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Grain size Analysis and Depositional Patterns of Injana, Mukdadiya and Bai Hassan formations (Upper Miocene- Pliocene) in Zakho and Bijel area northern Iraq

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ABSTRACT

A grain size analysis of thirty-eight sandstone samples from Injana, Mukdadiya and Bai Hassan formations in Zakho and Bijel sections has been conducted to interpret the depositional patterns. The samples are basically medium to coarse sand, poorly to very poorly sorted, different skewed and leptokurtic to mesokurtic in nature. The relationships between the different parameters shows a bimodal nature of sediments having dominance of medium to coarse sand. Depending on the results of grain size analysis, a fluvial environment of deposition is interpreted for three formations, and the Bijel section was closer to the source area than Zakho section.

Keywords: grain size, Injana, Mukdadiya, Bai Hassan, Zakho, Bijel, Depositional pattern.

1. Introduction

Grain size is the is one of the most important physical properties of sedimentary rocks, that depends on the nature of source rocks and transporting agent. The nature of sediments reflect the type of denudation and transportation. Thus the grain size analysis of the sandstone grains was a good tool in the reconstruction of the sedimentation processec (Das and Sharma, 2010). The environmental interpretation of grain size analysis found in sediments has been still a basic aim of sedimentology (Venkatesan et al., 2017). Injana, Mukdadiya and Bai Hassan formations are of the age of Upper Miocene to Pliocene that are extinsively exposed in the middle and north of Iraq. They were described for the first time by Busk and Mayo in 1918 (Bellen et al., 1959). Injana Formation representing the lower fine grained sediments deposited initially in the transitional then fluvial environments progressively (Buday, 1980). Mukdadyia Formation consists of fining upward and coarsening upward successions of conglomerate, sandstone, gravelly sandstone and mudstone which deposited in a fluvial environment (Basi and Jassim, 1974). The Bai Hassan Formation consists of coarsening upward successions of conglomerate, sandstone, gravelly sandstone and mudstone which were deposite in a fluvial and alluvial fans environments in rapidly subsiding basin. Names of the Upper Fars and Bakhtiari Formations are replaced

respectively by Injana, Mukdadiya and Bai Hassan formations (Al-Rawi et al., 1992). These formations are extensively studied by researchers because of their wide extension and their good exposure, like the study of (Al-Banna, 1982), (Al-Juboury, 1994), for Injana Formation and (Al-Shammmary, 2009), (Al-Khalidi, 2014) for Mukdadiya Formation and (Al-Adool, 1982), (Issa, 2012) for Bai Hassan Formation. The aim of this study is the generation of fundamental data on textural parameters such as median, mean, skewness, sorting and kurtosis. Depending on inter-relationship between various parameters have also been conducted to explain the depositional patterns of the three formations. Zakho section is located south of Zakho city in Dohuk Governorate in the north of Iraq at the high folded zone in the northeastern limb of Bekhair anticline. The coordinates of this section are Longitude 42° 39' 30.7" E, Latitude 37° 05' 20" N for Injana Formation and Longitude 42° 41' 24.7" E, Latitude 37° 07' 31.6" N for Mukdadiya Formation and Longitude 42° 40' 36.6" E, Latitude 37° 07' 54.3" N for Bai Hassan Formation, while Bijel section is located east of Bijel city in Erbil Governorate northern Iraq at the high folded zone in the south limb of Perat anticline. The coordinates of this section are Longitude 44° 03' 08.1" E, Latitude 36° 42' 50.5" N for three formations (figure-1).

