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# Major And Trace Element Geochemistry Of The Clastic Sediments Of Yinkiong Group Of Yamne Vally, Arunachal Pradesh, India

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***ABSTRACT*** **- Major, trace and rare earth element (REE) studies have been conducted on the Yinkiong Group of rocks exposed along the Siang and Yamne River section, East Siang District, Arunachal Pradesh, to determine their provenance, tectonic setting and palaeoweathering conditions. Geochemically the sandstone samples are classified as sub lithic wacke with rich to intermediate SiO2 content. The chemical index of alteration values and the A-CN-K diagram suggest that the clastic rocks in this study underwent moderate to intensive weathering. Provenance discrimination plots of sediments based on major oxides depicts that the sandstone was derived from intermediate igneous provenance. The geochemical characteristics suggest an active continental margin setting for the Yinkiong Group of rocks and also a shallow marine environment. Chondrite normalized pattern and a significant negative Eu anomaly and high LREE/HREE ratio, suggests felsic source rocks. The Eu/Eu* (~ 0.65), La/Sc (~ 8.76), Th/Sc (~ 1.36), La/Co (~ 2.92), Th/Co (~ 0.93) and Cr/Th (~ 5.31) ratios indicate derivation of the samples from felsic rock source. Th/Co versus La/Sc bivariant plot, La-Th-Sc ternary diagram and also the Th/Sc versus Zr/Sc plot suggests felsic provenance.**

***Keywords: Yinkiong Group geochemistry, provenance, tectonic setting, depositional environment.***

## I. INTRODUCTION

The present area is a part of Eastern Syntaxial Bend in which different litho sequences occur in the form of distinct thrust bound litho units. Yinkiong Group of rocks in association with volcanic sequence are well exposed in the area under study. The rocks are mostly sandstone, shale and limestone with minor amounts of marls of Palaeocene- Eocene age.

The present study aims at understanding weathering, climate, source rock characteristics and tectonic settings of the study area.

***GEOLOGY AND STRATIGRAPHY OF THE STUDY AREA:***

The Arunachal Himalaya contains distinctive tectonic belts comprising characteristic geological units. Nandy *et.al.*, [16] recognized four major tectonic zones in the Arunachal Himalaya, viz., Mishimi Massif, Daling Belt, Gondwana-Buxa Belt and Siwalik Foredeep. The study is mainly confined to the Yinkiong Group of rocks of Yamne valley. This group of rocks named by Jain *et.al*.,[12] has a widespread lithosequences in the form of distinct thrust bound litho-tectonic belts with pronounced deflection of trends from NE-SW in the west to NW-SE in the east across the Siang-Yamne gorge.

Stratigraphically, the Yingkiong Group of Palaeocene-Eocene age consists of two formations viz.the lower Geku Formation and the upper Dalbuing Formation. The Geku Formation named by Tripathi *et.al.*, [21] has its lower part made up of sandstone, shale with volcano clastic rocks-ignimbrite and tuffs.The upper part constitutes the continental facies yielding Sikot plant fossils like *Apocynophyllum Sp.*,*Canavalia Sp.*, *Hicora Sp.*, *Grewiopsis Sp.* and *Sophera Sp.* Tripathi *et.al.*, [21]. The Upper Dalbuing Formation exposed in the Yamne valley in a narrow linear NW – SE trending zone from east of Yinkiong to southeast of Dumro along the eastern limb of the Siang synclinal structure mainly comprises of Limestone with shale intercalations with the presence of *Nummulitesatacicus*, *N. lahirii*, *N. obtusus*, *Assilinadandotica*, *A. granulose*, *Rotaliatrochidiformis* fossils. The General stratigraphy of the study area shown in Table 1.

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## II. METHODOLOGY

For the present study, representative samples belonging to the Yinkiong Group of rocks have been collected from the study area. Six samples have been selected for major oxides and nine samples were analyzed for Trace and Rare Earth elements. X – ray fluorescence (XRF) analysis for major oxides was carried out at Sophisticated Analytical Instrument Facility (SAIF), Department of Instrumentation & USIC, Gauhati University, Guwahati. Quantitative analysis of trace and rare earth elements were done by Inductively Coupled Plasma Mass Spectrometry (ICPMS) at Shiva Analyticals Private Limited, Bangalore. These Sandstone samples were reduced to small sized rock chips using a ball mill and powdered to 200 mesh size using a mortar. For trace elements and rare earth elements interpretation Upper Continental Crust (UCC) normalization and chondrite normalization factors listed in Taylor & McLennan (1985)[22] have been used respectively.

