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Research Article

LITHO-GEOCHEMICAL AND PETROGENETIC CHARACTERISTICS OF SOME MASSIVE AND SCHISTOSE QUARTZITES IN EKITI STATE, SOUTHWESTERN NIGERIA

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ABSTRACT

Itawure, Efon, Okemesi and Ido-Ile massive quartzite complex is part of the rocks of EfonPsammite Formation which lies between latitudes $7^0 43^1$N to $7^0 47^1$N and longitudes $4^0 54^1$E to $4^0 57^1$E respectively. Sixteen quartzite samples of varying colours and textures were randomly collected in all the sampling locations, while ten representative samples were systematically selected and analyzed for major and rare earth elements concentration using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The results of the geochemical analysis were later subjected to multivariate statistical analysis. The conclusion drawn from the integration of the geochemical and multivariate analyses revealed that the quartzites are highly siliceous (<75%) based on the silica content which is responsible for its hardness and high resistance to weathering, and makes them economically useful for construction, ornamentation and tiling purposes. The result also indicated that the quartzites in the study area are richer in base metals such as Ni, Fe and Zn based on their enrichment factor determination, while the result of geo-accumulation index for the study area revealed that the anomalies detected in the samples are from geogenic and anthropogenic sources. Also, the quartzites are derived from tholeitic source which were formed from the metamorphism of the sedimentary protolith probably (sandstone) in the study area as revealed by the AFM plot.

Keywords: Lithologies; Structures; Enrichment Factor; Statistics; Geochemical plots.

INTRODUCTION

The Precambrian rocks are usually rocks that evolved during the Precambrian Era (4570±542Ma). Precambrian precedes the Cambrian, and it includes all the geologic time from the Earth origin 4.6Ma to the beginning of Phanerozoic Eon (545Ma). The Precambrian basement complex or rocks in Nigeria consists of Migmatite-gneiss-quartzite complex dated Archean to Early Proterozoic (2700±2000Ma). Otherlithologic units are NE – SW trending schist belt mostly developed in the western half of the country and the plutons of Older granite suites dated Late Proterozoic to Early Phaneozoic (750-450Ma). The study area isItawure in Efon local government area of Ekiti State, which lies between EfonAlaayeEkiti and AramokoEkiti. Other localities include Effon, Ido-Ile and Okemesi, which are also made up of both massive and schistose quartzites of varying colours and textures, fabric and mineralogy.

A lot of work has been done in the study area and similar areas, such work includes, Rahaman (1988), Odeyemi (1993) and Oyawoye (1964), Grant (1978), Anifowose et al., (2006), Anifowose and Borode (2007), Ayodele (2010) amongst others have given account of the geology of this area.Oyawoye (1964), Rahaman (1976), Odeyemi (1977) noted that the rocks in the basement complex show evidence of polyphase deformation with the plutonic episode of the Pan African event being the most pervasive. Rahaman (1988) noted that the basement complex of south western Nigeria lies within the rest of the Precambrian rocks in Nigeria, he grouped the rocks in this region as migmatite – gneiss complex comprising largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes. Odeyemi et al., (1999) suggested that almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusives are tectonic in origin, because pre-existing primary structures have been obliterated by-subsequent deformation. Okunola and Okorojafor (2009) studied the schistose rock around the Okemesi fold belt with a view to evaluate their compositional features and petrogenic affinities and to contribute further to the understanding of the geodynamics evolution of Nigeria's schist belts. Oyinloye (2006) on the basis of pb-pb isotopic dating suggested an age of 2750$\pm$25Ma for the metasedimentary complex in the Ilesha schist belt which is an Archean age.Anifowose and Borode (2007); carried out a photo geological study of the fold structure in Okemesi and indicated the existence of isoclinals limbs of a mega fold in association with other minor folds and subsequently fracturing which resulted in the plunging of the folds.Anifowose (2004) also noted that joints ranging from minor to major ones are found in all the rock types, some of which are filled with quartz, feldspars or a combination of both which lie generally in the NE-SW direction while Boesse and ocan (1992) reported that the south western basement complex of Nigeria has been affected by two phases of deformation namely D_1, D_2, the first phase (D_1) produced tight to isoclinals folds while the second phase (D_2) is characterized by more open folds of variable style and large vertical NNE-SSW trending fault. Oluyide (1988) gave evidence that within the basement complex, tectonic deformation has completely obliterated primary structures except in a few places where they survived deformation (Okonkwo, 1992).

However, the aim of this research is to determine the litho-geochemical and petrogeneticcharacteristics of these quartzites with the objectives of determining its mineral potentials as well as its economic viability.

Location, Acessibility and Human Settlement:

The study area can be located within latitudes $7^0 43'44''$N to $7^0 47'38''$N and longitudes $4^0 54'20''$E to $4^0 57'40''$E respectively (Fig.1).The surrounding townsinclude Aramoko and IjeroEkiti. The area is made accessible by good, road network which makes accessibility to the outcrops easier. Also, the villages and towns around and within the study area are interconnected with minor roads and footpaths. Also, linear andnucleated pattern of settlement predominates in the study area.

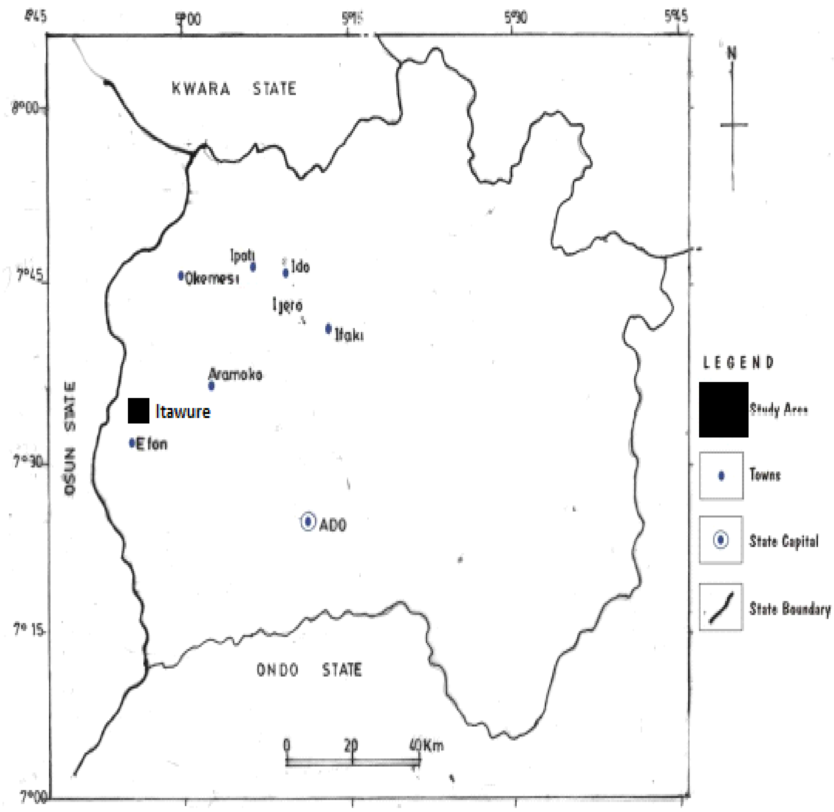

Figure 1: Location Map of the study area

Topography and Drainage:

The eastern part of the study area is dominated by prominent north-south trending ridges underlain by quartzites and quartz-schist, constituting the EfonPsammite Formation. This ridge is an excellent structural marker that delineates the Okemesi Fold Belt. Less prominent ridges associated with the Psammites are also present in the southeastern part of the area. There are isolated hills which are underlain by rocks of the Older Granite suite in the northwestern part of the area. The hilly parts, described, are separated by a dissecting peneplain underlain by pelitic schist, gneiss and migmatite.The drainage pattern in the southeastern part of the area where the topography is dominated by a series of ridges is the trellis type.

This suggests that the drainage here is structurally controlled. In the other parts of the study area, the drainage pattern is dendritic. (Fig.2)

