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CHEMOSTRATIGRAPHIC ANALYSIS OF ASN-1 WELL, UGHELLI DEPOBELT, NIGER DELTA

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ABSTRACT

Chemostratigraphy is a valuable tool in the correlation of sedimentary successions based on sensitive changes in concentration of key major, minor and trace elements. Fifteen ditch cutting samples collected within the depth range of 5660ft - 8550ft from well ASN-1, Greater Ughelli depobelt, Niger Delta were analysed for their litho logic and elemental concentration with the aim to investigate depositional environment, source area composition, provenance and the weathering index of the samples. The lithologic descriptions were interpreted from gamma ray well logs and petrographically and their elemental values were analysed using AAS Spectrophotometer. The Lithosection indicates shale and sand units' indexes inferring maturity and area of deposition, the depositional environment is a transitional zone (fluvial deltaic terrain). The weathering indexes CIA, CIW and PIA values ranges from 1.06 to 41.8, on average indicates low to moderate weathering in the source area with weathering of some sand fraction. Various calculated values of the weathering indices: Chemical Index of Alteration (CIA), Plagioclase Index of Alteration (PIA), Chemical Index of Weathering (CIW) and scatter plots of formulated ratios of Al/Na vs chemical index of alteration (CIA) were plotted to determine the weathering indexes. This also inferred their recycling processes are insignificant. The clay content is low and feldspars are averagely high implying immaturity.

Keywords: *Depositional environments, immature sediments, PIA, CIW, CIA, AKF, weathering index,*

Introduction

Chemostratigraphy is a tool that can be applied to any lithofacies, any depositional environment and from any sedimentary age. This is possible because mineralogical and chemical composition of clastic sedimentary rocks are controlled by various factors including the composition of their source rocks; environmental parameters that influence the weathering of source rocks; duration of weathering, transportation mechanisms of clastic material from source region to depocenters, depositional environment and post-positional processes (Hayashi *et al.*, 1997). Chemostratigraphy are defined because the study of temporal and spatial geochemical variability of rocks with a view to determine mappable rock units, defined in terms of unique geochemical composition, isotopic ratios and elemental and/or elemental oxide ratios or a combination of any or all of these.Numerous investigations are substantiating the above aspects pertaining to genesis of both ancient and modern siliciclastic sediments (Dickinson *et al*., 1983; Roser and Korsch, 1988; McCann, 1991; Condie, 1993; McLennan *et al*., 1993; have also been focused on the identification of palaeotectonic settings of provenances based on geochemical signatures of siliciclastic rocks (Bhatia, 1983; Bhatia and Crook, 1986; Roser and Korsch 1986; McLennan and Taylor, 1991). Among the terrigenous sedimentary rocks, shales are considered to represent the average crustal composition of the provenance much better than any other siliclastic rocks (McCulloch and Wasserburg, 1978). Shales retain most of the mineral constituents of the source and their bulk chemistry preserves the near-original signature of the provenance and more faithfully reveal palaeo-weathering conditions (Pettijohn, 1975; Graver and Scott, 1995). Few worker have also investigated the Nigerian Basin for provenance, depositional environments (Ikhane *et al*, 2014, Aduomahora, *et al.*2109).

The aim of this paper is to present the result of chemostrat investigations penetrated by sediments of ASN-1 well in the Ugehelli depobelt, Niger Delta, in order to identify depositional environment, source area composition, provenance and the weathering index of the samples.

Location of Study Well

The ASN-1-well, in this study is located in the Greater Ughelli depobelt of the Niger Delta Basin (Figure 1). Greater Ugehlli is one among the other Depobelts in the Niger delta Basin.

