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Petrography and Geochemistry of Kolosh Clastic Unit in Selected Location North and North-East Iraq

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Abstract: ***Kolosh Formation (Paleocene – Lower Eocene) is located in the Unstable Shelf within the High Folded Zone of Zagros belt northeastern Iraq. The sandstones of two sections from Kolosh Formation; one in Dyana area northeastern and one in Koisinjac southeastern Erbil Governorate, (the latter represents the type section), were studied covering mineralogy and geochemistry. These sandstones are classified as litharenite dominated by lithic fragments which are mainly carbonate followed by metamorphic, igneous, (both plutonic and volcanic), and chert. Next to the lithic fragments, quartz appeared of both monocrystalline and polycrystalline. Feldspar is found in minor amount dominated by K-feldspar and rarely plagioclase. Pyroxenes both ortho- and clinopyroxene are in high amount. The accessory minerals are iron oxides, chromite, micas, clay, and spinel. These sandstones are texturally immature. The cementing materials are mainly carbonate with rare iron oxide cement. The Qt-F-L provenance plot of these sandstones suggests arc-derived sediments. Major elements geochemical data show that the sandstones of the type section have lower SiO2, Al2O3, Fe2O3, MgO, TiO2 and higher CaO, MnO contents than those of Dyana section. The sandstones of the type section are highly depleted in SiO2, Al2O3, Fe2O3, and TiO2 relative to UCC than the sandstones of Dyana section. Positive and negative correlations between these oxides reveal the mineral phases present. The trace element data normalized to UCC show depletions in LILE and HFSE and enrichment in transitional elements. With high concentration of Cr and Ni compared to UCC. The chondrite-normalized REE patterns is homogeneous with LREE enrichment relative to HREE, $(La/Yb)_N$ = 4.43 and 1.11 and have negative slopes, $(La/Sm)_N$ = 3.35 and 1.5 in the type section and Dyana section respectively. Both sections also show negative Eu anomalies especially the type section which reflects Eu fractionation with the major element Ca. These sandstoes are classified geochemically as wacke.***

Keywords: Kolosh Formation, litharenite, provenance, spinel, Dyana section

1. Introduction

Kolosh Formation represents the sediments of the deepest and most mobile sedimentary basin of the Paleocene - lower Eocene cycle. It belongs to the Unstable Shelf which is exposed in the High Folded Zone in northern and northeastern of Iraq and extended to the southwest to be subsurface in the Foothill Zone which appears in Kirkuk wells [1]. The Kolosh basin which occupied the area of the High Folded Zone was partly isolated from the Red Beds basin in the northeastern by a ridge along the Balambo-Tanjero Zone from Amadiya in the northwestern through Rowanduz and Ranya towards Halabja in the SE [2]–[4]. Both the NW and SE continuations of this ridge can be traced to Dohuk [4] and probably to Mardin [5]. Immediately SW part of the marginal ridge a relatively narrow foredeep developed during the Early Palaeogene which was filled in with the Palaeogene clastics of the Kolosh Formation. The formation also regionally extends into Turkey, where it is represented by the clastic facies of the Kermav Formation [6]. In SE Iran the upper part the Amiran Formation and the purple shales of the Lower Pabdeh Formation can be correlated with the Kolosh Formation [7], [8]. The formation consists of green shales and green sandstones, chert, and radiolarite. In the upper most parts, the Kolosh is interfingering with the Sinjar Limestone Formation. The detailed section given by [9]. In this paper we present the result of the petrography study and the whole rock geochemical analysis of sandstone from Dyana and Type sections of the Kolosh Formation.

2. The Study Area

Two studied localities are chosen in Erbil Governate to represent the Kolosh Foreland Basin. In general The Kolosh Formation is distributed in all the outcropped regions in north and north east Iraq from Zakho to Derbendikhan/Shameran area. The studied localities are; Dyana, and Koisinjac the later represents Kolosh Type section Figure (1).

