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Trace Element Geochemistry of the the pyroclastics in Afikpo basin southern Benue Trough.

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Abstract

The Pyroclastics in the Afikpo basin were study in order to determine their petrogenesis, The trace element geochemistry of the pyroclastics in Abakaliki- mine 1 igneous suite show high concentrations of high field strength elements (HFSE, Nb, Ta, Th), low concentrations of large ion lithophile elementa(LILE, Rb, Ba, Sr) and low concentrations of the transitional elements (Ni,Cr). The pyroclastics in Abakaliki – Ogoja road has high concentrations of HFSE, inconsistent concentration of LILE and moderate enrichment of transitional elements. Akpoha pyroclastics show high contents of HFSE, LILE and low concentrations of transitional elements. Zircon(Zr) and Strontium(Sr) are high in all the rocks of the study area while Chromium(Cr), Nickel(Ni), Zinc(Zn) and Vanadium(V) are high in Abakaliki mine 1 pyroclastics , low in Akpoha pyroclastics and moderate in the pyroclastics of Abakalikik-Ogoja road. The rocks plot on the ocean floor setting and within plate setting, which signify that the rocks are product of ocean floor volcanism and the volcanism finally terminated on the continental setting.

Keyword

Pyroclastics, Afikpo Basin, Petrogenesis, Ocea floor volcanism

Introduction

Benue trough is an intracontinental basin in which the sediments in it have been strongly folded faulted, and was probably a rifted depression [1]. Benue Trough originate from the failed arm of a triple rift that occurred during the separation of south America from Africa in the Cretaceous [2]. The study area (Afikpo basin) is within the lower Benue trough and it is a sedimentary terrain with some minor igneous intrusion. The sediments were formed by series of trangressive and regressive sedimentary cycles. Tectonic event truncated the sedimentation in the trough and resulted to the folding and faulting of the pre-Santonian sediments.The sediments suffered two episodes (Cenomanian and Santonian) of deformation. The Santonian deformation gave rise to the Abakaliki anticlinorium. Afikpo basin is on the eastern flank of the Abakaliki Anticlinorium. Sediment thickness in some part of the Benue trough is about 6500km [3]. The Santonian deformations of the sediments gave rise to series of fractures and fold along the fold axis [4,5,6]. The Santonian tectonic events were accompanied by magmatism which gave rise to some igneous intrusive and extrusives in the trough. Some previous authors believed that Benue Trough is wholly a sedimentary terrain with insignificant igneous rocks. [7] documented that some workers in the area believed that pyroclastics volcanism was associated with the sediments [2]. Magma are characterized by their constituent minerals/or elements [8]. This paper focus on using the trace element geochemistry of the pyroclastics of the study area to characterize the nature and source of the magma that gave rise to them.

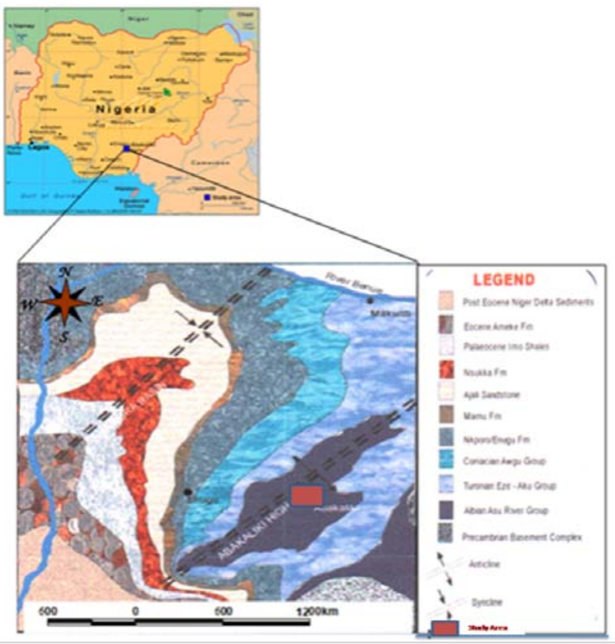

Fig .1. Map showing the study area, retrieved from Google map on 11:09:2015 , modified by [9] .

