

GEOCHEMISTRY OF PALEOGENE RED BEDS IN THE NORTHERN IRAQ FORELAND BASIN: EVIDENCE FOR PROVENANCE

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ABSTRACT: The Paleogene Red Bed deposits in northern Iraq crop out as a narrow northwest-southeast trending belt within the thrust zone in an active foreland basin developed adjacent to the Zagros orogenic belt. The Red Beds are divided vertically into four units. The lower part (unit 1) is mainly composed of red mudstone and siltstone. The middle part (unit 2) is mainly composed of sandstone with thin interbeds of red siltstone. The upper part is composed of conglomerate (unit 3) covered by 100-120 m of red mudstone, siltstone and sandstone (unit 4). The geochemical stratigraphy shows an increase in transition elements and REEs while LILE and HFSE elements decrease in the lower part of the sequence. These features indicate that a mafic source supplied detritus during the deposition of the lower Red Beds and decreased in importance during the deposition of the middle and upper parts as a result of erosion or tectonic activity.

Keywords: Red Beds, Mafic Source, Iraq, Zagros Orogenic Belt

1. INTRODUCTION

The geochemical composition of rocks is generally a useful tool to determine the chemical characteristics of the source area [1] and draw tectonic conclusions [2]. The diagenesis, nature of the source rock and the weathering of the source area can also be deduced from the geochemical composition of clastic rocks [3], [4], [5], [6].

One section was selected from the Mawat area (Sorakalat section) in the south-eastern part of the basin and one section was selected from Qandel area (Suwais section) on the northwest side of the basin (Fig. 1). Rare earth element studies are very useful because their distribution is stable in various rocks and minerals under different conditions, such as weathering, transportation and metamorphism.

Rare earth elements were normalized to chondrite, average shale and upper continental crust and plotted on spider diagrams and showed that the lower parts of the sequence in the Mawat area is enriched in HREEs in comparison to the middle and upper parts of the Red Beds which have less HREEs. Trace elements were normalized to Upper Continental Crust [7] and plotted on spider diagrams and also plotted versus stratigraphic height to assess their vertical distribution.

The REE patterns indicate the lower part derived from a mafic source with minor contributions from a felsic source. This is distinctly different from the middle and upper parts of the sequence. Trace element diagrams show a concentration of transition elements and high field strength elements (HFSE) in the lower parts of the

Red Beds and depletion of HFSE upward towards the middle and upper parts. This pattern probably reflects regressive erosion of the mafic components upwards through the section with the effect of a minor felsic source in the middle and upper parts of the Red Bed sequence.

Laterally, the Mawat-Chwarta area section has been more affected by mafic and ultramafic sources than Qandel area section (Suwais).

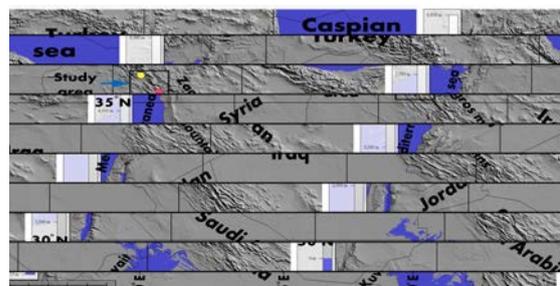


Fig. 1. Location map of the study area (Qandel and Mawat-Chwarta areas).

2. GEOLOGICAL SETTING

The Zagros Mountains of northern Iraq are geologically part of the extensive Alpine mountain belt. They form a narrow strip along the border between Iraq and Iran and include two main zones: the Zagros Simply Folded Belt in the southwest and the Zagros Suture Zone in the northeast. These zones are included in the Zagros Orogen. A foreland basin occurs southwest of the Zagros Mountains. The tectonic development of the Zagros

