Geochemistry And Origin Of Metasediments From TheKazaure Schist Belt In The Precambrian Basement Of NW Nigeria

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ABSTRACT

On the basis of major and trace element characteristics of metasediments (mica schists and quartzites) from the Kazaure schist belt in the Pan-African domain of NW Nigeria, it has been indicated that shale-greywacke sediments were their protolith. Further evaluation of the rare earth element contents in the mica schists from the Kazaure area has also indicated that clay sediments were their protolith. Their source area was the upper crust where acid magmatic rocks are dominant. The quartzite occurring in association with the mica schist differs in having very high values of SiO_2 and very low values of TiO_2 and Al_2O_3. The mica schist samples are lowest in SiO_2 but have the highest CaO content of all the metasediments. The reults from this geochemical study are corroborative and have confirmed observed field and thin section geologic observations that the protolith of the metasediments are rich in clay materials.

INTRODUCTION

Metasediments comprising mica schists and quartzites represent typical lithologies of the Nigerian crystalline basement complex[1,2,3]. Their spatial distribution in the Kazaure Schist Belt was mapped and presented in maps on a 1:100 000 scale[4]. The metasediments are characterised by distinct metamorphic foliation defined by muscovite, biotite, quartz and feldspars. The quartzite samples are essentially composed of quartz (96% of the rock by volume) with minor amounts of muscovite and opaque minerals. The mica schist samples are composed of variable amounts of K-feldspar, plagioclase, muscovite, biotite and quartz. Accessories include zircon, apatite, sphene and opaque minerals.

Different workers have adopted, in each case, a systematic approach to studying polydeformed and polymetamorphosed terrains[5,6]. Such studies involve geochemical analysis for the major, trace and rare earth elements (REE) of rocks in the terrains, among others. These are in turn used as guides in interpreting the ancient tectonic environments of such terrains.

Such a systematic approach is hereby employed in the study of the metasediments from Kazaure Schist Belt. Samples of the metasediments were prepared for whole-rock geochemical analyses. All of these were analysed for major and trace elements while only the mica schists samples have been analyzed for ten REE. In this paper, we present the result of the geochemical characterisation of the metasediments from Kazaure area.

EXPER I MENTAL

Sample collection and preparation

2-8 kg representative samples of the quartzites (UD26, UD4O, UD72, UD62, UD65) and mica schist (UD1O, UD36, UD48, UD57, UD59, UD6O) were collected from different localities exhibiting fresh rocks. Whole-rock samples preparation was carried out in the Geochemical laboratories of the Department of Earth and Planetary Sciences, McGill University, Montreal, Canada. Specimens were initially washed, dried and split into smaller fragments using a hydraulic splitter. These fragments were then crushed and reduced to powder in an agate barrel Tema grinder for about 22 minutes. The powdered specimens were used for the preparation of fused glass beads and pressed pellets for

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several chemical analyses using the geochemical analytical procedures applied at McGill University, as described below.

Fused glass beads were prepared for X-ray fluorescence (XRF) analysis of major elements using 0.40g of the sample powders mixed with borax flux (mixture of prefused lithium tetraborate, lithium metaborate and LiF), and ignited for 20 mins at 1200°C in graphite crucibles. In addition, about 8g of the rock powder from each sample was used to prepare pressed pellets for trace elements determination. The rock powder was bound using 'movial' as a binder and later pressed under hydraulic pressure. The pellets were then dried at 110°C for about 5 hours.

For REE determination 0.50g mica schist sample powder was mixed with 10.00g lithium metaborate ($LiBO_2$) in a platinum crucible. The mixture was fused at 1000°C in a Sanyo 551 electric muffle furnace for 30 mins and the resulting bead dissolved in 110ml dilute HCl. The REE were then eluted in an ion exchange column using 100 ml of 6M HNO_3 containing 0.63g of oxalic acid dihydrate[7]. The eluate was dried and redissolved in 5 ml of 10% HNO_3 and analysed.

