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MINERALOGICAL AND GEOCHEMICAL STUDIES ON CRETACEOUS SEDIMENTS OF MISRI-1 WELL, NORTHEASTERN SINAI, EGYPT

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ABSTRACT

This paper deals with petrographic studies, x-ray analysis, D.T.A analysis and chemical characteristics of twenty core samples collected from the subsurface Cretaceous well "Misri-1" Northeastern Sinai. Petrographically the carbonate core samples of Misri-1 well can be classified from surface to bottom as sparry biomicrite; dolomitized micrite; marly dolomitized sparrymicrite and marly micrite facies. All these facies indicates deposition, in outer neritic zone with comparatively shallow marine environments. Mineralogically, these rocks are composed of calcite, dolomite, kaolinite and quartz as major contents whereas gypsum and illite are the minor constituents as detected by x-ray analysis. The shaly samples examined by D.T.A analysis show a broad endothermic peak at the temperature range of 115 °C to 140 °C and 530 - 560 °C indicate loss of structural water from kaolinite.

Chemically, four main rock types have been established; pure limestone, sandy limestone, dolostone and shales. The interelement correlation revealed a strong negative correlation between CaO and Sr content with acid insoluble residue and positive correlation between K_2O content and acid insoluble residue. Also Sr froms strong positive correlation with the calcium content.

Finally, the subsurface Cretaceous core samples at

Misri-1 well was attributed to the effect of three types of diagenetic processes, recrystallization as neomorphic process dolomitization and silicification.

INTRODUCTION

This study is based on the geological data obtained from the exploratory Misri-1 well (Fig.1). It lies in the northeastern part of Sinai at longitude 34° 02′ E and latitude 30° 52′ N.

Recently, several studies are going on in order to adequately assess the hydrocarbon potenial of north Sinai. A gas field was discovered in the Cenomanian carbonates of Road structure, south of Rafah, and weak oil shows were found in the Cenomanian dolomite in Nakhl-1 and in the Aptian dolomite in Sneh-1 well.

Hence, the Cretaceous rocks seem to be qualified for hydrocarbon generation and entrapment in northern Sinai. The entrapment capacity of the Cretaceous is favoured by their deformation by the syrian arc movements which led to the development of many structures and anticlines.

Twenty core samples of the Cretaceous section in Misri- 1 well form the material of this study. The sedimentological and lithological data were utilized to accomplish the objectives of this study which are :

1 - To define the petrographical, mineralogical and geochemical characteristics of the Cretaceous deposits in the study well.

2 - To provide a depositional environments for the Cretaceous

sediments in the studied well as detcted in the constructed log (Fig. 2).

3 - To elucidate the diagenetic processes affecting the depositional environments.

For these purposes, fifteen core samples have been selected to represent the petrographic study in thin section. All the studied samples have been subjected to x-ray analysis using CaF_2 as internal standard for estimating semi-quantitively the mineral percent age after Carver (1971) All samples are chemically analyzed using complexmetric, gravimetric, colorimetric, flame photometric and atomic absorption spectrophotometric techniques by the present author in the Central Laboratory of the Faculty of Science, Menoufia University.

LITHOSTRATIGRAPHY

The lithologic succession of the studied core samples of the expolatory Misri-1 well (about 1359 m. thick) is composed mainly of limestone, shales and dolostone. Figure, 2 includes a description of this section.

PETROGRAPHY

The classification of Folk (1959 & 1962), for carbonate rocks is followed in the present work. The different petrographic facies recognized are arranged from surface to bottom as sparrymicrite; dolomitized micrite; marly dolomitized sparrymicrite and marly micrit.

