GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL. 3, NO. 2, 2005: 187 - 193
ISSN 1596-6798. COPYRIGHT BACHUDO SCIENCE CO. LTD. PRINTED IN NIGERIA.

GEOCHEMICAL CHARACTERISTICS OF THE JOS-PLATEAU BASALTS, NORTH-CENTRAL NIGERIA.

U. A. LAR and M. S. TSALHA

(Received 28 September 2004; Revision accepted 24 May 2005)

ABSTRACT

The Jos Plateau basalts are subdivided into two subtypes based on their textures and mode of occurrence viz, Newer and Older Basalts. The Newer Basalts occur as cones and lava flows and are mainly built of basaltic scoria and pyroclastics. The Older Basalts are characterized by small eroded, partly decomposed remnants, and with a number of plugs or dome-like outcrops. These two sub-types, however, present the same mineralogical composition (phenocrysts of both olivine, plagioclase (bytwonite-labradorite) and rarely pyroxene (diopside-augite) set in a groundmass of labradorite laths, magnetite, ilmenite, biotite, minor k-feldpars, nepheline and volcanic glass.
Geochemical data show that the basalts are nepheline normative and have relatively low SiO_2 contents (39.8 - 46.49 wt %). These compositional characteristics are typical of alkaline olivine basalts and are consistent with their mineralogy (biotite, k-feldspar and nepheline), their deficiency in silica (understaturated) and their enrichment in incompatible elements (V, Y, Ti, Zr, Sr, Nb, to Th). This alkaline nature is further attested to by the positive Nb anomalies exhibited by these basalts. The narrow difference in the ratios Al_2O_3/TiO_2 (4.44-6.13); CaO/TiO_2 (3.04-4.30); Al_2O_3/CaO (1.07-1.61) and the very similar chondrite normalized distribution exhibited by these basalts are in support of their formation by partial melting process. The Jos Plateau basalts, present Zr/Nb ratios (2.4-3.0) comparable to those of the alkali basalts of the lower Benue valley, and of the Cameroon volcanic line, suggesting that they were possibly derived from the same mantle source.

KEYWORDS: Jos Plateau, alkali basalt, mantle, partial melting, incompatible elements.

INTRODUCTION

The Cenozoic volcanism of the Jos Plateau outcrops within the Pan-African Basement in form of thin flows or rarely as domes as in the case of Bokkos hill (Mackay et al., 1949; Wright, 1969). Radiometric ages obtained on these rocks constrained a time interval of between 2.1 to 0.9 Ma (Grant et al., 1972). Their time of emplacement is therefore contemporaneous with the formation of the Biu volcanic Plateau which forms the northwestern branch of the Cameroon line (Grant et al., 1972). The volcanism of the Jos Plateau represents an intraplate alkaline series evolving from basalts to phonolites (Irving and Price, 1981). In view of their petrographic, mineralogical and geochemical characteristics, this volcanism is identical to the Cenozoic magmatism of the Upper Benue Trough which is a branch of Gongola, Biu and Longuda Plateaux (Carter et al., 1963; Turner, 1978).
The petrography of the Jos Plateau basalts has relatively been studied in detail (Carter et al, 1963; Wright, 1976). Geochemical data on these basalts, however remain very scanty. This paper presents the geochemical characteristics of Jos Plateau basalts with a view to the understanding of their evolution and relationship that exists between them and those of the Biu Plateau (north of the Jos Plateau), the Benue valley (south of the Jos Plateau), the Cameroon volcanic line and the Ocean Islands in the Atlantic (to the southeast).

GEOLOGIC SETTING

The Jos Plateau lies precisely within the North Central Basement Complex of Nigeria (Fig.1). The Basement Complex rocks of the Lower Palaeozoic to Precambrian ages underlie about half of its entire landmass. These rocks are represented by gneiss-migmatites and intrusive into these Basement rocks are the Pan-African granites and the predominant Jurassic non-orogenic alkaline Younger Granites (Turner, 1976). Tertiary and Quaternary basaltic volcanics are the youngest rocks in the area and overlie directly the basement and in places the Younger Granites (Wright, 1976). Two main basalt subtypes have been distinguished based on these periods of emplacement and textural differences. They are the Older (Tertiary) and the Newer (Quaternary) basalts (MacLeod, 1971).
The Newer Basalts occupy nearly 150 km^2 in the western and southern Jos Plateau. They also extend towards the Kafanchan area and Southwards down to the Shemankar valley. They occur as cones and lava flows characterized by steep-sided central craters rising a few metres above their surroundings. The Newer Basaltic cones are aligned in NNW - NNE direction, corresponding to the trend of dolerite dykes (MacLeod et al., 1971). They are mainly built of basaltic scoria and pyroclastics, with the vesicles filled with a variety of inclusions (olivine, lherzolite, websterite etc)..
Partly decomposed basaltic boulders, plugs or dome-like outcrops represent the Older Basalts. They are very visible from the Werram Valley southward of Jos extending to the Keffi-Abo area to Rukuba, Ganawuri, South Ropp, Mbar and Mangu. The lateritized basalt represents the product of weathering of mainly the Older Basalts (MacLeod et al., 1971).