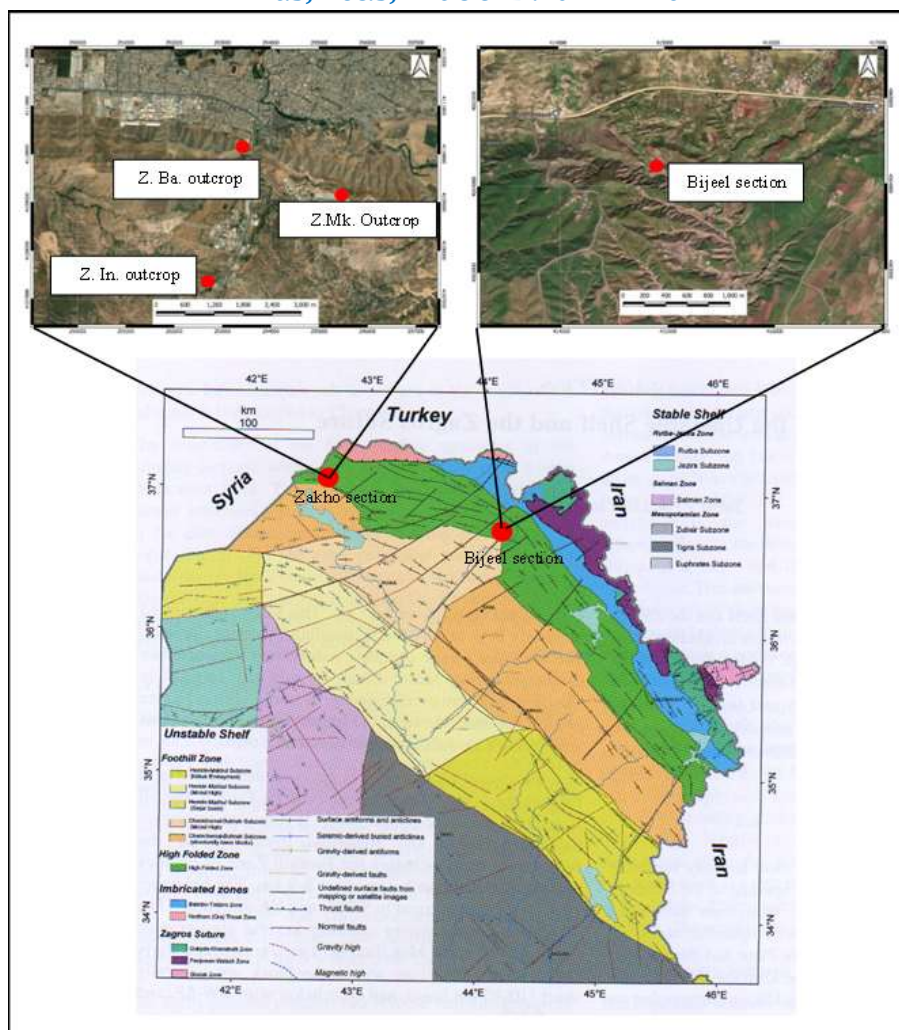


Fig. 1: Tectonic map shows the sits of studied sections (modified from Jassim and Goff, 2006) and satellite image from google earth..

2. Sampling and Methods

In the current study, 38 sandstone samples were collected and placed in dry and transparent nylon bags for laboratory analysis from Zakho section (Z), with 15 samples for Injana Formation (In), 3 samples for Mukdadiya Formation (Mk) and 2 samples for Bai Hassan Formation (Ba), while in Bijeeel section (B), there were 10 samples for Injana Formation, 6 samples for Mukdadiya Formation and 2 samples for Bai Hassan Formation. Sieving technique has been conducted to separate the clasts into different size portions, as suggested by (Carver, 1971). The textural parameters such as median, mean, standard deviation, kurtosis and skewness were calculated according to the technique suggested by (Folk and Ward, 1957). The inter relationship between statistical parameters are represented by diagrams on the methods of (Folk and Ward, 1957); (Friedman, 1961); (Friedman, 1967); (Moiola and Weiser, 1968) to interpret the various aspects of depositional environments. Ways of transportation were concluded using CM-plot as proposed by (Passega, 1957).

