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MINERALOGY AND DIGENETIC IMPACTS ON CHEMICAL COMPOSITION OF PALEOZOIC MUDROCKS, SOUTHWESTERN SINAI, EGYPT

Ibrahim A.M.[1], Abdalla Soliman Alshami [2], Abayazeed, S. D.[3], and Saadawy D. A.[4]

**1 and 4 Al-Azhar University, Faculty of Science, Geology Department.*
**2-Nuclear Material Authority – Egypt.*
**3-Geological Science Department, National Research Center – Egypt.*

ABSTRACT

The present study deals with mineralogy, diagenesis and their impact on chemical composition for Early Paleozoic; Cambro-Ordovician (Adediya and Abu Hamata Formations) and Late Paleozoic; Early Carboniferous (El Hashash and Magharet El Maiah) mudrocks at South Western Sinai area.

Mineralogical study reveals the presence of kaolinite and illite clay minerals. The detection of kaolinite and illite clay minerals favour that the environment of formation was alkaline, and the origin of the clay minerals present is chlorite more probably than illite origin where illite can be derived from weathering of chlorite.

Diagenetic study reveals that; kaolinite can be neo-formed, transformed at high rainfall and a temperate climate which can transform muscovite and biotite into kaolinite together with some illite.

Chemical composition study; abundance, behavior and distribution of major and trace components reveals that the studied mudrocks seem to be formed under reducing alkaline environment.

Keywords: Paleozoic mudrocks – South Western Sinai – Mineralogy - Paleoenvironment- Diagenesis – kaolinite -illite- Chemical composition.

INTRODUCTION

Early and Late Paleozoic rock unites recorded at south western Sinai, to the east of Abu Zenima city, lies between latitudes ٢٨° ٥٧' 00″ and ٢٩° ٠٥' 00″ N and longitudes 33° 2٠' 00″ and 33° ٢٥' 00″ E approximately were studied (Fig.1).

The mudrocks constitute about 15.42 % of the studied Paleozoic studied rock units. The study of their mineral composition, diagenesis

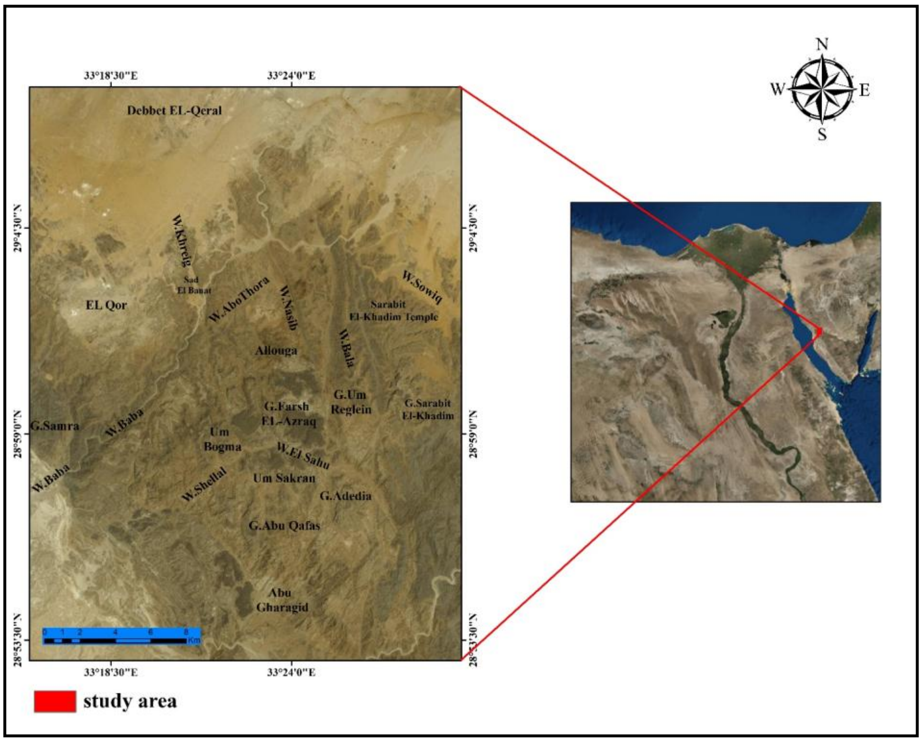

Fig (1): Location map of the studied area.

as well as the abundance and distribution of their major and trace chemical components aim to understand the long history of these units.

Early and Late Paleozoic in the studied area varies either in thickness or in facies and is subdivided according to **Soliman and Abu El Fetouh (1969)** into seven formations, where the Lower Series comprises Sarabit El Khadim, Abu Hamata and Adediya Formations, the middle carbonate comprises the Um Bogma Formation and the Upper Series comprises El Hashash, Magharet El Maiah, Abu Zarab Formation (Fig.2). The mudrocks samples is recorded in Early Paleozoic; Cambro-Ordovician (Abu Hamata and Adediya Fms.) and Late Paleozoic; Early Carboniferous (El Hashash and Magharet El Maiah Fms.).

