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SCHISTOSE ROCKS FROM OKENE-LOKOJA AREA, SW NIGERIA

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ABSTRACT

Schistose rocks from Okene-Lokoja area, SW Nigeria, consist of quartz-biotite schist, quartz-muscovite schist, amphibole schist, and quartz schist. Major element compositions (oxide wt. %) of the schists together with their trace element contents (Ba, Ce, Cr, La, Li, Ni, Rb, Sr, V, Y, Zn, and Zr) are presented. The schists (excluding the quartzitic variety) are enriched in SiO_2, K_2O, Rb and Ba but depleted in total Fe_2O_3, MnO, TiO_2, MgO, Ni and Zn compared with rocks of similar composition from Ilesha (SW Nigeria) and other parts of the world. Petrochemical peculiarities suggest that the quartzitic schist is derived from sedimentary rocks (arkoses and arenites) whereas the other schists (quartz-biotite, quartz-muscovite and amphibole schists) are considered to be pre-metamorphosed basic igneous rocks probably derived from magmas (with calc-alkaline/tholeitic affinity) emplaced in a continental environment.

INTRODUCTION

The Pan-African schist belt which trends N-S has its eastern fringe traversing the Chokochoko-Obajana-Eganyi-Ilubeachi district between Okene and Lokoja, southwestern Nigeria. The district is delimited by longitudes, $6^{0}15'$ and $6^{0}30$E and latitudes $7^{0}3'$ and $8^{0}00'$N (Fig. 1). Distinct types of schistose rocks recognised in the area are quartz-biotite schist (QBS), quartz-muscovite schist (QMS), amphibole schist (AMS) and quartzitic schist (QS).

The regional geology of adjacent and slightly overlapping areas was undertaken by Hockey *et al.* (1986). Annor (1983) and Annor and Freeth (1984, 1985) studied the style of metamorphism and thermotectonic evolution of the tract just W. of this district, whereas Okeke and Meju (1985) investigated the basement terrain about 100km to the SW. In 1988, Gabako made a detailed survey of the relationship between geology and mineralisation around Chokochoko and Obajana.

The main aim of this paper is to provide detailed chemical analyses of the Okene-Lokoja schistose rocks and to discuss their petrogenesis and tectonic constraints.

GEOLOGY AND PETROGRAPHY

The quartz-biotite schist forms a U-shaped outcrop (about $90km^2$) in the north as well as an almost rectangular exposure (approximately $100km^2$) in the east central sector (Fig. 1). Occurrence of amphibole schist is in the form of six oval-shaped outcrops, each with area extent of - km^2, completely surrounded in the north by quartz-biotite schist or gneiss and in the south by gneiss. The eastern flank of the quartz-biotite schist shares a common contact with an elongated exposure (1.5 x 8km) of quartz-muscovite schist which in turn grades eastwards into quartzitic schist outcrop measuring 0.5 x 6km.

Figure 1 shows that the schistose rocks in the Okene-Lokoja area are associated with other Basement Complex rocks such as gneisses and granitic intrusives. Vertical to near vertical joints trend mostly NE and NW. Steeply dipping faults of short strike length, usually with NW orientation, are wide-spread in the southern section, of the district. Prominent foliations trend mostly NE or N with varying dips (14^{0}—40^{0}) to the NW, SE, E or W. Lineation is most often oriented NW or N with erratic plunge value ranging between 3^{0} and 30^{0} Evidence of folding is recognised in the plunging antiform outlined by the quartz-biotite schist in the north (Fig. 1).

The quartz-biotite schist is typically dark, mediumgrained and foliated with biotite and quartz-feldspar segregated into bands. Early quartz forms rounded inclusions in Na-plagioclase and later quartz occurs as large granoblastic crystals with irregular boundaries. Biotite is fine-to medium-grained with Zr inclusions. Table 1 shows that the chief minerals are quartz, plagioclase and biotite.

The amphibolite schist is dark gray, medium-grained and has mafic minerals (hornblende plust biotite) predominant over felsic minerals (quartz plus plagioclase). Green prismatic hornblende (actinolitic) is poikiloblastic against quartz, sphene and iron oxide. Hornblende and biotite have mutually parallel orientation. Plagioclase is idioblastic andesine or labradorite. A few samples carry accessory diopside with octagonal basal sections. Modal analysis (Table 1) reveals the compositioin of amphibolite schist as 48% hornblende, 20% quartz, 17% plagioclase, 7% biotite and 8% accessory minerals.

Quartz-muscovite schist comprises quartz (15%), muscovite (69%), chlorite (9%) and iron oxides (7%) (Table 1). Muscovite and chlorite have preferred orientation in layers interleaved with bands of granoblastic quartz. The quartzitic schist is made up mainly of quartz (85%), biotite (3%), muscovite (2%) and accessories (10%) Table 1).

