

Ba-Pb MINERALIZATION IN UGWUAJIRIJA ISHIAGU AREA, LOWER BENUE TROUGH, SOUTHEASTERN NIGERIA: GEOCHEMICAL EVIDENCE

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ABSTRACT

Study of rocks of Ugwuajirija Ishiagu area was carried out to determine their mineralization characteristics. This involved 38 samples and elemental ratios, including Ba, Be, Co, Cu, Cs, Nb, Ni, Pb, Sr, Y, Zn and Ba/K₂O, Ba/Ni using ICP-MS and ICP-AES techniques. Geological mapping reveals that the area is underlain by four lithostratigraphic formations: Asu River group, Eze-Aku Shale, Nkporo Shale and Mamu Formation. The pre-Santonian formations were affected by magmatic intrusion and emplacement of dolerites, diorites and other diabasic rocks, and hydrothermal solutions leading to mineralization of economic mineral deposits. Modal analysis reveals the dolerite has average plagioclase concentration (41 %), ortho-pyroxene (29 %), clino-pyroxene (7 %), and olivine (9 %). Marly mudstone has quartz (10 %), plagioclase (25 %), orthopyroxene (20 %), clino-pyroxene (8 %) and olivine (8%). Trace and rare earth element analytical results show that all the analyzed samples were depleted in Cs, Sn, and Be < 1.0ppm, but enriched in Ba- 802ppm through 936ppm in the dolerite, to >10,000ppm in the marly-mudstone respectively, which are 2 to 100 times above the average crustal abundance of Ba-400ppm. The mean concentration of Cu, Pb, and Zn increased from 66.2 to 94 ppm in the dolerite at Ugwuuele, to 1049ppm in the marly-limestone, to >10,000ppm in the ferruginized mudstones at Ugwuajirija respectively. These enrichments which are above average crustal abundance show that the mudstone and marly limestone in Ugwuajirija Ishiagu area are Ba and Pb mineralized. Further exploration and exploitation are recommended for effective youth empowerment and national development.

KEYWORDS: Ba-Pb Mineralization, Ugwuajirija, Lower Benue Trough, Trace Element

INTRODUCTION

Ugwuajirija is a part of Ishiagu area, located in the sedimentary basin of Southeastern Nigeria (Fig. 1), and forms part of the Afikpo Basin in the Lower Benue Trough. The Benue Trough is a NE –SW trending structure, stretching over 800km from the Niger Delta in the south to Chad Basin in the North, with a width of ~ 400km – 600km in places (Benkheilil, 1987). It harbors clastic sediments varying from ~ 450km to 800km depth range in places (Benkheilil, 1987; 1982). The trough received sedimentation of the Asu River Group during the Albian period, followed by the Eze-Aku Shale, which was unconformably overlain by Mamu formations during the Campanian- Maastrichtian times of the Cretaceous Period (Reyment, 1967). During the Santonian orogeny, which affected the earth globally including Nigeria, tectonic uplift, deformation and magmatism resulted in faulting, folding and other fractural features. These features thus, created favourable environment for intrusion of intermediate to basic magma, and emplacement of dolerites, dioritic and pegmatitic

igneous rocks, generation of hydrothermal solutions and mineralization of sphalerite, bornite, galena, pyrite, hematite, and magnetite etc. in the area (Ofor, 1997). Though some work had been published on mineral potentials and occurrence in the area (Ofor, 1997), more work is still needed to properly and systematically define the rocks and economic mineral characteristics of the area. This work uses petrography, major and trace elements occurrences and characteristics of the rocks to unravel the Ba- Pb-Zn mineralization and economic potentials in the Ugwuajirija area Ishiagu Lower Benue Trough.

1.1 Location of Study Area

Ugwuajirija is a part of Ishiagu in the present Ebonyi State of Nigeria. It is located within latitudes 5°49' to 6°00'N and longitudes 7°30' to 7°40'E (Fig. 1). It is bounded in the north by Awgu in Enugu State, in the west by Lokpa-Lekwesi in Abia State, in the south by Obinago and in the east by Aka-Eze in Ebonyi State. It covers an area of about 672.22km².