Mountains indicates that the foreland basin was initiated in the Late Cretaceous during ophiolite obduction along the Zagros Suture Zone followed by continental collision of the Arabian plate with Eurasia in the Cenozoic [8], [9]. Late Cretaceous and Paleogene foreland basin deposits have been folded and are therefore now part of the Zagros Simply Folded Zone. In northeast Iraq, the former Zagros foreland basin included Cretaceous shallow-marine deposits of the Shiranish and Tanjero Formations overlain by continental deposits of the Paleogene Red Beds (Fig. 2). The Paleogene sedimentary rocks in the foreland basin record sedimentation developed during the Alpine orogeny. The Red Beds are structurally overlain by thrust sheets that are part of the Zagros Suture Zone. In the Mawat-Chwarta area the Red Beds are structurally overlain by the volcanic rocks of the Naopurdan Group [10] whereas the contact with the underlying Tanjero Formation is gradational as confirmed by the current study.

2.1 Tanjero Formation (Maastrichtian)

The Tanjero Formation is another rock unit of the Late Cretaceous succession in the study area. It is widespread in the Kurdistan region of northern Iraq [11] (Fig. 3). The formation is over 2010 m thick. The upper part of the Tanjero Formation contains foraminifera consistent with a Maastrichtian age for the unit. The lower part of the succession is composed of 480 m of globigerinal marl and rare siltstone. Its upper part consists of 1530 m of mixed siliciclastic and carbonate sedimentary rocks including silty marl, siltstone, sandstone, conglomerate, and organic detrital limestone. An interfingering interval ~45 m thick with gradational contacts between the Tanjero and Aqra Formations occurs in the Mawat-Chwarta area (Sorakalat section). It is composed of sandy detrital limestone, which progressively changes upwards to a calcareous sandstone, rich in shell debris. The boundary between the Tanjero Formation and the overlying Red Beds in the Mawat-Chwarta area is locally marked by Quaternary sediments. Furthermore, such a boundary is also recognized in nearby Sorakalat village, where fossiliferous limestone beds are recognized within the lowermost part of the Red Beds.

2.2 Red Beds (Paleocene-Eocene)

The Red Beds are composed of mudstone, sand stone and conglomerate. Clastic sedimentary rocks are distributed throughout the succession while carbonate beds are confined to the lower part of the unit. In most places the lower contact of the Red

Beds with the Tanjero Formation is conformable, as occurs in the Mawat-Chwarta area (Fig. 3). This contact is sharp in some areas and a transition in others [12]. An angular unconformity was also recorded in the study area close to the Suwais sections (Fig. 3). The variety of detrital components in the stratigraphic column through the Red Beds reflects the unroofing history of the thrust sheets that provided the components to the Red Bed basin.

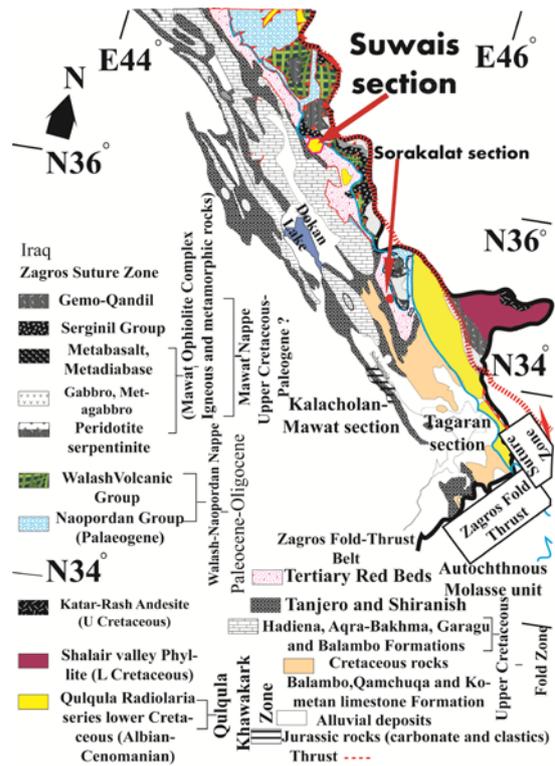


Fig. 2. Regional geological map of northern Iraq (Kurdistan area) and northwestern Iran showing locations of the study areas and Late Cretaceous formations and thrust sheets [13].