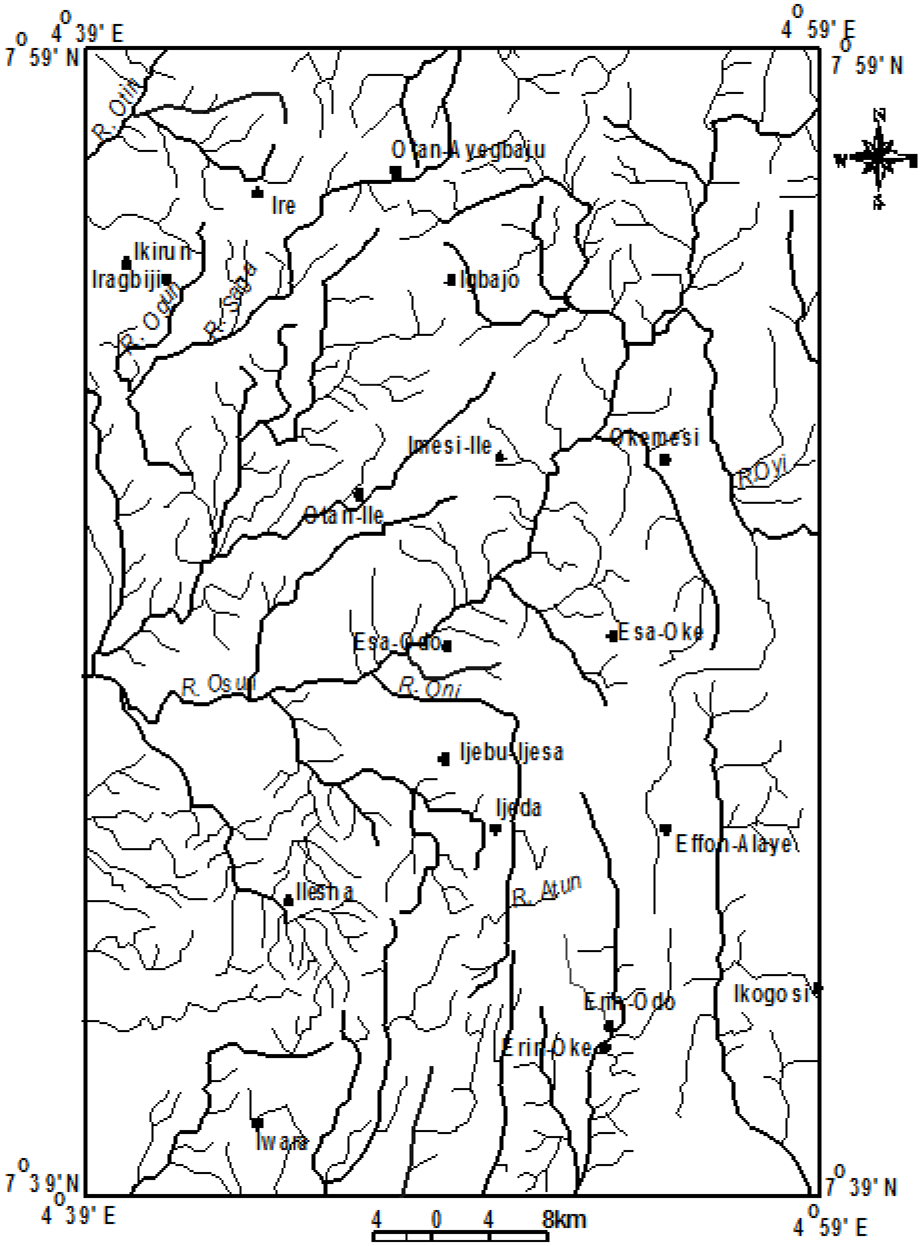

Figure 2: Drainage map of the study area (After Ayodele,2010)

Local geology of the area:

The study area lies within the Ilesha schist belt which is part of the basement complex of southwestern Nigeria. The Ilesha schist belt is divided into two segments of contrasting lithologies which are separated by the major fault zone “Ifewara fault” (Hubbard, 1975), namely the eastern and western segments.The western segment is underlain by amphibolites, amphibolites schist, quartz schist, associated pegmatites and gneisses, while the eastern segment of the schist belt in which the study area lies is referred to as “EffonPsammite formation”. The EffonPsammite Formation is made up of quartzite, quartz schists andquartzo-feldsparthic gneisses with minor iron rich schists and granulites which is about 180km in a general NNE-SSW direction showing thickness of quartzite due to overthrusting of theEfonpsammites (Fig.3). In addition, the eastern and western part of the study area is also an area of undifferentiated schists. Among the lithologies described are epidorites, amphibolite schist and talcose rocks which may be of volcanic origin. The association of volcanic and clastic rocks suggests a eugeosynclinal environment of deposition (Hubbard et al, 1966; Deswardt 1953 andDempster, 1967. However, the quartzites in this area are pelitic because they are metamorphosed from sandstone and tend to form good topographic features with bands of long-hogback ridges around Okemesi through Itawure and extending to Aramoko, with an elevation of approximately 100mabove the surrounding terrains.There are two varieties of quartzite mapped in the study area which are the massive quartzite and schistose quartzites. The texture ranges from medium-fine grained and the colours vary from purple, brown, yellow to milky, which has been subjected to at least three deformational episodes (Oyawoye 1972) such as fracturing, faulting and folding (Fig.4).

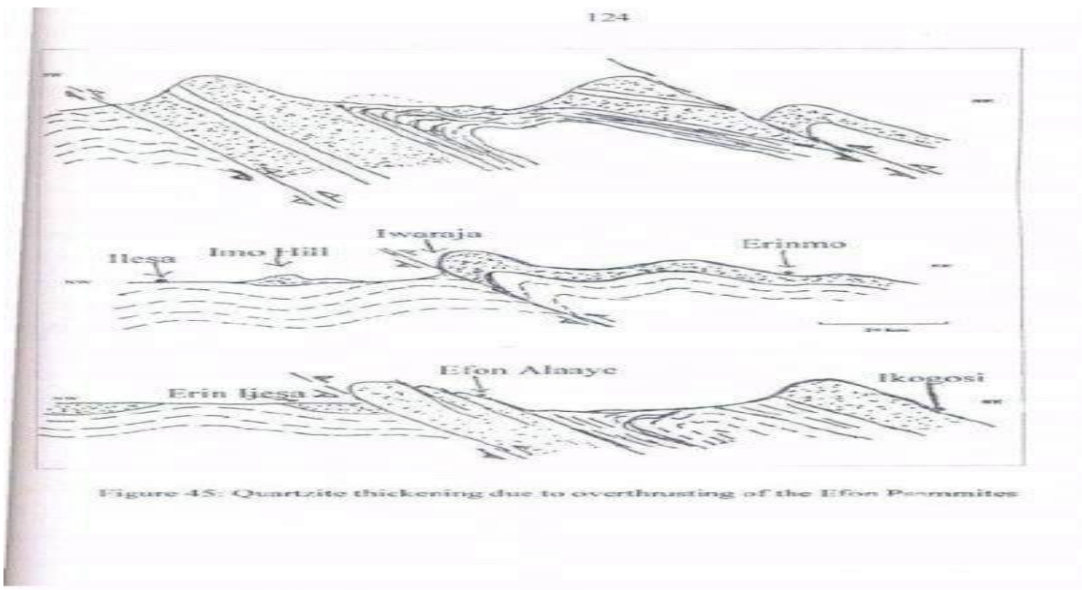

Figure 3: Quartzite thickening due to overthtrusting of the EfonPsammite (after Odeyemi,1993)

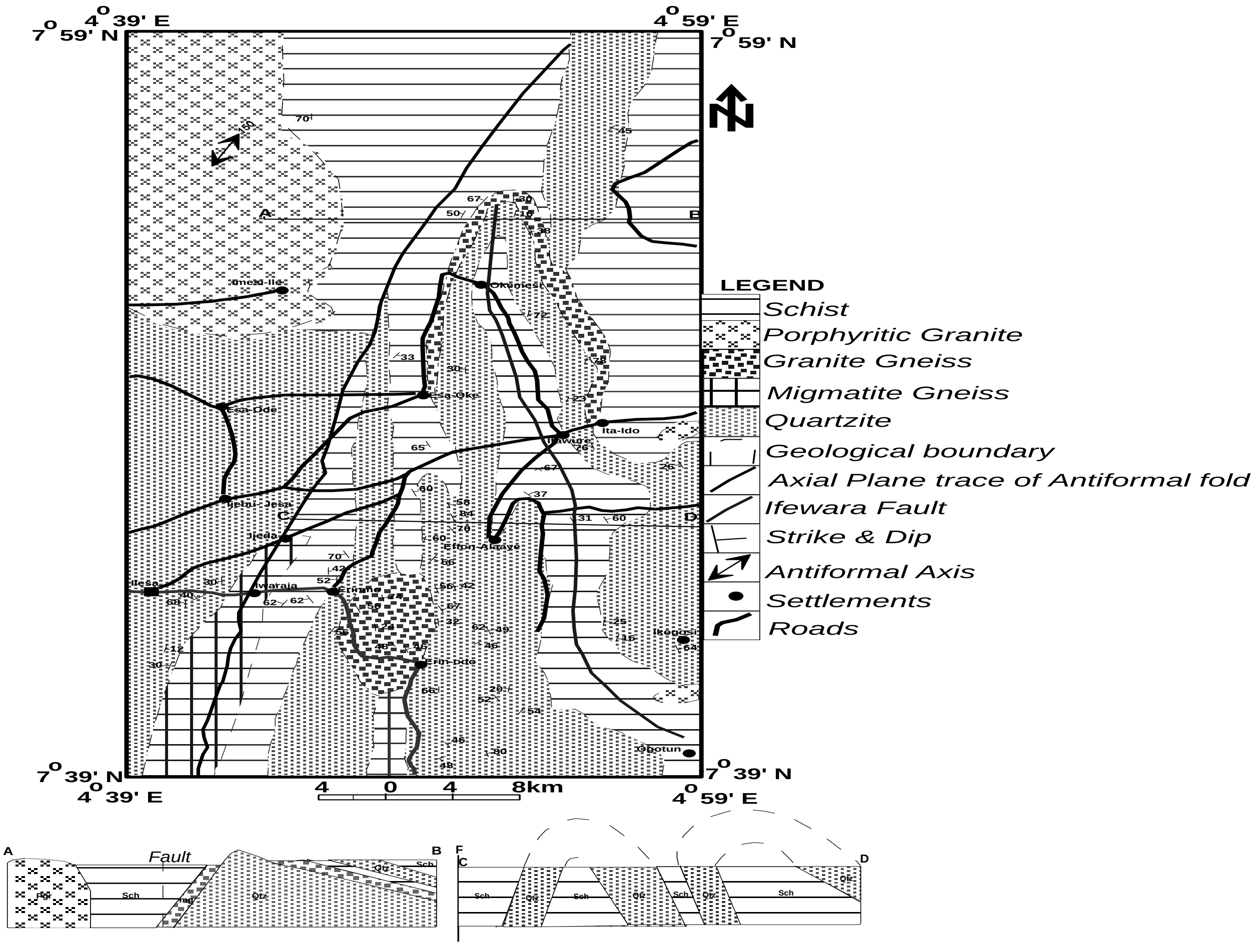

Figure 4: Geological Map of the study area (After Ayodele,2010)

