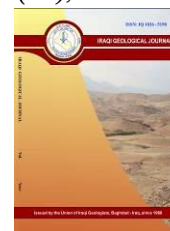




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Geochemistry and Genesis of the Paleocene–Eocene Kolosh Formation Northeast of Iraq

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Abstract

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Geochemical investigation on mudstones from clastic sediments was conducted to deduce the origin and successive post-depositional changes in the Kolosh Formation north of Iraq during the Paleocene–Eocene period. The analysis of the major oxides exposes a relatively constant descent for the mudstones. The geochemical examination indicates that these mudstones are carbonate-rich (calcareous to dolomitic mudstones) by predilection pattern terrigenous shales, and CaO + MgO dominance, elucidating a carbonate mud mode, denoting the limited terrestrial clay inputs and control of carbonate deposition. These signatures suggested accessible carbonate rock, probable inclusive of limestone and dolostone genesis. Furthermore, the low content of siliciclastic rocks proposed a shallow marine environment with low energy. Established on the elemental rates, these mudstones are categorized as graywacke and lithic arenite, which are derived from mixing igneous source rocks. The mudstone in the descent recognition diagrams locus in the oceanic island arc, continental island arc, and active continental margin maintains the signature of a recycled source. The Chemical Index of Alteration, Chemical Index of Weathering, and Index of Chemical Variability propose recycling processes, and that the provenance area has endured a moderate grade of chemical weathering and immature sediments. The geochemical individuality ratios display immature texture. It has been obvious, that such chemical weathering for the source materials is mightily influenced by arid and dry climate status allowing moderate weathering and the arid environment directing to simple ratio of maturation.

Keywords: Geochemistry; Mudstone; Provenance; Paleoweathering; Paleoclimate; Kolosh Formation

1. Introduction

In order to comprehend and deduce the origin of clastic sedimentary rocks, numerous studies have been conducted to determine the source rocks, the tectonic environment in which they were generated, the weathering they were previously subjected, and the climate in geological ages. Finding the geochemistry of clastic rocks to ascertain the synchronism of sedimentary cycles and the evolution of sediments over geological time is one of the most significant uses of this study. The geochemistry of sedimentary rocks has been used to diagnose and visualize the circumstances and weathering processes, as well as the origin of the rocks to which they are an extension, because it contains indications and relationships with the origin and genesis of the mineral groups of the rocks (McLennan et al., 1993). Clastic geochemistry gives consideration to the mineral constitution of sedimentary rocks and the diagenesis activity that impacts deposits throughout the sedimentation process (Roser et al., 1996).

In a widespread region in the north of Iraq, the Kolosh Formation has been classified as flysch-type sediments that were deposited during the Middle Paleocene and trended northwest to southeast. The formation is composed of interbedded sandstone and mudstone/shale layers grouped within graded turbidite cycles (Ditmar et al., 1971). It is mostly composed of a layered sequence of clastic sediments of different thicknesses, such as shale beds, dark grey to black clayey sandstone beds, dark green shales, green sandstones, chert, and radiolarite. Along with few conglomerate beds, it also includes beds of limestone and siltstone (Jassim and Goff, 2006). The Kolosh Formation's superior border is appropriate with the Khurmala Formation, whereas its lower boundary is incompatible with the Tanjero Formation and displays total biogenic alteration without any transitional features. The formation has an unconformable boundary overlying the Tanjero Formation in the type section; elsewhere, overlies the Shiranish Formation. The clastic sediments of the Kolosh Formation were derived from the erosion of the Tanjero, Qulqula and other Cretaceous-Jurassic formations. Proposed that the upper boundary of the Kolosh Formation is unconformable; however, when Paleocene-Early Eocene limestone layers cover the Kolosh Formation, the upper boundary is consistent and stepped (Jassim and Goff, 2006).

Several studies have investigated the stratigraphy and depositional environment of the Kolosh Formation; for example, the study by Dathan et al. (2022) depends on lithofacies analysis of the northeastern part of the Kolosh Formation in Iraq. The findings indicated that the Kolosh Formation in the north of Iraq was deposited in an active margin basin when the northeastern part of the Arabian Plate collided with the Eurasian Plate at the end stages of Neo-Tethys closure, which resulted in vast uplifts and subsidence events due to eustatic sea level rise and fall.

Few studies have investigated the mineralogy and geochemistry of the Kolosh Formation in Iraq. For example, a study by Mahdi et al. (2021) examined the mineralogy and geochemistry of the Kolosh Formation in the Dokan area, and reported that the formation sequence includes grey and dark grey marl that derived from a clastic submarine environment dominated by detrital sediments with kaolinite, illite, and slightly by quartz.

The main objective of this study is to elucidate both the provenance of the Kolosh Formation through inclusive geochemical inspections. In addition, the current study attempts to remodel the depositional conditions and diagenesis of the Kolosh Formation by combining these geochemical data to evolve a logical model for the genesis, sediment inputs, and depositional environment of the Kolosh Formation.

2. Geological Setting

The Kolosh Formation was first described by Dunnington (1952 in Van Bellen et al., 1959) from Kolosh Village, north of Koi Sanjak town, in the High Folded Zone. As claimed by Ditmar and the Iraqi-Soviet Team (1971), the type section comprises a portion of the Sinjar carbonate Formation (Jassim and Goff, 2006).

The Kolosh Formation contains chert, greenish grey mudstones, siltstones, argillaceous limestones, detrital limestone and radiolarian parts in the Chemchemal, TaqTaq and Mushorah anticlines. The lithology specifies that interference between the Kolosh and Sinjar formations occurs in the northern limb of the Kirkuk structure and in the Derbendikhan Area (Jassim et al., 1975).

