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PETROGENESIS OF SCHISTS IN SOUTHEAST LOKOJA, CENTRAL NIGERIA

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ABSTRACT

Schists in southeast Lokoja, central Nigeria are enriched in SiO_2 and Al_2O_3. Cr, Ni and TiO_2 are also relatively high in these rocks. The chemical compositions of the schists indicate that they were derived from a shale-greywacke sequence of sedimentary rocks. As a result, they have high TiO_2/Al_2O_3 and variable K_2O/Na_2O ratios. The grey wackes had a granodioritic provenance. The high TiO_2 and Ni content of these metasediments suggest that mafic debris were possibly mixed in their source-rocks. The schists are products of metamorphism of immature sediments which were deposited in an intracratonic extensional basin. Available geochronological data indicate that the most intensive reworking of these sedimentary rocks occurred ca. 687 $\pm$ 13 Ma ago during the Pan-African orogeny. Earlier metamorphism of the sediments could have occurred ca. 1315 Ma ago during the Kibaran orogeny.

Keywords: Lokoja, shale-greywacke, immature-sediments, Pan-African, Kibaran

INTRODUCTION

Lokoja area is located around the confluence of Rivers Niger and Benue and in the centre of Nigeria (Fig. 1). It is the eastern geologic border zone of the southwestern Nigerian basement complex towards the Createaceous rift known as the Benue Trough. It is bounded in the east and south by coal measures, in the west by the River Niger and in the north by an area of Quaternary alluvium which extends to the River Benue. Southeast Lokoja belongs to the Nigerian basement complex, a metavolcanosedimentary or schist belt which forms a supracrustal cover on the former and intrusive rocks of acidic, intermediate, basic and ultrabasic compositions (Oyawoye 1972).

Of particular interest is the Nigerian schist belts whose areal extent is still not well known and until recently were thought to occupy a N-S trending trough which does not extend beyond longitude 8° E. Schist belts have recently been described from other parts of the basement e.g. in southeastern Nigeria (Ekwueme and Onyeagocha 1986). These schists in southeast Nigeria are believed to be extension of the Poli schist in Cameroon Republic (Toteu et al. 1987). Among the rock units in southeast Lokoja are schists whose field occurrence and petrography have been reported by Ekwueme (1983), Ekwueme and Onyeagocha (1988) and Jones et al. (1986). The geochemistry of these rocks have however, not been discussed. In this paper, I discuss the major and trace element composition of the Lokoja schists with a view to throwing light on their source rocks and tectonic setting. This is important in two ways: (1) petrographic analyses of structurally deformed and regionally metamorphosed sedimentary rocks may not uniquely define the mineral assemblages resulting from pre- and syn- depositional processes (Argast and Donnelly 1986) and (2) the schist belts of Nigeria have been compared to rocks of Archaean greenstone belt (Wright and McCurry 1970; Hubbard 1975; Klemm et al. 1984; Ige and Asubiojo 1991) and the understanding of the composition of these schists is crucial in unravelling the evolution of the basement complex. Though the rocks in Lokoja area appear to be extension of schist belts in northwest and southwest Nigeria, it is only geochemical data that can reveal their compositional similarity or otherwise with other metasedimentary belts and show their possible relationship to rocks of the greenstone terrane. This is

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important since ages indicating Kibaran and Pan-African tectonothermal activities have been obtained in the Lokoja area (Caen-Vachette and Ekwueme 1988) and Hubbard (1975) as well as Klem et al (1984) believe that the schist belt-granite associations in Sw Nigeria represent a Kibaran greenstone belt reworked in the Pan-African event.

FIELD RELATIONS AND PETROGRAPHY

Rock types mapped in southeast Lokoja are schists, migmatites, gneisses, granites and gabbro. Detailed descriptions of the field relations and petrography of these rocks can be found in Ekwueme (1983) and Onyeagocha (1988). A summary is given here.

