Chemostratigraphy: Major/Minor Elemental Ratio Trends in Goml-1 Well Benin Flank in the Northern Delta Depobelt Nigeria (A Case Study of Na:Zn And K:Mn.)

Lucas F. A.[a], Efiebuke Esther O.[b], Omodolor Hope E.[c*], Benedict Oghenemaro Aduomahor[d]

[a,b,c,d]*Department of Geology, University of Benin, P.M.B. 1154 Benin City, Edo State Nigeria*
[a]*Email: drfalucas@gmail.com*
[b]*Email: efiebuke1@gmail.com*
[c]*Email: hopeomodolor@gmail.com*
[d]*Email:bennymarose@gmail.com*

Abstract

Chemostratigraphy is a technique used to correlate sedimentary successions based on subtle changes in concentration of key major, minor and trace elements. This project work is aimed at using chemostratigraphic analysis of cutting samples from Gom1-1 well in the Northern Delta depobelt to determine the major/minor element ratio as a basis of determining the depositional evironment of the sediments. Subsuface cutting sample collected from Gom1-1 well were analysed using Atomic Absorption Spectroscopy (AAS) technique. Lithofacies such as coarse grained sandy facies, fine grained sandy facies, medium grained sandy facies, silty sand facies, shaly sand, sandy shale, and calcareouse shale were analysed and coded A,B,C,D,E,F respectively. Data acquired from the analysis of the ratios of Na:Zn and K:Mn were calculated and graph of the ratios and individual element were plotted against depth. Inference drawn from the graphs indicate a relative abundance of element with depth. Maximum peak values of the element were observed first at depth 2314m and 3096m.

----

*corresponding author.

Three prominent peak in the transitional zone and one prominent peak in the marine zone are indications of abundance of the various element in the transitional to marine depositional environment. The well was zoned into four chemostratigraphic intervals value as follows; 3891m, 3096m, 2313m and 1717m as zone1, zone2, zone3, zone4 respectively.

Keywords: Chemostratigraphy; lithofacies; bulk geocheminstry; depositional environment; major, minor and trace elements.

1. Introduction and background of study

Chemostraigraphy is the study of the characteristics and stratigraphic zonation of sequence due to change in bulk geochemistry as a result of variation in mineralogy caused by changes in some source rock composition and facies due to weathering or diagenesis. Chemostratigraphy as a field is relatively young, having only come into common usage in the early 1980s, but the basic idea of chemostratigraphy is nearly as old as stratigraphy itself. In some stratigraphic sequences, there is a clear variation in colour between different strata. Such colour differences often originate from variations in the incorporation of transition metal-containing materials during deposition and lithifaction. The well is located in the Northern Delta depobelt of the Niger Delta basin. Twenty-one (21) cutting samples at various depth between 329.18meters (top depth) to 4239.77meters (bottom depth) from Goml-1 well were analysed using atomic absorption spectroscopy (AAS) procedure. The study area is located in the Tertiary Niger Delta which have revealed three lithostratigraphic units [8] which from top to bottom. They are; The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick [5].
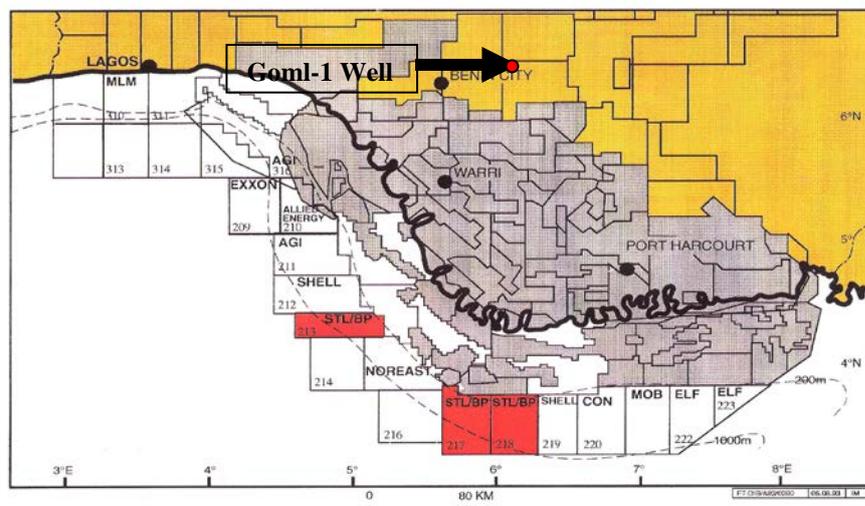
Figure 1: Map of southern Nigeria showing location of study well

The age of the Akata formation ranges from Paleocene to Recent The Agbada Formation is the major petroleum-bearing unit in the Niger Delta. The formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres. The age of the formation ranges from Eocene-Recent. The Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence [2], and consists of continental sands and gravels. The age of the formation is estimated to range from Oligocene to Recent [8]

2. Materials and methods

Two broad methods were employed in this study.