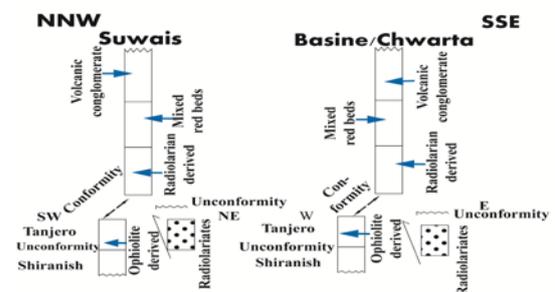


Fig. 3. The stratigraphic relationships of the Late Cretaceous-Paleogene rocks from the Suwais section (Qandel area) and Basina-Chwarta area within the former foreland basin [13].

Geochemical studies show that a diversity of source rocks supplied detritus to the Red Beds,

reflecting uplift of older rocks coupled with intensive orogenic movements during Red Bed deposition. The Red Beds are divided on the basis of provenance into two parts. A lower unit is dominated by radiolarian chert detritus with a minor component of ophiolitic detritus. An upper unit lacks radiolarian chert and ophiolitic detritus and has a mixed provenance of volcanic, metamorphic and sedimentary rocks.

3. SAMPLING AND METHODS

The current study used conventional geological methods including geological surveys in the field; X-ray fluorescence (XRF) and inductively coupled plasma-mass spectrometer (ICP-MS) analysis.

Fifty five samples from the Suwais and Sorakalat sections were analysed by XRF for trace elements in the School of Earth and Environmental Sciences at the University of Wollongong. Twenty four samples were analysed using ICP-MS in Brisbane for REEs from two sections (Suwais and Sorakalat, Tables 1-2).

4. RESULTS AND DISCUSSION

4.1 Rare Earth Elements (REEs)

Rare earth elements (Tables 1-2) provide very important evidence for determining sedimentary source rocks because they are stable in different rocks and minerals and are not modified during metamorphism [14].

Fig. 4 shows the different patterns for the average shale [16] and upper continental crust [12] normalized to chondrite [17]. The figure shows enrichment in the LREE in the upper continental crust as a result of the LREEs fractionating into the liquids generated during magma formation and intrusion into the upper crust. For this reason the composition of REEs in the MORB and upper continental crust is different. The enrichments of La to Sm are similar in the Qandel and Mawat areas but with some increase in La in the Mawat area.

All the samples were plotted on spider diagrams after being normalized to chondrite [4] (Figs 4-5). Generally there is a similarity pattern of the geochemical signatures between all the samples in the current study. These patterns are stratigraphically characterized by non-uniformity of REE distributions showing relative enrichment of LREEs with little flat pattern or depletion of HREEs. The LREEs increase in abundance towards the middle and upper parts of the Red Beds in

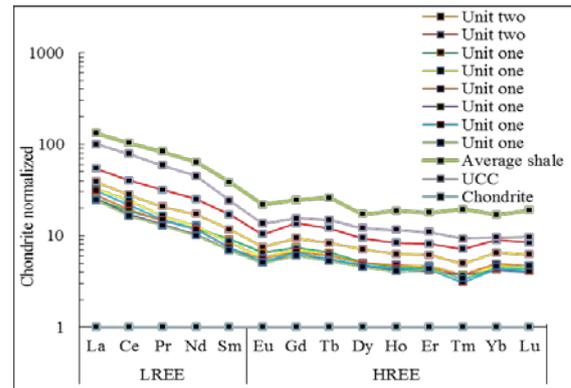


Fig. 4. Plots of REEs from average shale [16], upper continental crust [12] and the selected samples from the Suwais section normalized to chondrite values [17].

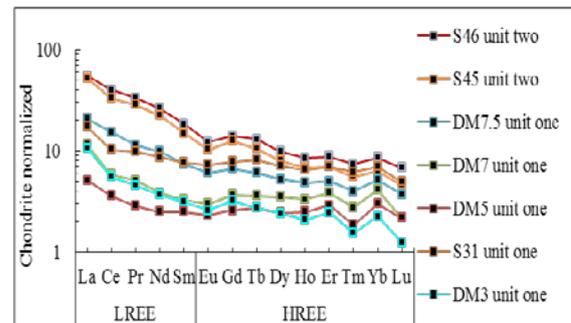


Fig. 5. Plots of REEs from selected samples in the Sorakalat section normalized to chondrite values [17].

