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Geochemistry of Merkhiyat Sandstones, Omdurman Formation, Sudan: Implication of depositional environment, provenance and tectonic setting.

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Abstract: Major oxides and selected trace elements geochemistry, their ratios and discriminated diagram of sandstones from Merkhiyat Member, Omdurman Formation have been investigated to determine their depositional environment, provenance and tectonic setting. Geochemistry of Merkhiyat sandstones indicate that they are sub arkose, lithic arenite, quartz arenite, Fe-sand, and varied in their maturity. The source area recognized by humid to semi humid condition resulted intermediate to strongly weathering affecting due to the CIA values, these conditions lead to form clay minerals (e.g. kaolinite). Merkhiyat sandstones derived from granitoid, gneissic supplemented by recycled sand with minor influence of mafic provenances. The clay minerals may response of the high value or concentration of ferromagnesian trace elements such as Cr, Ni and V. The source rocks of the sediments material tectonically may continental margins; passive and active, and very restricted to oceanic island arc settings, and deposited on the passive basin.

Keywords: Merkhiyat member, Omdurman formation, depositional environment.

1. Introduction

Sandstone of Merkhiyat Member of Omdurman Formation occurs in Omdurman area is a north western part of Khartoum basin of central Sudan. Merkhiyat Member in the study area is composed of coarse to medium grained sandstone, conglomerate and minor mudstone. They represent, fining upward cycle and each sequence (cycle) based on conglomerate facies represent fill of minor channel and/or sand body of channel fill (CH) facies to over bank deposits facies(OF) deposit in fluvial environment. Over the years, the use of trace and major elements geochemistry for discrimination of tectonic setting and provenance had been commonly applied to sedimentary rocks (Tijani et al., 2010). The tectonic setting of a depositional environment influences composition of sediment (Pettijohn et al., 1987; Bhatia, 1983). Transport mechanism and mixing of materials from diverse source area may obscure the original signatures and thus prevent reconstruction of the paleogeography from geochemical analysis (Pinto et al., 2004). The usefulness of major (Bhatia, 1983; Roser and Korsch, 1988; McLennan, 1989; Armstrong-Altrin and Verma, 2005; Al-Juboury,2007; Huntsman-Mapila et al.,2009;Zaid,2012) and trace (Bhatia and Crook, 1986; Etemad-Saeed et al.,2011) elements geochemistry discrimination diagrams to infer the tectonic setting of sedimentary rocks. Trace elements are defined as any element that is present in relatively small amounts in soil and rock (Albright, 2004). Some immobile trace elements as such Y, Sc, Th, Zr, Hf, Cr, Co and REE are believed to be useful to be indicator of geological processes, provenance and tectonic setting (Cullers 1994; Bhatia and Crook, 1986; Taylor and McLennan et al.,1985; Liu et al.,2007), because there are relatively low mobility during sedimentary processor , these elements probably are transferred quantitatively into clastic sediments during weathering and transportation, reflecting the signature of the parent materials, hence are expected to be more used (Armstrong-Altrin et al.,2004). In this chapter major oxides and selected trace elements used to get signature of depositional environment, provenance and tectonic setting of Merkhiyat sandstones in study area**.**

2. General Geology and tectonic setting

The general geology in Omdurman area is Pre-Cambrian basement rocks (gneisses, marbles, foliated batholitic granite and sheared acidic dyke), Cretaceous Omdurman Formation (Merkhiyat Member), Tertiary volcanic rock (basic and acidic) and Quaternary deposits (Fig.1). The study area is northwestern part of Khartoum basin (KB) west the Nile, Omdurman area. The KB is a one of Sudanese rift basins, which are mainly intra-continental basins, they characterized by thick non-marine clastic sequence of Jurassic? Cretaceous and Tertiary age (Shull, 1988). KB is a NW-SE trending rift basin lies on the eastern side of CARS (Jorgensen &Bosworth, 1989). KB is a large elongated basin aligned NW-SE, boarded to North the Sabaloka basement complex and to the south by faulted basement blocks North of Sinnar and Elduaim (Omer, 1983).