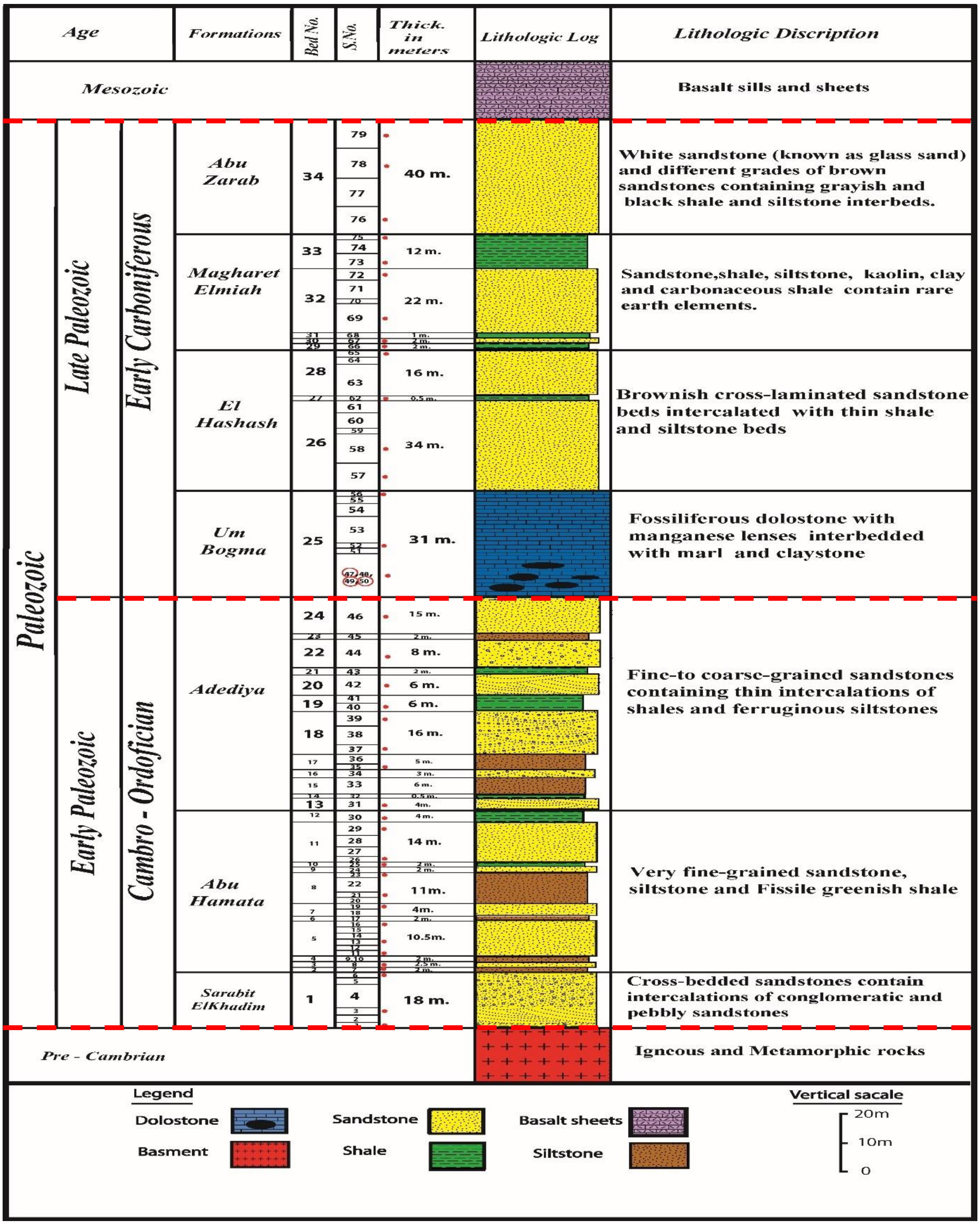

Fig.2: Composite columnar lithologic section of Paleozoic sedimentary formations in south western Sinai (modified after Aita, 1996).

MATERIALS AND METHODS

Eighteen samples which represented Early (12 samples) and Late (6 samples) Paleozoic mudrocks were collected from the studied area. X-ray diffraction analysis was carried out at The Egyptian mineral resource authority (E.M.R.A) using the Philips X-ray diffract to meter (Type PW/1050) with Ni-filter, Cu-radiation, λ = 1.5AA18 A^o at 30 kv, 10 mA, and a normal scanning speed 2θ/min was used for Seven clay samples were selected to represent Early (3 samples) and Late (4 samples) Paleozoic rock units.

Nine selected samples were chemically analyzed using X- Ray Flourocense analysis (N.R.C.E Labs.).to determine the Major oxides (Si, A1, Fe, Mg, Ca, Na, K, P, S and Cl) and trace elements (Ti, Cr, Y, Co, Mn, V, Ni, Cu, Zn, Pb, Sr, Ba, Rb, Zr, Ce, Th and Ga) chemical components

MINERALOG1CAL COMPOSITION

The X-ray diffraction analyses data of the studied clay samples is shown in (Table 1and Figs. 3-5) favour the presence of kaolinite and illite clay minerals.

The detection of kaolinite and illite clay minerals in Early and Late Paleozoic clays favour their formation under alkaline waters and alkaline digenesis and this agree with the conclusion of **(Millot, 1970)**.

The study of clay mineral associations reported in the Paleozoic clays reveals that the environment of formation was alkaline environment and that the origin of the clay minerals present is chlorite more probably than illite origin where illite can be derived from weathering of chlorite **(Droste et al., 1962)**.

DIGENESIS

Clay minerals are particularly sensitive to pressure and temperature variations and to the chemical environment. This sensitivity is expressed in terms of their chemistry and mineralogy. According to **Gutierrez-Mas et al., 1997; Srodon, 1999; Carretero et al., 2002; Lopez Aguayo, 1990 and Merriman, 2002**Clay minerals mostly form from pre-existing minerals, primarily from rock-forming silicates by transformation, and/or neoformation, where rocks are in contact with water, air, or steam.

1. Weathering

The weathering environment is usually sub-aerial. It involves physical disaggregation and chemical decomposition, leading to the transformation of original minerals into clay minerals. The factors controlling rock weathering include: rock type, climate (rainfall, chemical factor and temperature), topography and the presence of organisms and organic matter **(Velde, 1992; Foley, 1999)**. The study area belongs to tropical zones and Mediterranean climates with seasonal contrast.

Table (1): X-ray diffraction data of Paleozoic different studied rock units.

Age			Fms.	S.No.	Mineral detected	Normal			Glycolated			Heated		
						dA^0	I/I_o	2θ	dA^0	I/I_o	2θ	dA^0	I/I_o	2θ
Paleozoic	*Late Paleozoic*	*Early Carboniferous*	*Magharet El Maiah*	75	*Kaolinite*	٣,٣٧	١٠٠	٢٦,٣٩	٣,٣٥	١٠٠	٢٦,٥٧	---	---	---
					Illite	١٠,٣٠	٣,٠٩	٨,٥٨	١٠,٠٧	٣,٣٣	٨,٧٧	٣,٣٨	١٠٠	٢٦,٣٤
				73	*Kaolinite*	٣,٣٦	١٠٠	٢٦,٤٥	٢٦,٥٣	١٠٠	٣,٣٥	---	---	---
					Illite	١٠,٢٤	٣,٩٤	٨,٦٣	١٠,٢٢	٣,٩٤	٨,٦٥	٣,٣٧	١٠٠	٢٦,٤٤
				66	*Kaolinite*	٧,١٧	١٠٠	١٢,٣٣	٧,١٦	١٠٠	١٢,٣٦	---	---	---
					Illite	٣,٠٧	١٢,٥٠	٢٩,٠٧	٣,٠٦	١٧,٢٢	٢٩,١٠	٣,٣٤	١٠٠	٢٦,٦٣
			El Hashash	62	*Kaolinite*	٧,١٨	١٠٠	١٢,٣٢	٧,١٩	١٠٠	١٢,٣٠	---	---	---
					Illite	4.48	7.18	19.77	4.48	8.81	19.80	٣,٣٦	١٠٠	٢٦,٤٤
	Early Paleozoic	*Cambro-Ordovician*	*Adedia*	40	*Kaolinite*	٧,٢١	١٠٠	١٢,٢٦	٧,٢٢	١٠٠	١٢,٢٤	---	---	---
					Illite	١٠,١٦	٧٣,٦٣	٨,٦٩	١٠,١٨	٥٩,٧٧	٨,٦٨	٣,٣٧	١٠٠	٢٦,٤٠
			Abu Hamata	30	*Kaolinite*	٧,١٩	١٠٠	١٢,٣٠	٧,٢٤	١٠٠	١٢,٢١	---	---	---
					Illite	٣,٣٥	٣٧,٨٦	٢٦,٥٤	٣,٣٦	٤٣,١٦	٢٦,٥١	٣,٣٧	١٠٠	٢٦,٤٠
				25	*Kaolinite*	٧,١٨	١٠٠	١٢,٣٢	٧,٢٣	١٠٠	١٢,٢٣	---	---	---
					Illite	١٠,٠٨	١٣,٣٠	٨,٧٦	١٠,٢٥	١٥,١٤	٨,٦٢	١٠,٠٧	١٠٠	٨,٧٧