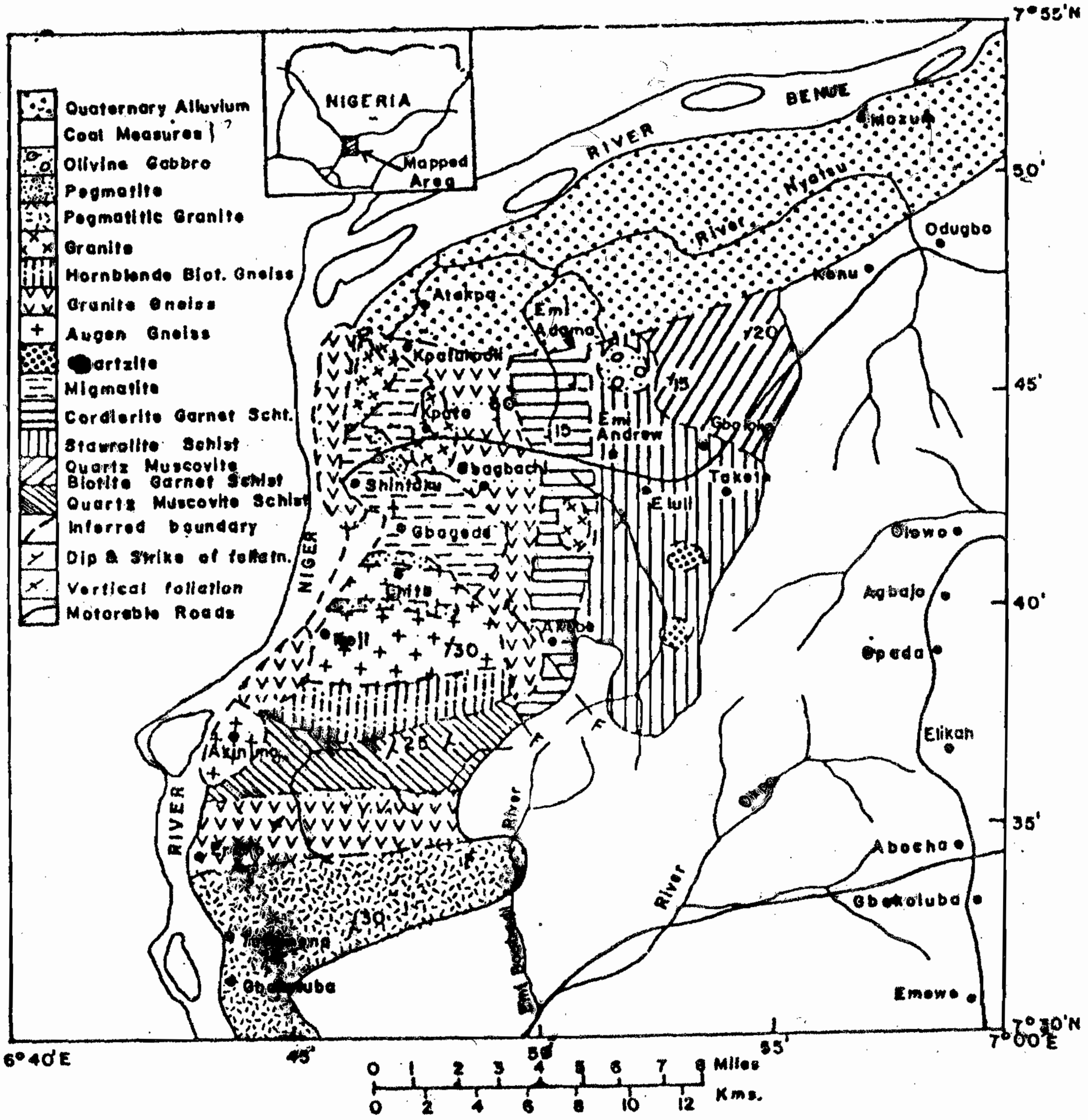

FIG. 1 GEOLOGICAL MAP OF SOUTHEAST LOKOJA, NIGERIA.

Schists include (i) Quartz-muscovite-biotite-garnet schist, (ii) Staurolite garnet schist, (iii) Cordierite-garnet schist and (iv) Quartz-muscovite schist (Fig. 1). The mineralogical assemblages occuring in the schists are shown as Table 1. The Quartz-muscovite garnet schist is fine-to- medium-grained and has foliation trending NW with dips varying from 15 to 20^0 NE. It is dark in colour reflecting the preponderance of biotite in the mode. The staurolite garnet schist is generally medium-grained and the texture becomes coarser towards the north (around Emi-Andrew) where crystals of staurolite as long as 5cm occur in the rock. This schist is light-coloured and contain flakes of muscovite and garnet porphyroblasts. The rock is associated with metaquartzites pointing to its possible sedimentary parentage. Schistosity is strong and trends N20 E with dips of 15^0 SE. The cordierite-garnet schist occupies a narrow band running approximately N-S in the middle of the map area (Fig. 1). It is medium to coarse grained and has been folded parallel to the foliation which trends NE-SW. It is also fractured. Madu and Onuoha (1984) report that these fractures trend dominantly NE-SW and that the sediments were deposited in them. Thin bands of mica and quartz are observed to alternate in outcrops of this schist. Porphyroblasts of garnet are conspicuous in hand specimen and emplacement of granite in the southern part of the cordierite garnet schist possibly triggered off boron metasomatism which resulted in the extensive tourmalinization of the rock. Dips of foliation range from 25^0 to 45^0 mostly NW and foliations dipping in opposite direction (SE) point to occurrence of a synclinal structure. This has been confirmed by geophysical study and the axis lies 5.5 km west to Gboloko (Madu and Onuoha 1984).

The quartz-muscovite schist is fine-grained and foliated. The foliation trend is N20^{0}E and dip is up to 25^{0}SE. Metaquartzitic selvages are present possibly indicating a sandstone-sequence of the original pre-metamorphic sedimentary rock. This rock is rich in muscovite and quartz and is consequently, light-coloured.

The schists contain index minerals garnet, staurolite and cordierite. Ekwueme (1983) and Onyeagocha and Ekwueme (1990) used these index minerals to place metamorphic isograds in Lokoja area. The mineral assemblages occurring in these schists indicate that the metamorphism was regional medium pressure type (3 - 6 kbar) and increased in grade from east to west. The schists have therefore, been metamorphosed from upper greenschist to medium amphibolite grade.

Gneisses also occur in southeast Lokoja. They include augen gneiss, hornblende-biotite gneiss and granite-gneiss. These rocks are medium to coarse-grained and rich in quartz, biotite and feldspar. The hornblende-biotite gneiss is distinct in its abundance of hornblende and biotite which impart a dark to very dark colour on the rock. Microcline is the dominant feldspar in the gneisses and the plagioclase composition ranges from An20 to An30. Variations in plagioclase composition were attributed partly to presence or absence of epidote (Ekwueme and Onyeagocha 1988). One characteristic feature of the gneisses is the occurrence of schist inclusions which in the augen gneiss attain a dimension of 150 x 60 cm. These inclusions which are foliated in the same direction as the schists trend NE-SW to N-S subparallel to the foliation of the gneiss. Gneisses are believed to be older than schists in the Nigerian basement (Grant 1970) and the occurrence of schist xenoliths in gneisses of Lokoja area as has also been reported in the Akwanga area of central Nigeria (Onyeagocha 1984) pose a stratigraphic problem since xenoliths are believed to be older than the rocks that enclose them. It is possible that metamorphic differentiation and segregation might have given rise to these schistose patches in the Lokoja gneisses.

Migmatites occur in southeast Lokoja and they are of lit-par-lit gneiss and agmatite types. Contortion and ptygmatic folds are pronounced in the lit-par-lit gneisses. In the agmatite, dissection of the gneissic or schistose rocks by quartzo-feldspathic aplitic dykes and pegmatites is widespread. The presence of these agmatites permit the interpretation that partial anatexis had occurred during the high grade metamorphism of these rocks. Muscovite is absent in the migmatites and K-feldspar is abundant. It has been referred to as muscovite-absent zone by Ekwueme (1983).