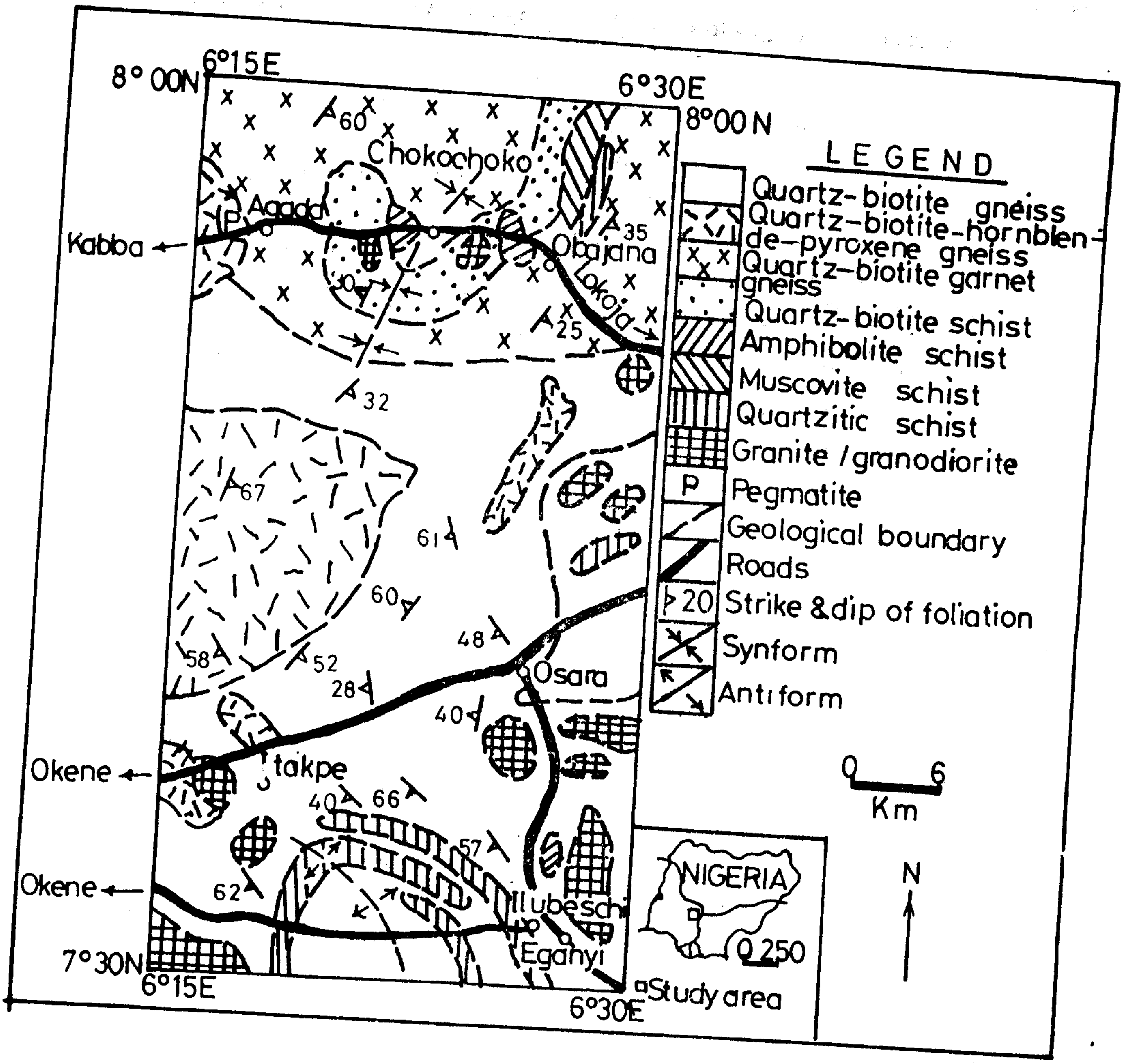

Fig. 1 Geological map of Okene-Lokoja Area, Southwestern Nigeria.

Foliation is not as pronounced as in the other associated schists because of the paucity of phyllosilicates.

GEOCHEMISTRY

Analytical Methods

Ten major elements and twelve trace elements (including three rare earths - Ca La, Y) were determined by inductively coupled plasma (ICP) and atomic absorption spectrometry (AAS) using the methods of Thompson and Walsch (1983) and Fifield and Kealey (1983). Accuracy, precision and sample homogeneity were ascertained by comparing results with the values for USGS lstandards—SDC-1, GS-N Granite, and BN-N Basalts. Precision for ICP was ±10% while that for ASS was ±5%. All the analyses were conducted in the Berlin Technical University, Germany.