-The Kolosh type section is located 70 km southeast of Erbil Governate and 15 km northeast of Koi Sanjaq city in coordinates:
E 44⁰ 35' 57.2''
N 36⁰ 09' 32.4''

-The Dyana section is located 150 km northeast of Erbil Governate and 80 km northeast of Shaqlawa town in coordinates:
E 44⁰ 22' 47.6''
N 44⁰ 33' 70.0''

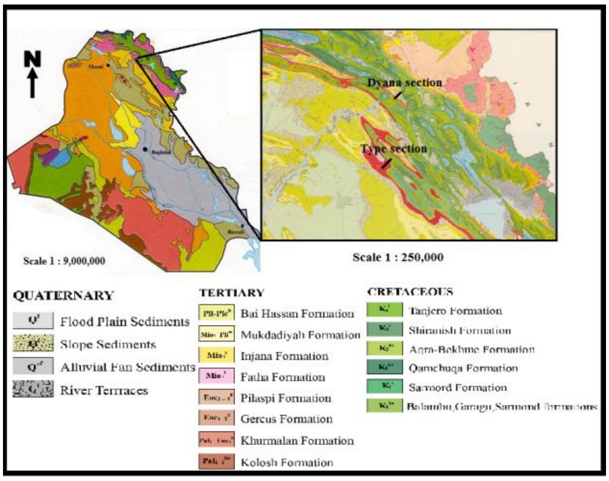

Figure 1: Geological Map 1:250,000 of Arbeel and Mahabad Quadrangles show the two studied Sections of the Kolosh Formation [10].

3. Petrography

Thin section petrographic analyses were carried out to define the framework mineral compositions, types of the cementing materials and textural relationship to gain information on the nature of the lithologies. Modal analysis of the representative samples was carried out by using point counter mechanical stage as suggested by [11]. (500) counts per slide were preformed covering (15) components. A summary of results including the average, range of percentage of each component in the sandstone of Kolosh are listed in Table (1). The framework of the sandstones composed of three components, sand grains, matrix (silt grains) and cementing materials. The sand grains constitute the majority of the sandstone components, while the matrix is entrapped in between the sands grains. The cementing materials are almost of chemical origin or argillaceous matrix which is of terrigenous origin. The mineralogical constituents of the sand grains are slightly varying from locality to another because of the distance of transportation and tectonic environments from which these sediments were derived. For example, the Kolosh sandstones in the Dyana section show abundance of pyroxene and olivine minerals varieties accompanied with abundance of ultrabasic and basic rock fragments whereas the sandstone of the Kolosh type section show an increase in metamorphic and chert fragments and decrease in the pyroxene which reach 0.9%, being angular with fresh grains. These varieties are co-exist with quartz and feldspar which make an average percentages of 3.20%-3.85% respectively. In general, the studed sandstone samples are characterized by low degrees of mineralogical and textural maturities. They display a wide range from course to fine-grained and a great variation in the degree of the roundness from rounded to angular.

The main detrital constituents encountered are quartz, pyroxene, and lithic fragments with minor amounts of other minerals (e.g. heavy minerals, micas,...etc.). In general, it is rich in lithic fragments which are mostly carbonate and metamorphic. The mineralogical constituents of the Kolosh Sandstones minerals fragments and cementing materials are showing in Table (1).

Table 1: The ranges and averages of the main detrital components of the study sandstone of the Kolosh formation

Components	Range	Average
Quartz	4.5 - 12.5	8.5
Alkali Feldspar	1.6 - 7.9	4.75
Plagioclase	0.1 - 0.9	0.5
Pyroxene	4.9 – 16	10.45
Carbonate Rock Fragment	15.1- 18	16.55
Chert Rock Fragments	0 – 10.3	5.15
Argillaceous Rock Fragments	5 – 5.2	5.1
Metamorphic Rock Fragments	3.2 – 18.3	10.75
Igneous Rock Fragments	1 – 1.6	1.3
Cement material	3.4 – 34.5	18.95
Argillaceous matrix	5 – 16.2	10.6
Pores	1.4 – 3.8	2.6
Opaque Grains	1.2 – 2.3	1.75
Others	0 – 6.5	3.25
Unidentified	0 – 1.2	0.6

3.1 Classification of Kolosh Sandstone

The more accepted and widely used classification is that proposed by [12], which based on [13]. In this classification the sandstone is divided into two major groups based on texture whether arenites if composed of grain only or wacke if contain more than 15% matrix [14].