3. Results

3.1. Statistical Parameters

The sedimentary properties of the sediments are clarified by the study of grain size statistical parameters and their scientific implications that lead to determining the nature and the origin of source rocks and sedimentary environment, as well as being used to compare between specific rocks in more than one area (Al-Hassan, 2015). In this study, statistical parameters were calculated using the laws set by (Folk and Ward, 1957).

3.1.1. Median

Median represents boundary between coarse and fine grain size in the sample, and it represents value of ϕ_{50} of cumulative weight. Its value is not affected by the two ends of cumulative frequency curve (Al-Banna, 1982). The median values for studied samples are summarized in table (1). It was found that the sandstone grains in Bijeeel section are coarser than their counterparts in Zakho section, and this indicates that Bijeeel section is closer to source rocks than Zakho section.

Table-1: Median values of samples of Injana, Mukdadiya and Bai Hassan Formations in Zakho and Bejel sections

The Formations	Zakho section		Bejel section	
	Range	Average	Range	Average
Injana Fm.	0.51-2.32	1.41	-0.5-2.01	0.75
Mukdadiya Fm.	1.52-1.71	1.61	-0.51-1.09	0.29
Bai Hassan Fm.	0.66-1.64	1.15	0.78-0.91	0.84

3.1.2. Mean

The mean size is indicative of the average grain size, which covers most of the volumes of sediments and is more useful than the median (Ahmad et al., 2021), and it is one of the factors that shows the nature and origin of source rocks and deposition environment (Kazwini, 1980). The mean values of studied samples are summarized in Table (2), which suggests that most of studied samples are medium-grained sands (figure 2A). There is little variability in the grain size of studied samples which make these samples well sorted.

Table-2: Mean values of samples of Injana, Mukdadiya and Bai Hassan Formations in Zakho and Bejel sections

The Formations	Zakho section		Bejel section	
	Range	Average	Range	Average
Injana Fm.	0.55-2.36	1.45	-0.64-1.96	1.32
Mukdadiya Fm.	1.81-2.07	1.94	-0.70-1.39	0.96
Bai Hassan Fm.	0.93-2.29	1.61	1.14-1.35	1.24

3.1.3. Standard deviation

Standard deviation is a measure of uniformity or sorting of grains size distribution which in turn indicates the type of deposition and energy prevailing conditions at the time of transportation and sedimentation (Srivastava and Mankar, 2009). The sorting values of studied samples are summarized in Table (3), where averages are ranging from (1.52-1.96) which indicate that most of the samples are poorly sorted, and some of them are very poorly sorted and moderately sorted (figure 2B).

3.1.4. Skewness

The skewness gauges the degree to which a size frequency curve approach symmetry in terms of predominance of coarse- or fine-sediments portions. The positive values denote fine-skewed material, while, the negative values represent more materials in the coarse-tail i.e. coarse-skewed (Friedman and Johnson, 1982); (Al-Rashidi, 2005). The skewness values of studied samples are summarized in Table (4). The average of the skewness value for the samples of Injana Formation was (0.05) and (0.04) in both sections which gives evidence that most of the samples are near symmetrical skewed, while the average values for Mukdadiya Formation samples were (0.34) and (0.25) in two sections, which gives evidence that all the samples are fine skewed. The averages of skewness values for Bai Hassan Formation samples in the two sections were very close, which are (0.37) and (0.38), its a clear indication of grains being strongly fine-skewed (figure 2C), and this supports that this formation was deposited by alluvial fans with braided rivers.

