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Mineralogical and Geochemical studies of Eocene Carbonate rocks at Wadi Tayiba and Wadi Feiran areas, Southwestern Sinai, Egypt

Ibrahim, A. M[1], A. R. Abou El Ezz[2], Ahmed S. Mousa[2], Tarek Y. M. A. El Hariri[2], and Abd El Ghany. A. A[2]

[1] Al Azhar University, Faculty of science, Geology Department
[2] Egyptian Petroleum Research Institute, Exploration Department.

Abstract: The present work deals with the Mineralogical and geochemical studies on Eocene rocks exposed at the south western Sinai along the western side of the Gulf of Suez. The study area lies between latitudes 28º 40' 00" and 29º 10' 00" N. and longitudes 33º 00' 00" and 33º 30' 00" E. The study areas are represented by two examined sections, namely Wadi Tayiba and Wadi Feiran sections. The study areas, are represented by five formations namely; Thebes (Lower - Middle Eocene), Darat and Samalut (Middle Eocene), Khaboba (Middle – Late Eocene) and Tanka (Upper Eocene) Formations. Mineralogical compositions of the studied carbonates reveal that the Eocene marine basin of deposition was relatively alkaline, close to the landmass that supplied the basin of deposition by quartz and clays. Limestone chemical characteristics reveal that; Eocene limestones were mostly deposited under relatively warm alkaline conditions. However the pH degree of alkalinity during the Darat Formation (Wadi Tayiba area) and Thebes and Samalut Formations (Wadi Feiran area) (less in SiO_2 content) was higher than that prevailed during the Thebes, Khaboba and Tanka Formation (Wadi Tayiba area) times.

Keywords: *Eocene, Wadi Tayiba, Wadi Feiran, Thebes, Darat, Samalut, Khaboba and Tanka Formation.*

1. Introduction

The present paper deals with petrography; paleo-depositional environmental and petrophysical characters of Eocene carbonate rocks exposed at the Southwestern Sinai along the Western side of the Gulf of Suez. The study area lies between latitudes 28º 40' 00" and 29º 10' 00" N. and longitudes 33º 00' 00" and 33º 30' 00" E **(Fig. 1).** The study area is represented by two examined areas, namely Wadi Tayiba and Wadi Feiran. The Eocene succession is subdivided into the following formations (from older to younger): Thebes, (Samalut equivalent Darat), Khaboba and Tanka.

The Eocene succession has been studied by several authors such as ***Ansary, (1955); Said, (1960); Viotti & Demerdash, (1968); Youssef & Abdel Malik, (1969a); Bassioni et al. (1980); Issawi et al., (1981); El-Heiny & Morsi, (1986); Faris et al., (1986); Abuel Nasr & Thunell, (1987); Barakat et al., (1988); Abul-Nasr, (1990); El–Heiny et al. (1990); Said, (1990); Morsi, (1992); Abul-Nasr, (1993a); Abul-Nasr, (1993b); Magdy, (1997); Chillingar & Bissell, (1963).***

2. Methodology:

The present work aims to flash up at mineralogical and chemical studies to evaluate the geochemical of Eocene carbonate rocks at Wadi Tayiba and Wadi Feiran areas. The samples were prepared and measured in Egyptian Petroleum Research Institute (Central lab. sector) and Egyptian Minerals Resource Authority (Central lab. Sector) as follows:

1- Twenty six samples were selected and analyzed by the X-Ray diffraction (XRD) at Egyptian Petroleum Research Institute (Central lab. sector) by using PanAlytica (type X- Pert pro) with Ni-filter Cu- radiation, N=1.54418A at 40 KV 40 mA, and a normal scanning speed of 20 /min.

2- Nineteen samples were selected for geochemical study to determine the major and trace elements. The detailed chemical analysis was carried out at the Egyptian Minerals Resource Authority (Central lab. Sector). The analysis was made through automated powder diffractometer system of Philips PW 1710.

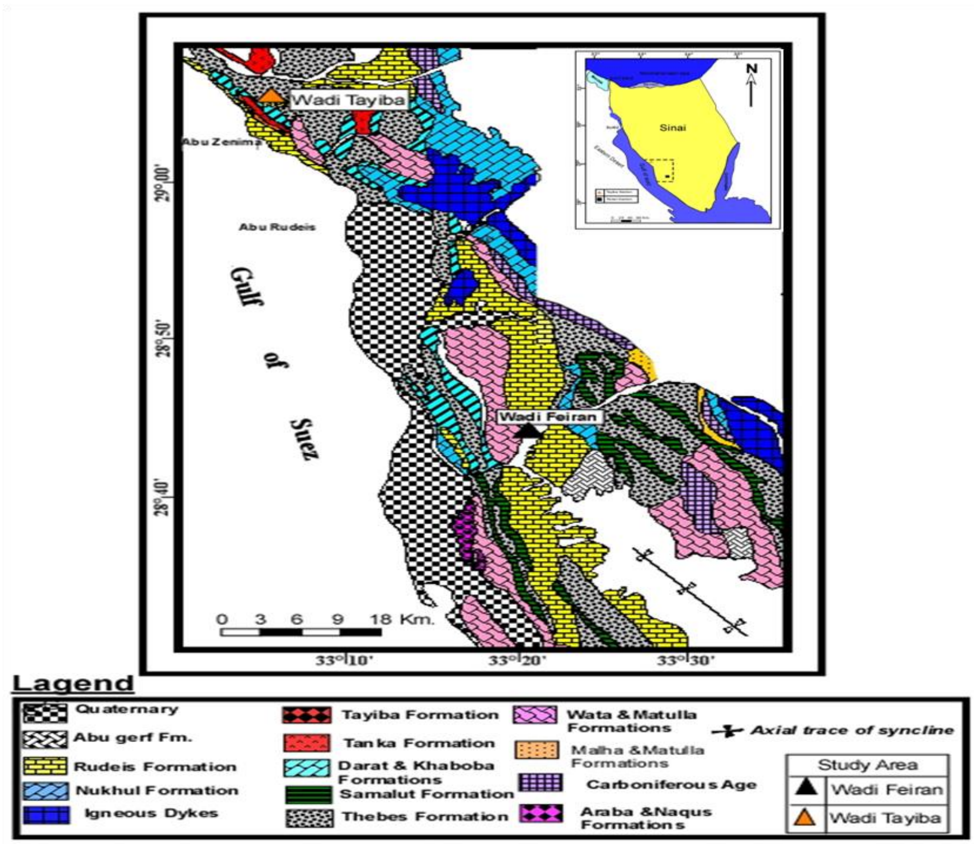

Fig. (1): Location and geological maps of the study area, After Conoco, 1992.

3. Lithostratigraphy

The Eocene successions exposed in the Southwestern part of Sinai are represented mainly by carbonate predominance. The Eocene successions recorded in the study areas range in thickness from 152 meters (at Wadi Tayiba) to 408 meters (at Wadi Feiran) **(Figs 2&3).**

Eocene rocks, of the study areas, are represented by five formations namely; Thebes (Lower to Middle Eocene), Darat and Samalut (Middle Eocene), Khaboba (Middle to Late Eocene) and Tanka (Upper Eocene) Formations.

The Thebes formation is well represented in the study areas. It attains an average thickness of 48 meters in Tayiba area and average thickness of 268 meters in Feiran area, Thebes formation is composed mainly of yellow to pale brown in color, thin bedded, moderately hard, and argillaceous limestones.

The Darat formation is well distributed in the studied areas. It is recorded in the Tayiba area with thickness of about 60 meters and overlies conformably the Thebes formation. The Darat Formation composed mainly from limestones of yellowish brown in color, argillaceous, moderately hard, alternated with shale and fossiliferous.

The Samalut formation is well represented in the study areas. It attains an average thickness of 140 meters in Feiran area. Samalut formation is equivalent to the Darat Formation in the Tayiba section.

The Khaboba formation is recorded in the Tayiba area with thickness of about 21 meters and overlies conformably the Darat formation. The Khaboba formation composed mainly from fossiliferous limestones.

The Tanka formation in the Tayiba area is recorded by thickness of 22 meters. This formation is overlies conformably the Khaboba formation. The Tanka formation composed mainly from yellowish brown limestones, argillaceous, moderately hard, alternated and fossiliferous.

Age	Rock unit	Bed No.	S.No.	Thick in Meter	Lithic log.	Lithic Description
Upper Eocene	Tanka	10	25,26 23,24	8		**Massive, grayish yellow, argillaceous, fine grained and fossiliferous (*G. index index*) limestone.**
Middle Eocene	Tanka	8	22 21	14		**Varicolored, calcareous and well banded shales.**
	Khaboba	7	20 19	11		**Massive, grayish yellow, argillaceous, fine grained and fossiliferous (*Tr. rohi*) limestone.**
		6	18 17	10		**Varicolored, calcareous and well banded shales.**
	Darat	5	15,16	6		**Varicolored, calcareous and well banded shales.**
		4	14 13 12 11	39		**Massive, grayish yellow, argillaceous , fine grained and fossiliferous(*M. lehneri* And *Globigerina thekasubconglobata*) limestone.**
		3	9, 10	7		**Varicolored, calcareous and well banded shales.**
Lower Eocene		2	8	8		**Massive, grayish yellow, argillaceous , fine grained and fossiliferous(*Globigerina theka subconglobata*) limestone**
	Thebes	1	7 6 5 4 3 2 1	48		**Massive, grayish yellow, argillaceous , fine grained and fossiliferous(*H. nttalli*) limestone**

lagend: limestone, Shale

Fig. (2): Idealized columnar Lithic Log of the Eocene Formations recorded at Wadi Tayiba area.

