Chemical Characteristics, Provenance Determination and Genesis Conditions of Clay Deposits of Kahrizak Formation (Early-Late Pleistocene), East of Tehran, Iran

Z. Valiani and P. Rezaee

Abstract— **The Early-Late Pleistocene deposits in South-East of Tehran (Kahrizak Formation) consist of gravel, sand and clay facies which are related to alluvial fan deposits. The XRD analysis on fine grained deposits of the formation indicated the existence of clay minerals including montmorillonite, illite and chlorite; also quartz, calcite and anorthite are present as the minor components. We determined provenance and paleoclimate condition of the deposits based on clay minerals type. Montmorillonite and illite were used as the provenance indicator showing volcanic rock as the source rock. All clay minerals indicate low to moderate leaching in temperate to cold climatic setting. Their ICV values are >1 indicating negligible recycling or weathering of the clays. K_2O/ Al_2O_3<0.4 and ternary plot of $CaO+Na_2O$-Al_2O_3-KO_2 suggests the deposits compositions same as basalt. Also that displays weathering trend. Low ICV values of the deposits exhibit low to intermediate degree of weathering for the parental rock. Based on Bhatia diagram, using DF1 and DF2and K_2O/Na_2O versus SiO_2, its tectonic setting was determined as being active continental margin.**

Keywords- Kahrizak Formation; clays; paleoclimate; active continental margin

I. INTRODUCTION

Early to Late Pleistocene strata of the Central Alborz, named as the Kahrizak Formation, were interpreted as alluvial fan deposits in the south and east of Tehran (Aghanabati and Rezaee, 2009). Becausethe fine grained parts of the formation have not studied yet; this paper struggles to study the mineralogical and geochemical characterization of its clay minerals in the east of Tehran and to assert appropriate interpretation for their development conditions and tectonics setting.

Clay minerals are of the indicators for determining paleoclimate, sedimentary and diagenetic conditions and also tectonics settings. In order to attain this goal, the authors used the strata color and sedimentary facies in the field study, petrographic, X-ray and chemical studies. All these techniques are widely used in studies of modern muds, but not used extensively in ancient mudstones, because the effects of diagenesis and low-grade metamorphism (Velde, 1977; Bhatia, 1983; Roser and Korsch, 1986; McLennan, 1993; Cox et al., 1995; Tucker, 2001; Potter et al. 2005). The results of this study is an example for application of mudrock geochemistry to tectonics analyses and showed the major-element geochemistry of mudrocks is a useful tool for establishing a comprehensive understanding on regional tectonics evolution.

II. GEOLOGICAL SETTING

The Kahrizak Formation is Quaternary alluvial fan deposits in southern Alborz (Fig 1). The formation was deposited following Plio-Pleistocene erosional cycles (Aghanabati, 2006). Ribben (1955) performed the first study on the Quaternary deposits in southern Alborz and classified them as 4 units (Hezar-darreh Formation/A, Kahrizak Formation/B, Tehran alluvial Formation /C and finally Recent alluvium/D) (Aghanabati, 2006). The Formation (Early-Late Pleistocene) unconformably rests on the Hezar-darreh Formation with an angular unconformity contact everywhere. It is overlain by Tehran Alluvial deposits and Recent Age deposits with an erosional disconformity. It was studied by many researchers (Berberian et al. (1992), Ahmadi and Feiznia (2006), Najafi (2012), Najafi et al. (2012)). Common characteristics of the formation are as the following:

1- The thickness of the Kahrizak Formation is varies from 10 to 60 m.

2- The Kahrizak Formation has different characters from layer to layer because of heterogeneous nature, mechanical resistance and high porosity.

3-Unsolidified, heterogeneous and poorly sorted conglomerates.

4-The gravels size is ranging from several cm to several m and the grains are situated in a sandstone matrix.

5-the formation has weak/low cement content and little mechanical resistance.

6-The slope of layers is few and reaches maximum to 15 degree.

7-The color of the Hezar-darreh Formation is usually dark.

Different lithostratigraphy units crop out in the studied area, from Paleozoic to late Cenozoic, such as: Zagun, Mila, Shemshak, Lar, Fajan, Karaj, Hezar-darreh, Kahrizak and

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Recent Age deposits, and there are several faults with general strike from west to east in this area (Fig. 2). This area is located from 56˚ 34'-56˚ 56' E and 39˚ 55'-39˚ 56' N. Jujrud River is the important river in the area.