The depositional condition of the formation was marginal marine in a narrow and swiftly subsiding trough, deposited as flysch clastic sediments (Ditmar et al., 1971).

The Kolosh Formation was deposited in a narrow basin extending from northwest to southeast, widening from the northwest in Mashora anticline, through Koi Sanjak to Kashti in the southeast. The basin was bordered to the north and northeast by a narrowing, interrupted ridge, which split it from the Balambo-Tanjero Zone where the Suwais Red Beds units were deposited in an individual basin through the Dohuk, Ranya, Sulalmaniya, and Halabja areas (Jassim and Goff, 2006).

The chosen sections under study are located in the Erbil Governorate. Twenty mudstone samples were collected from the Kolosh Formation. The first section is located in the Bakhma area (KA) with coordinates 36°39'50.0151" N and 44°14'04.1152" E. The formation at this section is made up of sandstone layers about 0.5-1 m thick and mudstone layers that are 3-4 m thick. The second section is within the Shaqlawa area (KB), with coordinates 36°24'34.1621" N and 44°19'31.3361" E. It is composed of sandstone layers that are 1-1.5 m thick and mudstone layers that are 3-4 m thick (Figs. 1 and 2).

The total thickness of the Kolosh Formation in selected sections is around 100 to 150 m, and it contains layers of pebbly to graded sandstone and layers of mudstone. The green mudstone layers are 0.5-1 m thick, and are characterized by their laminated structures, while the pebbly sandstone layers are 4-5 m thick, and they are light to green pebbly sandstone, and they contain a sedimentary structure of scoured and filled up, accompanied by little solid, extremely thin beds of secondary gypsum in the pebbly sandstone (Figs. 1 and 2).

3. Methodology

The current study is focused on the analysis of samples collected from two sections that are dispersed along outcrops within the Shaqlawa and Bekhme areas of the Erbil Governorate. Twenty samples from the Kolosh Formation were collected from two sections. The XRF analysis was used to achieve major oxide concentrations in the Iraqi-German Lab at Baghdad University, Department of Earth Sciences. The used technique has low detection limits for numerous elements of the Periodic Table. The XRF spectrometer's material analysis mode can analyse a wide range of materials; it is possible to properly detect material composition ranging from 0.1% to 100% (Kanngießer et al., 2005).

4. Results and Discussion

The geochemistry of the major oxides explains the whole vision of the content of sedimentary rocks, as well as the distribution of elements forming primary minerals (Murray, 2007). In this respect, the total of twenty outcrop samples that were collected from mudstone beds of the Kolosh Formation at the Shaqlawa and Bekhme areas, north of Iraq, were investigated by an X-ray fluorescence spectrometer (XRF). The following major oxides SiO₂, Al₂O₃, Fe₂O₃, CaO, MgO, MnO, Na₂O, K₂O and P₂O₅ are demonstrated in percentages as shown in Table 1.

The major oxide (wt%) results were compared with the major oxides in the Upper Continental Crust (UCC) (Taylor and McLennan, 1985) and Post-Archean Australian Shale (PAAS) (Ramasamy et al., 2007; Taylor and McLennan, 1985).

Table 1 shows the results of the geochemical investigation of the mudstone samples of the Kolosh Formation, which have the highest concentrations of CaO, followed by SiO₂ and MgO, depending on their abundance. Comparatively with the major oxides of the UCC and average of the PAAS, the results show a general increase in MgO, CaO and Fe₂O₃ over almost all samples, companion by a reduction in SiO₂, Al₂O₃, MnO, Na₂O, K₂O, TiO₂ and P₂O₅ relative to the UCC and average of PAAS, which may be linked to the chemical alteration within oxic circumstances or belong to the geochemistry of the origin sediments (Table 1; Fig. 3).

These may indicate that these mudstone beds are carbonate-rich (calcareous to dolomitic mudstone) by preference model terrigenous shales. The CaO + MgO predominance indicates a carbonate mud regime, not a clay-rich siliciclastic mudstone. The content of MgO seems to have increased compared to PAAS and UCC, suggesting dolomite presence, dolomitization, or Mg-marine water. While the SiO₂ is less than that of the PAAS and UCC, it indicates low inputs of detrital quartz and clay minerals. The Al₂O₃ and TiO₂ lower values imply restricted terrestrial clay inputs and dominance of carbonate sedimentation (Morse and Mackenzie, 1990).