TABLE 1. AVERAGE MODAL COMPOSITIONS, MINERALOGICAL ASSEMBLAGES, METAMORPHIC METAMORPHIC ZONES OF SCHISTS IN SE LOKOJA

Rock types	1	2	3	4
Quartz	30	20	20	30
Plagioclase	10	5	5	15
K-felspar			12	20
Biotite	35	20	25	2
Muscovite	6	9	10	32
Chlorite	15	10	5	
Staurolite		30		
Cordierite			10	
Garnet	2	2	5	
Tourmaline	2	4	6	1
Clinozoisite	-		2	1
Mineralogical Assemblages	Qtz-plag-musc biot-garn	Qtz-plag-musc-biot-garn-staur	Qtz-plag-musc biot-garn-cord-ksp	Qtz-plag-Musc biot-garn-Ksp
Metamorphic zones	Garnet	Staurolite	Cordierite	Cordierite

1: Average of 15 samples of Quartz-muscovite-biotite-garnet schist
2: Average of 40 samples of Staurolite garnet schist
Average of 40 samples of Cordierite-garnet schist
4: Average of 12 samples of Quartz-muscovite schist

Granites which belong to the Older Granites series (Pan-African) occur in the study area. They are foliated in N-S to NE-SW direction and spatially in association with migmatites. Pink, euhedral microcline porphyroblasts up to 4 x 5 cm in size occur in the granites. The granites are criss-crossed by pegmatite dykes. Olivine gabbro is the only basic intrusion recognized in southeast Lokoja. It is dark in colour, coarse-grained and equigranular. It consists of olivine, pyroxenes, plagioclase and opaque oxides.

GEOCHEMISTRY

Major and trace element concentrations of schists in southeast Lokoja were obtained by x-ray fluorescence analysis at Geochemistry Laboratory, Technical University of Berlin following the method outlined by Norrish and Hutton (1969). The results are given in Tables 2 and 3. Chemical composition of rocks similar to those of the schists in Lokoja area are also given in Table 4 for the purpose of comparison.

MAJOR ELEMENTS:

Schists in southeast Lokoja are characterised by high silica content (55-76%) as reflected in their modal composition which shows a quartz content of 20-30%. The Niggli norm values for si and q are consequently, high (Table 2) confirming the siliceous nature of these rocks. The Al_2O_3 content (10-22%) is moderate to high and in Table 2 it is observed that Niggli normative al is greater in most samples than Niggli normative (alk + c) values. According to Barth (1962) rocks having such characteristics contain excess of al which is supposed to combine with an equal amount of si resulting in the formation of sillimanite. Though no sillimanite has been identified in Lokoja schists, probably because the metamorphic grade was not high enough for its crystallization, the presence of staurolite and cordierite confirms the aluminium excess nature of these rocks. Most schists in Lokoja area have corundum in their CIPW norm and have Al_2O_3: ($Na_2O+K_2O+2CaO$) greater than 1 which is characteristic of pelites. The TiO_2 content of the schists is however, high (0.52-2.07) compared to the values expected of clay-rich sediments. Only samples 4, 7, 8, 9 and 18 have TiO_2/Al_2O_3 ratios approximately equal to 0.040 which according to Goldschmidt (1954) is the value for clays. Such high values for TiO_2/Al_2O_3 ratios in aluminium-rich metamorphic rocks have been interpreted as indicative of sediments contaminated by a basic to intermediate volcanic component (Spears and Kanaris-Sotirious 1976). The compositions of Lokoja schists correspond to values given for continental or near-shore argillaceous and arenaceous sediments (Migdisov 1960).

CaO and MgO of the schists are normal for metasediments but there is no consistency in the K_2O/Na_2O ratios. Some samples of the same rock type have K_2O greater than Na_2O which is characteristic of metamorphosed argillaceous rocks (pelites and semi-pelites). Other samples of the same rock type have however, K_2O/Na_2O ratios less than one which is characteristic of Greywackes. A ratio of K_2O/Na_2O less than unity is also characteristic of volcanogenic greywackes (Taylor and Mclennan 1985). The variation of K_2O/Na_2O ratios in metasediments has been explained by Pettijohn 957) as due to: (i) the mixed nature or association of two compositionally different lithologic units e.g. shale-greywacke sequence as the parent rock, (ii) facies change and (iii) addition of materials through metasomatism. For the Lokoja schists the variation in K_2O/Na_2O ratio in samples of the same rock type is pronounced and is most likely due to the shale-greywacke lithologic sequence of the original pre-metamorphic rocks. However, only samples 2, 6 and 7 have Al_2O_3/Na_2O ratio of 4.8 suggested as an average value for greywackes by Pettijohn (1957). The Al_2O_3/Na_2O ratio is a maturity index for sediment. Mature sediments have values of 10 or more. Most samples of Lokoja schists have values less than 10 indicating that they were mostly immature sediments.

Compared with other analyzed metasediments from other parts of the world, the major element composition of Lokoja schists except for their higher values of SiO_2, TiO_2 and Al_2O_3 of some of them are similar to shales and greywackes. For instance, samples 2, 4, 5, 7, 8, 11, 15, and 17 compare well in their major element content with

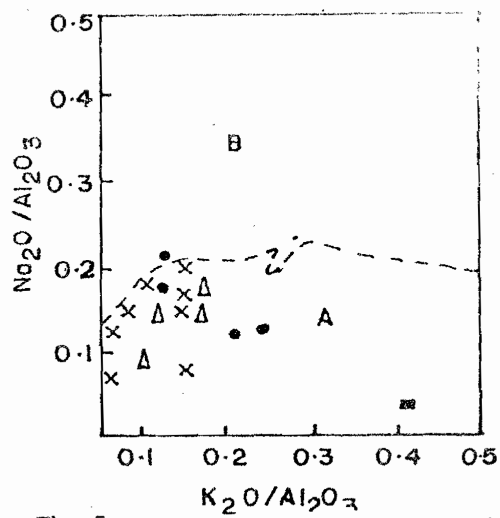

Fig. 2: Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot for Lokoja schists (indicated fields after garrels and Mackenzie 1971).

A ..... Sedimentary & Metasedimentary rocks.
B ..... Igneous rocks
- - - Boundary between A & B
X = SGS , ● = QMBS
Δ = CGS , ■ = QMS

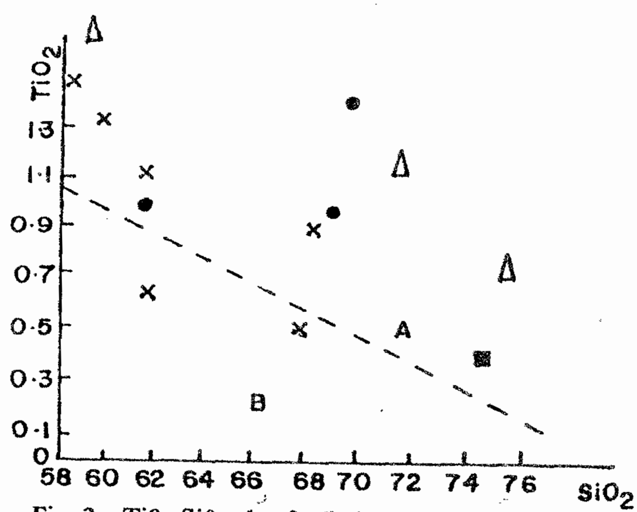

Fig. 3: TiO_2-SiO_2 plot for Lokoja schists (indicated field after Tarney 1976).