Table 1. Average REE results for Suwais section.

LREEs								
Units	La	Ce	Pr	Nd	Sm	GdYb	LaSm	
Unit1	4.9	8.2	1	4.4	1.1	3.5	4.5	
Unit2	7.7	16	2	8.2	2.1	2.4	3.1	
HREEs								
Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
0.4	1.5	0.3	1.5	0.3	1.0	0.1	1.0	0.1
0.6	2.4	0.4	2.6	0.6	1.8	0.2	2.1	0.3

Table 2. Average REE results for Sorakalat section.

LREEs								
Units	La	Ce	Pr	Nd	Sm	GdYb	LaSm	
Unit1	8.6	16	1.8	6.9	1.5	1.8	5.8	
Unit2	14	27	3.2	13	2.8	1.8	5.3	
HREEs								
Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
0.4	1.7	0.3	1.6	0.3	0.9	0.1	0.9	0.1
0.7	2.0	0.5	2.6	0.5	1.5	0.2	1.6	0.2

comparison to the lower parts. The increase of LREEs in the lower mudstone-dominated facies probably results from their adsorption onto clays, which coincides with findings in the eastern desert of Egypt [15].

The Gd/Yb ratio ranges from 1.06-3.2 in the lower and middle parts decreasing to 0.6-0.8 in the upper part. The pattern of the samples is ordered from bottom to top of the sections. In Figs 4-5 the pattern of the elements in all sections was similar but there are differences between samples from the lower, middle and upper parts. Samples from units one and two reflect high ratios of HREEs while samples from units three and four have lower HREE ratios. The chondrite normalized samples also show positive anomalies represented by Eb, Er and Gd with negative anomalies represented by Tm, Eu and Ce. In sandstone samples the Ce content from the lower, middle and upper parts is very high ranging from 32-118 ppm.

The patterns in the middle and upper parts are similar to each other with similar HREE patterns and a little enrichment by LREEs in the upper part relative to the middle part. Although the middle and upper parts were at least partly derived from felsic or different thrust source rocks, the patterns for these parts are slightly less than 1; therefore, a mafic source has still affected these parts as well. In contrast, patterns from the lower part of the Red Beds are well below 1 which indicates that a main mafic and ultramafic source has affected this part. Also the depletion of LREEs within this lower part indicates that the source area for this part was different from the middle and upper parts and it was not derived from the upper crust. The REE patterns in the current research are similar to the clayey-siliceous rocks (normalised to shale) from the Bazhenov Formation in Russia [18]. They also stated that the Ce distribution was not affected by early diagenesis and variable redox conditions which is similar to the Red Beds. The enrichment of LREEs in some samples from the lower and middle parts does not necessarily mean that these samples were affected by the felsic source because of two reasons.

4.2 Transition trace elements (TTE)

This group, also called ferromagnesian trace elements, is composed of V, Co, Ni, Cr and Cu which show convergent behaviour during the evolutionary processes of volcanic rocks and they decrease with increasing silica content. These elements are very important for determining provenance and tectonic setting [19]. It is well known that these elements concentrate in mafic and

Table 3. Average concentrations of transition elements in the Suwais section of the Red Beds.

Units	V	Co	Ni	Cr	Cu	Ce
Unit1	56	26	26	237	484	26
Unit2	63	24	23	172	459	32

Table 4. Average concentrations of transition elements in the Sorakalat section of the Red Beds.

Units	V	Co	Ni	Cr	Cu	Ce
Unit1	98	40	39	399	711	29
Unit2	64	64	71	22	38	40

ultramafic rocks and they are more common in pelitic rocks than in shale and the NASC [6]; [20]; [21].