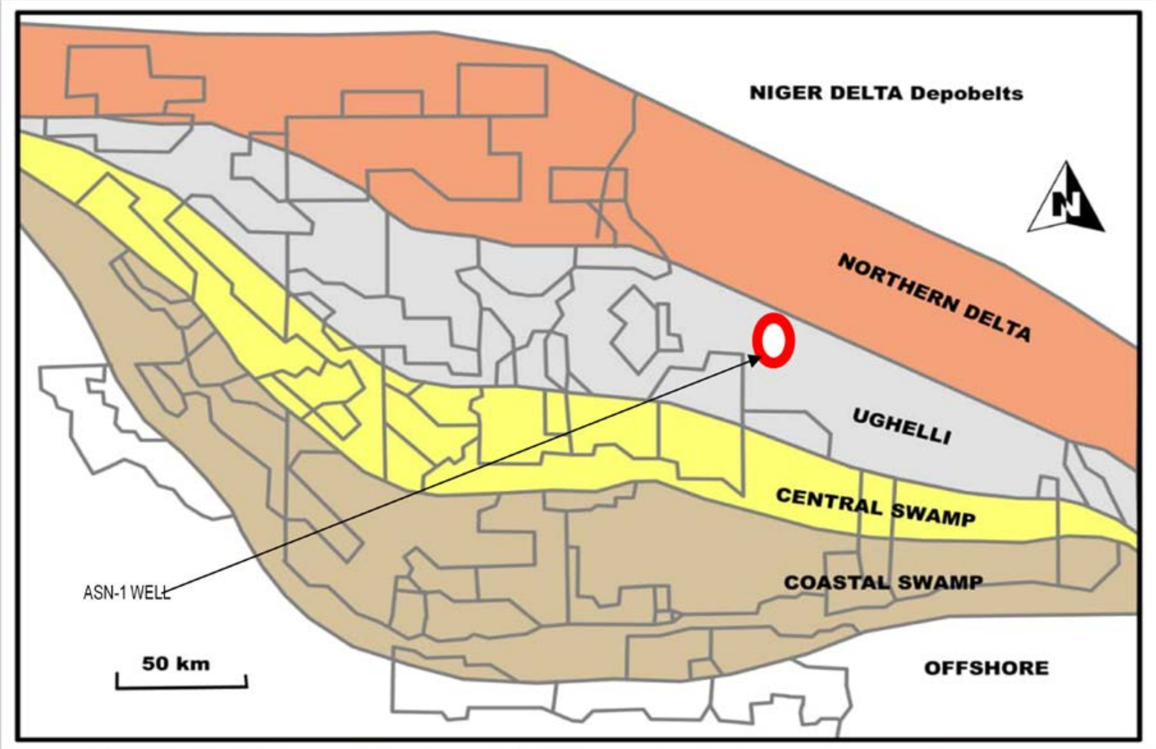

Fig. 1: Map showing Depobelts in the Niger Delta Basin and approximate location of well ASN-1 (Modified after Onikoyi *et. al.,* 2014)

Geology and Stratigraphy of the Study Area

The Niger delta is situated within the continental margin of the Gulf of Guinea in southern Niger Delta Basin, it borders the Atlantic Ocean and extend from about latitude 3° and 6° N longitudes 5° and 8° E, covering about an area of 75,000 square kilometres and includes the geologic extent of the Tertiary Niger Delta (Akata-Agbada) Petroleum System.(Knox and Omatsola, 1989; Reijers *et al*.1997; Adegoke, 2012). The Tertiary deltaic stratigraphic fill of Niger Delta Basin is represented by a diachronous sequence (Eocene – Recent) which is usually divided into three subsurface lithofacies units (Short and Stauble 1967). They are Benin (continental sands and gravels), Agbada (sequence of alternating shales and sands) and Akata Formations (marine shales).

Materials and Methods

Gamma ray and Resistivity well logs and ditch cuttings samples from ASN-1well, Ughelli Depobelt, Niger Delta were obtained from an oil producing company in Nigeria. Fifteen samples within the range of 5660ft to 8550ft were analysed for lithologic characteristics and geochemical properties.

A depth by depth description of lithology arising from the combination of petrographic analysis under a Stereo-binocular microscope and interpretation from well log signatures were used to determine the physical properties in terms of texture, colour, of the samples, this was used to draw up a lithostratigraphic column for the study well (Fig. 2).