Four sections from Kahrizak Formation selected in east area of Tehran.

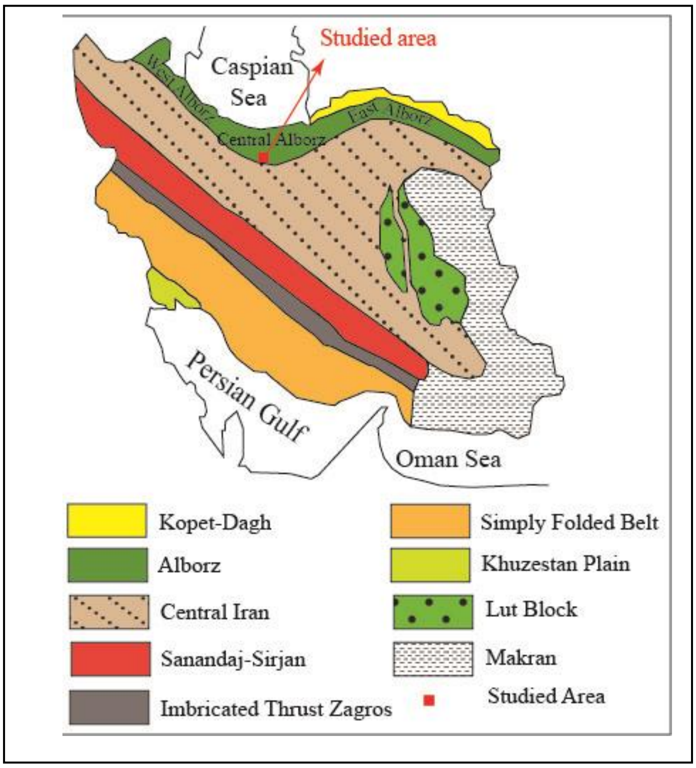


Figure 1. General map of Iran showing the nine geological-structural zones. The study areas are located in the South part of Alborz zone (modified from Stocklin 1968)