- Lithostratigraphy: Lithologic descriptions and grain size interpretations.
- Chemostratigraphy: Study of variation of chemistry within sedimentary sequences.

A Binocular microscope was used to describe the 21(twenty-one) samples in terms of lithology, textural characteristics, accessory minerals and fossil content. Subsequently, a grain size log was generated on the basis of the dominant grain sizes in each lithologic unit and dilute HCl was used to test for calcareous material. Chemostratigrahic analysis was carried out using the atomic absorption spectroscopy (AAS) analytical procedure. Spectroscopic anlaytical procedure is used for quantitative and qualitative determination of chemical elements using the absorption of optical radiation (light) by atoms in gaseous state. It determines concentration of elements in a particular sample to be analysed.

Sample selection include clay to coarse sand of any lithology and the sample type ranges from side-wall (chips 2-3cm^3) and cuttings (5-10g dry cuttings).

Materials used for the analysis include

- AA spectrometer
- Vibrator
- Sample scale
- Conical flask
- Filter paper
- Funnel

3. Results

3.1 Lithostratigraphic interpretation

Lithostratigraphic interpretation of samples from Goml–1 well in the northern delta depobelt indicate a dominant trend of sandstone lithofacies at shallow well depth to approximately mid depth (117m-2500m), with colours ranging characteristically from whitish, white-grey to milkish. Intercalation of coarsed-medium-fine

grained lithofacies was seen to depth of 2500m. Fine grained, light-grey to dark-grey shale lithofacies occupy intervals from 2500m to 4617m. (Figure 2).

3.2 Chemostratigraphic analysis

The result of the chemostratigraphic analysis, which involved atomic absorption spectroscopy (AAS) analytical procedure, is as tabulated in Table 1 and 2 below. Graphs of the ratio of the result of some of the elements and some individual elements (Na, Zn, K and Mn) were plotted against depth, as seen in Figure 3 and 4.
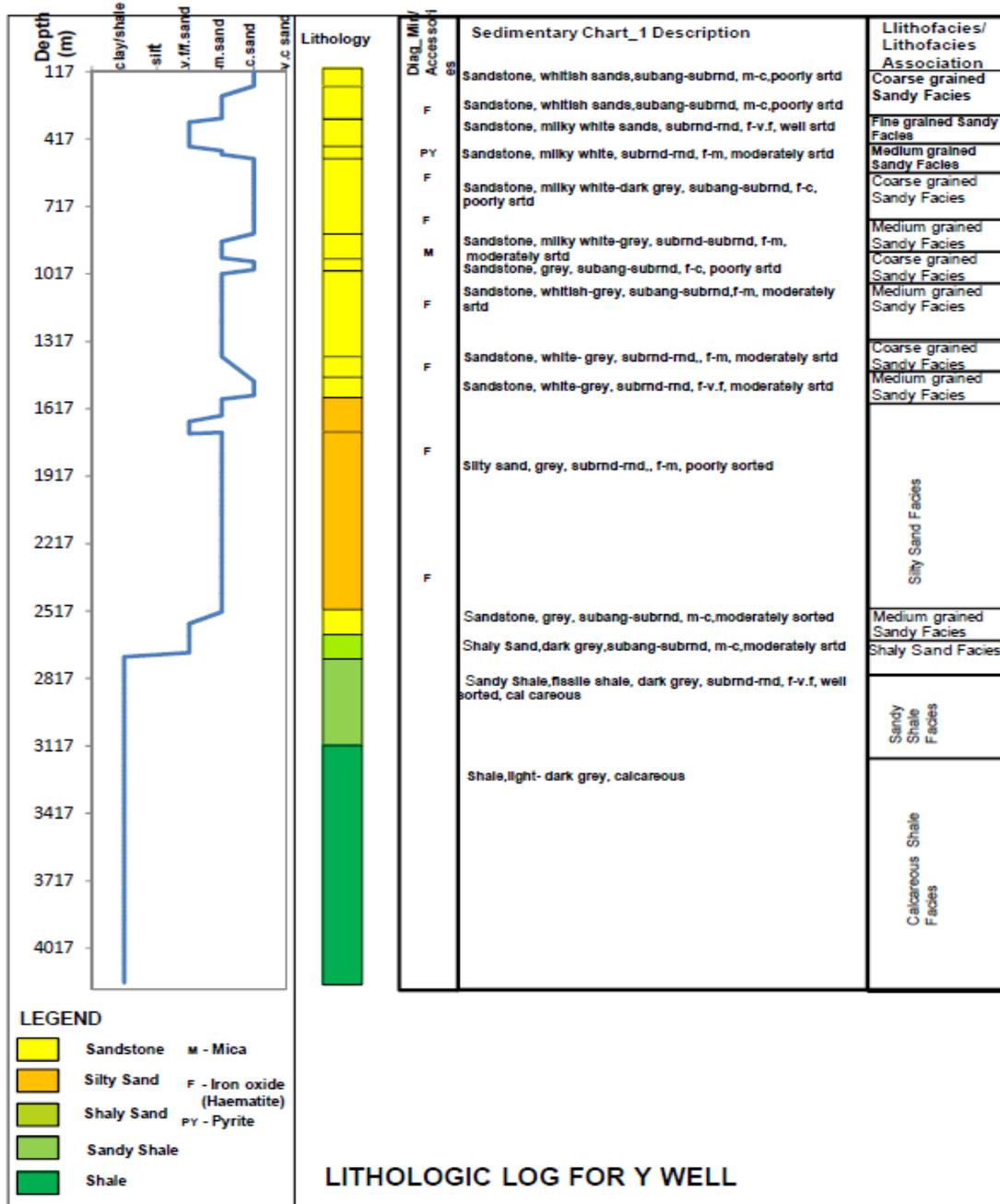
Figure 2: Lithostratigraphic interpretation of Goml-1 well