3. Material and Methodology

Ten samples of sandstones were analyzed for major oxides and trace elements by using ICP of central petroleum laboratories CPL for (Al, Fe, Mg, Mn, Ca, K, Na, Ag, Ba, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sr, V, Zn), XRF of University of Khartoum for (Ti, As, Rb, Zr, Y, Nb, Sc and Th), and photometer of CLSESR for SiO_2 .

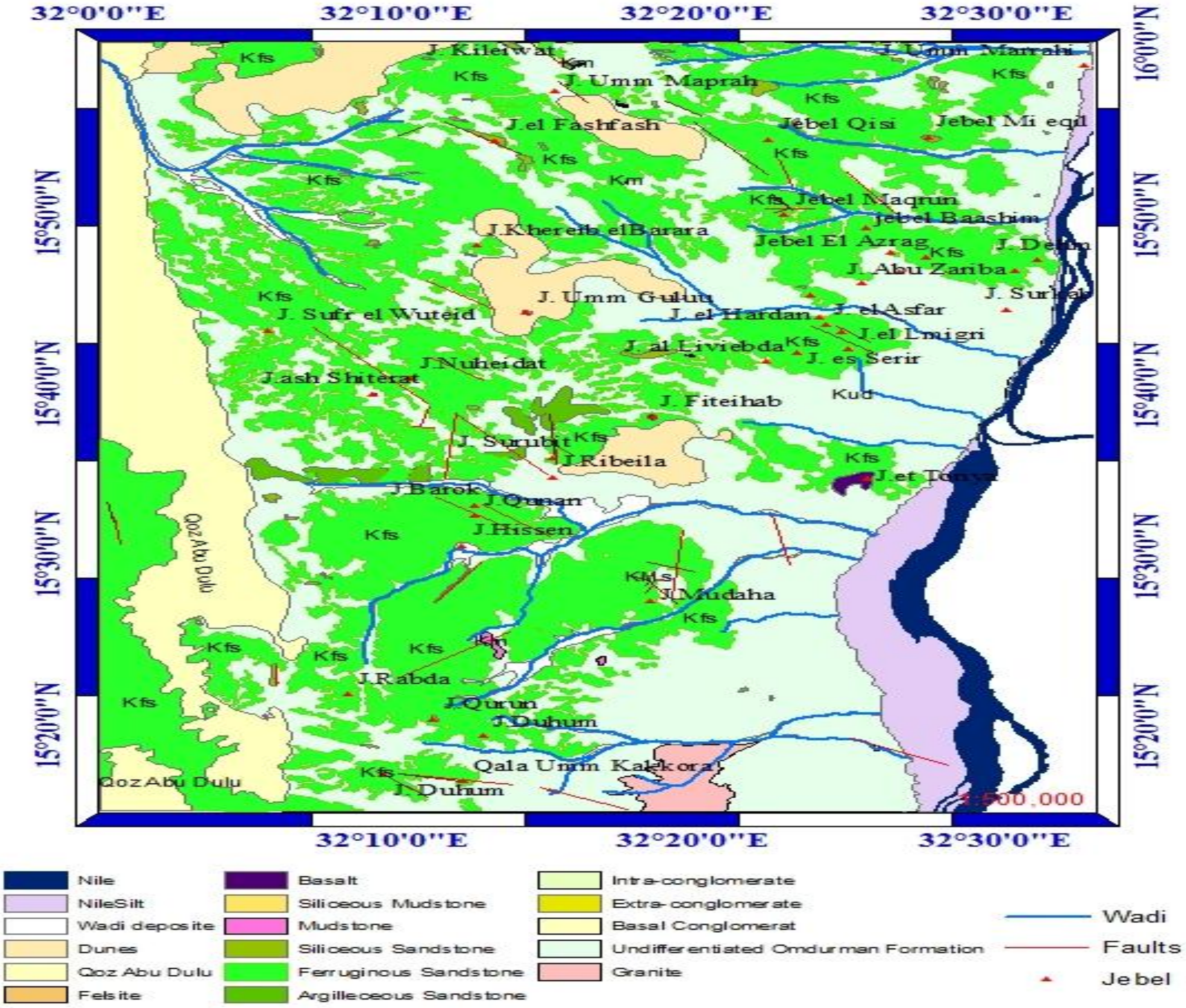

Fig. (1): Geological map of the study area.