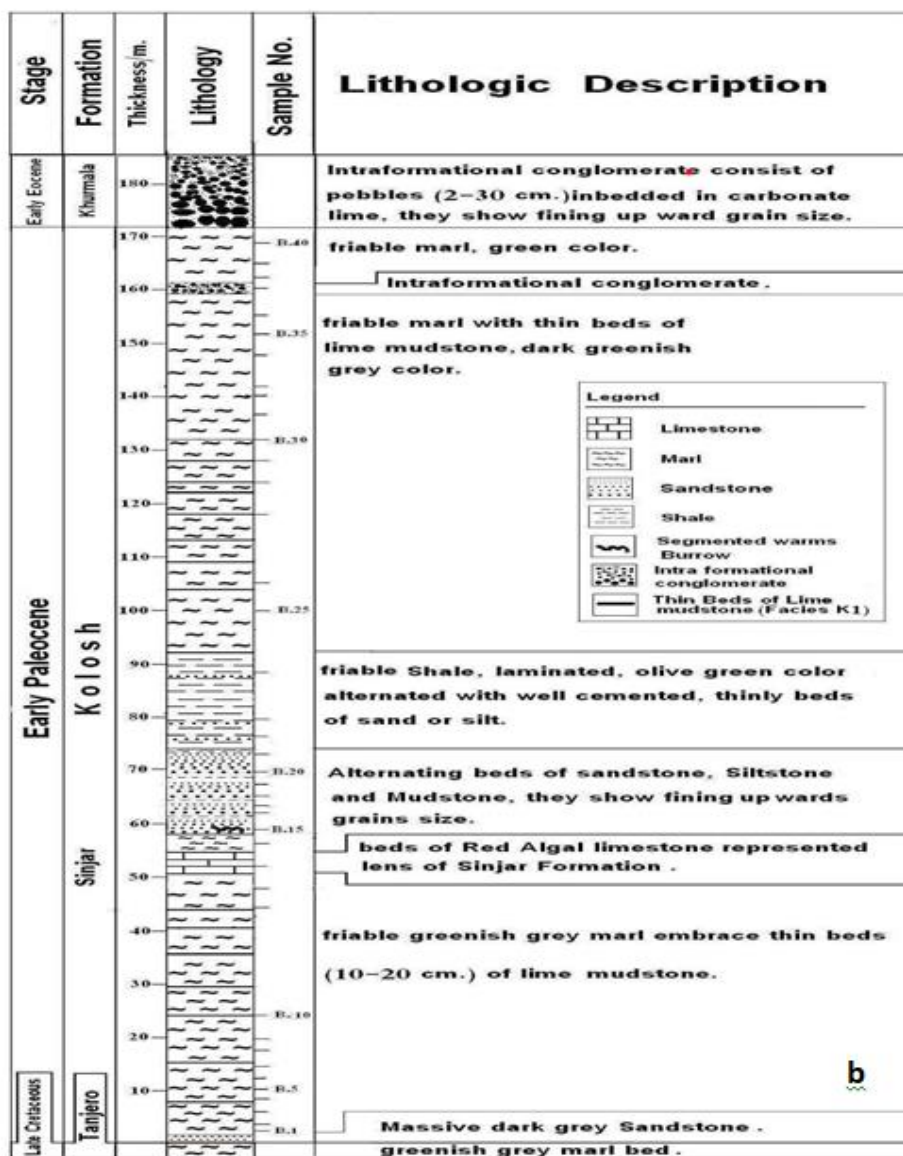
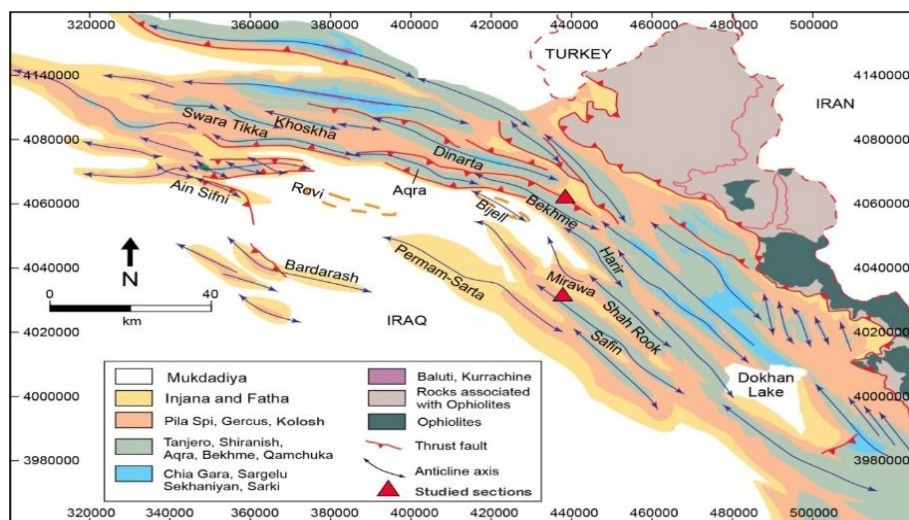


Fig 1. a): Site map of Kolosh Formation in the research area (modified after Sissakian and Fouad, 2015), b): Lithological section of the Kolosh Formation (modified after Al-Banna et al., 2012)

There is a high depletion in K_2O and Na_2O , relative to the PAAS and UCC, suggesting a decrease in the content of feldspar and leaching within the diagenesis process. These essential structures are ideal for marine carbonate mudstones, but not for continental shales (Tucker, 2001).

The alkaline elements had been reduced throughout weathering actions for the reason that the chemical disintegration of rocks (Roser et al., 1996). The Fe_2O_3 are comparable to the PAAS, the iron held in clay minerals and carbonate lattice or in Fe oxide cement, while the MnO is slightly increased, referring to carbonate deposition within a redox marine environment (Morse and Mackenzie, 1990). Subsequently, the mudstones represent mixed carbonate–siliciclastic facies, carbonate-dominated.

