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Comparative geochemistry of the sedimentary and metasedimentary clastic rocks of the Kuantan area, Pahang, Malaysia

SIDIBE YAYA TIEMOKO*, TAN TEONG HING AND AHMAD JANTAN

Department of Geology
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor D.E.

Abstract: In Northeast Pahang and South Terengganu, the Kuantan Group and Taweh beds rocks are redefined in terms of stratigraphic nomenclature. The Kuantan Group consists of Charu Formation, Panching Limestone and Sagor Formation.

Charu Formation which is the oldest sequence (Lower Carboniferous), is subdivided into 3 units with a status of member for each, i.e. Kolek Member, Cheneh Member and Lepar Member. Cheneh Member is synonym of Sg Perlis beds. In the Berkelah area, the lower and metamorphosed part of the Lepar Member is assigned a status of bed, i.e. Berkelah Bed. The unmetamorphosed unit in the Lepar Hilir area is named as Lepar Hilir Bed. The Taweh beds (Tan, 1972) are upgraded to the status of formation and is considered as of Triassic age.

Factor Analysis, as a statistical technique, is used to discriminate the above rock units based on their geochemical variables such as major elements concentrations. In the method, a large number of correlable variables (concentrations) are reduced into a small number of uncorrelable variables (factors). The elements which characterise the factors are selected.

Based on this discrimination study, the lithostratigraphic units are defined as below: Charu Formation is characterised by the predominance of K_2O, Al_2O_3 and Fe_2O_3 in the shales of Kolek Member, by feldspathic and MgO-rich mudstones of Berkelah Bed and Mg-Ca rich mudstones of Lepar Hilir Bed; Sagor Formation is dominated by potassic shales and subarkose, both of which are poor in Fe_2O_3 and Al_2O_3. Taweh Formation is composed of shales rich in SiO_2 and sandstones rich in ferromagnesian elements.

INTRODUCTION

Investigations on the geology of the Kuantan area as shown in Table 1 revealed several rocks units. Fitch (1951) named them as Arenaceous and Calcareous Series. Alexander (1956) classified them as Kuantan Group. Tan (1972) subdivided the rocks of this group into (in stratigraphic order) Charu beds, Panching limestone and Sagor beds with the latter overlained unconformably by Taweh beds. Metcalfe *et al.* (1980) formalised and retained the term Kuantan Group upgrading Tan's (1972) classification to the status of formation, i.e. Charu Formation, Panching Limestone and Sagor Formation, with Visean to late Carboniferous (?) age based on their fossil content. The Taweh beds (Tan, 1972) in the Felda Bt. Sagu 1, Sg Endan and Sg Taweh areas were upgraded to the status of formation, i.e. Taweh Formation (Sidibe *et al.*, 1991; Sidibe, 1993) and is considered as Triassic in age.

The lithochemistry study of the various rock types revealed a relatively high reliability of the analytical method and procedure used (see Sidibe, 1993). The total number of geochemical analytical data obtained was also high. Hence, the variation in the distribution of the elements present in the clastics would be important for interpreting the differences in chemical composition of these rocks. The simultaneous variations in the composition of these clastics is investigated using statistical technique such as Factor Analysis which condenses a large number of variables into a smaller number of independent combinations as according to Davis (1973), Cheeney (1983), Cooper (1983) and Weber and Davis (1990). The combinations of the various factors would indicate the relationship between elements in a rock type. Thus each rock unit (formation, member/bed) of the study area, can be characterised using the main chemical characteristics of an individual rock or group of rock types (sandstone, shale and etc.). The results of these analyses are discussed in this paper.

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* Permanent address: Departement de Geologie, Ecole Nationale d'Ingenieurs, B.P. 242 Tel. 222736, Bamako, Republique du Mali (West Africa)

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Table 1. Evolution of the lithostratigraphic terminology in the study area.

Fitch (1951)	Alexander (1956)	Tan (1972)	Metcalfe (1980)	In this study (1992)
				Mesozoic (Triassic) rocks • Tawah Formation
				Upper Paleozoic
• Calcareous Series • Arenaceous Series	**Kuantan Group** • Calcareous Series • Arenaceous Series	**Kuantan Group** • Tawah beds • Sagu beds • Panching Limestone • Charu beds	**Kuantan Group** • Sagor Formation • Panching Limestone • Charu Formation	**Kuantan Group** • Sagor Formation • Panching Limestone • Charu Formation = — Lepar Member/ Berkelah Bed — Kolek Member [1] — Kolek Member [2]

[1] — Kolek Member is equivalent to Cheneh Member (Lower Carboniferous age)

[2] — Cheneh Member is synonyme of Sg. Perlis beds (Chand, 1968)

LITHOCHEMISTRY

The intension of this study is to compare the geochemical characteristics of each lithostratigraphic unit previously defined by Sidibe *et al.* (1991) and Sidibe (1993).

Method of sampling

In most geochemical investigations, it is paramountal that proper representative sampling procedures be adopted, especially those methods in which portions of the material are sampled based on principal of statistical probabilities.

In the study area, the sampling sites (Fig. 1) were chosen according to the type localities of the lithostratigraphic units. At the outcrops, grid lines at one metre interval were drawn perpendicular and parallel to the bedding planes (see example in Fig. 2). About half a kilogram of rock sample was taken at the intersection of the grid lines (Fig. 2). Here, rock samples of small size from randomly selected numbered intersections were combined, homogenized and analysed as one representative sample. Though each sample represents the composition at a specific grid intersection; the combined samples over the entire grid system is assumed to be representative of the whole rock.

Method of analysis

The concentrations of the elements were determined using X-ray fluorescence spectrometry method. Ferrous iron (FeO) was determined by titration using standard potassium dichromate solution, while Na_2O (in some cases) was determined using flame photometry. Water and CO_2 were not determined, but the loss on ignition values in the analytical data can be considered as to represent these content as well as other volatile elements.

In this study, pressed sample powder pellets were used for the analysis of major and some minor elements using X-ray fluorescence spectrometers PW 1130 and PW 1480 at the Department of Geology, Universiti Kebangsaan Malaysia (UKM). The element concentrations of each rock sample are available in that department. The main results are discussed as below.

RESULTS

Short account for major element content

The average chemical composition of the clastics of the Kuantan area shown in Figures 3, 4 and 5 reveal that several elements in the sandstones, siltstones as well as mudstone and shale, have certain trend of distribution especially in term of their stratigraphic disposition. Elements with similar trends of distribution are grouped for the purpose of characterising the rock types from various ages in term of their provenance and their physical and chemical environments of deposition. In the following discussion the letter T (for trend) is used as symbol for each group of elements, and the subscribes s, st and m indicate sandstone, siltstone and mudstone + shale respectively.

Major elements distribution in sandstones

In the Charu Formation (Fig. 3a) there are two main trends where element concentrations increase (T_{s1}) or decrease (T_{s2}) from the older Kolek Member to the younger Lepar Member sandstones. The elements with increasing T_{s1} and decreasing T_{s2} trends are listed as below:

T_{s1} = **MgO, Na_2O and K_2O**

T_{s2} = **Al_2O_3, P_2O_5 and L.O.I.**

However, some elements express both T_{s1} and T_{s2} trends from lower to upper units within Charu Formation. These elements are:

$T_{s'1}$ = **SiO_2, CaO and TiO_2** with concentrations increasing from shallower marine sediments of the Kolek area to the relatively deep marine sediments of Berkelah Bed and deeper marine sediments of Cheneh Member (see Fig. 3a).

$T_{s'2}$ = **Fe_2O_3** with concentration decreasing up to Berkelah Bed but followed by an increase in Lepar Hilir Bed.

Two main chemical trends are observed starting from Lepar Member and ending at Taweh Formation (Fig. 3b). These are: T_{s3} = **Al_2O_3, Na_2O and L.O.I.** with increasing element concentrations and

T_{s4} = **Fe_2O_3 and MgO** with decreasing element concentrations.

Within these two main chemical trends, there are two subtrends. One of the latter (known as $T_{s'3}$

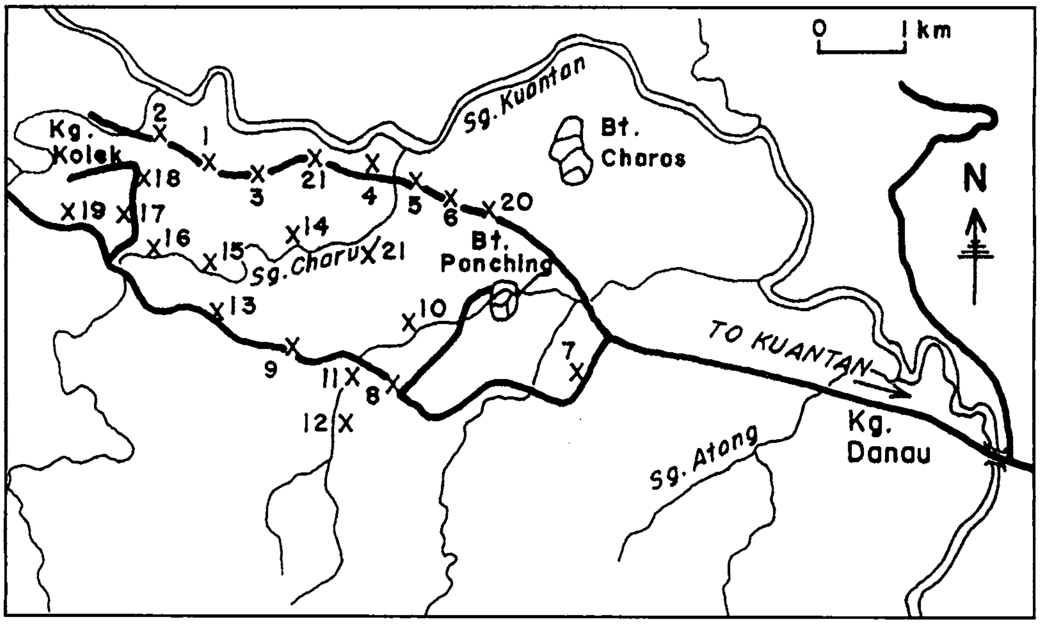

Figure 1a. Sampling localities of the Kolek Member.