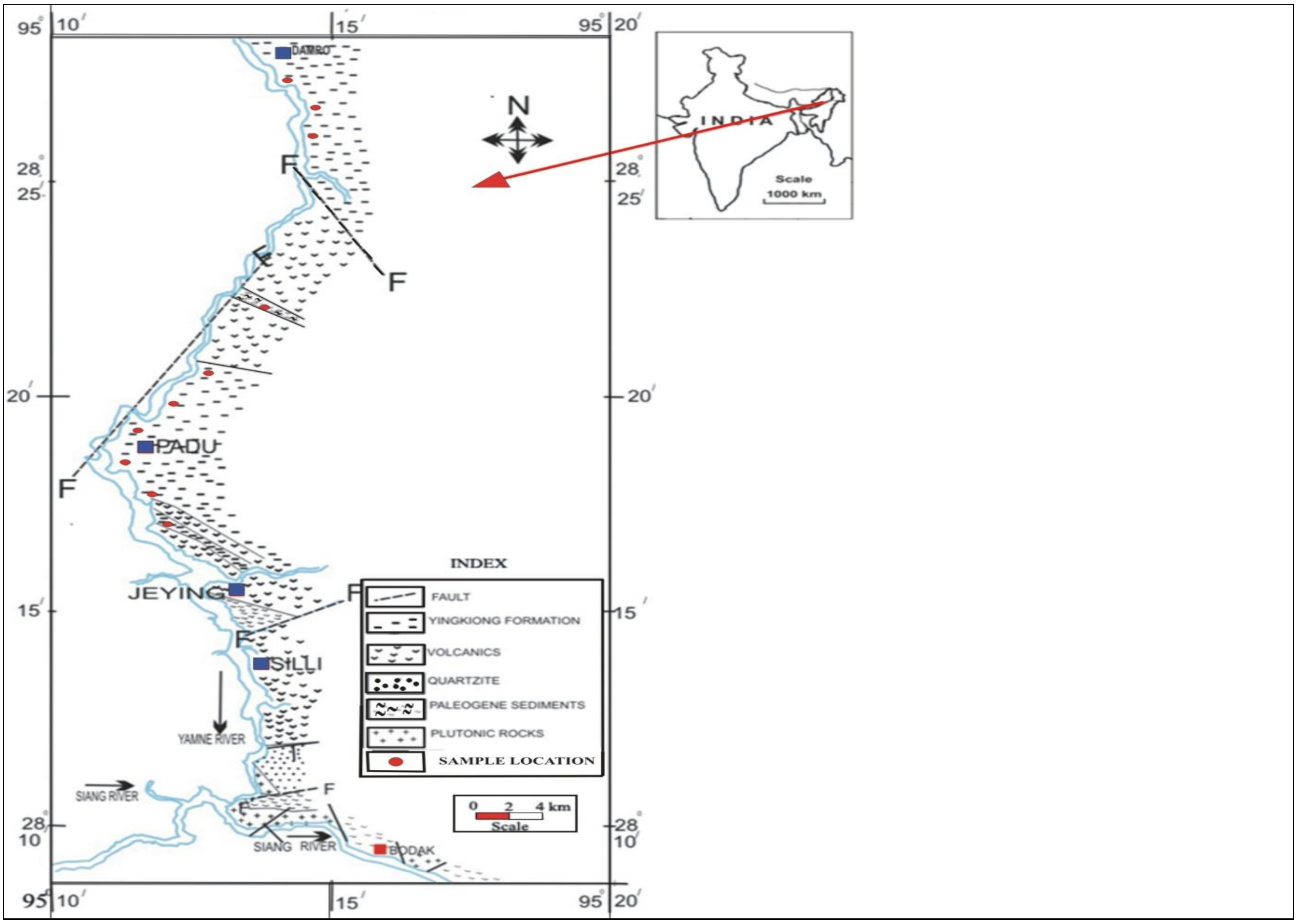


**Fig1**: **Geological map of the study area (modified after Taye,C., and Bhattacharyya,P., Chakrabati,R. 2014)[23]**

**Table 1: Stratigraphic succession of the Himalyan belt of Arunachal Pradesh, after Kesari *et al.* (2010)[13]**

| GROUP | FORMATION | LITHOLOGY | AGE |
|---|---|---|---|
| QUATERNARY SEDIMENTS | Hapoli (Newer Alluvium) | Sand Clay And Peat | Holocene to Recent |
| | Older Alluvium | Unconsolidated Sediments represented by Boulders, Cobble, Pebble, Sand and Sandy Clay beds | Middle to Upper Pliestocene |
| --------------------------------------------------MAIN FRONTAL FAULT-------------------------------------------- | | | |
| SIWALIK | Kimin (Upper Siwalik) | Boulder Conglomerate, pebble Sandstone | Mio-Pliocene |
| | Subansiri (Middle Siwalik) | Salt and pebble lithic Arenite | Mio-Pliocene |
| | Dafla (Lower Siwalik) | Micaceous Sandstone with calcareous concretions | Miocene |
| TOURMALINE BEARING LUECOGRANITE | | Unfoliated two Mica medium to coarse grained Tourmaline bearing Leucogranite | 29 ± 7 Ma |
| YINKIONG | Dalbuing | Limestone with Shale intercalation | Early to Mid Eocene |
| | Geku | Purple and pale green Shales, Sandstones, black Shale, nodular grey Shale, Quartzite (occasionally calcareous) | Late Paleocene to Early Eocene |
| GONDWANA GROUP | Yamne | Pale brown ferruginous Shale | Upper Permian |

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| | | | |
|---|---|---|---|
| | Abor Volcanics | Porphyritic aphyric Basalt, Andesite, acidic tuffs, Agglomerates, aquagine tuff, volcanic sediments | |
| | Bhareli/Khelong | Upper Member: Feldspathic Sandstone, black and carbonaceous Shale with thin impersistant lenticular Coal.<br>Lower Member: Arkosic red Sandstone, Siltstone and black carbonaceous Shale with thin impersistant lenticular Coal | |
| | Lichi Volcanics | Light to dark green basic Volcanics | Permo-Carboniferous |
| | Bichom | Sesa Member: Grey to balck tuffaceous(?) Shale with impersistant band of Quartzite<br>Bomte Member: Grey to black Shale with calcareous and phosphatic Chert nodules<br>Rilu Member: Diamictite with subordinate Sandstone, Shale and Grits | |
| | Miri | Purple to pinkish, white to grayish white feldspathic Quartzite, purple micaceous Shale, diamictite Conglomerate | Lower Paleozoic |
| BIOTITE GRANITE | | Biotite Granite (Deed Granite/Hawa Pass Granite/Tamen Gneiss | 500 ± 19 Ma & 480 Ma |
| THINGBU | | Low –grade Crabonaceous mica Schist and micaceous Quartzite | Neo-Proterozoic |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity (?) ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| DIRANG/LUMLA | | GARNTIFEROUS mica Schist, Phyllite, sericite Quartzite, calc silicate and tremolite-actinolite Marble | Meso-Proterozoic |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| BOMDILA | Bomdila/Ziro/Daporijo Gneiss | Biotite granite Gneiss | 1536 ±23 to 1914 ± 23 Ma |
| | Chilliepam/Dedza/Menga/ Mukatang | Niumi Member: Crabonates (Limestone and Dolomite) with alteration of greenish grey, purple and dark grey carbonaceous Phyllite<br>Kabak Member: Basal oligomictic Conglomerate, Quartzite with impersistant bands of Dolomite and black to dark grey Phyllite | Paleo-Proterozoic |
| | Tenga/Potin/Dublo/ Kho/Ragidodoke | Reyang Member: Basic Meta-Volcanics and Chlorite-Biotite-Garnet Schist interbedded with flaggy Quartzite and thin beds of Marble<br>Garubutham Member: White to grayish white Schist, Quartzite, purple Quartzite with purple silky Shale, sericite Quartzite and Phyllite | |
| | Khetabari | Sericite-quartz Phyllite, garnetiferous Phyllite and Schist, graphite/carbonaceous Phyllite, Quartzite, minor Carbonates, Chert and para-Amphibolite | |
| -----------------------------------------------------Tectonic Contact----------------------------------------------- | | | |
| SE LA | Galensiniak | High grade Schist, Gneiss and Migmatites (intruded by younger tourmaline Granite) | |
| | Taliha/Taksing | Graphite Schist, Calc-silicate, Marble, Amphibolite and schistose Quatzite | Paleo-Proterozoic |

# III. RESULTS

MAJOR ELEMENT GEOCHEMISTRY:

Major oxides composition of the studied samples in wt % is given in Table 2. The results are evident that the major portion of the oxides are constituted by SiO2 (56.6 – 66.16%; on average 60.38%) followed by Al2O3 (12.14 – 20.73%; average 16.66%), Fe2O3 (6.72 – 10.73%; average 9%), CaO (0.2 – 5.2% ; average 1.69) and Na2O (2.26 –3.2% ; average 2.49). The K2O and MgO content ranges from 2.43 – 4.04% (average 3.24%) and 1.25 – 2.98% (average 1.82%) respectively. However, the concentrations of TiO2, P2O5 and MnO are present in minor amounts 0.57 – 1.91%, 0.08 – 0.47% and 0.021 – 0.079% respectively.