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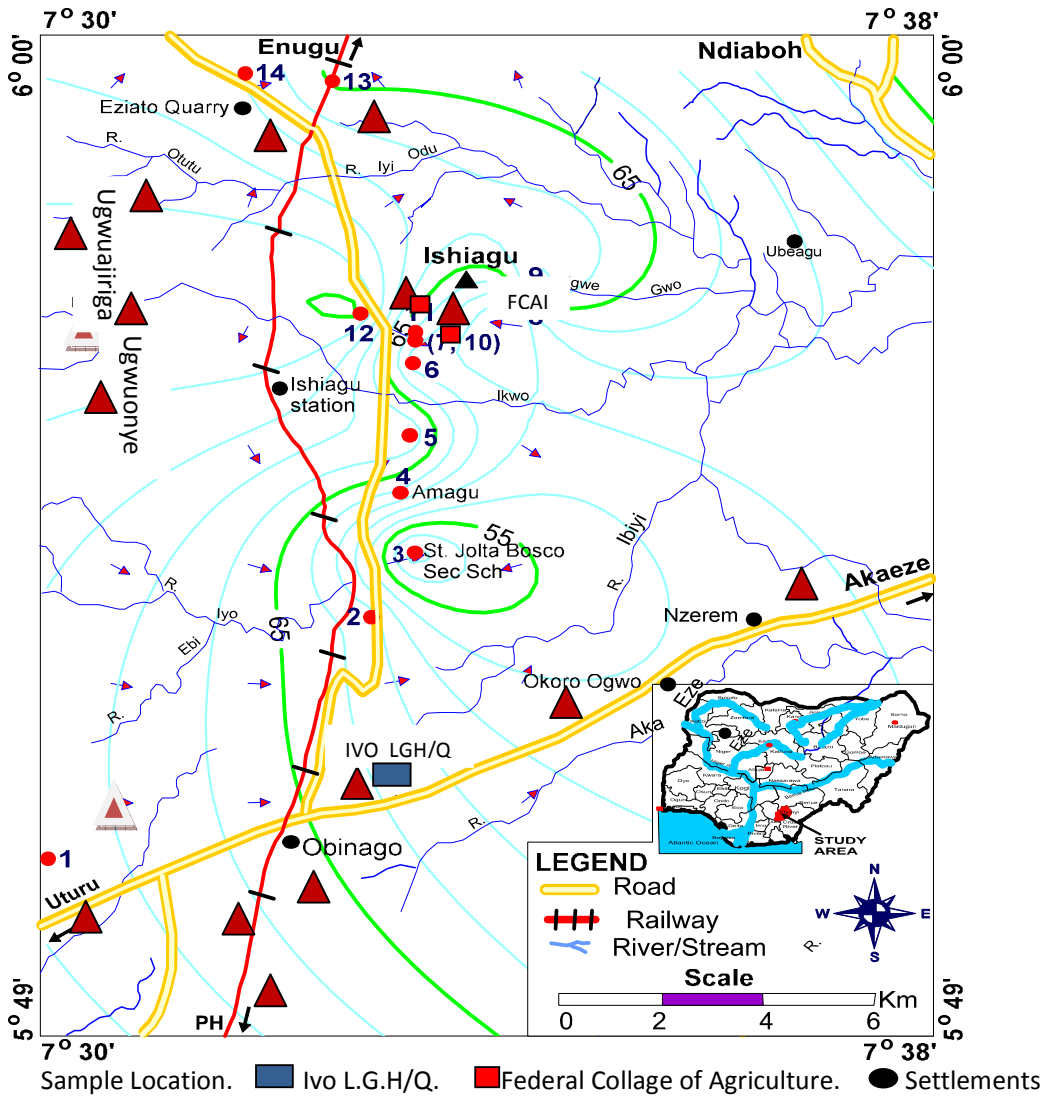


Fig. 1: Sample location map of the Study area showing drainage. Inset: Map of Nigeria showing location of the study area.

It experiences two seasons –dry November to March and rainy March to October each year (Udo, 1970). The average annual temperature is about 27°C to 30°C with average rainfall of about 1200in to 2000in. The inhabitants engage in moderate agricultural activities in the area. The vegetation is the Savanna. The area can

be accessed by the Awgu-Ishiagu-Ivo roads and Okigwe-Ivo- Afikpo roads. Fig.2 is the geological map of the area, and Table 1 summarizes the stratigraphy of the area.