Table 1: Showing result of chemical analysis of element in samples from Goml-1 well using atomic absorption spectroscopy (AAS) procedure

Foot ft	Meter m	Si mg/kg	Cu mg/kg	Ba mg/kg	Sc mg/kg	Sr mg/kg	V mg/kg	Co mg/kg	Sn mg/kg	Hg mg/kg	Mn mg/kg
1080	329.18	0.031	0.33	0.126	ND	ND	0.475	0.012	ND	ND	36.767
3670	1118.62	0.01	0.104	0.04	ND	ND	0.15	0.004	ND	ND	24.545
5190	1581.91	0.031	0.33	0.126	ND	ND	0.475	0.012	ND	ND	53.716
5820	1773.94	0.014	0.144	0.055	ND	ND	0.207	0.005	ND	ND	60.097
6180	1883.66	0.019	0.195	0.074	ND	ND	0.282	0.007	ND	0.003	33.83
6840	2084.83	0.021	0.22	0.084	ND	ND	0.317	0.008	ND	ND	56.518
7590	2313.43	0.015	0.159	0.061	ND	ND	0.229	0.006	ND	0.006	65.499
8400	2560.32	0.013	0.137	0.052	ND	ND	0.198	0.005	ND	ND	62.798
9530	2904.74	0.038	0.397	0.151	ND	ND	0.572	0.014	ND	ND	36.261
10160	3096.77	0.038	0.394	0.15	ND	ND	0.568	0.014	ND	ND	65.06
10180	3102.86	0.019	0.205	0.078	ND	ND	0.295	0.007	ND	ND	46.018
10310	3142.49	0.025	0.26	0.099	ND	ND	0.374	0.009	ND	ND	51.015
10690	3258.31	0.024	0.247	0.094	ND	ND	0.356	0.009	ND	ND	56.72
11110	3386.33	0.021	0.217	0.083	ND	ND	0.312	0.008	ND	0.003	23.026
11320	3450.34	0.026	0.275	0.105	ND	ND	0.396	0.01	ND	ND	36.328
12520	3816.1	0.026	0.278	0.106	ND	ND	0.4	0.01	ND	ND	56.18
12050	3672.84	0.017	0.177	0.067	ND	ND	0.255	0.006	ND	ND	12.357
12980	3956.3	0.018	0.189	0.072	ND	ND	0.273	0.007	ND	ND	59.32
13440	4096.51	0.018	0.189	0.071	ND	ND	0.268	0.007	ND	ND	53.007
13840	4218.43	0.017	0.174	0.066	ND	ND	0.251	0.006	ND	ND	49.765
13910	4239.77	0.037	0.385	0.147	ND	ND	0.554	0.014	ND	ND	39.063

3.3 Discussion of result

Lithostratigraphic interpretation of samples from Goml-1 well produced a lithologic log. For the purpose of discussion, the lithofacies from the log (Figure 2) are coded thus (Table 4).