PETROGRAPHY

Petrographically, the two main basalt sub-units (Newer/Older) exhibit similar mineralogical compositions consisting of olivine, pyroxene (augite-titanaugite), plagioclase (labradorite) with opaque minerals (mostly ilmenite and/or magnetite) and a few quartz as accessory minerals. The Newer Basalts however present higher percentage of olivine. Texturally however, these two sub-types are different. The Newer Basalts are mainly vesicular, riddled with small cavities attributed to escaping gases and water vapour. The vesicles are sometimes filled with minerals like olivine etc. The Older Basalts are mainly porphyritic, where large phenocrysts of one or more of the major mineral constituents is/are set in a finely crystalline groundmass.

ANALYTICAL TECHNIQUES

Fourteen (14) rock samples were crushed and milled to a grain-size of less than 125μm powder for geochemical analysis.
Major element analysis (SiO_2, Al_2O_3, Fe_2O_3, TiO_2, MgO, CaO, K_2O, etc) was carried out at the National Steel Raw Materials

U.A. LAR, Department of Geology and Mining, University of Jos, Jos, Nigeria. e-mail: ualexanderlar@yahoo.co.uk
M. S. TSALHA, Centre for Geodesy and Geodynamics, Toro, Bauchi State, Nigeria.

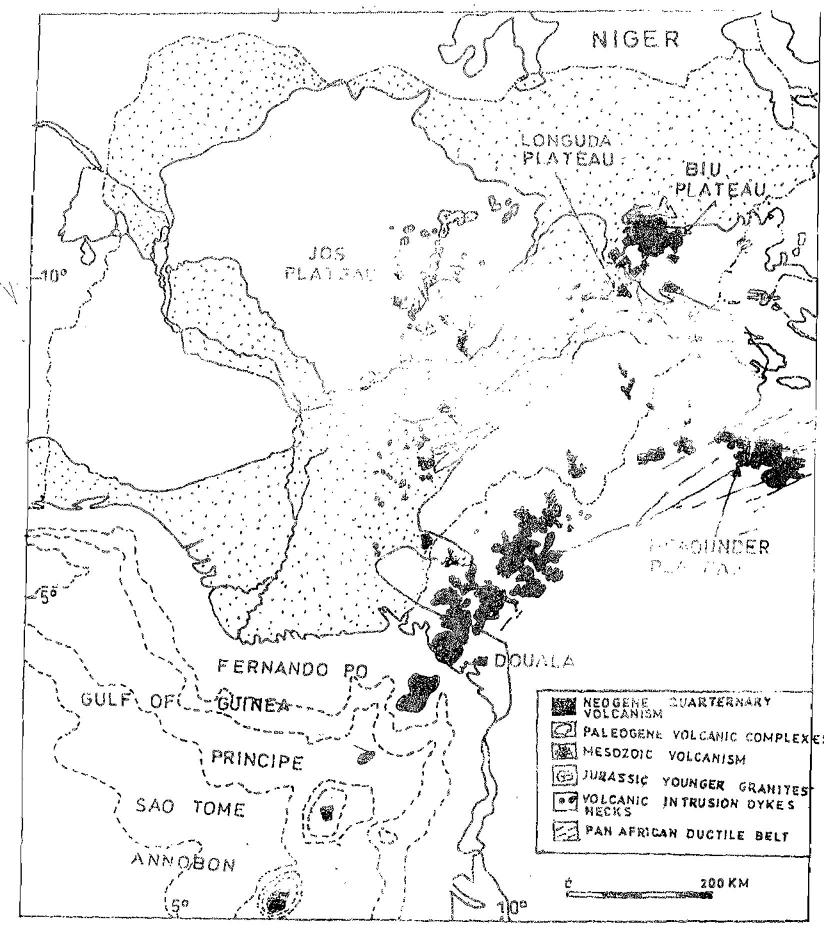

FIG.(1) Simplified Map of the location of Cenozoic volcanism showing the location of the Jos Plateau. (After Fitton, 1980).

Exploration Agency (NSREA), Kaduna, using X-Ray Fluorescence (XRF) techniques. Trace element [illegible] (Ti, Cr, Ni, Cu, Zn, Nb, Co, Ta, Zr, Rb, etc) [illegible] Centre for Energy, Research and Training (CERT), Zaria, using Energy Dispersion X-Ray Fluorescence (EDXRF) techniques.

For both major and trace elements analyses, the rock powder was pressed into pellets (see details of sample preparation in Bougault et al., 1977). The instruments were calibrated using recommended international rock standards [illegible] analysis. The precision and accuracy of the data were [illegible] than 2% for major elements and 0.5% for trace elements.

GEOCHEMICAL RESULTS

The major and trace elements compositions of the [illegible] rock samples from the study area are presented in Table (1). For the ease of comparison, geochemical data of basalts from different regions of the globe are presented in Table (2).