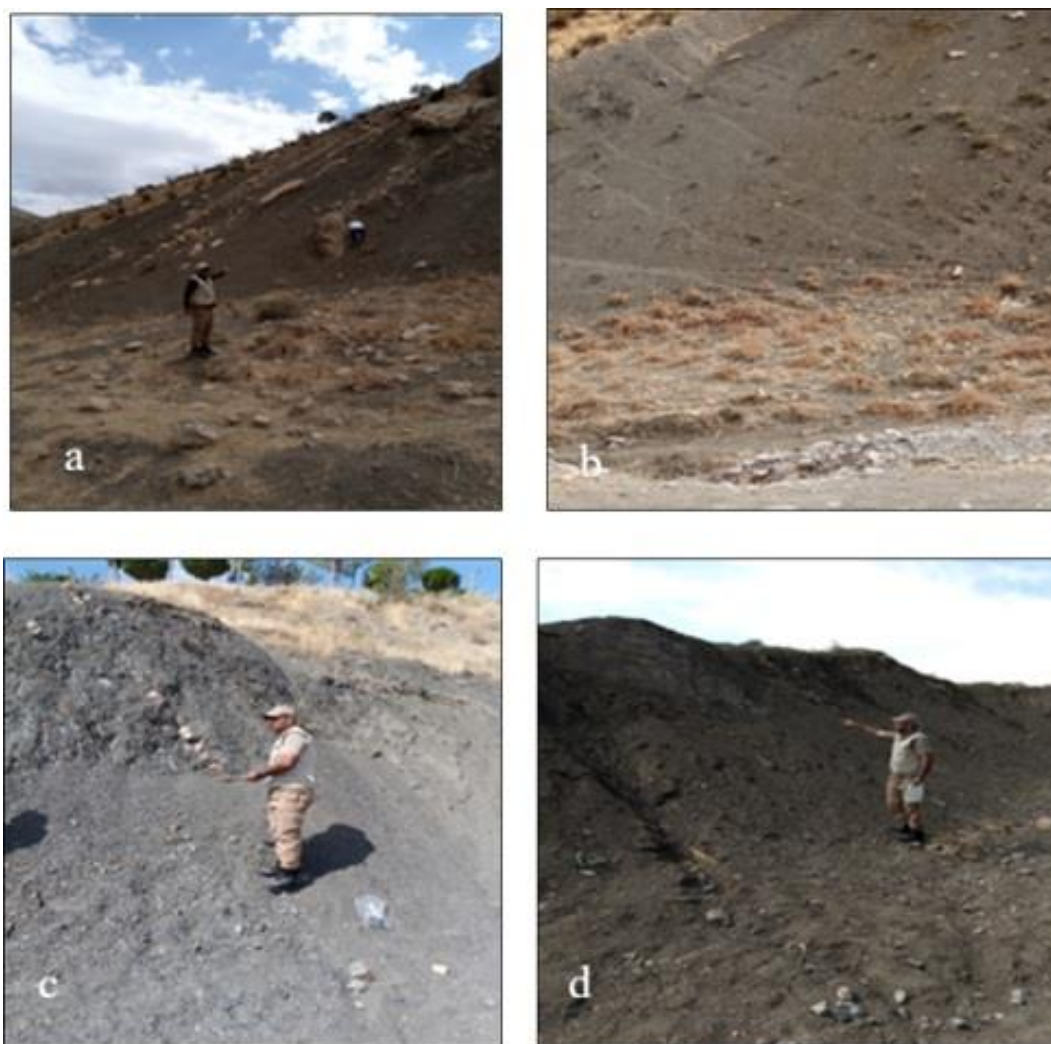


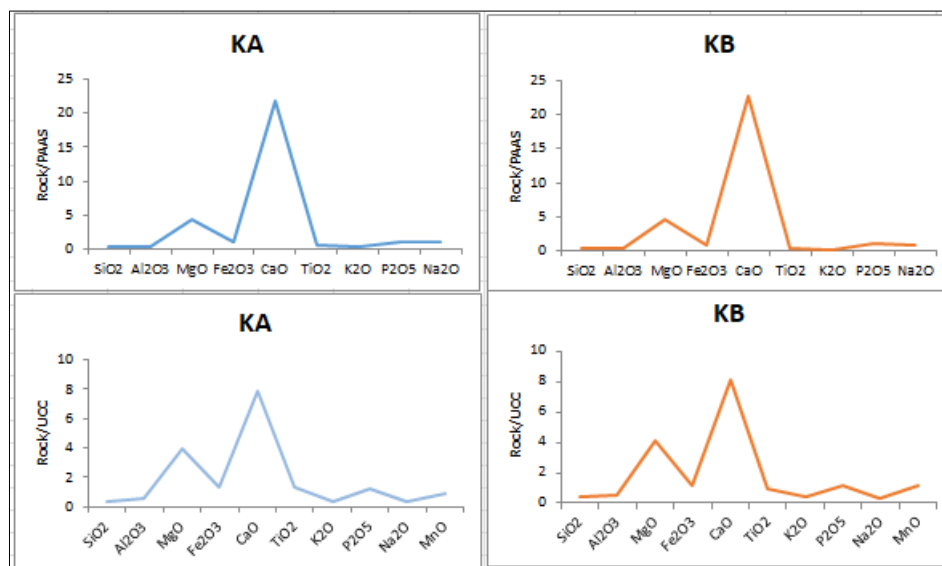
Fig. 2. Field photographs: a and b) show section KA (Bekhme), and c and d) show section KB (Shaqlawa)

The increased CaO is ascribed firstly to the amplitude of calcite-rich carbonate sediments, and the season-raised MgO , suggesting an offering from dolomitic rocks. These signatures suggested that the origin of the sediments was mostly from accessible carbonate rock origin, probably inclusive of limestone and dolostone genesis (Krauskopf and Bird, 1995).

Moreover, the dominion of carbonates, together with a small part of siliciclastic load, reinforces the downfall in a shallow marine environment distinguished by a low energy state and finite terrigenous inflow. These situations are representative of a carbonate platform or shelf territory, where chemical and biochemical sedimentation of carbonates is common (Rollinson, 1993).