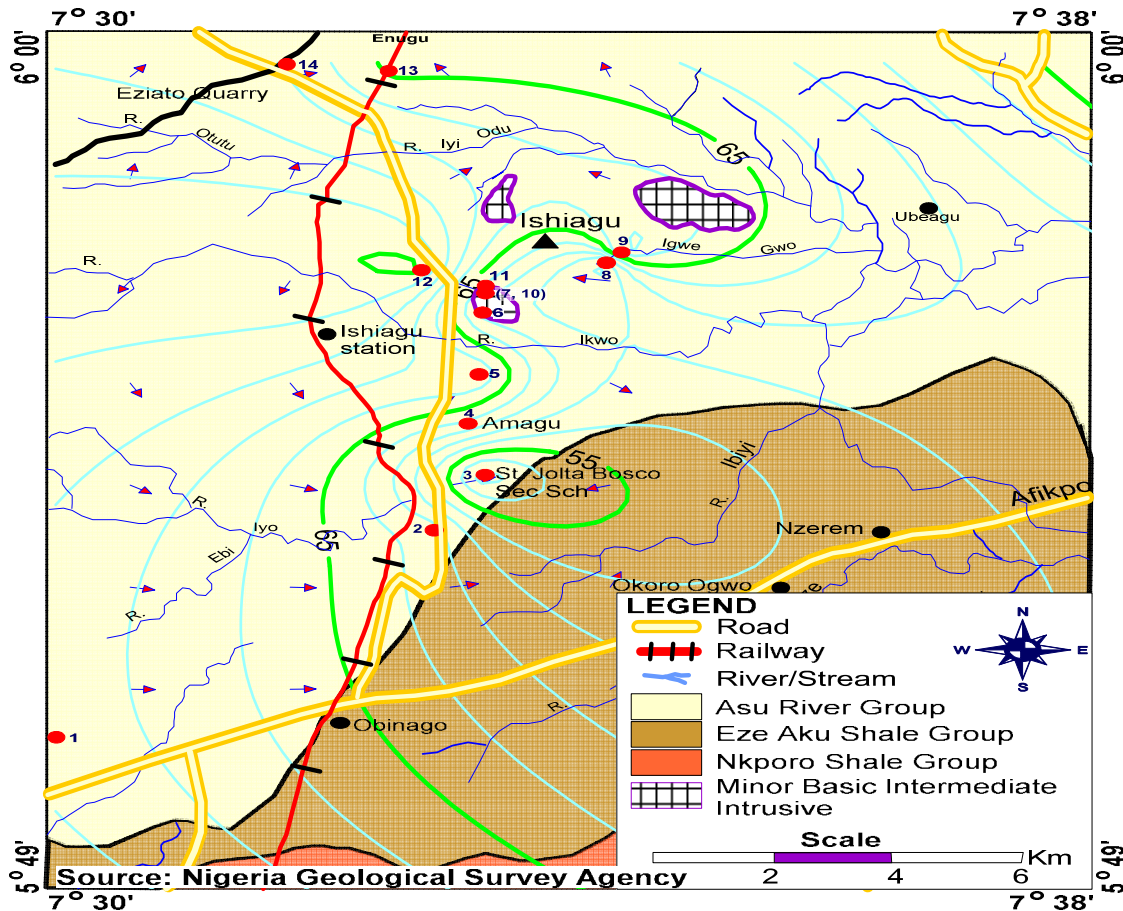


Fig. 2: Geological Map of study area

Table 1: Lithostratigraphy of Study Area (Ugwuajirija Ishiagu area Lower Benue Trough, Southeastern Nigeria)

Period	Period	Formation	Lithology	Environment	Cycle of Sedimentation
C R E T A C E O U	Campanian-	Nsukka	Sandstone, Shale,	Regressive;	3 rd Cycle*
	Maastrichtian	Ajali Mamu	Coal Seam, Clay, Limestoness	Fluvial-Deltaic	
	Santonian- Coniacian	///////	///////	///////	2 nd Cycle*
	Turonian- Cenomanian	Eze-Aku Shale	Shale, Sandstone, Coal Seam, Clay	Transgressive Marine	
Albian	ASU River Group (ARG)	Sandstone, Shale, Limestone, Clay	Regressive	1 st ..Cycle*	

Key: *After Gideon et al, 2014.

2.0 GEOLOGICAL SETTING

The area of study lies within the Afikpo Basin in the Lower Benue Trough of Southeastern Nigeria Sedimentary basin. The Lithostratigraphic sequence comprises of the Asu River Group (ARG) -Albian the Oldest litho-sequence which unconformably overlies the basement complex. This is overlain by the Eze-Aku Formation-Turonian, unconformably juxtaposed by the Mamu Formation-Campanian/Maastrichtian (Table 1), (Reyment, 1965, 1967). The disappearance of the Awgu and Nkporo Formations in the area corroborates the occurrence of unconformity. According to Kogbe (1976),

the area must have suffered non-deposition, weathering and/or erosion, which led to the juxtaposition of the stratigraphically younger Mamu Formation on the superior Eze-Aku Shale.

The lithology of these formations consists of shale, sandstone, limestone/carbonate and clay, with coal seams measuring between 1.2 to 2.5m thickness, occurrences in the Mamu Formation, based on which the Mamu Formation was formally call Lower Coal Measures (Reyment, 1967). The Pre-Santonian sediments had been intruded by basic to intermediate magmas resulting in the emplacement of igneous rocks mainly dolerites, diorites and other diabasic rocks. That

intrusion created faults, folds, joints and other deformational structures and caused metamorphism, and these favoured the mineralization of economic mineral deposits of barite, galena, sphalerite and bornite

(Ekwueme,1993a; Ofor, 1997). The field relationships and structures of various outcrops are shown in Figs. 3 A – B. The photomicrographs of the various rock outcrops in the area are shown as Figs (4 and 5).