A = Sedimentary field
B = Igneous field
- - - = Boundary between A & B
other Symbols as in Fig.2

TABLE 2: MAJOR ELEMENT COMPOSITION AND NIGGLI VALUES OF SCHISTS IN SE LOKOJA

Samples:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO2	69.81	62.26	70.71	57.88	62.89	69.57	62.1	56.8	68.13	62.24	58	60.84	61.34	76.55	63.13	73.78	61.92	75.04
TiO2	1	0.95	1.43	0.81	1.05	0.96	0.67	0.99	0.52	1.13	1.57	1.39	1.7	0.81	0.91	1.17	2.07	0.47
Al2O3	13.99	16.13	11.58	20.66	17.02	14.23	16.4	20.44	14.44	18.09	22.08	19.58	20.99	10.76	17.19	11.29	18.45	13.47
Fe2O3*	5.99	7.57	6.44	6.98	7.54	5.71	5.05	9.31	6.14	8.17	5.45	5.6	7.9	4.49	7.06	4.3	7.08	3.01
MnO	0.12	0.17	0.06	0.07	0.15	0.12	0.08	0.11	0.07	0.11	0.13	0.13	0.09	0.07	0.16	0.04	0.07	0.01
MgO	2.97	3.61	3.7	3.54	4.06	2.55	2.64	3.74	2.7	3.34	3.25	2.5	2.01	1.57	3.23	2.2	3.56	0.57
CaO	1.07	1.77	1	3	1.44	1.72	4.19	1.32	3.14	1.3	3.69	3.31	2.02	1.68	1.8	2.74	2.23	0.17
Na2O	1.63	3.45	1.41	3.67	2.86	2.87	3.42	1.57	2.17	2.49	2.56	3.28	1.45	1.49	2.46	1.84	1.66	0.34
K2O	3.27	2.79	2.6	2.76	2.49	2.03	3.51	3.3	2.29	1.83	2.18	2.2	1.32	2.06	2.66	2.12	2.02	5.59
P2O5	0.18	0.24	0.07	0.18	0.04	0.16	0.3	0.23	0.08	0.08	0.1	0.04	0.06	0.13	0.27	0.07	0.08	0.1
H2O	0.2	0.13	0.1	0.08	0.18	0.13	0.23	0.21	0.2	0.16	0.2	0.12	0.2	0.1	0.11	0.05	0.08	0.1
LOI	1.51	0.91	1.1	0.62	1.45	1.01	0.41	1.15	0.69	1.24	1.03	1.18	1.96	0.71	0.83	0.49	1.1	1.62
Total	101.74	99.98	100.2	100.25	101.17	101.06	99	99.17	100.57	100.18	100.24	100.17	101.11	100.42	99.81	100.69	100.24	100.49
Niggli Values																		
al	41	38	36	48	40	41	38	45	39	45	47	45	54	42	42	38	45	56
fm	34	33	42	31	36	30	23	35	29	34	25	23	26	27	32	28	33	14
c	6	8	6	13	6	9	18	6	15	6	14	14	9	12	8	16	10	2
alk	18	21	16	21	17	20	21	14	16	15	14	18	10	19	17	18	12	28
si	352	249	372	227	252	339	241	215	311	261	208	237	270	510	264	414	255	535
k	0.57	0.35	0.55	0.34	0.36	0.32	0.4	0.58	0.4	0.33	0.36	0.31	0.38	0.48	0.41	0.43	0.44	0.92
mg	0.65	0.65	0.69	0.66	0.68	0.63	0.67	0.61	0.64	0.61	0.69	0.63	0.5	0.57	0.64	0.66	0.66	0.42
q	180	65	208	43	84	159	57	59	147	101	52	65	130	334	96	242	107	323

*Total Fe as Fe2O3

1-4^ Quartz muscovite biotite garnet schist; 5-13= Staurolite/garnet/schist; 14-17= Cordierite garnet schist; 18= Quartz muscovite schist

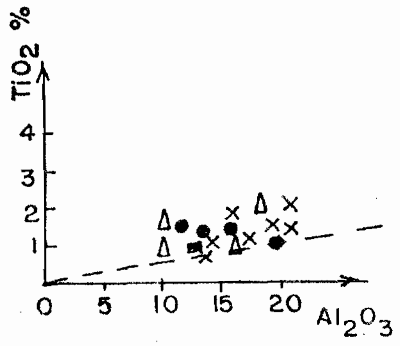

Fig. 4: Plot of TiO_2 versus Al_2O_3 ratio for clay after Godschmidt 1954).

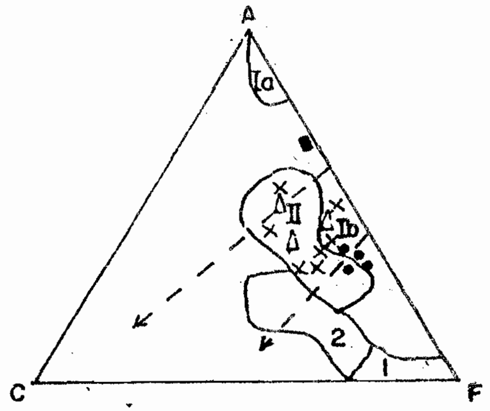

Fig. 5: Plot of the Lokoja schists on the ACF diagram of Winkler (1967) (la: Al-rich clays and shales; lb: clays and shales either free of carbonate or containing up to 30% carbonate, between arrows marks containing 35-65 carbonate; 11: greywackes; 1: ultrabasic rocks; 2: basaltic and andesitic rocks).

the pelitic schists analyzed by Shaw (1956), Clark (1924) and Ferry (1982). The quartz-muscovite schist (sample 18) is similar in composition to the siliceous shale of Pettijohn (1975) (Table 4). Other samples of Lokoja schists are comparable in composition to the greywackes analyzed by condie (1967), Pettijohn (1975) and Scott and Donnelly (1986). The mixed nature of the pre-metamorphic lithology of Lokoja schists probably contributed to the complexity in their chemical compositions.