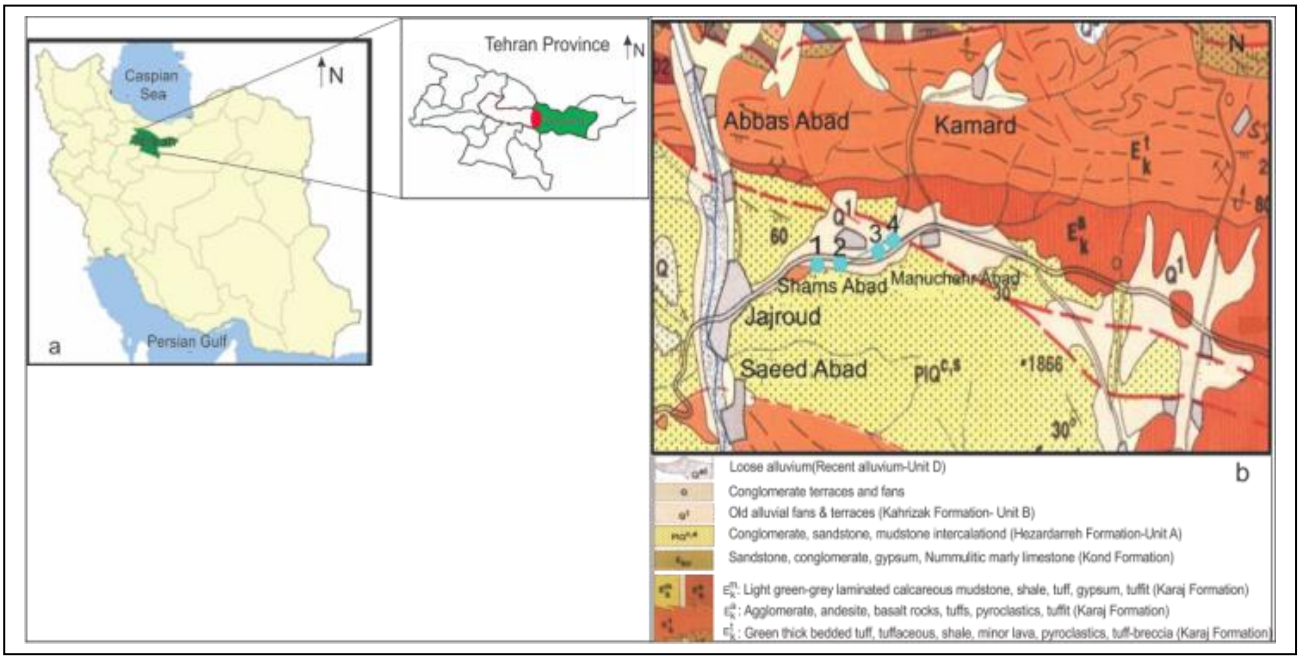


Figure 2. a: Geographical setting of the study area is illustrated by circle, b: geological map of study area (1:100,000) (Sahbaee et al., 1992). Locations of 4 sections, are illustrated by blue circIII