V in the Red Beds includes high values reaching up to 208 ppm in some parts of the Red Beds, especially within the Kalacholan-Mawat section (Table 3). This element occurs in the structure of pyroxene, amphibole, biotite and the oxides that contain titanium [22]. Therefore, V has high values in some samples that are probably rich in pyroxene. Cr occurs in igneous rocks in spinel minerals, such as chromites, and it also occurs in ferromagnesian minerals, such as pyroxene and olivine [23]. In ultramafic igneous rocks Cr content is more than 2000 ppm, in basalt it ranges between 150-200 ppm; it reduces to 25-80 ppm in intermediate rocks while it decreases to less than 20 ppm in granitic rocks. During weathering of the source rocks the behaviour of Cr⁺³, which occurs in the silicate minerals, is geochemically similar to Fe⁺³ and Al⁺³, therefore, it occurs in the clay minerals. During more intense oxidation conditions Cr⁺³ is probably oxidised to Cr⁺⁶ to form CrO₄²⁻ that may be deposited in chromate minerals such as CaCrO₄ and PbCrO₄. The Cr that occurs in chromite and spinel is generally resistant to geochemical weathering; therefore, it is transported from the source area to the sedimentary environments in the resistant minerals which strongly reflect the Red Beds.

The increase of Co and decrease of other transition elements may not reflect a mafic rock origin but could reflect sedimentary sorting processes [21]. This has happened in the Red Beds in the Mawat-Chwarta area in the upper part (unit 2) of the Sorakalat section (Table 4). There is a negative relationship between Co/Ni versus Cr in several samples from the upper part of unit two in the Sorakalat and Suwais sections (Tables 3 and 4) while generally there is similarity in the Co/Ni in the other samples although strong variability occurs in Cr contents in unit one. This probably indicates that the Cr in the Red Beds occurs mainly in detrital chromite mineral grains. Chromite was not

uniformly distributed in the source rocks but was concentrated in pockets and, therefore, the amount of chromite derived from this source depends on the surface area of chromite bodies that were exposed to weathering.

The ratio of Co/Ni in the Red Beds is not affected by the previous factors because these elements occur in the silicate minerals and their abundance is related to weathering products such as illite-smectite and montmorillonite that are common in the Red Beds. The small variation in the Co/Ni ratio in the lower part of the Red Beds indicates little variation in the nature of the source rocks during their sedimentation. The stronger variation of this ratio in the upper parts of the Red Beds reflects contribution from another source whereas there is little variability in the Cr content in this part of the sequence relative to the lower parts. When the Co/Ni ratios and Zr contents were compared to data from other rocks from northern Iraq and elsewhere it was shown that most of the lower Red Bed samples were close to values from dunite, harzburgite, lherzolite and basalt while most of the middle Red Bed samples plus sample S20 from the lower part are similar to the upper continental crust analyses (Table 3). Recently analysed Cr-spinels from serpentines in northern Iraq showed that much of the matrix of the serpentines was derived from harzburgite and lherzolite of forearc affinity [24].

The amount of Ni in the Red Beds increases in the upper parts within the conglomerate facies, which probably reflects a contribution of felsic components. It should be mentioned that the Cr and Ni in the Red Beds have low concentrations in the Merga and Kanarroy sections which probably reflects less exposure to an ultramafic source during the deposition of these sections or because a different river channel supplied these deposits to the basin. The Cr contents in the Taconian orogen from North America reached 3950 ppm [1]. If Cr and Ni > 100 ppm and they show a high correlation they probably indicate derivation from ultramafic components in the source area [3]. A Cr/Ni ratio of 2 or more indicates a mafic source and, therefore, since most Cr and Ni values from the lower part of the Red Beds plotted within this range they would have come from a mafic source while the middle (sandstone) and upper part (conglomerate) of the sequence were under this range and would have had a less mafic source. These results exactly coincide with findings from the Bastar craton [21].

Pelite samples tend to be enriched with Cr and Ni [21] but contents are slightly lower than the actual mafic volcanic rock samples from the Bastar

craton [22]. In contrast, their coarser grained samples of sandstone and quartzite plotted in the field of post-Archean crust reflecting derivation from granite and gneiss in the Bastar craton [25].

