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GEOCHEMISTRY OF CRYSTALLINE BASEMENT ROCKS SW UGEP, NIGERIA

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ABSTRACT

Geochemical data on low-grade metasedimentary phyllites and schists of SW Ugep show that they were derived from predominantly pelitic parent rocks. They form a supracrustal cover on an orthogneiss of granitic composition. The metasediments are enriched in SiO_2, Al_2O_3 and Zr but improverished in Ni. Intrusion of pegmatite was accompanied by boron metasomatism and tourmalinization. This, as well as, the unconformable contact of the basement rocks with a calcareous sandstone of Cretaceous age, may have raised the Na_2O, SiO_2, CaO and MgO contents of some outcrops. The TiO_2, Al_2O_3 values (0.033 to 0.144) confirm that the metasediments were derived from a parent rock rich in quartz and clay. A dark- coloured garnet-mica schist has a composition of metagreywacke.

The first episode of calc-alkaline magmatism in the area shows the emplacement of the peraluminous orthogneiss whilst the last episode indicates the intrusion of the granodiorite. Rocks in SW Ugep area correlate well in both petrography and geochemistry with those of Uwet area in the south. This confirms earlier studies, which indicated that metasedimentary schists occur in the Oban massif of southeast Nigeria and that metamorphism in the area increased in grade from upper greenschist facies in the west to upper amphibolite and locally granulite facies in the east.

Key Words: Ugep, metasediments, orthogneiss, metasomatism.

INTRODUCTION

The Nigerian basement located in a mobile belt lying between the West African and Congo cratons consist dominantly of migmatites, gneisses, schists and intrusive rocks of acidic to ultrabasic composition (Oyawoye 1972).

The schists form supracrustal cover on the migmatites and gneisses and their location in elongate, tight, steeply isoclinal belts trending N-S has been considered crucial to the understanding of the geodynamic evolution of Togo- Benin-Nigerian shield (Hubbard 1975; Odeyemi 1982; Ajibade and Wright 1989; Affaton et al. 1991)

The chemical compositions of the schists, their associated amphibolites and ultrabasic rocks collectively termed "metasedimentary series" (Klemm et al. 1984) are of petrologic interest because they are the basis for the suggestion that the schist belts are similar to typical greenstone belts (Wright and McCurry 1970; Hubbard 1975; Klemm et al. 1984; Ige and Asubiojo 1991). According to Klemm et al. (1984), a typical schist belt in the SW Nigerian basement consists of an amphibolite complex and metasedimentary sequence. The amphibolite complex consists of pyroxenite, metagranodiorite and amphibolite whilst the metasedimentary sequence consists of gneisses, migmatites and schists intruded by granitic plutons. In NW Nigeria, Wright and McCurry (1970) indicated the sequence as greenschist to lower amphibolite facies metasediments with well- developed schistosity occupying elongate, tight to isoclinal synformal remnants within the high-grade banded gneisses and migmatites which also include homogeneous

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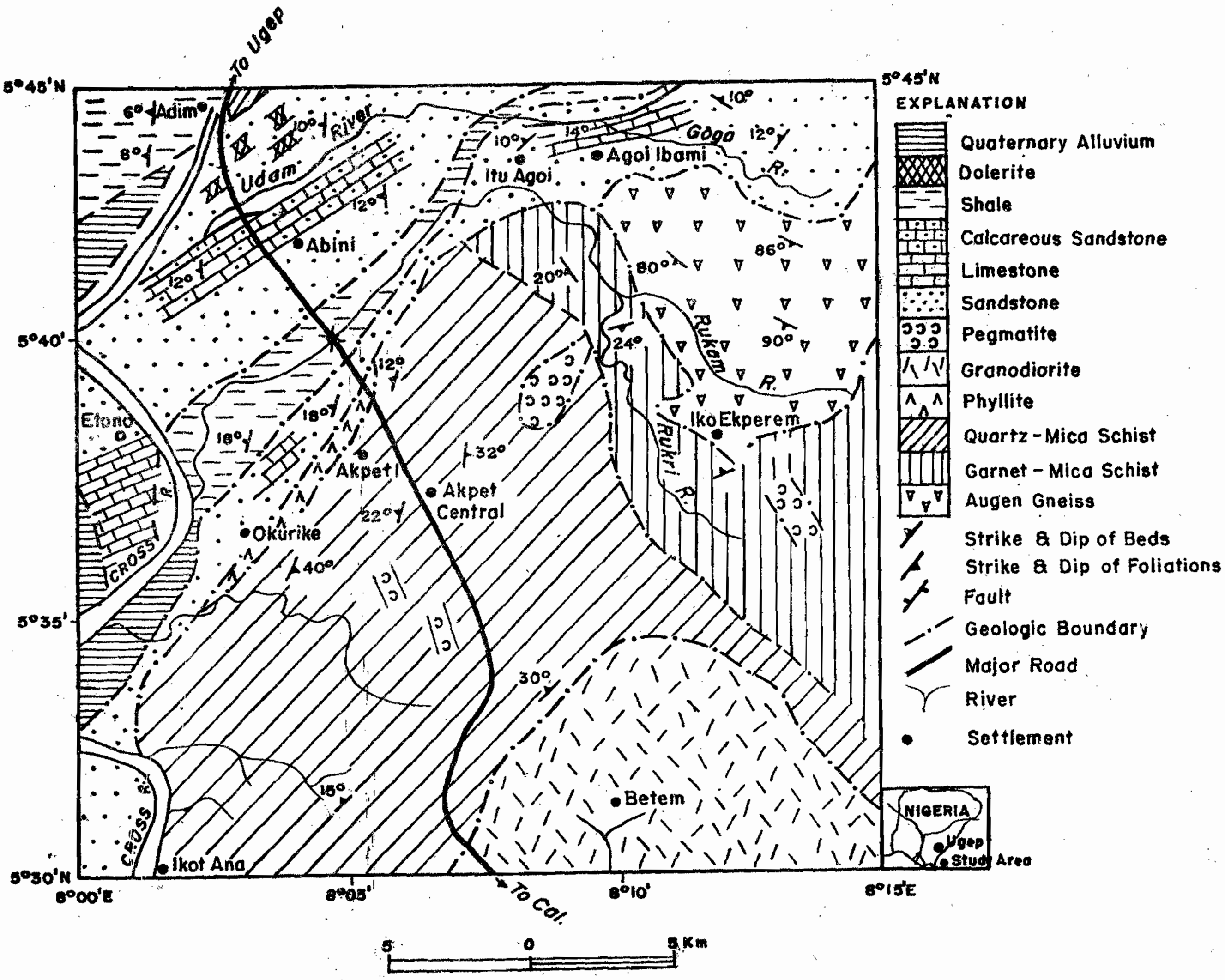