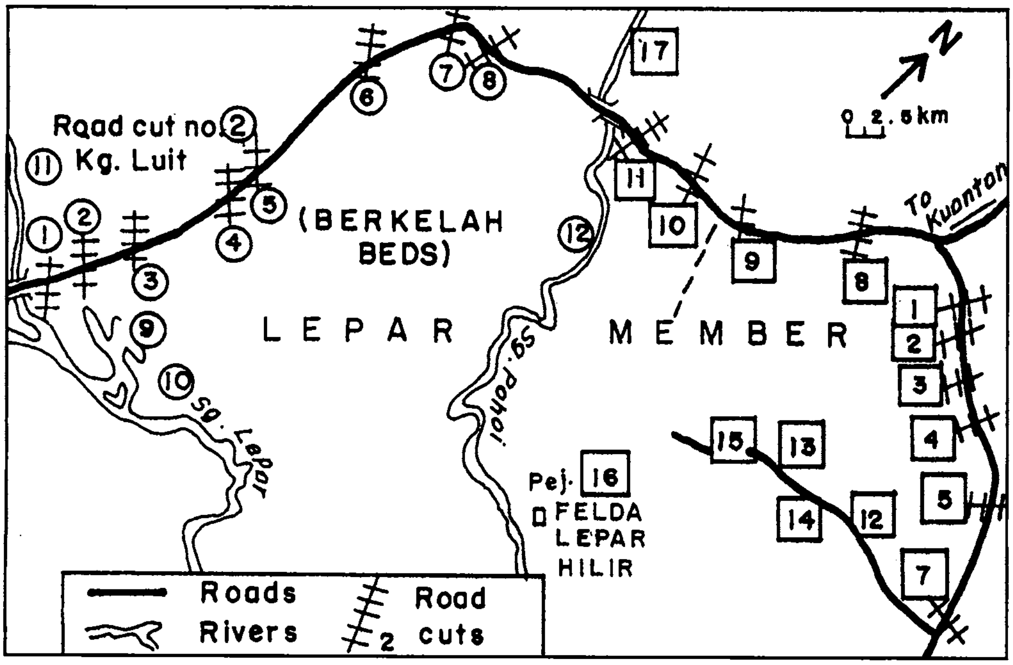

Figure 1b. Sampling localities of the Lepar member.

① Berkelah Bed samples

[1] Lepar Hilir Bed samples

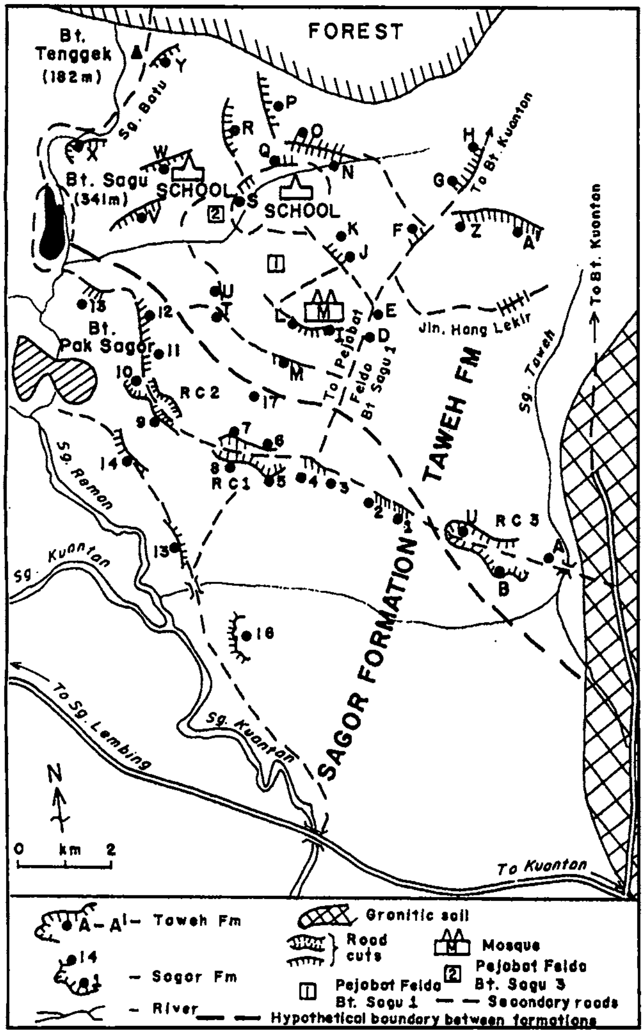

Figure 1c. Sampling localities of Sagor and Taweh Formations.

= K_2O **and** TiO_2) shows an increasing concentration trend for its elements from Lepar Member to Sagor Formation; whilst the other (known as $T_{s'4}$ = SiO_2) shows a decreasing concentration trend for silica throughout the same rock units.

The interpretation of the above chemical trends in sandstones as well as in siltstones, mudstones and shale is treated in Sidibe (1993).

Major elements distribution in siltstones

Figure 4 compares the concentrations of major elements in siltstones of Kolek Member and Lepar Hilir Bed (Lepar Member). Kolek Member siltstone is laminated whilst that of Lepar Hilir Bed is massive. There are three main groups of trend, v.i.z T_{st1}, T_{st2} and T_{st3}.

T_{st1} is characterised by an increase in element concentration from Kolek to Lepar Members siltstones while T_{st2} by elements with concentration decreasing in the same rock types. T_{st3} is characterised by a constant or near constant value for its major element content in both Kolek and Lepar Members siltstones. The characteristic elements of these trends are:

T_{st1} = **Fe_2O_3, MnO and K_2O**
T_{st2} = **SiO_2, Al_2O_3, Na_2O and L.O.I.**
T_{st3} = **P_2O_5 and CaO**

TiO_2 and MnO content vary insignificantly and hence are not classified.

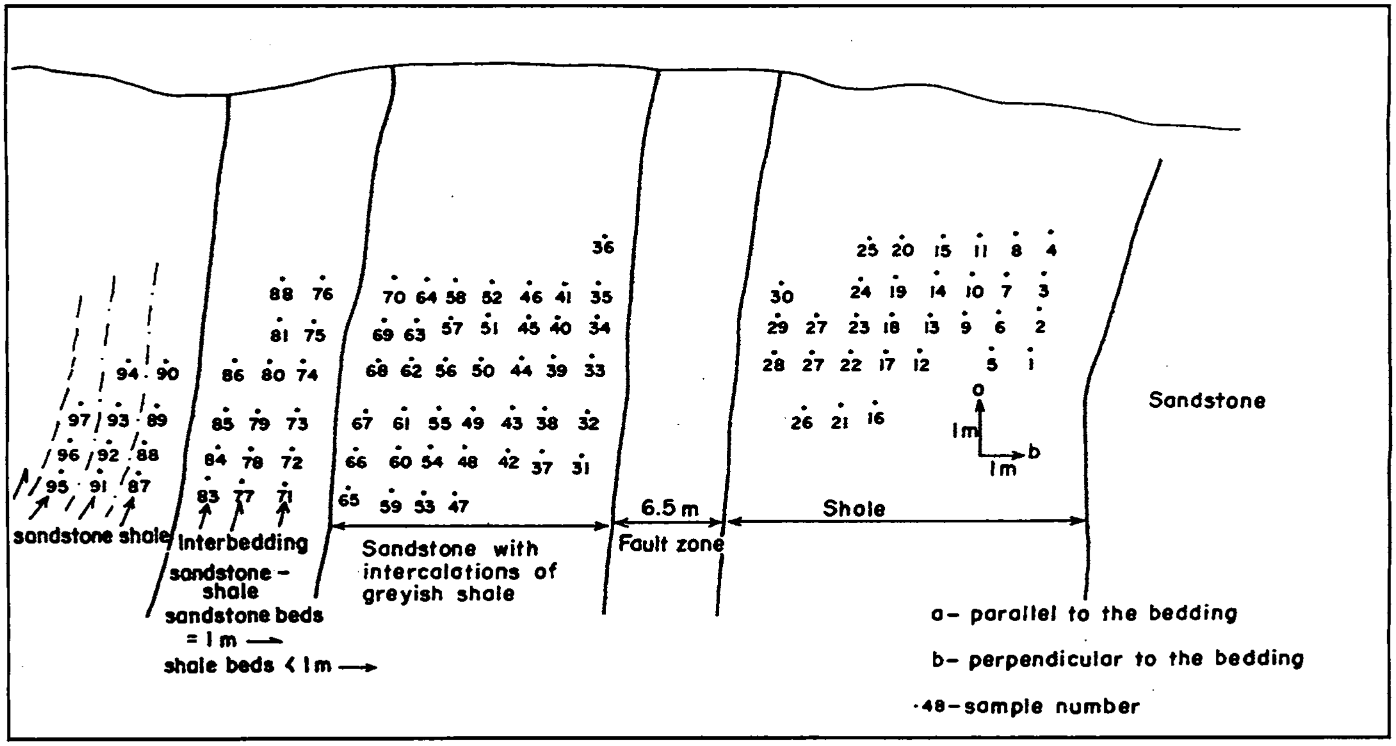

Figure 2. Grid intersection sampling method used for geochmical sampling e.g. Tawah Formation, road cut no. 3 (R.C.3) not to scale.