Major Elements

Table 2 indicates that SiO_2 averages 59% in amphibolite schist (AMS), 69-70% in quartz-biotite schist (QBS) and quartz-muscovite schist (QMS) and 94% in quartzitic schist

(QS). This variation seems to corresond with modal quartz in the four types of schist (Table 1). TiO_2, total Fe_2O_3, MnO and CaO are enhanced in AMS relative to QBS, QMS and QS, this distribution pattern being in sympathetic relationship with the

Table 1: Modal Analysis of Schists from Okene-Lokoja Area, SW Nigeria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Qz	12	23	20	32	15	20	15	18	23	38	40	35	35	77	92	83	86
Plag	20	18	10	12	20	20	x	x	x	20	25	30	27	2	x	x	x
K-feld	x	x	x	x	x	x	x	x	x	12	5	3	10	x	x	x	x
Bio	11	12	10	8	x	x	x	x	x	22	20	20	30	13	x	x	x
Musco	x	x	x	x	x	69	67	62	x	x	x	x	x	x	x	5	x
Hb	48	40	55	41	50	53	x	x	x	x	x	x	x	x	x	x	x
Chl	x	x	x	x	x	x	9	9	8		4	5	9	x	x	x	x
Sphene	x	2	x	x	10	2	x		x	x	x	x	x	x	x	x	x
Zr	x	x	x	x	x	3	x	x	x	x	x	x	x	1	x	2	1
Mt + Hm + 11m	5	5	4	4	2	7	6	7	7	3	2	3	3	4	4	9	11
Epi	x	x	1	x	x	x	x	x	x	x							
Ap											x	x	x	x	3	x	x
Rutile											z	z	1	x	x	x	x

Columns 1—6 amphibolite schists; columns 7—9 = quartz-muscorite schists; columns 10—14 = qtz-biolite schists; columns 14—17 = quartzite schists. x = not present.

Table 2: Average Chemical Composition of Schists from Okene-Lokoja District, SW Nigeria

	1	2	3	4	5	6	7	8	9	10
SiO_2	48.10	69.06	70.00	54.11	60.25	50.67	70.01	69.90	71.01	69.01
TiO_2	0.73	0.46	0.44	0.88	0.50	0.83	0.39	0.47	0.43	0.31
Al_2O_3	10.48	16.55	15.62	11.33	16.99	14.03	18.27	18.50	10.10	15.59
Fe_2O_3	11.00	3.16	3.94	10.69	5.65	12.49	3.86	4.01	3.84	3.57
MnO	00.19	0.03	0.6	0.18	0.07	0.22	0.01	0.02	0.01	0.05
MgO	12.25	1.53	1.15	10.48	2.23	6.94	0.18	0.20	0.19	2.39
CaO	9.52	4.08	3.09	9.80	7.13	12.18	0.01	0.01	0.01	3.37
Na_2O	1.81	3.65	3.48	1.25	3.40	2.15	0.24	0.25	0.22	3.76
K_2O	1.53	1.30	1.87	0.94	1.15	0.67	4.35	4.40	4.21	1.05
P_2O_5	0.11	0.11	0.11	0.20	0.13	0.07	0.09	0.08	0.07	0.05
LOI	3.89	0.42	0.39	0.37	1.17	0.54	1.95	1.69	1.60	0.23
Total	100.19	100.36	100.51	100.22	100.67	101.80	99.41	99.53	99.69	100.05
Ba	207	236	335	161	629	81	339	350	331	239
Ce	31	34	37	31	91	17	143	139	137	32
Cr	542	42	34	597	8	151	28	26	30	72
La	10	16	19	16	35	6	74	78	70	12
Li	25	15	31	11	11	6	15	13	17	34
Ni	141	96	24	128	23	138	9	12	8	29
Rb	44	30	67.	11	33	6	148	153	138	125
Sr	10	464	186	84	900	53	2	5	4	152
V	199	58	62	227	91	313	14	12	16	46
Y	33	5	14	21	21	23	14	13	17	14
Zn	68	29	103	56	27	72	21	19	23	49
Zr	40	137	44	116	110	4	333	339	321	90

Columns 1 - 6 = amphibolite schists; columns 7 - 9 = quartz-muscovite schists; columns 10 - 13 = quartz-biotite schists; columns 14 - 17 = quartzite schists; columns 18 - 20 = averages of columns 1 - 6, 7 - 9, 10-13 respectively. x = not detected.