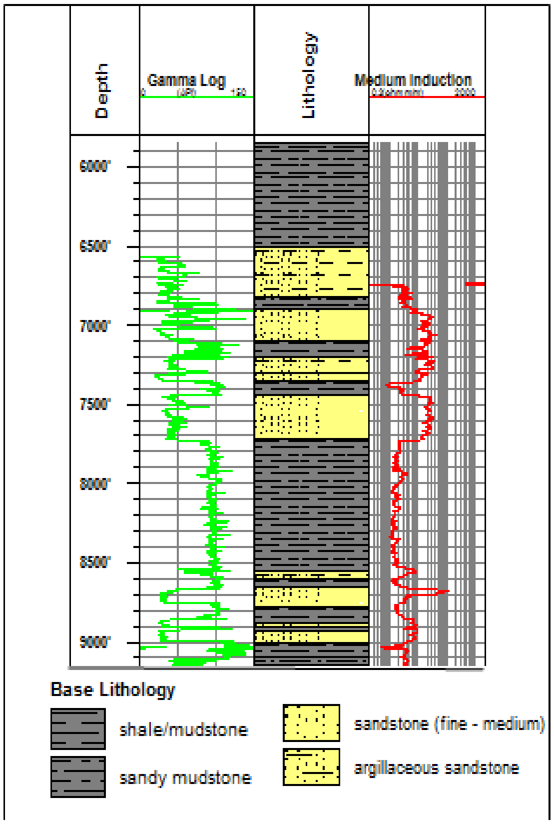

Figure 2: Litho-section of well ANS -1.

Ditch cutting samples were processed for partial digestion technique described by Jarvis (1991) and Jarvis and Jarvis (1992) before carrying out Atomic Absorption Spectroscopy which was to determine the quantitative and qualitative chemical elemental concentrations of the samples.

Ternary plots of Englund and Jørgensen (1973) proposed that certain classification of soil samples may be employed to ascertain the depositional environment of the sediments of the basin. This employs the chemical classification on the basis of AKF [Al_2O_3-(K2O+Na2O+CaO)-(Fe_2O_3+MgO)] contents. The samples was plotted on the ternary diagram of the AKF plots which reveals whether the sediments are deposited in continental, transition and/or marine zone. The statistical analysis included the Mean, Median, Range and standard deviation to determine the distribution of the elemental concentrations across the various depths

Results and discussions

Lithologic interpretation of samples from ASN-1 well in the Greater Ughelli Depobelt indicates dominant trend of shaly sand, sandy shale and shale with characteristically brown, greyish lithofacies, medium grain size, subrounded to rounded and well sorted grain sizes. The study of the lithofacies generally suggests a paralic environment (alternation of sand and shale Fig. 2) which may be said to have penetrated the Agbada formation of the Niger delta (Kogbe, 1989).

A total of 10 elements were analyzed for each ditch cuttings sample and these includes, Aluminium(Al), Calcium(Ca), Magnesium(Mg), Sodium (Na), Potassium (K), Iron (Fe), Lead (Pb), Copper(CU), Cadmium(Cd), Chromium(Cr), (Table 1). The result of the statistical analysis in a scattered plot (Fig. 3) shows ranges for each element and their average value (Table 2).