Fig. 1: Geological map of southwest Ugep southeastern Nigeria (after Ekwueme 1990a)

granitic bodies and show indications of extensive mobilization and potash metasomatism. These authors pointed out that the main difference between the schist belt and the greenstone belt is the preponderance of the metasediments over their metavolcanics. Until recently, it was thought that schists and the schist belts are restricted to SW and NW Nigerian basement and that only granitic rocks and gneisses occur in the eastern part (Oyawoye 1972). However, Rahman et al. (1981) reported the occurrence of schists in parts of the Oban massif of southeast Nigeria. Ekwueme and Onyeagocha (1985) reported more schist occurrences and also discussed the metamorphism of the Uwet area. They located isograds, which indicate that the area was affected by Barrovian type metamorphism, which increased in grade from middle greenschist in the west to uppermost amphibolite facies in the east. Ekwueme and Onyeagocha (1986) reported on the geochemistry of these rocks including the schists in Uwet area.

Southeast Ugep is situated in the north of Uwet area. Ekwueme (1990a) mapped phyllites, schists, gneisses, pegmatites and granodiorites in the area and correlated these rocks to some rocks in the Uwet area in the south. Schists here are of a low-grade type, are similar to those of typical schist belts in NW and SW Nigeria. Amphibolite is however, not exposed in the area. Odigi and Oti (1990) have however, reported occurrences of amphibolites in parts of NW Oban, which fall within the Nigerian topographical sheet 314 entitled "Ugep SW". The authors also delineated chlorite, biotite, almandine and amphibolite zones in the area. Furthermore, they recognized a progressive metamorphic sequence trending south to north in contradiction to the west to east trend observed by Ekwueme and Onyeagocha (1985)

In this contribution, the author discusses the chemical compositions of crystalline basement rocks of southwest Ugep with a view to identifying the exact lithologic units in the area and throwing light on their petrogenesis.

FIELD RELATIONSHIP AND PETROGRAPHY

The Nigerian survey topographic sheet 314 (Ugep SW) covers an area lying between longitudes 8^0 to 8^0 15'E and latitudes 5^0 30' to 5^0 45'N. The Precambrian crystalline and Cretaceous sedimentary rocks in the area have been studied by Ekwueme (1987, 1990a). The area termed NW Oban massif which was discussed by Odigi and Oti (1990) is a part of SW Ugep area and lies between 8^0 and 8^0 15E and $5^0 35^1$ and 5^0 45^1N. Studies carried out on the Precambrian rocks in this area so far are field – oriented and the interpretations of the rock genesis were based only on field and petrographic data.

Ekwueme (1990a) recognized the following lithologic units in SW Ugep: phyllites, quartz-mica schists, granodiorites (Fig. 1). Phyllites and schists constitute the low-grade metamorphic rocks in the area. They are generally fine-grained and foliated. The foliations dip moderately (12 –14^0) dominantly eastward and westward (89^0 and 270^0) with minor variation to the northwest (290-320^0). Elongate quartz crystals define a lineation of the schist. The lineation is parallel to the foliation and plunges 24-30^0. The schists have been intruded by pegmatites and rods of tourmaline also define a

Table 1: AVERAGE MODAL COMPOSITIONS, MINERALOGICAL ASSEMBLAGES AND METAMORHIC ZONES OF BASEMENT ROCKS OF SW UGEP (After Ekwueme 1990)

Mineral	PHY	QMS	GMS	AG	GD
Quartz	20	20	35	20	20
Plagioclase	7	10	8	20	24
K-Feldspar	-	-	-	20	12
Biotite	5	30	20	15	22
Muscovite	60	22	21	-	7
Garnet	-	-	10	-	-
Hornblende	-	-	-	14	10
Chlorite	8	5	2	3	-
Epidote	-	-	4	5	2
Tourmaline	tr	13	tr	tr	tr
Sphene	-	-	-	2	3
Apatite	-	-	-	1	-
Mineralogical Assemblages	Qtz-Alb-Chl-Musc-Biot	Qtz-Alb-Chl-Musc-biot	Qtz-Alb-Musc-Biot-garnet	Qtz-Olig-Biot Hornb-Epid-Ksp	
Metamorphic Zones	Biotite	Biotite	Garnet	Oligoclase	

PHY: Average of 16 samples of Phyllite; QMS: Averages of 25 samples of Quartz-Mica schists;
GMS: Average of 32 samples of garnet-mica schist; AG: Average of 40 samples of Augen gneiss;
GD: Average of 12 samples of Granodiorite; tr. : traces

lineation in these rocks. Faulting of the schists occurred near Ikot Ekperem. The modal composition of the rocks in SW Ugep is shown as Table 1. Phyllosilicates comprising chlorite, biotite and muscovite make up about 50% of the modes of the schists and phyllites. The preponderance of biotite and garnet in some outcrops of the garnet-mica schist gives them a dark colour and possibly led to their misidentification as amphibolites by Odigi and Oti (1990)

The gneiss is coarse-grained and the predominant foliation and lineation trend is NW – SE. The foliation is defined by alternation of weakly defined mafic and light-coloured bands whereas the lineation was formed by lenticular arrangement of feldspar and quartz. Both the foliations and lineations dip and plunge respectively 80-90^0 towards the northeast (40-60^0). The most conspicuous feature of the gneiss in the field is the occurrence of abundant, occasionally equidimensional rhombs of potassium feldspar (sometimes plagioclase) porphyroblasts. The porphyroblasts, which measure up to 3cm across, give the rocks a characteristic appearance of augen gneiss. A network of quartzo-feldspathic veins producing a structure akin to agmatites has dissected the gneiss. This suggests that partial melting of the gneiss may have taken place. Some of these veins have been folded and faulted. The fold axes trend 20^0 and it appears folding and faulting of the gneiss possibly post-date the deformation that produced the lineation and foliation of the gneiss (cf. Grant 1978; Annor and Freeth 1985; Ekwueme 1987).