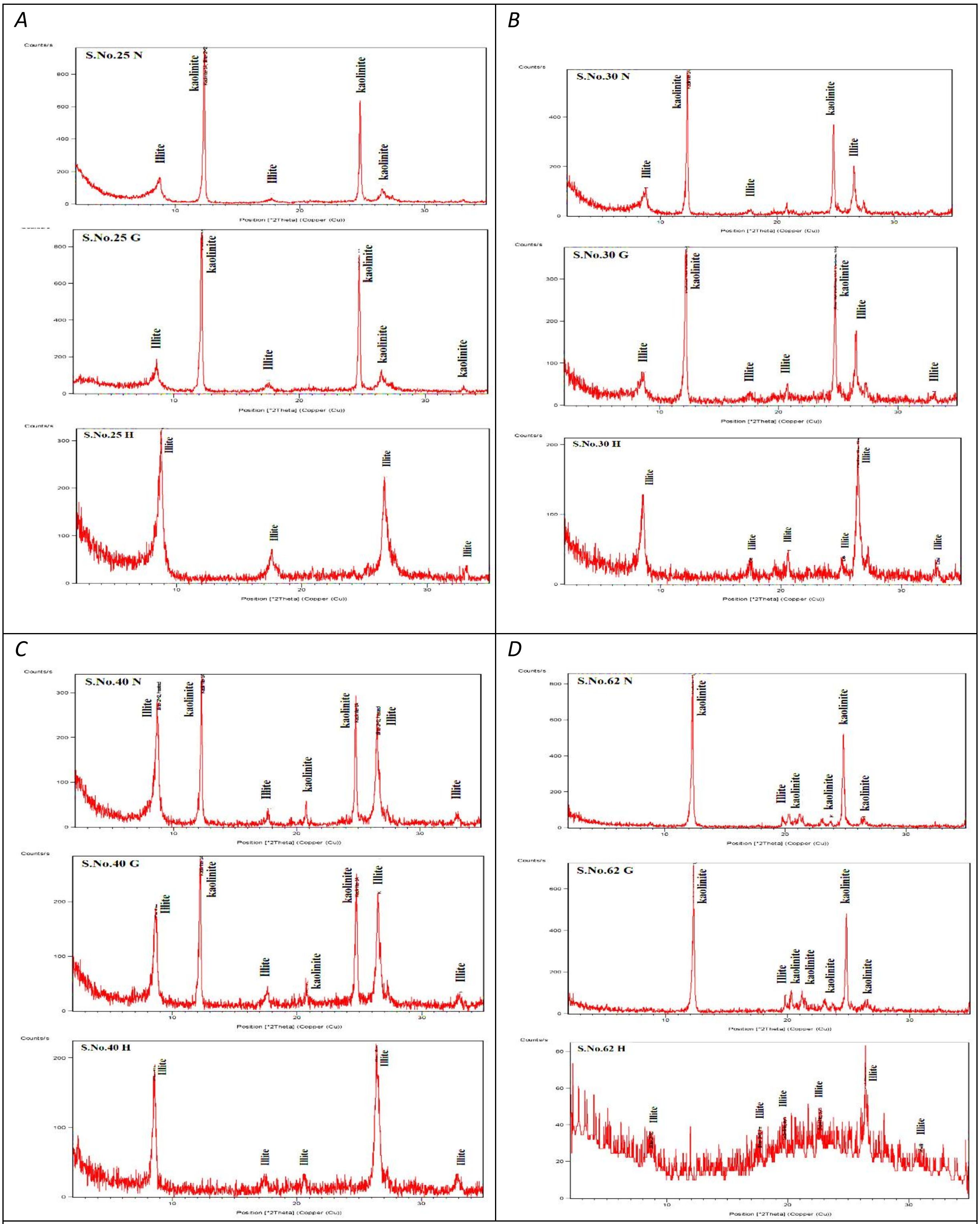

Fig. (٣) :X-ray diffraction pattern of oriented clay samples of Paleozoic mudrocks, (A) :S. No. 25, (B) :S. No. 30, (C) :S. No. 40 and (D) :S. No. 62.

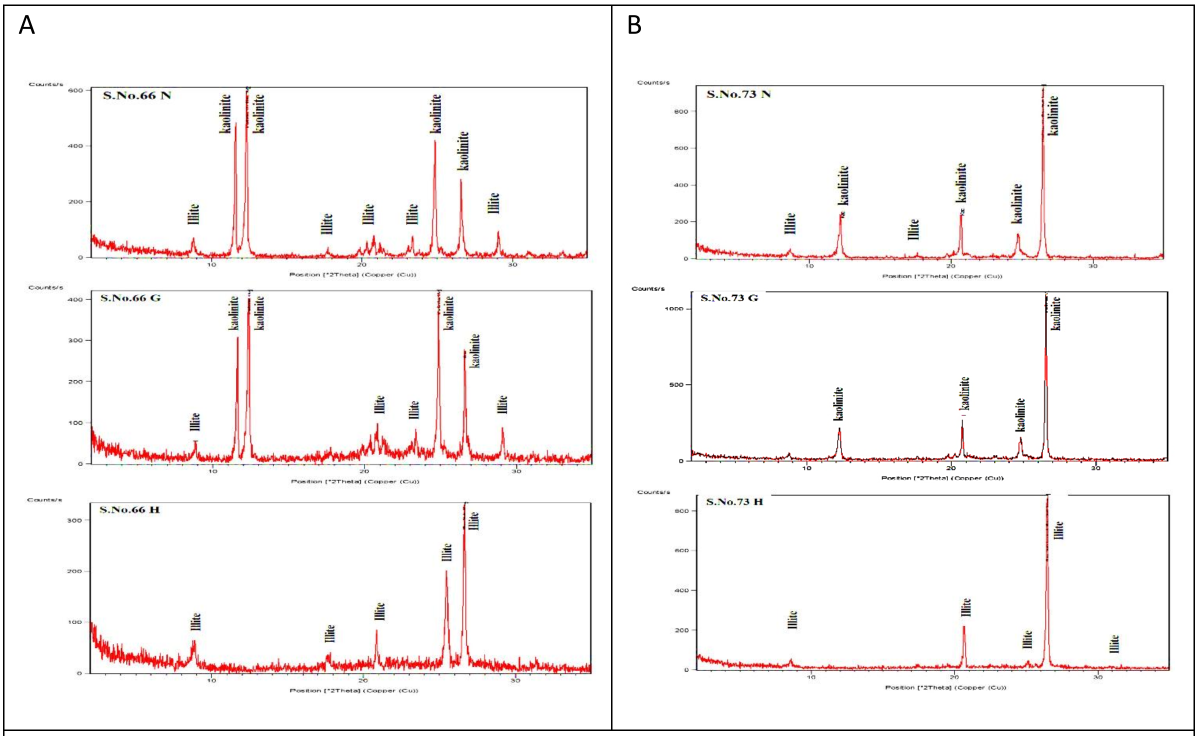

Fig. (٤) :X-ray diffraction pattern of oriented clay samples of Paleozoic mudrocks, (A) :S. No. 66 and (B) :S. No. 73.

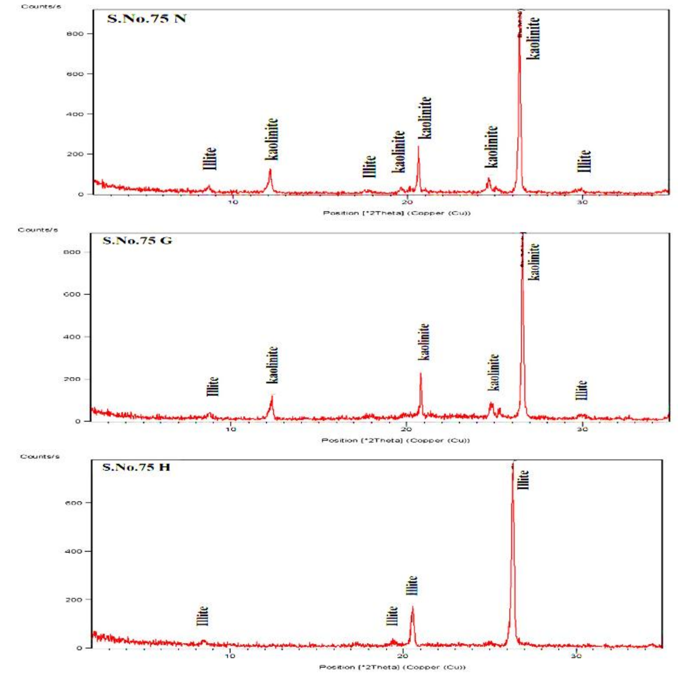

Fig. (٥) :X-ray diffraction pattern of oriented clay samples of Paleozoic mudrocks, S.No. 75.