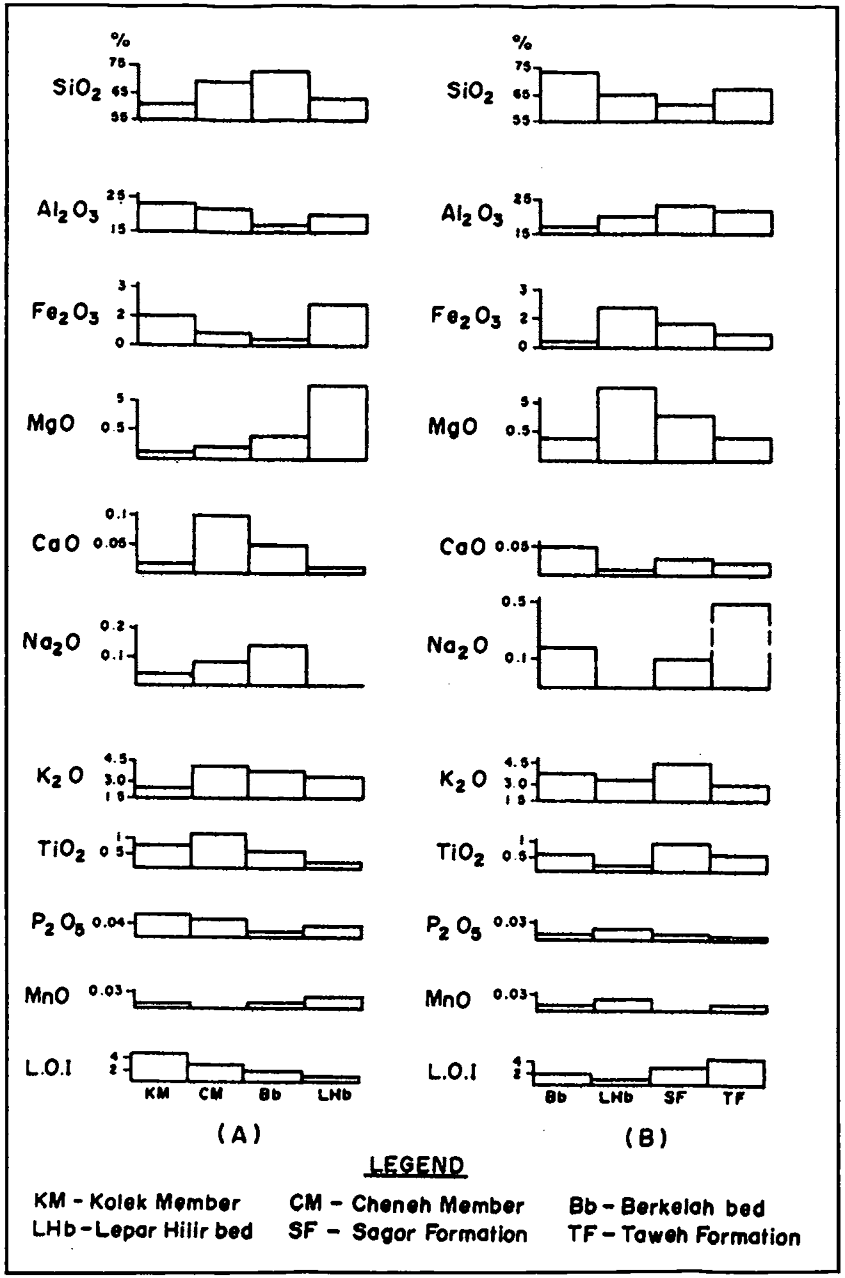

Figure 3. Major elements composition of sandstones.
(A) Charu Formation (Kolek Member, Cheneh Member, Lepar Member)
(B) Lepar Member (Berkelah bed, Lepar Hilir bed) Sagor and Taweh formations