The modal composition of the gneiss (Table 1) indicates that it is quartzo-feldspathic and also contains hornblende (14%), biotite (15%), chlorite (2%) and epidote (4%). Ekwueme (1990a) suggested that the gneiss is an orthogeneiss of granitic composition. Plagioclase in the rock is oligaclase of An_{25-28}. In some samples a twinned oligoclase is enclosed in a K-feldspar. This is an evidence of exsolution, which resulted in the formation of abundant microperthites. K-feldspar is mostly microperthitic microcline, which may enclose grains of quartz, tourmaline and plagioclase. Muscovite is rare in the gneiss and some biotite has been chloritized. The presence of sericite and the chloritization of biotite suggest the gneiss has undergone retrograde metamorphism.

The granodiorite intrudes the schist at Betem. It is coarse-grained, non-foliated and has sharp contacts with the schists. It has been subjected to exfoliation. The granodiorite contains schist xenoliths suggesting that magmatic stoping was probably the emplacement mechanism. The mineral composition of the granodiorite is shown in Table 1. Pegmatites occur as veins (approximately 40 x 100 cm) and bodies of rock (10mx50m) in the area. Large bodies of pegmatite occur in the schists (Fig. 1) whilst small pegmatitic veins are abundant in the gneiss. The pegmatites are all coarse-grained and contain quartz, feldspar, muscovite and tourmaline as their dominant minerals. There is no unequivocal evidence that the pegmatite dykes were formed by anatexis of the surrounding schists since these rocks did not attain the amphibolite facies grade of metamorphism. The pegmatites are, therefore considered to be intrusive and the abundance of tourmaline indicates the liquid was boron-rich.

Based on the mineralogical assemblages recognized in rocks of SW Ugep, Ekwueme (1990a) assigned the phyllites and quartz-mica schist to the biotite zone, the garnet-mica schist to the garnet zone and the augen gneiss to the oligoclase zone of the Barrovian sequence (see Table 1). He correlated these zones with the Uwet area, which lies to the south of Ugep (Ekwueme and Onyeagocha 1985). On the contrary, Odigi and Oti (1990) mapped no gneiss, no pegmatites and no granodiorite in this area. They however, misidentified the garnet-mica schist as amphibolite. These authors provided no modal composition or chemical data for these rocks. Nevertheless, they list the following zones as occurring in SW Ugep: chlorite, biotite, almandine-garnet and amphibolite. In their chlorite zone, biotite is listed as a member of a stable mineral assemblage; in their biotite zone, garnet and oligoclase (An_{20}) are listed as members of mineral assemblage and in their amphibolite zone hornblende and quartz are claimed to be major constituents though the

TABLE2 MAJOR ELEMENT COMPOSITION AND NIGGLI VALUES OF ROCKS IN SW UGEP

	PHYLLITE		GARNET MICA SCHIST						GRANITE GNEISS				GRANODIORITE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	65.81	61.11	63.20	64.79	61.58	93.04	87.37	55.87	65.53	72.63	69.71	70.61	69.73	66.09
TiO_2	0.68	1.05	0.96	0.90	0.89	0.32	0.17	2.00	1.11	0.66	0.71	0.55	1.32	0.78
Al_2O_3	16.01	18.12	17.45	15.56	17.64	3.38	5.13	13.92	15.11	14.18	15.13	14.72	14.80	15.73
Fe_2O_3*	3.67	4.23	7.63	6.39	8.47	2.41	3.51	16.96	6.72	2.59	2.70	3.36	3.13	4.02
MnO	0.07	0.05	0.13	0.13	0.19	0.06	0.03	0.01	0.01	0.03	0.03	0.01	0.02	0.07
MgO	1.99	3.89	3.45	3.07	4.33	0.36	2.00	3.97	3.40	0.95	1.06	1.69	0.95	2.31
CaO	3.47	3.58	0.82	2.14	0.73	0.04	0.03	0.40	1.64	2.13	2.43	3.00	2.31	3.24
Na_2O	3.45	3.21	1.93	3.55	1.20	0.00	0.00	0.42	3.35	3.53	3.87	2.53	3.40	3.35
K_2O	3.69	3.47	3.79	2.21	4.03	0.52	0.53	2.02	1.98	3.67	3.55	3.21	3.64	3.91
P_2O_5	0.20	0.14	0.17	0.17	0.15	0.03	0.02	0.06	0.15	0.13	0.14	0.28	0.08	0.22
H_2O	0.10	0.11	0.08	0.06	0.14	0.05	0.04	0.31	0.06	0.09	0.11	0.11	0.08	0.07
LOI	0.64	1.16	2.15	0.72	1.97	0.76	0.78	4.08	0.80	0.57	0.67	0.24	0.60	0.56
TOTAL	99.78	100.12	101.46	99.69	101.32	100.94	99.98	100.02	99.86	101.16	100.11	100.31	99.98	100.35
Nigglia Values														
al	40	36	43	39	42	51	39	36	39	44	44	43	45	39
fm	19	25	35	30	40	38	55	55	33	13	14	19	14	21
c	16	20	4	10	3	2	1	2	8	12	12	16	13	15
alk	24	18	18	21	15	9	5	7	20	31	30	27	29	25
si	282	208	269	276	248	2423	1129	248	287	386	344	347	368	280
k	0.41	0.42	0.56	0.3	0.69	1	1	0.75	0.28	0.41	0.68	0.45	0.41	0.44
mg	0.68	0.78	0.63	0.65	0.66	0.38	0.69	0.48	0.67	0.60	0.59	0.67	0.55	0.69
q	86	36	97	92	88	2287	1009	120	107	162	124	159	142	80

*Total Fe as Fe_2O_3

1-2: Phyllite; 3-9: Garnet schist; 10-13: Granite Gneiss; 14: Granodiorite.