MAJOR ELEMENTS

The proportion in SiO_2 ranges from 39.08 to 46.49 wt.% in most of the rocks studied. However, some have very low SiO_2 of between 38.85% (KS1) and 39.64 wt.% (KG1). The lowest SiO_2 wt% concentration of 27.97% (GS1), is far below the other values obtained, which could be attributed to analytical error. Samples RY1 and RY2 have the highest SiO_2 of 46.38 and 46.49 wt.% respectively (Table 1). $A1_2O_3$ varies from 11.81% to 14.44 wt.% (APW1), while MgO varies from 15.30% (for RY1) to 23.44 wt.% (for GS1). Sample GS1 with the [illegible] MgO (23.44 wt.%) content has the lowest SiO_2 content [illegible]. K_2O varies from 0.97% (VM1) to 1.96 wt.% [illegible] Fe_2O_3 varies from 9.75% (AH1) to 13.85 wt.% in [illegible] and [illegible] respectively. TiO_2 varies from 2.36% (VM1) to 2.34 wt.% (RY1). All the rocks display very high Mg numbers (70-80). The major element data were plotted in different variation diagrams. In the SiO_2 versus CaO, MgO, Fe_2O_3 and TiO_2 correlation diagrams (Fig.3a-d), a general positive correlation is observed in each case. The ratios [illegible] (4.44-6.13); CaO/TiO_2 (3.04-4.30); Al_2O_3/CaO [illegible] lie within [illegible] ranges.

TRACE ELEMENTS

[illegible] data are plotted in chondrite-normalized [illegible]. The chondrite-normalized element distribution patterns (Fig. 4a & b) show that all samples with concentrations [illegible] (Ch) are enriched whereas those with values < 1x chondrites (Ch) are depleted in those elements.

In general, all the basalts, display high concentrations in incompatible elements (K, Rb, Th, Nb, Sr, Zr, Ti, Y and V) relative to the compatible elements (Zn, Cu, Ni, Cr). There is a general progressive increase in the concentrations of the incompatible elements from V (10x), Y (10-40x Ch), Ti (20x Ch), Zr (60x Ch), Sr (100x Ch), Nb (400x Ch), to Th (900x Ch) (Fig.4a&b). Rb and K present concentrations close to those of V, Y, and Ti. The basalts also exhibit relatively similar Large-Ion-Lithophile Elements (LILE) (K, Rb, Pb, Sr etc) distribution patterns, thus, attesting to their similar origin or similar process of formation. As observed in all the basalts, Nb and Th are

TABLE .1: Major (in wt%) and Trace Element (in ppm) Abundances of basaltic rocks from the Jos Plateau.

Wt	KG1	HP2	AM1	AH1	RY2	RY1	VM1	KS1	HP1	RH1	GS1	APW1	KS3	KS2
SiO_2	39.64	40.90	45.89	44.94	46.36	46.49	42.37	38.85	40.43	42.58	27.97	39.08	40.46	42.75
Al_2O_3	11.18	13.11	12.40	14.40	14.15	13.99	14.10	13.85	13.45	14.64	14.28	14.44	13.67	13.53
Fe_2O_3	12.92	9.93	10.36	9.75	10.28	9.79	12.68	12.68	13.85	13.85	10.88	13.63	12.37	12.18
TiO_2	2.52	2.43	2.71	2.37	2.62	2.84	2.36	2.36	2.39	2.39	2.69	2.56	2.51	2.47
CaO	10.43	8.77	8.57	9.72	8.53	8.64	9.71	9.71	9.78	9.78	8.65	10.92	10.29	10.66
MgO	18.79	21.66	17.82	16.31	14.98	15.30	15.87	15.87	16.48	16.48	23.44	15.99	17.56	15.33
MnO	0.08	0.07	0.09	0.07	0.07	0.07	0.07	0.09	0.07	0.07	0.08	0.07	0 .08	0.08
K_2O	1.64	1.64	0.97	1.42	1.67	1.41	1.96	1.80	1.96	1.84	0.67	1.84	1.50	1.55
P_2O_5	0.48	0.62	0.57	0.48	0.48	0.46	0.65	0.70	0.65	0.61	0.44	0.71	0.54	0.54
SO_3	0.02	0.01	0.04	-0.01	0.02	-0.01	-0.01	0.05	-0.02	0.02	0.12	0.02	0.11	0.06
V_2O	Bd	Bd	0.02	0.02	Bd	0.02	0.02	0.02	0.02	0.02	0.02	0.02	Bd	0.02
Na_2O	0.95	0.62	0.82	0.77	0.76	0.85	0.88	0.88	0.76	0.63	0.56	0.63	075	0.85
Cr_2O	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.2	0.03	0.03
Total%	98.69	99.79	99.79	100.28	99.97	99.97	99.82	99.77	99.91	100.14	99.85	99.93	99.87	100.07
Mg#	74.24	81.20	77.31	76.81	79.27	71.23	71.25	72.19	70.21	68.79	81.01	69.91	73.76	71.37
Cr	1110	541	794	621		724	973	955	536	805	713	697	1000	786
Ni	227	376	251	219	202	299	398	246	208	184	528	236	509	411
Co	438	371	369	418	269	395	595	478	319	425	317	308	304	334
V	1210	810	919	877	1000	952	1000	966	1000	1080	992	1530	848	842
Ga	94.1	65	94.3	70.2	70.8	76.3	66.8	93.5	103	69.9	72.1	90.4	74.9	74.2
Cu	150	151	17 5	146	134	138	167	141	141	145	158	144	209	137
Ta	185	248	347	234	275	265	243	245	272	242	257	252	250	24
Sr	1480	1310	2050	1130	1060	1254	1640	1900	1380	1660	2540	2040	1360	1310
Zr	452	287	338	308	318	368	471	520	279	410	297	365	316	322
Zn	151	83.4	163	189	104	102	248	321	137	148	165	210	154	223
W	193	171	279	244	231	Lod	173	187	2	182	229	274	193	180
As	56.8	59.2	59.1	55.8	58.5	57.5	65.1	59.8	55.4	61.5	59.1	64.4	76.4	71.9
Pd	83.7	103	86.3	79.9	83.3	82.2	73.7	86.4	83.9	82.5	86.3	91.2	111	108
Br	20.9	19.4	21.2	21.3	25.4	24.5	20.2	21.3	19.7	21	21.2	22	21.7	23
Rb	103	68.2	37.1	69.5	75.6	72.5	112	96.7	68.5	95.8	37.11	69.5	80.1	83
Th	39.2	26.3	29.4	27.1	28.9	27.8	30.7	28.9	27.7	35.4	29.4	36.8	33.6	33.5
Y	23.8	25.3	13.5	74.2	73.5	72.4	35.9	50.3	26.4	24.7	13.5	49.2	36.2	25.7
Nb	131	118	40.2	101	88.6	87	158	177	105	136	40.2	157	127	108
Zr/Nb	3.5	2.4	8.4	3.0	3.6	4.2	3.0	2.9	2.7	3.0	7.4	2.3	2.5	3.0