5. CONCLUSIONS

Generally, the trace and REEs indicated that the sediments in the Red Beds were affected by a major ultramafic to mafic source, especially in the mudstone facies from the lower part, and the geochemical data were compatible with a mixed to mafic impact especially within the coarse-grained sediments in the middle and upper parts. The data also indicated that the Red Beds were affected by a moderate degree of weathering and a lack of recycled sediments. Rare earth elements were normalized to chondrite, average shale, upper continental crust and mid oceanic ridge values. The diagrams of chondrite normalised values generally show enrichment in LREEs with negative Eu anomalies and the lower part of the Red Beds is mainly enriched with HREEs ascribed to mafic and ultramafic source rocks contrary to the middle and upper parts which have less HREEs and were probably affected by a felsic source.

The concentration of transition elements the lower parts and depletion in the upper parts reflect regressive erosion of the mafic components upwards through the section with little effect from a felsic source. Spider diagrams reflect the main derivation of mafic sediment in lower parts of the Red Beds with a minor felsic contribution fed into the middle and upper parts.

According to their geochemical signatures the Red Bed sediments were deposited in a range of sedimentary environments and derived from a source area with varied source rocks. The provenance of the Red Beds can be inferred from the geochemical evidence to be predominantly mafic as shown by the REEs and transition elements.

6. ACKNOWLEDGEMENTS

I offer my great thanks to the Ministry of Higher Education and Scientific Research in Iraq for the financial support of my research. I also extend my great thanks to the School of Earth and Environmental Sciences, University of Wollongong, for the generous support including equipment and facilities that were provided for this work. Great thanks to the directory of water well drilling for their kind support during my research.