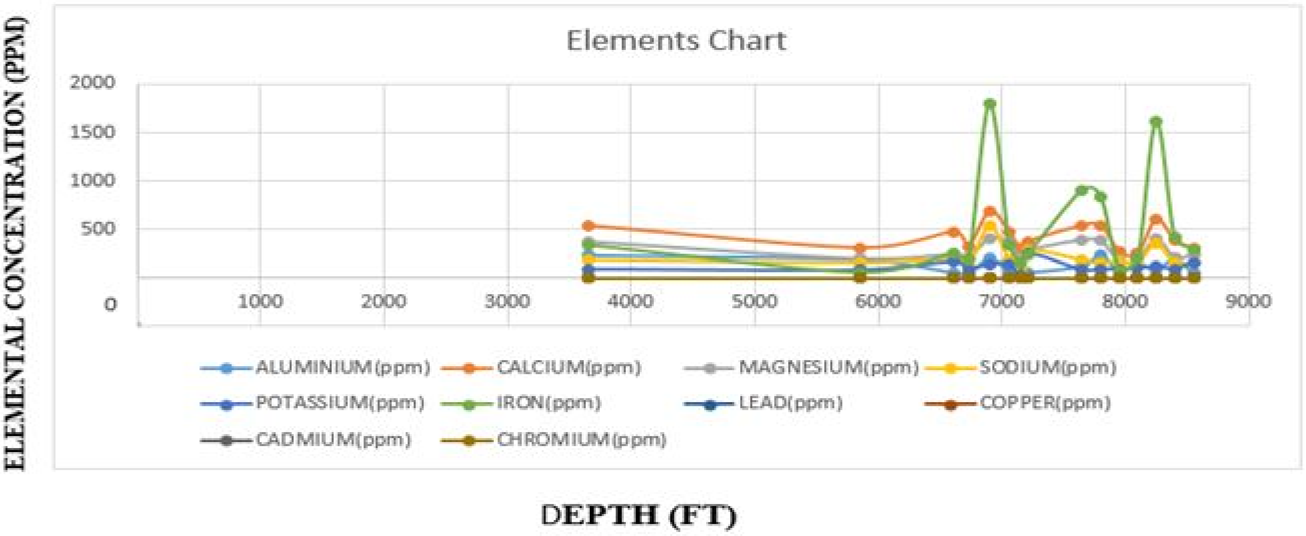

Figure 3: Scattered plot showing the Distribution of elemental concentration (ppm) against Depth (ft)

Generally, the alteration of the parent rock during weathering results in the depletion of alkali and alkaline earth elements and preferential enrichment of Al_2O_3 in the sediments. Al_2O_3 and K2O content may relate to the presence of potassium feldspars (orthoclase and microcline), illite and mica. The low Al_2O_3 are characteristics of immature sedimentary rocks and indicate low chemical weathering in source regions. The source of Na_2O is principally related to plagioclase feldspar since its (Ca-Na) feldspar. MgO content is said mostly to the presence of dolomitic materials as fragments or cement. Calcite

Table 1: Result of chemical analysis of element in samples from ASN-1-well using atomic absorption Spectroscopy (AAS).

S/N	**TEST**	**SAMPLES**														
	Depth (ft)	**5660**	**5850**	**6610**	**6730**	**6900**	**7060**	**7150**	**7210**	**7650**	**7800**	**7950**	**8100**	**8250**	**8400**	**8550**
1	ALUMINIUM (ppm)	238.23	190.81	56.60	43.21	206.69	66.40	87.88	60.71	125.70	244.01	71.30	158.09	82.90	202.51	52.61
2	CALCIUM (ppm)	533.86	310.31	472.54	326.81	678.73	471.49	296.55	374.89	536.93	541.22	275.73	251.02	598.65	388.76	301.21
3	MAGNESIUM (ppm)	368.14	197.78	243.69	214.62	399.34	364.81	180.25	279.84	388.61	379.87	179.53	185.44	397.49	208.75	237.21
4	SODIUM (ppm)	186.58	156.40	203.23	128.30	528.93	183.45	110.61	288.55	186.58	155.36	170.97	158.48	349.95	152.24	154.32
5	POTASSIUM (ppm)	87.72	79.40	165.76	92.92	136.36	140.79	24.25	247.97	79.40	92.92	84.60	99.17	112.70	93.96	159.52
6	IRON (ppm)	330.51	52.01	246.03	193.00	1806.23	335.49	156.01	237.10	907.19	842.42	79.02	196.03	1620.01	414.53	292.50
7	LEAD (ppm)	0.79	0.15	0.34	0.02	1.66	0.22	0.02	0.12	1.39	2.27	0.32	1.51	2.19	1.22	0.30
8	COPPER (ppm)	1.16	0.13	0.24	0.24	1.00	0.22	0.20	0.20	0.63	1.04	0.09	0.64	0.80	0.64	0.20
9	CADMIUM (ppm)	0.16	0.046	0.003	0.006	0.028	0.001	0.038	0.004	0.015	0.015	0.034	0.019	0.019	0.034	0.001
10	CHROMIUM (ppm)	1.06	0.33	1.80	1.54	2.07	1.39	0.62	0.72	1.40	1.32	0.29	0.64	1.58	0.86	3.35