Age	Rock unit	Bed No.	S.No.	Thick in meter	Lithic log	Lithic Description
Middle Eocene	Samalut	9	36 35	130		Massive, grayish yellow, argillaceous, coarse grained and fossiliferous, Barren of planktonic foraminifera Tests. Rich in (*Nummulites gizzahensis*) limestone.
		٨	34 32,33 30,31			
		٧	28,29 26,27 24,25			
		٦	22,23	10		Varicolored, calcareous and well banded shales.
Lower Eocene	Thebes	٥	21 20 19 18 17 16 15 14 13	125		Massive, grayish yellow, argillaceous, fine to coarse grained and fossiliferous (*H. nttalli*) limestone.
		4	12	15		Varicolored, calcareous and well banded shales.
		3	11 10 9 8 7 6 5 4	105		Massive, grayish yellow, argillaceous, fine to coarse grained and fossiliferous (*Acarinina pentacemarta*) limestone.
		2	3	8		Varicolored, calcareous and well banded shales.
		1	2 1	15		Massive, grayish yellow, argillaceous, fine grained and fossiliferous limestone.

Fig. (3): Idealized columnar Lithic Log of the Eocene Formations recorded at Wadi Feiran area.

4. Carbonate Mineralogical Composition

The x-ray diffraction analysis received special attention owing to its active role in the field of mineralogy and petrography. ***Chillingar & Bissell, (1963)*** pointed out that "using x-ray diffraction analysis, it was possible to differentiate, not only between formations of the same age but also between carbonate rocks belongs to two different ages", **Tables (1&2) and (Figs.4&5).**

The purpose of this study is to determine the variations and differences in the mineralogical composition of the different Eocene Formations carbonate sediments, represented in the studied areas and its significance in the environmental interpretations.

Table (1): X- ray diffraction data for Eocene Carbonate bulk Samples of Wadi Tayiba area.

Age	Formation	Sample No	Mineral detection	2θ	I/T^0	dA^0	2θ	I/T^0	dA^0	2θ	I/T^0	dA^0
Upper Eocene	Tanka	T24	Calcite	23.11	9.70	3.84	29.45	100.00	3.03	48.56	13.00	1. 87
			Quartz	20.88	6.52	4.25	26.64	17.64	3.34	36.05	12.00	2.49
			Kaolinite	5.92	3.01	14.91	12.40	3.26	7.1 3	28.06	6.00	3.17
		T23	Calcite	23.09	6.80	3.85	29.45	100.00	3.03	48.55	12.00	1.87
			Quartz	26.67	3.84	3.34	39.46	12.20	2.28	57.46	4.00	1.60
		T21	Calcite	23.09	7.54	3.85	29.43	100.00	3.03	48.56	13.00	1.87
	Khaboba	T20	Calcite	23.10	7.77	3.84	29.42	100.00	3.03	48.54	15.00	1.87
			Kaolinite	12.36	4.65	7.15	24.88	4.94	3.57	47.54	18.00	1.91
		T17	Kaolinite	11.65	100.00	7.59	20.73	4.01	4.28	23.40	20.00	3.80
Middle Eocene			Calcite	29.41	16.81	3.03	39.43	1.95	2.28	48.56	2.00	1.87
	Darat	T16	Calcite	23.09	6.74	3.85	29.45	100.00	3.03	48.57	10.00	1.87
			Kaolinite	11.62	2.37	7.61	21.78	3.49	4.08	47.57	10.00	1.91
		T14	Calcite	23.08	7.60	3.85	29.44	100.00	3.03	48.57	13.00	1.87
		T13	Calcite	23.08	7.65	3.85	29.42	100.00	3.03	47.54	15.00	1.91
		T11	Calcite	23.04	8.47	3.86	29.38	100.00	3.03	31.41	3.00	2.84
			Kaolinite	9.80	8.46	9.01	21.81	7.99	4.07	35.96	11.00	2.49
		T10	Calcite	23.08	9.23	3.85	29.42	100.00	3.03	47.54	15.00	1.91
			Quartz	26.64	12.9	3.34	39.45	15.35	2.28	57.47	5.00	1.60
		T9	Calcite	23.16	7.55	3.85	29.44	100.00	3.03	31.65	15,00	1.91
			Quartz	20.87	4.26	4.25	26.65	19.85	3.34	39.46	16.00	2.28
Early Eocene	Thebes	T8	Calcite	23.16	5.61	3.83	29.51	100.00	3.02	36.09	12.00	2.48
		T7	Calcite	23.06	6.25	3.85	29.42	100.00	3.03	31.47	14.00	2.28
		T4	Calcite	23.08	7.62	3.85	29.41	100.00	3.03	47.51	17.00	1.91
			Quartz	20.85	4.06	4.26	26.63	27.47	3.34	39.46	17.00	2.28
		T1	Calcite	23.11	7.40	3.84	29.45	100.00	3.03	47.58	14.00	1.91
			Quartz	26.65	3.34	3.26	36.03	11.13	2.49	39.44	13.00	2.28

Table (2): X- ray diffraction data for Eocene Carbonate bulk Samples of Wadi Feiran area.

Age	Formation.	Sample No	Mineral detection	2θ	I/I°	dA°	2θ	I/I°	dA°	2θ	I/I°	dA°
Middle Eocene	Samalut	F37	Calcite	23.07	7.17	3.85	29.41	100.00	3.03	47.52	11.93	1.91
		F33	Calcite	23.09	7.70	3.85	29.43	100.00	3.03	43.19	13.05	2.09
		F29	Calcite	23.04	9.23	3.85	29.42	100.00	3.03	39.4	14.45	2.28
			Dolomite	21.64	8.60	4.1	30.75	15.26	2.90	47.55	11.07	192
		F27	Calcite	23.11	12.26	3.84	29.46	100.00	3.03	47.57	13.94	1.91
			Dolomite	21.70	16.76	4.09	30.80	17.98	2.90	64.79	3.39	1.43
		F23	Kaolinite	12.25	19.24	7.21	19.76	26.65	4.49	25.39	100.00	3.51
			Calcite	29.42	20.47	3.03	31.66	100.00	2.28	43.21	26.50	2.09
Early Eocene	Thebes	F15	Calcite	23.0	6.37	3.85	29.41	100.00	3.03	47.51	12.83	1.91
		F12	Calcite	23.11	9.02	3.84	29.46	100.00	3.03	36.05	10.71	2.49
			Quartz	26.66	9.68	3.34	31.73	23.79	2.81	57.51	5.22	1.60
			Kaolinite	12.37	6.98	7.15	24.96	6.68	3.57	45.50	4.47	1.99
		F5	Calcite	23.10	7.69	3.85	29.43	100.00	3.03	48.53	15.30	1.87
		F4	Calcite	23.07	7.52	3.85	29.41	100.00	3.03	48.53	16.67	1.87
			Quartz	26.65	8.59	3.34	39.44	13.56	2.28	57.39	5.90	1.60
		F3	Quartz	20.88	14.11	4.25	26.62	100.00	3.34	50.01	9.00	1.82
			Calcite	23.09	2.60	3.85	29.43	35.08	3.03	39.45	10.20	2.28
		F2	Calcite	23.08	7.32	3.85	29.41	100.00	3.03	48.51	16.07	1.87
		F1	Calcite	23.10	8.16	3.84	29.42	100.00	3.03	47.53	18.78	1.91

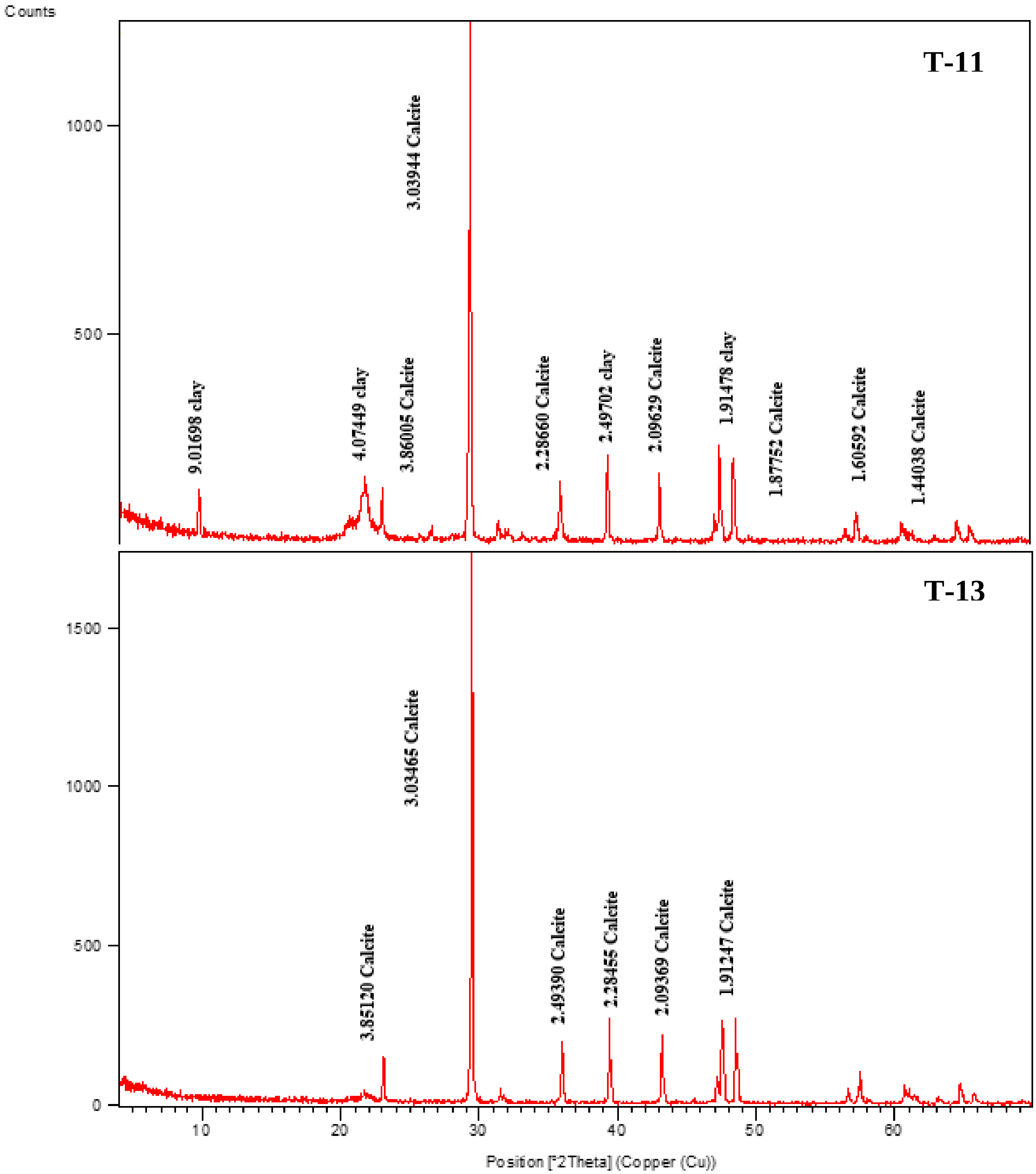

Fig. (4): X- ray diffraction pattern of Early Eocene Carbonate bulk samples No T11, T13 at Wadi Tayiba area.