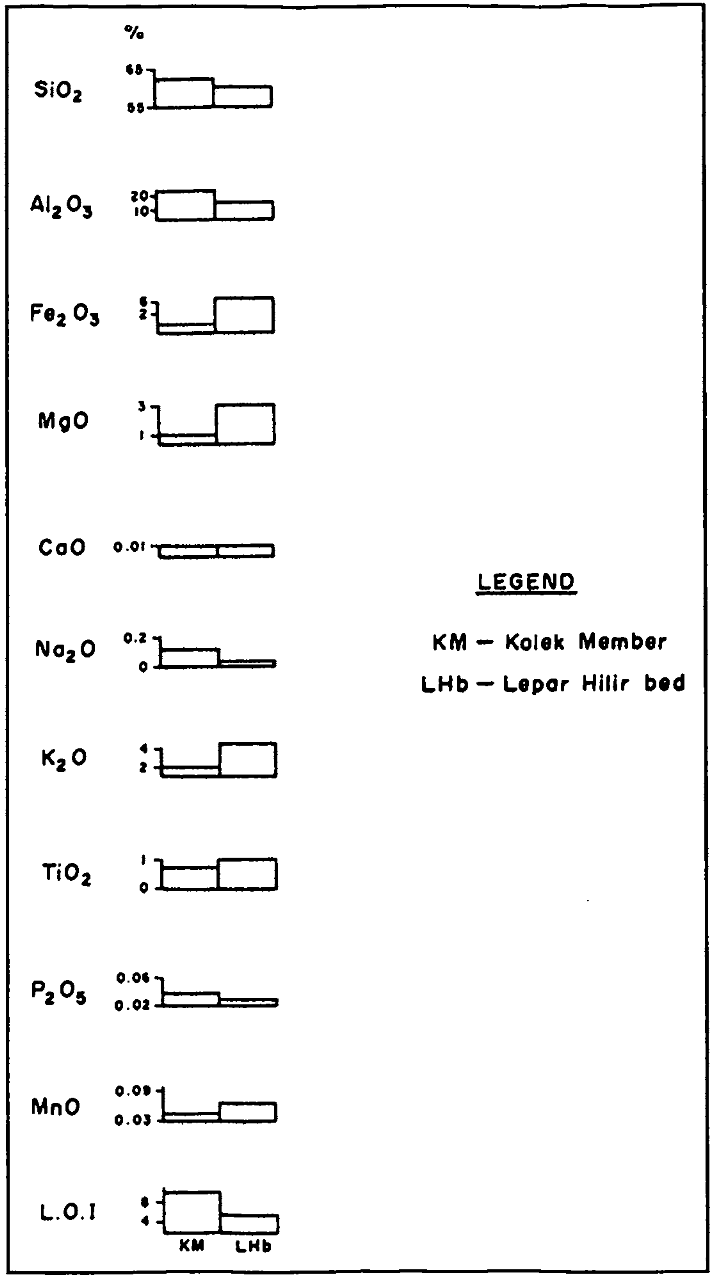

Figure 4. Major elements composition of siltstones of Charu Formation

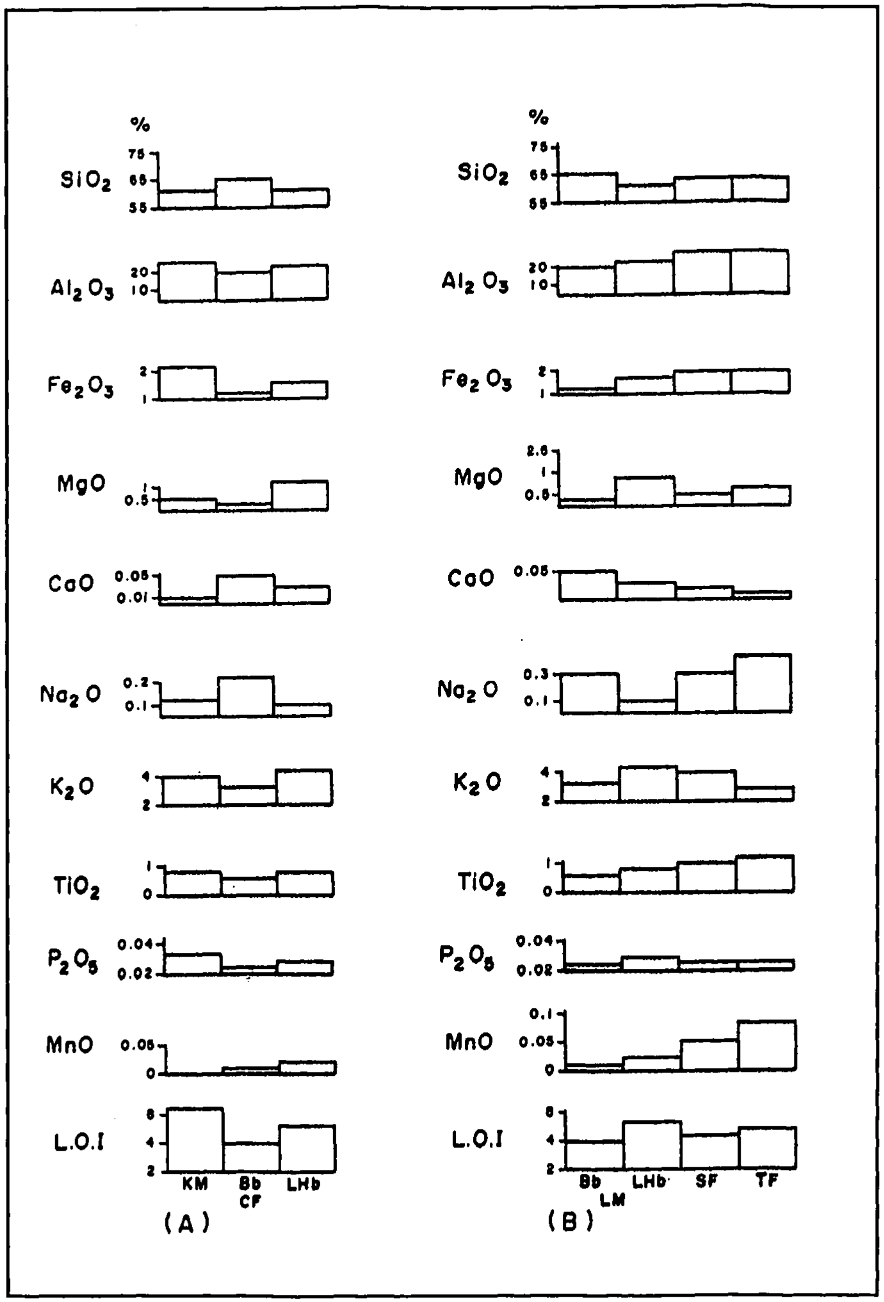

Figure 5. Major elements composition of mudstone and shale.
(A) Charu Formation
(B) – Lepar Member, Sagor and Taweh Formation

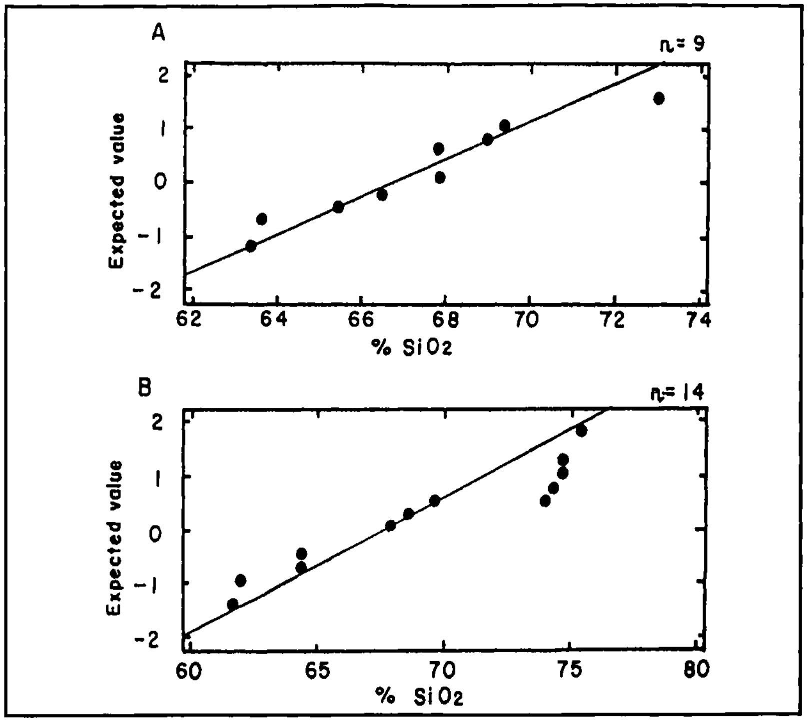

Figure 6. Examples of normal probability plot showing the trend of normal distribution of major elements.
A – Sandstone (Kolek Member)
B – Laminated mudstone (Kolek Member)

Major elements distribution in mudstones and shale

In the Kuantan area, mudstone occurs bedded in the lower part of Lepar Member (Berkelah Bed) while it is massive and bedded in the uppermost part (Lepar Hilir Bed). Shale is found in Kolek Member, Sagor and Taweh Formations. Both mudstone and shale are grouped together based on their geochemical similarity in term of their major and minor elements content distribution. The discussion which follows is based on Figure 5.

The trend of distribution of major elements in mudstones and shale of Charu Formation (Kolek and Lepar Members) are grouped into three main groups, v.i.z T_{m1}, T_{m2} **and** T_{m3}

T_{m1} = **SiO_2, CaO and Na_2O**; these element concentrations increase from the mudstone of Kolek Member to that of Berkelah Bed, and followed by a decrease in concentration for those of Lepar Hilir Bed.

T_{m2} = **Al_2O_3, Fe_2O_3, K_2O, TiO_2, MgO and L.O.I.**; here the element concentrations decrease from Kolek Member mudstone to that of Berkelah Bed, followed by an increasing trend of element concentration in that of Lepar Hilir Bed.

T_{m3} = **MnO**; this element concentration increases from Kolek to Lepar Member.

From Lepar Hilir Bed to Sagor and Taweh Formations, two main trends are recognised, v.i.z T_{m4} and T_{m5}.

T_{m4} trend is characterised by an increasing concentration of elements in mudstones and shale from Lepar Hilir Bed to Taweh Formation, while T_{m5} trend by a decreasing concentration of elements in the mudstone from Lepar Hilir Bed to Taweh Formation. The elements which characterise these trends are listed as below:

T_{m4} = **SiO_2, Al_2O_3, Fe_2O_3, Na_2O and MnO**
T_{m5} = **CaO, K_2O, MgO and L.O.I.**

P_2O_5 is almost constant throughout the rock units

Statistical method of analysis

Prior to Factor Analysis, the test for normal distribution and correlation of major elements were conducted to ascertain that the analysis is reliable.

Test for normal distribution of major elements

The System for Statistics (SYSTAT) programme of Wilkinson and Leland (1990) was used to study the distribution of the major elements in the samples. The results obtained are the correlation coefficients and their associated probabilities. The normal distribution is proven where $p \leq 0.05$. The normal probability plot of each element shows a trend which generally has a correlation coefficient (r) better than 0.97. Some examples are shown in Figure 6. The results for normal distribution analysis are tabulated in Table 2.

Correlation of major elements in sediments

Although the construction of a scatter diagram is a convenient mean of graphical representation of a bivariate sample or two of the variables from a multivariate sample as demonstrated by Cheeneh (1983), the Pearson Coefficient (r) applicable to ratio-scale measurements is used in this study.

The Pearson Correlation Matrix was obtained using SYSTAT programme. The data which were computed are available in Sidibe (1993), and some results are shown in Figure 7. The correlation between variables is considered as good when $r > 0.5$; fair when $r = 0.5–0.3$ and low when $r < 0.3$. The Pearson Matrix of probabilities for the correlation coefficients were also determined and they show (in the matrix) the "p" values for each correlation. These values allow one to assess the significance of the correlations. The probability of significance is fixed to $p \leq 0.05$). Figure 8 shows some matrices of probabilities for the Pearson Correlation Coefficients.

FACTOR ANALYSIS

Material and Procedures

Concentrations of 10 major elements and L.O.I. were determined in all samples using a PW 1130 and PW 1480 spectrometers and wet chemical methods of analysis. Some elements in some samples have their concentrations below the detection limit of the analytical procedure used. In order to prevent extreme statistical distortion of the analytical data, the writers set the concentrations of these elements to their detection limits. Prior to the analysis, concentrations of all oxides for each sample were transformed to proportions totaling 100%. A factor varimax solution accounting for high percentage (usually = 75%) of the variance in the original data was assumed along with sample commonality which was also a good agreement. The factor analysis reduced the measured variables to a defined composite geochemical factors. The intensities of these composite geochemical factors are given by the factor loadings that describe the relative importance of each composite factor for each sample but give no indication regarding each of the factors. To determine which elements have the most influence on each factor, the factor scores were treated as composite chemical variables, and the correlation coefficients were computed between each of the loadings and each of the observed composite variables. Thus, there are two steps for this analysis

Table 2a. Test for normal distribution — Kolek Member, Charu Formation.