Table 2: Maximum and Minimum Values, Mean and standard deviation of the Elements across the Samples

Elements	**ALUMINIUM**	**CALCIUM**	**MAGNESIUM**	**SODIUM**	**POTASSIUM**	**IRON**	**LEAD**	**COPPER**	**CADMIUM**	**CHROMIUM**
Mean	125.8433	423.9133	281.6913	207.5967	113.1627	513.8720	0.834667	0.495333	0.028200	1.264667
Median	87.88000	388.7600	243.6900	170.9700	93.9600	292.5000	0.340000	0.240000	0.019000	1.320000
Maximum	244.0100	678.7300	399.3400	528.9300	247.9700	1806.230	2.270000	1.160000	0.160000	3.350000
Minimum	43.21000	251.0200	179.5300	110.6100	24.25000	52.0100	0.020000	0.090000	0.001000	0.290000
Std. Dev.	73.33428	133.0457	89.83362	107.6567	51.70149	545.3368	0.800597	0.369514	0.039245	0.785028
Jarque-Bera	1.734176	1.086127	1.933215	17.72565	3.747502	5.954272	1.663327	1.642171	47.22714	4.242359
Probability	0.420173	0.580966	0.380371	0.000142	0.153547	0.050939	0.435324	0.439954	0.000000	0.119890
Sum	1887.650	6358.700	4225.370	3113.950	1697.440	7708.080	12.52000	7.430000	0.423000	18.97000
Sum Sq. Dev.	75290.83	247816.2	112981.1	162259.4	37422.62	4163492.	8.973373	1.911573	0.021562	8.627773
Observations	15	15	15	15	15	15	15	15	15	15

cement and rock fragments are the most source for CaO. The higher iron anomaly indicates that the deposition was in transitional anoxic/oxic environment.

Tectonic and Paleoclimatic History

Weathering is as a complex interaction of physical, chemical and biotic processes which alter and disintegrate rocks at the surface or close to the surface (Selby, 1993). The weathering history of sedimentary rocks may be evaluated by examining the relationships among alkali and alkaline earth elements (Nesbitt and Young 1982). The Chemical Index of Alteration (CIA) quantitatively expresses the degree of weathering of feldspars to clays. It represents a ratio of predominantly immobile Al_2O_3 to the mobile cations Na+, K+ and Ca2+ given as oxides. The CIA is defined as Al_2O_3 x 100/ (Al_2O_3 + CaO + Na_2O + K_2O) by Nesbitt and Young, (1982). Where the major element of ASN-1 are given in molecular proportions. CaO* represents the CaO content of silicate minerals only (Fedo *et al*., 1995) and thus eliminates one of the disadvantages of the WIP. Kaolinite has a CIA value of 100 and represents the highest degree of weathering. Illite is between 75 and 90, muscovite at 75, the feldspars at 50. Fresh basalts have values between 30 and 45, fresh granites and granodiorites of 45 to 55. The chemical index of weathering (CIW) was proposed by Harnois (1988) and is calculated using the equation

$$CIW = Al_2O_3/ (Al_2O_3 + CaO + Na_2O) \times 100.$$

With Al_2O_3 treated as an immobile component and CaO and Na_2O used as mobile elements (Fig. 4). K, in contrast, is not included in this index, because it may be leached and/or accumulated in the residual weathering products. Fedo*et al*. (1995) pointed out that Al in this index is used without any correction for its inclusion in K-feldspar, and therefore K-feldspar rich rocks yield very high CIW values.