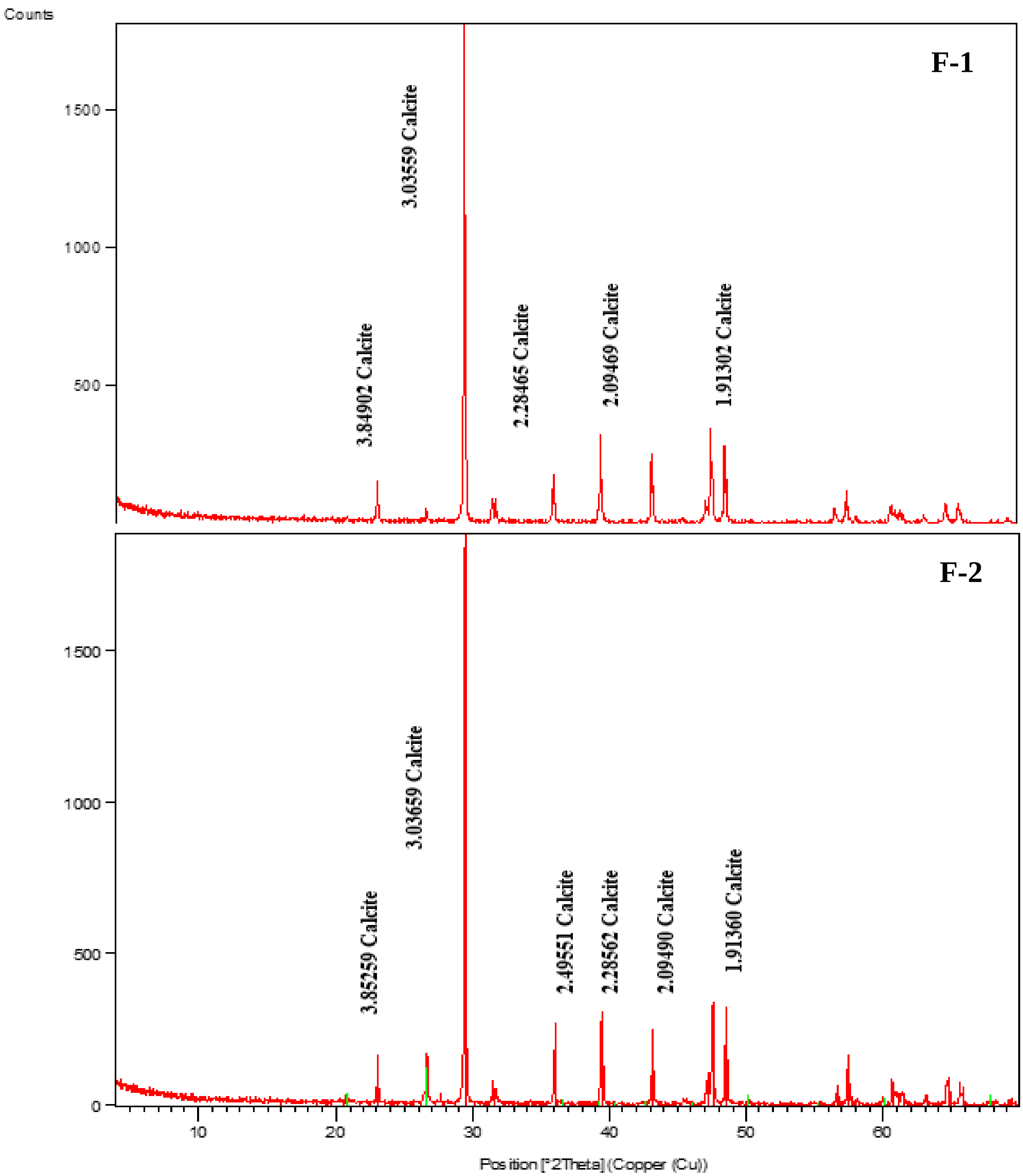

Fig. (5): X- ray diffraction pattern of Early Eocene Carbonate bulk samples F1, F2 at Wadi Feiran area.

The x-ray diffraction analysis data of the bulk limestone samples representing the studied Wadi Tayiba and Wadi Feiran Formations **(Tables 1&2)** and **(Fig.4)** at Wadi Tayiba and **(Fig.5)** at Wadi Feiran. Detected the presence of a number of carbonate minerals; mainly calcite and dolomite, and non-carbonate minerals of quartz and clays in variable amounts. The identification of these minerals was carried out using the ***ASTM, 1960.***

The X-ray diffraction analysis reveals that the carbonates of Eocene Formation recorded at Tayiba area are characterized by the presence of calcite as carbonate minerals in additions to the non- carbonate minerals of quartz and clay. Wadi Feiran area x-ray diffraction analysis reveals that the studied carbonates are characterized by the presence of both calcite and dolomite carbonate minerals in additions to the non-carbonate minerals of quartz and clay.

Generally, the Eocene marine basin of deposition was relatively alkaline close to the landmass that supplied the basin of deposition by quartz and clays.

5. Limestone Geochemical Characteristics

The Eocene carbonate rocks recorded at Wadi Tayiba (10 samples) and Wadi Feiran (9 samples) areas, distributed as follows: lower Eocene Thebes Formation recorded in both areas (8 samples). Middle Eocene, Darat and Khaboba Formations of Wadi Tayiba area (6 samples). Middle Eocene, Samalut Formation of Wadi Feiran area (4 samples). Upper Eocene, Tanka Formation of Wadi Tayiba area (1 sample). The analyzed samples were used in this study paper to understand and interpret the abundance and distribution of major and trace components, classify the studied Eocene limestones and correlate facies changes.

Krauskopf, (1979) stated that "weathering means the approach to equilibrium of a system involving rocks, air and water, and the agents of chemical weathering namely moisture, free oxygen, carbon dioxide, organic acids and nitrogen acids". He suggested the following weathering index to compare between the degree of decay for a series of rocks, and that as the weathered material Loses Ca, Mg, Na and K and appears to gain Al and Fe, this fraction will obviously decrease

$$\textit{Weathering index} = \frac{CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + Fe_2O_3 + CaO + MgO + Na_2O + K_2O}$$

The computed weathering index for the Eocene carbonate sediments are shown in **Table (3).** The weathering index values are high fraction (except for the Khaboba and Tanka Formations limestone) suggesting that the studied rocks are slightly affected by the agents of weathering. The low value of the Khaboba and Tanka Formations limestone is mostly due to the predominate clastic materials rich in SiO_2, Al_2O_3 and Fe_2O_3. Consequently the abundance and distribution characteristics of the major components and trace elements reflect that occurring due to effect and nature of medium of deposition of the study carbonates.

Table (3): Weathering index values of the studied Eocene carbonates.

Age	Early Eocene		Middle Eocene			Upper Eocene
Study area	W. Tayiba	W. Feiran	W. Tayiba		W. Feiran	W. Tayiba
Formation	Thebes Formation		Darat	Khaboba	Samalut	Tanka
Weathering index	0.84	0.91	0.86	0.69	0.87	0.71

6. Abundance and Distribution of Major Components

The range and the average contents of SiO_2, Al_2O_3, Na_2O, and K_2O of the different Formations of the studied areas are shown in **Tables (4-8)** and **(Figs. 6-8).** The oxides forming silicate minerals of the Eocene limestones are considerably low, except those of the Thebes, Khaboba and Tanka Formations (Tayiba area). However, regarding the values of $A1_2O_3$ relative to those of SiO_2. The Thebes, Khaboba and Tanka Formation limestones are characterized by abundant free quartz. The consistent distribution of Al_2O_3 and Na_2O_3 and occasionally K_2O suggests their presence in the form of alumino-silicate minerals.

Table (4): SiO_2/ Al_2O_3 ratio of the studied Eocene carbonates.

Age	Early Eocene		Middle Eocene			Upper Eocene
Study area	W. Tayiba	W. Feiran	W. Tayiba		W. Feiran	W. Tayiba
Formation	Thebes Formation		Darat	Khaboba	Samalut	Tanka
SiO_2/Al_2O_3 ratio	6.31	15.35	0.57	2.91	9.00	1.91

Silica

The distribution of the silica content is the studied Eocene limestones reveals that there is no particular trend for distribution. The presence of free quartz suggests shallow marine conditions. The higher silica content of the Thebes, Khaboba and Tanka Formations limestone than those given by ***Pettijohn, (1957).*** 0.7 to 7.91%. can be attributed to the presence of SiO2 in the form of quartz grains which were microscopically identified.