Al2O3 present in high concentration indicates the presence of clay minerals and feldspar and subsequently the low values of Al2O3/SiO2 ratio is indicative of quartz enrichment in sandstones. The lower value of Na2O/K2O ratio than the K2O/Na2O ratio is symptomatic of the dominance of the K-feldspar over plagioclase feldspar in the sandstones samples. Cox *et al.*, [5] suggested that the K2O/Al2O2 ratios of clay minerals (0.0 to 0.3) and feldspar (0.3 to 0.9) are different. The K2O/Al2O2 ratio of the collected samples varies from 0.18 to 0.23 (avg. 0.19) is demonstrative of the fact that the clay minerals are abundant as compared to the K-bearing minerals such as K-feldspar and mica in the source rocks.

TRACE ELEMENT GEOCHEMISTRY:

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Trace element concentration of the samples is shown in Table 3. By means of the upper continental crust values of Taylor and McLennan,1985[22] all the trace element values were normalised and plotted in Fig. 2. Relatively immobile trace elements are advantageous for determination of provenance and tectonic setting (Bhatia and Crook, 1986 [1]). The elements are transported quantitatively in clastic sedimentary rocks during weathering and transportation and thus would give forth to the signature of the parent material (McLennan *et. al.*, [14]; Bhatia and Crook, 1986 [1].

Trace elements such as Cr (~44.42ppm), Ni (~37.65ppm), Co (~14.64ppm) and V (~80.32ppm) have lower values revealing that the samples have a felsic source rock. The studied sediments are seen to be deficit in most of the trace elements, in comparison to the UCC (Taylor and McLennan, 1985 [22],. The depleted value of Sr (~91.66ppm) signifies the sediments being highly affected by diagenesis.

**Table 2: Major oxide composition of the collected samples in wt%.**

| MAJOR OXIDES | YAM 5 | YAM 8(A) | YAM 8(B) | YAM 9 | YAM 24 | YAM 17 |
|---|---|---|---|---|---|---|
| SiO2 | 56.6 | 60.45 | 58.62 | 59.71 | 60.76 | 66.16 |
| Al2O3 | 20.73 | 18.96 | 18.48 | 16.47 | 13.21 | 12.14 |
| Fe2O3 | 10.73 | 8.7 | 10.53 | 10.22 | 6.72 | 7.15 |
| MnO | 0.079 | 0.047 | 0.021 | 0.03 | 0.051 | 0.029 |
| MgO | 1.44 | 1.25 | 1.19 | 2.41 | 2.98 | 1.63 |
| CaO | 0.2 | 0.51 | 0.49 | 1.03 | 5.2 | 2.72 |
| Na2O | 2.52 | 2.4 | 2.49 | 2.36 | 3.2 | 2.26 |
| K2O | 4.04 | 3.57 | 3.64 | 3.81 | 2.6 | 2.43 |
| TiO2 | 0.97 | 0.75 | 0.81 | 1.91 | 0.57 | 0.9 |
| P2O5 | 0.21 | 0.41 | 0.47 | 0.08 | 0.36 | 0.37 |
| CIA | 75.4 | 74.5 | 73.6 | 69.9 | 54.1 | 69.7 |
| Al2O3/SiO2 | 0.367 | 0.314 | 0.315 | 0.276 | 0.217 | 0.183 |
| K2O/ Na2O | 1.603 | 1.488 | 1.462 | 1.614 | 0.813 | 1.075 |
| Na2O/ K2O | 0.624 | 0.672 | 0.684 | 0.619 | 1.231 | 0.930 |
| Al2O3/ TiO2 | 21.37 | 25.28 | 22.814 | 8.632 | 23.175 | 13.488 |
| K2O/ Al2O3 | 0.195 | 0.188 | 0.197 | 0.231 | 0.197 | 0.200 |

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**Table 3: Trace element and rare earth element concentration of the collected samples in ppm**

| Trace and REE | Yin 1 | Yin 2 | Yin 4 | Yin 5 | Yin 6 | Yin 7 | Yin 8 | Yin 9 | Yin 10 |
|---|---|---|---|---|---|---|---|---|---|
| Hf | 1.5 | 1.4 | <0.5 | 0.9 | 0.7 | 0.6 | <0.5 | <0.5 | 1 |
| Ta | 0.8 | 0.8 | <0.5 | <0.5 | <0.5 | 0.5 | <0.5 | <0.5 | 1 |
| Th | 12.2 | 11.3 | 6.2 | 7.4 | 7.9 | 7.4 | 2 | 2.2 | 19.4 |
| U | 1 | 1.2 | 0.5 | 0.8 | 0.7 | 0.6 | 1.3 | 4.9 | 2.3 |
| Pb | <5 | 34 | <5 | 36 | <5 | <5 | <5 | <5 | <5 |
| Zn | 107 | 123 | 103 | 141 | 142 | 150 | 26 | 36 | 60 |
| Cr | 61 | 42 | 62 | 68 | 61 | 58 | <10 | <10 | 28 |
| Cu | 31 | 30 | 63 | 116 | 119 | 122 | 224 | 44 | 17 |
| Ni | 37 | 30 | 46 | 58 | 60 | 60 | 11 | <5 | 32 |
| Ba | 277 | 246 | 165 | 196 | 199 | 203 | 54 | 55 | 553 |
| Sr | 73 | 71 | 45 | 52 | 53 | 54 | 217 | 180 | 80 |
| V | 128 | 118 | 82 | 94 | 96 | 99 | <10 | 30 | 66 |
| Ti | 4841 | 5132 | 2860 | 3280 | 3413 | 3426 | 409 | 380 | 3776 |
| Be | 3 | 2.3 | 1.4 | 1.5 | 1.3 | 1.5 | <0.5 | 1.4 | 1.4 |
| Sc | 13.9 | 14.2 | 10 | 11.8 | 11.8 | 11.6 | 1.4 | 2.4 | 9.2 |
| Co | 26.6 | 19.3 | 14.1 | 16.3 | 16.2 | 16.5 | 4.5 | 4.9 | 13.4 |
| Ga | 20.5 | 18.4 | 13.9 | 15.8 | 16.1 | 16.1 | 3.8 | 4.2 | 16.7 |
| Rb | 85.8 | 72.4 | 47.1 | 55.2 | 54.9 | 55.4 | 14.4 | 18.4 | 155.3 |
| Y | 9.4 | 14.6 | 5.5 | 7 | 7.1 | 6.1 | 29.3 | 34.5 | 19.4 |
| Zr | 113.9 | 98.6 | 60.7 | 70.5 | 71.1 | 68.9 | <20 | <20 | 45.3 |
| Nb | 10.5 | 10.2 | 4.6 | 5.2 | 5.8 | 5.5 | 1.2 | 1.2 | 10.6 |
| La | 24.4 | 23.8 | 26.1 | 30 | 32.2 | 31.3 | 22.2 | 20.2 | 43.1 |
| Ce | 54.4 | 53.8 | 51.9 | 60.6 | 64 | 61.9 | 55.6 | 48.8 | 84.5 |
| Pr | 6.2 | 6 | 6.8 | 7.8 | 8.1 | 8.2 | 5.9 | 5.2 | 9.6 |
| Nd | 23.1 | 23 | 26.2 | 30.1 | 30.8 | 31.1 | 22 | 19.4 | 33.9 |
| Sm | 5.1 | 5.1 | 5.5 | 6.2 | 6.7 | 6.4 | 4.7 | 4.6 | 6.3 |
| Eu | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1 | 1 | 1.1 |
| Gd | 4.4 | 5 | 3.8 | 4.3 | 4.4 | 4.4 | 4.9 | 5.2 | 5.5 |
| Tb | 0.6 | 0.7 | <0.5 | <0.5 | 0.5 | <0.5 | 0.9 | 1 | 0.8 |
| Dy | 2.8 | 3.7 | 1.8 | 2.1 | 2.2 | 2 | 5.5 | 6.5 | 4.4 |
| Ho | <0.5 | 0.7 | <0.5 | <0.5 | <0.5 | <0.5 | 1.1 | 1.4 | 0.8 |
| Er | 1.2 | 1.8 | 0.8 | 1 | 0.9 | 0.8 | 3.4 | 4 | 2.4 |
| Tm | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.6 | <0.5 |
| Yb | 1 | 1.6 | 0.6 | 0.8 | 0.6 | 0.6 | 3.2 | 3.8 | 2 |
| Lu | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.5 | <0.5 |
| ∑REE | 125.87 | 127.38 | 126.66 | 146.16 | 153.17 | 149.96 | 131.38 | 122 | 195.38 |