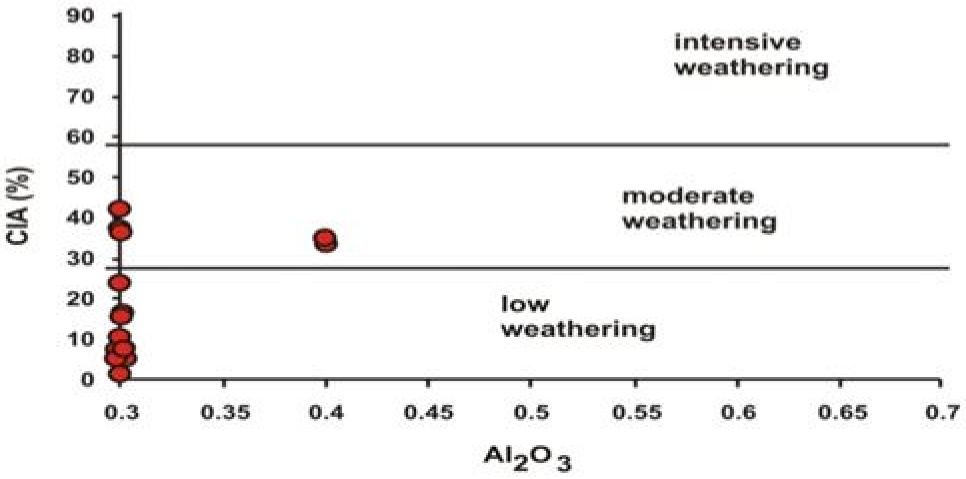

Figure 4: Plot of CIA (%) against Al_2O_3

The CIA values of the samples range from 1.06 to 41.8 (average 20.5), The CIW values range from 8.7 to 31.86 and The PIA value range from 2.01 to 22.29 with much variations within individual samples (Table 3). This implies that weathering is still at a very early stage (Fig.5). The higher CIA values closer to 100, the more weathered the rock. A CIA value of 100 suggests complete alteration of feldspar and labile to fine argillaceous aluminium rich clay weathering products, which are basically kaolinite and chlorite (with no feldspar). Weathering indices of sedimentary rocks could provide useful information of tectonic activity and climatic conditions in the source area. According to Jacobson *et al*. (2003), increase in chemical weathering intensity can be attributed to decrease in tectonic activity and/or the change of climate towards warm and humid conditions which are more favourable to chemical weathering in the source region. The low to intermediate weathering of the observed sediments may thus be linked with increase in tectonic activity and/or climate change towards arid and cold conditions that are unfavourable to weathering from situ.

Table 3: CIA, CIW and PIA values

Sample	CIA	CIW	PIA
5660	34.3	27.2	22.29
5850	41.8	31.86	15.3
6610	8.09	8.7	9.2
6730	9.48	9.7	4.1
6900	18.67	16.88	12.5
7060	10.22	10.3	10.96
7150	23.4	19.65	15.6
7210	8.4	9.79	20.6
7650	6.6	16.1	10.7
7800	35.96	27.4	2.01
7950	16.31	15.69	4.4
8100	38.17	31.07	20.2
8250	9.32	21.43	2.03
8400	37.7	29.8	22.3
8550	1.06	11.75	13.8

Tectonic and Paleoclimatic Conditions History (Source Area Weathering Provenance)

Chemical weathering is an important mechanism driving elemental fractionation away from parental bedrock signatures (Nesbitt and Young, 1982). The extent of fractionation depends on bedrock, and local weathering conditions are generally associated with the warm and humid climates, whilst a more arid climate is generally associated with relatively weak chemical weathering (Nesbitt and Young, 1982). The relationship between climate and the degree of rock weathering has shown that higher rainfall corresponds to the increased loss of labile minerals, and higher CIA values in the resulting sediments (Basu, 1981; James *et al*., 1981; Suttner *et al*., 1981; Dutta and Suttner, 1986; Gritty, 1991; White and Blum, 1995). Consistent rainfall will continuously flush a weathering profile with unsaturated fluids for hydrolysis, remove the