Analytical Procedures

All the major elements (wt.%) and trace elements concentrations were analysed by XRF using a Phillips PW2400 XRF Spectrometer. An automated Spectrometer with data control relying on a Phillips X40 software package was used for the analysis. The major elements were analysed from the fused beads prepared from ignited whole-rock samples as described earlier. The lower limits of detection for the major elements is 0.01% (100 ppm). Volatile constituents (H_2O and loss on ignition (LOI) were determined by drying the sample at 110°C (H_2O) followed by roasting in the Sanyo 551 muffle furnace at 1000°C.

The trace elements were determined by using sequential XRF analysis on pressed powder briquettes by comparing the samples absorptions with those of standards[8]. The lower limits of detection for the trace elements is 2 ppm. REE concentrations were determined using a Phillips 733 inductively coupled plasma atomic emission spectrometer (ICP-AES)[9].

RESULTS AND DISCUSSION

The whole-rock geochemical data obtained from the analysed rock samples were used to classify them in terms of origin and geotectonic setting. Geochemical discrimination between the mica schists and the quartzites is easily achieved in spite of the uncertainties inherent in their field relationships (Tables 1 and 2). The quartzite samples contain the highest values of SiO_2 and lowest values of TiO_2, Al_2O_3, total iron and MgO compared to the values of these in the mica schist samples.

Table 1: Chemical (weight percent) and trace element (parts per million) composition of the Mica Schist from the Kazaure Schist Belt area.

	Sample no.					
	UD10	UD36	UD48	UD57	UD59	UD60
CHEMICAL						
SiO_2	71.00	69.20	64.20	67.04	62.07	65.85
TiO_2	1.08	1.34	1.22	0.80	1.07	0.92
Al_2O_3	11.42	13.59	18.98	16.07	17.05	15.48
$(Fe_2O_3)T$	7.50	5.49	6.59	4.53	6.49	4.89
MnO	0.06	0.16	0.17	0.18	0.33	0.07
MgO	1.92	2.38	1.30	2.37	2.83	3.30
CaO	1.07	1.09	1.09	2.09	1.83	2.73
Na_2O	2.72	1.69	1.57	2.02	1.69	2.57
K_2O	2.86	3.40	2.89	2.72	3.81	2.89
P_2O_5	0.22	0.20	0.26	0.23	0.26	0.27
LOI	1.16	1.44	1.59	2.16	1.69	0.79
Total	100.01	99.98	98.86	100.21	99.92	99.76
TRACE ELEMENT						
Nb	121	109	74	89	53	119
Zr	205	218	212	115	138	129
Y	15	11	14	25	24	26
Sr	221	234	288	258	238	277
U	22	44	54	78	62	89
Rb	256	230	271	196	189	111
Th	116	115	108	126	128	127
Pb	12	14	22	27	22	26
Ga	24	29	28	102	106	111

(Fe_2O_3) T = total FeO + Fe_2O_3

A systematic decrease of total iron and alkalis is noticeable as you move from the mica schist to the quartzites. An exception is in the total iron contents (48.59 and 44.53 weight %) of the two ferruginous quartzite samples (UD72, UD81) of Table 2. Of all the metasediments, the mica schist samples are lowest in SiO_2 but have the highest CaO content (Tables 1 and 2).

Table 2: Chemical (weight percent) and trace element (parts per million) composition of the Mica Schist from the Kazaure Schist Belt area.

	Sample no.					
	UD26	UD40	UD72	UD62	UD65	UD81
CHEMICAL						
SiO_2	89.44	81.99	41.20	84.90	86.85	44.04
TiO_2	0.08	0.34	0.22	0.07	0.29	0.26
Al_2O_3	4.42	9.50	5.98	8.05	6.26	6.07
(Fe_2O_3) T	1.50	1.49	48.59	0.49	0.99	44.53
MnO	0.16	0.06	0.07	0.33	0.27	0.18
MgO	0.39	1.58	0.30	1.33	0.48	0.37
CaO	0.27	0.69	0.20	0.83	0.73	0.32
Na_2O	0.72	1.20	0.57	0.69	0.79	0.62
K_2O	2.42	2.10	2.19	2.31	2.49	2.22
P_2O_5	0.02	0.06	0.06	0.26	0.07	0.23
LOI	0.16	0.46	0.59	0.69	0.79	1.16
Total	99.58	99.41	99.97	99.95	99.91	100.00
TRACE ELEMENT						
Nb	11	9	4	5	11	9
Zr	105	108	112	118	119	115
Y	15	11	14	24	26	21
Sr	132	147	206	138	135	198
U	22	44	56	22	39	18
Rb	56	30	71	89	91	76
Th	116	115	108	118	120	116
Pb	12	14	11	22	20	17
Ga	24	29	28	36	31	32