Method of Study:

Topographic map sheet of Ilesha 243 N.E at a scale of 1:50,000 were acquired for the purpose of this research to serve as guide map to locating the outcrops as well as for geologic field mapping and collection of rock samples. Sixteen fresh quartzite samples consisting of massive and schistose types were collected randomly from four locations namely; Itawure, Efon-Alaaye, Ido-ile and Okemesi respectively and ten (10) samples were systematically selected for geochemical analysis, after which they were labeled accordingly to avoid mix up. The location of each outcrops were determined with the aid of a Global Positioning Systems (GPS) and the lithologic and field description of each samples were correctly recorded in the field notebook. The photographs and associated structures on the quartzites are shown in Figs 5-10 respectively.The samples were bagged and transported to Petroc Laboratory, No.2, Shasa Road, Ibadan, where it was pulverized and crushed using standard procedures and were later digested using the total digestion method. 30g of the digested samples were packaged into containers provided and properly labeled, and were sent to ACME Laboratories, East Vancouver, Canada for geochemical analysis to determine the major oxides and rare earth elements using Multi-Collector High Resolution Inductively Coupled Mass Spectrometry (MC-ICP-MS).

Figure 5: Photograph of Efon Quartzite s displaying jointing

RESULTS AND DISCUSSION

The results of various geochemical analyses and statistical evaluation performed on the raw geochemical data from the study area (Itawure) and the surrounding localities (EffonAlaaye, Ido-Ile and Oke-mesi) are presented in Tables 1-10 respectively.

Location 1 (Itawure):

This location is dominated by massive quartzites with varying coloursranging from reddish brown, brownish, milky to brownish with yellow specks and grey colourations (fig.6). The texture also varies from medium to coarse grained and fine to medium grained size (Table.1). The mineral composition of the samples in this location includes quartz, feldspar, tourmaline and mica with impregnations of some transition elements which could be responsible for the colour variations in the quartzites (Fig.7). The structures mapped are basically fractures, joints and minor crenulations (fig.6). The quartzites are also jointed and they display several joint sets. Some of the samples in this location have smoky appearance which could be an entrapment of some gases within the crystal lattice of the quartzite.

Figure 6: Photograph of Itawure Quartzite displaying fractures

Samples	Latitude and longitude	Texture	Mineralogy	Strike and dip	Colour	Structure
A	$7^{0}43^{I}44^{II}$N $4^{0}57^{I}20^{II}$E	Fine to medium grained	Quartz tourmaline	347^{0} 60^{0}E	Greyish in colour	Jointed showing joints of weakness
B	$7^{0}41^{I}41^{II}$N $4^{0}54^{I}23^{II}$E	Powderish	Quartz and mica	295^{0} 12^{0}E	Brownish in colour	Jointed
C	$7^{0}43^{I}42^{II}$N $4^{0}57^{I}16^{II}$E	Fine to medium grained	Quartz, iron	316^{0} 69^{0}E	Brownish in colour	Jointed
D	$7^{0}43^{I}42^{II}$N $4^{0}57^{I}15^{II}$E	Fine to medium grained	Quartz feldspar biotite,trace element	316^{0} 68^{0}E	Greynish in colour	Jointed
E	$7^{0}47^{I}38^{II}$N $4^{0}57^{I}40^{II}$E	Fine to medium grained	Quartz, mica and trace element	226^{0} 50^{0}W	Greyish in colour	Folds, joints, dykes, crenulation, heamatite
F	$7^{0}43^{I}43^{II}$N $4^{0}57^{I}17^{II}$E	Fine to medium grained	Quartz, mica, iron	320^{0} 68^{0}E	Brownish in colour	Jointed
G	$7^{0}40^{I}15^{II}$N $4^{0}54^{I}42^{II}$E	Fine to medium grained	Quartz	225^{0} 26^{0}E	Whitish and brownish	Joint and fracture
H	$7^{0}40^{I}15^{II}$N $4^{0}54^{I}42^{II}$E	Fine to medium grained	Quartz	200^{0} 50^{0}E	Greyish in colour	Jointed
K	$7^{0}43^{I}43^{II}$N $4^{0}57^{I}26^{II}$E	Medium to coarse grained	Feldspar, mica and quartz	342^{0} 30^{0}E	Milky to brownish with yellowish speck	Jointed
L	$7^{0}43^{I}43^{II}$N $4^{0}57^{I}19^{II}$E	Medium to coarse grained	Feldspar mica and quartz	356^{0} 38^{0}E	Brownish in colour	Jointed

Table 1: Field Data Report

Sample A, C, D, F, K and L = Itawure (Location 1)

Sample G = Ido-Ile (Location 2)

Sample B and H = Efon (Location 3)

Sample E= Okemesi (Location 4)

Figure7: Photograph of Itawure Quartzite Showing brownish coloration

Location 2 (Ido-Ile):

The colours of the quartzite in this location are whitish and brownish, with fine to medium grain size. The mineral composition revealed higher percentage of quartz, while the outcrop is capped with thick lateritic cover which is 5m thick and covered with vegetation. The structures present are joints and fractures (Fig.8).

Figure 8: Photograph of Ido Ile fine-grained massive Quartzite

Location 3 (Efon):

The quartzites are brownish and are fine to medium grained. The mineral compositions of the sample are quartz, feldspar and mica. Field studies also revealed that the outcrops belong to the schistose types and prominent structures noticed on the outcrops are well developed joint systems (Fig.5).

Location 4 (Okemesi):

Okemesiquartzites have grayish colour with fine to medium grain size. The mineral compositions are quartz, mica with lateritic concretions in some places, which is an indication of ferruginization, a similar feature displayed in the quartzites at Itawure. Various structures displayed on the outcrop such as folds, crenulations, joints, veins, simple pegmatite intrusions (Figs9&10).However, the result of field examination on the various quartzites studied from the different locations combined with remote sensing evaluation of the Landsat™ imagery of the area revealed that tectonic deformation pervaded the entire area in the geologist past leading to several episodes of deformation resulting in fracturing, folding and faulting of the entire area (Fig.11).

Figure 9: Photograph of Okemesi Quartzite displaying folds

Figure 10: Photograph of foliations and veins on Okemesi Quartzite

Litho-geochemical and petrogenetic characteristics of the massive and schistose quartzites in Itawure, Effon-Alaaye, Ido-Ile and Okemesi area has been carried with the aim of determining the petrogenetic characteristics and their mineral potentials. The quartzites in these localities were chosen for this study because they have suffered from several episodes of structural and tectonic deformation. Recent remote sensing and geological studies carried out in some parts of the study area (Ayodele, 2010) revealed that these quartzites have been greatly affected more than any other rocks, by the impact of the Ifewara fault system, a transcurrent fault that runs from iwaraja through Ijeda to Okemesi (Odeyemi, 1992) resulting in the shattering of the quartzites and its eventual permeation with ore bearing fluids emanating from the loci of the fault and deposited along the fractures, shear zones and joints of the quartzites. Combined remote sensing studies with ground truth around Okemesi area revealed the existence of overturned antiformal and assymetrical folds (Fig.11) with other minor folds such as isoclinal folds, tight folds, synforms and a major antiform (Ayodele, 2010) with overthrusting of the migmatites and gneisses with the quartzites.