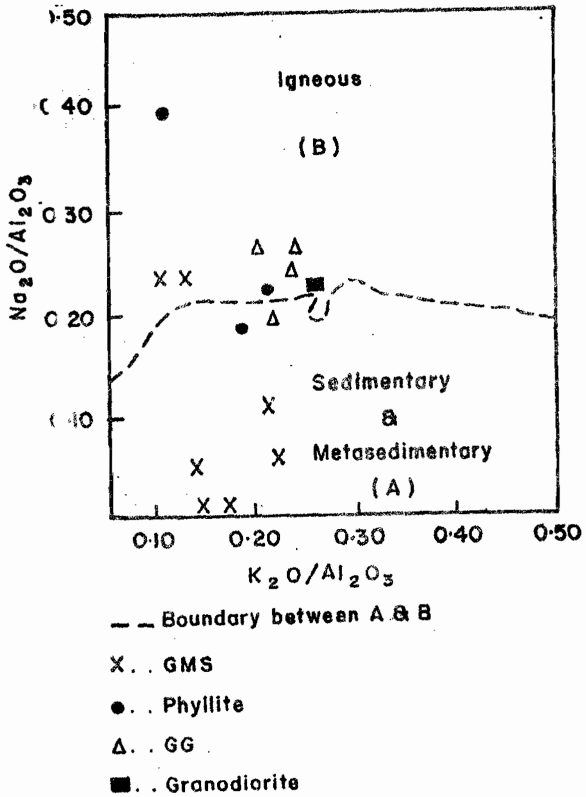

Fig 2: Na_2O/AL_2O_3 vs K_2O/Al_2O_3 plot for rocks of SW Ugep area (indicated fields after Garrels and Mackenzie 1971).

modal percentage of hornblende or any other mineral was not given. It was on the basis of this petrographic data that Odigi and Oti (1990) claimed that they have discovered metamorphic grades showing progressive increase from south to north in the Oban massif contrary to a trend of west to east observed by Ekwueme and Onyeagocha (1986)

GEOCHEMISTRY

ANALYTICAL METHOD

Bulk-rock analysis of representative samples from southwest Ugep was carried out using X-ray fluorescence spectrometry at the Geochemistry laboratory of Technical University of Berlin, Germany. Sample preparation involved drying each sample at 105^0c overnight to determine the amount of H_20. The samples were then placed in an oven at 800^0c overnight and the weight difference calculated to obtain the loss on ignition. 1.5g powder of each of these samples for which LOI had been determined was mixed with 6g of $Li_2B_40_7$ and La_20_3 in a platinum crucible and fused at 1200^0c to produce melt beads used for the analysis of major elements. The pressed powder tablets used for trace element analysis were produced by mixing 7g of each powder with 0.7g of carnabar wax. The mixture was homogenized by milling in an agate mortar after which the powder was pressed in an automatic pressure machine to produce the pressed tablets.

CHEMICAL COMPOSITION

The chemical compositions of the crystalline basement rocks in southwest Ugep area are shown in Table 2 and 3. In Table 4 are compositions of some rocks in Uwet area and Eastern Oban massif for the purpose of correlation with the rocks in Ugep area. Also included in Table 4 are chemical compositions of rocks from other parts of the world, which are comparable to those of SW Ugep.

MAJOR ELEMENTS

A careful study of Table 2 and comparison with Table 4 indicate that the phyllites and the schists are close in their major element content and approximate the composition of metasediments. On the other hand, the gneiss and the granodiorite are close in composition and similar to igneous rocks. The phyllite is moderately enriched in silica and aluminium and this is consistent with the modal composition, which shows that quartz and muscovite are the major minerals in the mode. The phyllite is also enriched in tourmaline and this probably explains its higher Na_20, K_20 and $Mg0$ content compared to other rocks in the area. The rock has a lower quartz index (36-86) compared to other rocks and the Niggli alk+c is greater than al which could account for the absence of an aluminium- excess mineral such as chloritoid in the phyllite (cf. Barth 1962). K_20 is higher than Na_20 in the phyllite and this is characteristic of metapelites (Pettijohn 1975). The $Ti0_2/Al_20_3$ ratio of the rock is 0.042-0.05 and is close to the value of 0.04 which, according to Goldschmidt (1954) is the value for clays. The slightly higher value of this ratio in Ugep phyllite may be indicative of a low level of contamination of the progenitors by igneous components (Spears and Kanaris –Sotiriou 1976). The Al_20_3/Na_20 ratio of 5.67 is confirmation of such igneous rock contamination. The sediments were generally immature since the Al_20_3/Na_20 is less than 10 or more expected of mature sediments (Pettijohn 1975).

Compared with the phyllites of the neighbouring Uwet area, the Ugep phyllite is different in having K_20/Al_20_3 greater than one and higher Al_20_3 content. On the other hand, the Ca0 and loss on Ignition of the Uwet phyllite are higher than those of Ugep (Table 3 and 4; see also Ekwueme and Onyeagocha 1986). The difference is explained by the preponderance of chlorite and biotite, which impart a dark hue on the Uwet phyllite compared to the light colour of Ugep phyllite. The high content of tourmaline in the Ugep phyllite and its unconformable contact with a calcareous sandstone could have complicated the chemistry. The composition is nonetheless close to the average shale of Shaw (1956).

The schists show a high degree of variation in major element composition (Table 2).

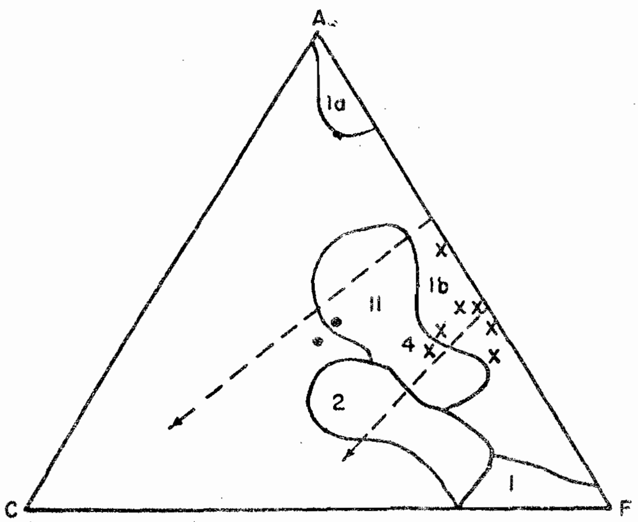

Fig. 3: Plot of phyllites and schists of SW Ugep area on the ACF diagram. (Indicated fields after Winkler 1967) (Symbols as in Fig. 2).