(Fe_2O_3) T = total FeO + Fe_2O_3

Compared with the quartzite, the mica schist samples have higher Al_2O_3, K_2O, and Na_2O. However, all the analysed metasediments of the Kazaure area are rich in alumina and their potash content is in excess of that of soda. Furthermore, MgO is in excess of CaO in these metasediments, possibly indicating the carbonate-free nature of their parent rock[10].

As for the trace elements (Table 2), apart from the mica schist samples which have the highest strontium contents among the metasediments, there is a general decrease in Sr with increasing SiO_2. Rubidium, zirconium and lead increase to a maximum at the composition of the mica schists, and then decrease in a fairly regular fashion to the fine to medium grained and massive quartzite varieties. All other trace elements [Yttrium, Niobium, and Uranium] decrease fairly regularly or have virtually identical values. Sample UD 52 has the lowest contents of Pb (11 ppm) and Nb (4 ppm) in the quartzites, but has the highest U (56 ppm) content (Table 3).

In addition to the field and petrographic evidence for the nature of the metasediments[4], geochemical criteria are also considered here. Several workers have used discrimination diagrams based on few elements or computed parameters to indicate the protolith of rocks[11, 12, 13]. For example, on an ACF diagram (Fig. 1), all the metasediments specimens plot in the metamorphic rocks field of shale-greywacke[11].

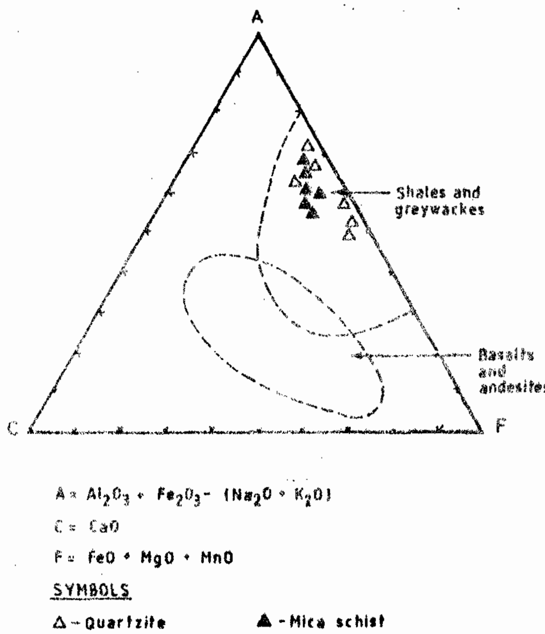

Fig. 1. The field of the Kazaure metasediments in an ACF triangular diagram after Miyashiro[11]

In addition, the SiO_2 and TiO_2 composition of the quartzite and mica schist specimens were plotted in a TiO_2 - SiO_2 discrimination diagram[12] In this diagram (Fig. 2), a clear sedimentary origin was also deduced for the metasediments. It has also been noted that there is an abundance of alumina and potash, generally in excess of soda in an average composition of shale[13]. These features are indicated in the Kazaure metasediments and, as such, this is a further evidence that the rocks falls within the range of analysed shales[14,15].

REE (Table 3) have a special importance in solving the protolith type of metamorphic rocks as