Lithofacies A: Coarse grained sandstone, whitish in colour and made up of subangular to subrounded grains of quartz. The quartz grains are hard and do not react to acid, they are poorly sorted with brownish tint indicating the present of iron oxide or ferruginious cement. Turns grey with depth.

Table 2: Showing result of chemical analysis of element in samples from Goml-1 well using atomic absorption spectroscopy (AAS) procedure

Foot Ft	Meter m	Na mg/Kg	K mg/Kg	Ca mg/Kg	Mg mg/Kg	Al mg/Kg	Fe mg/Kg	Pb mg/Kg	Cr mg/Kg	Ni mg/Kg	Zn mg/Kg
1080	329.18	216.457	267.673	156.626	212.384	58.199	119.016	1.84	3.927	1.068	56.652
3670	1118.62	144.503	178.695	104.561	141.785	38.853	79.454	5.52	1.236	0.336	37.82
5190	1581.91	316.237	391.063	228.826	310.288	85.027	173.88	4.523	3.927	1.068	82.767
5820	1773.94	353.804	437.519	256.009	347.148	95.128	194.536	4.14	1.709	0.465	92.599
6180	1883.66	199.164	246.289	144.113	195.417	53.55	109.508	8.663	2.327	0.633	52.126
6840	2084.83	332.735	411.464	240.763	326.475	89.463	182.951	3.142	2.618	0.712	87.085
7590	2313.43	385.607	476.846	279.021	378.352	103.679	212.022	9.967	1.891	0.514	100.922
8400	2560.32	369.705	457.183	267.515	362.75	99.403	203.279	3.91	1.636	0.445	96.761
9530	2904.74	213.475	263.986	154.468	209.459	57.397	117.377	2.99	4.727	1.286	55.871
10160	3096.77	383.023	473.651	277.151	375.817	102.984	210.601	4.217	4.69	1.276	100.246
10180	3102.86	270.919	335.022	196.034	265.822	72.842	148.962	2.147	2.436	0.663	70.906
10310	3142.49	300.336	371.4	217.32	294.686	80.752	165.137	3.067	3.091	0.841	78.605
10690	3258.31	333.927	412.939	241.626	327.645	89.784	183.607	2.913	2.945	0.801	87.397
11110	3386.33	135.559	167.634	98.089	133.008	36.448	74.536	8.893	2.582	0.702	35.479
11320	3450.34	213.873	264.478	154.756	209.849	57.504	117.596	6.67	3.272	0.89	55.976
12520	3816.1	330.747	409.006	239.325	324.525	88.929	181.858	2.453	3.309	0.9	86.564
12050	3672.84	72.748	89.962	52.64	71.38	19.56	40	6.9	2.109	0.574	19.04
12980	3956.3	349.232	431.866	252.701	342.662	93.899	192.022	1.993	2.254	0.613	91.402
13440	4096.51	312.063	385.902	225.805	306.192	83.905	171.585	2.377	2.218	0.603	81.674
13840	4218.43	292.982	362.305	211.998	287.47	78.774	161.093	5.213	2.073	0.564	76.68
13910	4239.77	229.973	284.387	166.406	225.646	61.833	126.448	4.217	4.581	1.246	60.189

Table 3: Ratio of K:Mn and Na:Zn in Goml–1 well

Foot	Meter	K	Mn	Ratio (K:Mn)	Na	Zn	Ratio (Na:Zn)
ft	m	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
1080	329.18	267.693	36.767	7.28	216.456	56.652	3.821
3670	1118.62	178.695	24.545	7.28	144.503	37.82	3.821
5.19	1581.91	39.063	53.716	7.28	316.237	82.767	3.821
5820	1773.94	437.516	60.097	7.28	353.804	92.599	3.821
6180	1883.6	411.464	33.83	7.28	199.164	52.126	3.821
7590	2084.83	476.846	56.518	7.28	332.735	87.085	3.821
8400	2313.43	457.183	65.499	7.28	385.607	100.922	3.821
9530	2560.32	263.986	36.261	7.28	369.705	96.761	3.821
10160	2904.74	473.651	36.261	7.28	213.475	55.871	3.821
10180	3096.77	335.022	65.066	7.28	383.023	100.246	3.821
10310	3102.86	371.4	46.018	7.28	270.919	70.906	3.821
10690	3142.49	412.939	51.015	7.28	300.336	78.605	3.821
11110	3258.31	167.634	56.72	7.28	333.927	87.397	3.821
11320	3386.33	264.478	23.328	7.28	135.559	35.476	3.821
12520	3450.34	409.006	36.328	7.28	213.873	55.976	3.821
12050	3816.1	89.962	56.18	7.28	330.747	86.564	3.821
12980	3672.84	431.866	12.357	7.28	72.748	19.04	3.821
13440	4096.51	385.902	59.32	7.28	349.232	91.402	3.821
13840	4218.43	362.305	53.007	7.28	312.063	81.674	3.821
13910	4239.77	284.387	49.765	7.28	292.982	76.68	3.821
13910	4239.77	229.976	60.189	3.821	229.976	60.189	3.821