$Si0_2$ is generally high (greater than 60%) except in sample no. 8 with a lower value of 55.87%. Two samples 6 and 7 have very high $Si0_2$ content (87-93%). The high $Si0_2$ content in the schist is reflected in the quartz index (q) which ranges from 88 to 2287. Compared to the phyllite, the Niggli (alk+c) is in all cases less than Niggli al and this could account for the predominance of biotite, muscovite and the presence of garnet in these schists. These rocks also have K_20/Na_20 greater than 1 (except sample 4 where the value is 0.62) and this indicates that their progenitors were dominantly pelitic to semi-pelitic sediments (Pettijohn 1975). The $Ti0_2/Al_20_3$ ratio (0.050 to 0.144) with the exception of sample 7 (0.033) is however, higher than the value of 0.040 given as standards for clays (Goldschmidt 1954). The ratio however, fits into the class of argillaceous rocks. The higher value of $Ti0_2/Al_20_3$ is indicative of the presence of igneous rock contaminant in the progenitors of these schists. Four samples (5, 6, 7, 8,) have Al_20_3/Na_20 values greater than 100 and this, together with the absence of Na_20 in sample 6 and 7, confirm that some of the sediments that were metamorphosed to form the schists, were mature to ultramature (cf. Argast and Donnelly 1986, p. 219)

Compared with the composition of metasediments published in the literature, the schists fit well into the class of average shale, siliceous shale and metapelites (Table 4). The exception is sample no. 4, which compares well with average greywacke. This rock is dark to very dark in colour and in hand specimen appears to be an amphibolite just as the garnetiferous phyllite in Uwet area (Ekwueme and Onyeagocha 1985). These two rocks are similar in chemical composition (Table 3 and 4) and fit well into the class of greywackes. Both rocks are interlayered in garnet-mica schists, which are also correlatable in their petrography (Ekwueme 1990a). Compared with other metamorphosed rocks in SW Ugep area, the gneiss has generally higher $Si0_2$ (69-72%) and alkali (5.7 –7.4%) but lower $Ti0_2$, Fe_20_3 (total) and Mg0. This is characteristic of granitic rocks. The Niggli quartz index is therefore, high (124 –162), so also the Niggli Si (344-386). These chemical features reflect the

TABLE 3: TRACE ELEMENT COMPOSITION (PPM) OF ROCKS IN SW UGEP

	PHYLLITE	GARNET MICA SCHIST									GRANITE GNEISS		GRANODIORITE	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
As	11	10	88	0	nd	9	9	8	0	3	0	0	4	12
Ba	1276	1250	1009	771	1427	155	150	700	772	909	944	940	910	1198
Ce	57	60	45	43	80	0	0	40	43	90	67	68	90	121
Co	103	90	51	44	56	54	54	51	45	30	26	26	31	49
Cr	91	100	172	195	219	158	155	160	195	101	125	128	105	157
Cu	53	50	47	25	80	87	90	44	4	43	82	82	45	47
Ga	28	28	27	19	31	8	5	25	19	29	32	30	30	29
La	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Mo	13	13	7	12	12	104	100	10	13	16	11	12	18	12
Nb	15	14	16	13	12	5	8	15	13	11	11	11	11	14
Nd	28	30	22	21	36	2	2	22	20	38	26	30	40	53
Ni	25	28	76	71	76	8	8	75	72	7	6	10	9	34
Pb	34	30	20	21	13	12	10	20	25	36	39	41	35	30
Pr	43	45	43	31	29	19	21	42	31	40	48	50	40	50
Rb	187	180	163	111	162	39	40	160	110	196	213	210	200	214
Sc	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sm	5	5	4	5	6	2	2	4	5	7	6	6	7	7
Sr	595	600	205	347	166	47	50	200	347	356	386	390	356	576
Th	0	0	4	3	4	8	6	4	2	2	1	1	2	4
U	0	0	4	4	6	6	8	4	6	4	6	4	6	5
V	94	99	215	176	261	42	42	220	176	22	32	35	25	110
Y	22	30	57	59	49	15	15	58	58	11	9	9	10	34
Zn	77	77	157	132	166	34	32	156	131	111	112	112	113	85
Zr	255	300	292	255	269	127	130	294	255	246	259	261	251	271
Sm/Nd	0.179	0.167	0.182	0.236	0.167	1	1	0.182	0.250	0.184	0.231	0.200	0.175	0.132
K/Rb	164	160	193	165	184	111	110	105	149	155	138	127	151	152
K/Ba	23.99	23.03	31.17	23.79	23.44	27.84	29.32	23.95	21.28	33.51	31.21	28.34	33.20	27.09
Rb/Sr	0.314	0.300	0.795	0.320	1.096	0.830	0.800	0.800	0.317	0.551	0.552	0.538	0.562	0.372

Sample numbers as in Table 2; bdl: below detection limit (detection limit is <0.001); nd: not determined dominance of quartz, plagioclase and K- feldspar in the gneiss. It has a relatively moderate Al_2O_3 content (14.18-15.13%) but this is enough to make the aluminium saturation index greater than one. This is shown by the Niggli values since al is greater than (alk+c) in all the samples except 12 in which al is equal to (alk+c). This indicates that the gneiss is peraluminous. The absence of aluminium-excess minerals such as staurolite, kyanite or sillimanite in these rocks is probably due to the fact that the composition approximates the granodiorite of Nockolds (1954). They are therefore, orthogneisses and correlatable to the granitic gneisses in Eastern Oban massif (Ekwere and Ekwueme 1991). Zen (1986, 1988) noted that peraluminous rocks could be derived from subaluminous magma by fractional crystallization or partial melting of a peraluminous source rock.

Compared to the gneisses, the unmetamorphosed granodiorite in Ugep area differs only in its lower SiO_2 content (66.09%). These two rock suites might therefore, have similar petrogenesis but differ in time of emplacement, the granite gneiss which has been metamorphosed being older than the granodiorite which is unmetamorphosed.

