PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 24 (6) 1115-1121 June 2020

Use of Sedimentological and Geochemical Parameters to Evaluate the Lithologies and Geochemical (Na/Zn and K/Mn) Ratios of OGE-1 Well, Niger Delta Basin

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ABSTRACT: This work focuses on subjecting ninety (90) sidewall core well samples to sedimentological and geochemical parameters to determine the lithologies and the geochemical ratios of the OGE-1 Well in the Niger Delta Basin. The sedimentological analysis with sample description yielded lithologies that are sand, shaly sand, sandy shale and shale. The sand lithologies ranged from fine to coarse grained, well sorted to poor sorted at different depths, while the shale lithologies ranged from light to dark coloured shales which is controlled by the organic matter content in the shale. This finally produced a lithologic frame work of the well. The result of the geochemical analysis led to the creation of the geochemical ratio of Na/Zn (0.739 – 5.610) and K/Mn (21.170 – 69.37) for 90 side wall core samples. Na and K had variations in their graphs showing intermittent alternating abundance downhole. Na and K being components of the weathering of feldspars are indicative of abundance of clay minerals. The variation of the Na/Zn and K/Mn profile indicates the alternate deposition of clay and sand size deposits giving the environment of deposition to be paralic.

DOI: https://dx.doi.org/10.4314/jasem.v24i6.27

Dates: Received: 19 April 2020; Revised: 22 May 2020; Accepted: 21 June 2020

Keywords: Chemo-stratigraphy, Paleo-environment, Sedimentological, Stratigraphy, Geochemistry

Geochemical or chemical stratigraphy involves the characterization and correlation of strata using major and trace element geochemistry (Ratcliffe *et al.*, 2006). Chemostratigraphy is a technique used to correlate sedimentary successions based on subtle changes in concentration of key major, minor and trace elements (Lucas *et al.*, 2016). Chemostratigraphy, which is termed "chemical/elemental stratigraphy", is the characterization or "fingerprinting" and stratigraphic zonation (and correlation) of strata from the changes of the bulk inorganic geochemical or elemental composition and signatures of sedimentary rocks (Ighodaro *et al.*, 2018). Sediments that appear homogenous in most physical respects often have significant geochemical variability. Jarvis (1998, 2001); Pearce and Jarvis (1995); De Lange (1987); Mabrouk (2005, 2006); and Totland (1992) have all used chemostratigraphy for different stratigraphic studies. Therefore the objective of this paper is to present data for subjecting ninety (90) sidewall core well samples to sedimentological and geochemical parameters to determine the lithologies and the geochemical ratios of the OGE-1 Well in the Niger Delta Basin.

MATERIALS AND METHODS

Geological Setting of the Niger Delta Basin: The Niger Delta Basin is located in the Gulf of Guinea in the southern part of Nigeria. It lies between longitudes 40°E and 8.80°E and latitudes 30°N and 60°N, and occupies the coastal ocean ward part of the Benue-Abakaliki Trough; hence its evolution has been linked with that of this larger sedimentary complex (Murat, 1972; Reijers *et a.l*, 1997). It is a clastic fill of about 12,000metres with sub-aerial portion covering 75,000 sq. km and extending more than 300km from apex to mouth (Doust and Omatsola, 1990). Various authors have identified the Benue-Abakaliki Trough as the failed arm of the three radial rift systems that met at an R-R-R triple junction in the Gulf of Guinea that was active in early Cretaceous due to crustal doming (Burke *et al*., 1971; Burke, 1972; Burke and Whiteman, 1973). The Niger Delta complex developed at the point where the three arms of a triple junction met. This triple junction was formed during