Table 1. The concentrations of the main oxides in the collected samples from the study area (wt%)

Sam.	SiO ₂	Al ₂ O ₃	MgO	Fe ₂ O ₃	CaO	TiO ₂	K ₂ O	P ₂ O ₅	Na ₂ O	MnO
1KA	32.44	10.74	7.231	6.366	25.05	0.91	0.979	0.2254	1.423	0.1153
2KA	28.4	7.237	9.066	8.832	26.33	0.8758	0.75	0.2146	1.447	0.0985
3KA	31.58	9.708	10.018	7.821	23.83	0.7967	0.666	0.1884	1.321	0.0975
4KA	24.33	8.04	11.801	8.026	26.61	0.8502	0.71	0.1728	0.913	0.1022
5KA	25.18	8.132	10.029	7.262	29.88	0.7965	0.566	0.2178	1.517	0.089
6KA	23.77	7.883	9.448	6.226	30.19	0.7202	1.481	0.1455	1.602	0.0805
7KA	24.34	8.908	10.968	7.42	26.4	0.3846	1.333	0.1496	1.424	0.0857
8KA	24.52	7.871	9.426	6.131	31.04	0.3813	1.425	0.1712	1.147	0.0859
9KA	21.45	8.125	10.685	6.87	31.25	0.5873	1.336	0.1714	0.844	0.0864
10KA	22.14	8.693	9.218	5.353	31.96	0.4411	1.388	0.1651	0.737	0.0897
AVG.	25.815	8.5337	9.789	7.0307	28.254	0.6743	1.0634	0.1821	1.2375	0.0930
1KB	20.35	9.035	7.817	6.477	34.83	0.3361	1.131	0.1523	0.965	0.1308
2KB	34.74	9.172	11.371	6.503	18.78	0.5973	1.38	0.3159	1.145	0.1174
3KB	20.84	8.307	9.176	6.115	32.24	0.2918	0.896	0.3044	1.267	0.116
4KB	18.23	8.603	9.784	6.225	34.15	0.4233	0.601	0.1446	0.89	0.1088
5KB	17.97	7.871	9.608	6.618	34.65	0.6735	1.097	0.1289	1.068	0.1219
6KB	23.05	9.129	10.547	6.59	29.93	0.4068	1.315	0.1544	1.673	0.1195
7KB	42.64	7.473	10.96	5.638	15.02	0.8075	0.8913	0.112	1.001	0.1038
8KB	19.5	8.329	11.774	6.861	32.68	0.249	0.9994	0.145	0.572	0.1148
9KB	28.79	8.559	12.54	6.334	21.88	0.3662	1.102	0.1429	1.696	0.1109
10KB	21.18	6.118	8.117	6.098	38.9	0.4636	0.9734	0.127	1.085	0.1187
AVG.	25.451	8.2596	10.169	6.3459	29.306	0.4615	1.0386	0.1727	1.1362	0.1162
UCC	66.60	15.40	2.48	5.40	3.59	0.5	2.80	0.15	3.27	0.10
PAAS	62.4	18.78	2.19	7.18	1.29	0.99	3.68	0.16	1.19	

**Fig. 3.** Major element concentrations of detritus sediments of the Kolosh Formation normalized to the UCC and PAAS

4.1. Provenance and Tectonic Setting

The geochemical composition of some elements has been used to draw discrimination and diagnostic diagrams to determine the tectonic settings. The diagram of Bhatia (1983) employs the association between major oxides, $\text{Fe}_2\text{O}_3 + \text{MgO}$, with TiO_2 and $\text{Al}_2\text{O}_3 / \text{SiO}_2$ ratio to determine the

tectonic position of the rocks. These ratios coincide with oceanic island arc, continental island arc and active continental margin with source rocks of the Kolosh Formation (Fig. 4).

The discrimination (Fig. 5) proposed by Roser and Korsch (1986) plots SiO_2 values versus $\log (\text{K}_2\text{O}/\text{Na}_2\text{O})$ of the studied sediments. The results of the samples of the Kolosh Formation confirm the oceanic island arc margin and active continental margin origin (Fig. 5); this may indicate that the sedimentary basin was probably created in a convergent plate boundary setting.

Moreover, the contrast of $\text{Fe}_2\text{O}_3 + \text{MgO}$ with the $\text{Al}_2\text{O}_3/\text{SiO}_2$ ratio indicates the comparatively uniform mafic component of parent rocks; nevertheless, the reduction in $\text{Al}_2\text{O}_3/\text{SiO}_2$ ratio is possibly due to increased SiO_2 and weak Al_2O_3 content, which is influenced by severe weathering in addition to mature deposits in the oceanic island arc region and active continental margin impact.