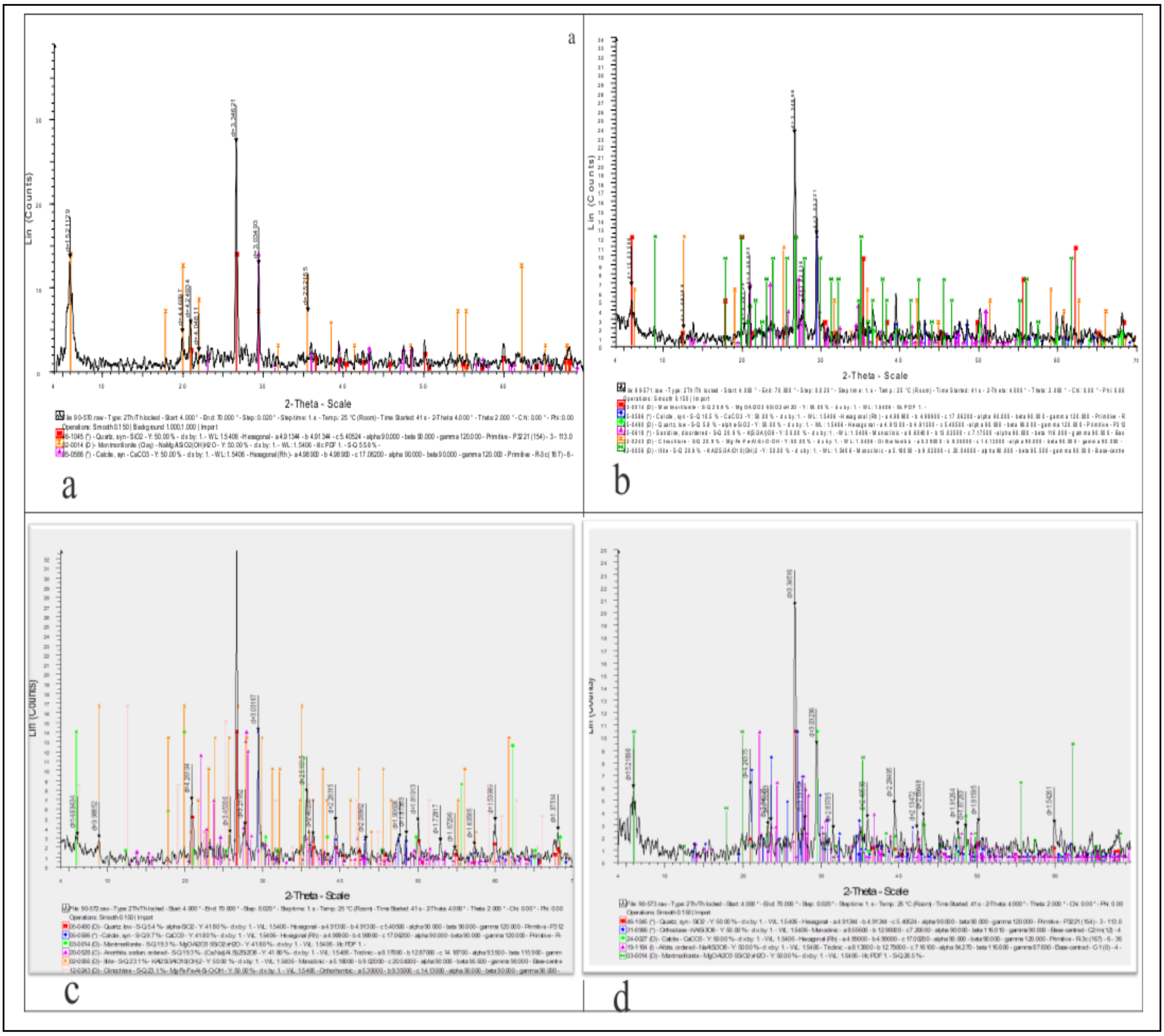
III. MATERIALS AND METHODS

According to the field studies, Kahrizak Formation is composed of gravel, sand and clay facies. Clay horizons have variable thicknesses in all sections. Sampling was done on parts with low weathering and a total of 2 samples were collected from each section. Mudrock samples were ground to <30 μm for determination of concentrations and type of minerals by XRF and XRD, respectively at Geological Survey of Iran's laboratory (Table I and Figs. 3 and 4). Moreover, coarse grained parts were collected from all of the sections and their thin-sections were provided for study under polarized microscope.

IV. RESULTS AND INTERPRETATIONS

A. *Mineralogy*

Results of the XRD analysis indicate montmorillonite is the major clay mineral, and illite and chlorite occur scarcely. Also there are quartz, calcite and anorthite in these clay deposits as the minor minerals (Figs. 3 and 4). Based on XRF analysis, SiO_2 and Al_2O_3 values in the section 1 are greater than the other 3 sections (62.96% and 14.15% respectively) whereas MgO, MnO, CaO, Na_2O and Fe_2O_3 are least in this section. We calculated values of K_2O/Na_2O, K_2O/Al_2O_3, CIA (chemical index of alteration), ICV (index of compositional variability), DF1 and DF2 (first and second discriminant functions) (table I).



Figre 3. XRD results of Kahrizak clay deposits in a: section 1, b: section 2, c: section 3 and d: section 4.

Normally, the source of illite, montmorillonite and plagioclase is volcanic rocks (Tucker, 2001; Nichols, 2009). Chlorite is the result of weathering of tuffs and lappilies (Potter et al., 2005; Tucker, 2001; Velde, 1977). In temperate areas with limited degree of leaching, illite is the typical clay mineral form. Montmorillonite forms in intermediate leaching and moderately weathering conditions, in temperate areas. Chlorite also forms during intermediate stages of leaching in temperate soils and due to more easily oxidization, it occurs in acid soils or at least weathering in cold climate (Potter et al., 2005; Tucker, 2001; Velde, 1977).