Table 2 (Contd.) Average Chemical Composition of Schists from Okene-Lokoja District, SW Nigeria

	11	12	13	14	15	16	17	18	19	20
SiO_2	73.37	66.56	66.13	90.14	96.02	95.27	94.10	59.00	69.00	70.30
TiO_2	0.14	0.63	0.47	0.30	0.83	0.59	0.76	0.65	0.39	0.43
Al_2O_3	14.63	17.57	15.53	5.20	-	-	-	14.16	15.83	18.29
Fe_2O_3	1.50	4.55	4.54	2.02	3.27	3.86	4.30	7.82	3.54	3.90
MnO	0.02	0.05	0.08	-	-	-	-	0.13	0.05	0.01
MgO	0.09	1.49	1.53	0.01	-	-	-	5.82	1.40	0.19
CaO	2.79	2.48	4.06	0.08	-	-	-	7.62	4.57	0.24
Na_2O	4.89	6.07	3.56	0.70	-	-	-	2.62	4.57	0.24
K_2O	0.661.53	0.40	1.43	0.60	-	-	-	1.24	0.90	4.32
P_2O_5	0.04	0.11	0.10	-	-	-	-	0.12	0.08	0.08
LOI	199	0.23	2.07	-	-	-	-	1.13	1.13	1.75
Total	100.12	100.07	99.43	100.62	100.63	100	100.06	100.62	99.93	99.52
Ba	95	26	382	x	x	x	x	273	185	340
Ca	30	30	79	x	x	x	x	40	43	140
Cr	2	7	23	x	x	x	x	229	26	28
La	110	17	36	x	x	x	x	17	18	74
Li	12	5	25	x	x	x	x	17	19	15
Ni	4	8	15	x	x	x	x	91	14	10
Rb	35	2	86	x	x	x	x	32	62	146
Sr	135	152	99	x	x	x	x	283	135	4
V	22	28	59	x	x	x	x	158	39	14
Y	3	14	21	x	x	x	x	20	13	15
Zn	29	41	54	x	x	x	x	59	43	21
Zr	138	38	143	x	x	x	x	75	102	327

Columns 1 - 6 = amphibolite schists; columns 7 - 9 = quartz-muscovite schists; columns 10-13 = quartz-biotite schists; columns 14-17 = quartzite schist; columns 18-20 = averages of columns 1-6, 7-9, Disrespectively. x = not detected.

modal iron oxide contents (Table 1). As is to be expected, both QMS and QS that are almost devoid of plagioclase contain only 0.01—0.02% CaO together with 0.24% Na_2O in QMS and 0.17% Na_2O in QS. Furthermore, QMS has the greatest concentration of Al_2O_3 (18.30%) and K_2O (4.35) compared with AMS (14.2% Al_2O_3, 1.2% K_2O), QBS (15.8% Al_2O_3, 0.9% Na_2O) and QS (1.3% Al_2O_3, 0.15% Na_2O). The behaviour of Al_2O_3 and K_2O is clearly controlled by modal proportion of muscovite in the rock groups (Table 1).

The comparative analysis that follows is between the Okene-Lokoja schists (OKLS) and selected rocks elsewhere, viz, (1) Amphibolites and (2) Talc-tremolite schists from (3) Average amphibolite, Holleindalen Greenstone Group, Norway (Elliot & Cowan 1966), (4) Average Archean Metabasalt, Superior Province, Canadian shield (Glikson, 1971), (5) Average Archean metabasalt,. Norseman, W. Australia (Hallberg, 1972), (6) Average oceanic tholeiite (Engel *et al.*, 1965), (7) Average continental tholeiite (Manson, 1967 and Condie *et al*, 1969) and (8) Average tholeiitic basalt (Manson, 1967, and Prinz. 1967). The average content of SiO_2 (63.4%) in Okene-Lokoja schist (OKLS) is significantly higher than in the Ilesha amphibolites and talc-tremolite schists (47.21—47.35%), amphibolite from Norway (47.21), Archean metabasalt of Canada (49.0%), Archean metabasalt. Australia (51.2%) average oceanic tholeiite (49.3%), average continental tholeiite (49.9%), and average tholeiitic basalt (51.1%), TiO_2 (0.48%) is less than in rocks from elsewhere (0.96—3.41%) whereas Al_2O_3 (15.14%) of OKLS is generally similar to most other samples (14.4—17%) but vastly more than Ilesha talc-tremolite schist (7.20%). The OKLS has total Fe_2O_3; 10.12—0.28% MnO; 6.2—7.82% MgO with 19.09% MgO in Ilesha talc-tremolite schist). CaO content of OKLS (5.32%) and Archean metabasalt from Canada (4.75%) but markedly less than in other rocks cited above (9.8—11.08%). K_2O in rocks of this work (1.39% K_2O) is consistently much higher than in similar rocks from elsewhere (0.04—0.56%).

Trace Elements

Table 2 shows Ba, Rb, Ce and La to be enriched in quartz-muscovite schist (QMS) relative to amphibolite schist

(AMS) or quartz-biotite schist (QBS) and this trend may be ascribed to modal muscovite (69%) in QMS; 0-2% in AMS, QBS and QS). Cr. Ni Sr and V are most enhanced in AMS presumably owing to its possession of highest proportions of honrblende and iron oxide and considerable amount of plagioclase.