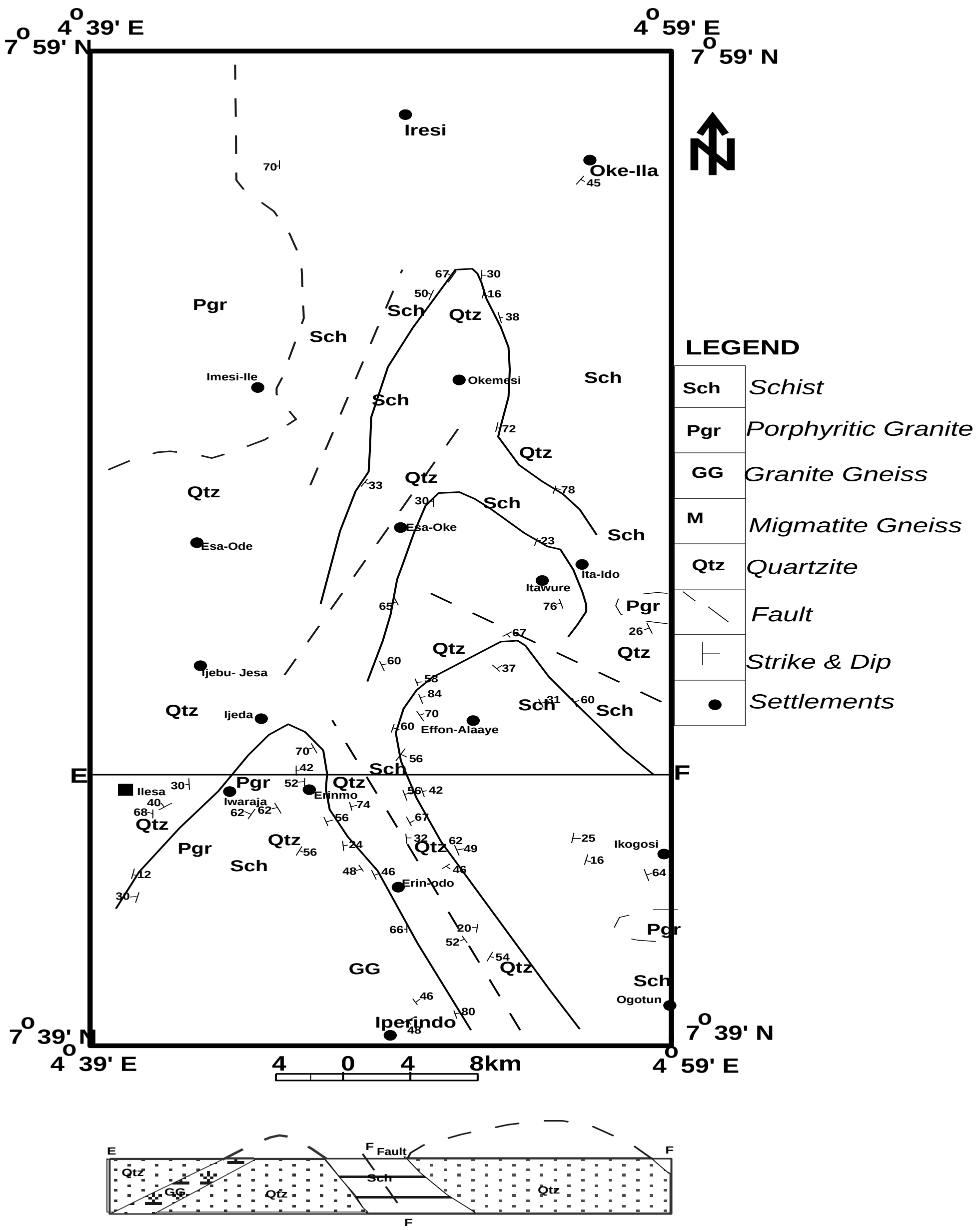

Figure 11: Structural map of the study area from Landsat ™ and Groundtruth(Ayodele,2010)

Major element analysis revealed that Silica (SiO_2) is the most abundant element with values ranging from 77.71-97.85% and an average value of 94.4%. Al_2O_3, Fe_2O_3, MgO, CaO and Na_2O have values ranging from 1.04-11.47%, 0.02-0.50%, 0.00-1.16%, 0.03-0.44% and 0.04-0.67% with average values of 2.10%, 0.26%, 0.14%, 0.10% and 0.17% respectively. Also K_2O, TiO_2, P_2O_5 and MnO have values ranging from 0.07-5.45%, 0.02-0.38%, 0.01-0.13% and 0.00-0.03% with average values of 0.80%, 0.09%, 0.03% and 0.00% correspondingly. The analysis of the raw geochemical data for the study area showed that Ba has the highest part per million compositions with values ranging from 101.1-13.0ppm and average value of 38.61ppm. V, La, Cr, ZrCe and Sn have values ranging from 4.0-0.0ppm, 44.0-5.9ppm, 4.0-1.0ppm, 29.2-2.1ppm, 63.0-7.0ppm and 2.4-0.0ppm with average values of 2.09ppm, 19.09ppm, 2.65ppm, 10.71ppm, 25.11ppm and 0.74ppm respectively. Other rare earth elements analyzed include Y, Nb, Li and Rb which have their concentration in part per million (ppm), and their values range between 6.2-1.0ppm, 5.2-0.0ppm, 13.6-4.9ppm and 104.5-0.0ppm and average values of 2.50ppm, 0.87ppm, 7.87ppm and 18.33ppm respectively (Tables 2, 3, 4,5 and 6).

Major Elements	**Sample A (%)**	**Sample B (%)**	**Sample C (%)**	**Sample D (%)**	**Sample E (%)**	**Sample F (%)**	**Sample G (%)**	**Sample H (%)**	**Sample K (%)**	**Sample L (%)**	**Range (%)**	**Average (%)**
SiO_2	97.15	95.90	93.96	96.28	77.71	96.08	97.58	95.25	97.85	96.46	97.85-77.71	94.4
Al_2O_3	1.70	2.51	3.91	2.06	11.47	2.37	1.05	2.78	1.04	2.14	11.47-1.04	2.10
Fe_2O_3	0.10	0.13	0.02	0.24	1.19	0.13	0.10	0.11	0.50	0.12	0.50-0.02	0.26
MgO	0.01	0.03	0.02	0.08	1.16	0.02	0.03	0.02	0.00	0.01	1.16-0.00	0.14
CaO	0.03	0.06	0.04	0.06	0.44	0.09	0.15	0.05	0.06	0.05	0.44-0.03	0.10
Na_2O	0.10	0.06	0.04	0.05	0.67	0.07	0.04	0.05	0.05	0.55	0.67-0.04	0.17
K_2O	0.10	0.27	0.07	0.15	5.45	0.60	0.23	0.55	0.07	0.10	5.45-0.07	0.80
TiO_2	0.07	0.03	0.15	0.03	0.38	0.08	0.03	0.02	0.04	0.09	0.38-0.02	0.09
P_2O_5	0.02	0.02	0.03	0.03	0.13	0.01	0.02	0.03	0.02	0.03	0.13-0.01	0.03
MnO	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.03-0.00	0.00

Table 2: Major Elements

Sample A, C, D, F, K, L = Itawure Quartzite

Sample B and H = Efon Quartzite

Sample E = Okemesi Quartzite

Sample G = Ido-Ile Quartzite

Sample H = Efon Quartzite

Rare Earth Elements	Sample A (ppm)	Sample B (ppm)	Sample C (ppm)	Sample D (ppm)	Sample E (ppm)	Sample F (ppm)	Sample G (ppm)	Sample H (ppm)	Sample K (ppm)	Sample L (ppm)	Range (ppm)	Average (ppm)
V	2.0	2.0	3.0	0.0	2.9	4.0	2.0	2.0	1.0	2.0	29.0-0.0	4.70
La	15.4	5.9	17.2	18.9	37.2	14.6	44.0	9.4	13.4	14.9	44.0-5.9	19.09
Cr	2.0	3.0	3.0	2.0	2.5	4.0	4.0	3.0	1.0	2.0	4.0-1.0	2.65
Ba	16.0	39.0	13.0	26.0	101.1	36.0	46.0	77.0	15.0	17.0	101.1-13.0	38.61
Zr	3.7	7.0	29.2	13.5	28.2	2.1	8.5	8.7	2.1	4.8	29.2-2.1	10.78
Ce	30.0	11.0	31.0	36.0	63.0	25.0	7.0	18.0	25.0	25.0	63.0-7.0	27.10
Sn	0.9	-	0.7	0.3	2.4	1.0	-	-	1.3	0.8	2.4-0.0	0.74
Y	1.9	1.8	2.6	2.9	6.2	3.0	1.0	2.3	1.5	1.8	6.2-1.0	2.50
Nb	0.5	-	0.7	0.6	5.2	0.9	-	-	0.3	0.5	5.2-0.0	0.87
Li	16.5	5.3	5.2	4.9	13.6	6.5	3.7	5.1	9.8	8.1	13.6-4.9	7.87
Rb	6.2	1.0	5.0	21.0	104.5	18.1	-	12.8	6.3	8.4	104.5-0.0	18.33

Table 3: Rare Earth Elements

Sample A, C, D, F, K, L = Itawure Quartzite

Sample B and H = Efon Quartzite

Sample E = Okemesi Quartzite

Sample G = Ido-Ile Quartzite

Major Elements	Mean	Median	Standard Deviation	Skewness	Kurtosis
SiO_2	94.42	96.18	5.980	-2.955	9.026
Al_2O_3	2.10	2.255	3.057	2.739	8.015
Fe_2O_3	0.26	0.125	0.351	2.485	6.399
MgO	0.14	0.020	0.359	3.141	9.899
CaO	0.10	0.060	0.123	2.768	7.985
Na_2O	0.17	0.055	0.235	1.818	1.794
K_2O	0.80	0.190	1.659	3.085	9.631
TiO_2	0.09	0.055	0.108	2.469	6.552
P_2O_5	0.03	0.025	0.034	2.937	8.999
MnO	0.00	0.000	0.009	3.162	10.0

Table 4: Statistical evaluation of major elements

Rare Earth Elements	Mean	Median	Standard Deviation	Skewness	Kurtosis
V	2.00	2.00	1.091	-0.232	1.023
La	19.09	15.15	12.03	1.417	1.211
Cr	2.65	2.75	0.944	-0.044	-0.321
Ba	38.61	31.00	29.42	1.348	1.098
Zr	10.71	7.75	10.05	1.310	0.408
Ce	25.11	25.00	15.45	1.277	2.939
Sn	0.74	0.75	0.745	1.162	1.756
Y	2.50	2.10	1.442	2.105	5.443
Nb	0.87	0.50	1.553	2.922	8.902
Li	7.87	5.90	4.224	1.252	0.580
Rb	13.33	7.35	31.03	2.887	8.702