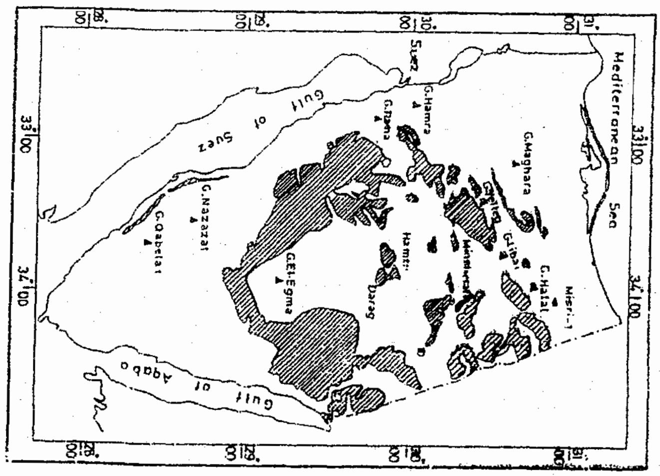


Fig.(1):Location map of the studied well, northeastern Sinai, Egypt.

Cretaceous outcrops.

• Misri-1

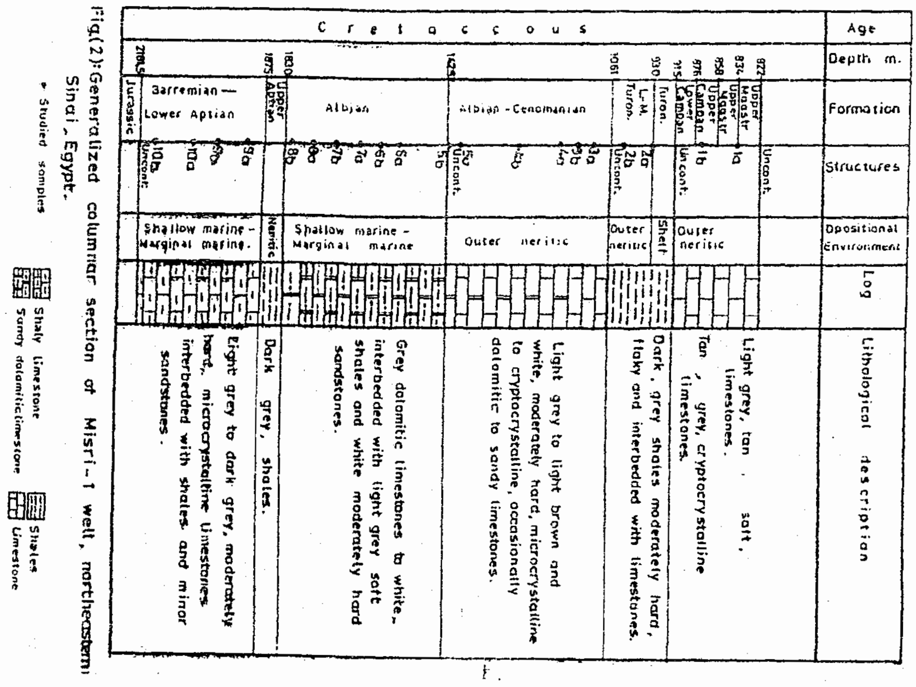


Fig.(2):Generalized columnar section of Misri-1 well, northeastern Sinai, Egypt.

• Studied samples

1 - Sparry Biomicrite Facies

This facies is represented in the limestone of Misri-1 well represented by samples No. 1_b and 3_a at depths 870 and 1083 m respectively. In hand specimen, the rock is pale grey, soft limestone. In thin section, the rock is composed mainly of micrite (Figs. 3 a & b). However small area of micrite have neomorphosed into sparry calcite. The discrete particles that form the rock framework are mainly non-skeletal particles and genetically grouped into fragmental and non-fragmental grains, few fragmented tests are also present. There are two types affecting the recrystallization of the particles; aggrading recrystallization (enlargment to coarse crystalline calcite) (Fig. 3_a) and degrading recrystallization (reduction in the grain size of the particle) (Fig. 4).

This lithofacies indicates deposition under comparatively shallow marine conditions of the neritic zone (outer neritic zone).