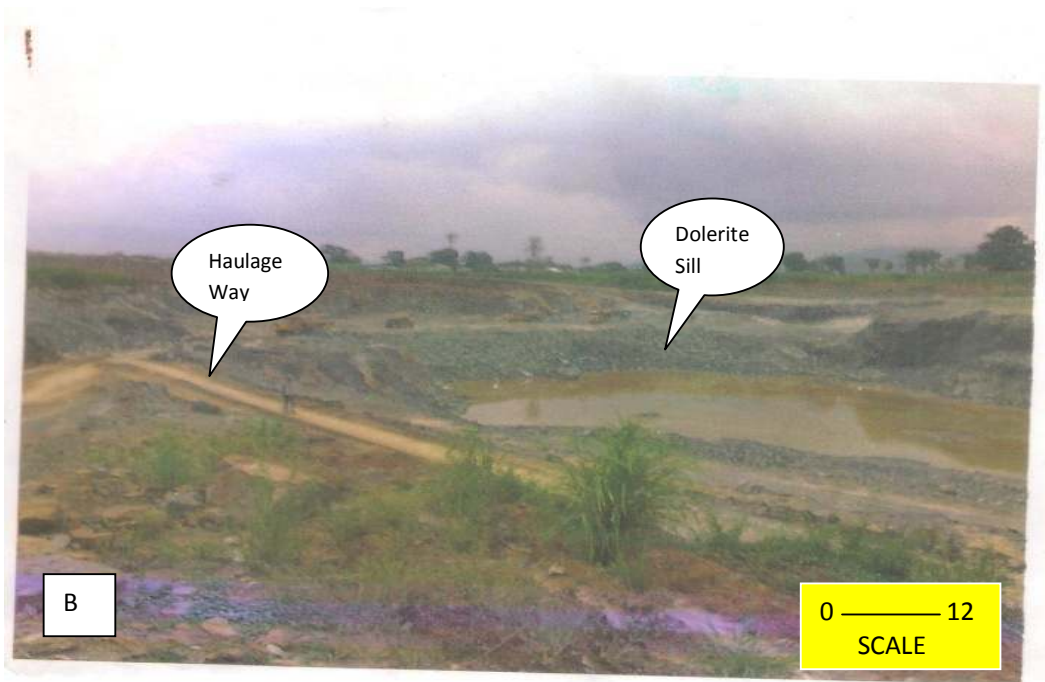


Fig. 3 A and B: Litho-structural field relations of the Ugwuajirija rock outcrop, Ishiagu. Lower Benue Trough SE. Nigeria. (A). Dolerite dikes outcrop at the raw materials excavation source pit, Crush Rock Quarry Ishiagu, displaying disconformal structural relationship. (B). Dolerite sills outcrop overlying diorite, at the Crush Rock raw materials source pit (Open Cast Quarry),