Under this conditions kaolinite is the main clay mineral components. Kaolinite together with some Illite can be a neo-formed due to high rainfall and a temperate climate.

2. Sedimentation

A typical clay mineral distribution found from the coastline to the open sea is: kaolinite-illite-smectite. In general, clay minerals of sedimentary sequences mainly reflect the climate, relief, and lithology of source areas. Kaolinite is a typical clay mineral formed by direct precipitation.

3. Origin of kaolin's clay deposits

Kaolinite can be formed by weathering (residual kaolin's) and hydrothermal activity (hydrothermal kaolin) or occur as an authigenic sedimentary mineral. Sedimentary kaolin's are composed of kaolinized material from a source area that was eroded, transported, and deposited in a continental or coastal environment.

The previous study about the mineralogy supports the assumption about the origin of kaolin clay deposits, whereas kaolinite can be neo-formed, transformed, as already mentioned, at high rainfall and a temperate climate which can transform muscovite and biotite into kaolinite together with some Illite.

ABUNDANCE AND DISTRIBUTION OF MAJOR OXIDES

The mudrocks constitute about 15.42 % relative to the total thickness of the studied Paleozoic rock units. Major (Si, A1, Fe, Mg, Ca, Na, K, P, S and Cl) and trace (Ti, Cr, Y, Co, Mn, V, Ni, Cu, Zn, Pb, Sr, Ba, Rb, Zr, Ce, Th and Ga) chemical components were done.

Oxides forming silicates:

The distribution of the average SiO_2 content in Early and Late Paleozoic mudrocks is shown in (Tables2 and 3) and Fig. (٦). The distribution shows no particular trend for silica distribution with decrease in age from Early towards Late Paleozoic rock units.

Alumina is similar to silica in its occurrence, where silica and alumina tend to organize together into clay minerals, if they do not, alumina stays in situ with iron, whereas silica is removed with lime and magnesia **(Millot, 1970)**.

According to **Pettijohn (1975)** the silica/alumina ratio for Paleozoic mudrocks were computed (Tables 4 and Fig. ٧). It

Table (2): Chemical composition (major components in Wt. %) of Paleozoic mudrocks.

Age			*Fms.*	S.No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3^{-2}	Cl^-	L.O.I
Paleozoic	***Late Paleozoic***	***Early Carboniferous***	***Magharet El Maiah***	**75**	63.38	17.13	0.63	0.31	0.34	0.65	1.12	0.07	4.38	0.07	10.08
				73	67.40	17.08	0.70	0.24	1.42	0.08	0.84	0.18	2.8	0.02	8.08
				66	39.24	17.02	0.62	0.50	10.00	0.30	0.53	0.09	17.42	0.24	12.44
			El Hashash	**62**	69.68	24.00	0.38	0.20	0.38	0.06	0.44	0.09	0.06	0.01	3.67
	Early Paleozoic	***Cambro-Ordovician***	***Adedia***	**40**	51.86	18.26	7.61	2.08	0.49	2.37	4.49	0.23	0.21	3.17	7.93
				35	59.55	22.02	1.17	1.82	0.57	0.50	5.54	0.13	0.04	2.35	5.19
			Abu Hamata	**30**	56.78	20.55	5.29	1.54	1.48	0.13	5.33	0.60	1.50	0.05	4.03
				25	54.70	23.57	6.19	1.99	0.56	0.89	5.75	0.24	0.15	0.53	4.08
				23	48.69	17.82	7.34	2.53	0.59	3.81	5.31	0.29	0.06	4.29	7.92

Table (3): Average chemical composition (major components in Wt. %) of Paleozoic mudrocks.

Age			*Fms.*	S.No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3^{-2}	Cl^-	L.O.I
Paleozoic	***Late Paleozoic***	***Early Carboniferou***	***Magharet El Maiah***	**Min.**	39.24	17.02	0.62	0.31	0.34	0.08	0.53	0.07	2.8	0.02	8.08
				Max.	67.40	17.13	0.70	0.50	10.00	0.65	1.12	0.18	17.42	0.24	12.44
				Average	**٥٦,٦٧**	**١٧,٠٨**	**٠,٦٥**	**0.35**	**٣,٩٢**	**٠,٣٤**	**٠,٨٣**	**٠,١١**	**٨,٢٠**	**٠,١١**	**١٠,٢٠**
			El Hashash	**Average**	**69.68**	**24.00**	**0.38**	**0.20**	**0.38**	**0.06**	**0.44**	**0.09**	**0.06**	**0.01**	**3.67**
	Early Paleozoic	***Cambro-Ordovician***	***Adedia***	**Min.**	51.86	18.26	1.17	1.82	0.49	0.50	4.49	0.13	0.04	2.35	5.19
				Max.	59.55	22.02	7.61	2.08	0.57	2.37	5.54	0.21	3.17	7.93	0.21
				Average	**55.71**	**20.14**	**4.39**	**1.95**	**0.53**	**1.44**	**5.02**	**0.18**	**0.13**	**2.76**	**6.56**
			Abu Hamata	**Min.**	48.69	17.82	5.29	1.54	0.56	0.13	5.31	0.24	0.06	0.05	4.03
				Max.	56.78	23.57	7.34	2.53	1.48	3.81	5.75	0.60	1.50	4.29	7.92
				Average	**53.39**	**20.65**	**6.27**	**2.02**	**٠,٨٨**	**١,٦١**	**5.46**	**0.38**	**0.57**	**١,٦٢**	**5.34**

indicates that the grain size of the Late Paleozoic mudrocks are coarser than that of Early Paleozoic mudrocks; suggesting that; the Late Paleozoic mudstone rock units are of the sandy type.

It seems that as Paleozoic mudrocks get younger they change from the clay to sandy through silty type and from immature to submature.

Iron oxides:

The distribution of Fe_2O_3 within Paleozoic mudrocks shows no particular trend for distribution with decrease in age from Early towards Late Paleozoic rock units. This can be attributed to the fact that Fe_2O_3 can occur in a