Major elements	LITHOLOGY				
	Reddish Sandstone I	Greyish Sandstone II	Laminated Siltstone III	Interbedded Sandstone-Siltstone IV	Shale V
SiO_2	N	N	N	N	N
Al_2O_3	N	N	LN	X	X
Fe_2O_3	X	LN	X	X	X
FeO	n.t.	n.t.	n.t.	n.t.	n.t.
MgO	N	X	X	N	X
CaO	N	X	X	N	N
Na_2O	X	X	LN	N	X
K_2O	N	N	N	N	N
TiO_2	N	N	N	N	N
P_2O_5	X	X	X	X	X
MnO	N	X	N	X	N
LOI	X	LN	N	N	N
No. Sample	9	14	26	23	9

Note: N — normal X — non normal
LN — Lognormal n.t. — not tested

Table 2b. Test for normal distribution Berkelah Bed (Kg. Luit 2 section) — Lepar Member, Charu Formation.

Major elements	LITHOLOGY	
	Mudstone	Siltstone to very fine Sandstone
SiO_2	LN	N
Al_2O_3	X	N
Fe_2O_3	X	X
FeO	n.t.	n.t.
MgO	X	N
CaO	X	X
Na_2O	N	LN
K_2O	N	LN
TiO_2	N	N
P_2O_5	N	X
MnO	X	X
LOI	X	N
No. Sample	5	12

Note: N — normal X — non normal
LN — Lognormal n.t. — not tested

Table 2c. Test for normal distribution Lepar Hilir Bed — Lepar Member, Charu Formation.

Major elements	LITHOLOGY			
	Reddish Sandstone	Bedded Siltstone	Massuve Siltstone	Mudstone
SiO_2	N	N	N	N
Al_2O_3	LN	X	N	N
Fe_2O_3	X	X	N	LN
FeO	n.t.	n.t.	n.t.	n.t.
MgO	X	X	N	X
CaO	N	LN	N	LN
Na_2O	X	LN	N	N
K_2O	X	N	N	N
TiO_2	X	N	X	LN
P_2O_5	N	LN	N	N
MnO	X	X	N	N
LOI	N	X	N	N
No. Sample	6	10	5	33

Note: N — normal X — non normal
LN — Lognormal n.t. — not tested

Table 2d. Test for normal distribution — Sagor Formation.

Major elements	LITHOLOGY									
	SS (1)	SS-Sh (a)	SS-Sh (b)	SS (2)	md-Sh (°)	SS-Sh (C)	Sh	SS (3)	md-Sh (o o)	SS (4)
SiO_2	N	N	X	LN	N	LN	LN	LN	X	N
Al_2O_3	N	N	N	LN	X	X	X	N	X	N
Fe_2O_3	X	X	LN	LN	X	LN	LN	X	N	X
FeO	LN	X	X	X	N	LN	N	X	LN	X
MgO	N	N	X	LN	N	X	LN	X	X	N
CaO	N	X	N	X	X	LN	LN	X	X	X
Na_2O	X	N	N	X	N	X	LN	X	N	LN
K_2O	N	X	N	N	N	LN	LN	X	N	N
TiO_2	X	X	X	N	X	N	X	N	X	X
P_2O_5	X	X	X	X	X	X	N	X	X	X
MnO	X	LN	X	LN	X	LN	X	LN	N	X
LOI	N	X	LN	N	N	X	N	LN	X	N
No. Sample	21	11	6	18	9	16	13	16	6	6

Note:
N — normal
LN — Lognormal
X — non normal
SS — not tested
Sh — Shale
md — mudstone

Table 2e. Test for normal distribution — Taweh Formation.

Major elements	LITHOLOGY			
	Shale (Sh)	Sandstone (SS)	Interbedded SS-Sh	SS + Sh (partly)
SiO_2	X	N	N	LN
Al_2O_3	N	N	N	N
Fe_2O_3	X	N	N	X
FeO	X	N	X	X
MgO	X	N	N	LN
CaO	X	LN	X	X
Na_2O	N	LN	N	N
K_2O	LN	LN	X	X
TiO_2	LN	N	X	N
P_2O_5	X	X	X	X
MnO	LN	LN	LN	X
LOI	N	X	N	N
No. Sample	30	40	16	8

Note:
N — normal
LN — Lognormal
X — non normal

	Al$_2$O$_3$	CaO	Fe$_2$O$_3$	K$_2$O	L.O.I.	MgO	MnO	Na$_2$O	P$_2$O$_5$	SiO$_2$	TiO$_2$
Al$_2$O$_3$	1.000										
CaO	–0.077	1.000									
Fe$_2$O$_3$	–0.357$^+$	–0.110	1.000								
K$_2$O	0.280$^+$	–0.138	0.005	1.000							
L.O.I.	–0.227$^+$	–0.135	0.066	0.585$^+$	1.000						
MgO	0.126	–0.034	0.054	0.241$^+$	0.079	1.000					
MnO	–0.136	–0.072	0.630$^+$	–0.097	–0.085	0.148	1.000				
Na$_2$O	0.132	–0.113	0.112	0.687$^+$	0.365$^+$	0.327$^+$	0.026	1.000			
P$_2$O$_5$	–0.024	–0.269$^+$	0.073	0.130	0.067	–0.349$^+$	–0.083	0.148	1.000		
SiO$_2$	–0.393$^+$	0.205	–0.194	–0.838$^+$	–0.697$^+$	–0.287$^+$	–0.066	–0.566$^+$	–0.066	1.000	
TiO$_2$	0.422$^+$	–0.107	–0.306$^+$	0.505$^+$	0.273$^+$	0.399$^+$	–0.116	0.298$^+$	–0.291$^+$	–0.496$^+$	1.000

$^+$ Where $P \leq 0.05$

Figure 7a. Pearson correlation matrix for Kolek Member (n = 81).

	Al$_2$O$_3$	CaO	Fe$_2$O$_3$	K$_2$O	L.O.I.	MgO	MnO	Na$_2$O	P$_2$O$_5$	SiO$_2$	TiO$_2$
Al$_2$O$_3$	1.000										
CaO	–0.452	1.000									
Fe$_2$O$_3$	–0.453	0.225	1.000								
K$_2$O	0.914$^+$	–0.575$^+$	–0.307	1.000							
L.O.I.	0.789$^+$	–0.421	–0.367	0.797$^+$	1.000						
MgO	0.808$^+$	–0.686$^+$	–0.428	0.918$^+$	0.752$^+$	1.000					
MnO	–0.640$^+$	0.356	0.599$^+$	–0.693$^+$	–0.738$^+$	–0.703$^+$	1.000				
Na$_2$O	0.858$^+$	–0.401	–0.463	0.822$^+$	0.830$^+$	0.680$^+$	–0.681$^+$	1.000			
P$_2$O$_5$	–0.011	0.736$^+$	–0.066	–0.248	–0.049	0.429	0.059	0.119	1.000		
SiO$_2$	–0.973$^+$	0.488$^+$	0.343	–0.954$^+$	–0.883$^+$	–0.848$^+$	0.675$^+$	–0.876$^+$	0.076	1.000	
TiO$_2$	0.876$^+$	–0.598$^+$	–0.404	0.962$^+$	0.732$^+$	0.915$^+$	–0.663$^+$	0.800$^+$	–0.278	–0.896$^+$	1.000

$^+$ Where $P < 0.05$

Figure 7b. Pearson correlation matrix for Berkelah Beds (n = 17).

	Al$_2$O$_3$	CaO	Fe$_2$O$_3$	K$_2$O	L.O.I.	MgO	MnO	Na$_2$O	P$_2$O$_5$	SiO$_2$	TiO$_2$
Al$_2$O$_3$	1.000										
CaO	0.077	1.000									
Fe$_2$O$_3$	–0.598$^+$	–0.156	1.000								
K$_2$O	0.476$^+$	0.308$^+$	–0.436$^+$	1.000							
L.O.I.	0.269$^+$	0.508$^+$	–0.404$^+$	0.692$^+$	1.000						
MgO	–0.055	0.154	–0.194	0.014	0.205	1.000					
MnO	–0.617$^+$	–0.250$^+$	0.813$^+$	–0.629$^+$	–0.618$^+$	–0.124	1.000				
Na$_2$O	0.013	0.325$^+$	–0.052	0.522$^+$	0.715$^+$	0.155	–0.280$^+$	1.000			
P$_2$O$_5$	0.323$^+$	0.303$^+$	–0.148	0.345$^+$	0.416	0.166	–0.320$^+$	0.478$^+$	1.000		
SiO$_2$	–0.488$^+$	–0.359$^+$	0.177	–0.661$^+$	–0.698$^+$	–0.502$^+$	0.428$^+$	–0.550$^+$	–0.495$^+$	1.000	
TiO$_2$	0.479$^+$	0.015	–0.102	0.467$^+$	0.329$^+$	0.092	–0.315$^+$	0.303$^+$	0.280$^+$	–0.620$^+$	1.000

$^+$ Where $P \leq 0.05$

Figure 7c. Pearson correlation matrix for Lepar Hilir Bed (n = 15).