4. Results

The major oxides and trace elements concentrations of sandstone in study area are listed in Tables (1-2).

Table 1: Major Oxides of Merkhiyat Sandstone (W %).

Oxide	S46	S33	S135	S131	S1213	S1211	S95	S93	S812	S88
SiO_2	56.46	55.05	94.99	91.10	91.77	71.45	79.81	93.78	83.80	85.19
Al_2O_3	2.09	4.20	3.23	5.94	5.90	5.42	3.90	5.56	4.61	8.92
Fe_2O_3	40.54	40.45	0.74	2.17	1.99	22.14	13.86	0.52	11.01	3.39
MgO	0.15	0.03	0.17	0.09	0.01	0.02	0.01	0.03	0.05	0.41
MnO	0.36	0.08	0.06	0.03	0.14	0.05	2.11	0.02	0.13	0.03
CaO	0.32	0.13	0.66	0.48	0.09	0.85	0.00	0.08	0.29	1.92
K_2O	0.03	0.03	0.10	0.12	0.07	0.05	0.04	0.00	0.07	0.10
Na_2O	0.04	0.02	0.05	0.06	0.03	0.02	0.24	0.02	0.03	0.04
TiO_2	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01
AIC	84.2	96.0	80.0	90.0	96.9	85.6	93.2	98.2	92.3	81.2

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Table 2: Trace Elements of Merkhiyat Sandstone (ppm).

Element	S46	S33	S135	S131	S1213	S1211	S95	S93	S812	S88
Ag	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035	<0.0035
Ba	413.3	68.05	201.2	64.43	156.8	60.16	4588	122.7	232.6	122.2
Cd	8.257	10.35	<0.0009	0.3806	0.3223	5.84	5.708	0.5386	2.501	0.375
Co	<0.0018	<0.0018	3.562	1.017	0.8401	<0.0018	86.86	<0.0018	<0.0018	<0.0018
Cr	139	47.01	184	104.7	84.3	200.2	88.88	59.71	137.7	57.13
Cu	63.17	12.92	12.23	10.87	5.695	63.21	25.32	4.213	81.17	8.796
Mo	2.732	<0.0051	9.44	172	2.721	2.598	4.711	4.719	2.45	4.258
Ni	101.1	38.16	20.27	11.48	7.815	26.56	250.8	32.9	23.98	21.68
Pb	65.69	76.21	<0.0148	<0.0148	<0.0148	39.15	31.84	<0.0148	20.4	<0.0148
Sr	43.04	27.7	60.84	31.02	10.43	16.05	273.5	20.19	24.17	35.99
V	88.83	71.14	26.93	49.55	51.9	151.9	78.09	40.81	80.55	45.38
Zn	259.1	206.3	31.13	13.69	22.72	57.89	519.9	7.683	72.96	32.05
Ti	29.8	52.7	Nd	34.7	30.7	36.3	111	Nd	34.7	42.1
As	Nd	Nd	Nd	Nd	0.677	0.252	0.316	Nd	Nd	Nd
Rb	0.875	Nd	Nd	1.37	1.21	1.13	16.4	1.66	1.37	1.08
Zr	2.45	1.66	6.26	13.6	14	5.14	15.9	11	12.9	9.38
Y	0.205	Nd	0.29	0.174	0.154	0.152	0.129	0.277	0.139	0.145
Nb	0.0779	0.127	0.118	Nd	0.155	0.145	0.0988	0.206	0.196	Nd
Sc	40.9	Nd	42.2	47.6	Nd	Nd	Nd	56.2	Nd	Nd
Th	5.92	Nd	0.588	0.346	Nd	Nd	Nd	Nd	Nd	Nd