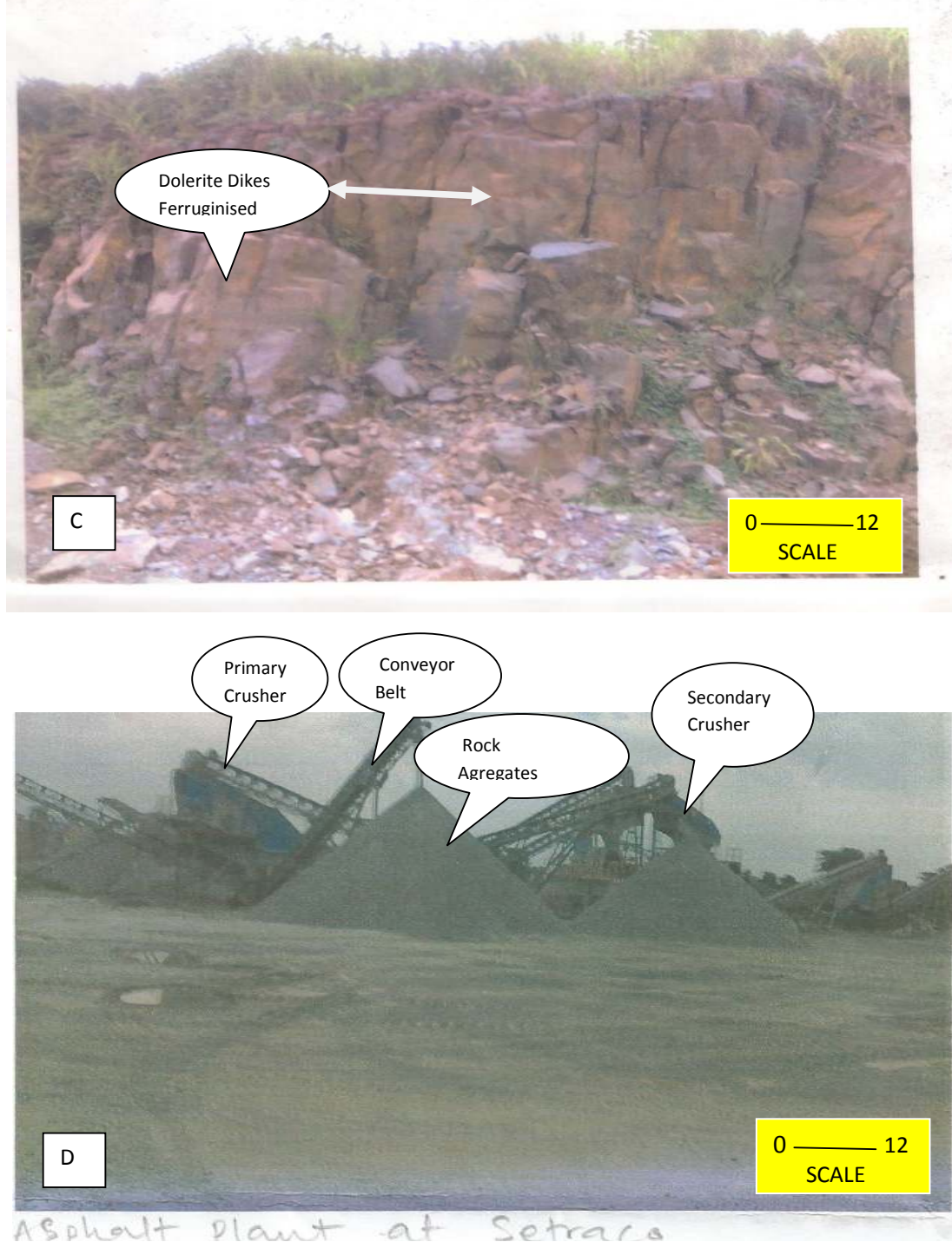


Fig. 3 C and D: Litho-structural field relations of the Ugwuajirija rock outcrop, Ishiagu. Lower Benue Trough SE, Nigeria. (C). Dolerite dikes outcrop at the raw materials excavation source pit, Setraco Quarry Ugwuele displaying disconformal structural relationship. (D). Setraco Rock Crushing Plants (Ugwuele, Ishiagu Area).

3.0 METHODS OF STUDY

The study involved field geological mapping and laboratory studies. The laboratory study consisted of thin section petrography and whole-rock geochemical analysis. The procedures were based on the method after Obioha et al, (2013).

3.1 Petrographic Analysis

The thin sections of the rock samples were made at the University of Calabar, Engineering Geological Workshop. The optimum diameter of 0.03mm was censured by continuous microscopic cross-viewing the mounting slide. The lithological, mineralogical, textural

and structural characteristics of the rocks were determined based on the method after Obioha and Ekwueme (2011) and representative photomicrographs (Figs. 4 & 5 A-D) were presented.

3.2 Whole Rock Geochemistry

The geochemistry study involved whole rock geochemical analyses of 35 representative rock samples from the study area. The analytical technique was the G4A-G4B; the digestive media were Li-borate and Li-tetraborate, followed by HCl dilution. The analytical procedures were the ICP-MS and the ICP-

AES, carried out at the Acme Mineral/Geochemical Analytical Laboratory, Vancouver, Canada. The cutting, crushing, pulverization and weighing were done by special electronic handling (SEH). The resolution was 0.001ppm for the trace and rare earth elements (REE), and 100% for the major elements. The analytical techniques were based on the methods after Skoog and West (1978), Ekwueme (1993b, 1994), Ofulume (2009) and Obioha, (2014). Photomicrographs of representative samples showing the mineral composition of the rocks are presented in Figs. 4 and 5.

Table 2: Average modal composition (vol. %) of rocks of Ishiagu area, Lower Benue Trough, Nigeria

Minerals	D1.L1; X5	D1.L2; X5	B1.L3; X5	DR.2.L4; X5	MRL-MST
Quartz				10	12
Orthoclase		tr		22	10
Plagioclase	42	40	20	38	23
Biotite			7	6	6
Calcite					25
Dolomite					20
Ortho-Pyroxene	28	30	40	12	
Clino-Pyroxene	9	8	18	8	
Olivine	10	8	6		
Hornblende		2			
Opaques	6	5	2	9	
Accessories	5	7	3	7	4
Total	100	100	100	100	100

D1.L1 = Dolerite from Crush Rock mining pit Ishiagu.

D1.L2 = Dolerite sample from Setraco mining pit Ishiagu.

B1.L3 = Basalt sample from Ugwuele mining pit Ishiagu.

DR2.L4 = Diorite sample from Crush Rock Industries mining pit Ishiagu.