	Al_2O_3	CaO	Fe_2O_3	FeO	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2
Al_2O_3	1.000										
CaO	–0.062	1.000									
Fe_2O_3	–0.318$^+$	0.071	1.000								
FeO	–0.096	0.090	0.098	1.000							
K_2O	0.368$^+$	0.052	0.106	0.017	1.000						
L.O.I.	0.255$^+$	–0.029	0.134	0.132	0.694$^+$	1.000					
MgO	0.203$^+$	0.085	0.080	–0.022	0.640$^+$	0.640$^+$	1.000				
MnO	–0.086	–0.051	0.059	0.277	–0.018	–0.088	–0.136	1.000			
Na_2O	0.256$^+$	–0.106	0.100	0.065	0.323$^+$	0.481$^+$	0.436$^+$	–0.061	1.000		
P_2O_5	0.197$^+$	–0.078	–0.032	–0.023	–0.082	–0.061	–0.256$^+$	–0.027	–0.049	1.000	
SiO_2	–0.577$^+$	–0.016	–0.359$^+$	–0.175	–0.773$^+$	–0.774$^+$	–0.618$^+$	0.030	–0.496$^+$	–0.012	1.000

$^+$ Where $P \leq 0.05$

Figure 7d. Pearson correlation matrix for Sagor Formation (n = 122).

	Al_2O_3	CaO	Fe_2O_3	FeO	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2
Al_2O_3	1.000										
CaO	–0.012	1.000									
Fe_2O_3	–0.064	0.127	1.000								
FeO	–0.135	–0.005	0.536$^+$	1.000							
K_2O	0.833$^+$	–0.080	0.097	–0.020	1.000						
L.O.I.	0.231$^+$	0.162	0.321$^+$	0.044	0.303$^+$	1.000					
MgO	0.135	0.151	0.307$^+$	0.179	0.280$^+$	0.093	1.000				
MnO	–0.251$^+$	–0.071	0.046	–0.045	–0.310$^+$	–0.165	0.153	1.000			
Na_2O	0.666$^+$	0.068	0.027	0.069	0.600$^+$	0.080	0.006	–0.263$^+$	1.000		
P_2O_5	0.041	0.024	–0.014	–0.020	0.001	–0.029	–0.153	–0.004	0.040	1.000	
SiO_2	–0.806$^+$	–0.059	–0.301$^+$	–0.065	–0.821$^+$	–0.718	–0.250$^+$	0.281$^+$	–0.524$^+$	0.011	1.000

$^+$ Where $P \leq 0.05$

Figure 7e. Pearson correlation matrix for Taweh Formation (n = 94).

	Al_2O_3	CaO	Fe_2O_3	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2
Al_2O_3	0.000										
CaO	0.492	0.000									
Fe_2O_3	0.001	0.329	0.000								
K_2O	0.011	0.220	0.963	0.000							
L.O.I.	0,042	0.228	0.557	0.000	0.000						
MgO	0.262	0.766	0.632	0.030	0.481	0.000					
MnO	0.226	0.521	0.000	0.388	0.450	0.187	0.000				
Na_2O	0.241	0.315	0.319	0.000	0.001	0.003	0.819	0.000			
P_2O_5	0.834	0.015	0.515	0.247	0.553	0.001	0.464	0.188	0.000		
SiO_2	0.000	0.066	0.083	0.000	0.000	0.000	0.560	0.000	0.558	0.000	
TiO_2	0.000	0.342	0.005	0.000	0.014	0.000	0.301	0.007	0.008	0.000	0.000

Figure 8a. Matrix of probabilities for Pearson correlation coefficients — Kolek Member (n = 81).

	Al_2O_3	CaO	Fe_2O_3	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2
Al_2O_3	0.000										
CaO	0.069	0.000									
Fe_2O_3	0.068	0.384	0.000								
K_2O	0.000	0.016	0.230	0.000							
L.O.I.	0.000	0.093	0.147	0.000	0.000						
MgO	0.000	0.002	0.086	0.000	0.000	0.000					
MnO	0.006	0.160	0.011	0.002	0.001	0.002	0.000				
Na_2O	0.000	0.110	0.061	0.000	0.000	0.003	0.003	0.000			
P_2O_5	0.968	0.001	0.801	0.338	0.852	0.085	0.821	0.648	0.000		
SiO_2	0.000	0.047	0.178	0.000	0.000	0.000	0.003	0.000	0.770	0.000	
TiO_2	0.000	0.011	0.108	0.000	0.001	0.000	0.004	0.000	0.280	0.000	0.000

Figure 8b. Matrix of probabilities for Pearson correlation coefficients — Berkelah Bed (n = 17).

	Al_2O_3	CaO	Fe_2O_3	FeO	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2
Al_2O_3	0.000										
CaO	0.909	0.000									
Fe_2O_3	0.541	0.223	0.000								
FeO	0.194	0.965	0.000	0.000							
K_2O	0.000	0.445	0.353	0.847	0.000						
L.O.I.	0.025	0.118	0.002	0.677	0.003	0.000					
MgO	0.194	0.146	0.003	0.084	0.006	0.372	0.000				
MnO	0.015	0.495	0.657	0.667	0.002	0.113	0.140	0.000			
Na_2O	0.000	0.516	0.795	0.508	0.000	0.410	0.504	0.010	0.000		
P_2O_5	0.696	0.822	0.894	0.846	0.993	0.782	0.141	0.969	0.699	0.000	
SiO_2	0.000	0.572	0.003	0.531	0.000	0.000	0.015	0.006	0.000	0.917	0.000

Figure 8c. Matrix of probabilities for Pearson correlation coefficients — Taweh Formation (n = 94).

	Al_2O_3	CaO	Fe_2O_3	FeO	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2
Al_2O_3	0.000										
CaO	0.498	0.000									
Fe_2O_3	0.000	0.440	0.000								
FeO	0.293	0.325	0.285	0.000							
K_2O	0.000	0.566	0.244	0.854	0.000						
L.O.I.	0.005	0.751	0.141	0.148	0.000	0.000					
MgO	0.025	0.353	0.378	0.811	0.000	0.000	0.000				
MnO	0.346	0.575	0.519	0.002	0.845	0.333	0.136	0.000			
Na_2O	0.004	0.244	0.272	0.476	0.000	0.000	0.000	0.502	0.000		
P_2O_5	0.029	0.395	0.727	0.800	0.371	0.506	0.004	0.768	0.590	0.000	
SiO_2	0.000	0.861	0.000	0.054	0.000	0.000	0.000	0.742	0.000	0.895	0.000

Figure 8d. Matrix of probabilities for Pearson correlation coefficients — Sagor Formation (n = 122).

	Al_2O_3	CaO	Fe_2O_3	K_2O	L.O.I.	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2
Al_2O_3	0.000										
CaO	0.543	0.000									
Fe_2O_3	0.000	0.216	0.000								
K_2O	0.000	0.013	0.000	0.000							
L.O.I.	0.030	0.000	0.001	0.000	0.000						
MgO	0.664	0.222	0.121	0.912	0.002	0.000					
MnO	0.000	0.045	0.000	0.000	0.000	0.325	0.000				
Na_2O	0.917	0.008	0.678	0.000	0.000	0.217	0.024	0.000			
P_2O_5	0.009	0.014	0.241	0.005	0.001	0.187	0.009	0.000	0.000		
SiO_2	0.000	0.003	0.158	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
TiO_2	0.000	0.906	0.417	0.000	0.007	0.466	0.010	0.014	0.024	0.000	0.000

Figure 8e. Matrix of probabilities for Pearson correlation coefficients — Lepar Hilir (n = 65).

which are (1) determination of the factor loadings which describe the relative importance of each composite geochemical factor and (2) establishing elements that have the most influence in determining each of the factors.

Determination of factor loadings

The statistical analysis showed 4 factors for Kolek Member (81 rock samples), and they account for 74.52% of the total variance in geochemical data. The factor loadings are shown in Table 3.

Table 4 shows component loadings of 10 major elements and L.O.I determined from 17 rock samples collected at Kg. Luit section (Berkelah Bed). The loadings are given as correlations between elements and the component. The factors account for 81.829% of the total variance in the geochemical data.

The analysis for Lepar Hilir Bed is shown in Table 5. Four factors were derived from data of 66 rock samples taken from Felda Lepar Hilir. They account for 77.8% of the total variance in the data.

Table 6 shows component loadings of major elements of 123 rock samples taken from road cutting 2 in Felda Bt Sagu 2 (Sagor Formation). Four factors were defined and they account for 66.7% of the total variance in the data.

In Table 7 four component loadings for 95 rock samples which have been taken at road cutting 3 (in Felda Bt Sagu 1 for Taweh Formation) are shown. They account for 70.9% of the total variance in the data.

This search for component (factor) loadings does not prove the characteristic elements within the factors. Hence, the factor scores of the elements are used in the second step of the analysis to determine the needed characteristic elements. Factor scores derived from this first step of the analysis are available in Sidibe (1993).

Determination of the characteristic elements

The elements which could give a better trend of the yielded factors are determined. The discussion will be focussed (a) on the distribution of the elements in each rock unit (member/formation) and (b) on the trend of distribution of elements in various rock units. The fundamental difference between members and formations may perhaps be revealed by this method of analysis.

Kolek Member

The member was characterised by four factors. After determining the characteristic elements for each factor only three factors were retained, and these are shown in Table 8.

Factor 1 or K_2O factor

Three elements characterise this factor, v.i.z K_2O, L.O.I. and TiO_2.