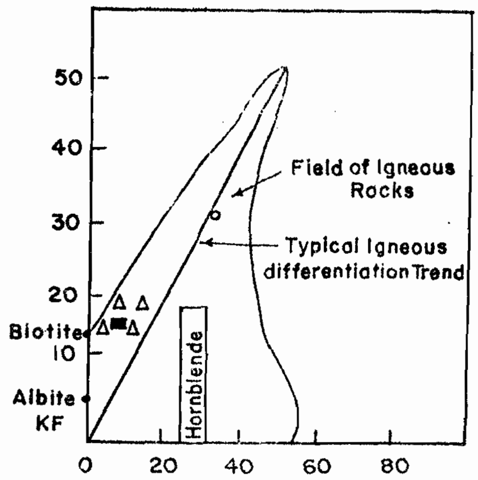

Fig. 5: Plot of the composition of gneisses and granodiorite of SW Ugep area on the Niggli al- alk vs. c diagram of Leake and Singh (1986) (Symbols as in Fig. 2)

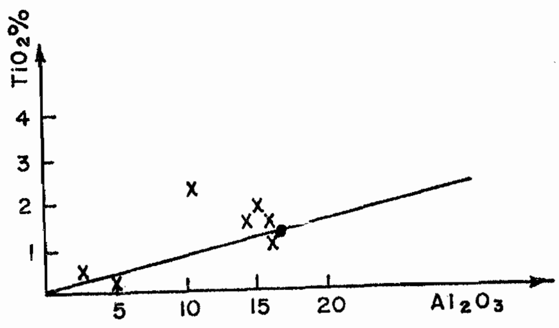

Fig. 4: TiO_2 vs Al_2O_3 plot for the phyllites and schists of SW Ugep area (solid line corresponds to the value for clay. after Goldschmidt (1954). (Symbols as in Fig. 2).

TRACE ELEMENTS

The trace element content of the crystalline rocks in SW Ugep is within the values quoted for crustal rocks (Taylor 1965). Ni, Cr, and V are low whereas Ba, Rb, Sr and Zr are relatively high. The phyllites have a low Ni and Cr contents of 17-19 ppm and 61-67 ppm respectively. These values are too low for greywackes and shales. In a similar manner, the K/Rb and Rb/Sr ratios are higher than for average greywacke. The schists have higher Ni content (up to 51 ppm). The exceptions are the more siliceous samples, 6 and 7, which have very low, value 5 ppm. The low value of Ni is consistent with the quartzo- feldspathic nature of the siliceous schist. It indicates a possible granitic source for the sediments. With the exception of these two samples, Zr is high in other samples and in most cases greater than 160 ppm quoted for shale and 140 ppm for greywackes. This high value of Zr may reflect the presence of zircon in these rocks and McCurry (1976) has interpreted similar values as indicative of the rocks in question being of crustal derivation and that they are reflective of a metamorphosed sedimentary suite. The Rb/Sr and Sm/Nd ratios of the schists are high confirming their crustal nature. The trace element content of these schists is comparable to those of pelitic and semi-pelitic rocks. The exception is sample no. 4 whose trace element composition compares well with that of the garnetiferous phyllite in Uwet area (Table 4). The trace element composition of the gneiss and

TABLE 4: CHEMICAL COMPOSITION OF ROCKS SIMILAR TO UGEP ROCKS INCLUDING SOME ROCKS OF UWET AREA

	B	C	D	E	F	G	H	I	J	K	L
SiO_2	61.00	62.00	51.98	68.75	59.93	61.54	55.74	84.14	64.43	66.88	67.20
TiO_2	0.80	0.85	1.28	0.33	0.85	0.82	0.94	0.22	0.62	0.57	0.50
Al_2O_3	13.10	16.30	13.33	15.47	16.62	16.95	18.16	5.79	15.48	15.66	15.50
Fe_2O_3	5.50	8.70	1.38	2.95	3.03	2.56	9.36	1.21	6.54	4.21	4.20
FeO	n.d	n.d	8.48	n.d	3.18	3.90	n.d	–	–	–	–
MnO	0.17	0.10	0.17	0.06	–	–	0.54	–	0.07	–	–
MgO	2.28	3.82	8.14	1.31	2.63	2.52	3.80	0.41	3.12	1.57	1.60
CaO	5.90	0.40	7.76	2.56	2.18	1.76	2.43	0.13	2.22	3.56	3.50
Na_2O	2.82	0.98	2.06	3.97	1.73	1.84	1.52	0.99	3.74	3.84	3.80
K_2O	1.88	4.50	2.73	4.39	3.54	3.45	4.16	0.50	2.44	3.07	3.00
P_2O_5	0.23	0.15	0.16	0.20	–	–	0.27	–	–	–	–
H_2O	–	–	–	–	4.34	3.47	–	5.56	–	–	–
CO_2	–	–	–	–	2.31	1.67	–	–	–	–	–
LOI	3.95	2.16	1.59	–	–	–	2.54	–	–	–	–

A = Uwet garnetiferous phyllite (new analysis B = Uwet garnetiferous phyllite (Ekwueme & Onyeagocha 1986)
C = Uwet garnet mica schist (Ekwueme & Oneagocha 1986) D = Uwet amphibolite interlayered with phyllite (new)
E = garnite of Eastern Oban massif (Ekwere & Ekwueme 1991); F = Average shale (Shaw 1956)
G = an average of 155 pelitic schist (Shaw 1956); H = pelitic schist (Ferry 1982);
I = siliceous shale (Pettijohn 1975) J = Average Wyoming greywacke (Condie 1967)
K= Average granodiorite (Nockolds 1954) L= High- Ca granite (Turekian & Wedepohi 1961). n.d = not determined.

granodiorite in SW Ugep is also comparable to that of granite in the eastern section of Oban massif (Table 4). The granite gneiss has Zr and

Rb contents close to but slightly higher than the values quoted for granites by Wedepohl (1991). The Sr and Ba contents are close to the values of 440 ppm and 420 ppm quoted for high –Ca granites (El Bouselly and El Sokkary 1975). The high- Ca granite of Turekian and Wedepohi (1961) correspond to quartz diorite and granodiorite. The Rb/ Sr ratio of these gneisses ranges from 0.551 to 0.5662 and are similar to value obtained for the Pan –African granites in northcentral Nigeria (Van Breemen et al. 1977). The Y content is rather low (6-7 ppm) and suggests that the granite gneiss may have been derived from a low degree of melting of the crust. The unmetamorphosed granodiorites in the area are generally similar to the gneiss in trace element composition. The granodiorite is however, slightly enriched in Ba, Ce, Nd V and Zr. Its Sr content of 384 ppm is comparable only to those of the phyllite in the area (Table 3). It seems the granodiorite was derived from a source richer in Sr than the gneisses.