In the Dyana section the Kolosh sandstones are classified as greywacke because it contains matrix percent more than 15%. In these localities the sandstones are containing more than 15% rock fragments; therefore, the sandstones are classified as lithic greywacke [12]. Due to the relatively high percentages of rock fragments the sandstones of the Kolosh type section are classified as lithic arenite Figure (2).

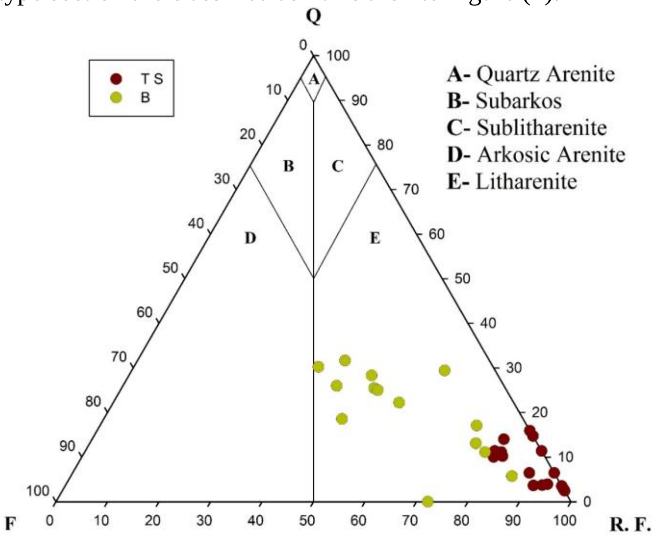

Figure 2: Sandstone classification [20]. Total quartz, feldspar, lithic fragments (Q, F, and L).

4. Geochemistry

4.1 Geochemistry of Major Elements

The ranges and averages of the chemical compositions of the Kolosh sandstones are listed in Table (2) with the average values of the UCC proposed by [15]. The study sandstones are highly depleted in SiO_2 and Al_2O_3 in the type section (average SiO_2 = 23.96%, Al_2O_3 = 4.41%), but slightly depleted in Dyana section (average SiO_2 = 44.51%, and Al_2O_3 = 11.72%) as compared to average values of these oxides in UCC, (SiO_2 = 66%, Al_2O_3 = 15.2%). K_2O is highly depleted in both sections (0.34% and 0.26% respectively) relative to that in UCC, whereas Na_2O is highly depleted in the sandstones of the type section (average 0.51%), but almost similar to the average concentration of Na_2O of UCC in the sandstones of Dyana section (average 3.36%). The differences in the SiO_2, Al_2O_3, K_2O and Na_2O contents in both sections could be due to the dilution of these oxides by carbonate precipitation during diagenesis and also due to the high carbonate rock fragments, [16], [17]. Furthermore, the low K_2O content may be attributed to the low feldspar content in the study sandstones or to the mobility of K_2O during weathering. In both section, the sandstones show enrichment in CaO (average CaO = 27.5% in TS and 8.63% in B section) compared to average CaO in UCC (4.2%). This enrichment is concurrence with the high carbonate rock fragments and also prevalence of carbonate cement as observed from the petrographic observation.

MgO and Cr_2O_3 contents are very high compared to those of the UCC (MgO = 10.31%, Cr_2O_3 = 0.17% in type section and MgO = 11.71%, Cr_2O_3 = 0.16% in Dyana section). These are related to the higher mafic minerals and rock fragments. Fe2O3 content is the same (4.31% in TS section and 6.82% in B section) very similar to the average Fe_2O_3 of the UCC (5.035). This is explained by the contribution of iron in iron-oxides, iron cement and in the ferromagnesian minerals such as olivine, pyroxene together with the MgO.

4.2 Geochemistry of Trace Elements

The concentration of the trace elements of the Kolosh sandstones are compared to the average concentrations in the upper continental crust rocks [17], (Table 2). The study sandstones are highly depleted in LILE, (BA, Rb) such depletion is probably due to their mobilities in aqueous solutions during weathering. Also the HFSE, (Zr, Nb, Y, Th, U, and Hf). Show depletion compared to UCC rocks. These elements are commonly concentrated in heavy mineral phases such as Zircon, Sphene, and Apatite which are mostly found as accessory minerals in felsic rather than mafic igneous rocks.