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1.Geologic Setting

The study area consist of Asu River Group (Albian) ,Eze-Aku Formation and topographic highs of pyroclstics. The Afikpo basin contains Albian, Turonian - Coniacian and Campanian – Maastrichtian sediments and spans well over 2500 km2 [10]. The Asu River Group is the oldest sediment in the study area.

Tab.1.Trace Element Compositions (ppm) of the pyroclastics in Afikpo basin

Samples	Abk1	Abk2	Abk3	Abk4	Abk5	Abk6	Abk7	Abk8	Abk9	Abk10	Akpoha 11	Abk ogoja rd 12	Av
Sc	20	9	20	19	19	21	24	21	24	20	4	14	17.91
Be	2	1	2	1	1	1	2	2	2	1	1	1	01.41
V	192	116	189	186	124	198	281	201	220	205	38	112	17.83
Ba	83	31	43	34	39	48	80	43	49	53	1291	73	15.58
Sr	322	141	228	164	183	131	289	306	276	322	448	256	25.50
Y	28	20	22	24	18	21	19	18	21	23	13	13	20.00
Zr	238	123	143	138	132	118	228	124	212	207	462	114	18.58
Cr	310	90	110	123	220	210	340	219	291	283	30	100	19.83
Co	32	21	25	28	22	23	45	29	25	31	5	25	25.91
Ni	250	100	241	210	190	150	230	220	210	240	20	60	17.75
Cu	40	20	20	30	29	20	50	40	30	30	10	40	29.91
Zn	100	230	140	110	100	50	140	70	90	80	30	210	11.50
Ga	22	25	25	23	22	15	25	23	25	21	13	13	21.00
Ge	1	2	2	2	1	1	3	2	2	1	1	1	01.58
As	5	5	5	5	5	5	5	5	5	5	5	5	05.00
Rb	5	2	2	2	2	2	2	2	2	2	83	2	09.00
Nb	34	17	19	23	21	25	45	25	28	21	4	21	23.58
Mo	2	2	2	2	2	2	2	2	2	2	2	2	02.00
Ag	7	0.5	6	7	0.5	0.5	0.8	0.9	0.5	0.9	1.6	0.5	02.23
In	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	00.20
Sn	2	1	2	2	1	1	2	2	2	1	1	2	01.58
Sb	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	00.50
Cs	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5	00.51
Hf	4.7	2.9	2.8	2.9	2.8	2.9	4.7	4.9	2.8	2.9	10.8	2.3	03.95
Ta	2.1	1.3	1.4	1.4	1.5	1.5	2.7	2.2	2.3	2.3	0.4	1.4	01.70
W	1	1	1	1	1	1	1	1	1	1	1	1	01.00
Ti	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	00.13

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Pb	8	5	5	5	5	5	5	5	5	5	16	33	08.50
Bi	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	00.40
Th	7.1	17.7	7.9	4.7	5.8	1.5	2.7	2.1	2.8	2.1	9.6	10	06.17
U	1.6	2.4	2.3	2.7	2.1	0.5	0.9	0.9	0.7	0.6	2.5	1.5	18.70
Rb/Ba	0.06	0.065	0.057	0.059	0.051	0.042	0.025	0.047	0.041	0.038	0.064	0.03	00.57
Ba/Nb	2.441	1.824	2.263	1.478	1.857	1.92	1.778	1.72	1.75	2.524	322.75	3.5	34.80
Ba/Ta	39.524	23.846	30.714	24.286	26	32	29.63	19.545	21.304	23.043	3227.5	52.1	36.50
Rb/Zr	0.021	0.016	0.014	0.014	0.015	0.017	0.009	0.016	0.009	0.01	3.o	0.02	00.16
Rb/Sr	0.016	0.014	0.009	0.012	0.011	0.015	0.007	0.007	0.007	0.006	0.2	0.01	00.32
Th/U	4.438	7.375	3.435	1.741	2.762	3	3	2.333	4	3.5	3.8	6.7	46.10
Hf/Ta	2.238	2.231	2	2.071	1.867	1.933	1.741	2.227	1.217	1.261	1.3	1.6	21.68

It is made up of brownish shales, micaceous sanstones and mudstones. The Eze-Aku Formation(Lower Turonian), has some black calcareous shales ,limestones , siltstones and the shales graded into sandstones. [7] stated that the initial marine transgression in the trough occurred in the mid Albian and documented from [11], that the source area of the Albian and Turonian rocks is thought to be the basement granitoid rocks of Oban and Cameroon massifs The emplacement of the pyroclastics were structurally controlled by the Abakaliki Anticlinorium. The pyroclastics were products of the magmatism that accompanied the Santonian tectonic events in the Cretaceous.