MRL-MST = MARLY Mudstone at Obinago

4.0 RESULTS AND DISCUSSIONS

The results of the modal analysis from the thin section petrography are shown in Table 2. The results of the whole rock geochemical analyses of the major elements are presented in Table 3. Table 2 shows that four main rock types: dolerite, basalt and diorites and marl occur in the area. Five (5) representative rock samples were collected from each of these outcrops and specimen thin sections prepared. The modal analysis (Table 2), shows that the dolerite (samples D1.L1 and D1.L2) consists mainly of plagioclase (An-30-70) in the andesine to bywtonite range, 40 to 42 average volume %, ortho-pyroxene 28 to 30 vol.% average, clino-pyroxene 8 to 9 vol. % average, olivine 8 to 10 vol. % average. Opaques and accessories constitute the rest of

the modal volume. These rocks show geochemical signature of basic magma of intermediate character (Grant, 1969). The basalt (samples B1.L3), consists of ortho-pyroxene 40 vol. %, clino-pyroxene 8 vol. %, plagioclase 20 vol. % and olivine (6 vol. %). Opaques and accessories constitute the rest of the modal volume. These properties show that the dolerites and basalts were derived from basaltic magma of tholeiitic composition (Ekwueme, 2003; 2010). The diorite consists of quartz (10 vol. %), plagioclase 38 vol. %, orthoclase 22 vol. %, ortho-pyroxene 12 vol. %, clino-pyroxene 8 vol. %. Opaques and accessories constitute the rest of the modal volume. The modal analysis results agree with the field geological results (Figs. 3 A-C).

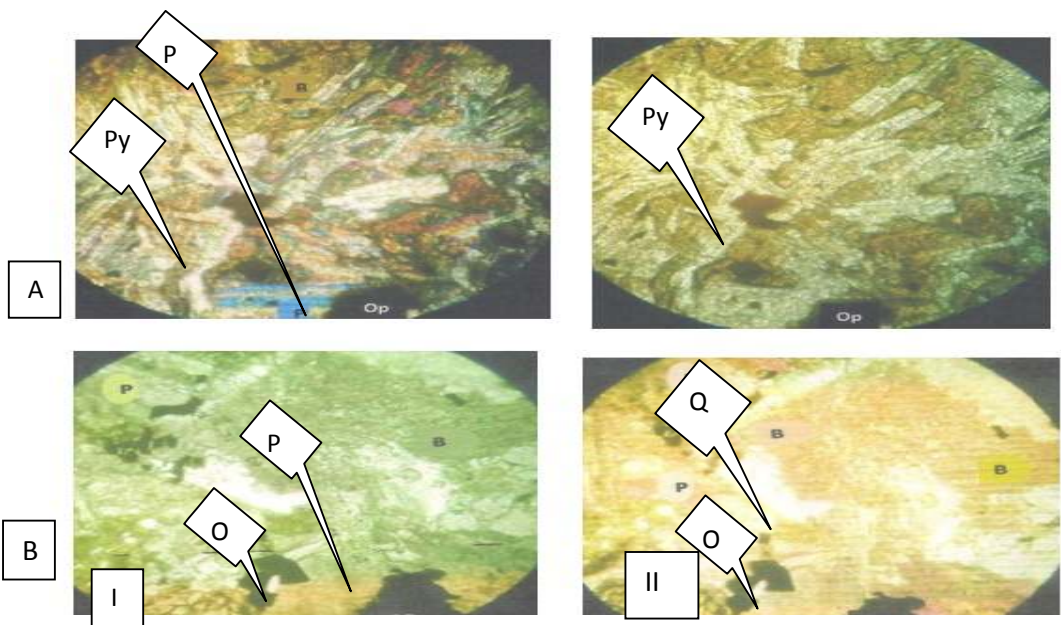


Fig. 4: Photomicrograph of rocks of Ugwuajirija area, Lower Benue Trough Nigeria. (A). Dolerite, showing laths of Plagioclase (P), pyroxene blades (Py), olivine (O): (I) XPL x20; (II) PPL x20 (B). Diorite showing plagioclase (P), pyroxene (Py), and quartz (Q): (I) XPL x20; (II) PPL x20