TRACE ELEMENTS: As in major elements, there are variations in trace element contents of the same unit of Lokoja schists again reflecting the mixed nature of the pre-metamorphic lithology. Cr is relatively high up to 100 ppm in most samples (Table 3).Zr, Ba andY are all within ranges expected in metasediments (Taylor 1965). The Rb content is higher in all samples than values of 60 and 30 ppm quoted for shales and greywackes respectively (Taylor 1965). They are closer to the value of 110 ppm given for high-ca granite (Turekian and Wedepohl 1963). The Sr values are higher than values given for normal and differentiated granites by El Bouselly and El Sokkary (1975) but close to that of high-Ca granites. This suggests that the greywackes in southeast Lokoja were probably derived from high-Ca granites (cf. condie et al. 1970). Some of the Sm/Nd ratios are close to the values listed for granites and metamafics by Wedepohl (1991). The K/Ba and K/Rb of some Lokoja schists (Table 3) fall within the range reported for metasediments in the Oban massif of southeast Nigeria and in Yaounde area of Cameroon (Ekwueme 1990; Nzenti et al. 1988). Some samples have their Zr, Nb and Y contents higher than those of active or passive margin greywackes (Bhatia and Crook 1986). The Cr, Ni, V, Rb and Zn contents in some Lokoja schists are close to values reported for the greywackes in Wyoming and Dhawar supergroup (Condie 1967; Argast and Donnelly 1986). The similarity in the values of Sr, K/Rb and Sm/Nd of some of the schists in Lokoja to the granitic rocks of quartz-monzonite and granodiorite compositions suggests that the greywackes could have been derived through reworking of rocks of granitic composition.

DISCUSSION

Ferry (1982) demonstrated that with the exception of carbonate rocks the concept of isochemical metamorphism founded by Shaw (1956) and corroborated by Yardley (1977) remain valid for sedimentary rocks undergoing metamorphism. He concluded from comparative geochemical studies that except for the loss of volatile compounds (mostly H_2O and CO_2) that relative to Al reference frame, there is no positive evidence for mobility of Fe, Mg, Ti, Si, Ca, K and Na during the metamorphism of pelitic rocks. This

TABLE 3: TRACE ELEMENT COMPOSITION (PPM) OF SCHISTS IN SE LOKOJA

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
As	bdl	1	bdl	1	bdl	4	3	4	bdl	bdl	3	4	3	18	15	17	15	7
Ba	901	404	900	400	665	311	457	477	900	666	460	311	400	337	587	339	579	729
Ce	41	36	43	37	36	27	44	40	40	37	44	27	47	89	57	89	60	96
Co	103	67	88	67	90	51	59	58	107	90	58	52	57	93	87	93	87	88
Cr	129	106	132	107	105	127	84	84	129	105	84	126	87	61	103	65	103	1
Cu	27	25	27	27	27	81	80	81	23	27	77	82	80	23	19	23	20	13
Ga	13	12	15	12	20	11	13	10	13	21	10	12	14	11	14	10	14	13
La	bdl	bdl	bdl	bdl	bdl	bdl	22	22	bdl	bdl	21	bdl	23	bdl	bdl	bdl	bdl	17
Mo	5	7	5	7	10	5	3	3	5	10	3	7	3	bdl	5	bdl	6	6
Nb	9	9	9	9	9	7	7	9	9	9	10	6	7	11	7	12	7	19
Nd	18	17	18	17	15	15	20	20	20	17	21	15	20	34	26	35	26	37
Ni	45	64	45	66	75	29	66	71	47	73	73	31	67	24	53	24	56	4
Pb	5	23	6	22	10	15	15	20	4	11	19	15	16	15	15	15	17	8
Pr	27	15	25	15	21	25	27	30	27	21	32	27	24	29	21	27	20	41
Rb	97	96	100	97	80	71	76	77	100	81	80	71	74	73	86	66	87	229
Sc	bdl	bdl	bdl	bdl	bdl	bdl	18	18	bdl	bdl	17	bdl	18	bdl	bdl	bdl	bdl	bdl
Sm	4	3	4	3	3	3	5	5	5	4	4	3	5	6	4	7	3	6
Sr	99	207	118	210	197	175	99	95	117	196	198	177	167	129	204	131	206	49
Th	3	3	4	3	1	5	5	5	3	1	5	4	5	5	1	5	1	35
U	2	2	2	2	3	4	2	3	2	3	3	4	2	3	3	3	3	4
V	111	119	111	121	153	88	87	88	113	156	87	90	87	71	143	73	144	10
Y	33	43	34	42	43	33	33	32	31	43	33	33	33	29	35	27	37	61
Zn	72	46	73	46	112	71	86	81	72	111	81	67	87	48	133	53	136	15
Zr	235	183	233	187	187	222	153	107	235	187	107	221	157	284	168	278	160	237
Sm/Nd	0.22	0.192	0.22	0.192	0.23	0.182	0.233	0.233	0.233	0.24	0.193	0.182	0.23	0.176	0.154	0.189	0.128	0.164
K/Ba	278	241	216	236	258	237	383	356	190	187	226	257	148	234	257	267	193	203
Rb/Sr	30	57	24	57	61	54	64	57	21	23	39	59	27	51	38	52	29	64
	0.82	0.465	0.85	0.46	0.407	0.403	0.765	0.812	0.86	0.415	0.404	0.4	0.44	0.567	0.422	0.505	0.424	4.712

1-4= Quartz muscovite biotite garnet schist; 5-13= Staurolite garnet schist; 14-17= Cordierite garnet schist; 18= Quartz muscovite schist.
<bdl=below detection limit

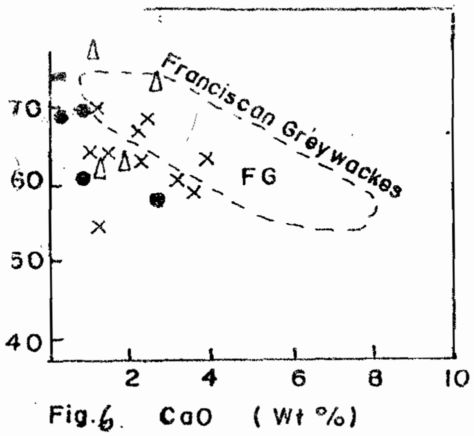

Fig. 6: SiO_2 CaO variation diagram for Lokoja schists (field of Franciscan greywackes after Brown et al. 1979).

