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Full Length Research Article

# Ferruginised Metapelites of The Kazaure Schist Belt, Northwestern Nigeria

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## ABSTRACT
Field, petrographic and geochemical evidence shows the occurrence of ferruginised metapelites (FMP) in the Kazaure Schist Belt (KZSB). The KZSB consists predominantly of quartzites, pelitic metasediments, and metaconglomerates. Minor rocks includes metavolcanics and iron formations (Banded Iron Formation and ferruginised metapelites). The FMP occurs as narrow bands associated with quartzites and phyllites. Magnetite as euhedral to subhedral crystals together with subordinate anhedral hematite forms the Fe band. The Fe content of the FMP (14.54 – 82.8 %) is comparable to that of banded iron formations in the schist belt. It contains lesser amounts of Mn (0.07 – 17.83 %), Ca (0.067 – 1.25%), and the lithophile elements average values: K (1.21 ppm); Rb (89.89 ppm); Sr (190.78 ppm). It is envisaged that the FMP developed from the alteration of the metasediments entrapped as a kind of tectonic mélange as a result of late tectonic brittle deformation and activity of fluids rich in iron.
**Keywords:** Banded Iron Formation, ferruginised metapelites, Oxide facies, Tectonic mélange, Silicate facies.

## INTRODUCTION
Many workers have reported the occurrence of iron formations in the Nigerian basement complex. Two broad groups are identified: the metamorphosed iron formations that are mostly Precambrian and the Sedimentary (oolitic) iron ore deposits that are Cretaceous. The Precambrian iron-formations are named differently by different workers. Some named them ferruginous quartzites (e.g. Truswell and Cope, 1963; Olade, 1978): and others simply called them `ironstones' (e.g. McCurry, 1976; Ajibade, 1976; Holt *et al*., 1978). In addition, banded iron formation (BIF) has been used by Adekoya (1993; 1996), Ibrahim (2003), Mucke *et al*., (1996) Ibrahim, (2008) to describe those banded and chert-bearing iron deposits in the metasedimentary belts of northwestern Nigeria with a high silica-iron minerals ratio. The employed term has genetic importance because it indicates the nature of the primary silicate minerals. However, the Kazaure schist belt contains another type of iron-formation, the ferruginised metapelites (FMP) occurring as a kind of tectonic mélanges along shear zone. The aim of his paper is to describe the field occurrence, petrography, geochemistry and origin of the FMP in the Kazaure schist belt.

## MATERIALS AND METHODS
Representative samples of the FMP (12 samples) were collected along traverse lines 50 m apart. Petrographic analysis was carried out using transmitted and reflected light microscopy. Polished thin sections of the samples were produced at the Department of Fundamental Geology, University of Silesia, Poland. Using a transmitted and reflected light microscope the various mineral phases in the samples were identified.

Determination for major and trace elements were done using XRF machine employing surface technique. The analyses were carried out at the Center for Energy Research and Training (CERT) Ahmadu Bello University, Zaria.

## RESULTS
### Regional geology and structure
The Precambrian rocks of Nigeria occur east of the West African Craton and northwest of the Congo Craton, and south of the Tuareg shield

(Figure. 1). The region was affected by the Pan African orogeny about 600 Ma. The Nigerian basement is on the basis of spread and proportion of rock suites divided into two provinces: the western province, approximately west of longitude $8^0$ E, comprising of schist belts in predominantly migmatite gneiss older basement and the whole is intruded by granitic plutons; the eastern province comprising mainly migmatite-gneiss complex intruded by large volumes of Pan-African granites and Mesozoic Younger Granites.

Geochronological evidence indicates that the Nigerian basement is polycyclic and includes rocks of Archaean 2.0-3.0 Ga, Eburnean 2000 ±200 Ma and Pan-African 750-450Ma (Turner, 1983; Fitches *et al*., 1985; Ajibade *et al*, 1989; Elueze, 2000). The rock types of the Nigerian Pan-African basement are divided into three units (Fitches *et al*., 1985, Ajibade *et al*., 1989):

(1) Gneisses and migmatites and the entrained supracrustal relics. Their metamorphism is generally in the amphibolite facies grade. These rocks are mainly quartzites, amphibolites, calcareous rocks, biotite hornblende gneisses, quartz schist and biotite-hornblende schist (Wright *et al*., 1985).