LEGEND

* KG1 = KERANG * HP1&2 = HEIPANG * AM1 = AMPER * AH1 = ASSOP HAUSA * RY1&2 = RIYOM
* VM1 = VOM * KS 1,2 & 3 = KASSA * RH1 = RICHA GS1 = GUMSHIR * APW1 = AMPANG WEST

(1.07-1.61) and in the similar chondrite normalized distribution patterns exhibited by these rocks (Fig.4a & b).

By their Alkali-Silica contents (Fig,5) (Irvine and Barager, 1971), these rocks are generally alkaline – sub-alkaline. In an AFM diagram (Fig.6), the basalts fall in a domain characterized by greater Mg enrichment and consequently lower Fe/Mg ratio and therefore do not seem to belong to the tholeiitic series, which on the other hand are characterized by greater Fe-enrichment (increase in Fe/Mg ratio) during fractionation than the alkali series.

The characteristic enrichment in incompatible elements exhibited by the Jos Plateau basalts is akin to those observed in the Mid Ocean Ridge Basalts (MORB) and the alkali basalts of the Biu Plateau basalts (Tables.1 and 2). (Carter et al., 1963; Thompson et al., 1970; Lar and Saidu, 2004). The enrichment in incompatible elements does not seem to conform to the relatively low SiO_2 content of these basalts. This will only leave us with the option of proposing that the source of these basalts was equally enriched in these elements before being partially melted. Most of the Jos Plateau basalts also present incompatible element (Zr/Nb) ratios (2.4-3.0) comparable to those of the alkaline basalts of the Biu Plateau, the lower Benue valley and those of the Cameroon volcanic line.

The strong positive Nb and Th anomalies observed in these rocks (Fig.4a & b) signify the alkaline nature of the magma that gave rise to these rocks (Baudin, 1991). Furthermore, the enrichment in incompatible elements and the mineralogy (biotite, k-feldpars and nepheline) of these rocks again attest to their alkaline character (Stopler, 1980).

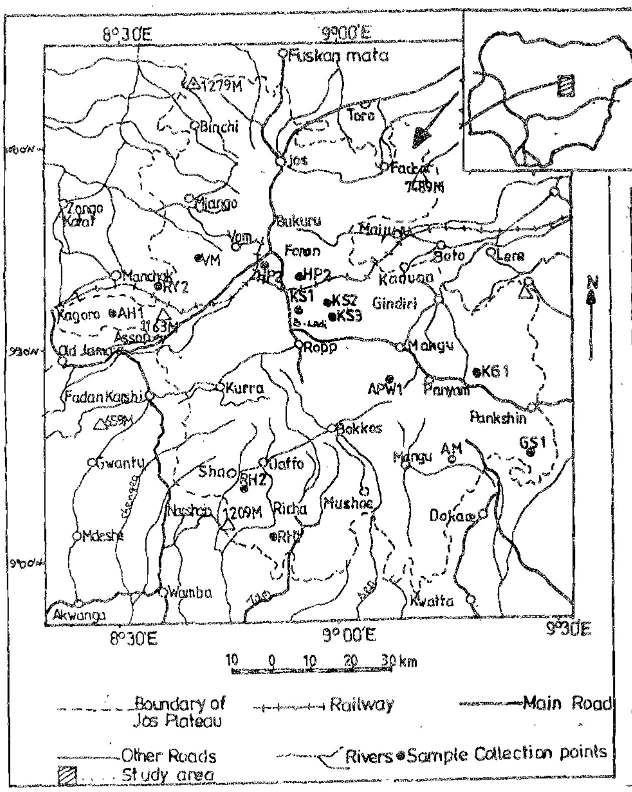

FIG.(2) Geological Map of the Jos Plateau Showing Sample Locations.

TABLE 2: Major (in wt%) and Trace Element (in ppm) Abundances of basaltic rocks from the Biu Plateau, Benue Trough, Island Arc and the Mid Oceanic Ridge (MORB).