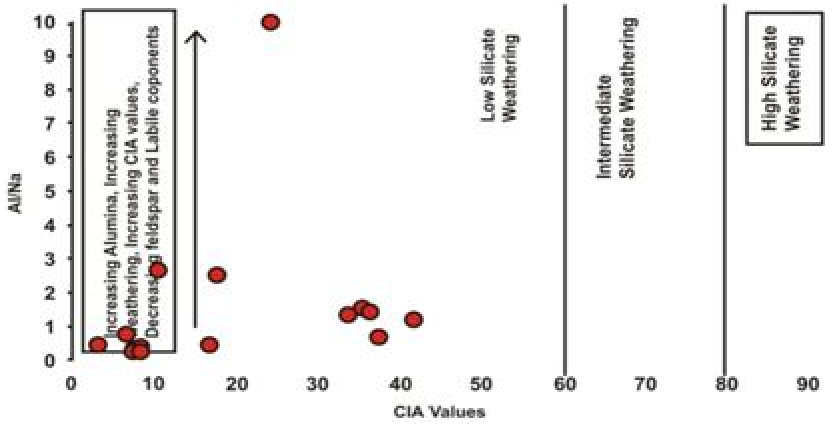

Figure 5: Scatter plot of Al/Na ratio versus chemical index of alteration (CIA)

products of ion exchange, and volumetrically more parent rock material will be subjected to decomposition over a given unit time.

Geochemical compositions of sedimentary rocks yield information on tectonic regime of the source region and source rock type of detrital sediments. Considering that most elements are easily redistributed as a result of weathering and alteration, they must be carefully used in source determination.

Shales are basically sedimentary rocks, the plot confirms that the sediments were originally sedimentary rocks except for a very few sediments which are from an igneous parent rock which might actually be from infiltrations (Fig.6).

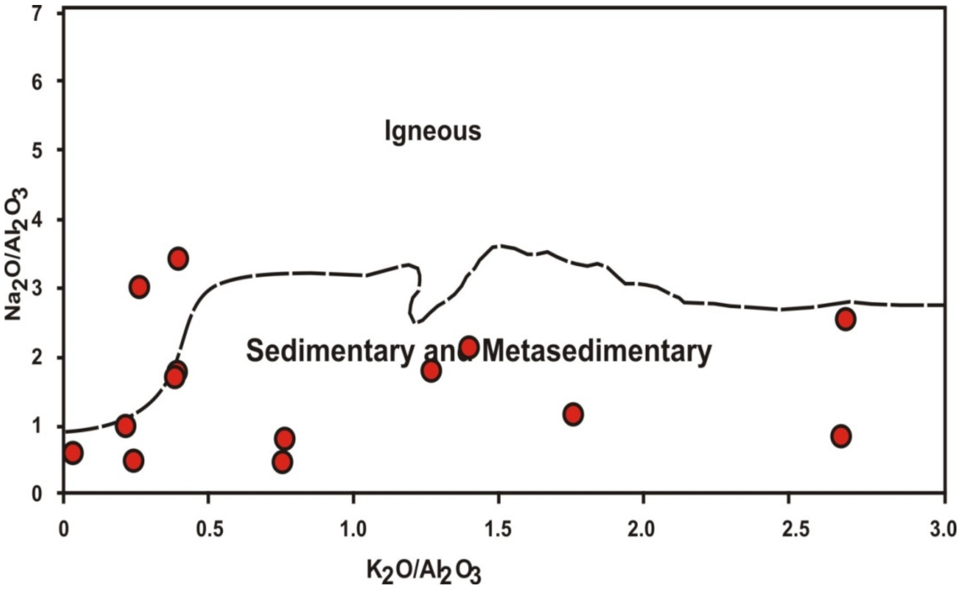

Figure 6: Binary plot showing altered parent rocks of sediments

Depositional Environments

Ternary plots of England and Jorgensen (1973) proposed that certain classification of soil samples may be employed to ascertain the depositional environment of the sediments of the basin. This employs the chemical classification on the basis of AKF [Al_2O_3-(K_2O+Na_2O+CaO) -(Fe_2O_3+MgO)] contents. The samples were plotted on the ternary diagram of the AKF plots which reveals whether the sediments are deposited in continental, transition and/or marine zone. The results show a gradual transition of the sediments of the basin from Transition to marine environment, majorly falling within the transition zone (Fig.7). The Carbonaceous zone indicates elevated amounts of organic matter of floral or faunal origin, which are indicative of reducing conditions. The ferruginous zone indicates an environment of concentrated iron which is indicative of the continental zone