Table 3: Standard deviation (Sorting) values of samples of Injana, Mukdadiya and Bai Hassan Formations in Zakho and Bejel section

The Formations	Zakho section		Bejel section	
	Range	Average	Range	Average
Injana Fm.	0.92-2.90	1.91	0.87-2.41	1.64
Mukdadiya Fm.	1.07-2.32	1.96	0.85-2.19	1.52
Bai Hassan Fm.	1.47-2.46	1.96	1.42-1.76	1.59

Table 4: Skewness values of samples of Injana, Mukdadiya and Bai Hassan Formations in Zakho and Bejel sections

The formations	Zakho section		Bejel section	
	Range	Average	Range	Average
Injana Fm.	-0.17-0.28	0.05	-0.17-0.25	0.04
Mukdadiya Fm.	0.25-0.44	0.34	0.05-0.46	0.25
Bai Hassan Fm.	0.27-0.47	0.37	0.36-0.40	0.38

3.1.5. Kurtosis

Kurtosis is a gauge of peakedness in a size frequency curve that gauges the ratio between medial part of the curve and sorting in the tails. If the medial part is best sorted than the tail, then it is called as leptokurtic, while, platykurtic, if the tails was better sorted, if both are evenly sorted then mesokurtic condition common (Folk, 1974); (Hartmann, 2004). Kurtosis values of studied samples are summarized in Table (5), where averages are ranging from (1.15-1.57) which indicate that most of the samples are leptokurtic, and a few of the samples were very leptokurtic and mesokurtic (figure 2D).

Table 5: Kurtosis values of samples of Injana, Mukdadiya and Bai Hassan Formations in Zakho and Bejel section

The Formation	Zakho section		Bejel section	
	Range	Average	Range	Average
Injana Fm.	0.73-1.58	1.15	0.89-1.62	1.25
Mukdadiya Fm.	1.09-1.46	1.27	1.01-2.14	1.57
Bai Hassan Fm.	1.16-1.25	1.20	1.31-1.49	1.40

3.2. Interrelationship of textural parameters

The interrelationship of different size parameters are important to interpret different conditions of various depositional environments, as the size parameters of the mostly environmentally sensitive (Passega, 1957); (Folk and Ward, 1957); (Visher, 1969); (Moiola and Weiser, 1968); (Friedman, 1979);. Number of statistical parameters in the form of bivariate drop has been used. The purpose of these drop is the supposition that textural parameters reliably reflect changes in the fluid movement mechanism of sediments transportation and sedimentation (Sutherland and Lee, 1994). Various researches assumed that these drop can serves as an active tool for determining processes of various environments of deposition (Martin, 2003); (Venkatesan et al., 2017).

3.2.1. Relationship between standard deviation and median

In the current study, the relationship developed by (Stewart, 1958) was used, in which he plotted the values of standard deviation vs median, and concluded that there are three zones for his study samples, which are the river processes zone, wave processes zone and quiet water zone. Most of the studied samples occurred within river processes zone

(figure 3), and this may indicate the deposition of most of rocks of studied formations in a fluvial environment.

3.2.2-Relationship between mean and standard deviation

The standard deviation against mean plot for the studied samples (figure 4), shows the accumulation of the values below and above the center of the right limb of reversed V-shape established trend of (Folk and Ward, 1957), denoting the samples to be medium to coarse size grained and poorly sorted. The spreading of the samples in a wide region indicates a mixture of sediments. All samples are located in the river deposits field according to (Moiola and Weiser, 1968) and (Martins, 2003).

3.2.3. Relationship between standard deviation and skewness

The relationship between standard deviation and skewness has a great importance to distinguish between the river deposits and beach deposits (Friedman, 1967); (Moiola and Weiser, 1968), and the distribution of the samples to the researchers' planners shows that they all fall in the field of fluvial deposits (figure 5). It also occurred in the field of river deposits when compared with the scheme prepared by (Martins, 2003).

3.2.4. Relationship between skewness and mean

The relationship between skewness and mean has a great importance in distinguishing between the river inland dune sand and beach sands, and it determines whether sedimentary environments are continental or beach (Mason and Folk, 1958); (Moiola and Weiser, 1968). The occurrence of most of the samples in (figure 6) in the inland dune sand field with the exception of some samples that occurred in the beach

sand field indicates that most of studied samples are deposited in a continental environment.