Table 5: Statistical evaluation of Rare earth elements

Sample ID	Mo	Cu	Pb	Zn	Ag	Fe	Bi	Cr	Tl	Ni	Nb
A	0.61174	1.37642	1.31088	3.67045	0.61174	1.22561	1.83523	1.22348	0.61174	3.05871	1.01957
B	0.41433	1.64251	3.01867	2.48597	0.41433	1.07912	0.41433	1.24298	0.41433	3.72895	0.69055
C	0.26597	0.43696	0.75993	1.0639	0.26597	3.30381	0.26597	0.79792	0.26597	0.93091	0.62061
D	0.50484	0.50484	1.47845	0.50484	0.50484	2.42741	0.50484	1.00967	0.50484	0.50484	1.00967
E	0.18134	0.46305	0.97792	1.54136	0.09067	2.16164	0.09067	2.2667	0.12694	4.35207	1.57158
F	0.4388	1.33208	0.4388	0.87761	0.4388	1.14286	0.4388	1.75521	0.4388	2.19401	1.31641
G	1.98088	1.52103	3.46654	1.98088	0.99044	1.98431	0.99044	3.96176	0.99044	4.45698	1.65073
H	0.37409	0.86842	1.3093	0.74817	0.37409	0.82442	0.37409	1.12226	0.37409	0.74817	0.37409
K	0.99996	1.53566	1.35709	0.99996	0.99996	1.0017	0.99996	0.99996	0.99996	2.49991	0.99996
L	0.48596	1.14549	1.07606	2.42982	0.48596	1.16833	0.48596	0.97193	0.48596	2.18684	0.80994

Table 6: Enrichment Factor of metals in the Quartzites

Sample A, C, D, F, K, L = Itawure Quartzite

Sample B and H = Efon Quartzite

Sample E = Okemesi Quartzite

Sample G = Ido-Ile Quartzite

Metals	Minimum	Maximum	Average	Standard deviation
Mo	0.18134	1.98088	0.62579	0.52501
Cu	0.43696	1.64251	1.08265	0.47655
Pb	0.4388	3.46654	1.51936	0.96546
Zn	0.50484	3.67045	1.6303	0.99966
Ag	0.09067	0.99996	0.51768	0.28855
Fe	0.82442	3.30381	1.63192	0.80324
Bi	0.09067	1.83523	0.64003	0.50845
Cr	0.79792	3.96176	1.53519	0.95733
Ti	0.12694	0.99996	0.52131	0.28275
Ni	0.50484	4.45698	2.46614	1.44431
Nb	0.37409	1.65073	1.00631	0.41068

Table 7: Statistical Summary of the Enrichment Factor

Class	EF <2	EF= 2- 5	EF=5-20	EF = 20-40	EF >40
Metals	Deficiency to Mineral Enrichment	Moderate Enrichmen t	Significant Enrichment	Very High Enrichment	Extremely High Enrichment
Mo	100	0	0	0	0
Cu	100	0	0	0	0
Pb	80	20	0	0	0
Zn	70	30	0	0	0
Ag	100	0	0	0	0
Fe	70	30	0	0	0
Bi	100	0	0	0	0
Cr	90	10	0	0	0
Ti	100	0	0	0	0
Ni	30	70	0	0	0
Nb	100	0	0	0	0

Table 8: Percentage enrichment factor of heavy metals in the Quartzites

A common approach to estimate how much rocks and sediments are impacted (naturally and anthropogenically) with heavy metal is to calculate the Enrichment Factor (EF). The EF of a heavy metal in sediment can be calculated with the following formula EF = [C_n(sample/Cnormalizer]Al/[Cmetal/Cnormalizer]control, where Cmetal and Cnormalizer are the concentrations of heavy metal and normalizer in sample and in unpolluted control. However, metals in the samples such as Ni, Fe, Zn and Pb show moderate enrichment in the quartzites of the study area (Tables 6,7,8 and Fig.12) while Index of Geo-accumulation (Igeo) has been used widely to evaluate the degree of metal contamination or pollution in terrestrial, aquatic and marine environment (Tijani et al., 2009). The Igeo of a metal in sediment can be calculated with formula: (Mediola et. al, 2008; Asaah and Abimbola, (2005) Igeo = Log2Cmetal/1.5Cmetal (control). For the study area, the index of geo-accumulation revealed metal concentration such as Pb, Zn, Fe, Cr, Ni and Nb in the samples are enriched from geogenic sources except Ni which have anthropogenic source of enrichment (Tables 9 and 10). However, the analyzed metals are pathfinder elements for gold which may be indicative of gold showings in the quartzites as reported by Anifowose and Borode (2007).

Sample	Mo	Cu	Pb	Zn	Ag	Fe	Bi	Cr	Tl	Ni	Nb	Al
A	-2.176	1.070	0.447	0.602	-2.176	5.212	-1.699	0.125	-0.778	-0.875	-1.176	7.519
B	-2.176	1.316	0.979	0.602	-2.176	5.326	-2.176	0.301	-0.778	-0.620	-1.176	7.688
C	-2.176	0.934	0.572	0.426	-2.176	6.004	-2.176	0.301	-0.778	-1.030	-1.030	7.880
D	-2.176	0.718	0.583	-0.176	-2.176	5.592	-2.176	0.125	-0.778	-1.574	-1.097	7.602
E	-1.875	1.426	1.149	1.054	-2.176	6.287	-2.176	1.222	-0.632	0.107	-0.159	8.348
F	-2.176	1.200	0.116	0.125	-2.176	5.326	-2.176	0.426	-0.778	-0.875	-0.921	7.663
G	-1.875	0.905	0.660	0.125	-2.176	5.212	-2.176	0.426	-0.778	-0.921	-1.176	7.309
H	-2.176	1.084	0.660	0.125	-2.176	5.253	-2.176	0.301	-0.778	-1.273	-1.398	7.732
K	-2.176	0.905	0.249	-0.176	-2.176	4.911	-2.176	-0.176	-0.778	-1.176	-1.398	7.305
L	-2.176	1.091	0.461	0.523	-2.176	5.291	-2.176	0.125	-0.778	-0.921	-1.176	7.619

Table 9: Geo-accumulation index of metals in the Quartzites

Sample A, C, D, F, K, L = Itawure Quartzite

Sample B and H = Efon Quartzite

Sample E = Okemesi Quartzite

Sample G = Ido-Ile Quartzite

Metals	Minimum	Maximum	Average	Standard deviation
Mo	-2.176	-1.875	-2.116	0.127
Cu	0.718	1.426	1.065	0.211
Pb	0.116	1.149	0.588	0.308
Zn	-0.176	1.054	0.323	0.388
Ag	-2.176	-2.176	-2.176	0.000
Fe	4.911	6.287	5.441	0.412
Bi	-2.176	-1.699	-2.128	0.151
Cr	-0.176	1.222	0.318	0.365
Ti	-0.778	-0.632	-0.764	0.046
Ni	-1.574	0.107	-0.916	0.445
Nb	-1.398	-0.159	-1.071	0.352
Al	7.305	8.348	7.667	0.298

Table 10: Statistical Summary of Geo-Accumulation Index

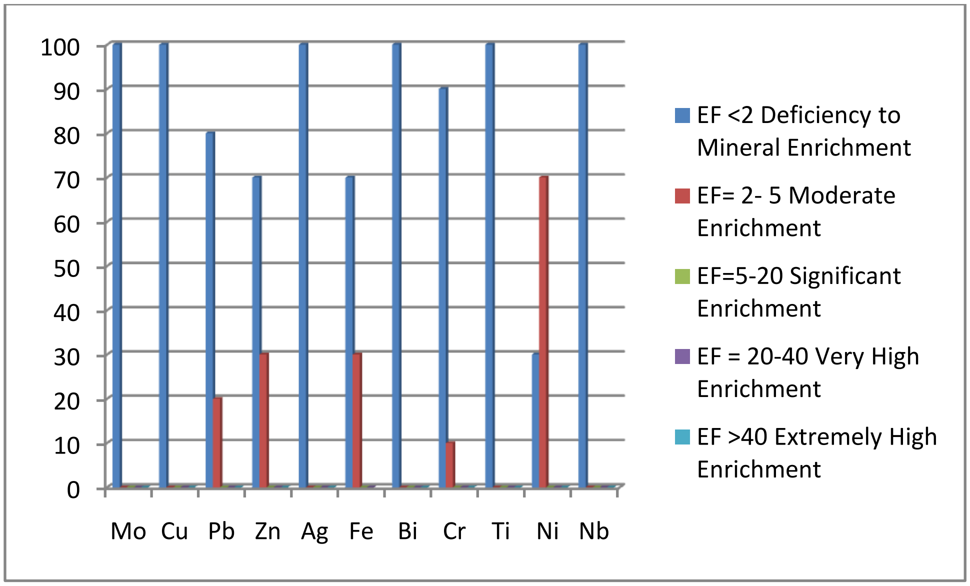

Figure 12: Distribution of metal content in the Quartzites

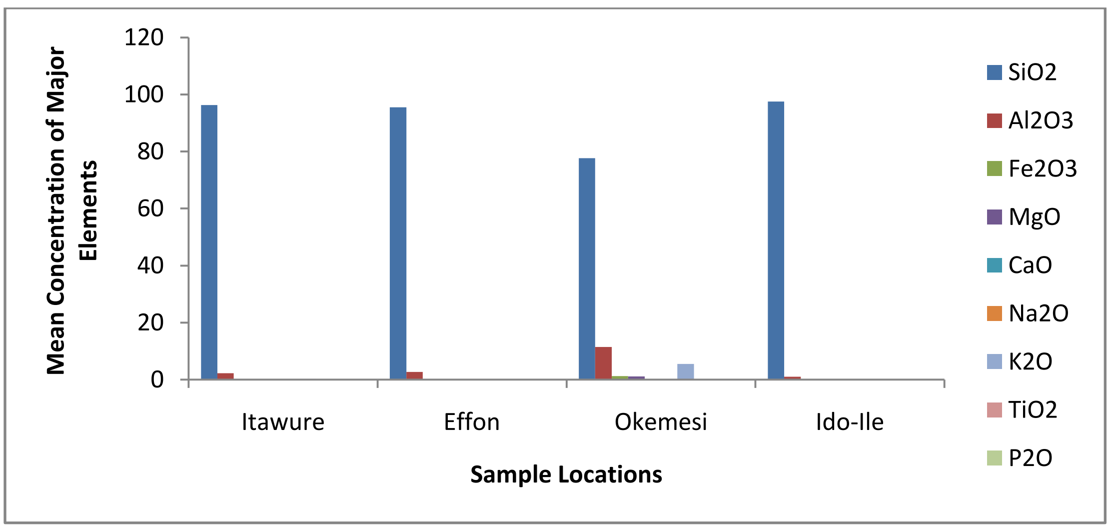

Figure13: Distribution of mean concentration of major elements against sample locations