5. Discussion and Interpretation

Merkhiyat Member sandstones are relatively high SiO_2 (55.05-94.99, Av.80.34), low of Al_2O_3 (2.09- 8.92, Av.4.98), very low of K_2O (0.00 -0.12, Av.0.06) and Na_2O (0.02-0.24, Av. 0.05) and high Fe_2O_3 (40.54- 0.52, Av. 13.68). The trace elements of Merkhiyat sandstones are generally, varied in their concentrations; Ba, Cr, Ni, Zn, and V are relatively high; the Ag is under detection limit. The Ba is (413.3-60.16, Av.267 ppm 7), Th (5.92-0, av.2.96 ppm), Zr (15.9-1.66, av.5.92 ppm), Cr (200.2-47.01, av.98.07 ppm), Ni (101.1-7.82, av.61.39 ppm) and V (151.9-26.93, av.67.11ppm) Figs (2). Depended on the concentration of three major oxide groups: silica and alumina, alkali oxide, and iron oxide plus magnesia (Lindsey, 1999), the Merkhiyat sandstones can classify into sub arkose, lithic arenite, quartz arenite (Table3), and Fe-sand by using diagram of Herron, (1988) (Fig.3).

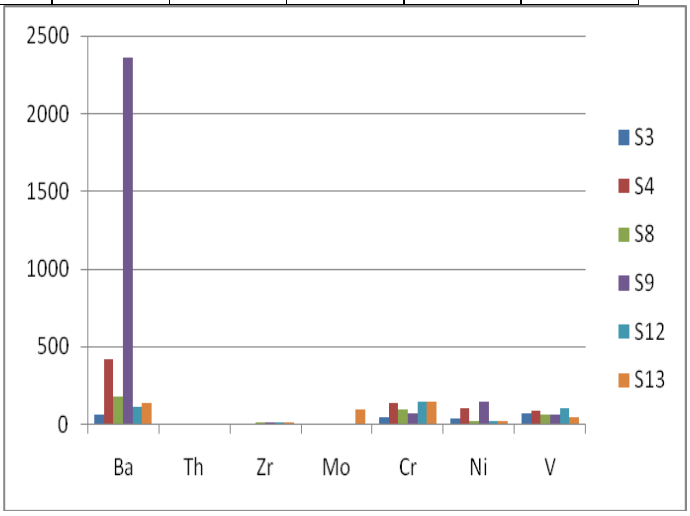

Fig. (3): Histogram shows trace elements distribution.

Table 3: Shows Chemical Classification of Merkhiyat Sandstone

SN	S46	S33	S135	S131	S1213	S1211	S95	S93	S812	S88
Log(K_2O/Na_2O)	-0.1	0.2	0.3	0.3	0.3	0.4	-0.8	-1.8	0.4	0.4
Log(SiO_2/Al_2O_3)	1.4	1.1	1.5	1.2	1.2	1.1	1.3	1.2	1.3	1.0
Classification	L.A	S.Ar	Q.A	S.Ar	S.Ar	S.Ar	S.Ar	L.A	S.Ar	S.Ar

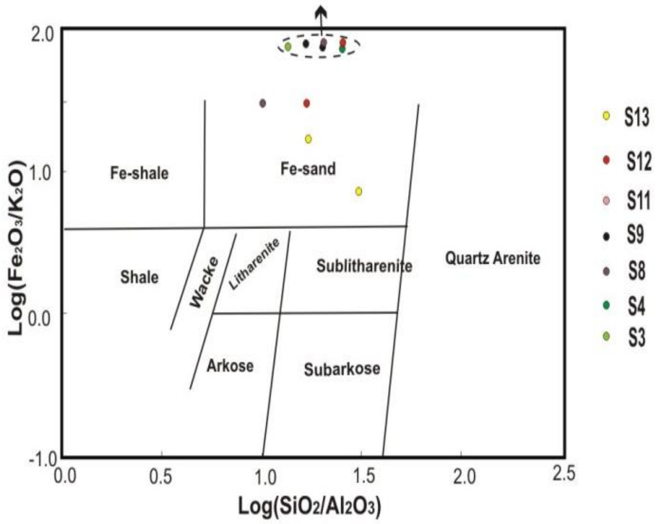

Fig.(3): Log(SiO_2/Al_2O_3) vs. Log(Fe_2O_3/K_2O) Herron,(1988),Merkhiyat sandstone.