As described in Sidibe (1993), Kolek Member consists of tuffaceous sandstone (subarkosic suite), siltstone and shale. These are known as having significant amount of Al_2O_3, K_2O, Na_2O and CaO. Trace oxides such as TiO_2, P_2O_5 and MnO may come from clay minerals or from precipitation of minerals such as celestile during diagenesis, or from detrital minerals such as rutile, zircon, monazite, ilmenite,, sphene, apatite and tourmaline. In shales, a high K_2O content may be due to detrital feldspars and muscovite, illite, authigenic glauconite, or potassium adsorbed by clay minerals.

In general L.O.I. express water, organic matter and volatile elements content in sediments. In the analysed rock samples, L.O.I. content is higher in shales than in sandstones. Thus in the Kolek Member, Factor 1 which is named as K_2O factor characterises the shales which are rich in carbonaceous matter, water and probably volatile elements. In the same member if we consider that sandstones and shales have approximately the same K_2O and TiO_2 content, then L.O.I. content can be used to support that K_2O factor here belongs to shales.

Factor 2 or Al_2O_3 factor

Al_2O_3 characterises this factor. It is known that shales of the member are richer in Al_2O_3 than sandstones and siltstones. Hence Al_2O_3 factor also belongs to shales.

Factor 3 or Fe_2O_3 factor

This factor is characterised by the negative anomaly expressed by Fe_2O_3 loading.

The three factors defined by the analysis are those characterising the shales in Kolek Member. This assumption is verified since shales are the dominant lithologic unit in the member. Factor 1 through Factor 3 account for 76.48% of the total variance in the geochemical data. Hence Kolek Member is recognizable by K_2O content in its shales. The average K_2O content in shales is 4.85 wt% (n = 85).

Lepar Member

Berkelah Bed

The unit is characterised by one factor consisting of six high positive weighed elements such as K_2O, TiO_2, MgO, Al_2O_3, Na_2O and L.O.I., and a negative loaded element SiO_2. This factor, named as Feldspathic factor, characterises the weakly metamorphosed mudstone beds of the unit. This assumption is true if the following points are considered (a) shales including mudstones, generally have high K_2O content which is the highest weighed element, (b) shales have higher amounts of most trace elements including Ti, (c) L.O.I. content is likely higher in mudstones than in sandstones of

Table 3. Factor analysis — Sg. Charu section, Kolek Member, Charu Formation (Rotated Loadings).

Elements	Factor 1	Factor 2	Factor 3	Factor 4
SiO_2	–0.899	0.114	0.015	–0.236
Al_2O_3	0.099	0.225	–0.045	0.867
Fe_2O_3	0.108	–0.864	0.102	–0.268
MgO	0.295	–0.256	–0.623	0.279
CaO	–0.185	0.262	–0.481	–0.406
Na_2O	0.733	–0.119	0.012	0.133
K_2O	0.904	0.072	0.018	0.184
TiO_2	0.498	0.228	–0.439	0.476
P_2O_5	0.123	0.003	0.871	0.017
MnO	–0.062	–0.880	–0.114	0.023
L.O.I.	0.823	0.084	0.034	–0.381
A	3.249	1.797	1.599	1.546
B	31.597	16.335	14.532	14.057
		47.932	62.464	76.521

Note: A — Variance explained by rotated components
B — Percent of total variance explained

Table 4. Factor analysis — Kg. Luit 2 section, Berkelah Bed, Lepar Member, Charu Formation (Rotated Loadings).

Elements	Factor 1	Factor 2
SiO_2	–0.937	–0.225
Al_2O_3	0.932	0.158
Fe_2O_3	–0.566	0.087
MgO	0.788	0.547
CaO	–0.450	–0.853
Na_2O	0.931	0.017
K_2O	0.880	0.391
TiO_2	0.853	0.416
P_2O_5	0.123	–0.961
MnO	–0.805	–0.096
L.O.I.	0.879	0.143
A	6.611	2.390
B	60.100	21.729
		81.829

Note: A — Variance explained by rotated components
B — Percent of total variance explained

Table 5. Factor analysis — Lepar Hilir Bed, Lepar Member (Varimax rotated factor matrix).

Elements	Factor 1	Factor 2	Factor 3	Factor 4
SiO_2	–0.670	0.139	–0.487	–0.443
Al_2O_3	0.090	–0.702	0.559	–0.063
Fe_2O_3	–0.046	0.959	0.0616	–0.124
MgO	0.108	–0.050	–0.011	0.984
CaO	0.451	–0.175	–0.458	0.100
Na_2O	0.876	0.071	0.033	0.020
K_2O	0.675	–0.468	0.273	–0.118
TiO_2	0.377	–0.123	0.773	0.064
P_2O_5	0.597	–0.097	0.188	0.124
MnO	–0.291	0.897	0.039	0.037
L.O.I.	0.834	–0.348	–0.0065	0.097
A	42.0	15.6	10.6	9.6
B		57.6	68.2	77.8

Note: A — Percent of total variance explained

Table 6. Factor analysis — Sagor Formation (Varimax rotated factor matrix).

Elements	Factor 1	Factor 2	Factor 3	Factor 4
SiO_2	–0.881	–0.271	–0.120	–0.219
Al_2O_3	0.461	–0.239	–0.140	0.683
Fe_2O_3	0.082	0.803	0.190	–0.254
FeO	0.094	0.084	0.782	–0.017
MgO	0.784	0.087	–0.172	–0.230
CaO	0.089	0.671	–0.169	0.239
Na_2O	0.577	0.247	–0.048	0.094
K_2O	0.869	–0.042	0.023	0.017
TiO_2	0.691	–0.231	0.0002	0.014
P_2O_5	–0.080	–0.079	0.771	0.0032
MnO	–0.179	0.124	0.053	0.797
L.O.I.	0.827	0.108	0.082	–0.051
A	33.2	12.8	10.4	10.3
		46.0	56.4	66.7

Note: A — Percent of total variance explained

Table 7. Factor analysis — Taweh Formation (Varimax rotated factor matrix).

Elements	Factor 1	Factor 2	Factor 3	Factor 4
SiO_2	–0.889	–0.248	–0.323	–0.0095
Al_2O_3	0.895	–0.124	0.035	–0.010
Fe_2O_3	0.055	0.861	0.196	–0.065
FeO	–0.084	0.823	–0.129	–0.088
MgO	0.168	0.306	0.194	–0.665
CaO	–0.169	–0.041	0.816	–0.101
Na_2O	0.748	0.075	–0.148	–0.038
K_2O	0.932	0.044	–0.0022	–0.123
TiO_2	0.930	0.029	0.042	–0.016
P_2O_5	0.042	0.025	0.082	0.758
MnO	–0.354	0.214	–0.296	0.272
L.O.I.	0.413	0.309	0.603	0.163
A	36.69	15.7	9.5	9.1
		52.3	61.8	70.9

Note: A — Percent of total variance explained

Table 8. Results of factor analysis, Kolek Member, Charu Formation.

Elements	Factor 1	Factor 2	Factor 3
SiO_2	0.005	–0.054	–0.196
Al_2O_3	0.284	0.640	0.272
Fe_2O_3	0.259	–0.165	–0.849
MgO	0.279	–0.284	–0.059
CaO	–0.003	–0.060	0.067
Na_2O	–0.089	–0.140	–0.079
K_2O	0.854	0.023	0.093
TiO_2	0.501	0.143	0.303
P_2O_5	0.061	–0.030	–0.053
MnO	0.185	–0.040	–0.402
L.O.I.	0.829	–0.347	0.236
Characteristic elements in the factors	K_2O L.O.I. TiO_2	Al_2O_3	Fe_2O_3 (–)
Names	K_2O factor	Al_2O_3 factor	Fe_2O_3 factor
Related rocks	Shales	Shales	Shales
Kolek Member ⟶ K_2O, Al_2O_3 — rich shales			

Table 9. Results of factor analysis, Lepar Hilir Bed, Lepar Member.

Elements	Factor 1	Factor 2	Factor 3
SiO_2	–0.855	–0.153	–0.245
Al_2O_3	0.408	0.716	–0.307
Fe_2O_3	–0.020	–0.939	–0.177
MgO	0.168	–0.036	0.559
CaO	0.252	0.133	0.383
Na_2O	0.709	–0.039	0.440
K_2O	0.679	0.498	0.103
TiO_2	0.780	0.133	–0.322
P_2O_5	0.591	0.097	0.278
MnO	–0.313	–0.817	–0.158
L.O.I.	0.646	0.357	0.480
Characteristic elements in the factors	SiO_2 (–) TiO_2 Na_2O K_2O P_2O_5 L.O.I.	Fe_2O_3 (–) Al_2O_3	MgO CaO
Names	Feldspathic factor	Al_2O_3 factor	Mg-Ca factor
Related rocks	Siltstones mudstones	Laminated mudstones	Massive mudstones

the unit and (d) the sandstones and mudstones in the unit have relatively equal amount of SiO_2 which could not be used in differentiating the rock types.

Lepar Hilir Bed

This unit is characterised by 3 factors, v.i.z Factor 1 or Feldspathic factor, Factor 2 or Al_2O_3 factor and Factor 3 or Mg-Ca factor (see Table 9).