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the separation of the African and South American plates in the Albian times (Whiteman, 1982). Two of the arms, which followed the south-western and south-eastern coast of Nigeria developed into collapsed continental margins of the South Atlantic, whereas the third failed arm developed into the Benue Trough. The Niger Delta now occupies the center of the triple junction. The Niger Delta Basin represents the third cycle in the evolution of the trough and its associated basins. The first cycle (Aptian-Santonian) brought about the evolution of the trough as the failed arm of a rift triple junction (RRFtype) associated with the separation of South American and African plates (Burke and Whiteman, 1973,). Two platforms (Anambra and Abakaliki) were formed on both sides of the trough during this period. The second cycle (Santonian-Eocene) began after the Campanian-Santonian folding episode. The Abakaliki Trough was uplifted to form Abakaliki Anticlinorium whilst the Anambra platform was downwarped to form the Anambra Basin (Weber and Daukoru, 1975) resulting in the westward displacement of the trough's depositional axis. During the Paleocene- Early Eocene, the upliftment of Benin and Calabar flanks initiated a major regressive phase. By the end of this cycle, rifting has diminished considerably. The third cycle (Eocene-Recent) brought about the development of the modern Niger Delta. However, true delta development commenced only in the Paleocene times when sediments began to accumulate in the troughs between basement horst blocks of the northern flank of the present delta area. The progradation of the Niger Delta first occurred during the Eocene, probably in response to epeiorogenic movements along the Benin and Calabar flanks (Evamy *et al.,* 1978), and this continued to the present time. Strata were deposited along an unstable progradation margin, this was later seen to result from paralic deposition into a series of depobelts which succeeded each other in time and space, leading to a regular step-like southward progression of the delta referred to as "escalator regression".

The development of the proto-delta was terminated in the Paleocene by a major sea transgression (Weber *et al.,* 1978). This was followed by a regressive phase in the Eocene as the sea progressively moved southwards. The regressive phase has continued until the present, but is frequently interrupted by generally minor transgressions, resulting in the formation of the modern Niger Delta, which is Eocene to Recent in age. The Niger Delta basin consists of massive and monotonous marine shale at its base. This grades upward into interbedded shallow marine fluvial sands, silts and clays, which form the typical paralic portion of the delta. The uppermost part of the sequence is a massive, non-marine sand unit. These are referred to as the Akata, Agbada and Benin Formations respectively (Short and Stauble, 1967). These three lithostratigraphic units are strongly diachronous. However, the Cenozoic Niger Delta complex is greatly affected by large scale synsedimentary features in the subsurface, such as growth faults, roll-over anticlines and diapirs (Evamy *et al.,* 1978**).**

Stratigraphy of Niger Delta Basin: The lithostratigraphy of the Niger Delta Basin consists of three main rock stratigraphic units of Cretaceous to Holocene origin (Short and Stauble, 1967; Franklin and Cordry, 1967; Avbovbo, 1978). These units represent the prograding depositional environments (Corredor, 2004).

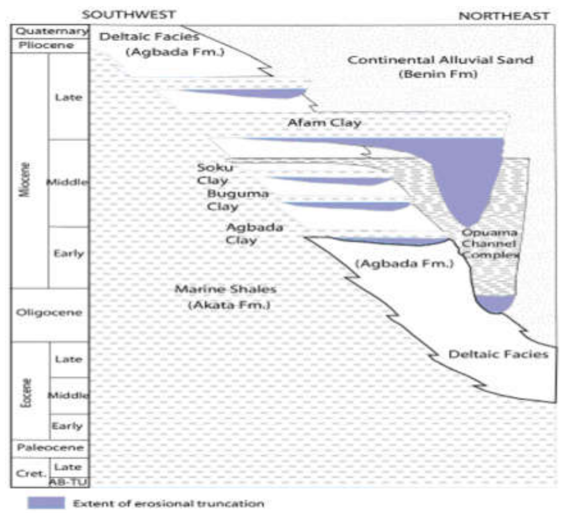


Fig 1. Stratigraphic column showing the three Formations of the Niger Delta, the Marine Akata shale, the paralic Agbada formation and the continental Benin sandstone. (Modified from Doust and Omatsola, 1990).

Location of Study: The well of study is located in the Greater Ughelli depobelt, Niger Delta Basin. This study was conducted using Ninety (90) side-wall core samples from OGE#1 Well; and subjected to both sedimentological and geochemical analysis. The samples were subsurface oil well samples got from the industry.