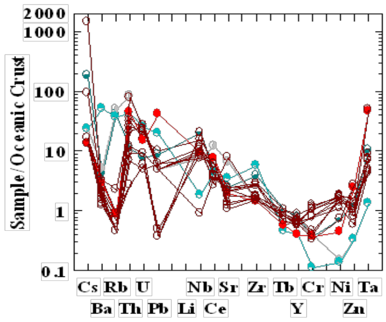
2.Sampling Techniques

Fresh rock samples were collected from different pockets in the igneous suite. The rocks samples were pulverised and geochemical analysis were carried out using ICP MS fusion method at activation laboratory Ontario. [12] described the fusion process of total dissolution using inductively Coupled Plasma mass spectrometry technique as extremely rapid analytical method which is capable of measuring most elements in the periodic Table with low detection limits.

The geochemical interpretation of the trace elements involved the use of spider diagrams / multi-element normalized diagrams, elemental abundances s well as triangular ternary diagrams for describing the geotectonic setting.

3.Trace Element Geochemistry

The trace element composition data for the pyroclastics is shown on Table 1 while the illustrating diagrams are shown in figures 2. The pyroclastics in Abakaliki –Mine 1 are characterized by high concentrations of HFSE, (Nb, Ta, Th), low LILE, (Rb, Ba, Sr) and low concentrations of the transitional elements (Ni,Cr). The pyroclastics in Abakaliki – Ogoja road has high concentrations of HFSE, inconsistent concentration of LILE and moderate enrichment of transitional elements. Akpoha pyroclastics show high contents of HFSE, LILE and low concentrations of transitional elements.



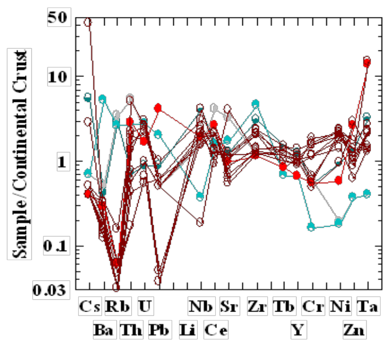


Fig. 2. Oceanic crust and Continental Crust –Normalized Multi-Element Diagrams of the pyroclastics showing the concentrations of the HFSE,LILE and the transitional elements.
Abakaliki mine 1 Pyroclastics, ● Abakaliki-Ogoja road pyroclastics; ● Akpoha pyroclastics

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4.Rare Earth Element Geochemistry

The rare earth element data is shown in table 2 while the rare earth element patterns are shown in figure 3.The pyroclastics have uniformity in their slopping rare earth element, they are characterized by enrichment of LREE, moderate enrichment of middle rare earth elements (MREE), and depletion of HREE. The pyroclastics in Abakaliki mine 1 has slight negative Eu anomalies in four of the samples.

In Akakaliki- Ogoja road, the pyroclastics have slight negative Eu anomalies. The Akpoha pyroclastics is characterized by positive Eu anomaly. The signatures of the Eu anomaly reflect to the concentration of plagioclase in the rocks. Fractionation of plagioclase from the melt results to the negative Eu anomaly but positive Eu anomaly in the Akpoha rocks is an indication that the pyroclastics may have contained plagioclase cumulate.