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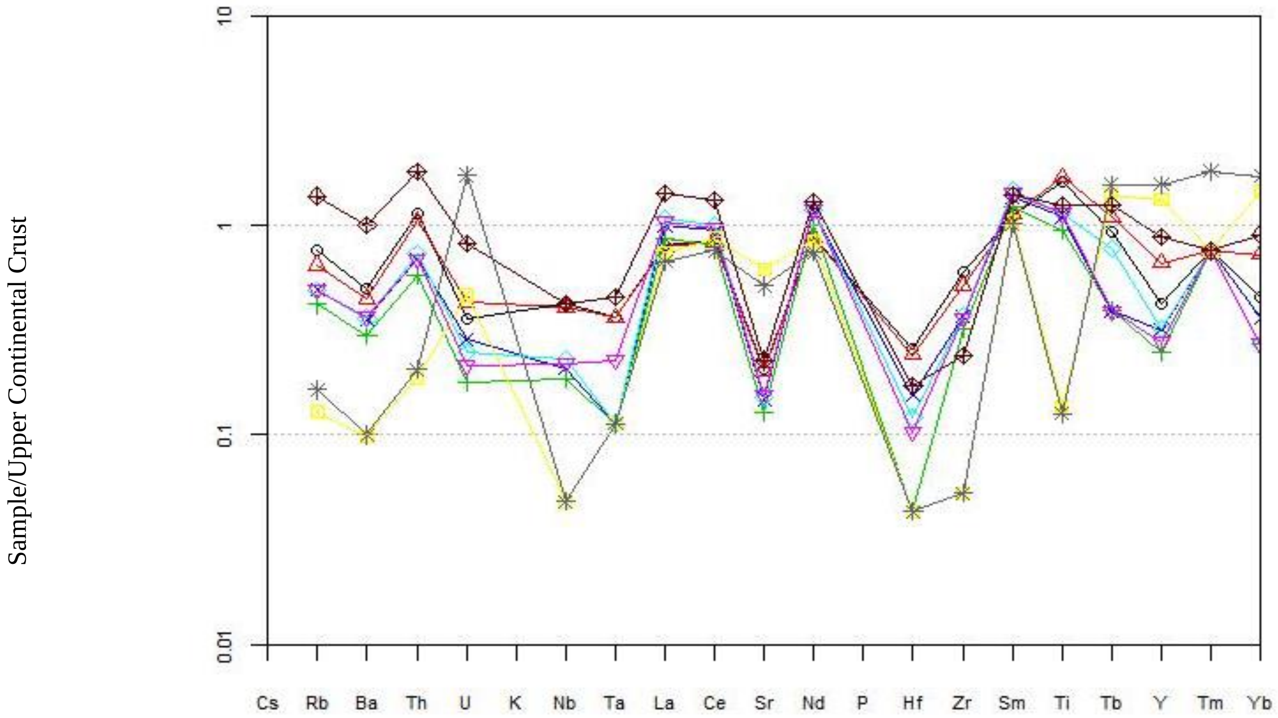


**Fig 2: Multi - element normalized diagram for the studied area, normalized against upper continental crust ( Taylor and McLennan, 1985)[22].**

***RAI***

Rare earth elements concentration of the studied area (Table 3) is shown as chondrite normalized pattern in Fig 3. Rare earth elements concentrations are fruitful for determining the characteristic of the source rock as well as the provenance. The sandstones have REE content ranging between 122-195.38 ppm with an average of 141.98 ppm which is less than the average UCC (143, Taylor and McLennan, 1985 [22]. The characteristic chondrite normalized pattern of the samples of the studied area with significant negative Eu anomaly along with high LREE/HREE ratio, implies that the likely source rocks are granites.