Elements (Wt%)	1	2	3	4	5	6	7	8	9	10	11
SiO_2	44.5	45.37	43.85	45.86	44.44	45.50	43.96	45.32	51.57	45.55	46.57
Al_2O_3	15.99	16.58	13.95	16.46	18.45	14.70	13.51	14.70	15.91	16.52	15.65
Fe_2O_3	3.61	2.95	2.60	3.93	4.71	6.82	5.99	5.31	2.74	3.71	4.20
FeO	7.73	7.44	9.19	7.17	7.52	7.69	8.96	8.00	7.04	7.55	6.32
TiO_2	2.43	1.87	2.29	2.61	2.13	2.12	2.03	2.14	1.25	3.01	2.61
CaO	9.83	9.11	10.61	10.22	8.93	8.88	8.37	8.50	11.74	9.42	7.50
MgO	7.00	8.26	10.13	7.90	5.54	6.22	6.59	5.59	6.73	5.99	7.48
MnO	0.19	0.18	0.21	0.17	0.20	n.d.	n.d.	n.d.	0.17	0.15	0.16
K_2O	1.84	1.93	1.54	0.56	1.85	0.21	0.30	0.81	0.44	0.90	1.31
P_2O_5	0.83	0.73	0.92	0.28	0.52	0.17	0.16	0.18	0.11	0.57	0.77
Na_2O	4.37	2.50	3.71	3.83	3.87	2.40	2.28	2.73	2.41	2.89	2.77
LI	2.21	2.76	1.05	1.62	1.66	5.80	7.16	5.28	0.45	2.85	3.70
Total%	100.68	100.12	100.25	100.63	99.82	99.53	99.31	98.56	100.56	100.11	100.13
Cr						40	50	40		65	192
Ni						55	60	45		72	139
Co						57	78	49		42	44
V						450	580	450		236	156
Ga						19	18	21			
Cu						50	140	175		51	53
Sr						165	185	355		609	620
Zr						110	95	145		204	319
Zn										119	108
Rb										12	23
Y						27	13	35			
Nb										32	55
Zr/Nb										6.4	5.8

1 – 5 : Basalts from the Biu Plateau (Source; Carter et al., 1963)
6 – 8 : Mid Oceanic Ridge Basalts (MORB) (Source; Thompson et al., 1970)
9 : Tholeiitic basalt, New Britain (Source; Jake and White, 1972)
10 – 11 : Basalts from Bima Hills and Gwol, Benue trough (Source; Baudin, 1991).

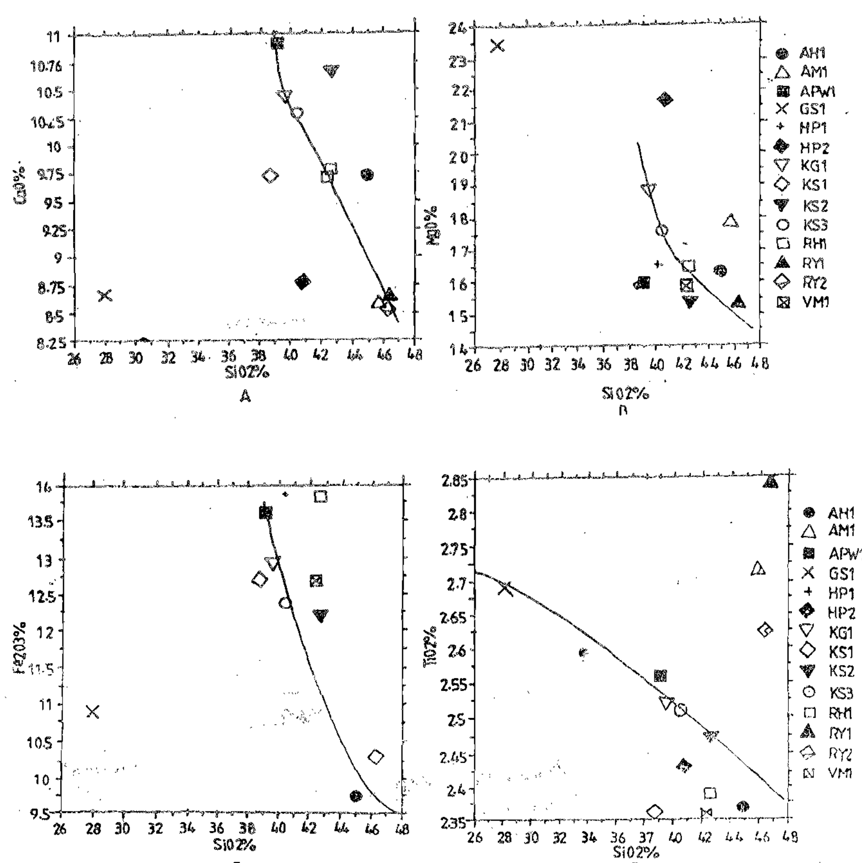

FIG.(3a-d) Variation diagrams of SiO_2 versus CaO, MgO, Fe_2O_3, and TiO_2 of the Jos Plateau basalts.