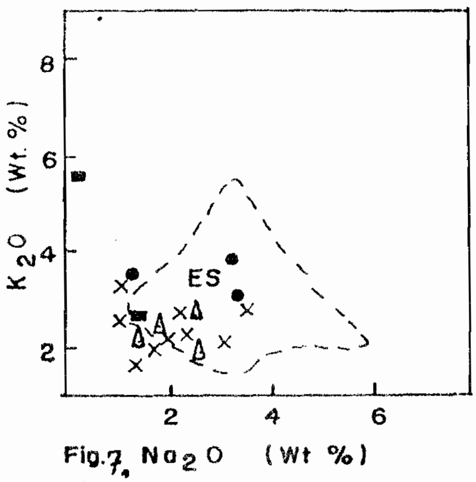

Fig. 7: Plot of Lokoja schists on K_2O versus Na_2O diagram (E.S.=eugeosynclinal sandstone field of Middleton 1960).

finding therefore, permits the use of major and trace elements discrimination diagrams in interpreting the petrogenesis of Lokoja schists.

The chemical data for Lokoja schists were plotted in the Na_2O/Al_2O_3 versus K_2O/Al_2O_3 diagram (Fig. 2) used by Garrels and Mackenzie (1971) to discriminate between metasedimentary rocks and their igneous counterparts. The schists of southeast Lokoja with the exception of two samples which plot at the boundary fall within the metasedimentary field. In a similar manner, most of the samples fall within the sedimentary field in the TiO_2-SiO_2 diagram (Fig. 3) of Tarney (1976). TiO_2 is closely correlated to Al_2O_3 (Fig. 4) but anti-correlated with SiO_2 (Table 2) indicating that these rocks contain significant amount of clay (cf. Nzenti et al. 1988).

On the ACF diagram of Winkler (1967) the Lokoja schists plot in the fields of shale and grewacke (Fig. 5). As a further evidence of the mixed nature of these sediments, it can be observed that samples of same rock unit plot both in the pelite and grewacke fields. The chemical data for these schists were also plotted in the SiO_2 vs. CaO variation diagram (Fig. 6). Most samples plot outside the field of Franciscan grewackesof Brown et al. (1979). Majority of the samples with the exception of those with pelitic composition in sensu stricto plot in the field of eugeosynclinal sandstones of Middleton (1960) (Fig. 7). Eugeosynclinal sandstones are in fact the grewackes of Pettijohn (1957).

It appears to be a consensus that metagrewackes are derived from igneous rocks of basic to intermediate composition (Condie 1967; Condie et al. 1970; Argast and Donnelly 1986. Condie (1967) wrote that the composition of the Wyoming greywackes indicate a source area composed chiefly of quartz-rich metasedimentary rocks with lesser amounts of granitic rock. From the chemical composition of his greywackes, Condie (1967) concluded that the source area was predominalty quartz diorite to granodiorite in composition. He interpreted the relatively large amounts of Fe, Mg and Ni as well as a high Mg:Fe ratio as indicative of a minor mafic component in the source area. In a similar manner, condie et al. (1970) on the basis of a high concentration of Ni in the metagreywackes of Fig Tree Group of South Africa suggested that the rocks were derived from mafic/ultramafic provenance. Argast and Donnelly (1986) wrote that the metagreywackes in the Upper Dhawar Supergroup India were derived predominantly from Peninsular tonalitic gneisses although mafic/ultramafic volcanic debris from unidentified sources is also important.

Table 4: Chemical composition of rocks similar to schists in SE Lokoja

Sample	A	B	C	D	E	F	G	H	I	J	K
SiO2	59.93	63.51	57.09	84.14	64.43	70.5	66.7	66.88	59.8	67.2	63.7
TiO2	0.85	0.79	0.88	0.22	0.62	0.47	0.6	0.57	0.55	0.5	0.72
Al2O3	16.62	17.35	19.39	5.79	15.48	10.8	13.5	15.66	12.9	15.5	12.3
Fe2O3	3.03	2	8.43	1.21	6.54	6.22	1.6	4.21	6.56	4.2	11
FeO	3.18	4.71	-	-	-	-	3.5	-	-	-	-
MnO	-	-	0.17	-	0.07	0.07	0.1	-	-	-	-
MgO	2.63	2.31	4.87	0.41	3.12	1.78	2.1	1.57	4.44	1.6	-
CaO	2.18	1.24	1.26	0.13	2.22	1.99	2.5	3.56	3.18	3.5	0.13
Na20	1.73	1.96	1.32	0.99	3.74	3.59	2.9	3.84	2.83	3.8	0.81
K20	3 54	3.35	4.48	0.5	2.44	1	2	3.07	2.23	3	1.7
P205	-	-	0.12	-	-	0.1	0.2	-	-	-	-
H20	4.34	2.42	-	5.56	-	-	3	-	-	-	-
CO2	2.31	0.22	-	-	-	-	1.2	-	-	-	-
LOI	-	-	1.73	-	-	-	-	-	-	-	-
Ni	-	-	-	-	91	55	-	-	160	15	400
Rb	-	-	-	-	88	52	-	-	90	110	83
Sr	-	-	-	-	424	129	-	-	354	440	16
Zr	-	-	-	-	196	14	-	-	184	140	112
Rb/Sr	-	-	-	-	0.23	-	-	-	0.27	0.25	5.19
K/Rb	-	-	-	-	2.3	-	-	-	204	229	170
Na:K	-	-	-	-	1.4	-	-	1.1	-	-	-
Al203/Na2	-	-	-	-	4.2	-	-	-	4.6	4.1	-

A= Average of Shale (Shaw 1956); B= high-grade pelitic rock (Shaw 1956); Pelitic schist (Ferry 1982), D= Siliceous shale (Pettijohn 1975); E= Average of Wyoming Precambrian grewackes (Condie 1967) F= Metagrewackes (Argast and Donnelly 1986); G= Precambrian grewacke (Pettijohn 1975); H= Average granodiorite (Nockolds 1954); I= Average Belvue grewacke (Condie et al. 1970(J= High-Ca granite (Turekian and Wedepohl 1961); K= Sheba shales (Condie et al.1970)