Corbel, (1959) Proved that there is an increase in SiO2 content towards the warmer climatic zone while ***Dekimpe, et al. (1961)*** noted that with increasing pH there is a decrease in the silica content. Accordingly the Eocene limestones were mostly deposited under relatively warm alkaline conditions. However the pH degree of alkalinity during the Darat Formation (Wadi Tayiba area) and Thebes and Samalut Formations (Wadi Feiran area) (less in SiO2 content) was higher than that prevailed during the Thebes, Khaboba and Tanka Formation (Wadi Tayiba area) times.

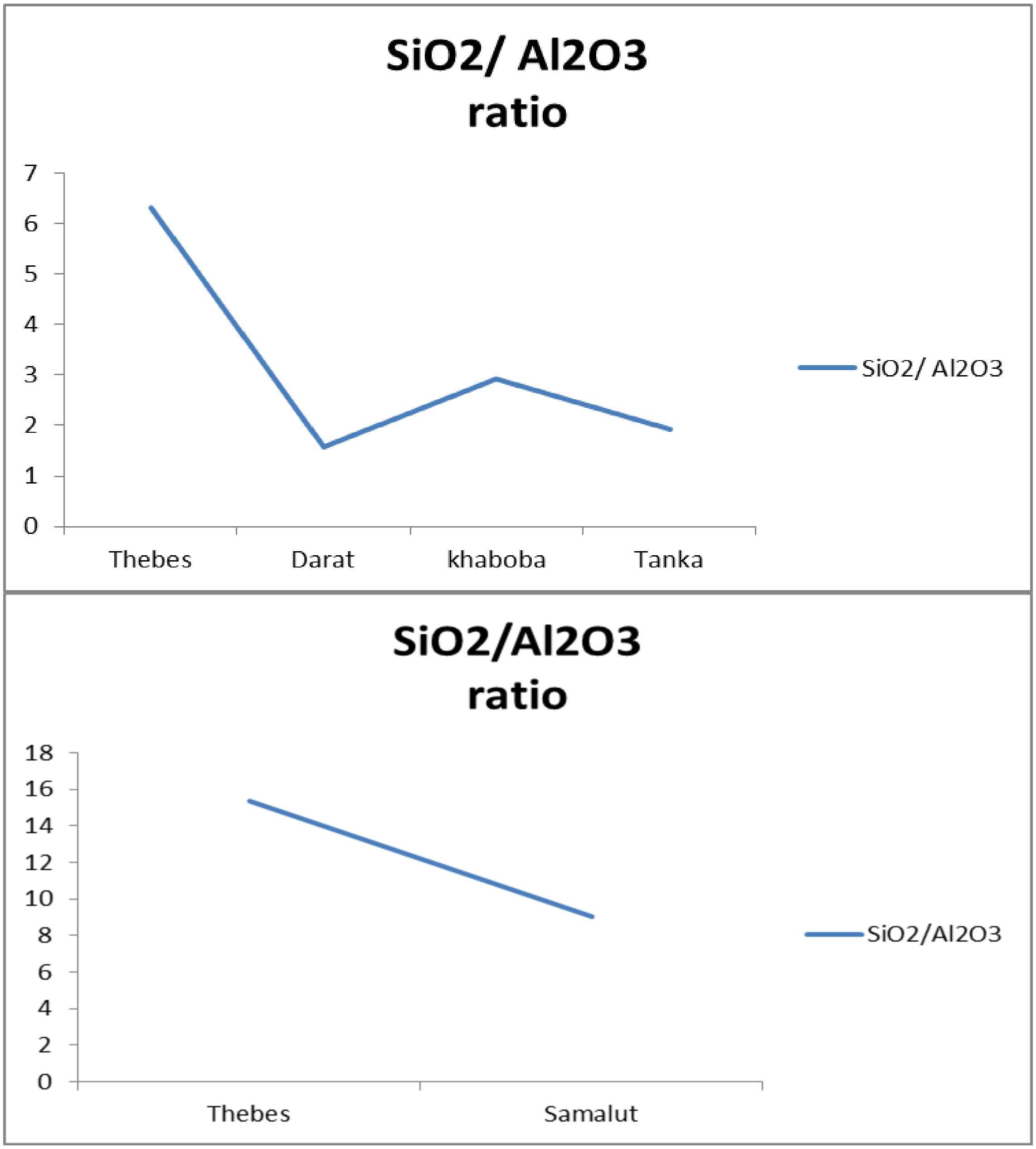

Fig. (6): SiO_2/ Al_2O_3 ratio of the studied Eocene carbonates (Wadi Tayiba and Wadi Feiran) areas.

Table (5):Chemical composition (major Oxides in wt %) of the Eocene Carbonate rocks (Wadi Tayiba area).

AGE	Formation	Sample No.	SiO_2%	Al_2O_3%	Fe_2O_3%	CaO%	MgO%	Na_2O%	K_2O%	L.O.I.%	TOTAL
Upper Eocene	Tanka	24	12.6	6.57	1.23	42.4	3.02	2.10	2.80	28.00	99.72
Middle Eocene	Khaboba	20	13.30	4.56	2.88	42.3	0.40	1.80	1.17	33.00	99.91
	Darat	14	1.20	2.40	0.33	55.1	0.12	0.08	0.07	40.00	99.59
		13	1.50	1.05	0.13	52.7	0.13	0.08	0.04	44.00	99.87
		11	3.30	4.80	0.18	50.6	0.30	0.23	0.13	40.00	99.86
		10	10.70	0.80	0.40	47.3	0.07	0.12	0.18	40.00	99.82
Early Eocene		8	1.30	2.4	0.54	55.4	0.03	0.11	0.09	40.00	99.92
	Thebes	7	1.50	0.00	0.44	53.5	0.01	0.23	0.10	44.00	99.99
		4	21.20	4.00	2.30	42.7	0.20	0.14	0.10	29.00	99.87
		1	3.26	0.11	0.40	50.6	1.90	0.20	0.19	43.00	99.90

Table (6): Average chemical composition (major Oxides in wt %) of the Eocene Carbonate rocks (Wadi Tayiba area).

Age	Early Eocene		Middle Eocene			Upper Eocene
Formation	Thebes		Darat		Khaboba	Tanka
Chemical oxides	Range	Average	Range	Average	---------	-----------
SiO2%	1.5 – 21.2	8.65	1.20 - 10.70	3.60	13.30	12.60
Al2O3%	0.00 – 4.00	1.37	0.80 - 2.40	2.29	4.56	6.57
Fe2O3%	0.40 - 2.30	1.04	0.13 - 0.54	0.35	2.88	1.23
CaO%	42.7 - 53.5	48.93	47.30 -55.40	52.22	42.30	42.4
MgO%	0.01 – 1.9	0.70	0.03 - 0.30	0.13	0.40	3.02
Na2O%	0.14 - 0.23	0.19	0.08 - 0.230	0.13	1.80	2.10
K2O%	0.1 - 0.19	0..13	0.04 - 0.18	0.102	1.17	2.80
L.O.I%	29.0- 44.0	38.66	40.00 – 44.00	40.80	33.0	28.00

Alumina

It seems that both Darat and Khaboba (Middle Eocene) and Tanka (Upper Eocene) Formations of Wadi Tayiba area limestones were deposited under relatively deeper conditions as evidenced by the low SiO_2% and Al_2O_3 % in Comparison with Lower Eocene, Thebes Formation of Wadi Tayiba and Wadi Feiran areas.

Middle Eocene of Wadi Feiran area, Samalut Formation, limestones which have many amounts of silts leading to the relative increase in the SiO_2 content. According to ***Krauskopf, (1956) and Wey, & Et Siffert, (1961),*** Al_2O_3 is more soluble in acidic medium than SiO_2 and in neutral medium (5-6 pH) Al_2O_3 is insoluble whereas SiO_2 retains its solubility. In alkaline medium the two solubility's meet and increase together F (PH over 9). The in constituent distribution of both $Al_2O_3$and SiO_2 favored their Formation in contemporaneous deposition suggesting that the pH of the medium was 7.8 to 8.0 **(Table 4), (Fig. 6).**

Sodium and Potassium oxides

Table (9) and (fig. 9) are obvious that K_2O predominate Na_2O in the Eocene Formations of the study areas limestones except for those of the Thebes (lower Eocene), Darat and Khaboba (Middle Eocene) of Wadi Tayiba area.

The outstanding characteristics of K_2O in Comparison with that of Na_2O has been noted for a long time in a way like that described by ***Noll, (1931); Urbain, (1933); Goldschmidt, (1937); Harvey, (1949) and Millot, (1949)*** stated that "one sees that in the course of continental weathering sodium turns out to be much more mobile than potassium and dominates the latter in natural water. Potassium is sorted up and conserved in a preferential way". Again ***Millot, (1970)*** mentioned that "if one considers the behavior of K^+ ions in solution, one sees that they are preferentially adsorbed by the fine-grained particles of the sediments".

Consequently the slight predominance of K_2O contents over Na_2O contents in Upper Eocene (Tanka formation) of Wadi Tayiba area, Lower Eocene (Thebes Formation) and Middle Eocene (Samalut Formation) of Wadi Feiran area limestones could be understood.

Table (7):Chemical composition (major Oxides in wt %) of the Eocene Carbonate rocks (Wadi Feiran area).