Depositional Environment (A): Is the shallow waters, outer shelf environment.

Lihtofacies B: Fine grained sandstone, milky white in colour made up of subround to rounded grains. The grain sizes ranges from fine to very fine sandy particles of quartz. The grains are well sorted and shows no reaction

with acid.

Depositional Environment (B): Shallow waters, outer continental shelf, low energy environment.

Lithofacie C: Medium grained sandstone, milky white to grey in colour, made up of subangular to subrounded grains of feldspars and quartz with the feldspars looking more cloudy. Narrow flakes of mica are seen. It does not show any reaction with acid it is moderately sorted with iron oxide or ferruginous cement.
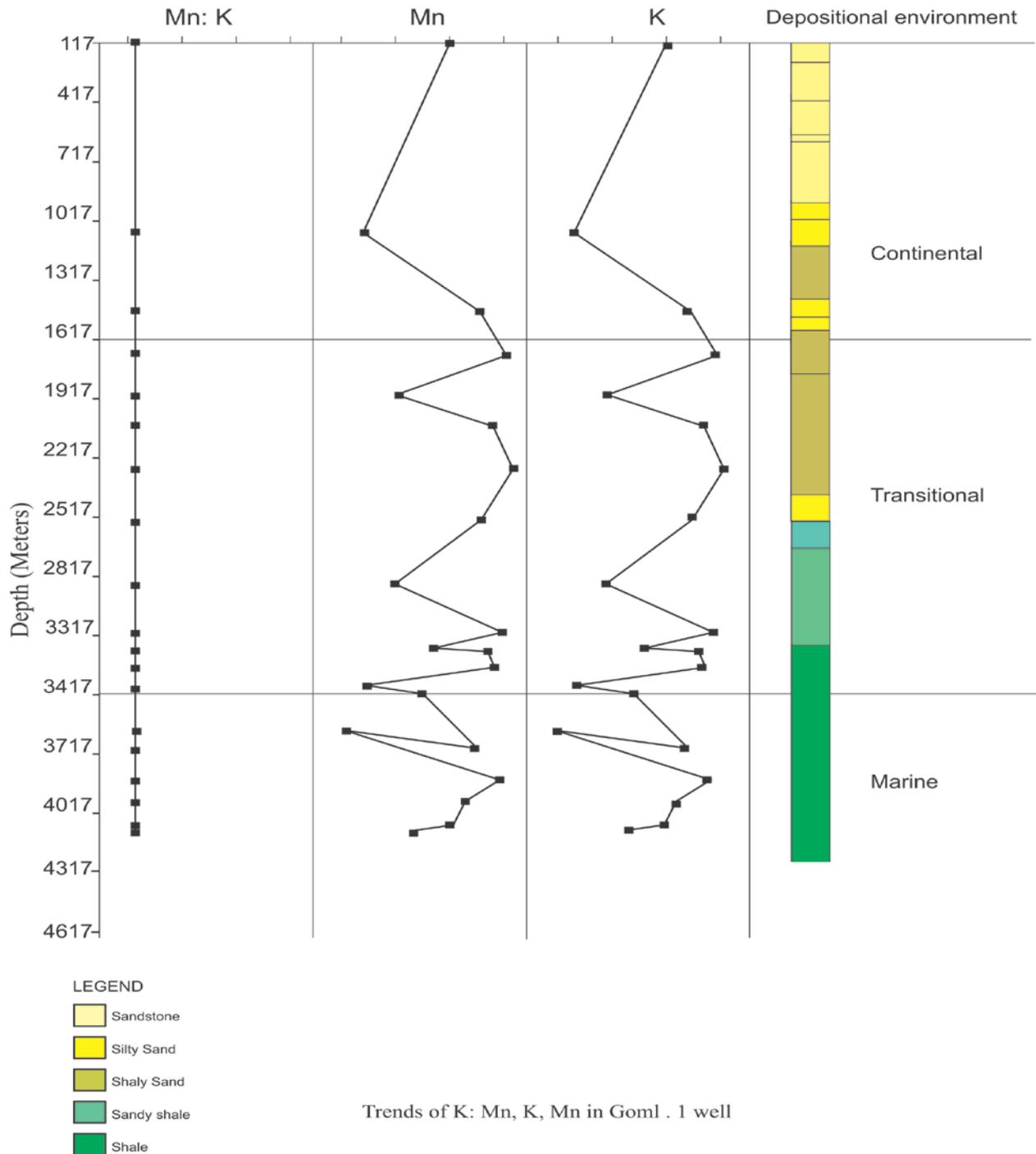
Figure 3: Trends in K:Mn, K, Mn in Gom1 Well
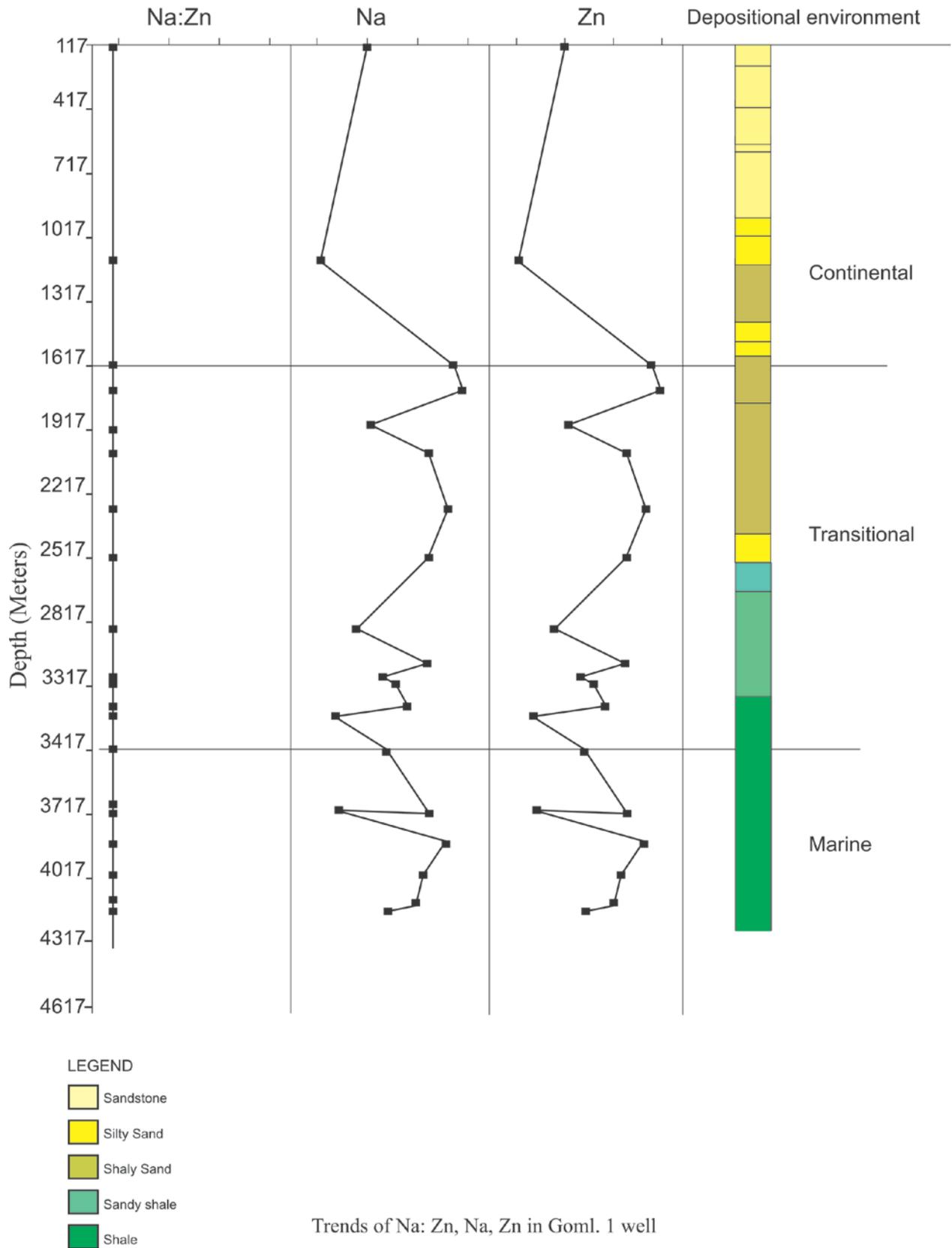
Figure 4: Trends of Na:Zn, Na, Zn in Gom. 1 Well

Table 4: Lithofacies code derived from the lithologic log

LITHOFACIES	CODE
Coarse grained sandy facies	A
Fine grained sandy facies	B
Medium grained sandy facies	C
Silty sandy facies	D
Sandy shale	E
Calcareous shale	F

Depositional Environment (C): Continental outer shelf shallow waters environment.