3.2.5. Relationship between kurtosis and mean

The relation between kurtosis and mean-size is complex and theoretical (Alharbi et al., 2016). The model plot in (figure 7) denotes a mixture of three or more size classes of grains. The plot of studied samples values indicates a dominance of leptokurtic category (1.11-1.5 ϕ) followed by mesokurtic (0.9-1.11 ϕ), in the size scale ranging between (-0.8-2.4 ϕ), it shows that the sediments is dominated by medium to coarse sand.

3.3. Passega diagram

Passega (1957) proposed C-M plot to determine the type of the hydrodynamic forces that operate the deposition of the sediments. It is a relationship between (M) which is median value measured in micron on log probability scale and (C) which is one percentile value measured in micron (grain size is converted from ϕ to millimeter using the equation: $\phi = -\log_2$ (grain diameter in mm)), and then converted to microns (Nichols, 2009). The diagram is consists of three overlapping fields representing the main transport ways of the sediments, namely uniform suspension, saltation or graded suspension and rolling, as well as the presence of an interconnected transport zone between the main types such as suspension-rolling. current study samples is plotted and interpreted following (Passega, 1964) and (Passega and Pyramjee, 1969). Depending on it, most of the samples of all formations are fall in field (2) which denotes saltation sediments and a few of it occurred in fields (1) and (3) which represent suspension and rolling respectively (figure 8), which confirms the predominance of medium grain size of sandy sediments.