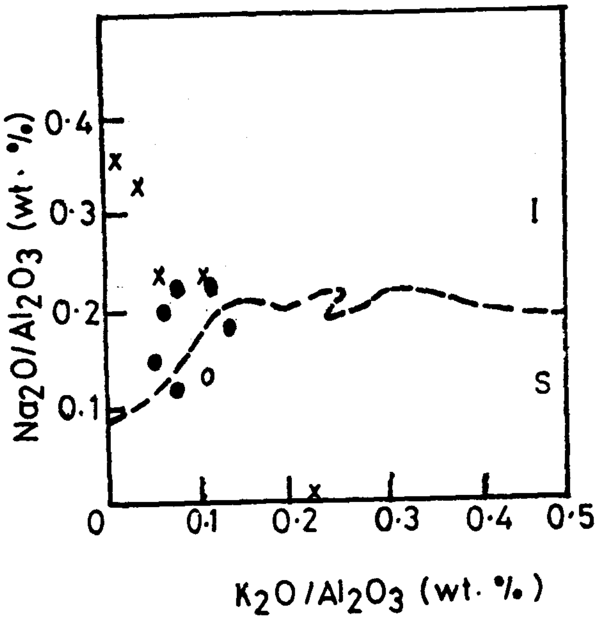

Fig. 2 Variation of Na_2O/Al_2O_3 against K_2O/Al_2O_3 in the Okene-Lokoja schists. I - Igneous field; S = sedimentary field; fiiled circles = amphibolite schists; open circles = quartzitic schists; crosses = quartz-biotite schists and quartz-muscovite schists. (After Garrels and Mackenzie, 1971).

Rb content (53 ppm) in rocks of this study is generally greater than in Ilesha amphibolite and talc-tremolite schist (<2ppm, Olade & Elueze, 1985), Archean metabasalts from Canada and Australia (≤ 10 ppm, Glikson, 1977; Hallberg, 1972), and tholeiitic rocks (up to 36 ppm, Engel *et al.*, 1965; Manson, 1967; Prinz, 1967; Condie *et al.*, 1969). Although Sr. in OKLS (203 ppm) is lower than in average tholeiitic basalts (400 ppm), it is comparable to Ilesha amphibolite (267 ppm) but higher than in Archean metabasalts (102—124 ppm), average oceanic theoloeiit (130 ppm, Engel *et al.*, 1965), and Ilesha talc-tremolite schist (16 ppm). Ba in OKLS (247 ppm) is higher than in most other rocks (12—144 ppm) excepting continental tholeiite with 352 ppm (Manson, 1967; Condie *et al.*, 1969). Zr (87) and Y(16 ppm) are in the same range as in rocks currently referenced in this paper. However, Ni (56 ppm) and Zn (50 ppm) in OKLS are invariably less than in similar rocks elsewhere (85-166 ppm Ni with 654 ppm for Ilesha schist; 100—1 ,0 ppm Zn).

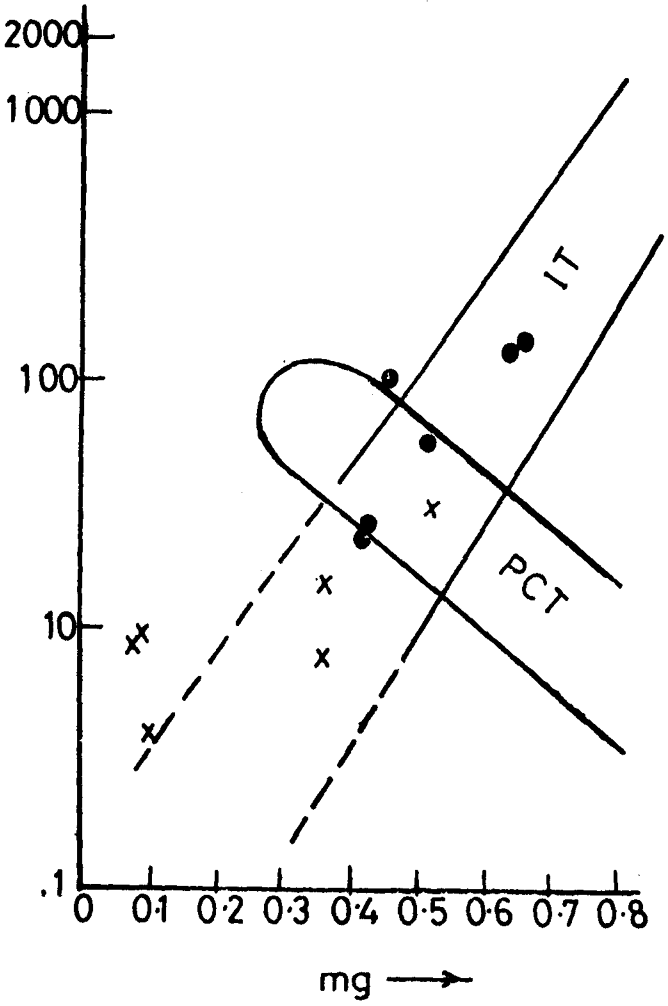

Fig. 3 Plot of Ni vs. Niggli mg. Filled circle = amphibolite schists; crosses = quartz-biotite schists and quartz-muscovite schists. IT = igneous trend; PCT = pelite-carbonate trend (After Evans and Leake, 1960; van de Kamp, 1970).