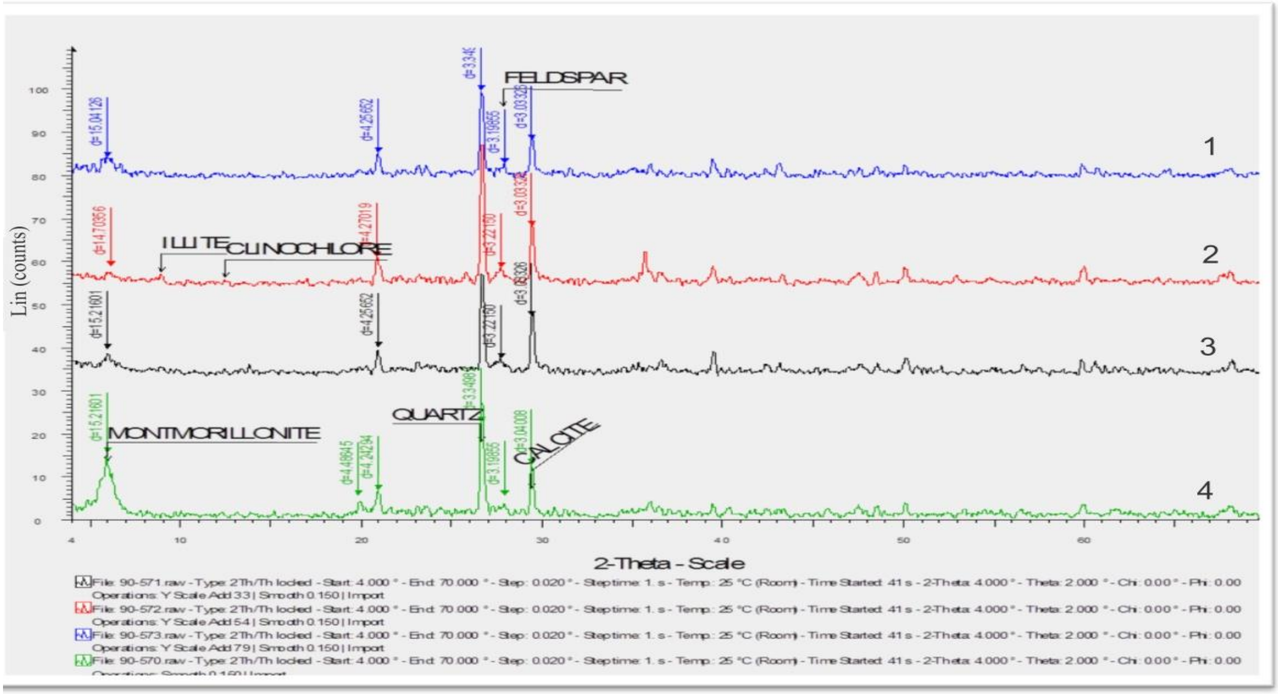


Figure 4. XRD analysis of clay deposits of 4 sections

B. *Geochemical provenance*

Major element geochemistry gives clue to the provenance type as well as weathering conditions which in turn is controlled by the tectonic setting of the basin. Major element oxide compositions of the Kahrizak's clays are given in the table I.

TABLE I. MAJOR ELEMENTS COMPOSITIONS REPRESENTATIVE KAHRIZAK FORMATION FINE GRAINED SAMPLES. MAJOR OXIDES IN WT%, LOI: LOSS ON IGNITION. FOR CIA, ICV, DF1 AND DF2 REFERENCE TO TEXT.

Element	Section 1	Section 2	Section 3	Section 4
SiO_2	53.51	51.21	50.73	50.13
Al_2O_3	12.03	10.99	10.65	10.22
Fe_2O_3	3.02	3.95	3.85	3.22
SO_3	<0.1	0.15	1.04	0.43
P_2O_5	0.16	0.15	0.16	0.15
Na_2O	0.45	0.66	1.10	0.54
K_2O	2.25	2.39	2.40	2.31
MgO	2.14	2.30	2.22	2.36
CaO	10.84	14.59	14.55	14.36
MnO	0.14	0.15	0.18	0.15
TiO_2	0.45	0.47	0.50	0.44
Cl	0.00	0.00	0.32	0.00
LOI	14.88	12.90	12.24	15.34
SUM	84.99	87.01	87.70	84.31
K_2O/Na_2O	5.00	3.62	2.18	4.28
K_2O/Al_2O_3	0.19	0.22	0.23	0.23
CIA	56.65	48.21	46.55	47.13
ICV	1.60	2.23	2.33	2.29
DF1	0.18	0.90	1.23	1.09
DF2	-3.79	-5.63	-4.65	-5.27

Also, chemical weathering can influence the major-element geochemistry of sedimentary rocks, with the most significant changes resulting from alteration of feldspars and volcanic glass (Nesbitt and Young 1982; Taylor and McLennan 1985). The degree of chemical weathering of a source area can be expressed using the chemical index of alteration (CIA; Nesbitt and Young 1982), which is calculated using mole proportions as:

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

CaO* values were calculated using the method of McLennan (1993), where CaO was corrected for apatite using P2O5. In general, CIA values are typically less than40-50 for unweathered igneous and metamorphic rocks and 100 for pure aluminosilicate weathering products (i.e., kaolinite; Taylor and McLennan 1985; McLennan et al. 1993). CIA values for clays of the Kahrizak Formation range from ~47-57 (Table I). The relationship between degree of weathering (i.e., CIA) and original source composition can be assessed by combining CIA with the index of compositional variability (ICV; Fig. 3B; Cox et al. 1995; Potter et al. 2005). The ICV can be used to discriminate source rock types based on major-element geochemistry of mudstones, where:

$$ICV=(CaO+K_2O+Na_2O+Fe_2O_3(T)+MgO+MnO+TiO_2)/Al_2O_3 \quad (2)$$

In this equation, CaO includes all sources of Ca including detrital carbonate. A high ICV value indicates compositionally immature source rocks riched in non-clay silicate minerals whereas low values represent compositionally mature source rocks. As weathering progresses, ICV values decrease due to conversion of feldspars to Al-bearing clays. Thus, variability in ICV values may be due to variations in source-rock composition or to differences in weathering (Cox et al. 1995; Potter et al. 2005). The ICV values for fine grained deposits of the formation range from 1.6 to 2.29 (Table I). Samples were plotted in ICV versus CIA diagram (Fig. 5b).The higher ICV value is likely due to elevated CaO from associated carbonates (Lamaskin et al., 2008), so higher ICV in the sections 2 to 4 can be resulted from calcite fragments, but the section 1 is in the weathering trend of basalt (Fig. 5a).