Tab. 2. Rare Earth Element compositions (ppm) of the pyroclastics in Afikpo basin

Sample	Abk1	Abk2	Abk3	Abk4	Abk5	Abk6	Abk7	Abk8	Abk9	Abk10	Akp 11	Abko 12	Av
La	36.1	30.6	28.6	29.9	18.8	14.8	22.7	21.9	20.6	26.7	26.2	47.6	27.04
Ce	71.2	70.5	69	71.8	70.3	31	46.6	43.2	44.8	39.2	51.1	87.1	58.10
Pr	8.57	9.04	7.37	7.65	6.56	4.17	5.77	5.58	5.85	4.96	6.07	9.7	6.77
Nd	33.9	32	31.4	32.4	30	18.3	23	24	21.4	24	22.5	34.6	27.29
Sm	7	6.6	7	6	6.5	4.7	4.6	4.5	4.9	4.4	4	5.8	5.50
Eu	1.96	1.02	1.34	1.43	1.57	1.63	1.24	1.26	1.45	1.21	1.6	1.17	1.41
Gd	6.1	4.6	5.3	5.6	4.3	4.9	4	4.8	4.2	4.1	3.1	3.8	4.57
Tb	0.9	0.7	0.8	0.9	0.7	0.8	0.6	0.6	0.7	0.5	0.4	0.5	0.68
Dy	4.8	4.1	4.7	4.6	4.3	4.1	3.7	4.2	3.9	4	2.4	2.7	3.96
Ho	0.9	0.8	0.7	0.9	0.8	0.7	0.7	0.8	0.8	0.7	0.5	0.5	0.73
Er	2.4	2.1	2.2	2.1	2.3	1.8	2	2.1	2.1	1.9	1.4	1.4	1.98
Tm	0.32	0.31	0.31	0.32	0.32	0.25	0.3	0.29	0.31	0.3	0.2	0.21	0.29
Yb	2.2	2	2	2.1	1.9	1.4	1.9	1.8	1.7	1.5	1.4	1.5	1.78
Lu	0.36	0.33	0.32	0.34	0.31	0.22	0.3	0.32	0.31	0.3	0.23	0.23	3.57
ΣREE	176.71	164.7	161.04	166.04	148.66	88.77	117.41	115.35	113.02	113.77	121.1	196.81	1683.38
La/Yb	16.41	15.3	14.3	14.24	9.89	10.57	11.95	12.17	12.12	17.8	18.71	31.7	185.16
La/Sm	5.16	4.64	4.09	4.98	2.89	3.15	4.93	4.87	4.2	6.07	6.55	8.21	59.74
Ce/Yb	32.36	35.25	34.5	34.19	37	22.14	24.53	24	26.35	26.13	36.5	58.1	391.05

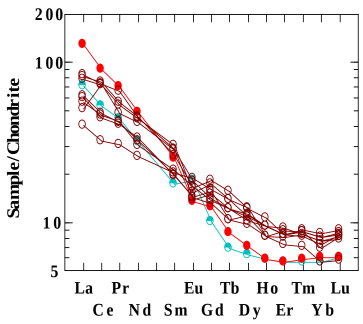

Fig.3. REE chondrite-normalized patterns for the pyroclastics [13] showing sloping patterns, which indicate variations in levels of fractionation of the magma.

5.Geotectonic Setting

The pyroclastics samples plot on the ocean floor basalt (OFB) setting on the Ti vs Cr (Fig.4), Ti/100- Zr-Sr/2 (Fig.5) variation diagram. These are signatures that the rocks were products of oceanic volcanism and were emplaced as ocean floor suites. The pyroclastics samples plot also in within plate (WPB) setting of Zr/Y vs Zr (Fig.6). The plot of the rocks in both OFB and WPB suggest intrusion into the ocean floor and magmatism ended in the continental setting.

Volcanic rocks have peculiar chemical characteristics with respect to their tectonic environments [14]. The

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volcanic rocks are associated with divergent plate margin (Ocean floor basalts, [14]).

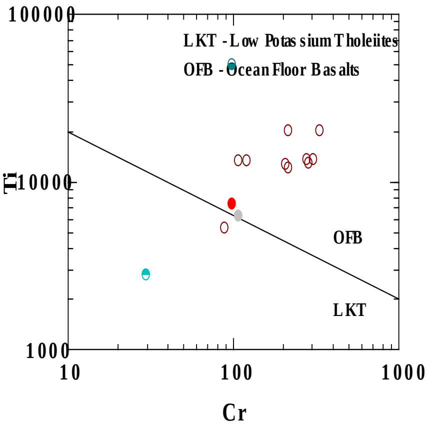

Fig. 4. Ti versus Cr discrimination diagram showing affinity of the pyroclastics to OFB characteristics (after [15]).