AGE	Formation	Sample No.	SiO_2%	Al_2O_3%	Fe_2O_3%	CaO%	MgO%	Na_2O%	K_2O%	L.O.I.%	TOTAL
Middle Eocene	Samalut	37	13.00	1.70	043	44.2	0.41	n.d	n.d	40.00	99.96
		33	n.d	n.d	n.d	54.16	0.78	n.d	n.d	43.10	99.94
		29	1.20	n.d	0.25	42.00	12.1	2.40	2.40	39.10	99.95
		27	3.10	0.20	1.03	53.45	0.62	n.d	n.d	41.00	99.97
Early Eocene	Thebes	15	6.16	0.60	0.45	47.66	1.38	n.d	n.d	42.90	99.98
		5	7.40	0.99	0.40	46.97	0.65	0.45	0.45	42.50	99.97
		4	8.50	0.50	0.30	47.20	0.95	0.53	0.53	42.70	99.95
		2	8.80	n.d	0.39	50.35	n.d	0.40	0.40	39.70	99.86
		1	1.40	n.d	0.59	52.15	0.60	0.13	0.13	44.40	99.94

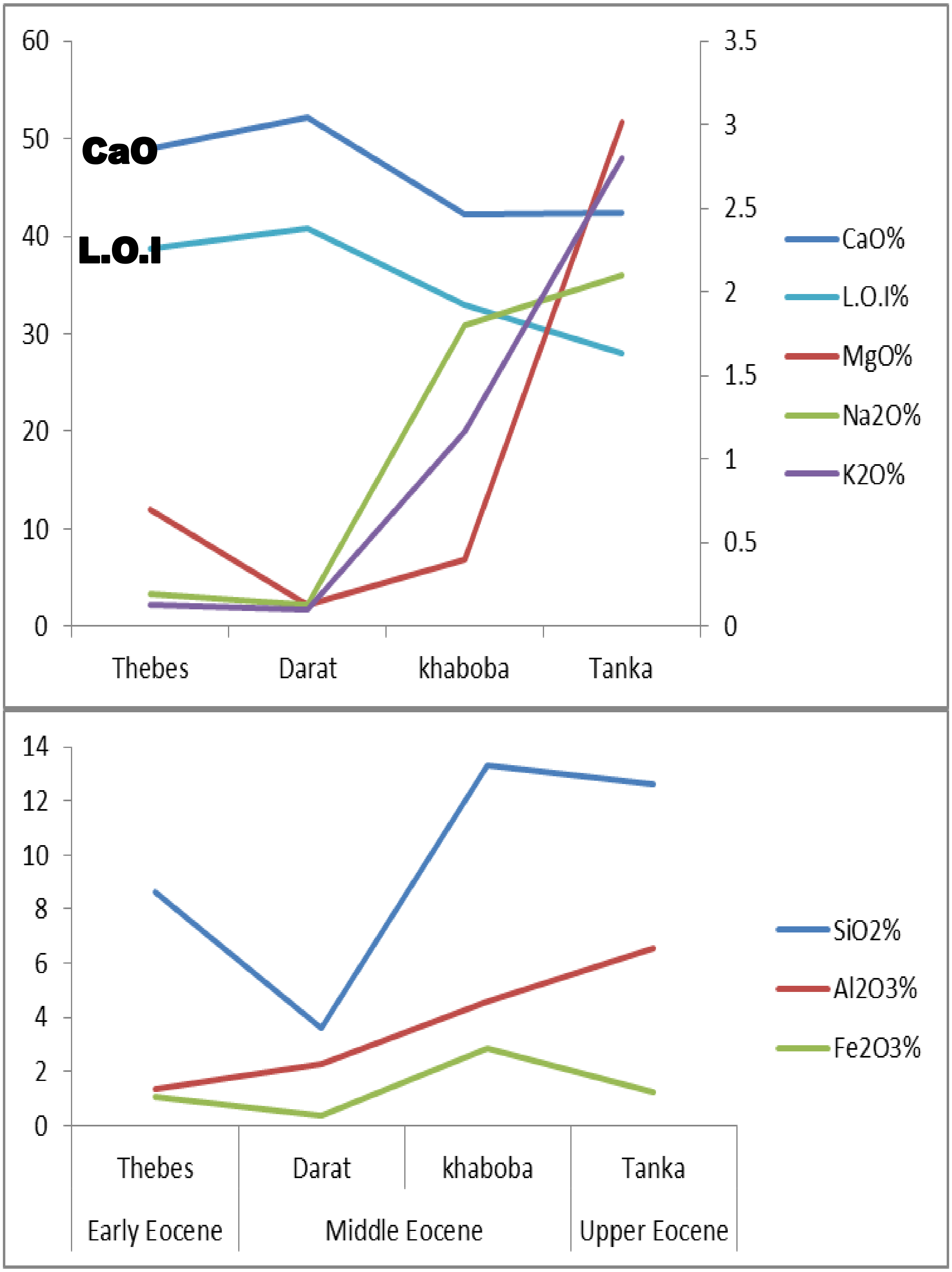

Fig. (7): Distribution curve of average major oxides of Wadi Tayiba samples.

Table (8): Average chemical composition (major Oxides in wt %) of the Eocene Carbonate rocks (Wadi Feiran area).

Age	Early Eocene		Middle Eocene	
Formation	Thebes		Samalut	
Chemical oxides	Range	Average	Range	Average
SiO2%	1.4 - 8.80	6.45	0.00 – 13.00	4.32
Al2O3%	0.0 – 0.99	0.42	0.00 - 1.70	0.48
Fe2O3%	0.3 - 0.59	0.43	0.00 - 1.03	2.90
CaO%	46.97-52.15	48.86	42.00 - 54.16	48.45
MgO%	0.0 - 1.38	0.72	0.41 - 12.1	3.45
Na2O%	0.05 - 0.28	0.17	0.00 - 1.90	0.46
K2O%	0.0 - 0.53	0.30	0.00 - 2.40	0.60
L.O.I%	39.7 - 44.4	42.44	39.1 - 43.1	40.8

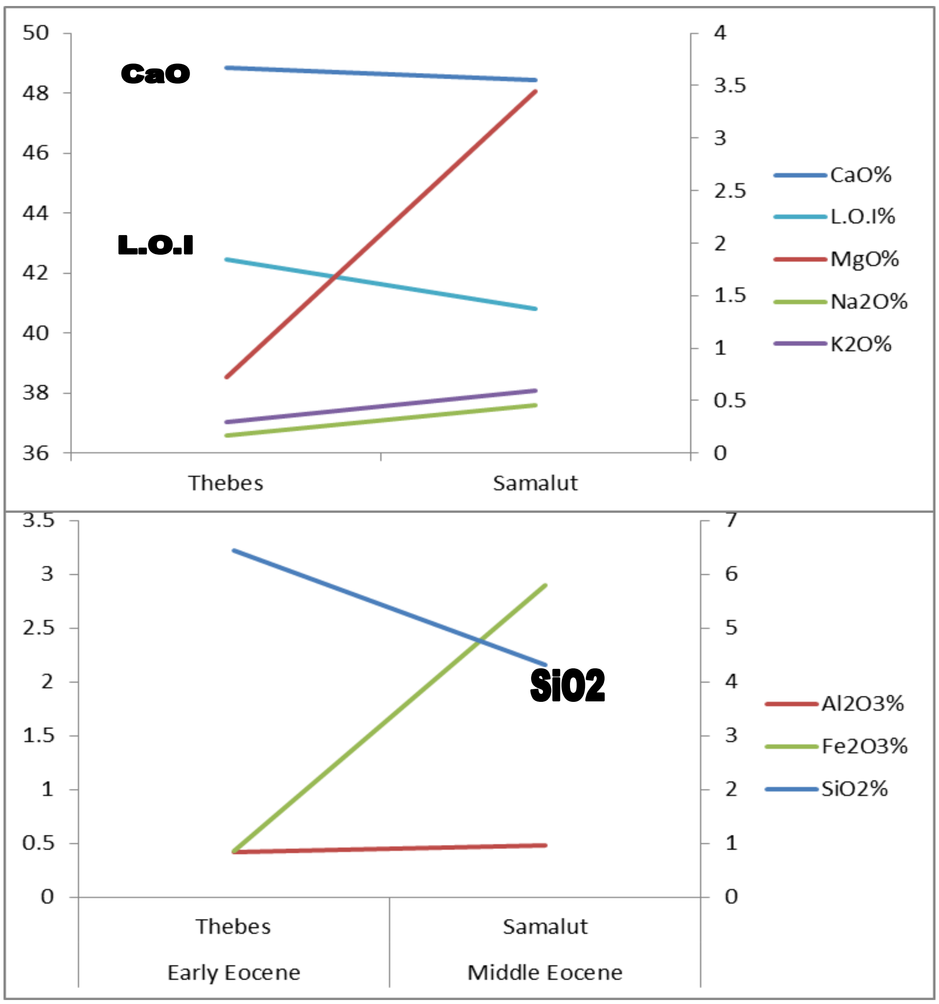

Fig. (8): Distribution curve of average major mineral of Wadi Feiran samples.

Iron oxides

The distribution of ferric oxide average contents in the studied areas show to a great extent inconsistent distribution with those of both SiO_2 and Al_2O_3 suggesting the presence of Fe_2O_3 is not connected with silt or clay fractions. ***Castano J. R. and Garrels, R.M. (1950)*** Stated that" the residence time for iron and alumina in sea in years is very short. Hence it should expect that iron, oxides silica and alumina are to be concentrated in continental and near-shore marine environments".

The variation in Fe_2O_3 concentration among the studied areas limestones can be attributed to variation in the environment of deposition. The relatively high concentrations of iron oxides silica and alumina of the Khaboba Formation (Wadi Tayiba area), Samalut Formation (Wadi Feiran area) Middle Eocene and Tanka Formation (Wadi Tayiba area) Upper Eocene limestones favour near-shore shallow marine environment of deposition. The Thebes Formation of (Wadi Feiran area) Lower Eocene and Darat Formation of (Wadi Tayiba area) Middle Eocene limestones with the relatively lowest concentrations of iron oxides silica and alumina suggest deposition in deeper environments. The Thebes Formation of (Wadi Tayiba area) Lower Eocene carbonates were deposited in an environment somewhere in between the previous environments.