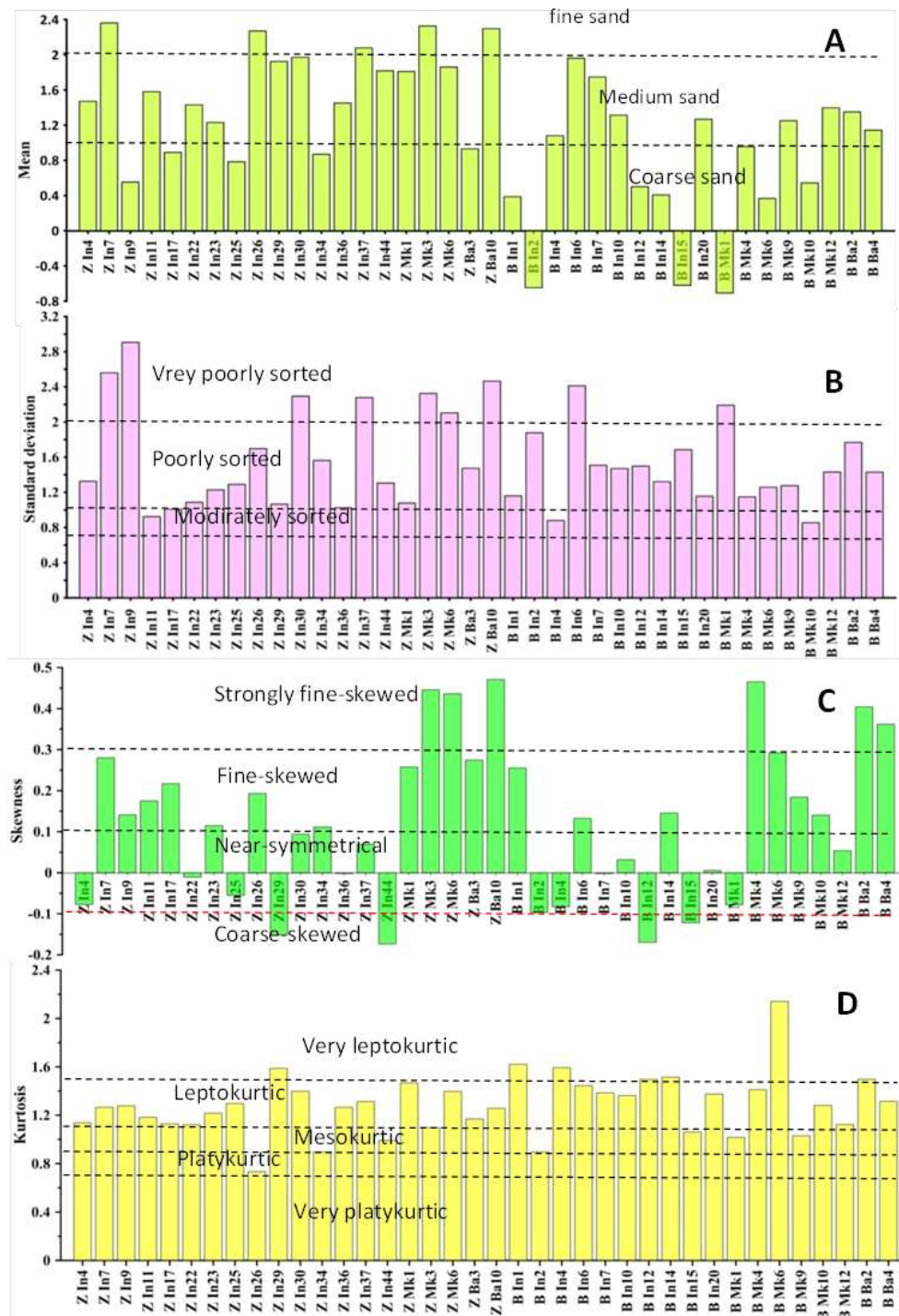


Fig. 2: Comparative histogram of studies samples showing A) Mean values B) Sorting values C) Skewness values D) Kurtosis values.

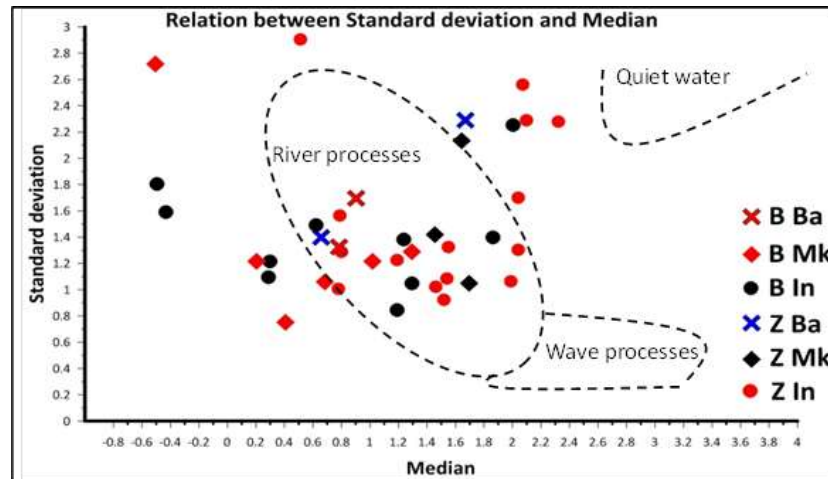


Fig.3: Relationship between Standard deviation and Median modified from (Stewart, 1958).