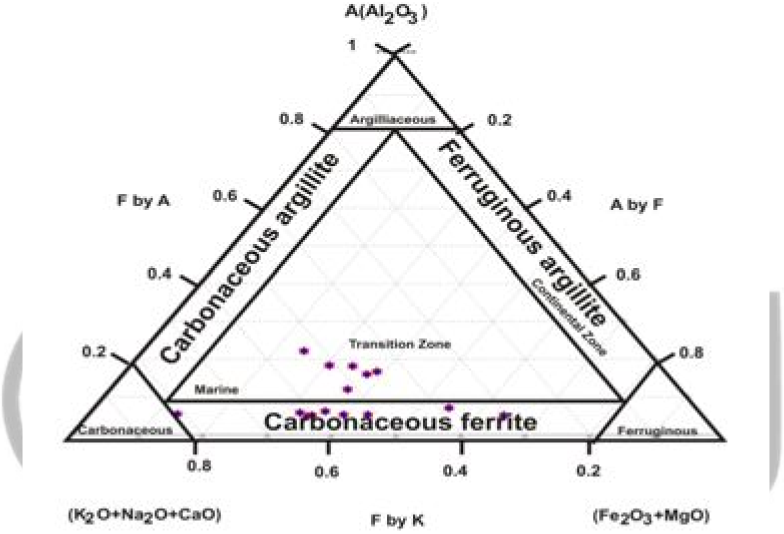

Figure 7: A-K-F plots for sediments from ASN-1-well after Ternary plots of England and Jorgensen (1973).

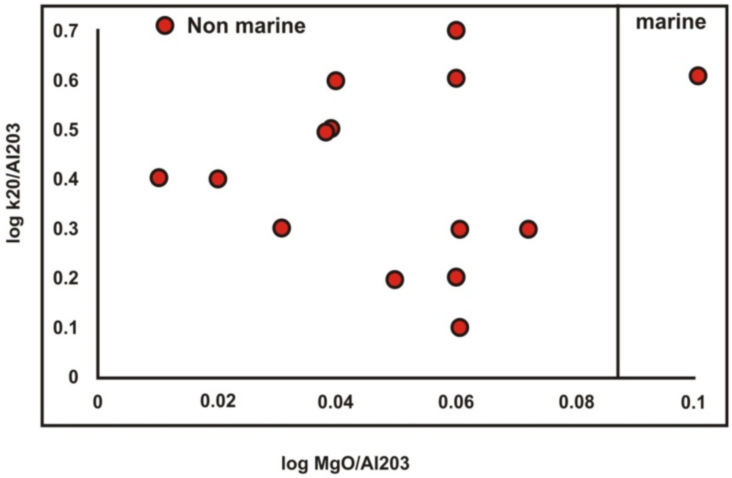

Figure 8: Binary plot showing log K_2O/Al_2O3 Vs log MgO/Al_2O3

Figure 8: can also be used to determine depositional environments. The plot shows majority of the samples align majorly with the non-marine boundary (Fluvial deltaic terrain) i.e. The Transition zone, which are also sedimentary terrains.

Conclusion

Chemostratigraphy is a powerful technique in its own right. It has diverse application to investigating rock record such as reconstruction of paleoenvironment, indirect dating and establishing source area weathering and provenance.

The chemostratigrahic analysis inferred moderately mature sediment. From the CIA, PIA CIW value obtained, it can be concluded that the trough has consistently received sediments (with feldspars) that have undergone very little or no chemical weathering and minimized sediment reworking. The dominance of unaltered feldspars as inferred from geochemical data emphasizes the immature nature of sediments. The less than 50 CIA and PIA average values is an indication of the immaturity of the sediment. Repeated cycles of weathering and abrasion during transport will eventually result in destruction of feldspars and formation of clay minerals and since feldspars persist, the sediments are compositionally immature.

From the results of the analyses, the sediments are immature to moderately mature and are of sedimentary (probably metasedimentary) origin. From the A-K-F ternary plot, the depositional environment is a transition zone between continental and marine zones. The samples were basically deposited in a fluvial deltaic terrain. The results of this work will greatly aid any further interest in the penetrated well as it characterises sedimentary sequences where biostratigraphy is lacking, and augments it where it is available.

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