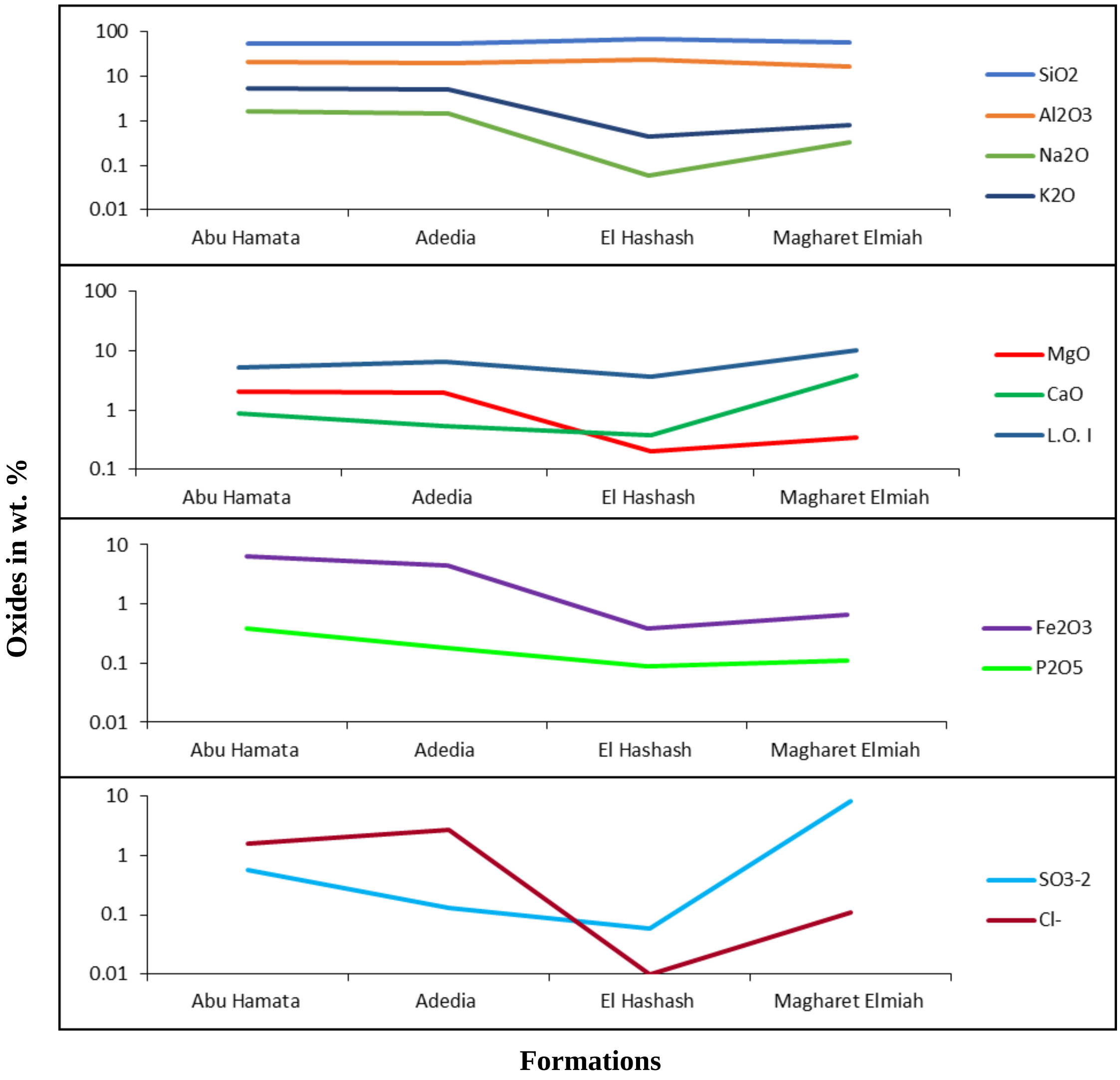

Fig. (4): Averages distribution curves of the studied mudrocks major chemical oxides.

Table (4) : SiO_2 / Al_2O_3 ratio of the studied Paleozoic Mudrocks.

Age	Paleozoic			
	Early Paleozoic		Late Paleozoic	
Formations	Abu Hamata	Adedia	El Hashash	Magharet El Maiah
SiO_2	53.39	55.71	69.68	56.67
Al_2O_3	20.65	20.14	24.00	17.08
Ratio	2.58	2.77	2.90	3.32

free state as pigment or in the silicate state.

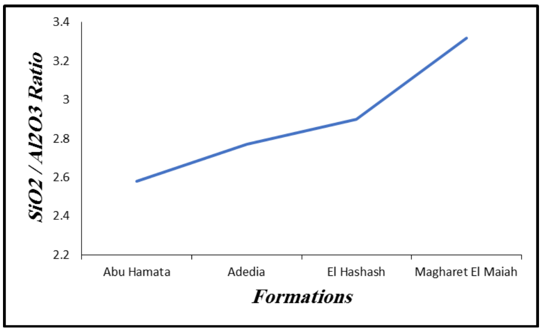

Fig. (٧): SiO_2 / Al_2O_3 ratio of the studied Paleozoic Mudrocks.

Calcium and Magnesium Oxides:

Calcium and magnesium are considered to be two ions with similar characteristics. The study shows that there is no particular trend for distribution of calcium and magnesium oxides with decrease in age from Early towards Late Paleozoic rock units. The relatively high values of CaO detected in Magharet El Maiah Formation can be attributed to the presence of calcareous material. Pettijohn (1975) stated that, lime in the shales occurs chiefly as carbonate, and can also present in the form of gypsum in some shales.

Vinogradov and Ronov (1956) suggest that the surface of the crystalline basement available for weathering has decreased through time. The computed Ca / Mg ratio for Early and Late Paleozoic studied mudrocks (Table 5 and fig.٨) show values contra with **Vinogradov and Ronov (1956)** and this may be attributed to the topography of the studied rock units.

Sodium and Potassium Oxides:

The distribution of both potassium and sodium oxide through Early and Late Paleozoic mudrocks show a consistency. Whereas both show inconsistency with the distribution of aluminium oxide and this can be attributed to their presence as chlorides rather than in the silicate form.

The computed K/Na ratio (Table 6 and Fig. ٩) favors according to that crystalline igneous and metamorphic rocks contain as much potassium as sodium, and the K/Na ratio equals 2.8 for clays.

Table (5): Ca / Mg ratio of studied Paleozoic Mudrocks

Age	Paleozoic			
	Early Paleozoic		Late Paleozoic	
Formations	Abu Hamata	Adedia	El Hashash	Magharet El Maiah
Ca	0.63	0.38	0.27	2.80
Mg	1.22	1.18	0.12	0.21
Ca/Mg Ratio	0.52	0.32	2.25	13.33

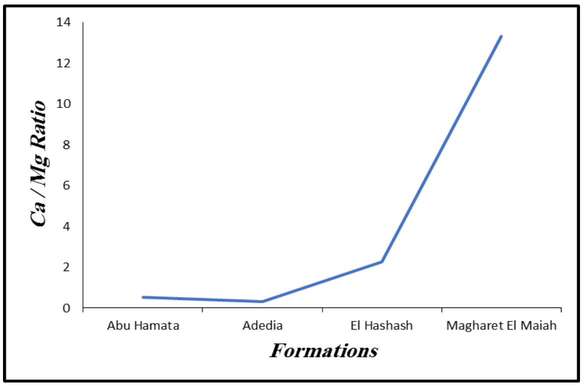

Fig. (٨): Ca / Mg ratio of the studied Paleozoic Mudrocks.

K/Na ratio are equally important whereas high ratio's favour the formation of illite in agreement with **Vinogradov and Ronov (1956)**. Also, the high values detected in the studied Paleozoic mudrocks can be attributed to formation in continental than marine environments in addition to the predominance of clays over silts **(Garrels and Christ 1965, and Weaver, 1967)**.

Table (6): K / Na ratio of studied Paleozoic Mudrocks

Age	**Paleozoic**			
	Early Paleozoic		**Late Paleozoic**	
Formations	**Abu Hamata**	**Adedia**	**El Hashash**	**Magharet El Maiah**
K	4.53	4.17	0.37	0.69
Na	1.19	1.07	0.04	0.25
K / Na	**3.81**	**3.90**	**9.25**	**2.76**

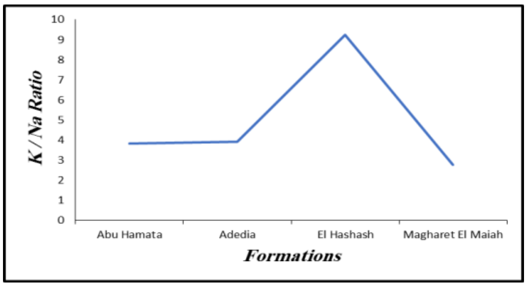

Fig. (9) K/Na ratio of the studied Paleozoic Mudrocks.