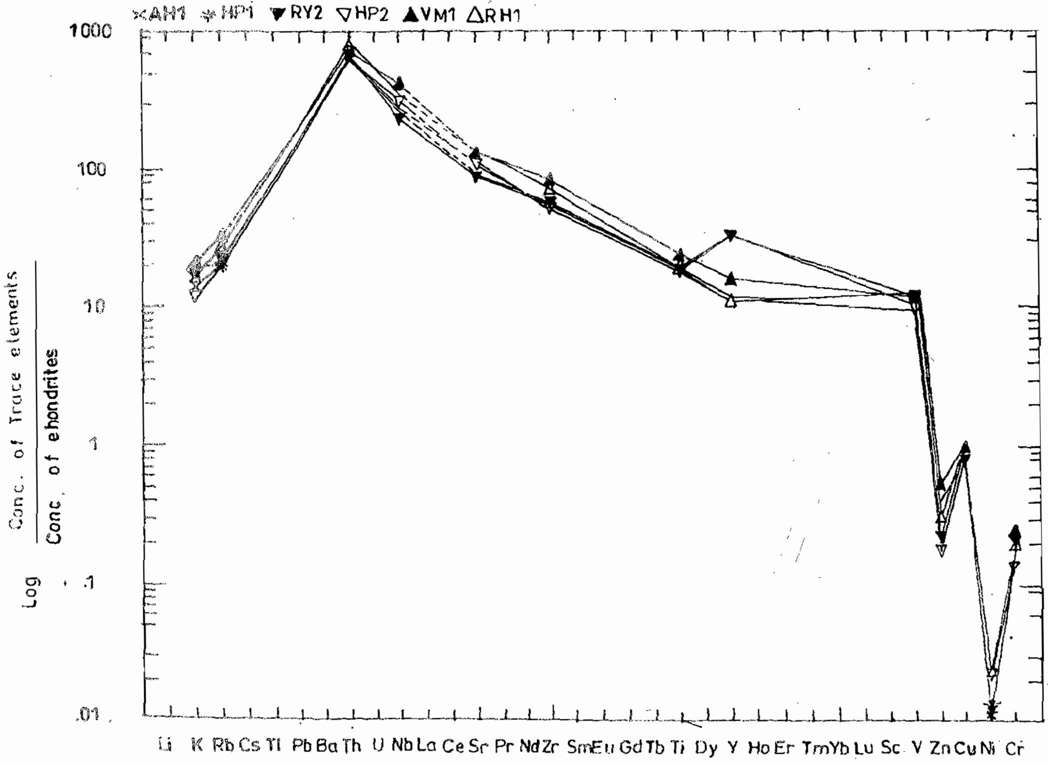

FIG.(4a) Chondrite-normalized lithophile element abundances of basaltic rocks (AH1, HP1, RY2, HP2, VM1, and RH1) from the Jos Plateau.

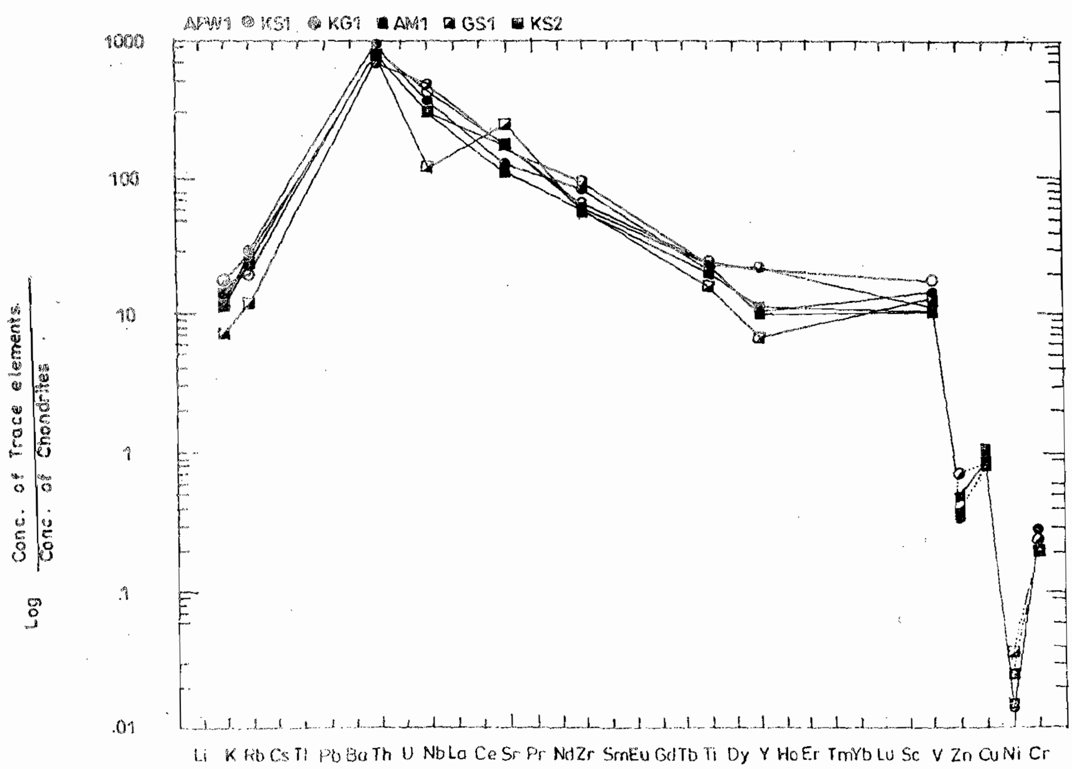

FIG.(4b) Chondrite-normalized lithophile element abundances of basaltic rocks (APW1, KS1, KG1, AM1, GS1 and KS2) from the Jos Plateau.