(2) Schist belts occur in a 300km wide zone, and predominantly west of longitude $8^0$E, which trends NNE, parallel to the boundary between the Pan-African and the West African Craton (Turner, 1983; Fitches *et al*., 1985; Ajibade *et al*., 1989; Adekoya, 1996). The schist belt zone is flanked by migmatite-gneiss-granite terrain to the East and West, and the same terrain separates the individual belts within the zone (Turner, 1983; Ajibade *et al*., 1989). The schist belts are believed to be metasedimentary-volcanic, deformed, low-grade (green schist facies) rocks (Turner, 1983; Fitches *et al*., 1985).

(3) Granitoid plutons of the Older Granites suite are considered as syntectonic to late tectonic granitoids emplaced during the Pan-African. They intrude both the migmatite gneiss complex and the schist belts. Earlier granitoids are foliated calc-alkaline granodiorite intrusions, while later undeformed late tectonic intrusions are monzonitic, sub alkaline to alkaline in character (McCurry, 1989). Other rock varieties are diorites, gabbros, charnockites and late tectonic high level volcanic and hypabysal rocks.

Several workers on the Nigerian Pan African belt have explained the origin and the pattern the various structures have manifested on the basement complex. The work of Garba (2002) has shown that the last stage of the Pan-African orogeny is represented by a conjugate fracture system of strike-slip faults. The faults have consistent trends and senses of displacement; i.e. the NNE-SSW trending system having dextral sense of movement and the NW-SE trending system having a sinistral sense.

The KZSB is composed of the following lithological units: gneisses, metasedimentary rocks and granites, as major rock types; with BIFs, Diorites and Pegmatites, and tourmalinites and FMPs as minor rock types.

Gneisses which are possibly the pre- Pan African basement are located at the extreme SW corner of the study area; the metasediments are to the east and the granites intruded the northern section of the area.

The metasediments are in places deeply weathered and the hills are covered with thick lateritic crust and exposures are difficult to find. Exposures found in deep gullies reveal that the metasediments are composed mostly of schist, phyllites and quartzite; and exhibit NNE – SSW structural tend. The ferruginised metapelites occur within the phyllites and quartzites as a disconcordant member; other rocks are fault breccias and mylonites, tourmalinites that occur as bands and lenses within the schist. The central part of the study area consists of granitic rocks. The granites consist of fine-grained and porphyritic varieties.

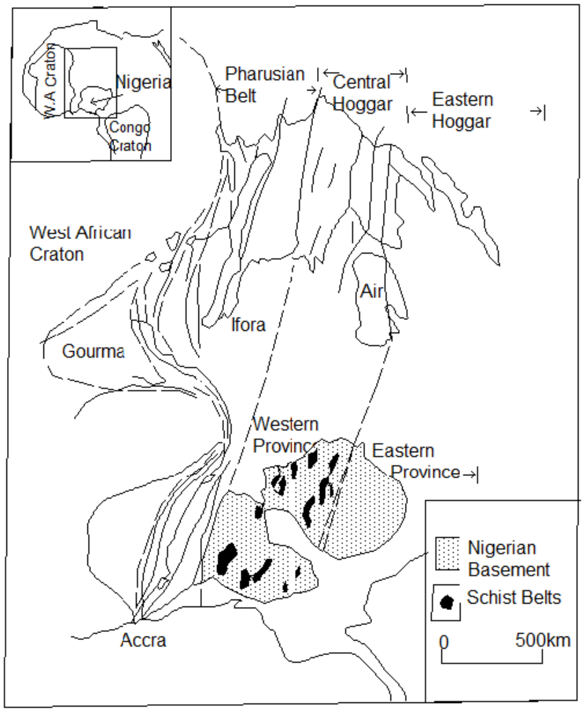


**Figure 1.** Location of Nigeria in West Africa relative to the West African Craton (inset); the regional setting of Nigerian shield in major structural units of West Africa following the pre Mesozoic construction of Caby (1989).