DISCUSSION AND CONCLUSION

To gain an insight into the pre-metamorphic parent material of the Okene-Lokoja schist (OKLS) it has been necessary to invoke a series of sensitive discriminant diagrams such as (a) Na_2O/Al_2O_3 vs. K_2O/Al_2O_3 (Fig. 2) of Garrels and Mackenzie (1971), (b) Ni vs. mg (Fig. 3) (Evans and Leake, 1960; Van de Kamp, 1970), (c) Cr vs. mg (Fig. 4) (opus cit), and (d) C vs. mg (Fig. 5) (Leake, 1963 and 1964). Among th four groups of schistose rocks of this work it is quite obvious that the quartzitic schist (QS) has a sedimentary anteceden (arenites) as is manifested by its extremely high average content of SiO_2, (91%) and modal quartz (85%). Moroever, all the QS samples plot well within the field of sedimentary rocks in Fig. 2. With the original material of QS identified, this rock group will not be considered further. Most of the other rock groups—QBS, QMS and AMS—plot in the field of igneous rocks in Fig. 2. and they also follow closely the igneous trends in

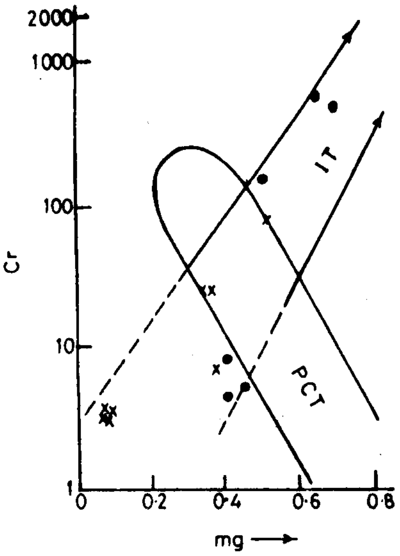

Fig. 4 Cr vs. Niggli mg. IT = igneous trend; PCT = pelite-carbonate trend, Rock symbols as in Fig. 3 (After Evans and Leake, 1960; van de Kampe, 1970).

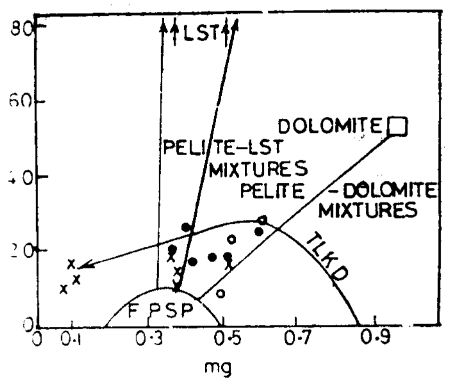

Fig. 5 Niggli C vs. LST = limestone; FPSP = Field in pelites and semi-plites ; TLKS = trend line of Karroo dolerite. Symbols as for Fig. 3. (After Leake, 1963 and 1961).

Fig. 3 and 4. Similarly, in Fig. 5 which contains the fields of common pelites and limestone, lines for pelite-carbonate mixtures as well as the differentiation trend of the Karroo dolerite (with tholeiitic affinity), the OKLS specimens plot in the igneous field along the Karroo doleritic liquid line of descent. Evidence from Figs. 2—5 suggestive of magmatic origin for OKLS. In the Na_2O-K_2O-CaO diagram (Fig. 6), the OLKS plot along the K_2O-Na_2O base line showing a conspicuous enrichment in alkalis and improverishment in CaO compared with similar rocks form Ilesha, S. W. Nigeria. The plot also demonstrates a trend from K_2O to Na_2O signifying perhaps some sort of magmatic differentiation. From the $Na_2O + K_2O$ vs. SiO_2 (Figs. 7 and 8) diagrams (Macdonald and Katura, 1964; Irvine and Baraggar, 1971) it is easily inferred that the OKLS rocks are subalkaline with tholeiitic

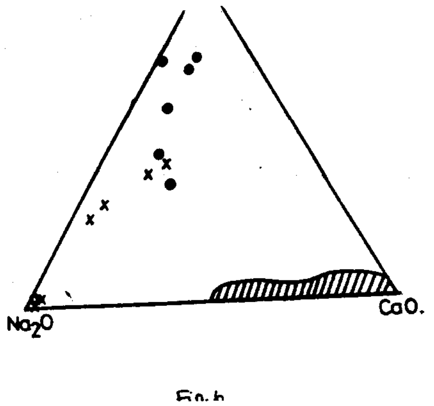

Fig. 6 Na_2O-K_2O-CaO diagram for Okene-Lokoja schists. Rock symbols as for Fig. 3. Shaped area = field of Ilesha amphibolites and talc-tremolite schists (Olade and Elueze, 1979).