Factor 1 or Feldspathic factor

Here SiO_2 has higher negative loading along with a high positive L.O.I loading. From there, the factor could be related to some argillaceous sediments which are commonly represented in the section by siltstones, massive and laminated mudstone. P_2O_5 content could be related to some apatite in fine-grained sediments such as siltstone or mudstones.

Factor 2 or Al_2O_3 factor

The aluminous factor is believed to be related to mudstones which are characterised by negative loading of Fe_2O_3 and MnO.

According to Brownlow (1979), Fe_2O_3 and MnO content in potassic and carbonaceous shales as well as mudstones of older rock units, have similar trends. Here the trends can be assimilate to the anomalies showed by these elements throughout the studied rock unit. The results of geochemical analysis showed that Fe_2O_3 and MnO content are invariably insignificant throughout the unit. The massive and laminated mudstones of Lepar Hilir Bed have low Fe_2O_3 (1.12%) and low MnO (0.009%) content.

Factor 3 or Mg-Ca factor

The MgO and CaO factors characterise the mudstones of this unit. MgO is a product of diagenesis, probably derived from some dolomites. CaO is present in the sediments in form of calcite fragments and cement.

Conclusion 1

The results of Factor Analysis for Kolek and Lepar Members (Charu Formation) suggest that:

(a) the whole sediments have negative loading of SiO_2 which cannot be used to discriminate the two members;

(b) the fine-grained sediments are the rock types which are suitable to differentiate the two members. Both of them have a first factor consisting of feldspathic elements but the shales of Kolek Member are richer in K_2O and TiO_2, and contain more carbonaceous material than the shales and mudstones of Lepar Member. In turn Lepar Member (especially Lepar Hilir Bed) differs from Kolek Member by its high P_2O_5 loading. However, shales are unusually rich in P_2O_5 and MgO. The younger and unmetamorphosed part of the Lepar Member

Table 10. Result of factor analysis, Sagor Formation.

Elements	Factor 1	Factor 2	Factor 3
SiO_2	–0.925	0.182	0.292
Al_2O_3	0.426	0.433	–0.775
Fe_2O_3	0.183	–0.981	–0.013
FeO	0.201	–0.110	0.173
MgO	0.732	0.048	0.180
CaO	0.014	–0.075	0.046
Na_2O	0.511	–0.009	–0.049
K_2O	0.855	0.054	0.046
TiO_2	0.587	0.202	0.138
P_2O_5	–0.069	0.035	–0.245
MnO	–0.043	–0.083	0.027
L.O.I.	0.924	0.041	0.236
Characteristic elements in the factors	SiO_2 (–) TiO_2 Na_2O K_2O MgO L.O.I.	Fe_2O_3 (–)	Al_2O_3
Names	SiO_2 factor	Fe_2O_3 factor	Al_2O_3 factor
Related rocks	Shales	Tuffaceous sandstones	Tuffaceous sandstones

Table 11. Results of factor analysis, Taweh Formation.

Elements	Factor 1	Factor 2	Factor 3
SiO_2	–0.875	0.459	–0.148
Al_2O_3	0.981	0.058	–0.170
Fe_2O_3	0.084	–0.212	0.897
FeO	–0.031	0.004	0.616
MgO	0.224	0.036	0.497
CaO	–0.017	–0.163	0.028
Na_2O	0.641	0.117	0.083
K_2O	0.900	–0.016	0.147
TiO_2	0.849	–0.223	0.017
P_2O_5	0.019	0.031	–0.074
MnO	–0.273	0.088	0.006
L.O.I.	0.307	–0.946	0.099
Characteristic elements in the factors	Al_2O_3 K_2O TiO_2 Na_2O	L.O.I. (–) SiO_2	Fe_2O_3 FeO
Names	Alumino-silicate factor	Silicate factor	Ferromagnesian factor
Related rocks	Siliceous shales	Tuffaceous sandstones	Tuffaceous sandstones

(Lepar Hilir Bed) differs from the older and metamorphosed Berkelah Bed by its Mg-Ca factor. Besides the lithologic characters such as the predominance of shales in Kolek Member and that of mudstones in Lepar member, geochemical characteristics can be used to define the two units. Kolek Member contains predominantly potassic shales rich in organic matter. They appear thinly bedded and are often laminated and interbedded with mudstone and siltstone forming rhythmic sequences.

The MgO-rich calcareous mudstones of Lepar Member appear massive and laminated and interbedded with sandstones and siltstone.

Sagor Formation

Three factors were defined for this unit (see Table 10).

Factor 1 or SiO_2 factor

It is characterised by high negative loading of SiO_2 and high positive loading of L.O.I. Such conditions are related to the argillaceous and carbonaceous materials present in the shales which are also characterised by high loadings of K_2O, MgO, TiO_2 and Na_2O suggesting that they are potassic in nature and rich in MgO. Although SiO_2 has negative loading, the SiO_2 could still be used in order to differentiate the shales of this formation from those of Charu Formation.

Factor 2 or Fe_2O_3 factor

It is characterised by negative loading of Fe_2O_3, CaO, FeO, MnO and Na_2O a moderate positive loading of Al_2O_3, TiO_2 and SiO_2 and a near zero loading of K_2O, L.O.I., MgO and P_2O_5. The factor characterises the subarkosic sandstones of the formation.

Factor 3 or Al_2O_3 factor

It is characterised by negative loadings of Al_2O_3, Fe_2O_3, Na_2O and P_2O_5; near zero loadings of K_2O, MnO and CaO; and moderate positive loadings of L.O.I., SiO_2, MgO, FeO and TiO_2. As for factor 2, factor 3 characterises the sandstones of the unit.

Conclusion 2

The analysis showed that Sagor Formation is characterised by the predominance of potassic shales rich in MgO and by Fe_2O_3- and Al_2O_3-poor subarkosic sandstones.

Taweh Formation

Three factors (Table 11) were defined from the analysis of data obtained from 123 samples of sandstones and shale.

Table 12. Results of Factor analysis.

Rock units			Number of factors	Characteristic elements	Names of factors	Related rocks	Discriminating elements
MESOZOIC (TRIASSIC)	TAWEH FORMATION		1	Al_2O_3, K_2O TiO_2, Na_2O, SiO_2^*	Alumino Silicate	Siliceous Shales	Shales rich in SiO_2 and sandstones rich in ferromagnesian elements
			2	L.O.I*, SiO_2	Silicate	Tuf. SS	
			3	Fe_2O_3, FeO, MgO	Ferromagn.	Tuffac. SS	
KUANTAN GROUP	SAGOR FORMATION		1	L.O.I, K_2O, MgO TiO_2, Na_2O, SiO_2	Silica	Shales	Potassic shales and arkosic sanstones both poor in Fe_2O_3 and Al_2O_3
			2	Fe_2O_3	Fe_2O_3	Tuffac. SS	
			3	Al_2O_3	Al_2O_3	Tuffac. SS	
	Panching Limestone		N D	ND	ND	ND	ND
	CHARU FORMATION	Lepar Hilir Bed	1	SiO_2, TiO_2, Na_2O K_2O, L.O.I, P_2O_5	Feldspathic	Siltstones mudstones	P_2O_5 and Mg - Ca rich mudstone
			2	$Fe_2O_3^*$, MnO^*, Al_2O_3	Al_2O_3	Lam. mudstones	
			3	Mg, CaO	Mg - Ca	Mass. mudstone	
		Berkelah Bed^2	1	K_2O, TiO_2, MgO, Al_2O_3, Na_2O, L.O.I, SiO_2^*	Feldspathic	mudstones	Feldspathic and MgO poor mudstone
		Kolek Member	1	K_2O, L.O.I, TiO_2	K_2O	Shales	K_2O, Al_2O_3 rich shales
			2	Al_2O_3	Al_2O_3	Shales	
			3	Fe_2O_3	Fe_2O_3	Shales	

1 — upper part of Lepar Member
2 — lower (metamorphosed) part of Lepar Member
* — elements which have negative loading in the factor
ND — not determined

Factor 1 or Aluminosilicate factor

This factor is characterised by high positive loadings of Al_2O_3 and K_2O followed by TiO_2 and Na_2O. SiO_2 loading is negative and that of L.O.I. is moderate indicative that the sediments in question are the siliceous shales which are poor in organic matter.

Factor 2 or Silicate factor

The factor is characterised by high negative loading of L.O.I. and moderate positive loading of SiO_2. Hence the factor is related to the arkoses which are predominant in the formation.

Factor 3 or Ferromagnesian factor

The factor is characterised by high loadings of Fe_2O_3, FeO and MgO which are related to the arkosic suite of the formation.

Conclusion 3

From the above results, Taweh Formation can be defined by its siliceous shales and arkosic sandstones.

General Conclusion

The geochemical characteristics derived from Factor Analysis are shown in Table 12. From there the conclusions for each rock unit are as below

Charu Formation is characterised by the predominance of K_2O, Al_2O_3 and Fe_2O_3 in the shales of Kolek Member, by the feldspathic and MgO-rich mudstones of Berkelah Bed and by P_2O_5 and Mg-Ca rich mudstones of Lepar Hilir Bed.

Sagor Formation can be defined by its potassic shales and Fe_2O_3- and Al_2O_3-poor subarkoses.

Taweh Formation is characterised by SiO_2-rich shales (siliceous shales) and arkoses rich in ferromagnesian elements.

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