6. Depositional Environment

During weathering results of alteration rocks are depleted of alkalis and alkaline earth, preferential enrichment of Al_2O_3 (Cingolani et al., 2003) and SiO_2. Feldspars are by far the most abundant of the reactive mineral, during weathering calcium, sodium and potassium are largely removed from feldspars (Armstrong-Altrin et al., 2004). Weathering effect can be estimate by using the chemical index of alteration (CIA= (Al_2O_3/ (Al_2O_3+CaO+Na_2O+K_2O))*100) of Nesbitt and Young,(1982). The CIA values range from 80 to 98.2, average 82.7 with SiO_2 range from55%to 94.99%, average 80.34%. The high CIA values in Merkhiyat sandstone (82.7) indicate intensive and strong weathering of first cycle sediment, or alternatively, recycling. CIA also represented as ternary plot of A-CN-K after Shao et al., (2012) (Fig.4), the samples plot mostly in upper part near kaolinite (60%) and smectite (40%), which may used to constrain initial compositions of source rocks (Etemad-Saeed et al.,2011).

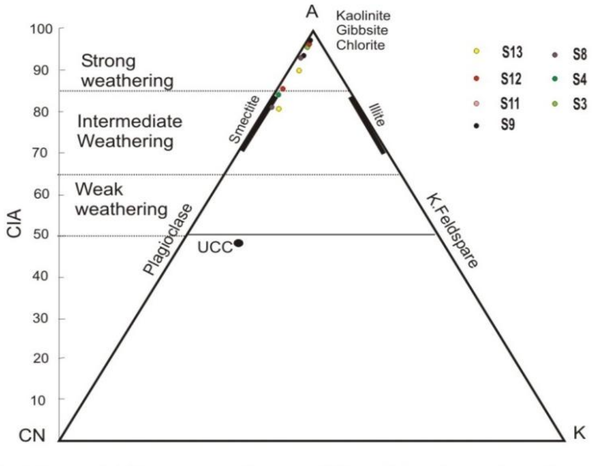

Fig.(4): A-CN-K diagram for Merkhiyat sandstone, (Shao et al., 2012) A: Al_2O_3, C: CaO, K: K_2O

Diagram of Suttner and Dutta, (1986) was used in order to indentify the maturity of Merkhiyat sandstone as a function of climate. The plotted samples revealed semi humid to humid conditions for the samples with varied maturity (Fig.5).

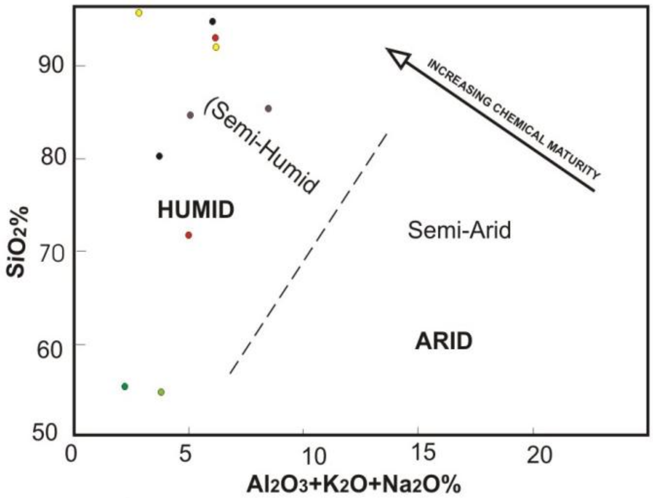

Fig.(5): Chemical maturity of Merkhiyat sandstone, (Suttner & Dutta, 1986).

7. Provenance

The source area located in humid to semi humid conditions, affected by intermediate to strong weathering, which appear in general view in silica enrichment and lack of sodium and potassium, and slight enrich in iron oxide. The discrimnant functions diagram of Roser and Korsch,(1988) has been used to construct the source of the sediments and provenance of the Merkhiyat sandstone (Fig.6). This diagram reveals that the plotted sandstones were mostly mature of recycled continental sedimentary rocks may derived from granitic-gneissic or sedimentary source, a little of mafic source.