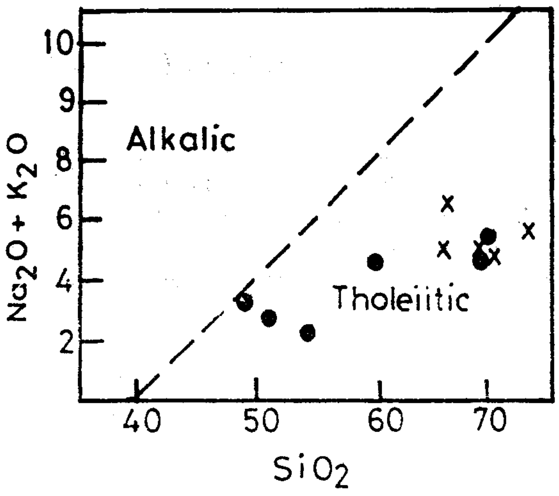

Fig. 7 $Na_2O + K_2O$ vs. SiO_2. Symbols as for Fig. 3 (After Macdonal and Katsura, 1964).

affinity. In addition, these rocks plot in the calc-alkaline field in AFM diagram (Fig. 9) of Irvine and Barggar (1971) although with a slight affinity for the tholeiitic differentiation trend. Several authors (Peace and Cann, 1971, 1973; Bloxam and Lewis, 1972; Pearce, *et al.*, 1975; Gill, 1979) have recommended the use of relatively immobile elements - Ti, P, Sr, Y, Zr, Nb, Ni and Cr—to elucidate the tectonic environment of magma genesis and emplacement. Application of some of these criteria has shown that the OKLS plot well within the continental basalt field in the TiO_2-K_2O-P_2O_5 diagram (Fig. 10) of Pearce *et al.* (1975). Moreover, these same rocks plot outside the fields of (i) mid ocean ridge basalts, (ii) marginal basin and (iii) island are tholeittes in Gill's (1979) tectonomagmatic diagrams: Fig. 11 (TiO_2 vs. Mg. number), Fig. 12 (Al_2O_3 vs. Mg. number), Fig. 13 (Ni vs. Mg number) and Fig. 14 (V vs. Mg number). The patterns exhibited by OKLS in Figs. 10—14 give a strong indication of their genesis from continental magmatism.

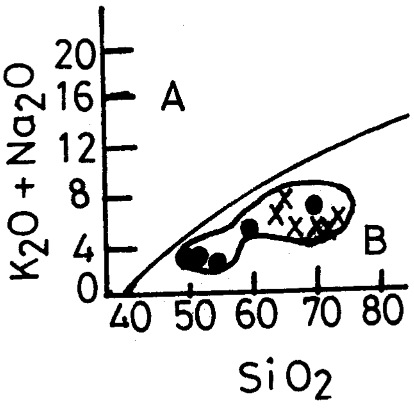

Fig. 8 Na_2O + K_2O vs. SiO_2. Symbols as for Fig. 3 A = alkalic field; B = tholiitic field (After Irvine and Baragar, 1971).

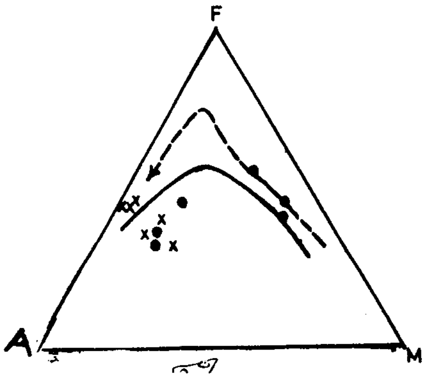

Fig. 9 AFM diagram for Okene-Lokoja schists. A = Na_2O + K_2O; F = total (Fe_2O_3); M = MgO; continuous curve = calc-alkaline trend; discontinuous curve = tholelitic trend. Symbols as for Fig. 3 (After Irvine and Baragar 1971.