ICV values of clay deposits in the formation is>1 indicating negligible recycling or weathering. Also, $K_2O/Al_2O_3<0.4$ display minimum K-feldspar content (Banerjee and Banerjee, 2010). This result is comparable to result of the XRD analysis.

CIA values of the clays range from ~46 to 57, which is significantly less than PAAS (average post-Archean Australian average shale is 70 in Mishra and Sen, 2012). This suggests the source rocks of these sedimentary rocks were subjected to weak weathering conditions under a temperate climate. The ternary plot of $CaO+Na_2O-Al_2O_3-K_2O$ (Fig. 5a) is a graphic representation, in order to evaluate the extents of chemical weathering, where unweathered rocks (basalt and granite) plot in it (Nesbitt and Young, 1982).The plot shows samples of all4 sections are near to basalt composition. Their weathering trend is also illustrated. The weathering of the section 1 is more than the other three sections, it implies that is more distal part of alluvial fan than the other sections. This result matches to result of ICV versus CIA diagram (Fig. 5b).

The studies of provided thin-sections of the coarse grained deposits of the formation confirm these results (Fig.6 a, b). Generally, basalt composition volcanic eruptions of Middle Eocene of the parental rocks, resulted from this research, implies to deriving from older formations in the area.

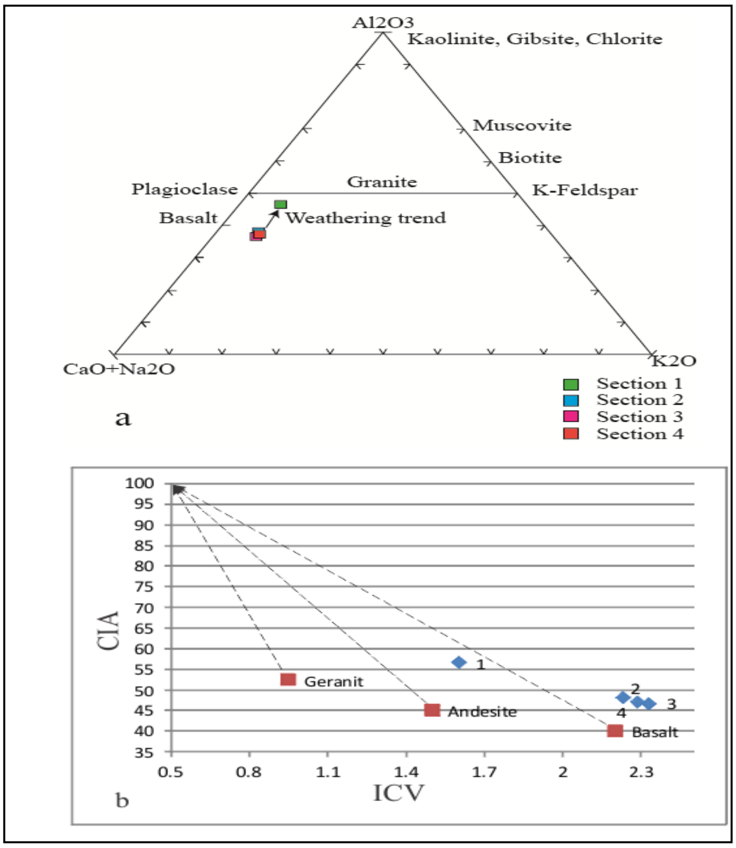


Figure 5. a: ternary plot $CaO+Na_2O-Al_2O_3-KO_2$. Average values of granite and basalt, taken from Taylor and McLennan (1985), b: Plot of CIA vs. index of chemical variability (ICV), after Potter et al. (2005), showing relationship ofdegree ofsource-area weathering and original detrital mineralogy. ICV values for basalt and granite are from Li (2000) and for andesite from Ewart (1982). Samples of sections 2 to 4 are not plotted due to elevated carbonate content but they are near the basalt composite and sample of section is in the weathering trend of basalt.