2 - Dolomitized Micrite Facies :

This facies is represented by samples No. 4 a and 5 a of the studied core samples at Misri-1 well at depths 1155 and 1374 m respectively. In hand specimen, the rock is grey hard dolomitic limestone. In thin section, the rock is composed mainly of various sizes from dolomite rhombes embedded in micritic groundmass (Figs. 5, 6), the dolomite rhombs ranges from 70 to 80 % of the rock volume; dolomite crystals are characterized by being subhedral to euhedral without zonation but interlocked in some parts (Fig. 5). Very rare detrital subrounded quartz can be noticed in some part of the groundmass. In sample No. 5 a, the groundmass suffered

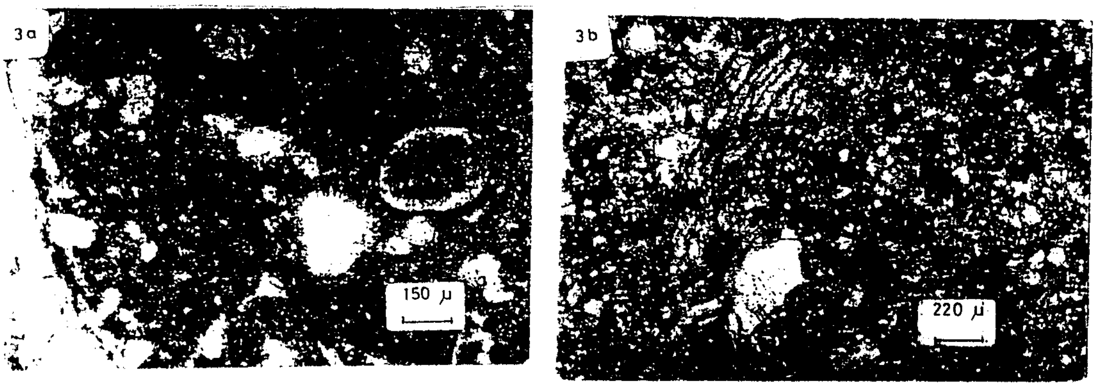


Figure 3 a, b : photomicrograph of sparrymicrite Facies showing aggrading recrystallization of the lime - mud matrix. Misri -1 Well. "Ordinary Light"

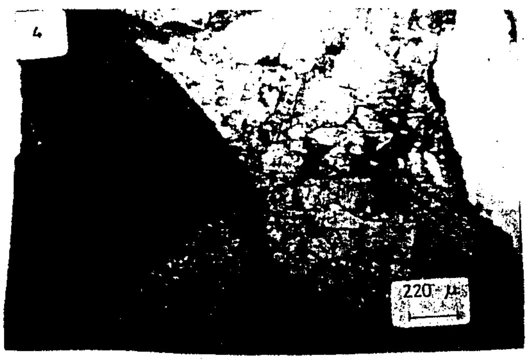


Fig. 4 : Photomicrograph of sparrymicrite Facies showing degrading recrystallization. Misri-1 Well "Ordinary Light:

Fig. 5 : Photomicrograph of dolomitized micrite Facies showing the lime-mud which suffered extensive dolomitization. Misri-1 Well. "Ordinary Light"

extensive dolomitization (Fig. 6). This microfacies association indicates deposition under comparatively shallow marine environment (outer neritic zone).

3 - Marly Dolomitized Sparrymicrite Facies :

This facies is represented by samples No. 6a and 9a at depths 1527 and 1944 m. respectively. In hand specimen, the rock is grey dolomitic hard limestone in sample No. 6a and moderately hard, slightly dolomitic in sample No. 9a.

In thin section, the rock is composed mainly of micrite showing recrystallization to microspars and pseudospars as shown in Figures 7a, b, c,. Very fine dolomite crystals and patches associated with argillaceous materials distributed haphazardly within the groundmass. Very small silt-size quartz grains with wavy extinction is present in sample No. 6a. The percent of dolomite is diminshed in sample No. 9a and replaced partially by lime-mud matrix. The lime-mud matrix was affected by recrystallization into sparry micrite. This facies indicates deposition under shallow to marginal marine environments.