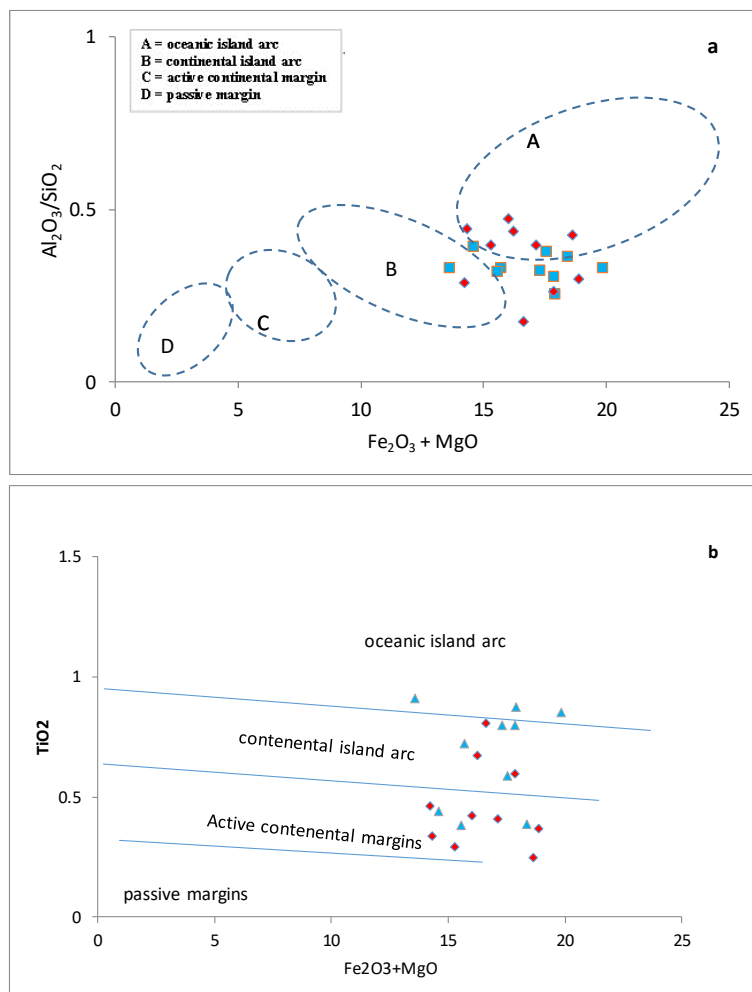


Fig. 4. Tectonic recognition diagram for the detritus sediments of the Kolosh Formation, based on Bhatia (1983) (red points are Shaqlawa section, and blue points are Bekhme section)

Increasing the ferro-magnesium constituents ($\text{Fe}_2\text{O}_3 + \text{MgO}$) refers to a high level in origin of the studied rock samples, which fall within the range of the oceanic island arc, continental island arc and active continental margin. The Al_2O_3 versus TiO_2 graph (Fig. 6) suggested by McLennan et al. (1979) refers to mixing igneous source rocks, from granitic to basaltic composition.

Roser and Korsch (1988) presented a discriminant function plot to distinguish between sediments that are primarily felsic, intermediate, or mafic igneous in origin and quartzose sedimentary sediments. Where the Discrimination Function1 = $30.638 * (\text{TiO}_2/\text{Al}_2\text{O}_3) - 12.541 * (\text{Fe}_2\text{O}_3(\text{t})/\text{Al}_2\text{O}_3) + 7.329 * (\text{MgO}/\text{Al}_2\text{O}_3) + 12.031 * (\text{Na}_2\text{O}/\text{Al}_2\text{O}_3) + 35.402 * (\text{K}_2\text{O}/\text{Al}_2\text{O}_3) - 6.382$. Discrimination Function2 = $56.500 * (\text{TiO}_2/\text{Al}_2\text{O}_3) - 10.879 * (\text{Fe}_2\text{O}_3(\text{t})/\text{Al}_2\text{O}_3) + 30.875 * (\text{MgO}/\text{Al}_2\text{O}_3) - 5.404 * (\text{Na}_2\text{O}/\text{Al}_2\text{O}_3) +$

$11.112 * (K_2O/Al_2O_3) - 3.89$; that Fe_2O_3 (t) belong to total iron (Fig. 7). Despite being close to the intermediate igneous field, all studied samples are shown in the quartz sedimentary provenance field. Those are probably recycled ancient sedimentary rocks (sandstones, quartz arenites), preferably derived straight from igneous provenance.

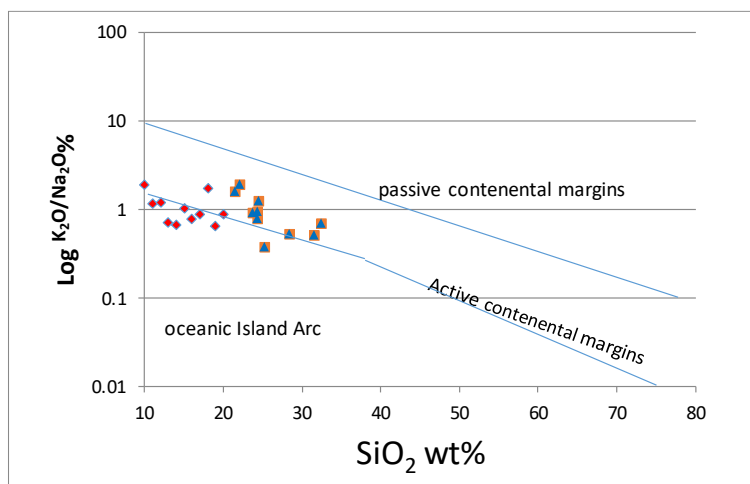


Fig. 5. Tectonic sectors' plot for detritus sediments of the Kolosh Formation, based on Roser and Korsch (1986), (red points are Shaqlawa section, and blue points are Bekhme section)