Phosphorous oxide:

According to **Turekian and Wedepohl (1961)**, the average concentration of phosphorous oxide in shales is 0.07 %. The higher averages detected in Paleozoic mudrocks than that given by **Turekian and Wedepohl (op.cit)** indicate that oxidizing conditions prevailed during the diagenesis of the deposited sediments causing fixation of the phosphate ions.

Total Sulphate:

Generally, the average content of the SO3 is higher than that given by **Clarke (1924)** (SO_3 = 0.64 %). This relatively high contents indicate evaporation effect enhancing formation of Paleozoic mudrocks in semi-restricted environment.

Soluble chlorides:

The soluble chlorides content in Paleozoic mudrocks are relatively higher than that given by **Clarke (1924)** (180 ppm) indicate formation in semi-restricted environment with the prevalence of warm climate.

ABUNDANCE AND DISTRIBUTION OF TRACE ELEMENTS

Titanium:

Titanium is the most abundant trace element recorded in Paleozoic mudrocks. The distribution of titanium content doesn’t shows any particular trend as the sediments get younger (Tables7 and8) and Fig. (١٠).

The higher titanium content of Early Paleozoic;Abu Hamata Fm. and Late Paleozoic; Magharet El Maiah Fm. mud rocks than those given by **Turekian and Wedepohl (1961)** (4,600 ppm) can be attributed to the occurrence of titanium in probably authigenic anatase and rutile and is also structurally bound in iron minerals **(Goldberg and Arrhenius, 1958)**. The lower titanium content of Early Paleozoic; Adedia Fm. and Late Paleozoic; El Hashash Fm. mudrocks can be attributed to the occurrence authigenic anatase and rutile in relatively small amount.

Isayeva (1971) suggested that under reducing environments titanium dissolved and can be adsorbed by clays. It seems that the prevailed conditions favour formation of titanium as hydrolysates at low alkaline pH values under reducing environment.

Chromium:

The detected chromium in the studied mudrocks reveals no particular trend for distribution as the sediments get younger.

The higher chromium content detected in Early and Late Paleozoic mudrocks than those given by **Turekian and Wedepohl (1961)** (100 ppm) can be attributed to that the prevailed conditions favour formation of chromium as hydrolysates at low alkaline pH values under reducing environment. The lower Cr content than that given by **Nicholis (1967)** (Cr > 150 ppm) indicates that: the environment of formation of Early and Late Paleozoic mudrocks was continental environment.

Yttrium:

The detected yttrium in the studied mudrocks reveals no particular trend for distribution as the sediments get younger. The detected average yttrium content in both Early and Late Paleozoic formation mudrocks show that the lower content relative to that given by **Turekian and Wedepohl (1961)** (90 ppm) can be attributed to the low alkaline pH values prevailed causing the depletion of Y element in the studied formations.

Cobalt:

The detected cobalt in the studied mudrocks reveals no particular trend for distribution as the sediments get younger.The higher Co content detected in the studied Early and Late Paleozoic mudrocks than this given by **Turekian and Wedepohl (1961)** (74ppm) can be attributed to the presence of magnesium although they have similarities in ionic radii and charge ($Co^{2+} = 0.83A^0$ and Mg^{2+} $0.080A^0$) (Fig. ١١). It is clear that theEarly and Late Paleozoic mudrocks were formed under alkaline conditions causing enrichment by cobalt trace elements

Niobium:

Niobium can substitute for Zr in zircon, since this mineral is widely distributed in igneous rocks. According to **Brookins (1988)** niobium displays very low mobility under alkaline environment whereas, acidic environment increases the solubility of Nb. The study reveals that the niobium content detected in the studied Early and Late Paleozoic mudrocks are higher than this given by **Turekian and Wedepohl (1961)** (14 ppm) and this can be attributed to not only the environment of formation but although the type of igneous rock detected.

Table (7): Chemical composition (major components in ppm) of the Paleozoic mudrocks.

Age			Fms.	S.No.	Ti	Cr	Y	Co	Nb	Mn	V	Ni	Cu	Zn	Pb	Sr	Ba	Rb	Zr	Ce	Th	Ga
Paleozoic	*Late Paleozoic*	*Early Carboniferous*	*Magharet El Maiah*	**75**	9500	100	68	42	47	63	182	58	75	128	118	240	n.d.	69	402	223	28	52
				73	9100	123	100	35	62	62	106	28	63	29	52	364	n.d.	41	586	263	45	26
				66	7200	113	40	50	35	32	273	36	41	13	479	1149	n.d.	21	621	191	19	25
			El Hashash	**62**	100	172	29	83	26	61	538	56	59	33	356	13	172	13	502	110	33	14
	Early Paleozoic	*Cambro-Ordovician*	*Adedia.*	**40**	5400	104	32	99	25	321	101	78	42	159	64	739	588	227	429	247	13	22
				35	200	117	23	68	20	116	58	62	47	53	39	436	1180	208	476	520	12	24
			Abu Hamata.	**30**	12300	129	83	81	39	487	169	71	42	107	81	299	880	234	2237	300	62	30
				25	5800	120	32	90	19	368	152	76	41	130	81	269	820	287	414	286	12	40
				23	5600	100	40	76	17	275	283	94	44	165	79	299	843	227	497	223	36	18

Table (8): Average chemical composition (Trace elements in ppm) of the Paleozoic mudrocks.

Age			Fms.	S.No.	Ti	Cr	Y	Co	Nb	Mn	V	Ni	Cu	Zn	Pb	Sr	Ba	Rb	Zr	Ce	Th	Ga
Paleozoic	*Late Paleozoic*	*Early Carboniferous*	*Magharet El Maiah*	**Min.**	7200	100	40	35	35	32	106	28	41	13	52	364	n.d.	21	402	191	19	25
				Max.	9500	123	100	50	62	63	273	58	75	128	479	1149	n.d.	69	586	263	45	52
				Average	8600	112	69	42	48	52	187	41	60	57	216	584	n.d.	44	536	226	31	34
			El Hashash	**Average**	100	172	29	83	26	61	538	56	59	33	356	13	172	13	502	110	33	14
	Early Paleozoic	*Cambro-Ordovician*	*Adedia*	**Min.**	200	104	23	68	20	116	58	62	42	53	39	436	588	208	429	247	12	22
				Max.	5400	117	32	99	25	321	101	78	47	159	64	739	1180	227	476	520	13	24
				Average	2800	111	28	84	23	219	80	70	45	106	52	588	884	218	453	384	13	23
			Abu Hamata	**Min.**	5600	100	32	76	17	275	152	71	41	107	81	269	820	227	414	223	12	18
				Max.	12300	129	83	90	39	487	283	94	44	165	79	299	880	287	2237	300	62	40
				Average	7900	116	52	82	25	377	201	80	42	134	80	289	848	249	1049	270	37	29
A.C					4600	100	90	74	14	850	120	80	50	90	20	400	600	110	150	345	7	20

N.B: A.C: Trace elements average concentration after **Turkian and Wedipohl (1961)**.