The Transitional elements (e.g. Cr, Ni, Co, Cu, V, Zn) concentrations in the study sandstones are variable but in general higher than those of the UCC rocks. Cr and Ni have very high concentrations in these sandstones: average Cr = 1166.25 ppm in the rocks of TS section and 1127 ppm in the rocks of B section, relative to the concentration of UCC (83 ppm), whereas the average concentrations of Ni are 534 ppm, 381 ppm in the rocks of TS and B sections respectively, (average Ni in UCC = 44 ppm). Such high concentrations reflect the abundance of ultramafic/mafic igneous rock source rocks, where both Cr and Ni are compatible trace elements that usually fractionate and replace Mg and Fe in mafic mineral such as olivine, pyroxene, chromite, and chromium-spinel. Furthermore, Co, Sc, and Cu also have higher concentrations than those of the UCC. Hence, such enrichment of these trace elements together with Cr and Ni reflects the contribution of mafic/ultramafic and their weathering products more than felsic source rocks during the depositional history of Kolosh sandstones**.**

4.3 Geochemistry of Rare Earth Elements

The sandstones of the Kolosh formation have REE contents ranging between 9.23 – 49.25 (ppm) in Type section and 11.25 – 23.26 (ppm) in Dyana section. Both have higher REE content than that of the average chondrite; (6.28 ppm), Table (3), but very low REE content compared with the average UCC 143 ppm, [15]. The concentrations of the REE in the study rock samples are shown as chondrite-normalized patterns Figure (3), normalization after [18]. In general, the patterns are more or less uniform for both sections showing LREE enrichment relative to the HREE (the ratios $(La / Yb)_N$ = 4.43 and 1.11 for TS and B respectively), and negative slope (the ratio $(La / Sm)_N$ = 3.35 and 1.54 for TS and B respectively). All samples of the TS section show negative Eu anomalies indicating plagioclase fractionation whereas samples of the B section show diversity but most also have negative Eu-anomalies. The higher LREE/HREE ratios and the negative Eu-anomalies of the Kolosh sandstones is a characteristic feature of mixed felsic and mafic rocks [15].

Table 2: Range and average concentration of major and trace elements of Kolosh sandstones with average UCC values (after mclennan, 1985).

Elements	Unit	Type Section			Dyana Section			UCC
		Range		Mean (Average)	Range		Mean (Average)	
		Min.	Max.		Min.	Max.		
SiO_2	%	16.45	43.10	23.96	39.40	47.00	44.51	66
Al_2O_3		2.84	7.25	4.41	10.35	12.95	11.72	15.2
Fe_2O_3		3.06	7.74	4.31	5.24	8.78	6.82	5.03
CaO		2.67	36.50	27.50	6.20	16.20	8.63	4.2
MgO		6.12	21.80	10.31	7.57	14.25	11.71	2.2
Na_2O		0.06	1.83	0.51	2.42	4.14	3.36	3.9
K_2O		0.09	0.70	0.34	0.09	0.85	0.26	3.4
Cr_2O_3		0.07	0.34	0.17	0.11	0.32	0.16	----
TiO_2		0.14	0.28	0.20	0.28	0.69	0.41	0.68
MnO		0.06	0.55	0.35	0.07	0.11	0.09	0.08
P_2O_5		0.01	0.16	0.07	0.01	0.03	0.02	0.15
LOI		14.75	32.60	27.39	10.35	17.10	12.27	----
Ba	ppm	10.7	49	29.01	12.3	47.1	19.52	550
Cr		470	2300	1166.25	750	2180	1127	83
Cs		0.21	2.61	1.01	0.26	0.76	0.5	3.7
Ga		2.7	6.3	3.99	6.4	9.8	8.26	17
Hf		0.4	0.5	0.44	0.5	0.9	0.76	5.8
Nb		0.5	2.5	1.38	0.3	0.7	0.47	12
Rb		2.5	14.8	7.86	2	7.9	3.67	112
Sn		0	1	0.75	1	2	1.6	5.5
Sr		152.5	409	236.13	75.10	176	120.47	350
Ta		0	0.2	0.05	0	0	0	2.2
Th		0.16	0.62	0.32	0.13	0.24	0.175	10.7
U		0.08	0.41	0.23	0.07	0.57	0.202	2.8