Sedimentological Analysis: The Sedimentological analysis was carried out with the aid of the Stereo zoom microscope, which was used to describe the ninety (90) samples in terms of lithology and textural characteristics, which include grain shape, grain colour, grain size and sorting. Subsequently, a grain size log was generated on the basis of the dominant grain sizes in each lithologic unit.

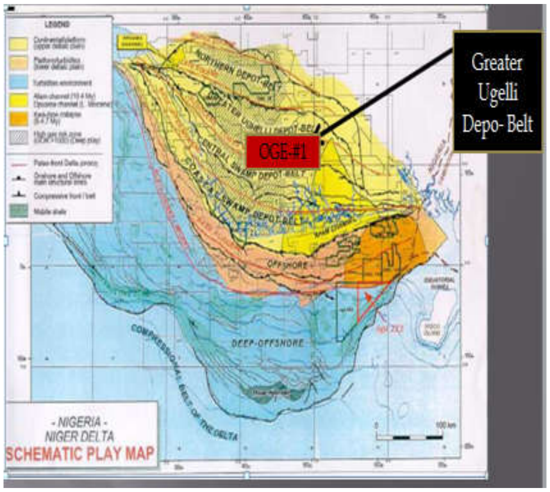
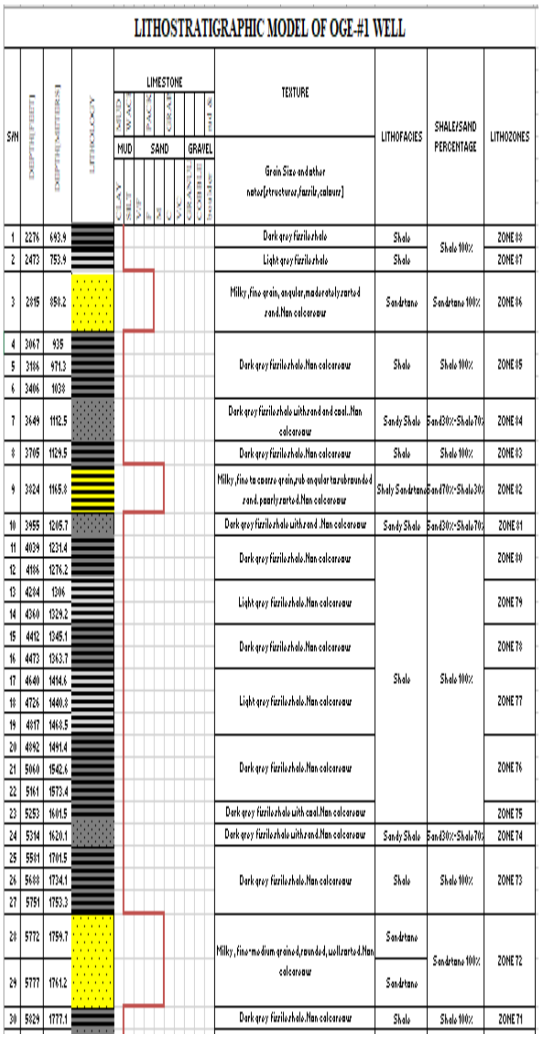


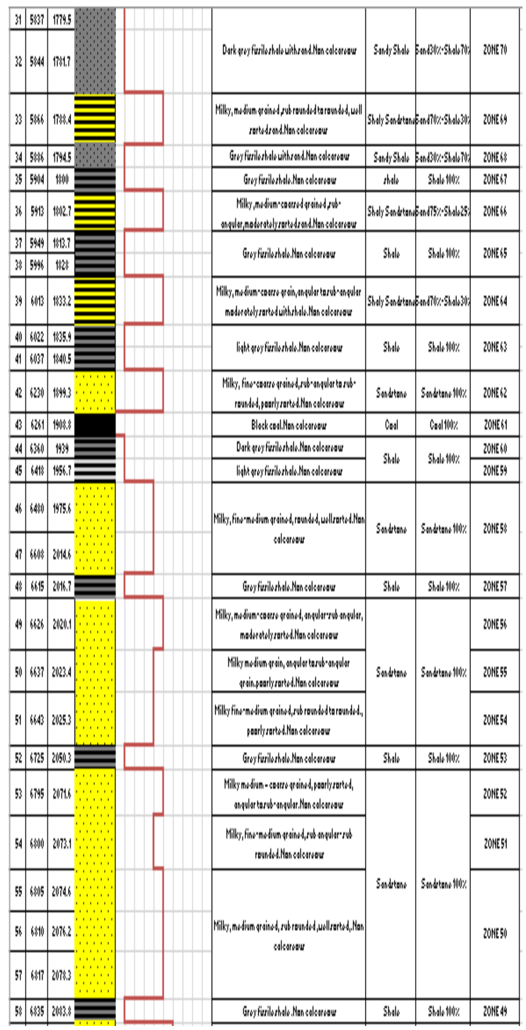
Fig 2: Showing Location of Study in Map of Niger Delta Depobelts (Nwozor et al., 2013)