PETROGENESIS

It is evident from the above analysis that the composition of the rocks in SW Ugep may have been contaminated through addition of rocks of igneous origin. For instance, the phyllites were invaded by pegmatitic intrusions, which also enriched the rock in tourmaline. In a similar manner, the schists especially the siliceous sample could have been derived from progenitors rich in quartzo-feldspathic igneous rocks.

Argast and Donnelly (1986, P.219) noted that the use of bulk chemical compositions to infer the original clastic compositions of metamorphosed sedimentary rocks is valid if the chemical changes resulting from metamorphism occurred within the volume of the hand sample taken for analysis. They however, observed that for a thick sequence of sedimentary rocks slightly metamorphosed to the greenschist facies and in the absence of excessive amounts of advecting fluids, it is reasonable to assume that metamorphism has proceeded in an essentially isochemical fashion. Yardley (1977) and Ferry (1982) have similarly demonstrated that except for carbonate rocks the concept of isochemical

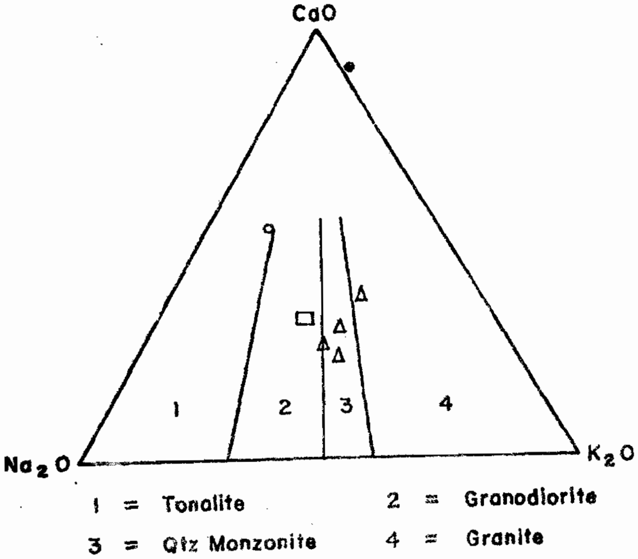

Fig. 6: $CaO-Na_2O-K_2O$ ternary diagram plot of the gneiss and granodiorite in SW Ugep (Symbols as in Fig. 2)

metamorphism founded by Shaw (1956) are generally valid.

The chemical data for the crystalline basement rocks of SW Ugep area were plotted on a Na_2O/Al_2O_3 versus K_2O/Al_2O_3 diagram used by Garrels and Mackenzie (1971) to discriminate between metamorphosed rocks of igneous and sedimentary origin (Fig. 2). Most of the schists plot in the metasedimentary field. Samples 4 and 9 plot in the igneous field reflecting their higher values of Na_2O. In a similar manner, one of the samples of the phyllites plots in the igneous field. The high Na_2O content may be due to the higher proportion of tournaline in these samples.

All the samples of the gneiss with the exception of sample NO. 12, which are low in Na_2O, plot in the field of igneous rock. The highly siliceous schists plot in the igneous rock field reflecting the quartzo- feldspathic nature of their progenitors. Pettijohn (1975) pointed out that siliceous shales contain silica from volcanic sources. In the ACF diagram of Winkler (1967), all the samples of the schists except sample no. 4 plot in the field of shale (Fig.3). Sample 4 plots in the field of greywacke, which is consistent with the value of the K_2O/Na_2O ratio which is less than 1 (cf. Scotford 1956). The mineralogical composition of this sample in which quartz, biotite and garnet dominate the mode is similar to the granetiferous phyllite in the Uwet area, which is also a greywacke (Ekwueme and Onyeagocha 1986).

The plot of the phyllite of SW Ugep area on the ACF diagram (Fig. 3) is however, not consistent with the K_2O/Na_2O ratio which is greater than one characteristic of pelites and semi-pelites. Mineralogically, the phyllites consist mostly of quartz and muscovite with the latter predominating. The next important constituent is tourmaline. The mineralogical composition is reflected in the chemical composition, which shows high silica, high alumina and high potash content. This chemical feature is characteristic of rocks derived from shales or for the phyllites may be due to the metasomatic addition of Ca considering that the phyllite is unconformably overlain in parts and is in places in contact with a calcareous sandstone. This could have contaminated the phyllite by raising the CaO content (Table 2).

Leake and Singh (1986) used the Niggli al-alk against Niggli c diagram to discriminate between gneisses of igneous and sedimentary derivation. On this diagram (Fig. 5) all the gneisses of SW Ugep as well as the unmetamorphosed granodiorite plot on the igneous envelope confirming that the gneisses

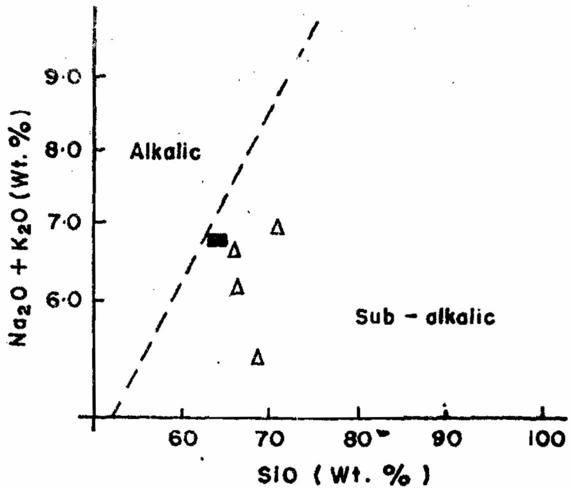

Fig. 7: Alkali- silica diagram for gneisses and granodiorite in SW Ugep (Symbols as in Fig.2)

are orthogneisses. When the rocks are plotted on a $CaO-Na_2O-K_2O$ ternary diagram (Fig. 6) and the compositional variation of acid to intermediate rocks (Condie 1967) are superimposed, the values show a wide spread from granodiorite to quartz monzonite and granite. The rocks plot in the subalkalic field in the alkali-silica diagram (Fig. 7). In the AFM diagram (Fig. 8) the gneisses and unmetamorphosed granodiorite plot in the field of calc-alkaline rocks. Hence, these rocks were derived from a differentiated calc-alkaline magma.