V		42	94	55.88	117	244	156.9	107
Y		4.3	12.7	8.25	8	11.5	9.25	22
Zr		12	19	15.63	18	31	24.5	190
Cd		0	0.5	0.19	0	0.5	0.2	0.098
Co		22	61	36.25	29	52	39.8	17
Cu		15	64	31.75	54	90	71.2	25
Li		10	20	11.25	10	30	19	20
Ni		273	960	534.25	288	512	381.2	44
Pb		0	5	2.25	0	13	5.3	17
Sc		8	18	11.63	21	33	26.8	13.6
Zn		26	65	42.13	42	74	59	71

Table 3: Range and average values of rare earth elements of Kolosh sandstone with average chondrite and the chondrite-normalized values (normalization after Boynton, 1984)

Elements	Unit	Type Section				Dyana Section				Average Chondrite
		Range		Mean (Average)	Normalized Value	Range		Mean (Average)	Normalized Value	
		Min.	Max.			Min.	Max.			
La	ppm	1.50	11.30	5.05	15.78	1.30	4.20	1.97	6.16	0.32
Ce		2.40	18.30	8.05	8.94	2.20	7.70	3.62	4.02	0.9
Pr		0.32	2.05	0.96	7.38	0.31	0.87	0.50	3.85	0.13
Nd		1.50	8.20	4.03	7.07	1.80	4.10	2.59	4.54	0.57
Sm		0.46	1.81	0.99	4.71	0.58	1.06	0.84	4.00	0.21
Eu		0.16	0.60	0.34	4.86	0.26	0.44	0.34	4.86	0.07
Gd		0.62	2.22	1.20	3.87	1.01	1.53	1.25	4.03	0.31
Tb		0.12	0.34	0.20	4.00	0.19	0.30	0.23	4.60	0.05
Dy		0.74	1.91	1.23	4.10	1.29	1.96	1.57	5.23	0.3
Ho		0.16	0.37	0.26	3.71	0.28	0.43	0.34	4.86	0.07
Er		0.50	0.97	0.71	3.38	0.87	1.30	1.02	4.86	0.21
Tm		0.07	0.17	0.11	3.67	0.11	0.22	0.15	5.00	0.03
Yb		0.51	0.88	0.64	3.56	0.74	1.34	1.00	5.56	0.18
Lu		0.08	0.13	0.10	3.33	0.13	0.22	0.16	5.33	0.03