C. Tectonics setting

The plot of Bhatia's (1983) first and second discriminant functions (DF1 vs. DF2) was used to determine tectonics setting. It is in favours of an active continental margin (Fig. 7a).

$$DF1=0.303-0.0447SiO_2-0.972TiO_2+0.008Al_2O_3-0.267Fe_2O_3+0.208FeO-3.082MnO+0.14MgO+0.195CaO+0.719Na_2O-0.032K_2O+7.51P_2O_5 \quad (3)$$

$$DF2=43.57-0.421SiO_2+1.988TiO_2-0.526Al_2O_3-0.551Fe_2O_3-1.61FeO+2.72MnO+0.881MgO-0.907CaO-0.177Na_2O-1.84K_2O+7.244P_2O_5 \quad (4)$$

Also plot of K_2O/Na_2O wt% versus SiO_2wt% (Roser and Korsch, 1986) illustrates similar tectonic setting (Fig. 7b).

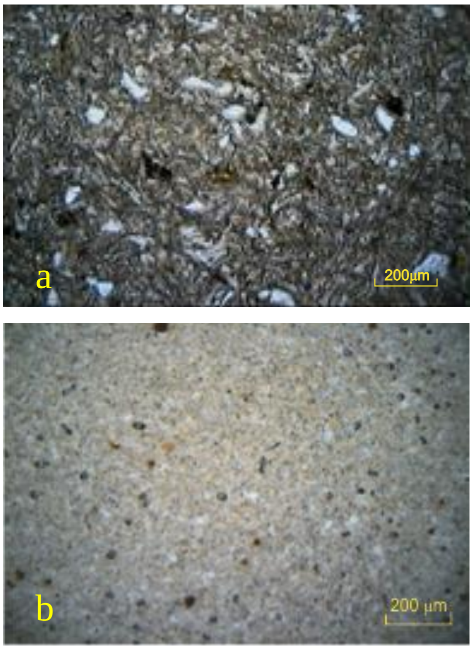


Figure 6. photomicrographs of a: crystalline tuff with shard in matrix, b: lime mudstone (PPL).

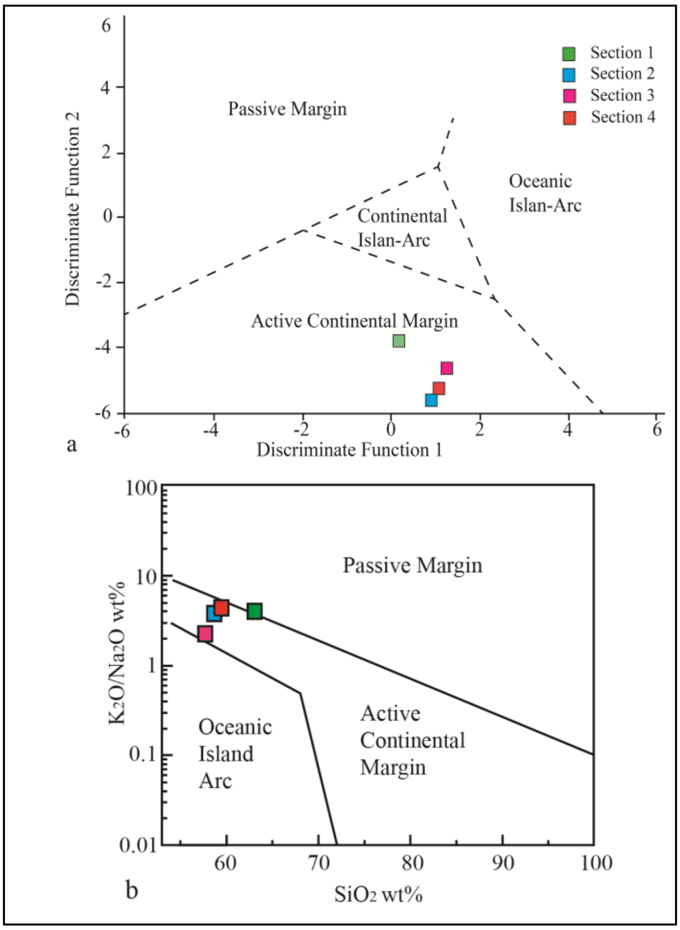


Figure 7. Plot for the tectonic setting of the sequences of Kahrizak Formation in a: Discriminant function diagram (modified after Bathia, 1983) for the fine grained deposits, b: K_2O/Na_2O vs. SiO_2 discriminant plot of tectonic setting for mudstone suites (modified after Roser and Korsch, 1986).