Calcium Oxide

The distribution of CaO in the studied areas limestones reveals a general decrease in the CaO content contrary to that of SiO_2, $A1_2O_3$ and Fe_2O_3. ***Trask, (1939)*** mentioned that" the higher the salinity, the greater the content of $CaCO_3$ this relationship is connected with higher temperature and greater organic production". In addition, ***Kukal, Z. (1971)*** stated that " the content of natural salts and increase in temperature decrease the $CaCO_3$ solubility and also the increased content of Ca^{2+} ions from other sources cause the decreased solubility of $CaCO_3$".

Nevertheless the higher $CaCO_3$ content at Wadi Tayiba area (Middle Eocene Darat Formation) limestones seems to be due to the fact that the depth of water during deposition of Darat Formation limestones, was not deep enough to cause a great variation in temperature and to increase the solubility of $CaCO_3$ or the amounts of the argillaceous materials derived to the site of deposition were inconsiderable leading to the relative increase in the $CaCO_3$ at the expense of SiO_2 and Al_2O_3 contents.

Magnesium oxide

The distribution of MgO in the studied areas Limestones reveals that there is no particular trend for distribution. This can be attributed to variations in the ecological and paleontological parameters of the environments under which the studied limestones were deposited.

Chave, (1954) suggested that there is a direct relation between the content of MgO and temperature. ***Chilingar, G.V (1963)*** stated that the MgO content increases with salinity but is simultaneously affected by so many other factors that it cannot serve as an adequate indicator" He also noted that in carbonate sediments the Ca/ Mg ratio increases seawards with depth.

Table (9): K_2O/ Na_2O ratio of the studied Eocene carbonates.

Age	**Early Eocene**		**Middle Eocene**			**Upper Eocene**
Study area	**W.Tiaba**	**W.Ferran**	**W.Tiaba**		**W.Ferran**	**W.Tiaba**
Formation	**Thebes Formation**		**Darat**	**Khaboba**	**Samalut**	**Tanka**
K_2O/NaO_2 ratio	**0.68**	**1.76**	**0.77**	**0.94**	**1.30**	**1.33**

Chilingar, et al. (1967) stated that "in as much as shallow near-shore waters are systematically warmer as a rule than deep off-shore waters; the gross Ca/Mg ratio reflects temperature-depth-distance from shore". The computed Ca/Mg ratio for the studied Eocene limestone areas are as follows **Table (10)** and **(Fig. 10).**

These values represented by figure (10), suggest that there is no particular trend for the distribution of Ca/Mg average ratio and this can be attributed, according to ***Chilingar, 1962***, to the selective adsorption of Mg^{2+} by illite clays besides the dolomite and so, the gross ratio reflects the illite content or perhaps the degree of diagenesis of the studied Eocene limestone.

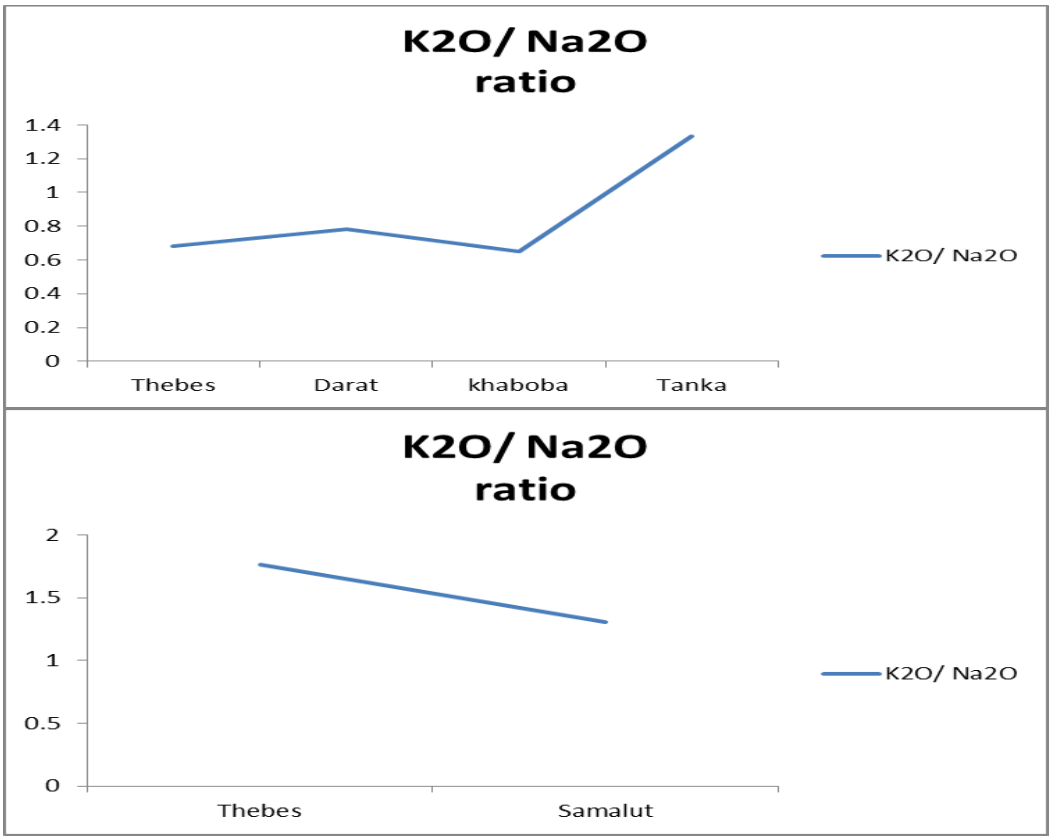

Fig (9): K_2O/ Na_2O ratio of the studied Eocene carbonates (Wadi Tayiba and Wadi Feiran area).

Table (10): CaO/MgO ratio in of the studied Eocene carbonates.

Age	Early Eocene		Middle Eocene			Upper Eocene
Study area	W. Tayiba	W. Feiran	W. Tayiba		W. Feiran	W. Tayiba
Formation	Thebes Formation		Darat	Khaboba	Samalut	Tanka
CaO/MgO ratio	69.9	65.14	401.69	105.75	14.04	14.03

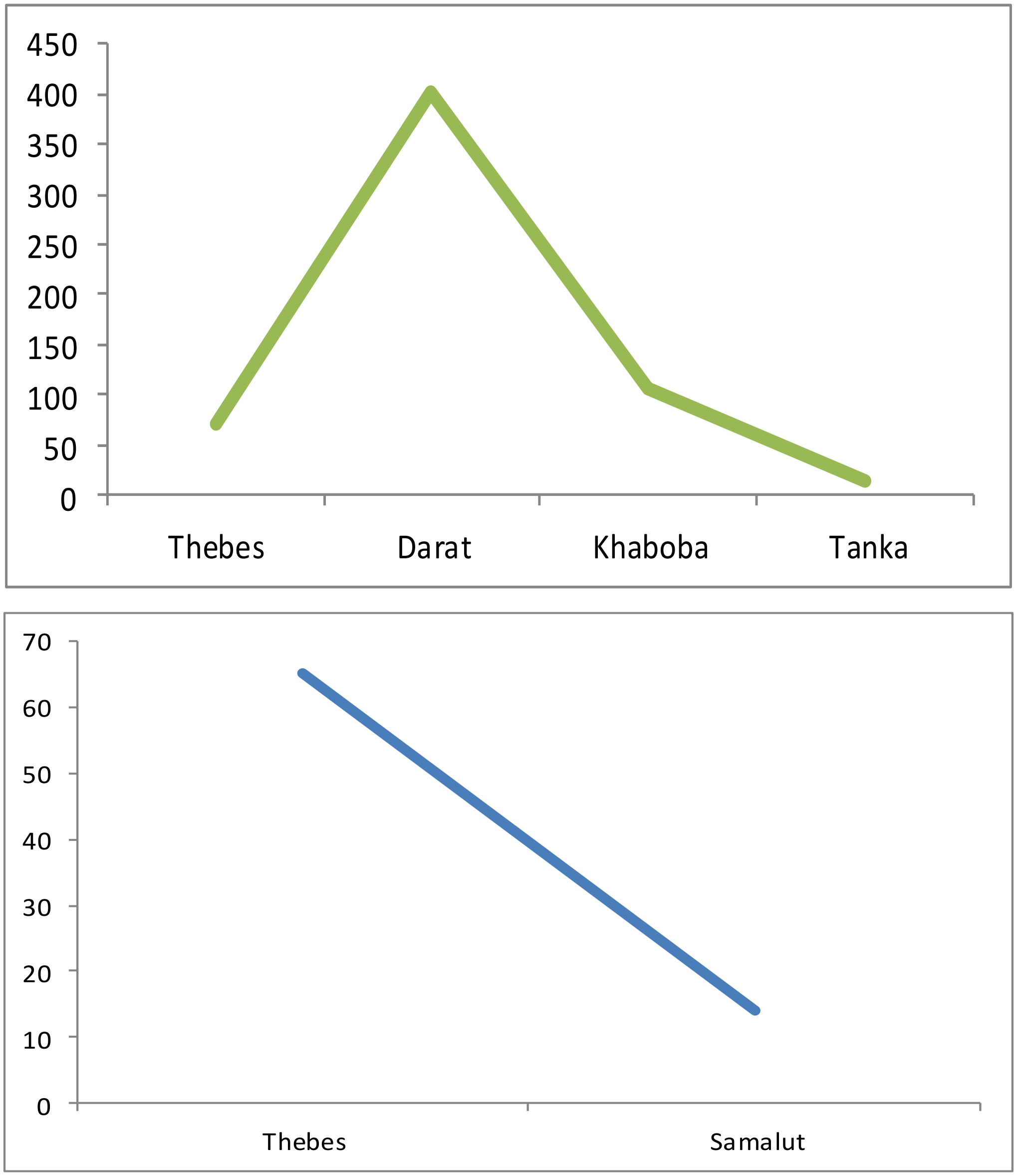

Fig. (10):Variation of Ca/ Mg average ratio in the Eocene Carbonate Wadi Tiaba and Wadi Feiran.