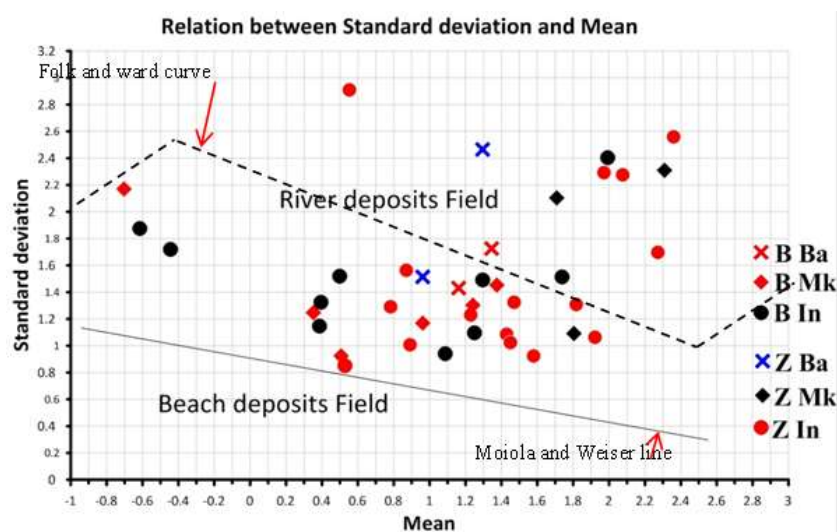


Fig. 4: Relationship between Mean and Standard deviation modified from (Folk and Ward, 1957) and (Moiola and Weiser, 1968).

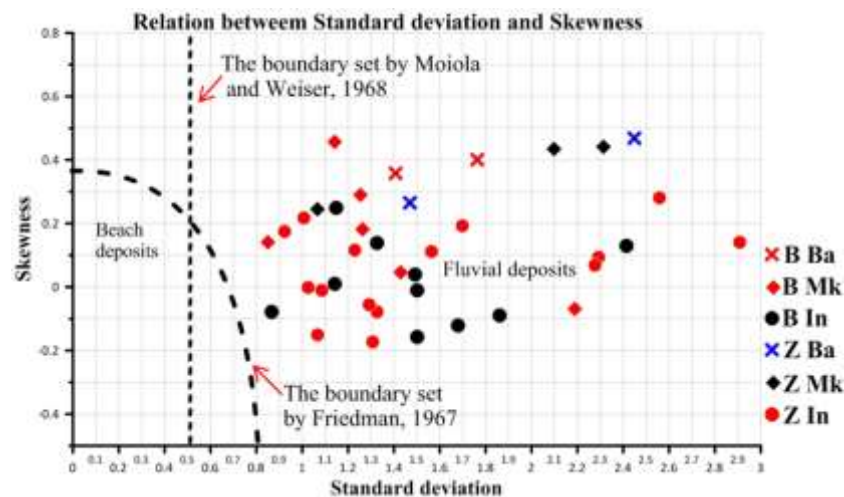


Fig. 5: Relationship between Standard deviation and Skewness modified from (Friedman, 1967) and (Moiola and Weiser, 1968).

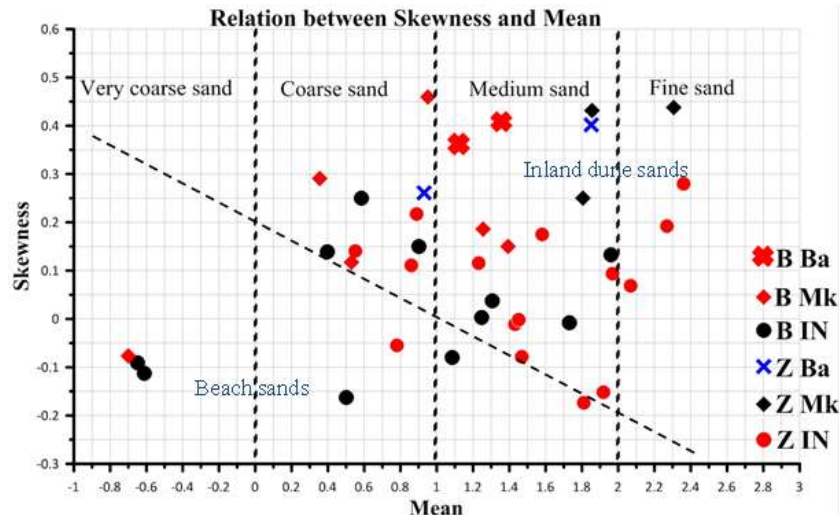


Fig. 6: Relationship between Skewness and Mean modified from (Mason and Folk, 1958).