## The Ferruginised Metapelites

The ferruginised metapelites, (FMP), outcrops on NNE-SSW trending ridges east of Wawarrafi Lake (Figure. 2). The FMP ridges separates the Newer Metasediments, to the east, and the Older Metasediments and the granites to the west. They also appear to coincide with a major fault in the area. The quartzites forming the ridge are massive and schistose. The massive and schistose varieties occur as alternating bodies along the main strike of the ridge. Within these varieties, rafts of highly ferruginised pelitic schist and metasandstone are found. The rafts measure 1 m to 15 m in width, and are composed of highly weathered and ferruginised schistose rock (Figure. 3). Consequently, no fresh samples could be obtained. They exhibit attitudes that are quite different from those of the host rock. Foliation directions of 100° – 120° and dips of 65 - 75° E are common within the ferruginised schist rafts, while the quartzites have foliation of 025 - 050° and dipping 68 – 70° W. Beside these rafts, certain areas of the quartzites are highly brecciated and filled with magnetite. Figure. 2 is the geological map of the FMP.

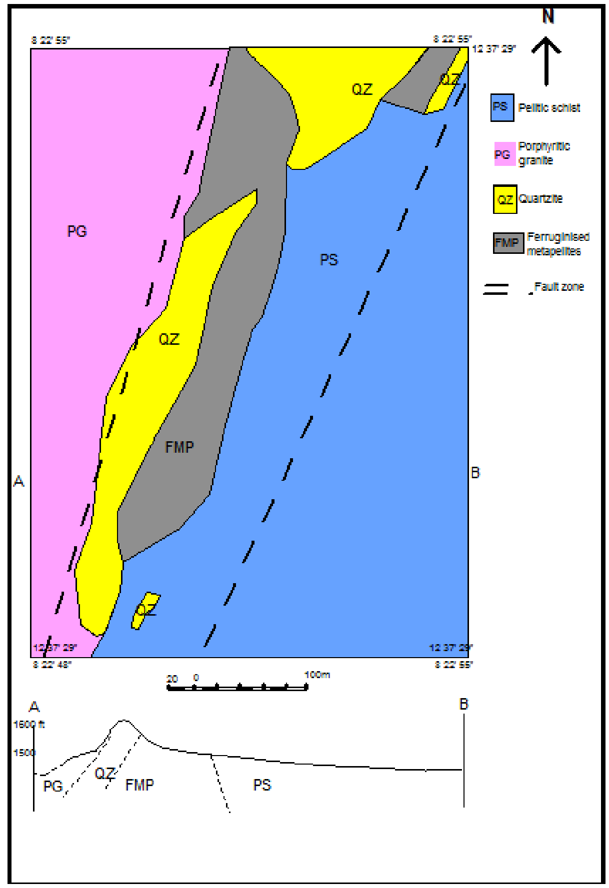


**Figure 2.** Geological map of the ferruginised metapelites.

## Petrography

The rock is massive, or schistose, rusty brown or earthy (Figure. 3). The bands or laminations are 5 mm-10 cm. It is composed of alternating magnetite rich bands, quartz band and schistose band. Euhedral crystals of quartz and the iron oxides

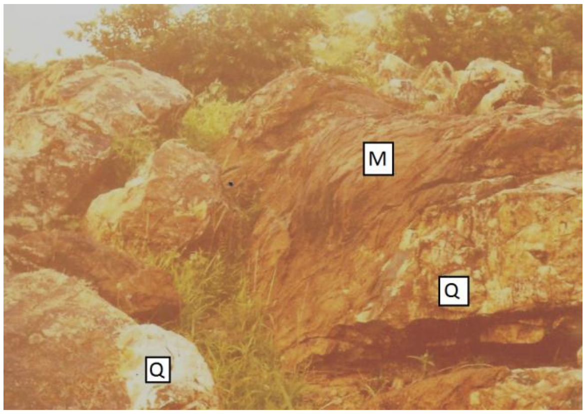


**Figure 3.** Field occurrence of the FMP. M – ferruginised metapelite raft within quartzite – Q.

Magnetite and hematite are observed in fractures especially within the rusty brown variety. Texturally the rock is fine-grained, with grains stretched parallel to the banding or foliation. Drag and simple folds are common especially within the schistose band. The rock shows directional fabrics in hand specimen and under the microscope. The rock is characterized by alternation of dark iron oxide-rich bands separated by the light quartz-rich bands. The quartz-rich band is mostly composed of quartz, muscovite, garnet porphyroblasts and subordinate hematite and limonite (60 vol %), the band is fine grained and granoblastic. The dark iron oxide rich band is composed of magnetite as the most abundant mineral (Figure. 4).