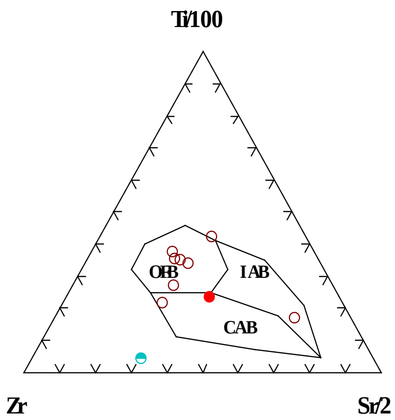

Fig .5.Ti/100-Zr-Sr/2 showing the plots of the pyroclastics to OFB characteristics (after [15]).

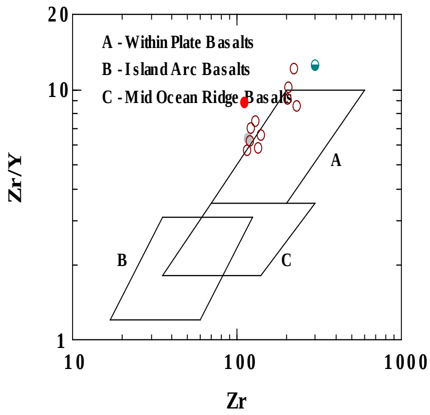

Fig. 6. Zr/Y-Zr showing the plots of the pyroclastics to WPB characteristics (after [15]).

6.Petrogenesis

The pyroclastics in specific suites show similar chemical features which is different from the pyroclastics in another suites, this probably could be that different tectonic regime produced different magma of a different chemistry. Floyd, 1982 stated that compositions of magma reflect the nature of particular mantle and melting processes.

Different features in the pyroclastics of Afikpo basin could be as a result of differentiation of magma as it ascends to the crust. Crustal input from different tectonic regions (in the Afikpo basin) into the magma could modify the chemical composition of the primary magma thereby causing heterogeneity in the pyroclastics. Eruption of magma through different satellite rifts could result to diversified natures of the pyroclastics.

The concentrations of the trace elements show differentials in the fractionation of the magma during the evolution. The magma probably represents different phases of differentiation; batch melting, assimilation and contamination seem to play vital role in the evolutionary history of the magma. Assimilation of elemental components of the host rocks probably affected the chemistry of the primary magma during the migration processes of the magma.

The inconsistent concentrations of the trace elements show that fractional crystallization have played major role in the evolution of the magma. The low concentrations of Ni and Cr in the magma signify the fractionation of olivine and clinopyroxene. [16] suggested that the total abundances of REE in magma depend on the type of melting and that each increment of melt inherits very different REE during fractional melting. The enrichment of the LREE implies magmatic evolution from mantle to crustal setting during magmatic ascent. The slight negative Eu anomalies in the rocks suggest that plagioclase fractionation is active in the evolution of the igneous processes. Positive Eu anomaly in the Akpoha pyroclastics indicates that the pyroclastics probably contain cumulate plagioclase. The pyroclatics in Afikpo basin appear to be controlled by different processes of magmatic differentiation and it depicts that one episode of wholesome crystallization did not characterize the magma.

7.Conclusion

The similarity in REE pattern of the pyroclastics in Afikpo basin seems to have genetic link from the same mantle source but magma differentiation processes contributed greatly to the diverse features in the rocks. The evolution of the rocks seems to be controlled by partial melting of the upper mantle, while the magma erupts at different episodes. The trace elements features as shown in the spider diagrams is an indication that the magma that form the pyroclastics of the study areas did not crystallize simultaneously, this could be that eruption in these areas are in sequence or in batches. Fractional crystallization, assimilation and contamination played important role in the evolution of the of the rocks.

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