Lithofacies D: Silty sand, fine to medium grained sandstone, greyish in colour and the shape of the grains are subrounded to rounded. It is moderately sorted with iron oxide or ferruginous cement.

Depositional Environment (D): Continental inner shelf environment.

Lithofacies E: Shaly sandstone, dark grey in colour. The grains are subangular to subrounded in shape and medium to coarse in size. It is moderately sorted.

Depositional Environment (E): Shallow waters, marine environment

Lithofacies F: Sandy shale, dark grey in colour, it is made up of fine to very fine grains. The shale shows fissility and it is calcarow. It shows efferversence on application of dilute hydrochloric acid.

Depositional Environment (E): Marine shallow waters environment.

Lithofacies F: Calcareous shale made up of very fine to fine grains, it is dark grey in colour. It is calcareous depicting the presence of calcareous fossils. It shows rapid effervescence on application of dilute hydrochloric acid.

Depositional Environment (F): Deep waters, marine environment.

The ratio of Na:Zn for all cutting sample shows the same value with depth in Goml–1 well , while the graph of Na:Zn resulted in a straight vertical line along the y-axis from top to bottom. The straight vertical line graph of Na:Zn ratio with no deflection to the left or right shows that sodium (Na) and zinc (Zn) varies proportionally with depth.

The graph of sodium(Na), against depth (Figure 4) shows a relatively maximum variation of Na with an increase in depth. At a depth of 2313meters there is a first observation of maximum peak value and a second maximum

peak value at a depth of 3096meters

The ratio of K:Mn for all cutting sample from Goml–1 well shows proportional relationship. The graph (Figure 3) shows direct proportionality of potassium (K) to Manganese (Mn) with depth in Goml–1 well.

The graph of zinc (Zn) against depth (Figure 4) shows an average variation of zinc with an increase in depth – zinc has it's maximum peak value at a depth of 3096meters indicating points of maximum abundance of zinc

The graph of Potassium (K) against depth (Figure 3) shows a continuous variation with increase in depth, becoming maximum at some point with a strong deflection to the right and minimum at other point with a strong deflection to the left. From the graph it can be observed that Potassium (K) first peaked at a depth of 2313meters where the deflection is maximum and also peaked a second time at 3096meters thus indicating maximum abundance of element at such points of maximum deflection or peak. It is also observed that the values of potassium varies maximally with depth.

From the graph Manganese (Mn) against depth (Figure 3), it can be observed that the values of Manganese (Mn) falls within a minimal range with depth with lesser points of maximum deflection as compared to points of minimum deflection. It is first peaked at a depth of 2313meters and also at a depth of 3096meters indicating point of maximum abundance of Manganese in the well.

The following can be observed from the inference drawn from the correlation of the graph of K, Mn, Na and Zn against depth (Figure 3 and 4):

- All four elements attained a first maximum peak at 2313m and a second maximum peak at a depth of 3096m.
- Variation in chemistry of elements with depth in a decreasing order is as follows: K has the maximum variation with depth followed by Na, Zn and Mn having the lowest variation with depth.
- The variation values of the relative abundance of element as observed from the point of maximum peak as follows.
- The relative abundance of the various elemental trends indicates a transitional to marine depositional environment

Table 5: Showing relative abundance value at peak depth for K, Na, Zn and Mn

Depth (m)	K (mg/Kg)	Na (mg/Kg)	Zn (mg/Kg)	Mn (mg/Kg)
2313	480.1	385	100.9	65
3096	480	384	100.2	65

4. Conclusion

Chemostratigraphy is a powerful technique in its own right. It has diverse application to investigating rock record such as reconstruction of paleoenvrionment, indirect dating and establishing global and regional elemental variations.

Chemostratigraphy is therefore an integral component of many investigation of ancient sedimentary rocks. Analysis have been carried out to ascertain the variation in major/minor elements in Goml–1 well and these variation were related to sediment provenance. Variation in abundance of element suggests changes in provenance of sediments. Major and minor element suites are not entirely controlled by source rock mineralogy, other reasons such as weathering, hydrodynamics and diagenesis may also influence the original provenance signal.