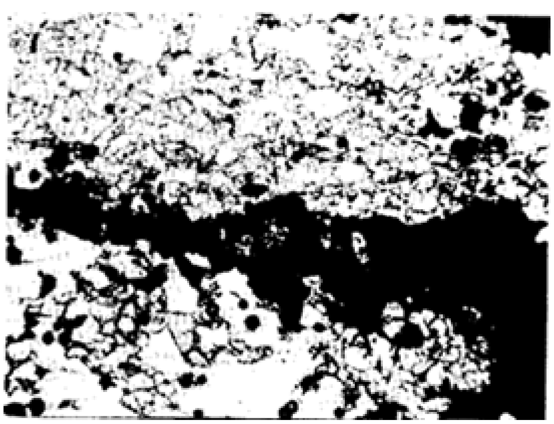

**Figure 4.** The photomicrograph shows the light quartz rich band and the dark iron oxide rich band. Transmitted light plane polarized. X40.

Magnetite is light grey in polish section, and occurs as subhedral and as microcrystalline masses (30-35 vol %), Figure.5).

**Figure 5**. Magnetite crystal as bright highly reflecting occur in middle of picture and top right. The dark band is silicate band. Reflected light, plane polarized, X40.

**Geochemistry**

The geochemical results are presented in Tables 1, 2, & 4. The total Fe as ($Fe_2O_3$) of the FMP (Table 1) ranges from 14.58 - 82.8 %, this value is comparable to the Itakpe iron ore deposit, and is much different from the iron content of the BIF body in the same schist belt (Elueze, 2000; Ibrahim, 2008). Some samples have excessively high iron content (TQ1 & TQ4/2); these are the massive ferruginised schists, while samples with smaller iron content (TQ2/1 and TQ6/1) are the vein filling type of ore. The Fe content averages 48 % (Table 2) which is comparable to other iron ore deposits in the country. $TiO_2$ content of the FMP is variable and no particular order could be observed. On the average, the FMP could be related to the Kakun iron ore in terms of ilmenite content, with averages of 3.61 % and 1.35 %, Elueze (2000) respectively, but this content is higher than that recorded for the BIF in this schist belt. The MnO content of the FMP is lower (0.007 – 17.83) than the values recorded for the BIF, but is comparable to the values of other iron ore deposits for example, Itakpe, Tajimi and Koriga (Elueze, 2000). $K_2O$ values of the FMP are also in the normal value range of most of the other iron ore deposits, although it is higher than the values recorded for the BIF. The CaO content of the FMP is lower than $K_2O$ values indicating that potash feldspars are higher than the plagioclase feldspars in the precursor of the FMP.

Chemical data on trace elements is presented in Table 1. Cr, Ni, Co and V in the FMP are comparable to their contents in normal metasedimentary rocks. This shows that the FMP could have been sourced from a non-basic precursor rock, since Cr, Ni and V are among the ferromagnesian elements that are sourced from mafic rocks. Lithophile elements (K, Rb, Ba, Sr) abundances and their inter-element relationships (Table 3) reveals meaningful patterns (Figure. 6). Rb and Sr have similar ionic radii consequently Rb – Sr plots shows a weak positive correlation (correlation coefficient “r” = 0.30. While Rb – K show coherent behavior because of the ready substitution of Rb in potassic rocks. Ba readily substitutes for K in K – bearing minerals. These concentrations are also comparable to other iron ore deposits having similar mode of formation. The average Rb content of 89.89 ppm is comparable to the 32 ppm in bulk crust (continental crust reservoirs (Kerrich, 1989)). Sr concentration of about 190.78 ppm this is in most part comparable to other iron ore deposits, for example, Imelu – 70 – 40 ppm; Itakpe – 51 ppm; Kakun – 1155 ppm (Elueze, 2000); Koriga – 24 ppm (Okonkwo, 1991) and correlates well with the felsic abundance (128 ppm (Kerrich, 1989)).