The shale-greywacke sequence of rocks that were metamorphosed to form the Lokoja schists included greywackes comparable in composition to those of Wyoming and Dhawar Supergroup. The major difference is the higher SiO_2 and Al_2O_3 content in the Lokoja schists. This is due probably to a higher proportion of clay in the Lokoja sediments. The Ti, Fe, Cr, Na_2O/K_2O, and Ni contents of the Lokoja metagreywackes are close to those of Wyoming and Dhawar (Tables 3 and 4). Hence, like in Wyoming and Dhawar areas it is possible that the sialic fractions of the sediments have been physically mixed with mafic to intermediate sedimentary debris. To test this hypothesis the chemical data for the schists in Lokoja area were plotted in the CaO-Na_2O-K_2O diagram of condie (1967) (Fig. 8). Most of the schists having the composition of greywackes in sensu stricto plot in the field of granodiorite. Only one sample of cordierite-garnet schist plots in the field of granite and quartz monzonite. All other samples (not having the composition of greywackes but pelites and semi-pelites) do not plot in any specific field in the diagram (Tables 2, 3 and Fig. 8). The average composition of granodiorite given by Nockolds (1954) is included in Table 4. It compares well with Lokoja metagreywackes.

Caen-Vachette and Ekwueme (1988) obtained Rb-Sr isochron ages for the schists in southeast Lokoja. As can be seen in Figures 9 and 10, the staurolite schists produced five isochrons which define ages of 1340+76 Ma (Io=0.70203) and 679±18 Ma (Io=0.7066) whereas the cordierite-garnet schist produced two isochrons giving ages of 1005±35 Ma (Io=0.70425) and 696±19 Ma (Io=0.70621). Because of the similarity in the initial $^{87}Sr/^{86}Sr$ ratios and large errors in the 1304±113 Ma and

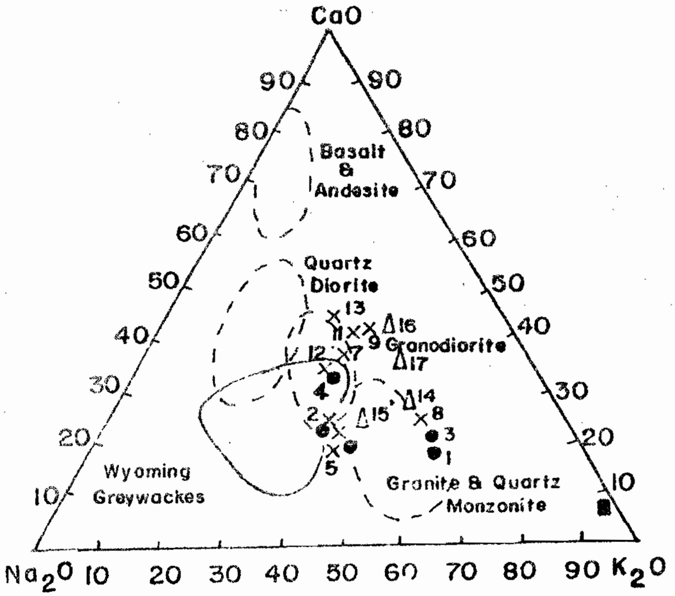

Fig. 8: CaO-Na_2O-K_2O diagram for Lokoja schists (fields indicated after Condie 1967).

1194±76 Ma ages, Caen-Vachette and Ekwueme (1988) grouped the points defining their isochrons to obtain a Rb/Sr whole-rock errorchron which yielded an age of 1315±72 Ma with initial $^{87}Sr/^{86}$ ratio of 0.70160±0.00060 and MSWD of 10.7. The interpretation given by these authors to the ages was that the schists in Lokoja area have suffered at least two episodes of metamorphism the first possibly during the Kibaran orogeny (1315±72 Ma) and the last during the Pan African age argues for older materials affected by this metamorphism. Ages similar to those of Lokoja schists had earlier been reported from schist belts in NW Nigeria which is not far from the study area (Grant et al. 1972; Ogezi 1977; Fitches et al. 1985). It was therefore, suggested that southeast Lokoja could be a southward prolongation of the Kibaran metasediments in northern Nigeria (Kushaka metasedimentary belt) which has similar petrologic, structural and isotopic characteristics. The metasediments in Lokoja could therefore be a part of a Kibaran basin which according to Fitches et al. (1985) are belts of quietly accumulating fine clastic sediments that denote slow steady subsidence uninterrupted by major tectonic activity. Like in other schist belts of the Nigerian basement the Lokoja schists were deposited in eugeosynclinal basin bounded by NE-SW trending fractures. The schists possibly belong to intracratonic extensional basins proposed by Ogezi (1977) and supported by Turner (1983).

The source of the greywackes that were metamorphosed to form the Lokoja schists could have been the gneisses in the area whose mineralogical composition is similar to orthogneisses. Another possible provenance for the metagreywackes are granodiorite gneisses in Okene area which is close (about 100 km) to the study area. Caen-Vachette and Umeji (1988) have obtained Rb-Sr isochron ages of 2202±31 Ma and 1683±56 Ma from the gneisses in Itakpe near Okene SW Nigeria. It is therefore, possible that the extensional basins of which Lokoja area is a part could have been filled since 1680 Ma, a period of destabilization for Burkinian event (Lemoine et al. 1985) recorded in the gneisses of Itakpe area. Though amphibolites have not been mapped in Lokoja, mafic rocks occur in Okene and also in the nearby basement of NW Nigeria. The mixture of the mafic debris from these sources and granodiorites could have contributed to high content of some elements such as Ti in the provenance of the metasediments in the area.

CONCLUSION

The chemical composition of schists in southeast Lokoja reflects the mixed lithology of its provenance. These rocks which were deposited in an intracratonic basin and metamorphosed possibly between 1300 and 690 Ma ago have composition of metapelites and metagreywackes. The schists are products of the metamorphism of immature sediments. This is contrary to the claim of Affaton et al. (1991, p.116) that they were derived from mature sediments. The low initial $^{87}Sr/^{86}Sr$ ratios given by the Kibaran isochron obtained from the staurolite garnet schist by Caen-Vachette and Ekwueme (1988) could be reflective of immaturity of these sediments and the mafic debris associated with the granodiorite provenance (cf. Imeokparia and Emofurieta 1991; Condie et al. 1970). The presence of such mafic components is indicated by the high TiO2, Cr.