It is also revealed that Itawurequartzites and Efon quartzite are positively correlated when compare to other locations (Table 11), while the quartzite are negatively correlated when the major elements (Al_2O_3, Fe_2O_3, MgO, Na_2O, CaO, K_2O, TiO_2 and P_2O_5) were plotted against silica (SiO_2), they showed negative correlation with SiO_2 indicating decrease in the concentration of the major elements with increasing SiO_2. Elements such as V, Ba, Li and Rb showed negative correlation with SiO_2 while other elements like La and Zr showed positive correlation (Table 12) when plotted against SiO_2.When the mean concentration of both major and rare earth elements is plotted against the sample locations (Fig.13), it is established that silica (SiO_2) is very high in all the samples at all the locations making about 96% of the chemical composition of the quartzites. Al_2O_3 is the second most abundant major element in all the locations while other major elements have insignificant concentration in all the locations. Also, from the plot of mean concentration of rare earth elements against the sample locations (Fig.14). Ba and Rb are very high in the samples taken at Okemesi than all other locations. Ce, Rb and La are averagely high in all the samples taken in all the locations. Elements such as V, Cr, Sn, Y, Nb and Li are very low in all the samples taken at all locations (Tables 13 and 14).

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
SiO_2	1									
Al_2O_3	-0.99578	1								
Fe_2O_3	-0.86888	0.831207	1							
MgO	-0.98177	0.961268	0.924139	1						
CaO	-0.92325	0.889096	0.889902	0.962761	1					
Na_2O	-0.72519	0.714804	0.664933	0.737722	0.68369	1				
K_2O	-0.98014	0.960901	0.911039	0.991685	0.963996	0.725624	1			
TiO_2	-0.95097	0.955345	0.806581	0.922348	0.861259	0.762891	0.911915	1		
P_2O_5	-0.97926	0.964584	0.89857	0.982537	0.920801	0.774253	0.965801	0.922108	1	
MnO	-0.98186	0.961692	0.927534	0.998186	0.961802	0.749568	0.993284	0.930855	0.981023	1

Table 11: Correlation Coefficients of Major Elements

	V	La	Cr	Ba	Zr	Ce	Sn	Y	Nb	Li	Rb
V	1										
La	-0.04953	1									
Cr	0.67082	0.390308	1								
Ba	0.096881	0.028897	0.529544	1							
Zr	0.056788	0.112256	0.161433	-0.14804	1						
Ce	-0.18871	-0.31882	-0.52306	-0.59078	0.281388	1					
Sn	0.181527	-0.2313	-0.49005	-0.70753	-0.23171	0.573898	1				
Y	0.218839	-0.43966	0.125471	-0.01208	0.334014	0.659377	0.131993	1			
Hb	0.33541	-0.14128	-0.05	-0.59092	0.192883	0.787664	0.658752	0.705149	1		
Li	-0.03974	-0.25393	-0.54588	-0.48005	-0.41507	0.381893	0.61277	-0.15084	0.224065	1	
Rb	-0.10992	-0.26724	-0.06635	0.100697	-0.07071	0.615801	0.162027	0.812758	0.567863	-0.09131	1

Table 12: Correlation Coefficients of Rare Earth Elements

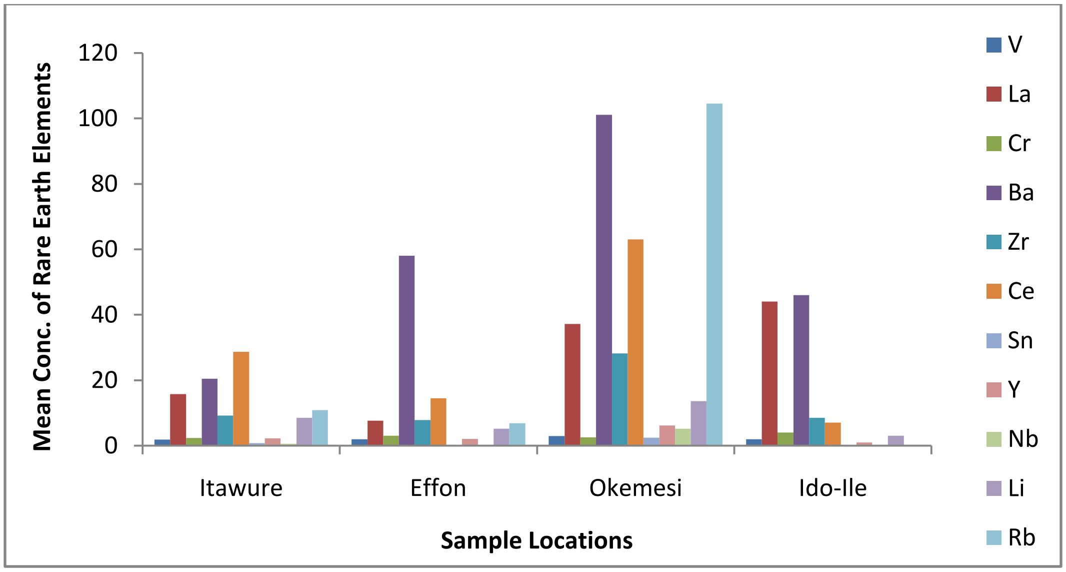

Figure 14: Distribution of mean concentration of rare earth elements against sample locations

Variation Diagrams for Major and Rare Earth Elements (Hacker Type)