4 - Marly Micrite Facies

This facies is represented by samples No. 8b, 9b and 10b at depths 1815, 1975 and 2145 m respectively. In hand specimen, the rock is grey, soft marly limestone. In thin section the rock is composed mainly of microcrystalline calcite ooze associated with clayey materials (Figures 8a, b and 9). Few angular to subrounded quartz grains are scattered within the matrix in sample No. 10_b

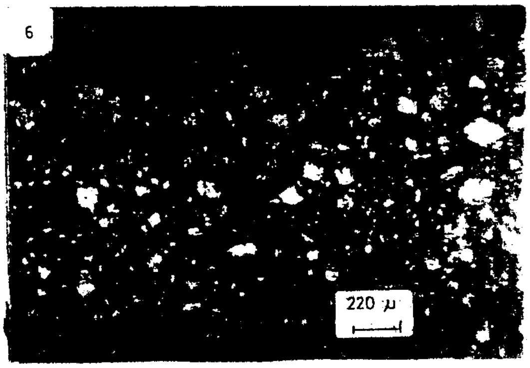
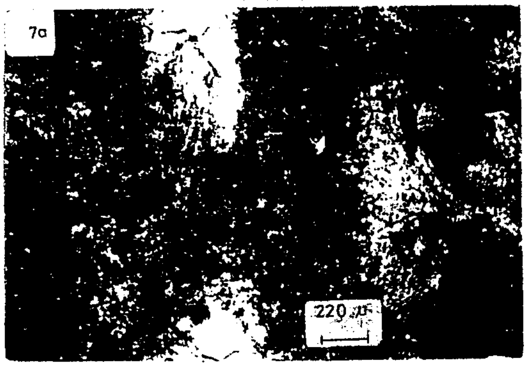


Fig. 6 : Photomicrograph of dolomitized micrite Facies showing varigated size of dolomite rhombs scattered haphatherdly within the lime-mud matrix. Misri-1 "Ordinary Light"



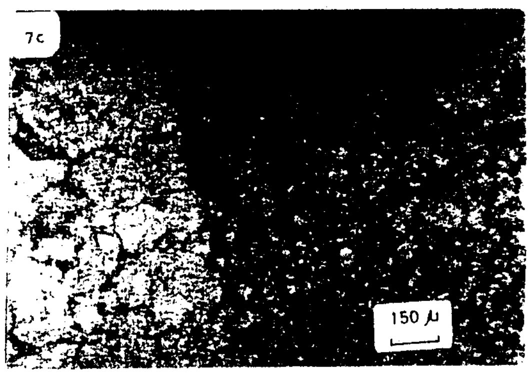


Figure 7 a, b and c : Photomicrograph of marly dolomitized sparrymicite Facies showing patches of clayey material associated with very fine dolomite crystals embedded in micritic matrix lime-mud which undergon recrystallization Misri -1 Well "Ordinary Light"