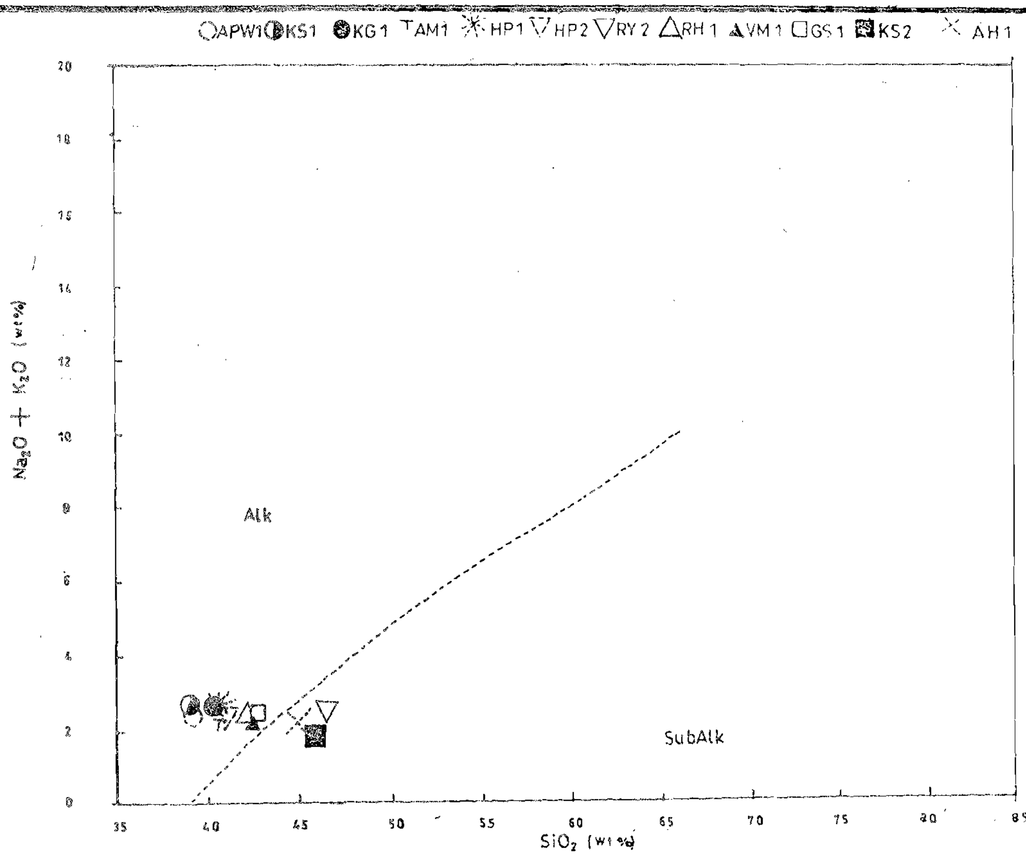

FIG.(5) The Jos Plateau basalts plotted in a Silica-Lime diagram of Cox et al.,(1979).

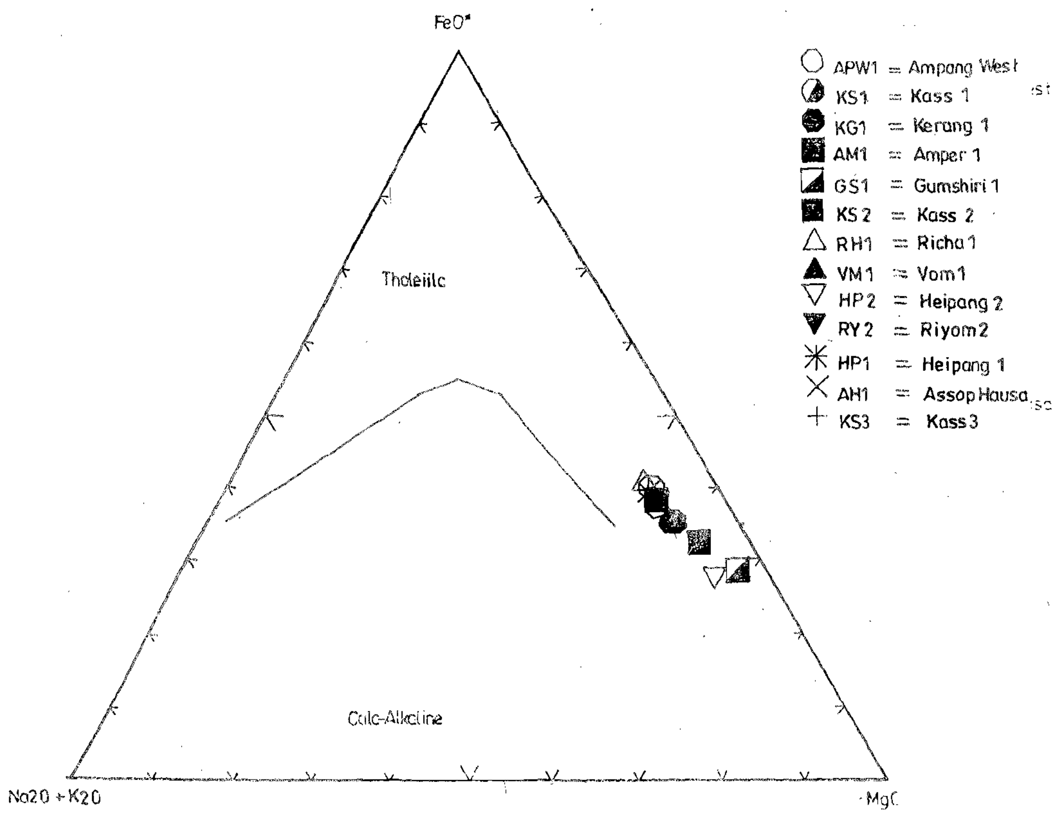

FIG.(6) Plots of the Jos Plateau basalts in an AFM diagram.