7. Abundance and Distribution of Trace Elements

Trace elements may be derived from weathering of rocks or they may be introduced into the hydrosphere by human activities ***Stumm, and Baccini (1978): Nriagu, et al. (1979): Galloway (1979)*** Particular trace element goes into solution during weathering depends on the mineral in which the element occurs and on the intensity of chemical weathering ***Harris &Adams (1966) and Kronberg et al. (1979).***

At very low pH there is essentially no adsorption, and at high pH all cations are strongly adsorbed, ***James and Healy (1972b).*** ***Suarez and Longmuir (1976)*** dominated that Cu, Ti, Cr, Sr, Ni, Zn, Mn, V, Ba, P and Pb in Pennsylvania soil were present largely in manganese and iron oxide phases. Other processes helping to determine the distribution of elements in sediments are precipitation following oxidation **or reduction** ***Garrelsa nd Christ (1965)*** and various reactions with organic matter ***Sholkovitz (1967 & 1973).***

In general no table concentrations of trace elements formed by sedimentary processes alone are not common ***Krauskopf (1979).*** Since the elements behave differently in their migration and deposition, so the abundance and behavior of each element in the Eocene carbonate sediments of the studied are as will beconsider at **(Tables 11-14)** and **(Figs. 11&12).**

Chow and Goldberg (1960) pointed out that barium concentration is dependent on pressure and temperature in the depositional environment and the increase in the barium concentration may partly be accounted for by production of sulphate ions in connection with biological processes. ***Kukal, Z. (1971)*** stated that strontium and barium this two pair of elements and their relation to salinity has been much discussed. It is generally believed that the Ba/ Sr ratio of the studied carbonate was computed and represented by **(Table 15 and Fig. 13).**

Table (11): Chemical composition (Trace elements in ppm) of the Eocene Carbonates (Wadi Tayiba area).

AGE	Formation	Sample No.	Sr ppm	P ppm	Mn ppm	Ti ppm	Pb ppm	Zn ppm	Cu ppm	Ni ppm	Cr ppm	V ppm	Ba ppm
Upper Eocene	Tanka	24	515	1700	3500	4800	ND	14	ND	ND	14	22	220
Middle Eocene	Khaboba	20	471	600	3200	1200	ND	24	ND	ND	11	23	213
	Darat	14	659	500	1600	800	ND	37	5.00	5.00	42	20	219
		13	609	800	1200	700	1.00	135	8.00	28	49	24	205
		11	603	1200	1100	900	2.00	130	8.00	27	48	23	202
		10	455	1000	700	800	ND	105	7.00	22	77	62	206
Early Eocene	Thebes	8	509	100	200	100	ND	92	16	46	62	50	206
		7	691	400	1500	200	2.00	110	26	54	131	83	210
		4	591	1500	700	100	ND	66	9.00	11	77	37	195
		1	642	1800	300	300	2.00	71	11	46	20	14	213

Table (12): Avarege chemical composition (Trace elements in ppm) of the Eocene Carbonates (Wadi Tayiba area).

Age	Early Eocene		Middle Eocene			Upper Eocene	Average concentration after Krauskopf (1979)
Formation	Thebes		Darat		Khaboba	Tanka	
Sample. No	1 , 4 , 7		8 , 10 , 11 , 13 , 14		20	24	
Trace elements detected	Range	Average	Range	Average	-----	----	
Ti	100 – 300	200	100-900	200	660	4800	400
P	400 – 1800	1200	100 – 1200	720	600	1700	400
Mn	300 -1500	800	700 – 1600	460	960	3500	1,100
Sr	591– 691	641	455-659	567	471	515	610
Pb	0 – 2	1	0 – 2	1	n.d	9	9
Zn	66 – 110	82	37 – 135	100	24	13	20
Cu	9 – 26	15	5 – 16	9	n.d	12	4
Ni	11– 54	37	5 – 46	26	n.d	81	20
Cr	20– 131	76	42 – 77	38	11	65	11
V	14 – 83	45	20 -62	36	23	113	20
Ba	195 -213	206	202 – 219	210	213	790	10

According to the above mentioned studies it seems that the abnormality high barium content recorded in the Eocene carbonates can be attributed not only to the salinity and the organic production but also to the pressure and temperature of the depositional environment. The Ba / Sr ratio of the Eocene limestone reveals that the environment of deposition was normal saline.

Table (13): Chemical composition (Trace elements in ppm) of the Eocene Carbonates (Wadi Feiran area).

AGE	Formation	Sample No.	Sr ppm	P ppm	Mn ppm	Ti ppm	Pb ppm	Zn ppm	Cu ppm	Ni ppm	Cr ppm	V ppm	Ba ppm
Middle Eocene	Samalut	37	431	2200	ND	ND	2.00	22	ND	ND	12	15	216
		33	492	19000	ND	ND	ND	53	ND	5.00	44	26	216
		29	320	5000	ND	5000	ND	87	ND	39	95	194	15
		27	425	4000	600	1100	ND	21	ND	ND	7.00	ND	180
Early Eocene	Thebes	15	440	3300	300	5500	ND	48	ND	23	21	34	312
		5	415	3800	4000	ND	1.00	28	ND	ND	12	17	150
		4	395	1400	1000	5300	3.00	53	2.00	ND	7.00	23	82
		2	430	100	200	300	7.00	134	17	91	85	133	110
		1	450	200	200	1000	2.00	64	ND	ND	8	15	95

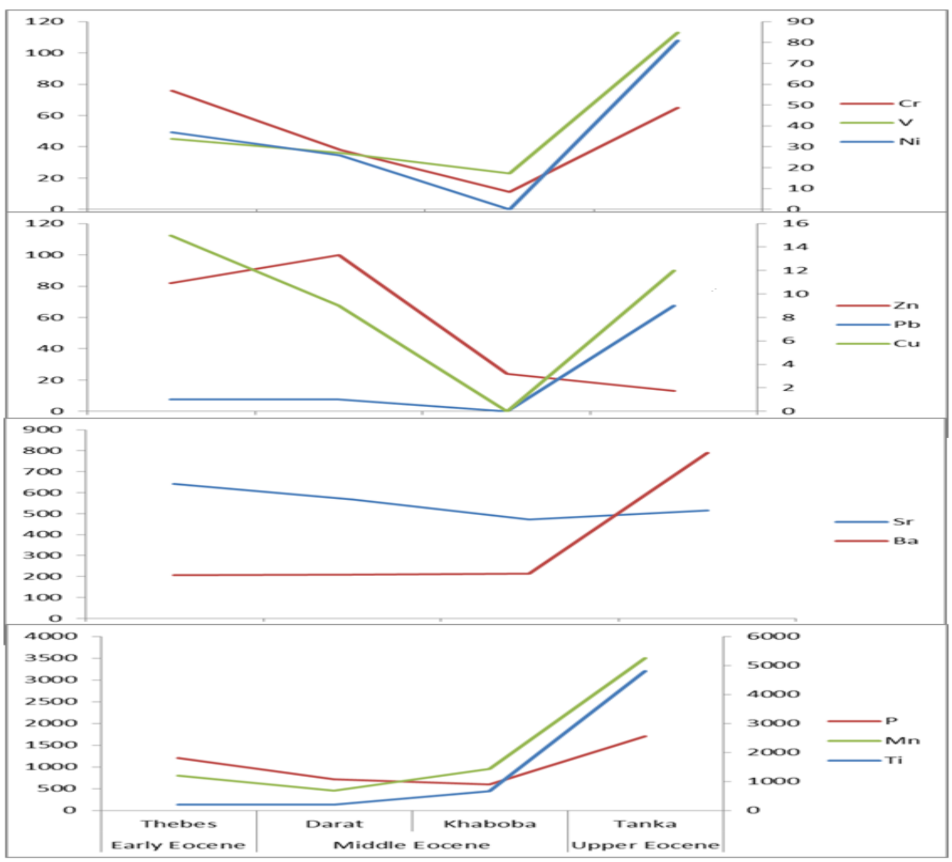

Fig. (11): Distribution curve of average trace mineral of Wadi Tayiba samples.

Table (14): Avarege chemical composition (Trace elements in ppm) of the Eocene Carbonats (Wadi Feiran area).

Age	Early Eocene		Middle Eocene		Average concentration after Krauskopf (1979)
Formation	Thebes		Samalut		
Sample. No	1 , 2 , 4 , 5 , 15		27 , 29 , 33 , 3 7		
Trace elements	Range	Average	Range	Average	
Ti	Range	2000	0 - 5000	1500	400
P	0 - 4000	900	2200 - 19000	7500	400
Mn	100 - 3800	1200	0 - 600	150	1,100
Sr	100 - 4000	426	320 - 490	417	610
Pb	355-459	3	0 - 2	1	9
Zn	0 – 7	65	21-87	46	20
Cu	28-134	4	ND	ND	4
Ni	0-17	23	0 - 39	11	20
Cr	0-91	27	7 - 95	40	11
V	7 - 85	44	0 - 194	59	20
Ba	15 - 133	150	15 - 216	157	10

Table (15): Ba/ Sr Ratio in of the studied Eocene carbonates.