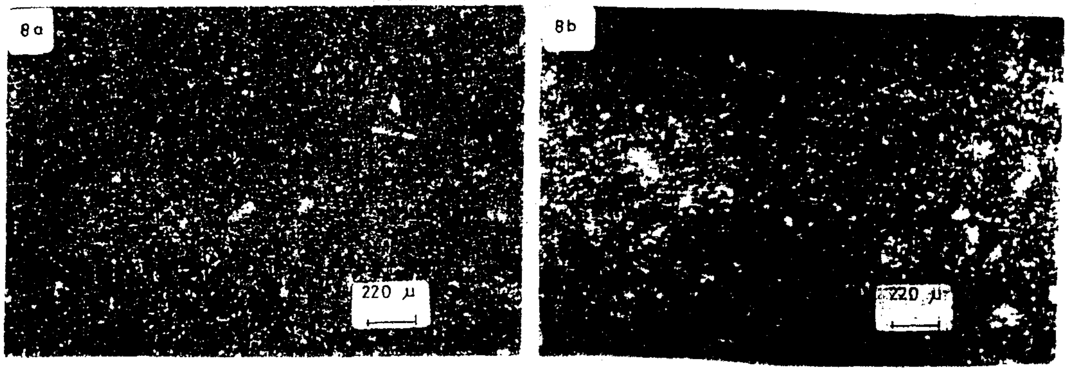


Figure 8 a, b : Photomicrograph of marly micrite Facies showing clayey materials dissiminated with the lime - mud matrix, Misri - 1 well "Ordinary Light".

Figure 9 : Photomicrograph of marly micrite facies showing very fine subangular quartz grains scattered within the marly lime - mud matrix, Misri - 1 Well "Ordinary Light"

(Fig. 9). The presence of argillaceous material makes it difficult to identify the other constituents. This facies indicates deposition under shallow to marginal marine environments.

Clay minerals are difficult to be identified with the petrographic microscope because of their fine crystal size. For this reason, clay minerals under consideration are identified by using x-ray diffraction method and D.T.A. method. They are represented mainly by kaolinite and illite.

To confirm the results of petrographic examination, all core samples from Misri-1 well were analyzed by x-ray diffractometry method. The identification of the mineral contents are carried out using the ASTM cards.

MINERALOGY

X-ray diffraction analyses of the exploratory. Misri-1 Well indicate that the major mineral species present are calcite, dolomite, kaolinite and quartz with minor amount of halite and gypsum.

The semi- quantitative data are presented in Table 1 and Figure 10 show the vertical distribution of mineral assemblages obtained from the x-ray analyses and by the aids of petrographic studies.

From the vertical distribution of mineral assemblege in Fig. 10, it can be concluded that :