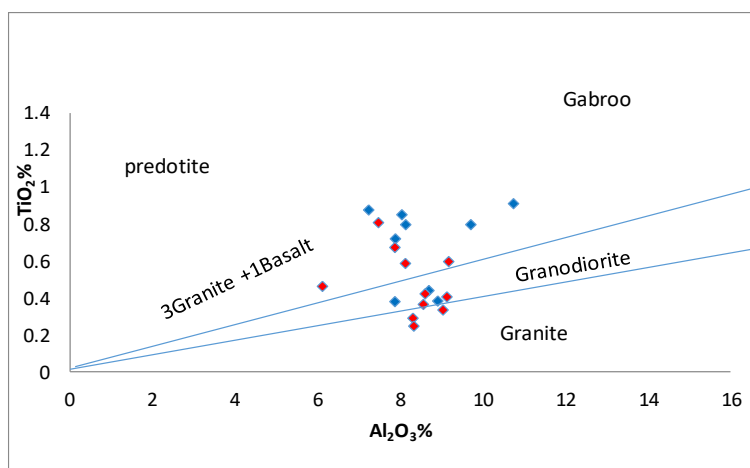


Fig. 6. Bivariate plot, Al_2O_3 vs TiO_2 for the samples of the Kolosh Formation, based on McLennan et al. (1979), red points are Shaqlawa section, and blue points are Bakhme section

4.2. Paleoweathering Conditions

It is scientifically proven that chemical weathering affects the components of the clastic sediments and leads to changes and alterations in the main components of sedimentary rocks. Just as weathering affects the source rocks, this effect is calculated or estimated using the Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW) coefficients (Fedo et al., 1995).

The CIA coefficient reflects the degree of chemical weathering of the sedimentary debris embedded within the source rocks. Therefore, it is important to estimate the climatic conditions that prevailed during the formation of these types of sedimentary rocks. The CIA coefficient for sedimentary rocks was proposed by Nesbitt and Young (1982) and calculated from equation (1).

$$CIA = [Al_2O_3 / (Al_2O_3 + CaO * + Na_2O + K_2O)] * 100 \quad (1)$$

The CaO^* can be regarded as Calcium in clastic silicate minerals (Fedot et al., 1995), so the specimen that has a high content of CaO belongs to the diagenesis of cement and needs to be set right as stated by Equation (2).

$$\text{CaO}^* = \text{CaO} - (10.3 \times \text{P}_2\text{O}_5) \quad (2)$$

If the CIA value is close to 100, this indicates that the source rocks have been weathered extensively.

The CIW is utilized to expose past-weathering of the provenance region and provide details to the chemical weathering grade for the studied rocks. The equation (3) calculates the CIW coefficient proposed by Garzanti and Resentini (2016) as follows.

$$\text{CIW} = [\text{Al}_2\text{O}_3 / (\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O})] * 100 \quad (3)$$

The CIW account ranges from 0 to 40, indicating less weathering process, while between 40 to 65 indicates modest weathering and if more than 70, then refer to severe weathering condition.

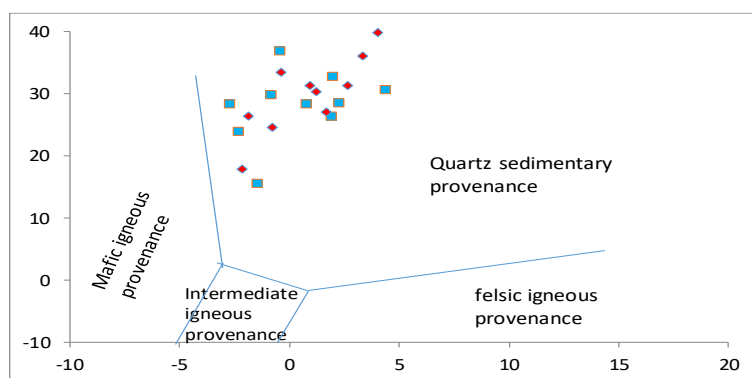


Fig. 7. Discriminant sections to identify the provenance of the studied samples, based on Roser and Korsch (1988), (red points are Shaqlawa section, and blue points are Bekhme section)

It is obvious from the results of the studied samples that the Kolosh Formation was exposed to moderate to high levels of weathering (Table 2), either in the source rock's origin area or during the sediment transport process before being deposited in the sedimentary basin.

Furthermore, CIA vs. Al_2O_3 plot (Fig. 8) illustrates moderate weathering in the source provenance.

The Index of Chemical Variability (ICV) is a very helpful tool for determining compositional maturity and weathering conditions (Cox et al., 1995). The equation (4) calculates the ICV (McLennan et al., 1993) as follows:

$$\text{CIW} = [\text{Al}_2\text{O}_3 / (\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O})] * 100 \quad (4)$$

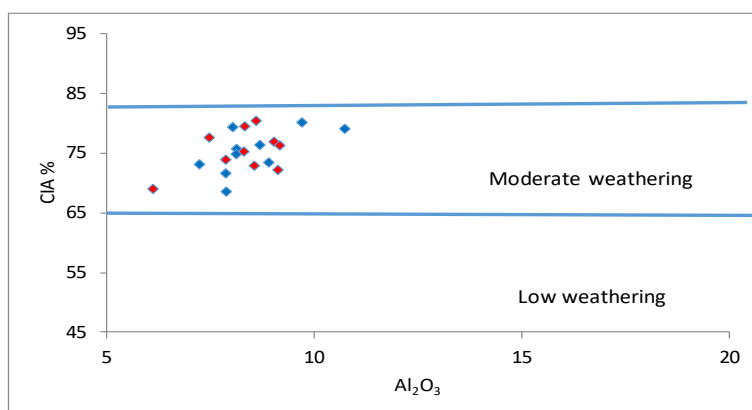


Fig. 8. Scatter plot of CIA versus Al_2O_3 for the studied samples of the Kolosh Formation, based on Nesbitt and Young (1982), red points are Shaqlawa section, and blue points are Bekhme section