CONCLUSIONS

(1) The Jos Plateau basalts, despite their textural differences, display very identical geochemical properties.

(2) They represent essentially the product of partial melting of the same mantle reservoir originally enriched in incompatible elements.

(3) They are clearly alkali continental basalts, with some of them exhibiting tholeiitic tendencies. They present geochemical and mineralogical characteristics comparable to the alkali basalts of the Benue trough,

the Cameroon volcanic line and the intraplate basalts of Ocean Islands of the Atlantic Ocean.

ACKNOWLEDGEMENTS

We are deeply indebted to the anonymous reviewers of this manuscript, who in one way or the other have contributed, encouraged, and provided constructive criticisms, which have improved the quality of the initial manuscript. Our profound gratitude also goes to **Silvent Computers** especially to Miss Cecilia Amos for her untiring efforts in typesetting and scanning of this work.

REFERENCES

Baudin, P., 1991. Le magmatism Mesozoique a Cenozoique du fosse de la Benoue (Nigeria). Geochronologie, Petrogenese, cadre geodynamique. Docteur en Sciences (unpublished) Universite de Droit, d'economie et des Sciences d'Aix-Marseille. 152p

Bougault, H., Gambon, P., and Toulhouat, H., 1977. X-Ray spectrometric analysis of trace elements in rocks. Correction for instrumental interference. X-Ray Spectrometry. 6: 66-72.

Carter, J. D., Barber, W. and Tait, E. T., 1963. Geology of parts of Adamawa, Bauchi and Borno province in Northern Nigeria. Geol. Survey of Nigeria Bull. No. 30: 76-86.

Cox, K. G. Bell, J. D. and Pankhurst, R. J., 1979. The interpretation of igneous rocks. George Allen and Unwin, London. 450pp.

Fitton, J.G., 1980. The Benue trough and Cameroon line : a migrating rift system in Africa. Earth Planet. Sci. Lett., 51: 132-138.

Grant, N. K., Rex, D. C. and Freeth, S. J. (1972): Potassium-Argon ages and Strontium isotope ratio measurements from volcanic rocks in Northern Nigeria. Contr. Mineral. Petrol., 35: 277-292.

Irvine, T. N. and Barager, W. R. A., 1971. A guide to the chemical classification of the Common volcanic rocks. Canadian Journal of earth Sciences, 8: 523-548.

Irving, A.J., 1978. A review of experimental studies of crystal/liquid trace element partitioning. G.C.A. 42: 743-70

Irving, A.J. and Price, R.C., 1981. Geochemistry and evolution of lherzolite-bearing phonolites lava from Nigeria, Australia, East Germany, and New Zealand, G.C.A. 45: 1309-20.

Jake, P. and White, J.R., 1972. Major and trace element abundances in volcanic rocks of Orogenic areas. Geol. Soc. Amer. Bull.83 : 29-40.

Lar, U. A. and Saidu, Y, 2004. Geochemical characteristics and evolution of the Biu Plateau basalts (in press).

Mackay, R.A., Greenwood, R and Rockingham, J.E., 1949. The Geology of the Plateau Tinfields Resurvey 1945-48. Geological Survey of Nigeria, Bull No.19

Macleod, W. N. Turner, D.C. and Wright, E. P.,1971. The Geology of Jos-Plateau, Vo.1 General Geology. Geol. Surv. Of Nigeria. Bull NO. 32.

Nockolds, S. R., Knox, R. W. O'B. and Chinner, G. A., 1978. Petrology for students, Cambridge University Press. 435p.

Olade, M. A., 1979. The Abakaliki pyroclastics of southern Benue Trough Nigeria: Their petrology and tectonic significance. Jour. Min. Geol. 16: 17-24.

Stopler, E., 1980. A phase diagram for the Mid Oceanic Ridge Basalts. EOS 61 : 405

Thompson, G., Bryan W.B., Frey F.A. and Sung C.M., 1970. Petrology and Geochemistry of Basalts and related rocks from sites 214, 215, 216, DSDP Leg 22 Indian Ocean. Initial Report of the Deep Sea Drilling Project, 22: 459-468

Turner, D.C., 1976. Structures and Petrology f the Younger Granite Ring Complexes. Geology of Nigeria. 2nd Edition.

Turner, D. C., 1978. Volcanoes of the Biu Basalts, Northeastern Nigeria. Jour. Min.Geol. 15: 49-62.

Wright, J. B., 1969. Olivine nodules and related inclusions in Trachyte from the Jos-Plateau, Nigeria. Mineralogical Mag., 37(287): 370-374

Wright, J. B., 1976. Fracture Systems in Nigeria and Initiation of fracture zones in the South Atlantic. Tectonophys. 34: 43-47