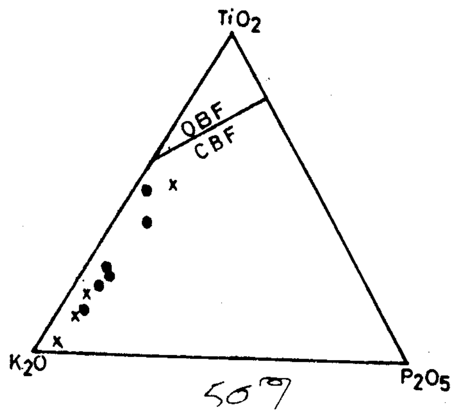

Fig. 10 TiO_2-K_2O-P_2O_5 diagram of Pearce et al. (1975) for Okene-Lokoja schists. Symbols as for Fig. 3. OBF = oceanic basalt field; CBF = continental basalt field.

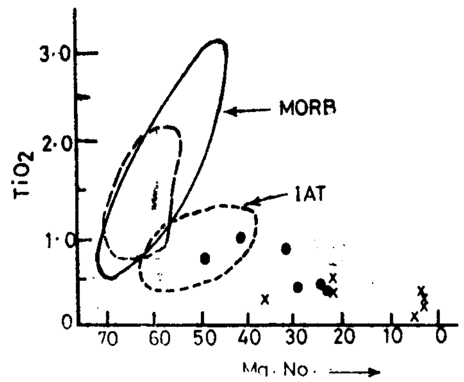

Fig. 11 TiO_2 vs. Mg No. Symbols as for Fig. 3 IAT = Island Arc tholelitic field; MB = marginal basin field; MORB = modern ocean ridge basalt field (After Gill, 1979).

The various strands evidence emanating from the above discussion urge the authors to conclude as follows:- (i) The Okene-Lokoja quartzitic schist has a sedimentary origin whereas the other groups (quartz-biotite schist, amphibolite schist and quartz-muscovite schist) have magmatic ancestory, (ii). The parent magmas to the schists (excluding

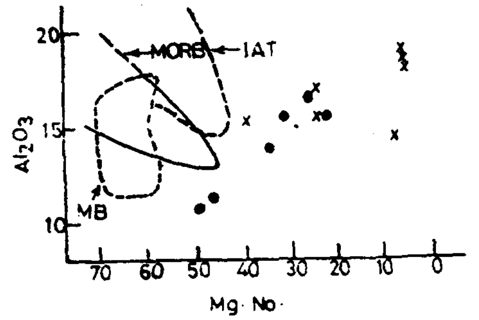

Fig. 12 Al_2O_3 vs. Mf. No. Symbols as for Fig. 3. IAT = Island Arc tholeiitic field; MB = marginal basin field, MORB = modern ocean ridge basalt field (After Gill. 1979).

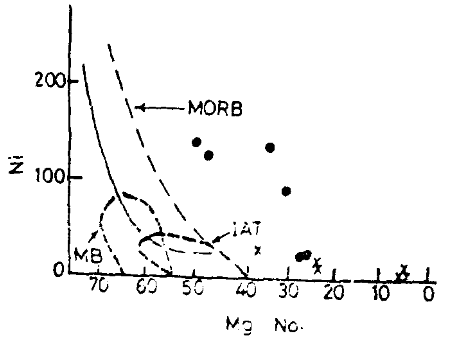

Fig. 13 Ni vs. Mg. No. Symbols as for Fig. 3. IAT = Island Arc tholeiitic field; MB = marginal basin field MORB = modern ocean ridge basalt field (After Gill, 1979).

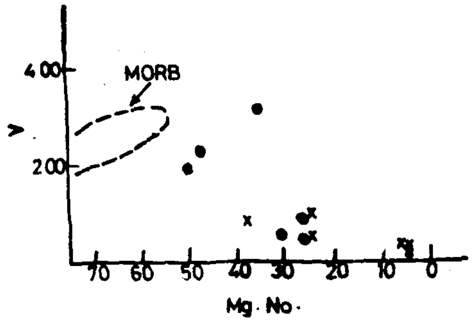

Fig. 14 V vs. Mg. No. Symbols as for Fig. 3. IAT = Island Arc Tholeiitic field; MB = marginal basalt field; MORB = modern ocean ridge basalt field (After Gill, 1979).

the quartzitic schist) must have been calc-alkaline to tholeiitic in composition, (iii) The magmas that gave rise to the premetamorphic rocks were most probably emplaced in a continental setting rather than in oceanic or island arc or marginal basin environment, (iv) The Okene-Lokoja schistose rocks are enriched in SiO_2, K_2O, Rb, and Ba but impoverished in Fe_2O_3 (total), MnO, TiO_2, MgO, Ni and Zn compared with amphibolite schists, Archean metabasalts, and tholeiitic rocks from SW Nigeria (Ilesha) and other parts of the world, and (v). The relative enhancement and depletion in elements mentionedin (iv) above may be linked to the imprint of continental crustal contamination probably coeval with or subsequent to magma emplacement.

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