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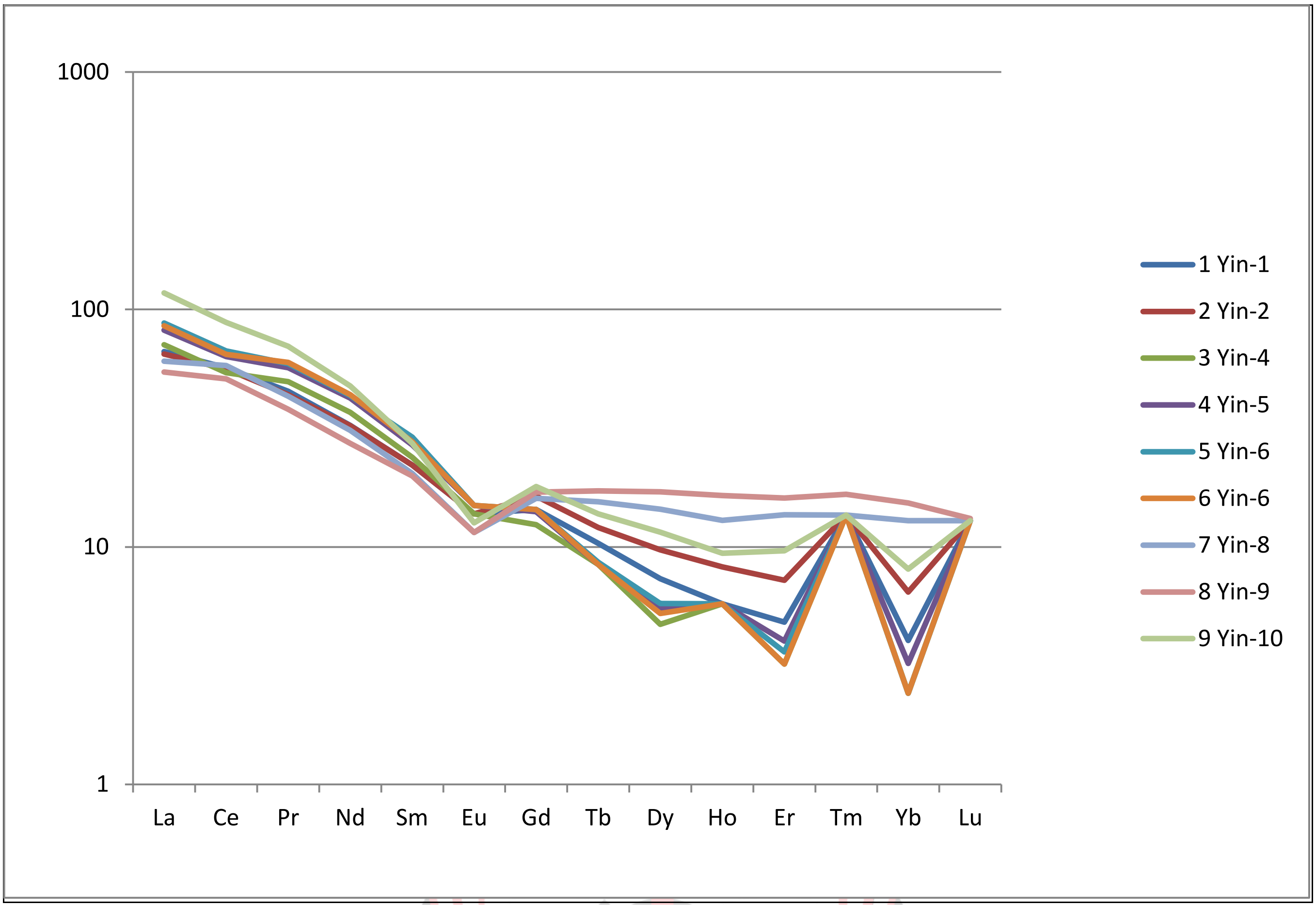


**Fig 3: Chondrite - normalized rare earth element plots for the studied area; chondrite values from Taylor and McLennan (1985)[22].**

## IV. DISCUSSION

GEOCHEMICAL CLASSIFICATION:

Different classification schemes have been proposed by various authors for clastic sedimentary rocks or sediments based on their geochemistry. Based on the geochemical classification diagram of Herron ,1988 [11], the studied samples were observed to be in the field of normal shale and the sandstone in the Wacke field (Fig 4(A)). Moreover the (Fe2O3 + MgO)-Na2O-K2O ternary diagram (Blatt *et al.*, [3]) also implies that the sandstones are lithic sandstone (Fig 4(B)). Whereas the Na2O-K2O diagram after Crook (1974 [6] shows quartz-intermediate and quartz rich characteristics (Fig 4(C)) for most of the samples.

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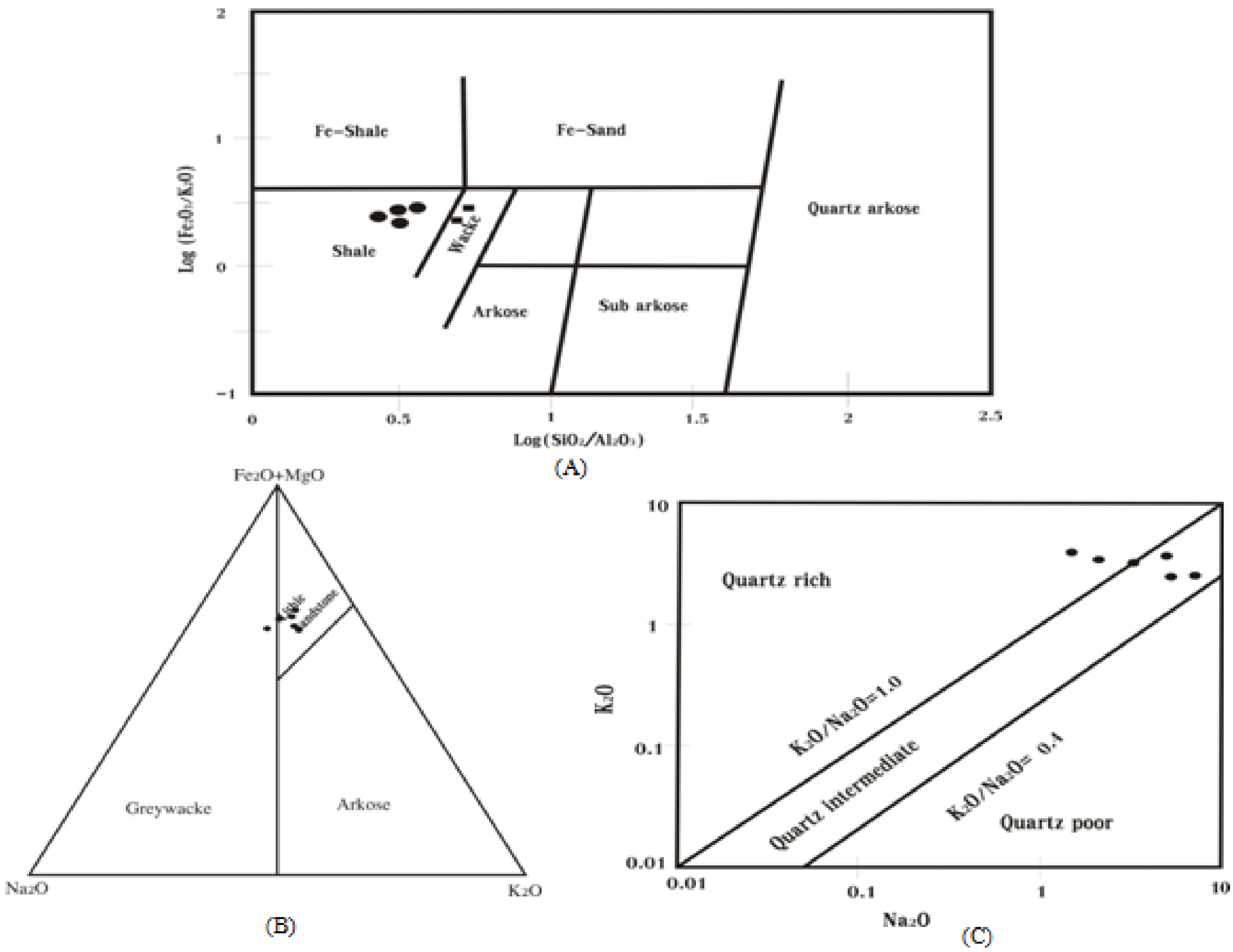


**Fig 4: Geochemical classification based on (A) LogSiO2/Al2O3-LogFe2O3/K2O diagram by Herron 1988, [11] (B)(Fe2O3-MgO)-Na2O-K2O ternary plot (Blatt *et. al.*,) [3] and (C)Na2O-K2O diagram by Crook, 1974 [6]**

PROVENANCE AND SOURCE ROCK COMPOSITION:

Sedimentary rocks belonging to different tectonic settings have varying geochemical characteristics (Bhatia, 1983[2]; Roser and Korsch, 1988 [20]. Major elemental data provides information regarding both the provenance and the effects of different sedimentary processes, such as weathering and sorting (McLennan *et al*., [14]). Discriminant function diagram for provenance characteristics of the sediments based on major elements provides intermediate igneous provenance for most of the analysed samples (Roser and Korsch, 1988 [20]) (Fig 5(A)). Ekosse ,2001 [9] used the Al2O3 versus TiO2 binary plot to distinguish between granitic and basaltic source rocks. In Fig 5(B), the Al2O3 versus TiO2 plot for the studied area samples indicates provenance material derived from a granitic and rhyolitic granite source region.