Geochemical Analysis: The geochemical analysis was carried out for some elements, which include Na, Al, U, Zr, K and Th using the Atomic Absorption Spectroscopy (AAS). Spectroscopic analytical 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. Apparatus and Reagents Materials used for the analysis include: - AA spectrometer - Vibrator - Sample scale - Conical flask - Whatman filter paper No:42 - Polythene funnels - Unicam 929 spectrometer (AA PG 550 Spectrometer) - Extracting solution (9ml of Conc. HCl, 3ml of HNO_3 and 2ml of perchloric acid and make up to a final volume of 1litres with deionized water. - 1000mg/l Stock Standard solution of (Na, Al, U, Zr, K/Th, etc) were used in concentration 0, 0.2, 0.4, 0.6, 0.8, and 1mg/l for each analyte analysed.



LITHOSTRATIGRAPHIC MODEL OF OGE-#1 WELL

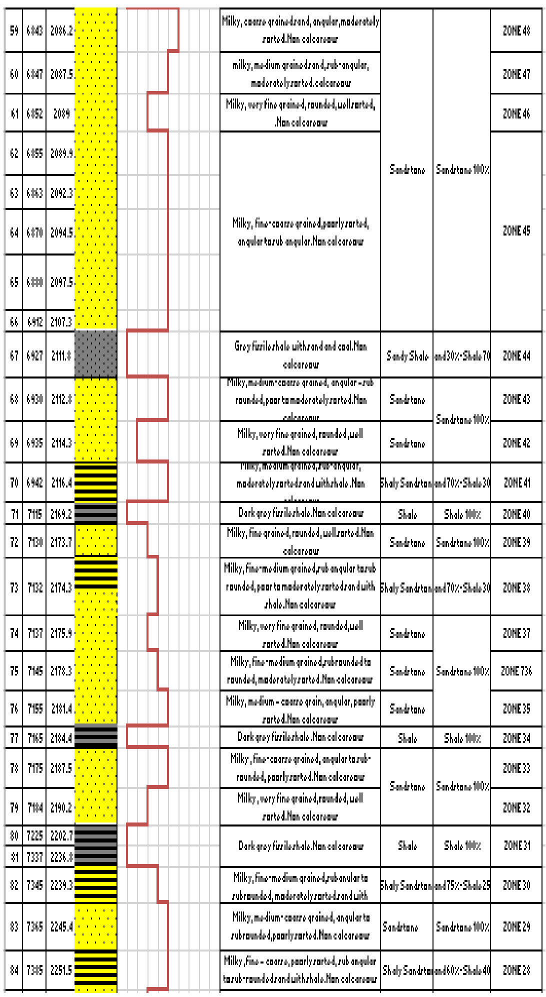
S/N	DEPTH[FEET]	DEPTH[METERS]	TEXTURE: Grain Size and other notes[structures,fossils,colours]	LITHOFACIES	SHALE/SAND PERCENTAGE	LITHOZONES
1	2276	693.9	Dark grey fissile shale	Shale	Shale 100%	ZONE 88
2	2473	753.9	Light grey fissile shale	Shale		ZONE 87
3	2815	858.2	Milky, fine grain, angular, moderately sorted sand. Non calcareous	Sandstone	Sandstone 100%	ZONE 86
4	3067	935	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 85
5	3186	971.3				
6	3406	1038				
7	3649	1112.5	Dark grey fissile shale with sand and coal.. Non calcareous	Sandy Shale	Sand30%-Shale70%	ZONE 84
8	3705	1129.5	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 83
9	3824	1165.8	Milky, fine to coarse grain, sub angular to subrounded sand, poorly sorted. Non calcareous	Shaly Sandstone	Sand70%-Shale30%	ZONE 82
10	3955	1205.7	Dark grey fissile shale with sand . Non calcareous	Sandy Shale	Sand30%-Shale70%	ZONE 81
11	4039	1231.4	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 80
12	4186	1276.2				
13	4284	1306	Light grey fissile shale. Non calcareous			ZONE 79
14	4360	1329.2				
15	4412	1345.1	Dark grey fissile shale. Non calcareous			ZONE 78
16	4473	1363.7				
17	4640	1414.6	Light grey fissile shale. Non calcareous			ZONE 77
18	4726	1440.8				
19	4817	1468.5				
20	4892	1491.4	Dark grey fissile shale. Non calcareous			ZONE 76
21	5060	1542.6				
22	5161	1573.4				
23	5253	1601.5	Dark grey fissile shale with coal. Non calcareous			ZONE 75
24	5314	1620.1	Dark grey fissile shale with sand. Non calcareous	Sandy Shale	Sand30%-Shale70%	ZONE 74
25	5581	1701.5	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 73
26	5688	1734.1				
27	5751	1753.3				
28	5772	1759.7	Milky, fine-medium grained, rounded, well sorted. Non calcareous	Sandstone	Sandstone 100%	ZONE 72
29	5777	1761.2		Sandstone		
30	5829	1777.1	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 71