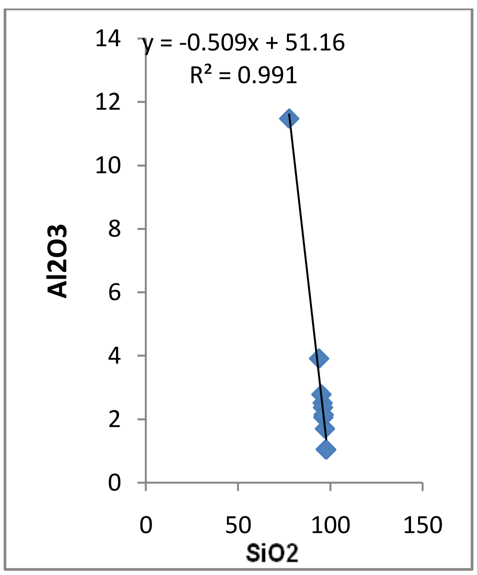

Figure15: Al_2O_3 againstSiO$_2$

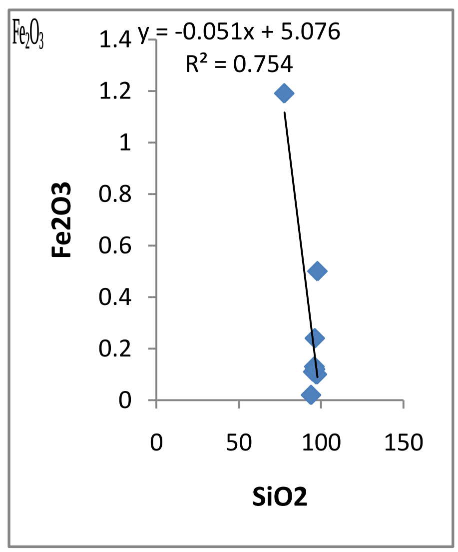

Figure 16: Fe_2O_3 against SiO_2

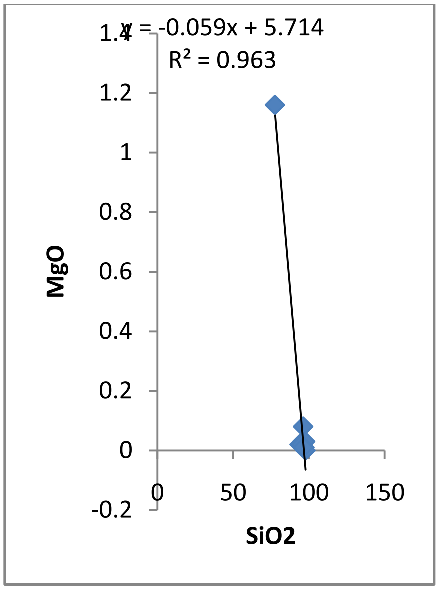

Figure 17: MgOaginst SiO_2

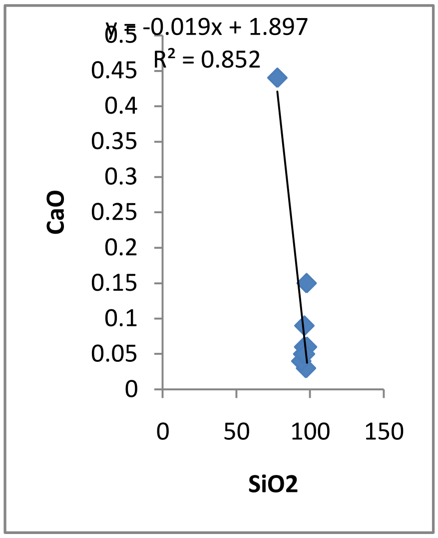

Figure 18: CaO against SiO_2

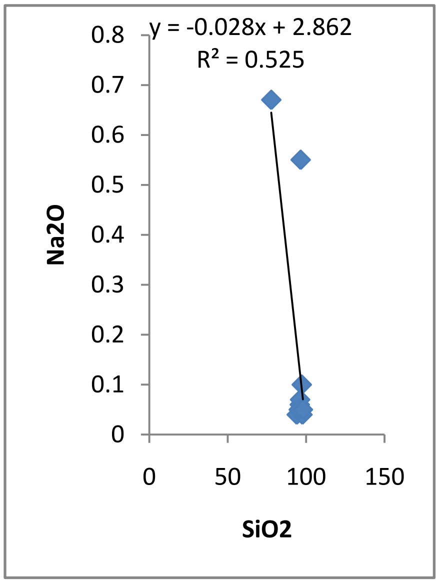

Figure 19: Na_2O against SiO_2

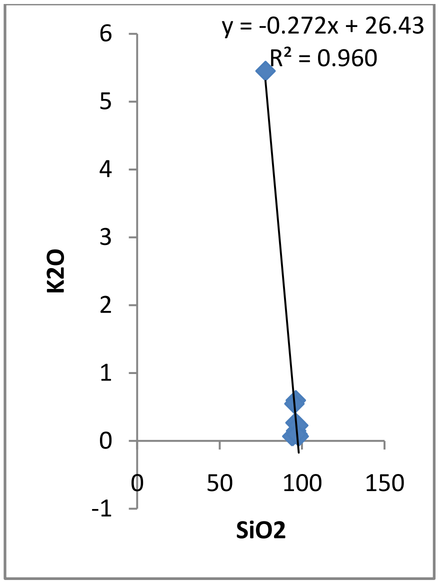

Figure 20: K_2O against SiO_2

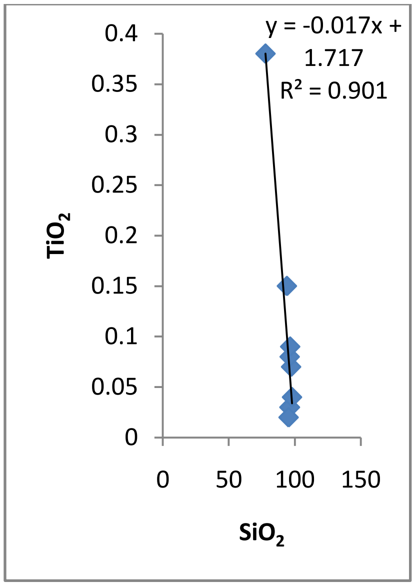

Figure 21: TiO_2 against SiO_2

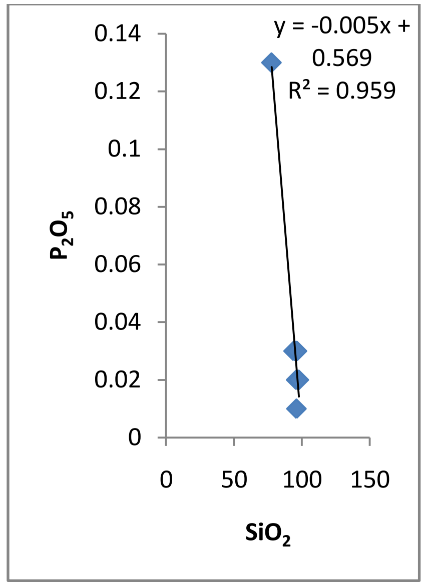

Figure 22: P_2O_5 against SiO_2

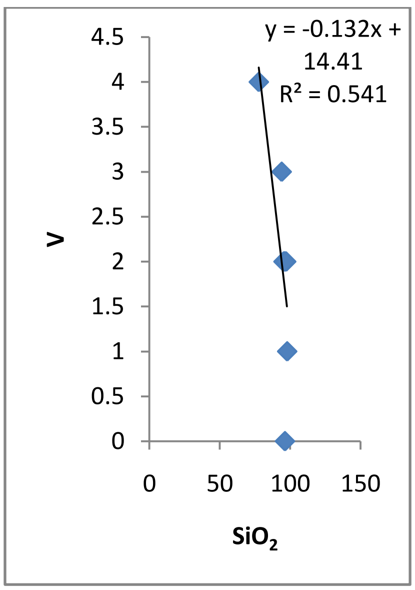

Figure 23: V against SiO_2

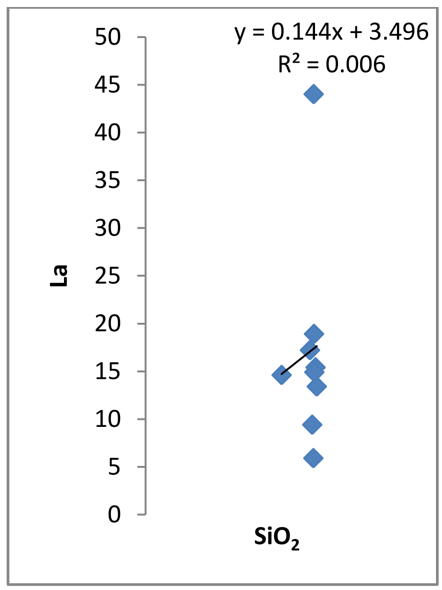

Figure 24: La against SiO_2

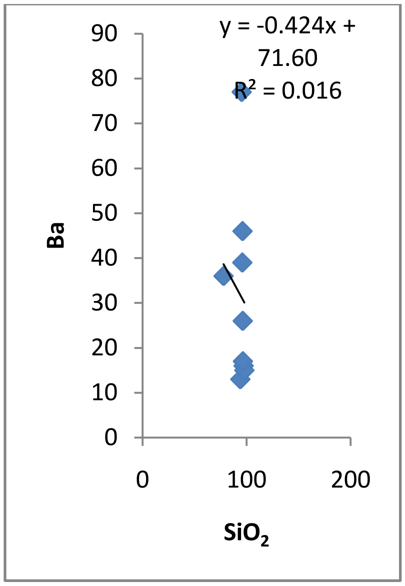

Figure 25: Ba against SiO_2

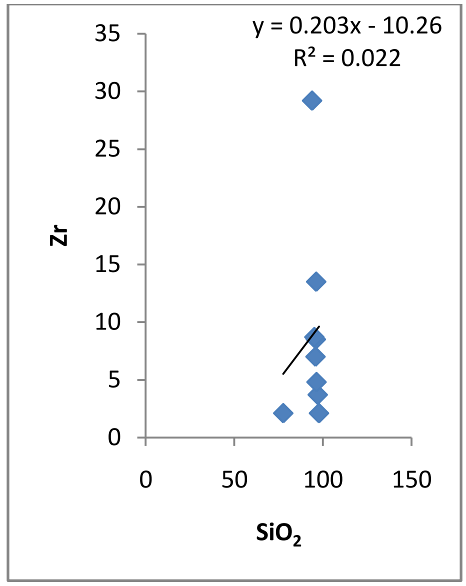

Figure 26: Zr against SiO_2

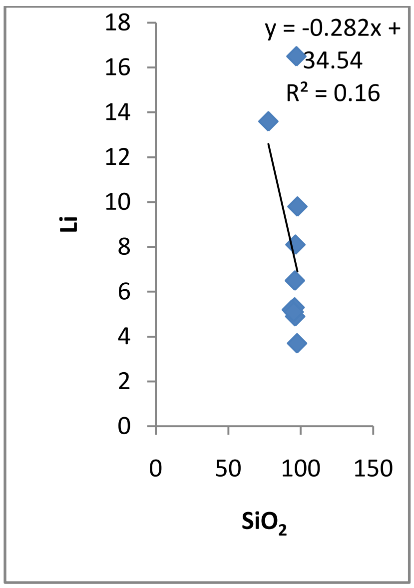

Figure 27: Li against SiO_2

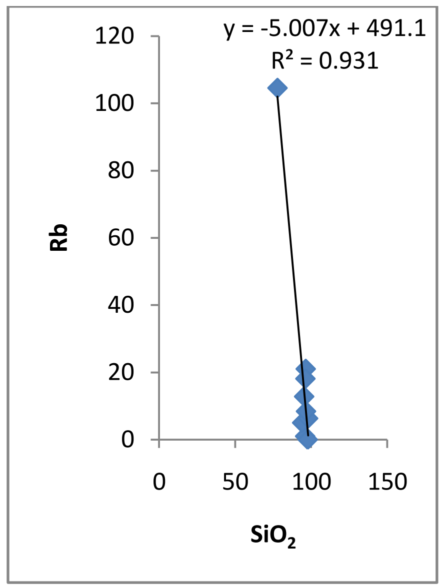

Figure 28: Rb against SiO_2

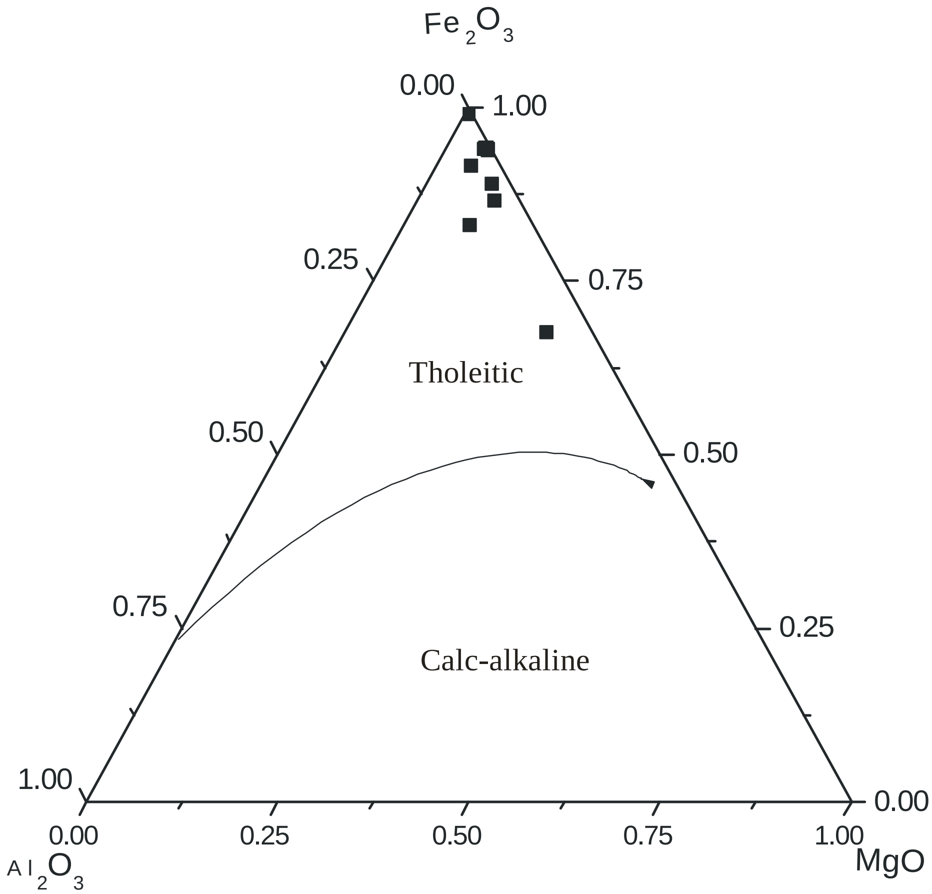

Figure 29: AFM diagram showing the geochemical plots of the Quartzites

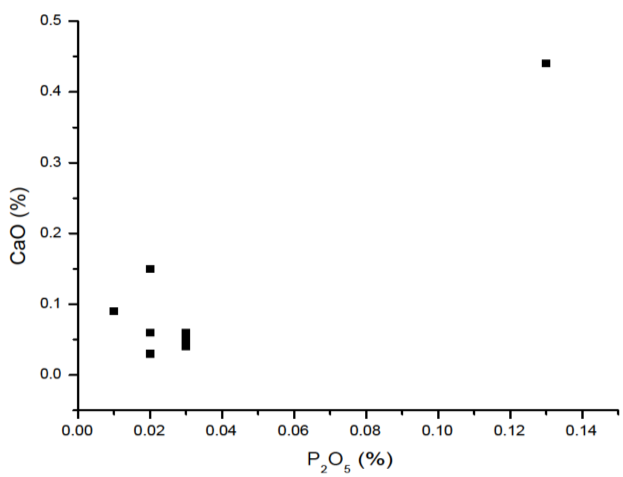

Figure 30: Plot of CaO against P_2O_5 for the Quartzites

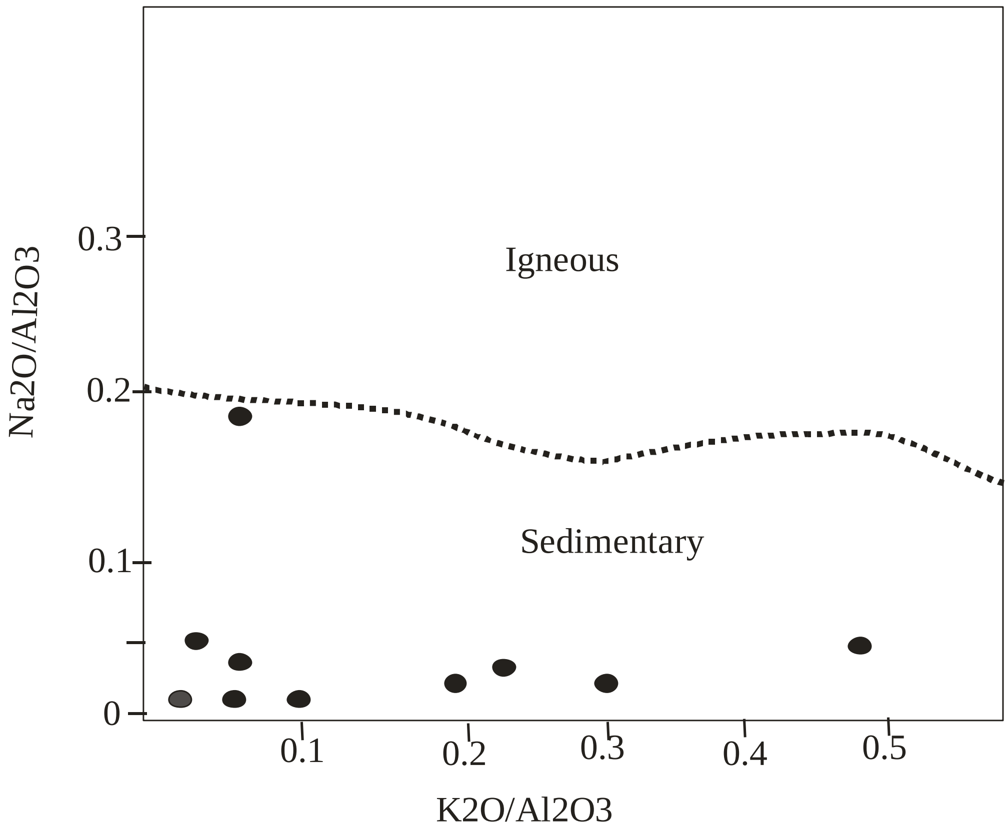

Figure 31: Plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 for the quartzites (After Garrels and Mckenzie, 1971)

The geochemical data are plotted on discriminatory diagrams to establish the geochemical evolution of the rock. On the plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 (After Garrels and Mckenzie, 1971) (Fig.31), all the ten samples plotted fell on the sedimentary field which indicated that these quartzites have a sedimentary origin, suggesting that they were formed as a result of metamorphism of a sedimentary protolith (sandstone) which was very rich in quartz. On the AFM diagram (After Irifine and Baragar, 1971) in figure 29, all the ten samples fell within the tholeitic field. Also, on the plot of CaO against SiO_2 (Fig.18), the concentration of CaO increases with increasing SiO_2 while on the plot of CaO versus P_2O_5 (Fig. 22), all the samples concentrated within the range of 0.0-0.2 on the CaO-axis and 0.0-0.02 on the P_2O_5-axis.