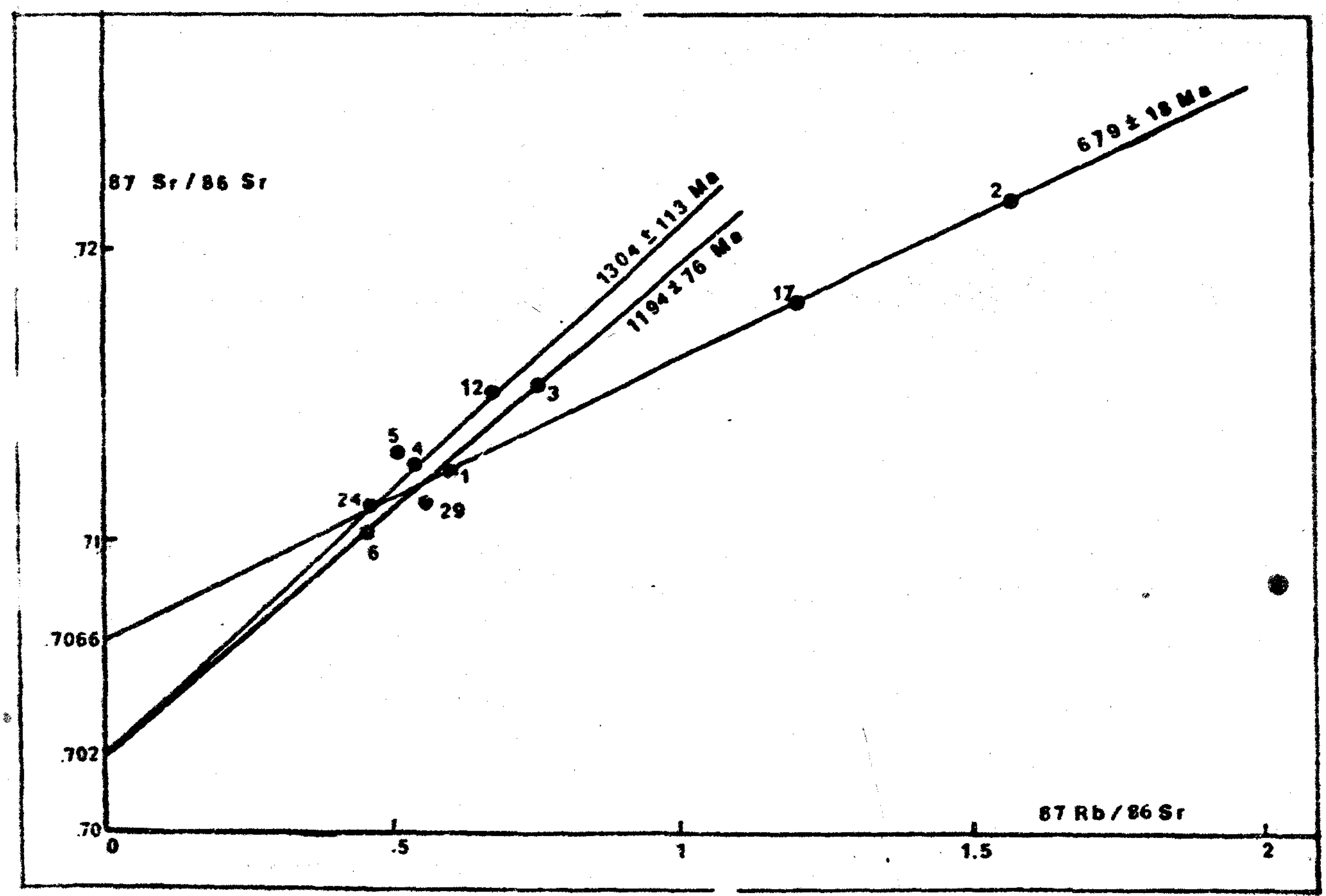

Fig. 9: **Rb-Sr isochron diagram for the staurolite garnet schist of southeast Lokoja (after Caen-Vachette and Ekwueme 1988).**

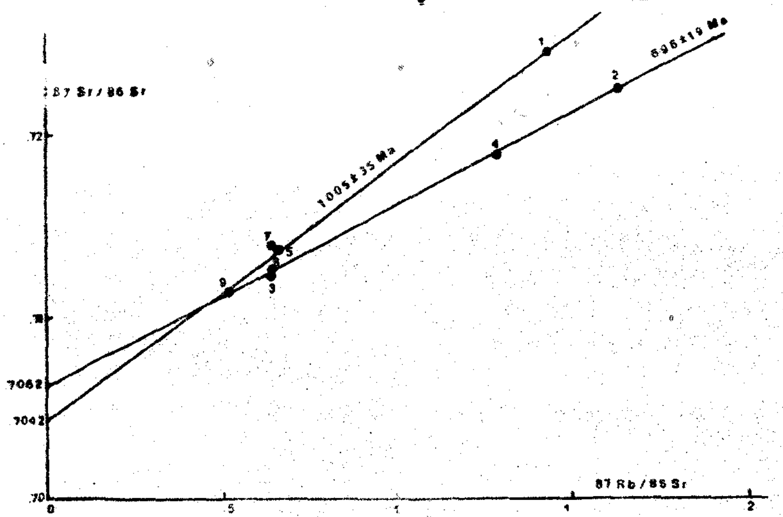

Fig. 10: Rb-Sr isochron diagram for the co rdierite-garnet schist of southeast Lokoja (after Caen-Vachette and Ekwueme 1988).

Na_2O/K_2O, Sm/Nd in the metagreywackes of Lokoja area.

Shale-greywacke sequence has been reported as the parent rocks of metasediments in various parts of Nigerian basement (Rahaman 1976; Ekwueme and Onyeagocha 1986; Ekwueme 1990; Imeokparia and Emofurieta 1991). It appears therefore, that sediment deposition in Nigerian sector of Pan-African mobile belt were brought about by turbidity current generation at different sites of submarine slope or on different sides of partially enclosed basins (cf. Condie 1967).

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