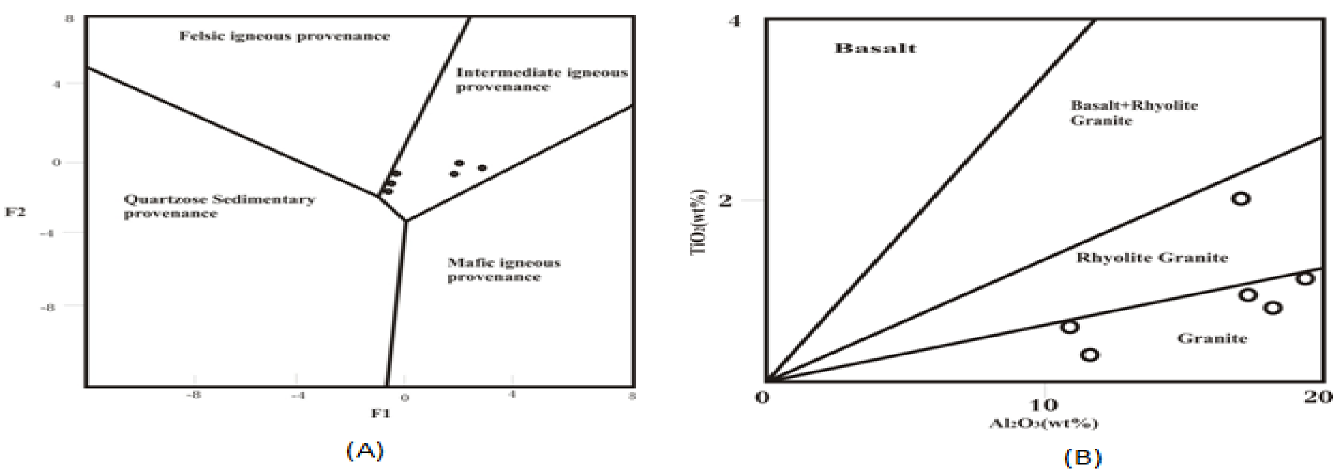


**Fig 5: (A) Tectonic discrimination diagram after Roser and Korch (1998) and (B) Al2O3-TiO2 bivariate plot of provenance after Ekosse, 2001**

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Rare earth elements, Th and Sc are more dominant in felsic rocks and their weathering products as compared to mafic igneous source rocks whereas Co, Sc and Cr are more abundant in mafic rocks and their weathering products than in felsic rocks (Cullers *et al.* [8]; Bhatia and Crook, 1986 [1]; Wronkiewiez and Condie, 1987[24]; Cox *et al*., [5]. In this study, Eu/Eu* (~ 0.65), La/Sc (~ 8.76), Th/Sc (~ 1.36), La/Co (~ 2.92), Th/Co (~ 0.93) and Cr/Th (~ 5.31) ratios indicates felsic rock source for the samples (Table 5). According to Nyakairu and Koeerl, 2001 [19], relative depletion in HREE's in comparison to LREE's is due to lack of heavy minerals. The higher LREE/HREE ratios and negative Eu anomalies are indicating felsic source rocks, whereas the mafic rocks exhibit lower LREE/HREE ratios with no or small Eu anomalies (After Taylor and McLennan,1985, [22] Wronkiewiez and Condie, 1989 [24]. The characteristic chondrite normalized pattern of the samples of the studied area with negative Eu anomaly and high LREE/HREE ratio, suggests that the likely source rocks are granite. (Fig 3, Table 4).

**Table 4: Elemental ratios of the studied area**

| ELEMENTAL RATIOS | Yin 1 | Yin 2 | Yin 4 | Yin 5 | Yin 6 | Yin 7 | Yin 8 | Yin 9 | Yin 10 |
|---|---|---|---|---|---|---|---|---|---|
| U/Th | 0.082 | 0.1062 | 0.0806 | 0.1081 | 0.0886 | 0.0811 | 0.65 | 2.2273 | 0.1186 |
| Zr/Sc | 8.1942 | 6.9437 | 6.07 | 5.9746 | 6.0254 | 5.9397 | 14.214 | 8.291 | 4.9239 |
| Th/Sc | 0.8777 | 0.7958 | 0.62 | 0.6271 | 0.6695 | 0.6379 | 1.4286 | 0.9167 | 2.1087 |
| La/Sc | 1.7554 | 1.6761 | 2.61 | 2.5424 | 2.7288 | 2.6983 | 15.857 | 8.4167 | 4.6848 |
| Th/Co | 0.4586 | 0.5855 | 0.4397 | 0.454 | 0.4877 | 0.4485 | 0.4444 | 0.449 | 1.4478 |
| Th/U | 12.2 | 9.4167 | 12.4 | 9.25 | 11.286 | 12.333 | 1.5385 | 0.449 | 1.4478 |
| La/Co | 0.9173 | 1.2332 | 1.8511 | 1.8405 | 1.9877 | 1.897 | 4.9333 | 4.1224 | 3.2164 |
| Cr/Th | 5 | 3.7168 | 10 | 9.1892 | 7.7215 | 7.8378 | 4.95 | 4.5 | 1.4433 |
| LREE/HREE | 6.15 | 4.30 | 8.83 | 8.61 | 9.02 | 9.57 | 2.29 | 1.77 | 5.17 |
| Eu/Eu* | 0.7566 | 0.7180 | 0.7614 | 0.7308 | 0.6888 | 0.7101 | 0.6322 | 0.6228 | 0.5588 |

**Table 5: Range of elemental ratios in this study compared to elemental ratios in sediments derived from felsic rocks, mafic rocks and in the upper continental crust**

| Elemental ratios | Yinkiong sediments | Ranges in sediments from felsic sources | Ranges in sediments from mafic sources | Upper continental crust |
|---|---|---|---|---|
| Eu/Eu* | 0.55-0.76 | 0.40-0.94 | 0.71-0.95 | 0.63 |
| La/Sc | 1.67-15.85 | 2.50-16.3 | 0.43-0.86 | 2.21 |
| Th/Sc | 0.62-2.10 | 0.84-20.5 | 0.05-0.22 | 0.79 |
| La/Co | 0.91-4.93 | 1.80-13.8 | 0.14-0.38 | 1.76 |
| Th/Co | 0.43-1.44 | 0.04-3.25 | 0.04-1.40 | 0.63 |
| Cr/Th | 1.44-9.18 | 4.00-15.0 | 25-500 | 7.76 |