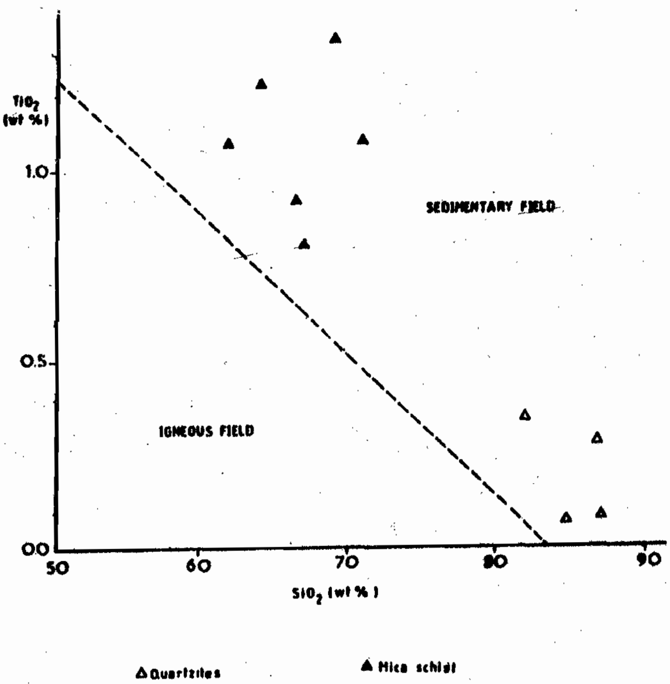

Fig. 2. TiO_2 versus SiO_2 discrimination diagram (after Tarney[12]). Dashed/line separates sedimentary from igneous rocks.

they are generally regarded as intact to chemical changes during diagenesis and metamorphism[16]. The normalized[17] REE in the Kazaure schists have revealed their protolith rock type and the character of their source area. N indicates the chondrite normalised concentrations.

All the samples have REE concentrations that are slightly enriched with respect to chondritic abundances (about 1-30X). Their chondrite normalized plotted distribution patterns are smooth curves of decreasing relative abundances towards the heavy Lanthanides (Fig. 3). A specific aspect best illustrated is the high La_N/Sm_N and low Gd_N/Lu_N ratios of the mica schists, ranging from 2.57 to 2.80, and from 1.20 to 1.27, respectively. This indicates the predominance of light REE over heavy ones in the Kazaure mica schists. In other words, the curves have a steep to moderate REE trend showing strong relative depletion of the heavy REE (HREE) relative to light REE (LREE).

All the specimens have small negative Eu anomalies (Eu/Eu^+ values of 0.59-0.69), indicating Eu depletion in the younger metasediments. The

Table 3: Weight Percent REE contents in mica schists from the Kazaure schist belt.

	Sample no.			
	UD1O	UD36	UD59	UD6O
La	18.37	24.21	29.43	17.45
Ce	45.15	49.20	53.31	43.91
Nd	23.24	25.44	26.83	22.81
Sm	4.31	5.13	6.34	4.32
Eu	0.93	0.99	1.06	0.89
Gd	3.96	4.59	4.14	3.74
Dy	4.23	4.56	4.67	3.93
Er	2.39	2.63	3.04	2.23
Yb	1.57	1.67	1.82	1.52
Lu	0.37	0.43	0.41	0.26
Total REE	104.50	123.00	126.00	108.86
CHONDRITE - NORMALISED				
La	55.5	73.1	88.9	52.7
Ce	51.9	56.6	61.3	50.5
Nd	37.0	40.4	42.63	5.1
Sm	21.6	25.7	31.7	21.6
Eu	11.8	12.6	13.5	11.4
Gd	14.5	16.6	15.1	13.7
Dy	12.6	13.6	13.9	11.7
Er	10.4	11.5	13.3	9.7
Yb	7.0	7.5	8.2	6.8
Lu	11.2	13.0	12.4	11.0
Total	234.0	276.0	296.0	227.6
La_N/Sm_N	2.57	2.84	2.80	2.44
Gd_N/Lu_N	1.27	1.27	1.20	1.25
Eu	17.00	20.00	23.00	17.00
Eu/Eu^+	0.69	0.63	0.59	0.67

curves of normalised REE contents themselves are similar to those of post-Archaen shales known throughout the world[17,18,19]. All post—Archaen clastic sedimentary rocks (of shale composition) have a negative Eu anomaly (with Eu/Eu^+ = 0.66) which is the average composition of the upper crust[17]. Eu^+ is the

Eu concentration obtained by a straight line interpolation between the concentrations of Sm and Gd.

By comparison, it is believed[17] that a lack of an Eu-anomaly ($Eu/Eu^{+} = 1.0$) or the presences of local positive Eu-anomaly indicates Archaen sedimentary rocks. On the other hand, a negative Eu-anomaly in post-Archaen clastic sedimentary rocks is attributed to detrital sources during the formation of Eu depleted feldspar granites after its formation by chemical fractionation[20].