The K/Rb and Rb/Sr ratios, averages 207 and 0.86 respectively. These ratios can be correlated with those in Post Archaean granites of 208 for K/Rb and 0.95 for Rb/Sr (Kerrich, 1989). The significantly high concentration of Ba ranging between 2,730 – 11, 500 ppm, when compared with 1,130 – 510 pmm from Imelu, 50 ppm from Kakun and 43 ppm from Tajimi (Elueze, 2000). This anomalous concentration might be due to the associated muscovite schist. This is in line with Kerrich (1989) who showed that Ba could reside in muscovite rather than being partitioned between K – silicates and other coexisting phases.

## DISCUSSION

### Origin of the FMP

The origin of the FMP could be considered in relation to their associated rock types and their location on a major fault zone. The FMP is found within quartzites in the metasediments that have been reworked during the Pan – African orogeny. Field observations have shown that the quartzites occur parallel to the NE – SW trending fault zone that caused silicification of rocks within the zone. McCurry, (1971), have shown that jointing, fracturing, faulting and silicification followed the Pan – African orogeny, and the development of major NE-SW trending transcurrent fault system that crosses the area. The fault can be traced southwards to coincide with the Kalangai fault, which has been identified as a transcurrent fault developed at the last stage of the Pan – African orogeny Ajibade and Wright, (1988); Ball, (1980) showed that the brittle conjugate fault system could be related to a single late Pan – African tectonic event on a continental scale.

**Table 1:** Major and minor element compositions (%, ppm) of the FMP.

| oxide | TQ1/1 | TQ1/2 | TQ2/1 | TQ2/2 | TQ4/1 | TQ5/1 | TQ6/1 | TQ6/2 | TQ7/1 | TQ7/2 | TQ8/1 | TQ8/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 21.13 | 35.76 | 63.46 | 20.97 | 15.67 | 23.48 | 22.18 | 15.77 | 20.32 | 21.6 | 20 | 26.08 |
| $TiO_2$ | 0.32 | 0.9 | 0.25 | 4.79 | 0.97 | 0.8 | 6.93 | 5.34 | 0.38 | 0.28 | 0.75 | 0.85 |
| $Al_2O_3$ | 5.65 | 6.09 | 9.77 | 6.28 | 19.64 | 9.3 | 19.65 | 6.06 | 12.54 | 13.94 | 11.07 | 15.7 |
| $Fe_2O_3T$ | 65.2 | 50.4 | 23.33 | 63.45 | 51.69 | 63.83 | 47.94 | 70.49 | 63.44 | 60.17 | 59.77 | 57.04 |
| MnO | 0.36 | 0.32 | 0.07 | 0.16 | 0.08 | 0.27 | 1.83 | 0.14 | 0.09 | 0.1 | 0.31 | 0.35 |
| MgO | 3.56 | 3.07 | 1.52 | 1.32 | 3.54 | 0.55 | 1.65 | 1.55 | 1.33 | 0.97 | 3.56 | 3.08 |
| CaO | 0.94 | 0.75 | 0.78 | 1.25 | 1.06 | 0.9 | 0.57 | 1.13 | 0.59 | 0.67 | 0.9 | 0.81 |
| $Na_2O$ | 2.05 | 3.06 | 0.3 | 0.37 | 0.02 | 0.1 | 0.46 | 0.13 | 0.2 | 0.17 | 3.45 | 0.09 |
| $K_2O$ | 1.06 | 1.01 | 0.77 | 1 | 5.98 | 0.8 | 0.65 | 0.68 | 0.74 | 0.72 | 0.56 | 0.66 |
| $P_2O_5$ | 0.45 | 0.05 | 0.03 | 0.05 | 0.2 | 0.02 | 0.07 | 0.03 | 0.03 | 0.05 | 0.08 | 0.06 |
| Total | 100.7 | 101.4 | 100.2 | 99.64 | 98.85 | 100 | 101.9 | 101.3 | 99.6 | 98.9 | 100.4 | 101.64 |
| K | 0.84 | 0.76 | 0.64 | 0.83 | 4.96 | 0.66 | 0.54 | 0.67 | 0.55 | 0.56 | 0.55 | 0.6 |
| Co | 1950 | 1305 | 533 | 1810 | 1370 | 1410 | 1700 | 1800 | 2017 | 2060 | 587 | 593 |
| Cr | 302 | 230 | 272 | 334 | 280 | 401 | 436 | 456 | 272 | 263 | 505 | 499 |
| Cu | 385 | 365 | 97.3 | 373 | 211 | 501 | 457 | 461 | 350 | 385 | 112 | 105 |
| Ga | 183 | 176 | 51.2 | 142 | 121 | 103 | 154 | 160 | 196 | 167 | 49.9 | 48.2 |
| Ni | 696 | 690 | 115 | 447 | 245 | 383 | 344 | 359 | 597 | 604 | 398 | 402 |
| Rb | 47.7 | 47.2 | 141 | 112 | 274 | 54.5 | 31.2 | 43.1 | 37.6 | 44.4 | 13.9 | 14.3 |
| Sr | 106 | 112 | 34.2 | 549 | 142 | 24.4 | 386 | 270 | 271 | 267 | 17.8 | 17.6 |
| V | 640 | 655 | 604 | 819 | 455 | 391 | 1720 | 1701 | 818 | 817 | 590 | 587 |
| Y | 92.2 | 90 | 12.7 | 173 | 53.4 | 230 | 234 | 238 | 132 | 129 | 13.4 | 14 |
| Zn | 947 | 950 | 225 | 1050 | 226 | 671 | 369 | 360 | 731 | 736 | 223 | 219 |
| Zr | 185 | 189 | 128 | 914 | 578 | 229 | 994 | 960 | 801 | 812 | 131 | 125 |
| Ba | 3250 | 3345 | 2730 | 4030 | 3210 | 2850 | 11500 | 12010 | 3167 | 3170 | 3274 | 3280 |