S/N	DEPTH[FEET]	DEPTH[METERS]	TEXTURE	LITHOFACIES	SHALE/SAND PERCENTAGE	LITHOZONES
31	5837	1779.5	Dark grey fissile shale with sand. Non calcareous	Sandy Shale	Sand30%-Shale70%	ZONE 70
32	5844	1781.7				
33	5866	1788.4	Milky, medium grained, sub rounded to rounded, well sorted sand. Non calcareous	Shaly Sandstone	Sand70%-Shale30%	ZONE 69
34	5886	1794.5	Grey fissile shale with sand. Non calcareous	Sandy Shale	Sand30%-Shale70%	ZONE 68
35	5904	1800	Grey fissile shale. Non calcareous	shale	Shale 100%	ZONE 67
36	5913	1802.7	Milky, medium-coarsed grained, sub-angular, moderately sorted sand. Non calcareous	Shaly Sandstone	Sand75%-Shale25%	ZONE 66
37	5949	1813.7	Grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 65
38	5996	1828				
39	6013	1833.2	Milky, medium-coarse grain, angular to sub-angular moderately sorted with shale. Non calcareous	Shaly Sandstone	Sand70%-Shale30%	ZONE 64
40	6022	1835.9	light grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 63
41	6037	1840.5				
42	6230	1899.3	Milky, fine-coarse grained, sub-angular to sub-rounded, poorly sorted. Non calcareous	Sandstone	Sandstone 100%	ZONE 62
43	6261	1908.8	Black coal. Non calcareous	Coal	Coal 100%	ZONE 61
44	6360	1939	Dark grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 60
45	6418	1956.7	light grey fissile shale. Non calcareous			ZONE 59
46	6480	1975.6	Milky, fine-medium grained, rounded, well sorted. Non calcareous	Sandstone	Sandstone 100%	ZONE 58
47	6608	2014.6				
48	6615	2016.7	Grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 57
49	6626	2020.1	Milky, medium-coarse grained, angular-sub angular, moderately sorted. Non calcareous	Sandstone	Sandstone 100%	ZONE 56
50	6637	2023.4	Milky medium grain, angular to sub-angular grain, poorly sorted. Non calcareous			ZONE 55
51	6643	2025.3	Milky fine-medium grained, sub rounded to rounded., poorly sorted. Non calcareous			ZONE 54
52	6725	2050.3	Grey fissile shale. Non calcareous	Shale	Shale 100%	ZONE 53
53	6795	2071.6	Milky medium - coarse grained, poorly sorted, angular to sub-angular. Non calcareous	Sandstone	Sandstone 100%	ZONE 52
54	6800	2073.1	Milky, fine-medium grained, sub angular-sub rounded. Non calcareous			ZONE 51
55	6805	2074.6	Milky, medium grained, sub rounded, well sorted,. Non calcareous			ZONE 50
56	6810	2076.2				
57	6817	2078.3				
58	6835	2083.8	Grey fissile shale . Non calcareous	Shale	Shale 100%	ZONE 49