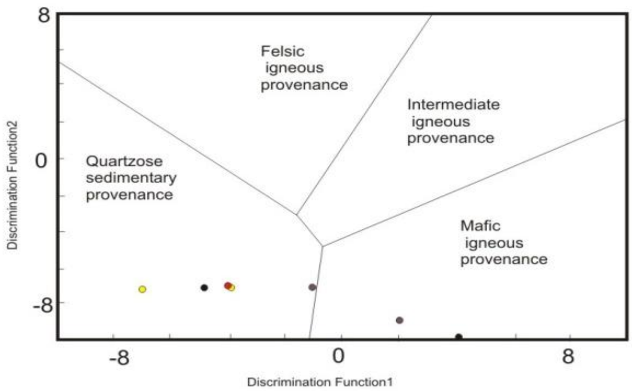

Fig.(6): Provenance discrimination function diagram of Merkhiyat sandstone, (Roser and Korsch, 1988).

The high concentrations of Cr, V and Ni, the ratio of Cr/Ni about 1.23 to10.8with average 2.82, these may probably indicate derivation of these elements from mafic rocks or this may suggest either a minor amount of ultramafic input into the depositional system or else that trace elements could have traveled into the depositional basin as adsorbed ion on clays (McCann, 1991 and Asiedu et al., 2000), never the less the clays observed as beds, intercalation and mudclast and the later widely distributed.. The V-Ni-Th*10 provenance diagram of Bracciali et al., (2007) has been used to infer the provenance of Merkhiyat sandstone, most of studied samples plotted in or near the mafic rocks field (Fig.7).

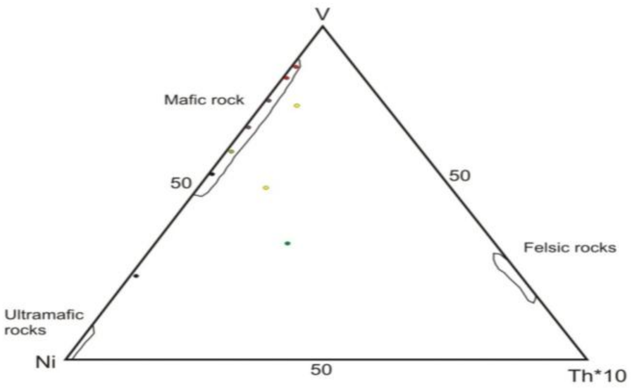

Fig.(7): Provenance diagram (V-Ni-Th*10) for Merkhiyat sandstone,
(Bracciali et al., 2007)

8. Tectonic setting

Many types of discrimination diagrams of tectonic settings that use major oxides chemistry have been proposed for clastic sediments. The K_2O/Na_2O vs. SiO_2 binary tectonic diagram of Roser and Korsch, (1986) discriminates between oceanic island arc (OIA), active continental margin (ACM) and passive margin (PM) tectonic setting, this diagram classified the Merkhiyat sandstone into continental margin (PM about 60%, ACM 20%) and oceanic island arc 20% (Fig.8). Also (SiO_2/20)-(K_2O+Na_2O)-$TiO_2+Fe_2O_3+MgO$) ternary diagram of Kroonenberg, (1994) has been used; all samples of the Merkhiyat sandstone plotted out the specific field except 30% into passive margin (D) (Fig.9).