**Table 2:** Calculated total elemental iron content of the FMP.

| Sample No. | %Fe |
|---|---|
| TQ1/1 | 80.5 ± 0.65 |
| TQ2/1 | 16.3 ± 0.14 |
| TQ2/2 | 68.1 ± 055 |
| TQ4/1 | 50. I ± 0.41 |
| TQ5/1 | 44.6 ± 0.36 |
| TQ6/1 | 33.5 ± 0.28 |
| TQ7/2 | 90.5 ± 0.66 |
| TQ8/2 | 11.3 ± 0.10 |

**Table 3:** Lithophile elements ratios of the FMP

| Sample/Ratio | TQ1/1 | TQ2/1 | TQ2/2 | TQ4/1 | TQ5/1 | TQ6/1 | TQ4/2 | TQ7/2 | TQ8/2 |
|---|---|---|---|---|---|---|---|---|---|
| K/Rb | 0.02 | 0.05 | 0.001 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.042 |
| K/Ba | 3E-04 | 0.0003 | 0.0002 | 0.002 | 0.0002 | 0.0005 | 0.0002 | 0.0002 | 0.0002 |
| Rb/Ba | 0.02 | 0.01 | 0.03 | 0.09 | 0.02 | 0.003 | 0.01 | 0.004 | 0.004 |
| Ba/Rb | 68.1 | 193.6 | 36 | 11.7 | 52.3 | 368.6 | 71.4 | 229.4 | 229.37 |
| Rb/Sr | 0.45 | 0.41 | 0.2 | 1.93 | 2.23 | 0.1 | 0.17 | 0.81 | 0.81 |