RESULTS AND DISCUSSION

Sedimentological Analysis: The Sedimentological analysis lead to the production of the lithostratigraphical framework of the OGE-1 Well, which is as expressed in Figure 3. The Sedimentological analysis with focus of lithologic type, sediment colour, grain shape, grain size and sorting produced different facie types that ranged from sandstone to shale, very fine to coarse grains, angular to rounded grains, poorly to well sorted sediments. The result of the sedimentological analysis showed parameters ranging from poorly sorted to well sorted sediments, very fine to coarse grained and lithology being either sand, shaly sand, sandy shale or shale. The sandy lithologies represented areas of relatively high energy of deposition, and shaly lithologies depicted zones of very low energy of deposition. The colouration of the shales varied form light to dark shales - depends on the organic content it has. The higher the organic content, the darker the shales.



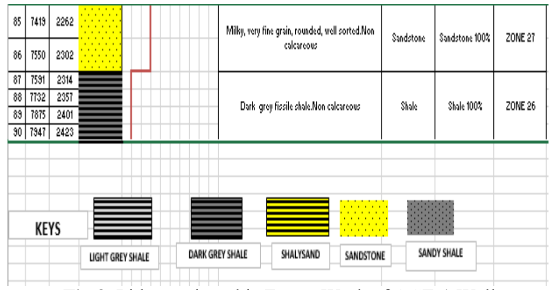


Fig 3. Lithostratigraphic Frame Work of OGE-1 Well

The shale lithologies represent probable sources and cap rocks. As petroleum source rocks are argillaceous shale sediments; while the sands represent probable source rocks. The lithologies that are heterolithic have sediment composition ranging fifty (50) percent of sand and fifty (50) percent of shale. Where the sand is 100 percent sand, it is noted to be a probable good reservoir, but where it has fines in it, it loses permeability, and hence a poor reservoir rock

Geochemical Profiles: The plot of Na/Zn shows a variation of Na/Zn with depth peaking at both top and bottom of the well. While the graph of K/Mn didn't show much variation in trend. The Na/Zn profile showed a peak of profile at the beginning of the well, and another peak at the bottom, showing that the concentration of Na reduced with relative to depth, and suddenly increased again toward the end of the graph. These were minor variations within the length of the well. While the value of Zn increased with depth with a sudden reduction at the bottom of well, also with minor variations along the well depth.

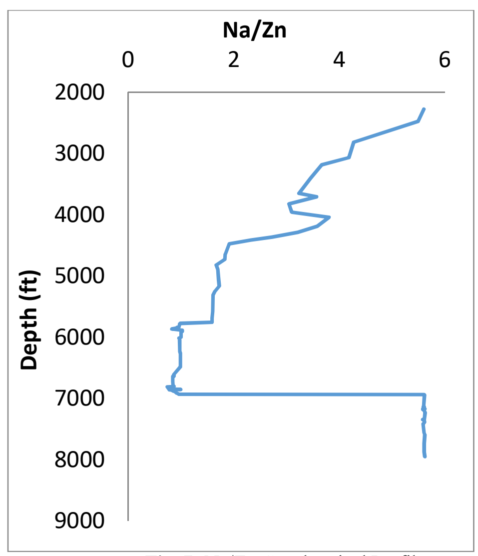


Fig. 7: Na/Zn Geochemical Profile

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Table 1: Geochemical Analysis