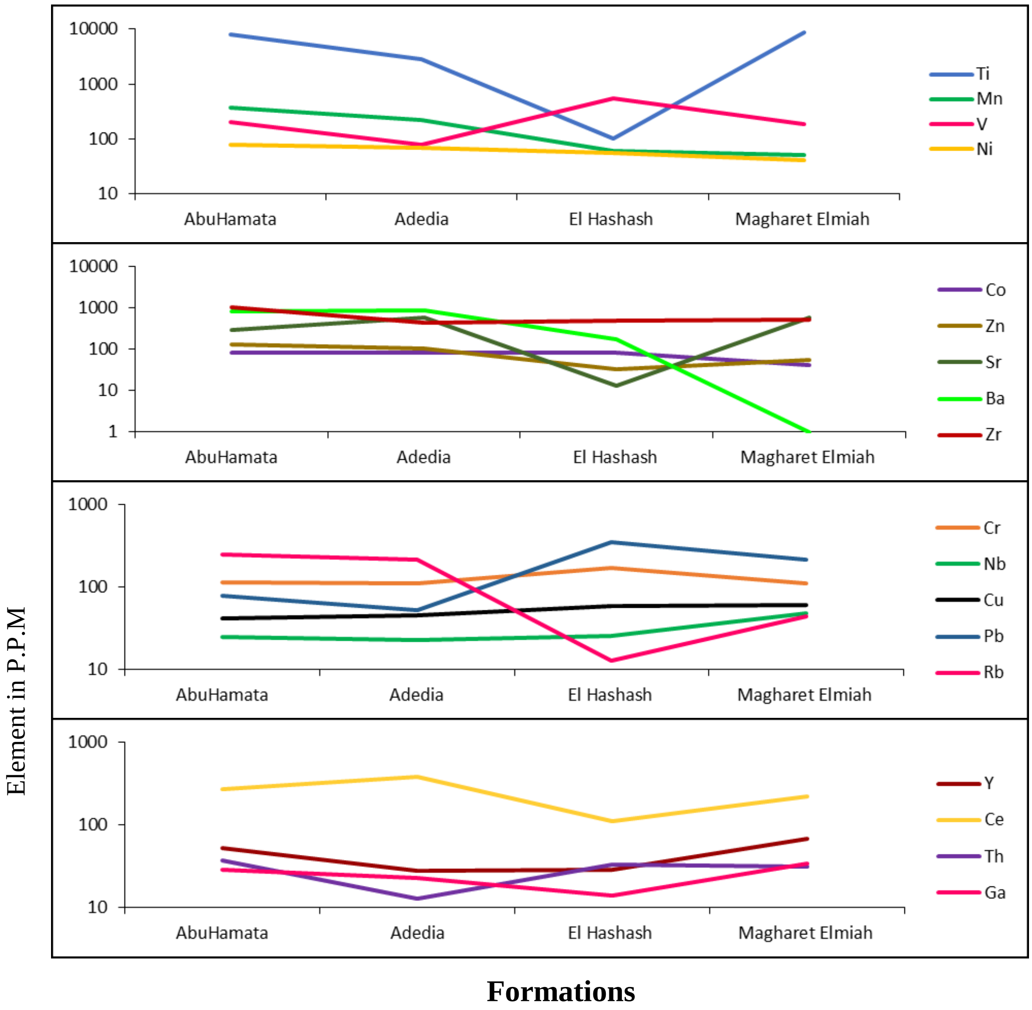

Fig. (10): Distribution curves of chemical components (Trace elements ppm of Paleozoic Mudrocks.

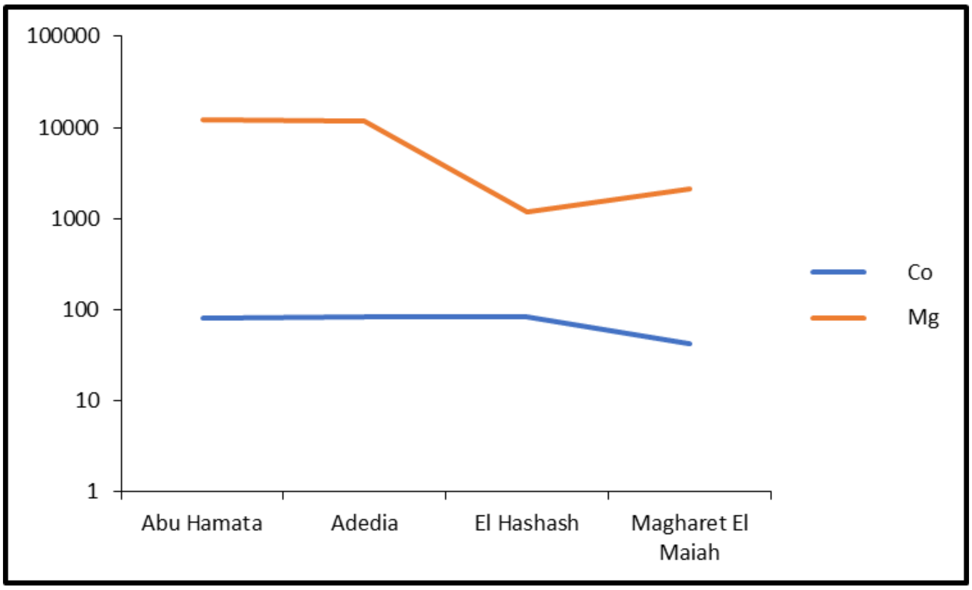

Fig. (11): Correlation between cobalt and magnesium in the studied Paleozoic Mudrocks.

Manganese

The lower manganese content than that given by **Turekian and Wedepohl (1961)** (850 ppm) can be attributed to that manganese is less mobile under oxidizing conditions and it will be mobilized in reducing environment **(Manheim, 1961; Wedepohl, 1964 and Hartmann, 1964)**.

It seems that Paleozoic mudrocks were formed under reducing environments causing leaching of manganese and lowering its detected values.

Vanadium:

The study of Early and Late Paleozoic mudrocks reveals higher average vanadium content relative to the average given by **Turekian and Wedepohl (1961)** (V=120 ppm). Supporting the idea that the prevailing environment was slightly reduced. Since vanadium's solution and migration take place only at relatively high redox potential.

Nickel:

The lower nickel content than the average given by **Turekian and Wedepohl (1961)**(80 ppm) can be attributed to formation under slightly reducing and alkaline environment.

Copper:

The higher copper content than that given by **Turekian and Wedepohl (1961)**(50 ppm) can be attributed to the relatively higher amount of organic matter recorded in the studied mudrocks.

Zinc:

The detected averages of zinc content show higher values than that givenby **Turekian and Wedepohl (1961)**(90 ppm) in Early Paleozoic and vice versa for Late Paleozoic.

According to **Krauskopf (1979)** Zn^{2+} (ionic radii = 0.83 A°) follows Mg^{2+} (ionic radii = 0.80 A°) in its way of distribution. Fig (١٢) shows that zinc in the studied mudrocks follows that of magnesium which may indicate its adsorption on the clay minerals.

Lead:

The detected lead average content shows higher values than that given by **Turekian and Wedepohl (1961)**(20 ppm) and this can be attributed to the environment of deposition which was alkaline, slightly reducing environment where the Eh was very low.