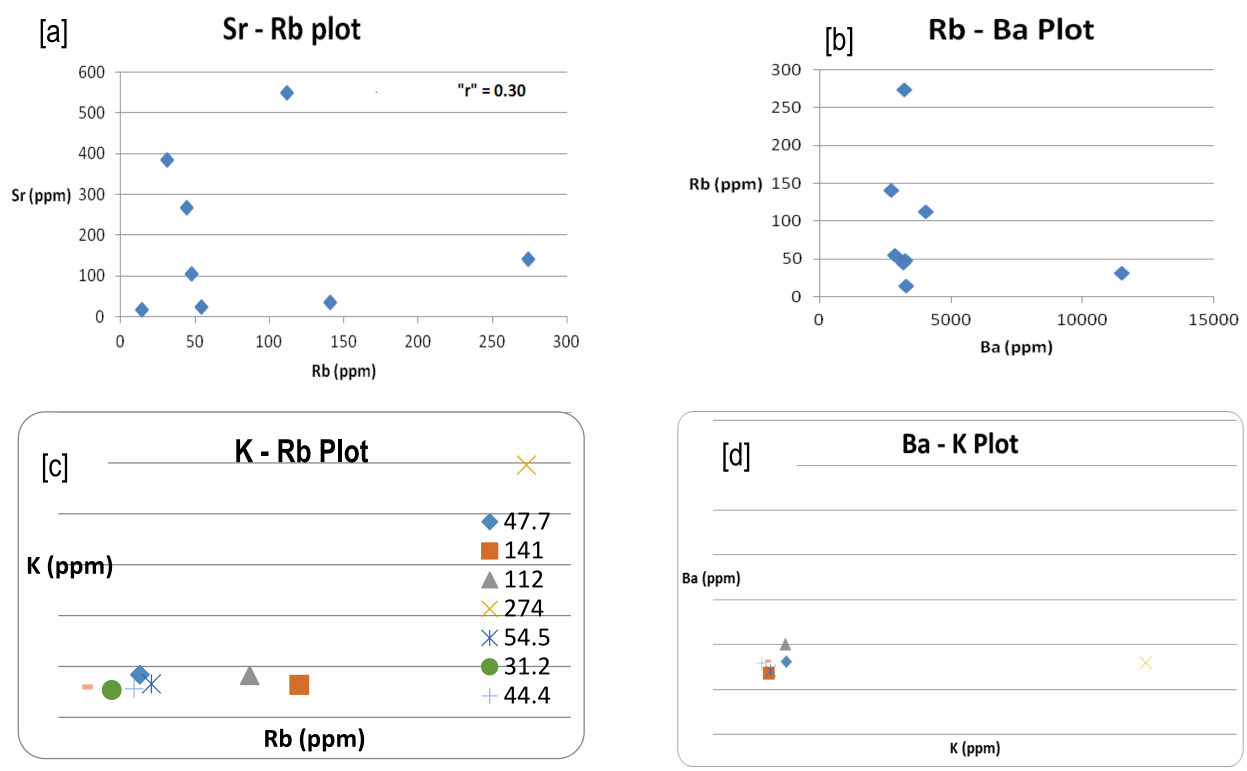


**Figure. 6**. Scatter plots showing lithophile elements distribution patterns. [a] Sr – Rb plot exhibiting weak correlation r = 0.30 [b] Rb – Ba plot showing weak correlation [c] K – Rb plot show coherent behavior because of the ready substitution of Rb in potassic rocks [d] Ba – K plot show good correlation; Ba readily substitutes for K in K – bearing minerals

## CONCLUSION

It could therefore be said that the quartzites were developed as a result of massive silicification that accompanied the brittle deformation of the metasediments along the fault line at the closing stages of the Pan-African orogeny than common quartzites of regional metamorphism, because the deformation must have been accompanied by temperature rise. As the deformation proceeds, the FMP was developed by ferruginisation as a result of hydrothermal activity that might have accompanied the faulting. The brittle fault is envisaged to have provided channel ways for the hydrothermal solutions, sourced probably from circulating meteoric waters. The meteoric water being an oxidizing medium might have reacted with the sulphides in the schist, such as pyrite to produce magnetite in the following way:

$2FeS + 2H_2O + 2O_2 \rightarrow 2H_2S + SO_2 + Fe_3O_4$

This could have accounted for the euhedral crystals of magnetite observed in the veins within the FMP and the highly ferruginised nature of the FMP.

The age of the FMP is estimated based on the age of the progenitors to the FMP. It is anticipated that the ferruginisation of the rafts of schist by hydrothermal activity took place subsequent to the transcurrent faulting related to the Late Pan – African (540 ± 40 Ma). Accordingly, the age of the FMP could be estimated as the Late Pan – African.

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