Th/Co versus La/Sc bivariant plot (Cullers, 2002 [7] for the studied samples also determines a felsic provenance (Fig 5(C)). In the La-Th-Sc triangular diagram the average composition of granite, andesite and basalt (Condie, 1993, [4] and UCC are used for comparison to determine the provenance characteristics. In the diagram, the samples plot closer to the UCC and granite field indicating that these sandstones were derived from the felsic rock source (Fig 5(D)). Also the Th/Sc versus Zr/Sc plot is generally used to differentiate between the effects of source composition and sedimentary processes on the composition of clastic sedimentary rocks (McLennan *et al*.,)[14]. In the Th/Sc versus Zr/Sc bivariant plot Trend-1 shows the direct contribution from the primary source rocks whereas Trend-2 shows the influence of sedimentary processes. In this diagram, the samples plot near the granitic and granodioritic composition that confirms derivation of sediments from an igneous rock (Fig 5(E)).

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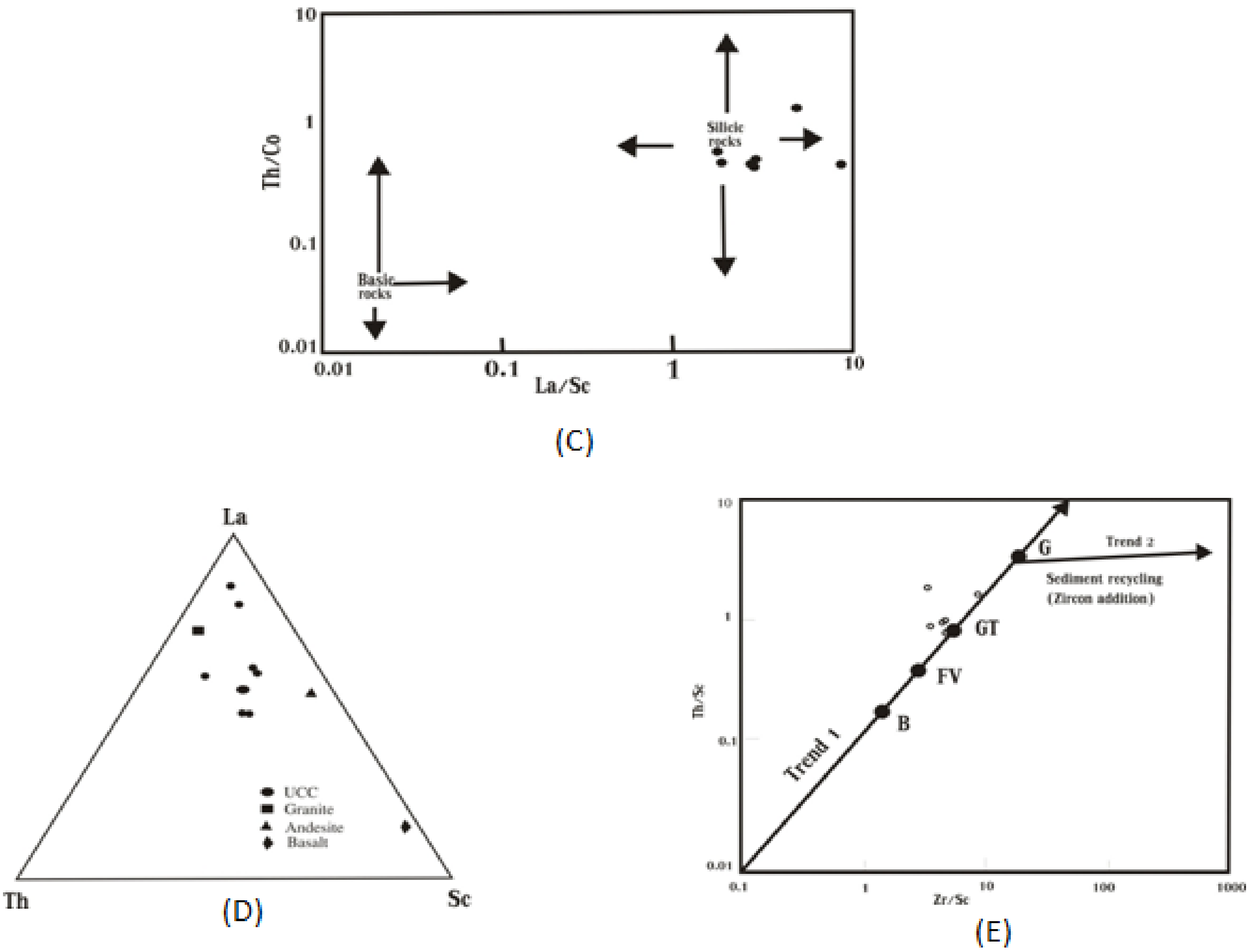


**Fig 5: (C) Th/Co versus La/Sc diagram (after Cullers, 2002)[7], (D) La-Sc-Th ternary diagram; values of UCC after Taylor and McLennan, 1985 [22]; and (E) Th/Sc-Zr/Sc diagram (McLennan et at., [14]). Values of G: granite, B: basalt, GT: granodiorite and FV: felsic volcanic are after Condie ,1993[4].**

TECTONIC SETTING:

Several types of discrimination diagrams that use major oxides compostion to determine the tectonic settings for clastic sediments have been proposed. The $K_2O/Na_2O$ vs. $SiO_2$ binary tectonic diagram of Roser and Korsch,1988 [20] differentiates between oceanic island arc (OIA), active continental margin (ACM) and passive margin (PM) tectonic setting. This diagram classified the Yinkiong sediments into Active Continental Margin (Fig 6(A)). Plots of $K_2O/Na_2O$ vs $SiO_2/Al_2O_3$ after Maynard *et al*., [15] also indicate active tectonic setting. (Fig 6(B)).