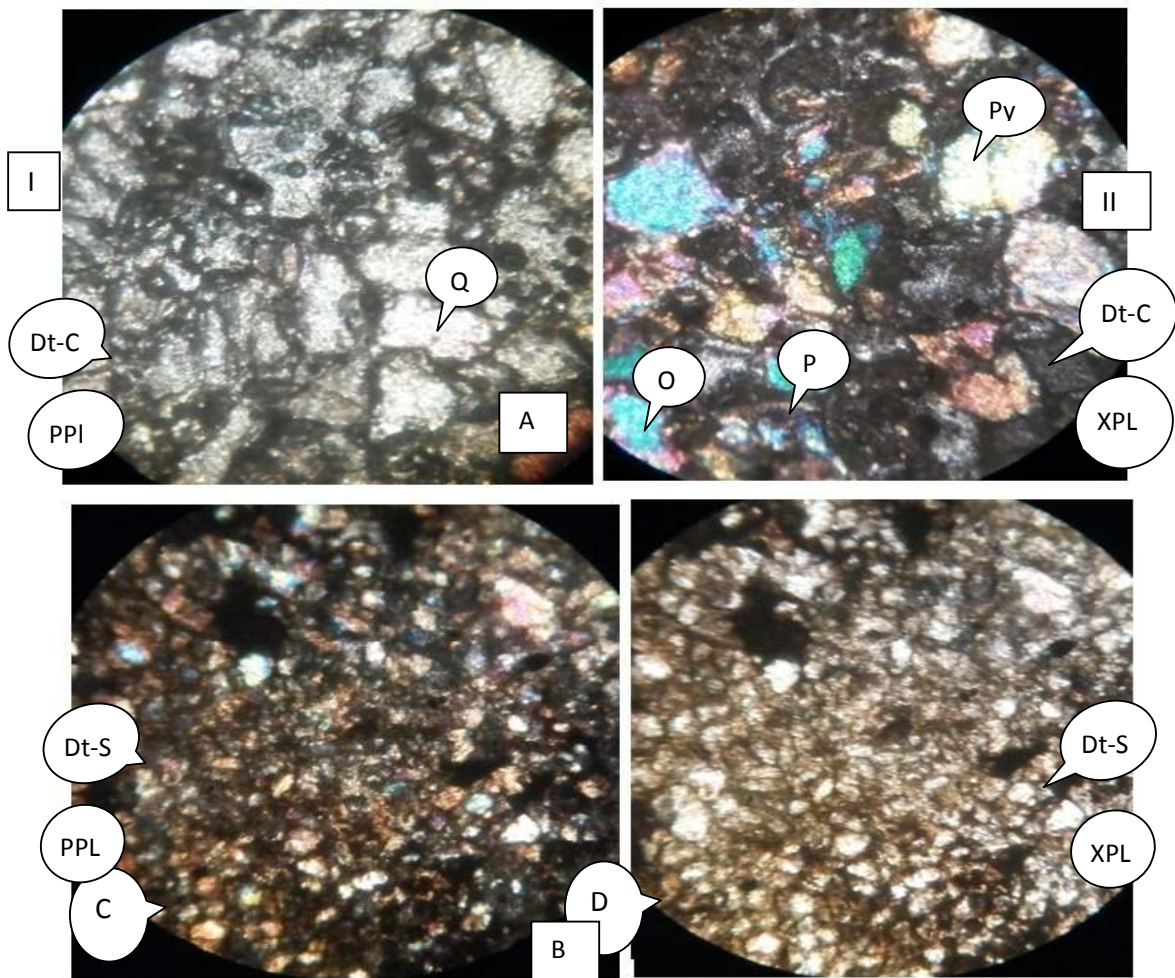


Fig. 5: Photomicrograph of rocks of Ugwuajirija area, Lower Benue Trough Nigeria: (A). Dt-C = Dolerite from Crush Rock Quarry, showing laths of Plagioclase (P), pyroxene blades (PY), and olivine (O). (B). Dt-S = Dolerite from Setraco Quarry, showing plagioclase (P), pyroxene (Py), and quartz (Q), (I) XPL x20; (II) PPL x20.

4.1 Geochemical Results

Table 3 shows that the SiO₂ concentration ranges from 46.52 wt. % (D1.L1) to 47.27 wt. % (D1.L3), indicating that the dolerites are of basic composition derived from basaltic magma of tholeiitic character. Sample D3.L2 (diorite) from Crush Rock quarry Ishiagu has SiO₂ concentration of 57.21 wt. % showing that this rock was derived from magma of intermediate composition. The Al₂O₃ concentration is high ranging from 12.95 wt. % in the diorite (D3.L2) through 13.60 wt.

% (D1.L4) to 15.80wt. % in the dolerite. The granitic sample from Crush Rock Quarry has Al₂O₃ content of 7.19 wt. % (Table 3). The alkalis content is 5.68 wt. % average in the diorite, and ranges from 3.83 wt. % to 4.95 wt. % in the dolerites, with a fairly constant low average value of 0.006 wt. % in the granitic sample (D2.L1). This is contrary to the expected high value of alkalis in granitic rock. This low value must have been as a result of hydrothermal alteration leading to removal of Na⁺ and K⁺ ions from the feldspar.

Table 3: Geochemical result of major elements composition (wt. %) rocks of Ugwuajirija Ishiagu area, Lower Benue Trough, Nigeria

Oxide	D1.L1	D1.L2	D1.L3	D1.L4	D1.L5	D2.L1	D3.L2
SiO ₂	46.52	47.17	47.24	47.27	47.20	67.9	57.21
Al ₂ O ₃	15.42	17.00	14.17	13.60	15.80	7.19	12.95
Fe ₂ O ₃	9.32	8.96	9.32	17.20	11.2	15.58	12.16
CaO	13.07	8.23	9.72	7.39	10.10	0.02	4.41
MgO	8.57	6.86	6.86	5.71	7.00	0.03	1.10
MnO	0.62	0.44	0.66	0.68	0.60	0.04	0.15
Na ₂ O	3.86	3.14	3.38	2.42	3.20	0.01	2.58
K ₂ O	1.09	1.60	1.50	1.41	1.40	0.05	3.10
P ₂ O ₅	0.48	0.42	0.53	0.48	0.48	0.04	0.51
TiO ₂	2.40	2.40	2.41	2.42	2.41	0.27	1.46
Cr ₂ O ₅						0.033	0.002
LOI	0.25	3.14	3.14	0.66	-	6.7	3.8
Total	100.69	99.36	101.69	99.22	99.94	99.95	99.96
Remarks	Bluish Unaltered sample	Redish slightly altered	Yellow intensely altered	Yellow intermediate Altered			