		Concentration (mg/kg)							
S/N	**Depth (Ft)**	**Na**	**Al**	**U**	**Zr**	**K**	**Th**	**Mn**	**Zn**
1	2276 - 2473	39.72	52.46	0.142	0.2835	175.22	0.057	5.68	7.16
2	2815 - 3067	30.25	46.34	0.105	0.2500	161.77	0.048	4.93	7.16
3	3186 - 3406	25.47	38.62	0.103	0.2175	151.55	0.044	4.60	7.16
4	3649 - 3705	23.03	44.23	0.104	0.075	139.90	0.014	4.21	6.80
5	3824 - 3955	17.96	40.91	0.069	0.083	117.46	0.017	3.75	5.86
6	4039 - 4186	16.24	28.34	0.088	0.066	106.65	0.014	3.75	4.40
7	4284 – 4360	13.04	28.30	0.081	0.054	100.96	<0.001	3.75	4.40
8	4412 – 4473	9.32	28.14	0.079	0.036	96.30	<0.001	3.46	4.40
9	4640 – 4726	8.00	27.55	0.039	0.017	92.52	<0.001	3.44	4.36
10	4817 – 4892	6.87	26,83	0.054	0.014	89.28	<0.001	3.36	4.09
11	5060 – 5161	6.64	21.23	0.052	0.015	88.54	<0.001	2.88	3.87
12	5253 – 5314	5.66	16.05	0.029	0.014	88.54	<0.001	2.60	3.50
13	5581 – 5688	5.51	13.24	0.048	0.014	84.60	<0.001	2.60	3.46
14	5751 – 5772	4.44	12.05	0.048	0.014	82.85	<0.001	2.60	3.46
15	5777 – 5829	3.36	11.76	0.017	0.014	80.64	<0.001	2.32	3.46
16	5837 – 5844	3.20	11.23	0.013	<0.001	76.20	<0.001	1.57	3.45
17	5866 – 5886	2.83	10.81	0.013	<0.001	69.98	<0.001	1.01	3.06
18	5904 – 5913	3.13	10.74	0.013	<0.001	69.68	<0.001	1.76	3.09
19	5949 – 5996	3.05	10.55	0.012	<0.001	65.24	<0.001	2.44	3.05
20	6013 – 6022	2.85	10.55	0.007	<0.001	59.90	<0.001	2.37	2.96
21	6037 – 6230	2.85	10.55	<0.001	<0.001	59.00	<0.001	2.35	2.93
22	6261 – 6360	2.85	10.1	<0.001	<0.001	59.00	<0.001	2.31	2.89
23	6418 – 6480	2.85	9.14	<0.001	<0.001	57.95	<0.001	2.31	2.89
24	6608 – 6615	2.49	8.54	<0.001	<0.001	56.89	<0.001	2.31	2.89
25	6626 – 6637	2.49	7.94	<0.001	<0.001	56.89	<0.001	2.31	2.89
26	6643 – 6725	2.32	7.50	<0.001	<0.001	53.67	<0.001	2.21	2.76
27	6795 – 6800	2.32	7.50	<0.001	<0.001	51.47	<0.001	2.17	2.71
28	6805 – 6810	2.15	7.50	<0.001	<0.001	51.47	<0.001	2.14	2.68
29	6817 – 6835	1.98	7.25	<0.001	<0.001	51.47	<0.001	2.11	2.63
30	6843 – 6847	1.98	6.47	<0.001	<0.001	49.92	<0.001	1.85	2.32
31	6852 – 6855	1.69	6.00	<0.001	<0.001	43.38	<0.001	1.51	1.89
32	6863 – 6870	1.39	5.94	<0.001	<0.001	41.39	<0.001	1.34	1.67
33	6880 – 6912	1.39	5.94	<0.001	<0.001	33.51	<0.001	1.24	1.55
34	6927 – 6930	1.39	5.47	<0.001	<0.001	31.08	<0.001	1.16	1.45
35	6935 – 6942	8.10	5.47	<0.001	<0.001	29.63	<0.001	1.16	1.45
36	7115 – 7130	7.94	5.47	<0.001	<0.001	27.91	<0.001	1.14	1.43
37	7132 – 7137	7.40	5.47	<0.001	<0.001	25.29	<0.001	1.06	1.32
38	7145 – 7155	6.30	5.47	<0.001	<0.001	21.52	<0.001	0.90	1.13
39	7165-7175	5.82	5.47	<0.001	<0.001	38.33	<0.001	0.83	1.04
40	7184 – 7225	5.70	4.96	<0.001	<0.001	18.86	<0.001	0.81	1.02
41	7337 – 7345	5.43	4.96	<0.001	<0.001	18.86	<0.001	0.78	0.97
42	7365 – 7385	5.36	4.96	<0.001	<0.001	18.86	<0.001	0.77	0.96
43	7419 – 7550	5.12	4.91	<0.001	<0.001	17.48	<0.001	0.73	0.92
44	7591 – 7732	5.14	4.69	<0.001	<0.001	15.71	<0.001	0.73	0.92
45	7875 – 7947	2.95	4.58	<0.001	<0.001	10.10	<0.001	0.42	0.53

