2O = 0.03	K_2O = 0.18
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (2.27 + 0.003) / (0.009 + 0.03)	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (3.71 + 0.05) / (0.02 + 0.18)
Log (2.273 / 0.039) = log (74.52) = 1.77	Log (3.76 / 0.20) = log (18.80) =

Table 20

Sample L_7	**Sample L_8**
Log SiO_2 / Al_2O_3	Log SiO_2 / Al_2O_3
SiO_2 = 81.66	SiO_2 = 86.85
Al_2O_3 = 11.76	Al_2O_3 = 7.93
Log SiO_2 / Al_2O_3 = log (81.66 / 11.76) Log (7.58) = 0.84	Log SiO_2 / Al_2O_3 = log (86.85 / 7.93) Log (10.95) = 1.04
Log (K_2O/Na_2O)	Log (K_2O/Na_2O)
K_2O = 0.05	K_2O = 0.02
Na_2O = 0.009	Na_2O = 0.009
Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)	Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)
Log (0.05) – log (0.009) = - 1.30 – (- 2.05) 0.75 0.75	Log (0.02) – log (0.009) = - 1.52 – (- 2.05) 0.53 0.53
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O)
Fe_2O_3 = 1.03 MgO = 0.02	Fe_2O_3 = 1.24 MgO = 0.02
Na_2O = 0.009	Na_2O = 0.009
K_2O = 0.05	K_2O = 0.02
Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (1.03 + 0.02) / (0.009 + 0.05) Log (1.05 / 0.059) = log (17.80) = 1.25	Log (Fe_2O_3 + MgO)/ (Na_2O + K_2O) = log (1.24 + 0.02) / (0.009 + 0.02) Log (1.26 / 0.029) = log (43.44) = 1.64

Table 21

Sample L_9
Log SiO_2 / Al_2O_3
SiO_2 = 80.57
Al_2O_3 = 7.00
Log SiO_2 / Al_2O_3 = log (80.57 / 7.00) Log (11.51) = 1.06
Log (K_2O/Na_2O)
K_2O = 0.03
Na_2O = 0.01

Log (K_2O/Na_2O) = log (K_2O) – log (Na_2O)

Log (0.03) – log (0.01) = - 1.52 – (- 2)

0.48

0.48

Log $(Fe_2O_3 + MgO)/(Na_2O + K_2O)$

Fe_2O_3 = 6.79

MgO = 0.05

Na_2O = 0.01

K_2O = 0.03

Log $(Fe_2O_3 + MgO)/(Na_2O + K_2O)$ = log (6.79 + 0.05) / (0.01 + 0.03)

Log (6.84 / 0.04) = log (171) = 2.23

Table 16: Classification of the Sandstone Samples from the Geochemical Result.

Sample	Log SiO_2/Al_2O_3	Log (K_2O/Na_2O)	Log $(Fe_2O_3 + MgO)/(Na_2O + K_2O)$	Interpretation
L_1	1.07	0.4	1.75	Sub–greywacke
L_2	0.31	0.9	1.14	Sub–greywacke
L_3	1.08	0.7	1.54	Sub–greywacke
L_4	0.9	0.63	1.87	Sub-greywacke
L5	0.93	0.53	1.77	Sub-greywacke
L6	0.28	0.96	1.27	Sub–greywacke
L7	0.84	0.75	1.25	Sub–greywacke
L8	1.04	0.53	1.64	Sub–greywacke
L9	1.06	0.48	2.23	Sub–greywacke

6. Conclusion

The presence of brownish red and purple coloration in the quartz shows the presence of hematite (Fe_2O_3) and they are typical of non- marine environment. Formations located in warm, humid climates often develop such coloration of quartz, showing that there is insufficient organic matter present to reduce the ferric iron to the relatively soluble ferrous state [10].

The presence of more than 15% of matrix in the rock samples shows is a greywacke and a greywacke is a high grade diagenetic or low grade metamorphic product.

The presence of larger clasts of quartz in the sandstone shows the sandstone is most likely deposited in high energy environments and is transported with lower energy making it have lesser impacts of weathering. They are characteristics of submarine fan, slope, and abyssal deposits. Detrital modes of sandstone also provide information about the tectonic settings of basins of deposition [11].

The relationship between sandstone petrography and tectonic setting has been studied by many authors

Acknowledgement

The author acknowledges the unflinching effort and support of Miss Lawal T.O and Mr. Olajolumo O. who assisted during the field work. Furthermore, Mr. Ibikunle O. and Mr. Oyekan O.O, Technologist of the department of Civil Engineering and Earth Sciences of Ladoke Akintola University of Technology, Ogbomoso, Oyo State Nigeria are greatly appreciated for their availability and immense assistance in the course of running the sieve analysis.

References

[1] Blatt, H., Middleton, G., & Murray, R., (1972) Origin of sedimentary rocks. Englewood Cliffs, New Jersey, Prentice-Hall, 634 p.

[2] Akintola, A.1 and Osinowo A. (2008), Geochemical And Mineralogical Composition Of Ishara Sandstone Deposit, South Western Nigeria. Earth Sciences Dept., Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Department of Geology, University of Ibadan, Ibadan. Oyo State, Nigeria. Continental Journal of. Earth Sciences 3:p. 33 - 39.

[3] Adegoke, O.S, (1969) The Eocene stratigraphy of southern Nigeria. Bull Bur Econ Geol. Mineral Mem 6:23–28,

[4] Adegoke, O.S., 1969, Omatsola, M.E and Adegoke O.S., (1981). Tectonic and cretaceous Stratigraphy of the Dahomey basin.Jour. Of mining Geol. 154 (1): 65-68.

[5] Jones and Hockey, 1964; Adegoke, 1969; Ogbe, 1972; Billman, 1976; Ako et al., 1980; Omatsola and Adegoke, 1981; Okosun, 1990. Cretaceous stratigraphy of the Dahomey Embayment, West Africa**) in Cretaceous Research 11(1):17-27**

[6] Jones, H.A. and Hockey R.D.. (1964) Omatsola, M.E and Adegoke O.S., (1981). "The Geology of part of Southwestern Nigeria", Geological Survey of Nigeria. Bulletin, 31, 101pp.

[7] Whiteman, A. J. (1982). Nigeria: Its Petroleum Geology, Resources and Potential.London, Graham and Trotman, vol.1.1, 66. pp.

[8] Folk, R.L and W.C Ward, (1957**)** Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology* **27**:3–26

[9] Blatt, H., Middleton, G. V., & Murray, R. C. (1972). Origin of Sedimentary Rocks. Princeton-Hall Inc., Eaglewood Cliff, M. J., 634. Boles

[10] (Pettijohn, F. J. and Potter, P. E. 1964). Atlas and Glossary of Primary Sedimentary Structures. New York: SpringerVerlag. https://www.abebooks.co.uk/

[11] Dickinson W.R., (1985) Interpreting provenance relations from detrital modes of Sandstones, in Zuffa G.G. (ed.), Provenance of Arenites. Dordrecht, D. Reidel Publishing Company, pp. 333-361