Table 2. Elemental ratios, CIA, CIW and ICV values of the studied samples

Samples	SiO ₂ /Al ₂ O ₃	K ₂ O/Al ₂ O ₃	CIA	CIW	ICV
1KA	3.020	0.091	79.063	85.204	3.833
2KA	3.924	0.104	73.107	79.100	6.429
3KA	3.253	0.069	80.125	84.785	4.507
4KA	3.026	0.088	79.336	85.313	5.990
5KA	3.096	0.070	75.693	79.902	6.068
6KA	3.015	0.188	68.538	78.667	6.219
7KA	2.732	0.150	73.420	82.482	5.347
8KA	3.115	0.181	71.598	82.262	6.258
9KA	2.640	0.164	74.823	85.320	6.286
10KA	2.547	0.160	76.356	86.957	5.607
Avg. KA	3.025	0.125	75.287	83.082	5.562
1KB	2.252	0.125	76.898	85.088	5.684
2KB	3.788	0.150	76.275	86.163	4.284
3KB	2.509	0.108	75.254	81.902	5.996
4KB	2.119	0.070	80.399	85.183	6.016
5KB	2.283	0.139	73.894	82.378	6.754
6KB	2.525	0.144	72.178	80.554	5.496
7KB	5.706	0.119	77.594	85.507	4.498
8KB	2.341	0.120	79.471	87.848	6.363
9KB	3.364	0.129	72.878	80.424	5.101
10KB	3.462	0.159	68.989	77.495	9.038
Avg. KB	2.994	0.126	75.405	83.304	5.825

4.3. Maturity and Paleoclimate

The maturity of clastic rocks is mostly identified by SiO₂/Al₂O₃ ratios; when the ratio has a value more than 5.0, it specifies highly mature sediments (Roser et al., 1996). The studied samples from the Kolosh Formation have SiO₂/Al₂O₃ ratios exhibiting textural immaturity (Table 2).

It can be relied upon Cox et al. (1995), the ratios K₂O/Al₂O₃ are < 0.4 in old clastic sediments, which indicates a low alkali feldspar abundance as compared to other minerals in the parent rocks. Thus, the average ratio of tested samples indicated a low feldspar content (Table 2). Moreover, the low K₂O/Al₂O₃ ratio in the studied samples could be due to the dominance of low K-feldspar content in the origin area (Pettijohn et al., 1987).

An average ICV value of 0.85 was recorded for the PAAS, and the ICV values of the studied samples were further higher than 0.85, ranging from 5.56-5.82 (Table 2), which suggested compositional immaturity of the source material.

According to the SiO₂ against Al₂O₃+K₂O+Na₂O diagram (Fig. 9) of Suttner and Dutta (1986), the tested samples exist in a dominant arid climate during the sedimentation period in the source area. It has been shown that the chemical weathering of parent rocks is strongly influenced by arid climate conditions, promoting moderate weathering and arid conditions leading to slower rates of maturation (Nesbitt and Young, 1982). As it is clear from the results, the studied samples of the Kolosh Formation have moderate CIA and CIW values, indicating that the parent rocks have undergone low, prolonged chemical changes and reactions under arid and dry climatic conditions.

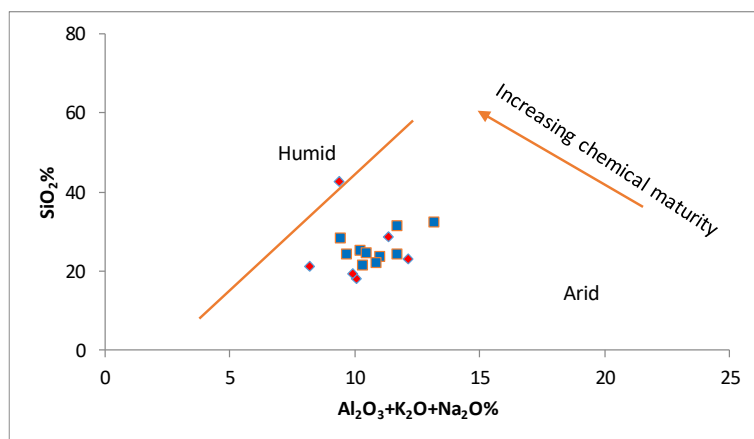


Fig. 9. Climatic identification for the samples of the Kolosh Formation using $\text{Al}_2\text{O}_3 + \text{K}_2\text{O} + \text{Na}_2\text{O}$ vs SiO_2 plot, based on Suttner and Dutta (1986), red points are Shaqlawa section, and blue points are Bekhme section

5. Conclusions

The clastic rocks of the Kolosh Formation are mainly composed of calcareous to dolomitic mudstones, deposited inside a carbonate-dominated marine environment accompanied by a slight terrigenous load. The major oxide composition is distinguished by carbonate reduction and comparatively low clay mineral content, as specified by contrast with the quality standards, such as the PAAS and UCC. The obtained geochemical data proposed deposition in tectonic settings, including oceanic island arcs, continental island arcs, and active continental margins.

Geochemical illustration diagrams further show a mixed igneous provenance, connected with a quartz-rich sedimentary origin, which refers to the recycling actions for the sediments. The derivation source rocks area is distinctly possible to experience moderate chemical weathering under arid to semi-arid climate situations, resulting in less fabric maturity and the accumulation of comparatively immature sediments enclosed by a vital dynamic tectonic basin.

Declaration of Competing Interest

The author declares that she has no competing financial interests or private relationships that could impact the effort reported in this study.

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Data Availability

Data are included in the article or supplementary material.

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