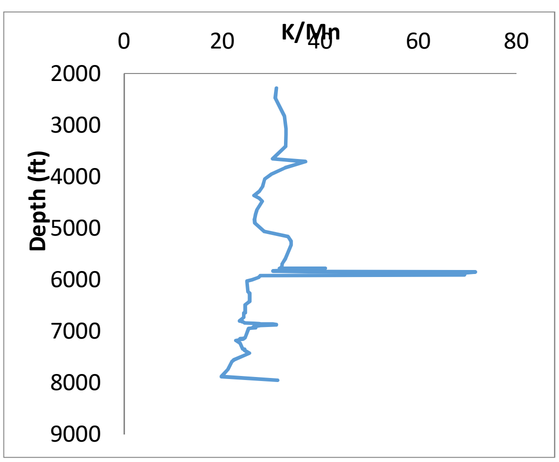

Fig. 8: K/Mn Geochemical Profile

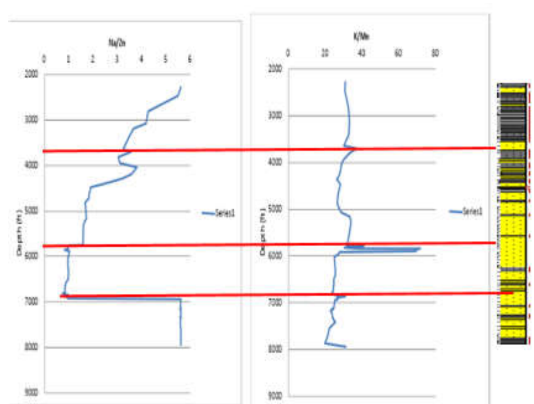

Fig. 9: Profile of Na/Zn and K/Mn against lithologic frame work of well

The K/Mn profile only slightly varied with depth around the mean, but a spike of K value broke put down hole, which gives credit to the increase value of K relative to Mn at that depth. Sodium (Na) and Potassium (k) concentrations chiefly reflect the higher proportion of clay minerals which were deposited in a marine environment. Sodium (Na) and Potassium (K) values are largely controlled by the abundance of clay minerals, therefore at the top and bottom of the well, was a high occurrence of clay mineral. Clay minerals are a product of the weathering of either plagioclase or orthoclase feldspar. This also follows that in-between the clay//shale at the top and bottom.With the inequality of the proportion of Na/K and Zn/Mn, it shows that the lithology ranged from sandy to clayey. The variation of the graphs of Na/Zn and K/Mn shows that the environment is one of intercalation of sandy and clayey sediment components. It therefore, tells that the environment of deposition is one of a paralic type with a repeated cycle of the deposition of sand and shale alternatively, which tells that the paleo environment reflected an alternation of marine and continental controls with time. So the environment was a paralic transitional environment, with the interfingered deposition of sand and shale sediments.

*Conclusion***:** This work has shown that geochemical ratio variations alongside sedimentological parameters can give pointers to the prevailing environmental conditions at the time of deposition of sediment based on their chemical constituents.

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