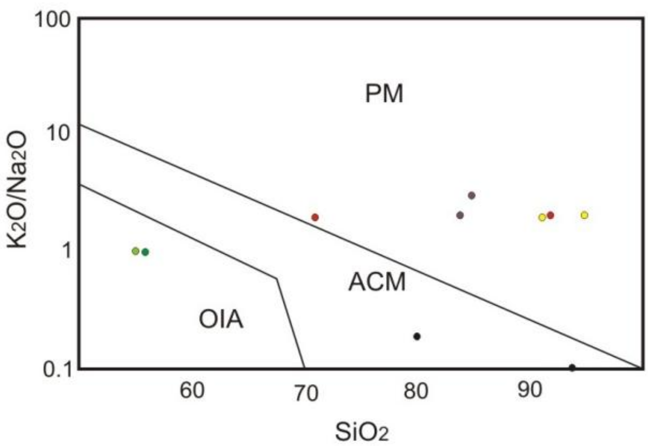

Fig. (8): Discrimination diagram K_2O/Na_2O vs. SiO_2,(Roser and Korsch, 1986) For Merkhiyat sandstone, (OIA): Oceanic island arc, (ACM): Active continental margin, (PM): Passive margin.

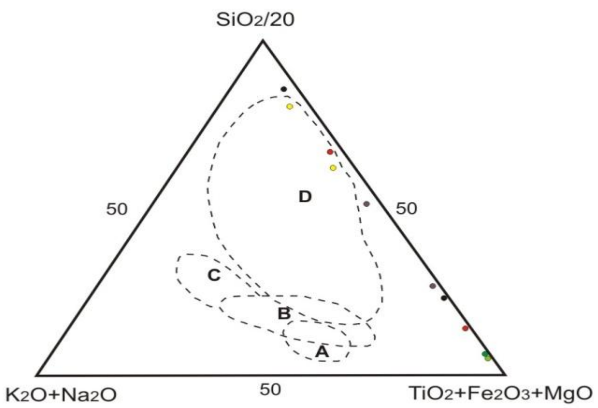

Fig.(9): Tectonic diagramKroonenberg,1994 for Merkhiyat sandstone,
(A): Oceanic island arc, (B): Continental island arc (C): Active continental margin,(D): Passive margin.

Immobile trace elements in detrital sediments have also been used successfully in discrimination diagrams of pale tectonic settings (Varga and Szakmany, 2004), these elements probably are transferred quantitatively into clastic sediments during weathering and transportation, reflecting the signature of the parent material (Armstrong—Altrin et al., 2004). The Th-Co-Zr/10 and Th-Sc-Zr/10 ternary diagrams (Bhatia and Crook, 1986) have been used to differentiate between oceanic island arc (OIA), continental island arc (CIA), active continental margin (ACM) and passive margin (PM) settings (Fig.10). Most of studied samples plotted in Zr corner, out of field except few in PM and near OIA.

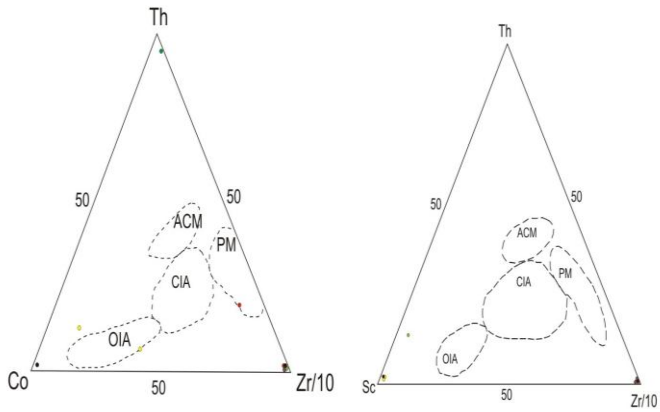

Fig.(10): Tectonic discrimination diagram for Merkhiyat sandstone,
(Bhatia and Croock, 1986.)

9. Summary and Conclusions

Major and selected trace elements geochemistry, their ratios and discriminated diagram revealed that the Merkhiyat Member sandstone are mostly sub arkose, lithic arenite and quartz arenite and Fe-sand, varied in their maturity of granitoid, gneissic supplemented by recycled sand with minor influence of mafic provenances on the passive basin. The source area recognized by humid to semi humid condition resulted intermediate to strongly weathering affecting due to the CIA values. These conditions lead to form clay minerals (kaolinite and smectite), which may response of the high value or concentration of ferromagnesian trace elements such as Cr, Ni and V and depleted in Th, Sc and to some extent Zr. The source material tectonically may deposit in continental margins; passive and active, and very restricted to oceanic island arc settings.

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