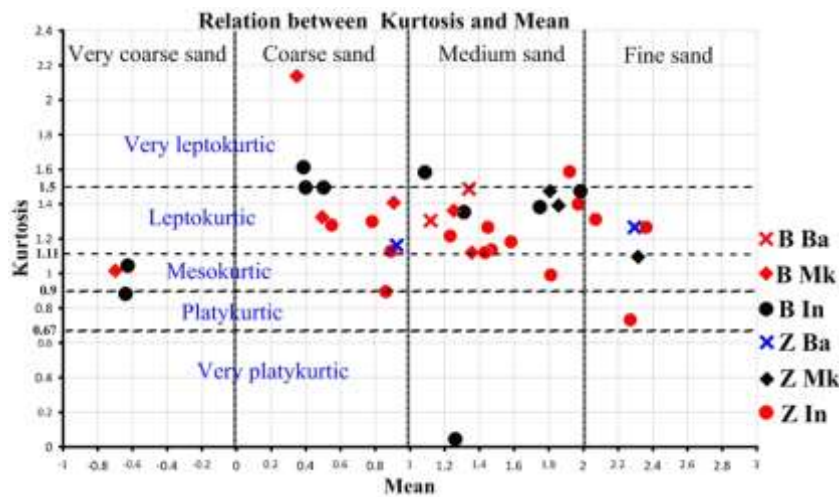


Fig. 7: Relationship between Kurtosis and Mean modified from (Folk and Ward, 1957).

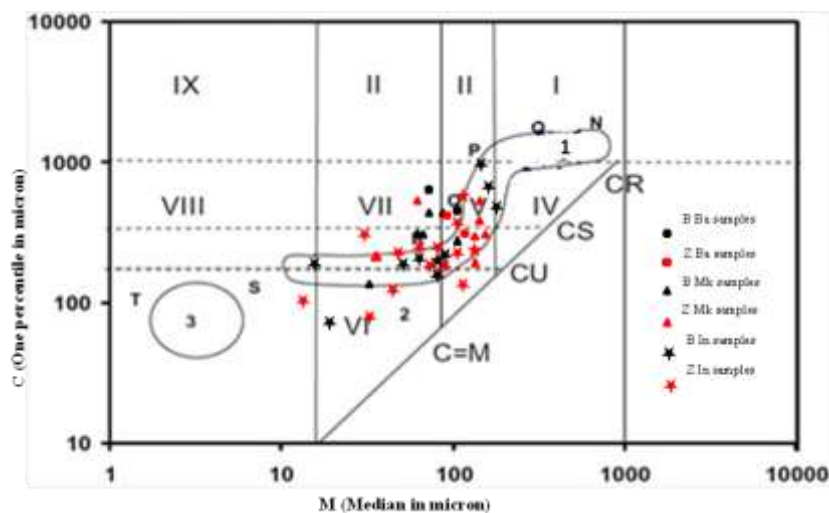


Fig. 8: C-M plot showing accumulation of samples.

4. Conclusions

1) The sandstone is a major component in the rocks of Injana Formation, while it is a minor component in Mukdadiya and Bai Hassan formations in both studied sections.

2) The sediments, in general are medium to coarse grained, and it appear in Bijel section coarser than the Zakho section, and this indicates that the Bijel section is closer to the source area.

3) The sediments are mostly fine to near-symmetrical skewed and dominantly poorly to very poorly sorting in nature. And show mainly leptokurtic to mesokurtic behavior with some of the samples also showing very leptokurtic behavior.

4) The relationship between statistical parameters deducted that all these sediments are deposited in

fluvial environment mainly by different types of rivers and alluvial fan processes.

5) C-M plot appears that the most of these sediments are transported by saltation and a few of samples are transported by suspension and rolling.

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**Proceeding of the Third International & the Fifth Scientific Conference of
College of Science - Tikrit University**

Int.3, Loc.5, Article ID:2022-P2-16

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