DISCUSSION AND CONCLUSION

Field data on SW Ugep area show that it is underlain by phyllite, schist and gneiss intruded by pegmatite and granodiorite (Ekwueme 1990a). No amphibolite has been mapped in the area. However, in hand specimen, some samples of garnet mica schist are dark in colour and could be mistaken for amphibolite. Similar rocks occur in the adjoining Uwet area where garnetiferous phyllite is also very dark in colour and similar in mineralogical composition with the garnet mica schist of southwest Ugep. Both rocks are of greywacke composition. In the Uwet area, amphibolite is in contact with the garnetiferous phyllite. The composition of this amphibolite, the phyllite and the garnet mica schist of Uwet area are shown in Table 4. The analyses were obtained from three different laboratories: Illinois State Geological Survey, Smithsonian Institution and Technical University of Berlin. The data show that even though the garnet mica schist and garnetiferous phyllite are as dark as amphibolite in hand specimen, they are greywackes.

It has been pointed out that petrographic analyses of structurally deformed and regionally metamorphosed rocks are not useful in placing source-rock and tectonic constraints on sedimentary systems (Schwab 1975; Dickenson and Suczek 1979). Argast and Donnelly (1986, p. 217) explained that this is because the mineralogical assemblages of metamorphosed sedimentary rocks may not uniquely define the mineralogical assemblages resulting from pre-and syn-depositional processes. Bulk chemical composition can however overcome this problem.

The petrographic and chemical data on SW Ugep rocks are not consistent with the findings of Odigi and Oti (1990) that the area is composed of amphibolite and that chlorite, biotite, almandine garnet and amphibolite zones can be deciphered in the area. Ekwueme (1990a) discussed the metamorphism of this area and showed that the metamorphic zones are

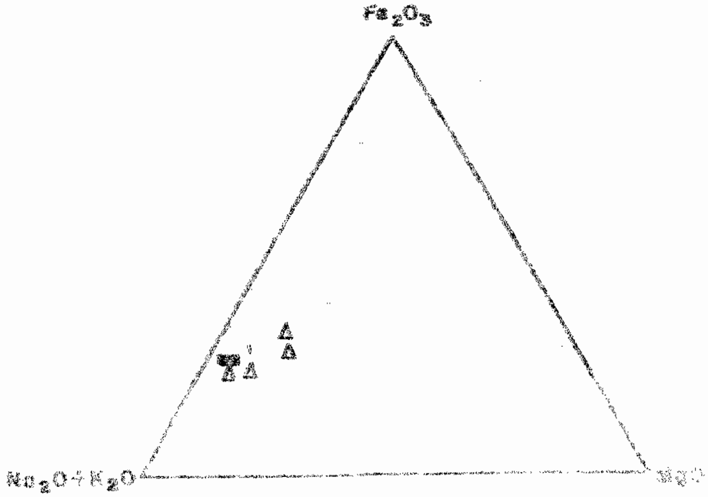

Fig. 8: AFM plot for gneisses of SW Ugep (symbols as in fig. 2)

correlatable with those of Uwet area, which lies south of SW Ugep area (see also Ekwueme 1990b). However, in the Ugep area there appears to have been a break in the metamorphic grade at the boundary between the gneisses and schists. The gneisses, which have been shown here to be orthogneisses, contain no index mineral to assist in assigning them to any of the classical zones of metamorphism. Nevertheless, the rock contains oligoclase as opposed to albite in the schist and phyllites. It was therefore, tentatively placed in the oligoclase zone (Ekwueme 1990a). The field features indicate that this gneiss could have attained even higher grade of metamorphism since it is dissected in some parts by quartz-feldspathic veins giving it the appearance of agmatite. Furthermore, the orientation NW-SE is contrary to the predominant N-S to NE-SW in the schists and phyllites. In the Nigerian basement structures trending NW –SE are assigned to the pre-Pan African tectogenesis (Grant 1978; Annor and Freeth 1985; Ekwueme 1987). In northern Cameroon, Toteu et al. (1990) have however, correlated such structural orientations to an older Pan-African deformation coeval with the emplacement of the Poli Schist.

In southwest Ugep the metasediments, which have been faulted in some parts, form the supracustal cover on the orthogneiss. The erosion of this metasedimentary cover has partially exposed the orthogneiss, which has a higher metamorphic grade and is possibly older in age. This gneiss has been shown to be mineralogically and chemically similar and correlatable to the granite gneiss in the eastern section of the Oban massif discussed by Ekwere and Ekwueme (1991). It is therefore, unlikely that the metamorphism in SW Ugep area shows a progressive increase from south to north of the area as claimed by Odigi and Oti (1990). These authors have not placed isograds to substantiate this claim. On the contrary, Ekwueme and Onyeagocha (1985) and Ekwueme (1990b) have mapped isograds showing that the Barrovian sequence in Oban massif including the area studied by Odigi and Oti (1990) increases in grade from middle greenschist in the west to upper amphibolite facies in the east. Local granulite facies grade was also attained in the eastern Oban in places where charnockites occur.

The chemical compositions of rocks in SW Ugep area indicate that like in other schist belt in the Nigerian basement the area is composed dominantly of metapelites and orthogneisses of granitic composition. Minor amounts of greywacke occur and the area was intruded by granodiorite and pegmatite. These intrusions may have contributed in the composition of the metasediments through the addition of boron and silica in the rocks. Amphibolites have not been recognized in the area but these rocks occur in neighbouring Uwet area and also in the eastern Oban massif.

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