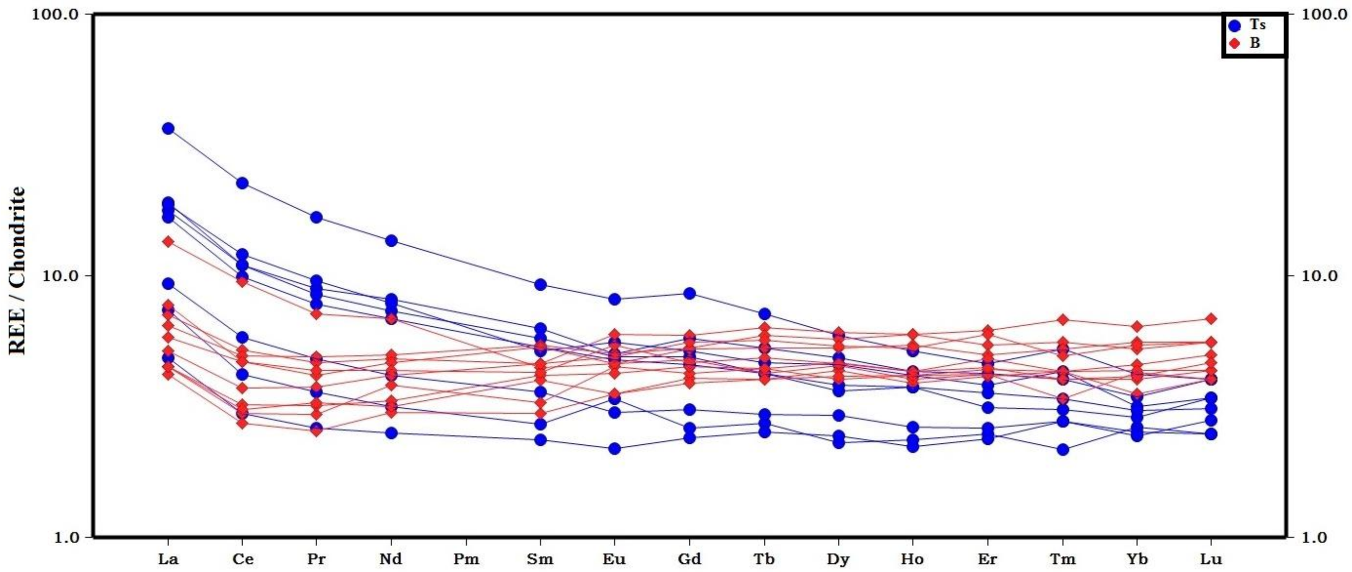

Figure 3: Chonderite-normalized REE pattern of the Kolosh sandstone Formation

5. Geochemical classification of Kolosh Sandstone

Using the geochemical classification scheme of [19], the Kolosh Formation sandstones are classified as albitized or pyrite- bearing sandstones to Fe-rich Shale (Figure 4). However, this distribution is likely controlled by a depletion of K_2O found in these sandstones and likely reflects the effects of weathering, diagenesis and secondary mineral formation on the geochemical composition of the sandstone. Taking this into account, the geochemical classification of wacke to litharenite better matches the petrographic data.

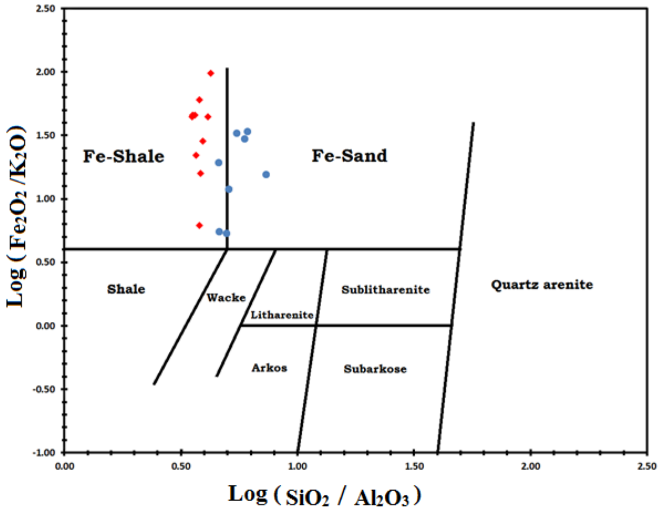

Figure 4: Major-element classification of the Kolosh sandstones (after Herron, 1988).

6. Conclusions

1) The sandstones of Kolosh Formation (Paleocene – Lower Eocene) from northeast Iraq were studied from mineralogical and geochemical point of view. Two sections were selected one is the type section (TS) in Koi-sinjac and one is Dyana section (B) the following conclusions are:
2) Petrographic study showed that these sandstones are rich in lithic fragments of carbonate, mainly with metamorphic, igneous and chert. Both monocrystalline and polycrystalline quartz are present with minor amounts of feldspar. Pyroxene present is high represented by ortho- and clino-pyroxenes with accessory minerals such as iron oxides, chromite, micas, and clays. The cementing material is mainly carbonate with rare iron oxide cement.
3) These rocks are texturally immature and classified as litharenites derived from arc (undissected and transitional) provenances on Qt-F-L diagram.
4) The geochemical study showed that the sandstones of the TS section have lower SiO_2, Al_2O_3, TiO_2, Fe_2O_3, and MgO, compared to those in B section. And higher CaO contents. In both sections the concentrations of the major oxides are lower than that of UCC especially those in the type section. This could be due to dilution of these oxides by precipitation of the carbonate rock fragments and carbonate cement.
5) The concentrations of the trace elements also variable in both section with higher Cr, Ni, Co, Cu, Y, V, and lower Th and U compared to UCC. The LILE and HFSE have lower concentrations relative to UCC.
6) The chondrite –normalized REE patterns are also homogenous with LREE enrichment relative to the HREE and negative Eu anomalies. The sum of the REE is higher than that of the chondrite but lower than that of UCC.

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