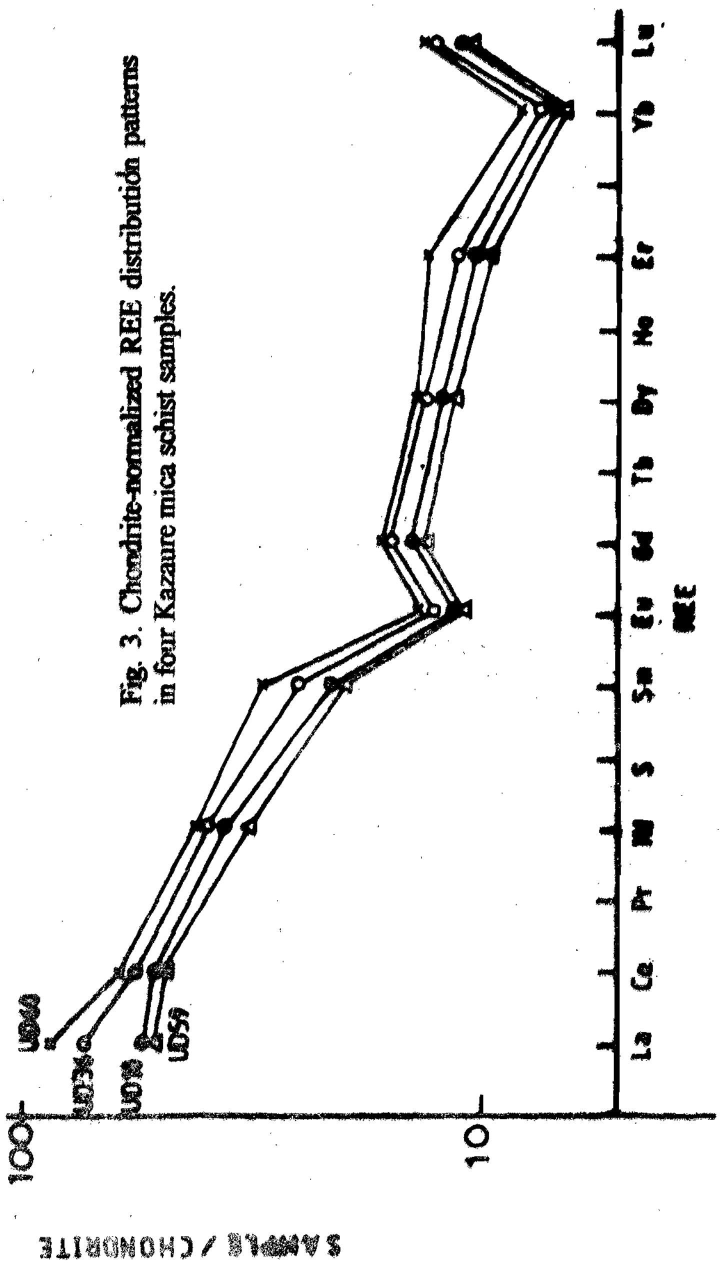

Fig. 3. Chondrite-normalized REE distribution patterns in four Kazaure mica schist samples.

The near equivalence of the REE pattern in the Kazaure schists to that of post-Archaen sedimentary rocks is important for understanding the genesis of the Kazaure schists. The comparable Eu/Eu^{+} values between the mica schists and the upper crust suggests that the rocks were derived from similar source areas with typical clay sediments. On the basis of the REE geochemical parameter, one can also conclude that the younger metasediments belong to the metamorphosed shale-greywacke sequence derived from the Continental Upper Crust where acid magmatic rocks are dominant[17,19].

CONCLUSION

The major and trace elements geochemical characterisation has shown that the mica schists and quartzites are derived from shale-greywacke sequences. The REE pattern in the mica schists has also proved that the protolith of the mica schist is represented by clay sediments (shales) from continental upper crust with the prevalence of acid magmatic rocks. Lastly, the suggested post-Archaen age of the metasediments in the Kazaure Schist Belt is in agreement with the suggested age of such metasediments in Nigeria.

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