Strontium:

The lower strontium content (Early Paleozoic; Abu Hamata Fm. and Late Paleozoic; El Hashash Fm.) and vice versa for (Early Paleozoic; Adedia Fm. and Late Paleozoic; Magharet El Maiah Fm.) than the

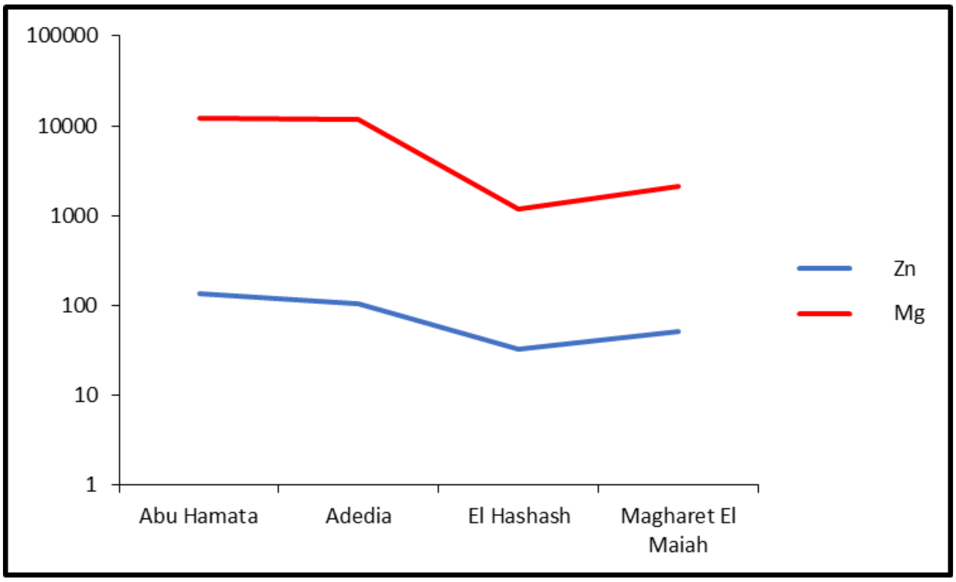

Fig. (12): Correlation between Zinc and magnesium in the studied Paleozoic Mudrocks.

average given by **Turekian and Wedepohl (1961)** (400 ppm) can be attributed to that Sr (1.21A°) can substitute both Ca^{2+} (1.08A°) and K^{+} (l.46 A°) so its trend is a compromise between the trends of the two major elements. Strontium appears to be a poor salinity indicator in mudrocks and is especially incorporated in the carbonate phase and suffers all the diagenetic changes of the carbonate.

Barium:

It is generally believed that the Ba /Srratio (Table 9 and Fig. ١٣) increases with salinity. The higher barium average content detected for the Paleozoic mudrocks (except Late Paleozoic Fms.) than that given by **Turekian and Wedepohl (1961)**(600 ppm) indicate formation under alkaline conditions causing leaching of barium from Late Paleozoic Formations, and vice versa for Early Paleozoic Formations.

Rubidium:

The higher rubidium average content detected for the Paleozoic mudrocks (except Late Paleozoic Fms.) than that given by **Turekian and Wedepohl (1961)**(110 ppm) can be attributed to the relative concentration of both sodium and potassium oxides and to the type of clay mineral present, whereas rubidium follows both two major elements in their way of distribution.

Zirconium:

According to **Turekian and Wedepohl (1961)** the average concentration of Zirconium content in mudrocks is 150 ppm showing that both Early and Late studied sandstones are characterized by abnormal Zirconium content due to adsorption onto clays.

Cerium:

The study of Early and Late Paleozoic mudrocks reveal lower average cerium content relative to the average given by **Turekian and Wedepohl (1961)** (345 ppm), supporting the idea that the prevailing environment was reducing. Since cerium’s solution and migration take place only at relatively high redox potential.

Thorium:

The study of Early and Late Paleozoic

Table (9): Br / Sr ratio of studied Paleozoic Mudrocks.

Age	Paleozoic			
	Early Paleozoic		Late Paleozoic	
Formations	Abu Hamata	Adedia	El Hashash	Magharet El Maiah
Ba	848	884	172	0
Sr	289	588	13	584
Ba/Sr Ratio	2.93	1.50	13.23	0

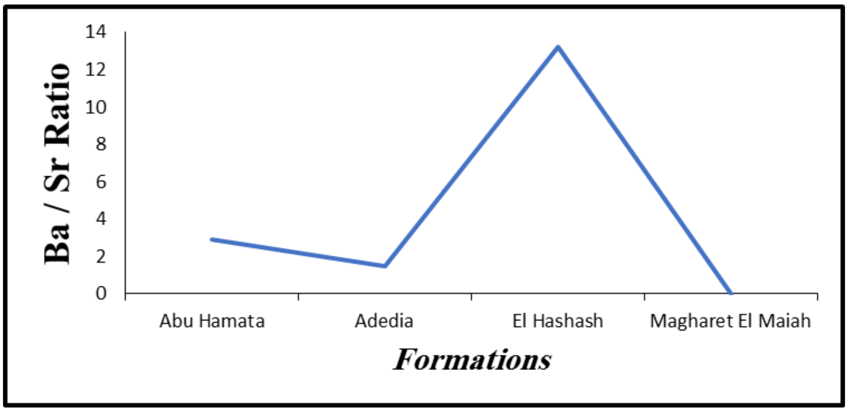

Fig. (13): Br / Sr ratio of the studied Paleozoic Mudrocks.

Formation mudrocks reveal higher average thorium content relative to the average given by **Turekian and Wedepohl (1961)** (7 ppm), supporting the idea that the prevailing environment was reducing. Since thorium's solution andmigration take place only at relatively high redox potential.

Gallium:

The great similarity between Ga^{3+} (r = 0.80A°) and Al^{3+} (r = 0.61A°) and the consequent extensive substitution of $Ga^{3+}$for Al^{3+}in aluminosilicate minerals reveals that gallium flow aluminum in its way of distribution. Accordingly, Paleozoic mudrocks seem to be formed under relatively warm and slightly alkaline conditions in agreement with **Corbel (1959)**.

CONCLUSIONS

Mineralogical study reveals the presence of Kaolinite and Illite clay minerals. The detection of kaolinite and illite clay minerals favour that the environment of formation was alkaline, and the origin of the clay minerals present is chlorite more probably than illite origin where illite can be derived from weathering of chlorite. **Diagenetic study** reveals that; kaolinite can be neo-formed, transformed at high rainfall and a temperate climate which can transform muscovite and biotite into kaolinite together with some Illite. **Chemical composition study**; abundance, behavior and distribution of major and trace components reveals that the studied mudrocks seem to be formed under reducing alkaline environment.

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ملخص البحث

يتناول هذا البحث دراسة التركيب المعدني وعمليات ما بعد الترسيب وتاثيرها علي التركيب الكيميائي للصخور الطينية التابعة لحقبة الباليوزوي المبكر:عصر الكمبرو-اوردوفيشي(متكون ابو حماطه وعديدية) وحقبة الباليوزوي المتاخر:عصر الكربوني المبكر(متكون الحشاش ومغارة المياه) المتواجدة بمنطقة جنوب غرب سيناء .

اوضحت الدراسات المعدنية ان هذه الصخور الطينية تتكون من معادن الكاولينيت والايليت ويدل وجود هذه المعادن علي ان بيئة التكوين كانت بيئة قلوية وان اصل هذه المعادن هو معدن الكلوريت حيث ان معدن الايليت قد تكون نتيجة عمليات التجوية التي اثرت علي معدن الكلوريت.

من خلال دراسة عمليات ما بعد الترسيب (Diagenesis) تبين ان معدن الكاولينيت قد يتشكل من جديد ويتحول عند هطول الامطار والمناخ المعتدل حيث يتحول معدن المسكوفيت والبيوتيت الي معدن الكاولينيت وبعض الايليت.

اظهرت دراسة التركيب الكيميائي وكذا وفرة وسلوك وتوزيع العناصر الغالبة والشحيحة للصخور الطينية ان هذه الصخور قد تكونت في بيئة قلوية ومختزلة.