There is marked change in the abundance of major/minor element suites; these changes in elemental indices suggest a change from a predominantly sedimentary provenance with some acid igneous rocks during deposition of Goml–1 well sequence. In terms of geochemical data sets, this change in provenance is reflected by an increase in Na and K values which implies a relative increase in plagioclase to K- feldspars. K/Na both K and Na are controlled by a variety of alumino-silicate minerals (for example, plagioclase, clay minerals, mica), but the ratio of the two elements should be recording the proportion of plagioclase feldspar vs. k- feldspar.

Sodium (Na) and Potassium (K) values are largely controlled by the abundance of clay minerals, therefore figure 3 and 5 suggest that the lower sections of Goml-1 well has a high proportion of clay minerals than the upper section. The close similarity between change in provenance of sensitive minerals and selected elements and elemental ratios have been used to characterized the lithologies in Goml-1 well. Sodium (Na) and Potassium (k) concentration chiefly reflect the higher proportion of clay minerals which were deposited in a marine environment. Manganese (Mn) can be attributed to the presence of manganese nodules on the seafloor. Furthermore, Chemostratigraphy has been demonstrated to be a hierarchical stratigraphic technique that has application in lithostrtigrpahic methodologies to independently characterize lithostratigraphic formations and units.

4.1 Recommendations

It is of paramount importance to understand the controls on the whole rock inorganics geochemistry before attempting to extend this zonation to create a chemostratgraphic correlation. Chemostratigraphy correlation does not necessitate understanding the mineralogical controls on elements and element ratios since the stratigraphic correlation produced are based on change in whole rock geochemistry. However trying to understand the controls on the key elements and ratios it is possible to extract additional geological information from chemostratigraphic correlation.

Acknowledgements

References

[1].   Avbovbo, A., 1978. A Tertiary Lithostratigraphy of Niger Delta: Geological Notes American Association of Petroleum Geologist Bulletin. 2, 295-306.

[2].   A.J. Whiteman, "Nigeria, Its Petroleum, Geology, Resources and Potential." *Graham and Trotman, London,* 1982.

[3].   Burke, K.C.B, Dessauvagie, T.F.J. and Whiteman, A.J. (1971) "The Opening of the Gulf of Giunea and Geological History of the Benue Depression and Niger Delta": Nature physics. 38, 51-55.

[4].   Burke, K.C.B., (1972) Longshore Drift, Submarine Canyons and Submarine Fans": American Association Petroleum Geology Bull. 56(10); 1975-1983.

[5].   Doust, H.E and Omatsola, E.M., 1990. Niger Delta. In:Edwards J.D and santagrossi, P.A (eds), divergence/passive basins. AAPG. Bull. Mem.45. 201-238.

[6].   Haqq, B. U Hardenbol, J. and Vail, P.R., (1988). Mesozoic and Cenozoic Chronostratigraphy and Eustatic Cycles of Sea-Level Change: Society of Economic Paleontologists and Mineralogist Special Publication. 42, 71-108.

[7].   Kaplan, A., Lusser, C.U., Norton, I. O., 1994. Tectonic map of the world, panel10: Tulsa, American Association of Petroleum Geologists, scale1:10,000,000.

[8].   K.C Short, and A.J. Stauble.: "Outline of Geology of Niger Delta". *AAPG Bulletin* Vol 51 pp761-779, 1967.

[9].   Kulke, H., 1995. Regional petroleum geology of the world. Part II: Africa, America, Australia and Antarctica: Berlin, Gebrüder Borntraeger. 143-172.

[10].   Lehner, P. and De Ruiter, P. A**.,** 1977. Structure History of the Atlantic Margin of Africa": American Association Petroleum Geology Bull 61, 961-981.

[11].   Aldahan, A., G.Possnert, R.Possnert, R. Scherern, N. Shi, J.Backman & K. Bostrom (2000): Trace-element and major-element stratigraphy in quaternary sediments from the Arctic Ocean and implications for glacial termination. – Journal of Sedimentary Research, **70:** 1095–1106

[12].   Frank, M., N.Whiteley, T. van de Flierdt, B. C. Reynolds & K. O'Nions (2006): Nd and Pb isotope evolution of deep water masses in the eastern Indian Ocean during the past 33 Myr. Chemical Geology, 226: 264–279.

[13].   Wissler, L., H.Weissert, J.-P.Masse & L.Bulot (2003): Chemostratigraphic correlation of Barremian and lower Aptian ammonite zones and magnetic reversals. – Int. J. Earth Sci., 91: 272–279.