Based on the results presented, the quartzites of Itawure, Okemesi, Ido-Ile and Efon can be concluded to be of sedimentary origin as evidenced by the discriminatory diagrams

CONCLUSION

Field examination and geochemical evidences have provided useful indications for the acidic nature of the quartzites. All the quartzites samples analyzed are very rich in silica. Silica makes up about 94.4% of the bulk chemical composition of the quartzites and this implies that the rocks are acidic in nature and that they were formed from the metamorphism of sedimentary protolith (Sandstone) which was very rich in silica. This high content of silica is responsible for their hardness and their high resistance to weathering which could make them useful materials for construction and ornamentation purposes.

The result also showed that the quartzites of the study areas are rich in rare earth elements like, Barium and Rubidium and moderately rich base metals such as Ni, Fe and Zn and highly deficient of precious metals. Also the base metals detected in the quartzites are indicators of gold which could serve as link to gold showing in the quartzites and possible sulphide mineralization since there is moderate enrichment of Pb (20%) in the samples (Table8, Fig.12). Furthermore, the rocks are also of tholeitic source which were formed from the metamorphism of a sedimentary protolith (Sandstone). Also the quartzites have undergone several episodes of deformation in the geologic past, resulting in their shattered nature and have also been affected by the thermo-tectonic episodes of the Ifewara fault system.

However, since the study area is a manifestation of Precambrian deformation, there is need to carry out detailed structural mapping of the area in order to map out the nappe structures and also evolve a realistic model of evolution for the study area. In addition, a detailed geochemical survey of the area using soils, stream sediment and borehole(water) samples is desirable in order to establish the occurrence of gold, since the study area is an extension of Ife/Ilesha schist belt.

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