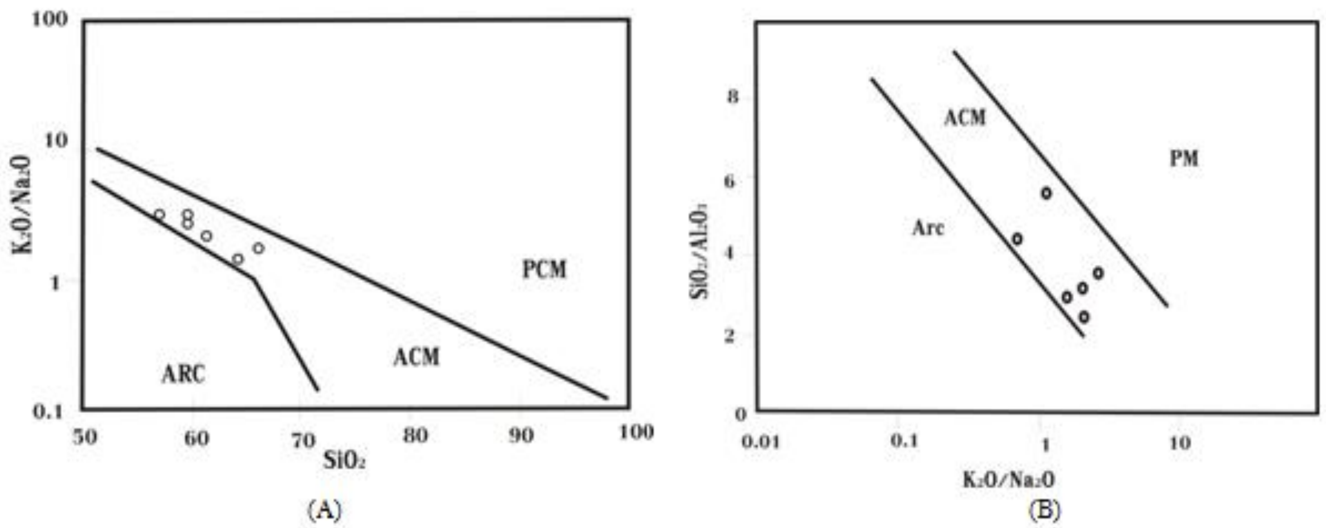


**Fig 6: (A) Tectonic discrimination diagram (after Roser and Korch, 1988) and (B) Tectonic discrimination plot after Maynard et. al.,1982**

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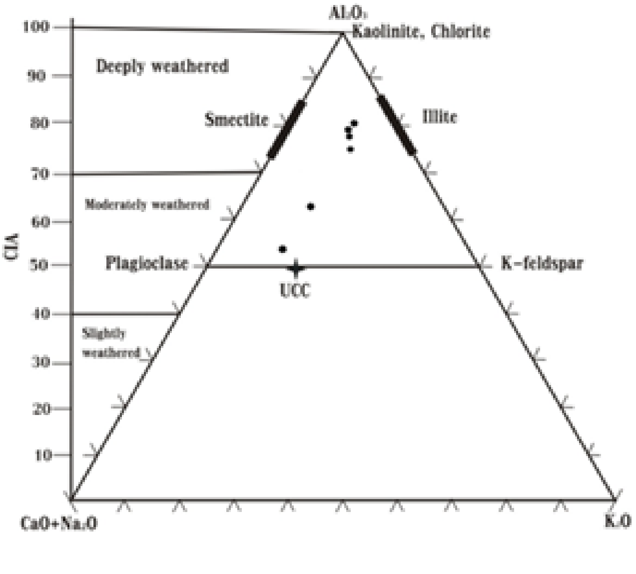
PALAEOWEATHERING AND DEPOSITIONAL ENVIRONMENT:

Climate as well as source rock composition and tectonics largely control the rate of chemical weathering of source rocks and the erosion rate of weathering profiles. Chemical Index of Alteration (CIA) is a useful way to interpret the palaeoweathering of the rocks. The most widely used Chemical Index of Alteration (CIA) by Nesbitt and Young, 1982 [17] which is used to determine the degree of weathering of the source area is calculated as follows:

CIA = [ Al2O3/( Al2O3+CaO*+Na2O+K2O)] * 100

Where, the oxides are expressed as molar proportions and CaO* represents the amount of CaO included in the silicate fractions only. CIA values of approximately 50 indicates an unweathered upper crust or weak weathering, but high values (i.e. 76-100) implies intense weathering with a complete removal of alkali and alkaline earth elements and an increase in $Al_2O_3$ (McLennan, 1993 [14]; Fedo *et al*., [10]. Thus with increasing weathering intensity the CIA value increases. The present CIA values of the samples are shown in Table 2. It ranges from 54.11% to75.4% i.e. average 68.41% which indicate moderate to moderately high intensity of weathering of source rock (Nesbitt and Young, 1982 [17]. (Fig 7(A))

The diagnostic plot of Na vs. Mg concentration of the sediments suggests that the studied area reflects a shallow marine depositional environment (Nicholson, 1992)[18]. (Fig 7(B))



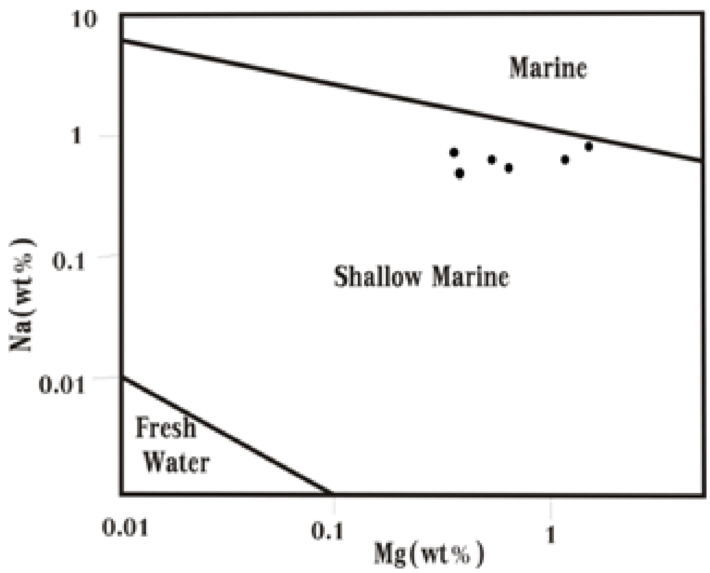




**Fig 7: (A) Mg vs Na diagnostic plot (after Nicholson, 1992)[18]and (B) A-CN-K ternary diagram (Nesbitt and Young, 1984)[17]**

## V. CONCLUSION

Geochemical analysis of Yinkiong group of rocks has been engaged to infer the provenance, tectonic setting and weathering of the source areas. The sandstones are classified as wacke type with rich to moderate SiO2 content, based on the major element chemical signatures.. Further, the major element geochemistry also indicates the source rock composition to be granitic and an intermediate igneous provenance. The CIA values of the samples shows moderate to moderately high intensity of weathering of the source rock. An active continental margin setting is inferred from the tectonic discrimination diagram for the Yinkiong Group. The diagnostic plot of Mg vs Na composition demonstrates a shallow marine depositional environment.

The characteristic chondrite normalized pattern of the samples of the studied area with significant negative Eu anomaly and high LREE/HREE ratio, suggests that the likely source rocks are granitic in character. The Eu/Eu*, La/Sc, Th/Sc, La/Co, Th/Co and Cr/Th ratios indicate derivation of the samples from felsic rock source. Th/Co versus La/Sc bivariant plot and La-Th-Sc ternary diagram for the studied samples also suggest a felsic provenance. Also the Th/Sc versus Zr/Sc plot, the samples suggests the granitic and granodioritic composition that confirms direct derivation from an igneous rock.

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