Table 4: Average result of Trace elements composition (ppm) of rocks of Ugwuajirija. Ishiagu area, Lower Benue Trough, Nigeria

Trace Elements	LOCATION			
	L1 x8	L2 x8	L3 x8	L4 x8
Cu	6.00	< 5	19.00	25
Ba	> 50,000	> 50,000	18125	2677
Zn	56	35	6.0	192
Ni	< 20	< 20	< 20	< 20
Co	< 20	< 20	< 20	< 20
Sr	6002	12,578	455	360
Zr	< 5	< 5	236	571
Ce	< 30	< 30	60	158
Y	< 3	< 3	6	67
Nb	< 5	27	14	43
Sc	< 1	< 1	8	20
Pb	> 10,000	> 10,000	1500	2500
Ba/K ₂ O	45879	31250	5410	1899
Ba/Na ₂ O	12953	15923	5362	1195
Ba/Ni	2500	2500	906	134
TOC/C (%)	0.55	0.68 Ugwuajirija.	0.45	1.12
TOC/S (%)	13.82	13.54	0.12	0.10

KEY: L1 = Marly mudstone from Obinago. L2 = Ferruginized Mudstone from Ugwuajirija. L3 = Diorite Sample from Ugwuele. L4 = Dolerite sample from

4.2 Trace Elements

Trace and REE result shows that all the analyzed samples were depleted in Cs, Sn, and Be < 1.0ppm, below the average crustal abundance, except

one sample that has Be concentration of 2.0ppm. The mudstone (MRL-MST at Obinago) has Ba concentration of 802ppm and 936ppm respectively, which are > x2 above the average crustal abundance of Ba 400ppm.

The trace elements concentration in the rocks vary, except Ni and Co, which has constant concentration of 20 ppm. The Cu concentration varies from 5 ppm (L2) through 6 ppm (L1) to maximum value of 25 ppm (L4, Table 3). The Ce varies from 30 ppm through 236 ppm to maximum enrichment of 571 ppm (Table 3). The Pb contents in all the analyzed samples were high, ranging from 1500 ppm in sample L3 through 2500 ppm in sample L4 to maximum enrichment of >10,000 ppm in samples L1 and L2 (Table 3). The Ba concentration increased from 2677 ppm in sample L4 from Crush Rock Quarry Ishiagu, through 18125 ppm in sample L3 from Ugwuele, to maximum concentration of. >50,000 ppm in samples L1 and L2 Obinagu and Ugwuajirija respectively (Table 3).

The Sr concentration showed significant variation and enrichment, ranging from 360 ppm in sample L4 from Crush Rock Quarry pit at Ishiagu, through 455 ppm in sample L3 from Ugwuele, to 6002 ppm in sample L1 from Obinago, to maximum concentration of 12,578 ppm in sample L3 from Ugwuele. These are all above the crustal average of 400 ppm for Ba (Taylor, 1965; Taylor and McLennan, 1985) and Sr 245 ppm for rhyolites, 355ppm for basaltic rocks and 525 ppm for andesites (Ekwueme, 1993a). The Pb gives a multiplicity of 3 to about 100 times the crustal thresh level (Taylor, 1965), and Ba gives a multiplicity of 6.6 to 125 times the average crustal abundance. The Zn concentration rises from 6.0 ppm (sample L1), through 35 ppm (sample L3), 56 ppm (sample L2), to maximum of 192 ppm in (sample L4, Table 3). These data strongly shows mineralization of Pb, Ba, Sr and Zn in Ishiagu area of the Lower Benue Trough Southeastern Nigeria. Currently both Pb and Zn are being mined at Ugwuele, Ugwuonye and Ugwuajirija areas in Ishiagu, Lower Benue Trough on artisanal and small scale bases.

CONCLUSION AND RECOMMENDATION

The study of rocks of Ugwuajirija Ishiagu area southeastern Nigeria indicates mineralization of Pb, Ba, Sr and Zn in Ishiagu area with threshold of > 3 to 100 times the average crustal abundance of Ba 400 ppm, (Taylor, 1965), Sr 355 ppm (Ekwueme, 1993a). These resources are currently being mined on artisanal and small scale levels in the area. Huge capital outlay by government and multinational investors is necessary for effective development of the resources which may secure employment for our teaming youth and revenue for domestic and national development.

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