Age	Early Eocene		Middle Eocene			Upper Eocene
Study area	W. Tayiba	W. Feiran	W. Tayiba		W. Feiran	W. Tayiba
Formation	Thebes Formation		Darat	Khaboba	Samalut	Tanka
Ba	206	150	210	213	157	790
Sr	641	426	567	471	417	515
Ba/Sr Ratio	0.32	0.35	0.37	0.51	0.38	1.53

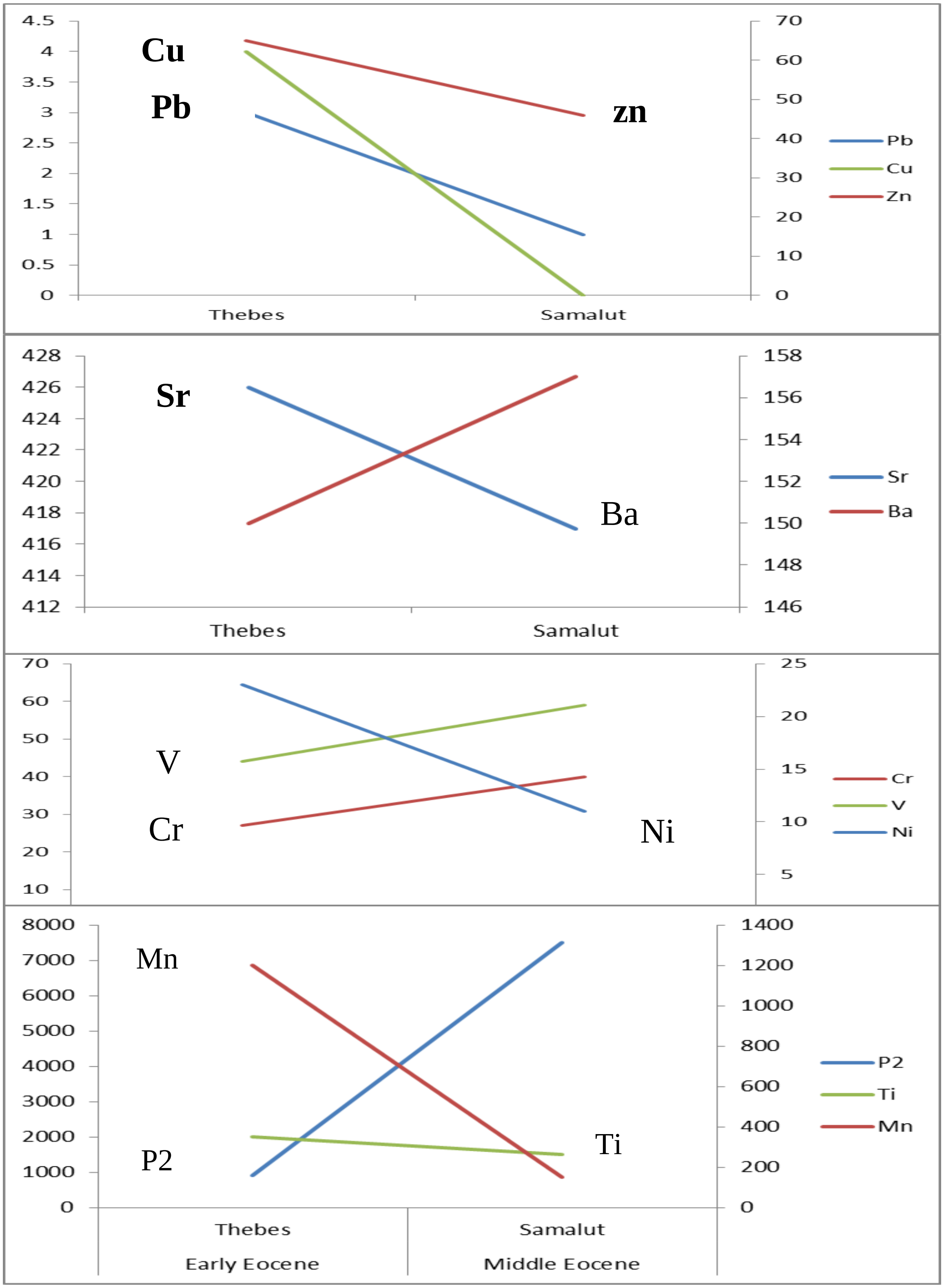

Fig. (12): Distribution curve of average trace mineral of Wadi Feiran samples

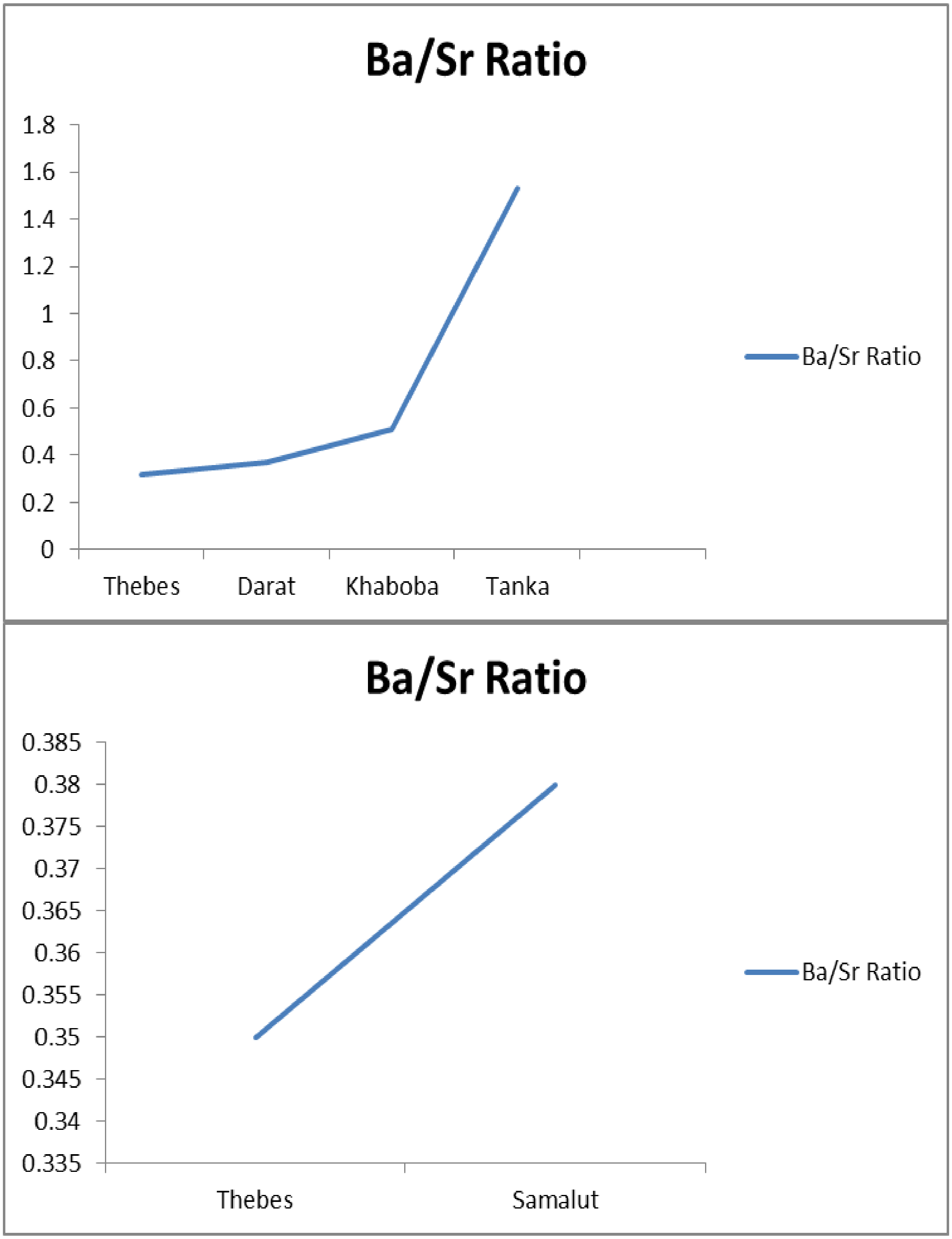

Fig. (13): Ba/ Sr Ratio in of the studied Eocene carbonates.

8. Conclusions

The present thesis deals with the geological, geochemical and petrophysical studies on Eocene rocks exposed at the south western Sinai along the western side of the Gulf of Suez. The study area lies between latitudes 28º 40' 00" and 29º 10' 00" N. and longitudes 33º 00' 00" and 33º 30' 00" E. The study area is represented by two examined areas, namely Wadi Tayiba and Wadi Feiran.

Lithostratigraphically; Eocene successions exposed in the south-western part of Sinai are represented mainly by carbonate predominance. The Eocene successions recorded in the study areas range in thickness from 152 meters (at Wadi Tayiba) to 408 meters (at Wadi Feiran). Lower, Middle and Upper Eocene rocks, of the study areas, are represented by five formations namely; Thebes (Lower - Middle Eocene), Darat and Samalut (Middle Eocene), Khaboba (Middle – Late Eocene) and Tanka (Upper Eocene) Formations.

Mineralogical compositions of the studied carbonates reveal that the Eocene marine basin of deposition was relatively alkaline, close to the landmass that supplied the basin of deposition by quartz and clays.

Limestone chemical characteristics reveal that; the studied Eocene limestones reveals that there is no particular trend for distribution. The study reveals that; Eocene limestones were mostly deposited under relatively warm alkaline conditions. However the pH degree of alkalinity during the Darat Formation (Wadi Tayiba area) and Thebes and Samalut Formations (Wadi Feiran area) (less in SiO_2 content) was higher than that prevailed during the Thebes, Khaboba and Tanka Formation (Wadi Tiaba area) times.

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