7. REFERENCES

- [1] Etemad-Saeed N, Hosseini-Barzi M, John S & Armstrong-Altrin, "Petrography and geochemistry of clastic sedimentary rocks as evidences for provenance of the Lower Cambrian Lalun Formation, Posht-ebadam block, Central Iran", *J. Afr. Earth Sci.*, Vol. 61, 2011, pp. 142-159.
- [2] Bhatia MR, "Plate tectonics and geochemical composition of sandstones", *J. Geol.*, Vol. 6, 1983, pp. 611-627.
- [3] Garver JI, Royce PR & Smick TA, "Chromium and nickel in shale of the Taconic foreland; a case study for the provenance of fine-grained sediments with an ultramafic source", *J. Sedim. Res.*, Vol. 66, 1996, pp. 100-106.
- [4] Hossain HMZ, Roser BP & Kimura JI, "Petrography and whole-rock geochemistry of the Tertiary Sylhet succession, northeastern Bengal Basin, Bangladesh: provenance and source area weathering", *Sed. Geol.*, Vol. 228, 2010, pp. 171-183.
- [5] Meinhold G, Kostopoulos D, Reischmann T, Frei D & BouDagher-Fadel MKF, "Geochemistry, provenance and stratigraphic age of metasedimentary rocks from the eastern Vardar suture zone, northern Greece", *Palaeo. Palaeo.*, Vol. 277, 2009, pp. 199-225.
- [6] Osae S, Asiedu DK, Banoeng-Yakubo B, Koeberl C & Dampare SB, "Provenance and tectonic setting of Late Proterozoic Buem sandstones of southeastern Ghana: evidence from geochemistry and detrital modes", *J. Afri. Earth Sci.*, Vol. 44, 2006, pp. 85-96.
- [7] Rudnick RL & Gao S, Eds, *Composition of the Continental Crust*. Oxford: Pergamon, 2003.
- [8] Agard P, Omrani J, Jolivet L, Whitechurch H, Vrielynck B, Spakman W, Monie P, Meyer B & Wortel R, "Zagros orogeny: a subduction-dominated process", *Geol. Mag.*, Vol. 148, 2011, pp. 692-725.
- [9] Alavi M, "Regional stratigraphy of the Zagros fold-thrust belt of Iran and its proforeland evolution', *Am. J. Sci.*, Vol. 304, 2004, pp. 1-20.
- [10] Al-Mehaidi HM, "Tertiary Nappe in Mawat Range, N.E Iraq", *J. Geol. Soc. Iraq*, Vol. 8, 1975, pp. 31-44.
- [11] Buday T, "The regional geology of Iraq", *Stratigraphy and Palaeogeography, Geological Survey Mining*. Baghdad, 1, 1980, 445pp.
- [12] Karim KH, Koyi H, Baziany MM & Hessami K, "Significance of angular unconformities between Cretaceous and Tertiary strata in the northwestern segment of the Zagros fold-thrust belt, Kurdistan Region, NE Iraq", *Geol. Mag.*, Vol. 148, 2011, pp. 925-939.
- [13] Hassan MM, 2012. "Sedimentology of the Red Beds in NE Iraq", PhD thesis, University of Wollongong, 400pp (unpublished).
- [14] Gao S & Wedepohl KH, "The negative Eu anomaly in Archean sedimentary rocks: Implications for decomposition, age and importance of their granitic sources", *Earth Plan. Sci. Lett.*, Vol. 133, 1995, pp. 81-94.
- [15] Dawood YH, Abd El-Naby HH & Sharafeldin AA, "Influence of the alteration processes on the origin of uranium and europium anomalies in trachyte, central Eastern Desert, Egypt", *J. Geochem. Explor.*, Vol. 88, 2004, pp. 15-27.
- [16] Piper DZ, "Rare earth elements in the sedimentary cycle". *Chem. Geol.*, Vol. 14, 1974, pp. 285-304.
- [17] Boynton WV, Ed. *Cosmochemistry of the Rare Earth Elements: Meteorite Studies*. Amsterdam: Elsevier, 1985.
- [18] Zanin YN, Eder V, Zamirailova A & Krasavchikov VO, "Models of the REE distribution in the black shale Bazhenov Formation of the West Siberian marine basin, Russia", *Chemie der Erde*, Vol. 70, 2010, pp. 363-376.
- [19] Armstrong-Altrin JS, Lee YI, Verma SP & Ramasamy S, "Geochemistry of sandstones from the Upper Miocene Kudankulam Formation, southern India: implications for provenance, weathering, and tectonic setting", *J. Sedim. Res.*, Vol. 74, 2004, pp. 285-297.
- [20] Feng R & Kerrich R, "Geochemistry of fine-grained clastic sediments in the Archean Abitibi greenstone-belt, Canada - implications for provenance and tectonic setting", *Geochim. Cosmochim. Acta*, Vol. 54, 1990, pp. 1061-1081.
- [21] Wani H & Mondal MEA, "Petrological and geochemical evidence of the Paleoproterozoic and the Meso-Neoproterozoic sedimentary rocks of the Bastar craton, Indian Peninsula: implications on paleoweathering and Proterozoic crustal evolution", *J. Asian Earth Sci.*, Vol. 38, 2010, pp. 220-232.
- [22] Mason B & Moore CB, *Principles of Geochemistry*. New York: Wiley, 1982.
- [23] Wedepohl KH, *Handbook of Geochemistry*. Heidelberg: Springer-Verlag, 1978.

- [24] Aswad KJA, Aziz NRH, & Koyi HA, "Cr-spinel compositions in serpentinites and their implications for the petrotectonic history of the Zagros Suture Zone, Kurdistan region, Iraq". *Geol. Mag.*, Vol. 148, 2011, pp. 802-818.
- [25] Mondal MEA, Hussain MF & Ahmad T, "Continental growth of Bastar craton, central Indian shield during Precambrian via multiphase subduction and lithospheric extension/rifting: evidence from geochemistry of gneisses, granitoids and mafic dykes. *J. Geosci. Osaka City Univ.*, Vol. 49, 2006, pp. 137-151.

Int. J. of GEOMATE, Sept., 2014, Vol. 7, No. 1 (Sl. No. 13), pp. 938-944.

MS No. 3243 received on July 23, 2013 and reviewed under GEOMATE publication policies.

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