Either in diagram of TiO_2 (wt%) versus Fe_2O_3(T)+MgO (wt%) in Fig. 8a or in diagram of Al_2O_3/SiO_2 versus Fe_2O_3(T)+MgO (wt%) in Fig. 8b, tectonic setting was illustrated as continental arc. Regarding alluvial fan as the sedimentary environment of Kahrizak Formation characterizing fault bounded highs, it can be mentioned the results of the last 2 diagrams are unacceptable.

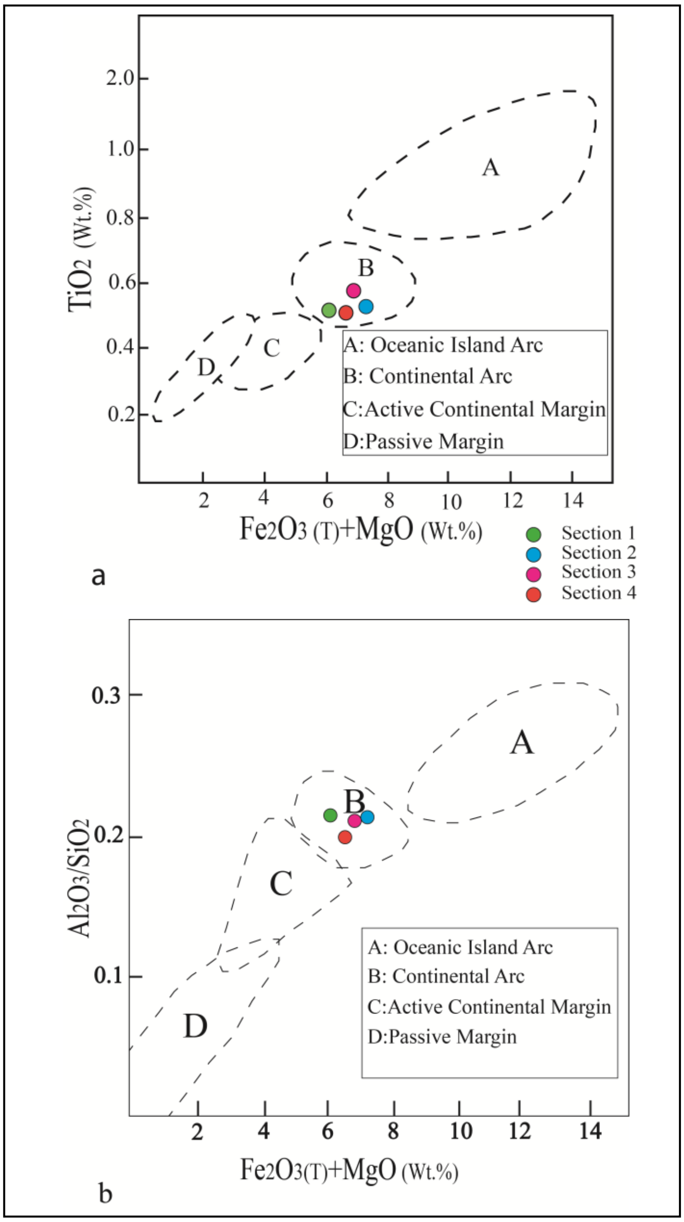


Figure 8. Plot for the tectonic setting of the sequences of Kahrizak Formation in a: TiO_2 (wt%) vs. Fe_2O_3 (T)+ MgO (wt%), b: Al_2O_3/SiO_2 vs. Fe_2O_3 (T)+ MgO (wt%).

V. Conclusion

XRD data of Kahrizak claystones indicate existence of mostly motmorinollite, illite and chlorite; also there are quartz, calcite and anorthite in them. Since the formation is modern deposits and was suffered low degree alteration, so clay minerals can be used to determine paleoclimate and their parental rocks. Source of illite, montmorillonite and peliagioclose are volcanic rocks. All clay minerals indicate low to moderate leaching in temperate to cold climatic setting. On based of chemical analysis and CIA values of the clays (range from ~46 to 57 (less than PAAS=70)) were indicated source rocks of these sedimentary rocks were subjected to weak weathering conditions under a temperate climate. Based on Bhatia diagram, using DF1 and DF2 and K_2O/Na_2O versus SiO_2, its tectonic setting was determined as being active continental margin.

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