Calcite content ranges from 12 % to 89 % with an average of

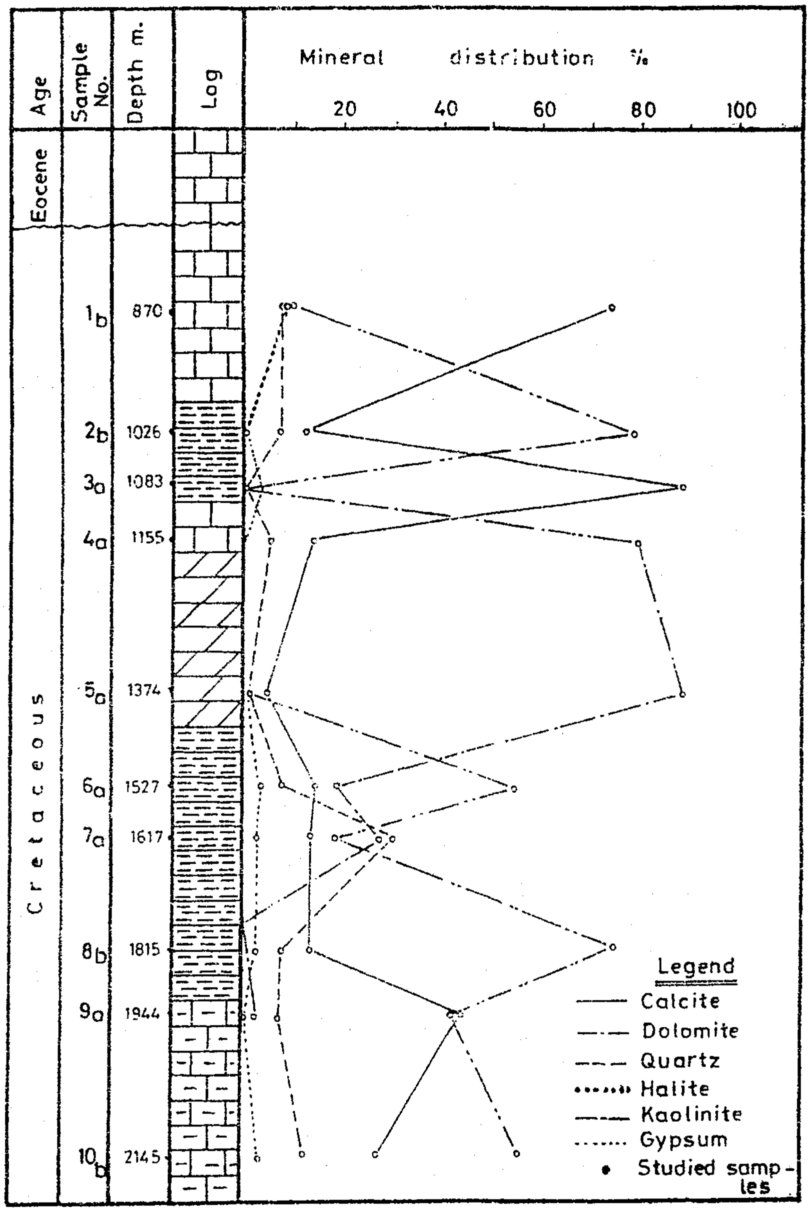


Fig.(10): Vertical distribution of Calcite, Dolomite, Quartz, Halite, Kaolinite and Gypsum in the rock samples under study.

Limestone
Dolostone
Shales
Shaly limestone

Table (1) : Semi- quantitative mineralogical composition of the selected core samples from Misri-1 Well.

Age	depth (m)	sample No	Calcite %	Dolomite %	Quartz %	Halite %	kaolinite %	Gypsum %	Illite %
					Mineral %				
Cretaceous	870	1_b	74	-	8	9	8	-	-
	1026	2_b	12	-	7	-	79	-	2
	1083	3_a	89	-	-	3	-	-	-
	1155	4_a	13	78	5	-	-	-	-
	1374	5_a	5	89	2	-	-	-	-
	1527	6_a	14	19	9	4	55	-	-
	1617	7_a	13	28	40	2	18	-	-
	1815	8_b	13	-	8	2	76	2	2
	1944	9_a	44	2	7	1	42	2	1
	2145	10_b	28	-	13	4	55	-	-

31 it is noticed that the maximum content of calcite was reported at depths 870 and 1083 m (upper part of Misri-1), dolomite content ranges from 2 % to 89 % with an average of 44, and the maximum amount of dolomite was reported at depths 1155 and 1374 m (middle part of Misri-1 well) this gives the indication that the metasomatic replacement is the origin of dolomite. Kaolinite content ranges from 8 % to 79 % with an average of 48 and reported its maximum values at depths 1026, 1527 and 1815 m. Quartz content ranges from 2 % to 40 % with an average, of 11, the higher amount of Quartz was reported at depth 1617 m whereas calcite and dolomite decreases. Halite content ranges from 1 % to 9 % with an average of 4 %, gypsum detected in two samples only with minor amount of 2 % and illite in three samples.

The formation of Kaolinite requires intense weathering and strong leaching of Al-silicate rocks. These processes bring about the removal of alkali and alkali earth metals such as Na, K, Ca and Mg (Enu *et al.*, 1981; Enu, 1986). Thus, the presence and relative abundance of Kaolinite in these sediments indicate rigorous weathering of aluminium-rich source rock with steep relief and exhausive leaching of weathered materials under a warm, humid and acidic milieu (Enu, 1986).

Differential thermal analyses was carried on the shaly samples in the range of 40 ° to 900 °C by 30 °C / min. The identification of minerals was carried out using the charts prepared by Ivanova (1961), Mackenzie (1957) and Warner (1974).

The shaly core samples examined show a broad endothermic peak at the temperature range of 110 °C to 140 °C as shown in fig. 11. The exothermic effect at 370° - 390 °C suggests the presence of

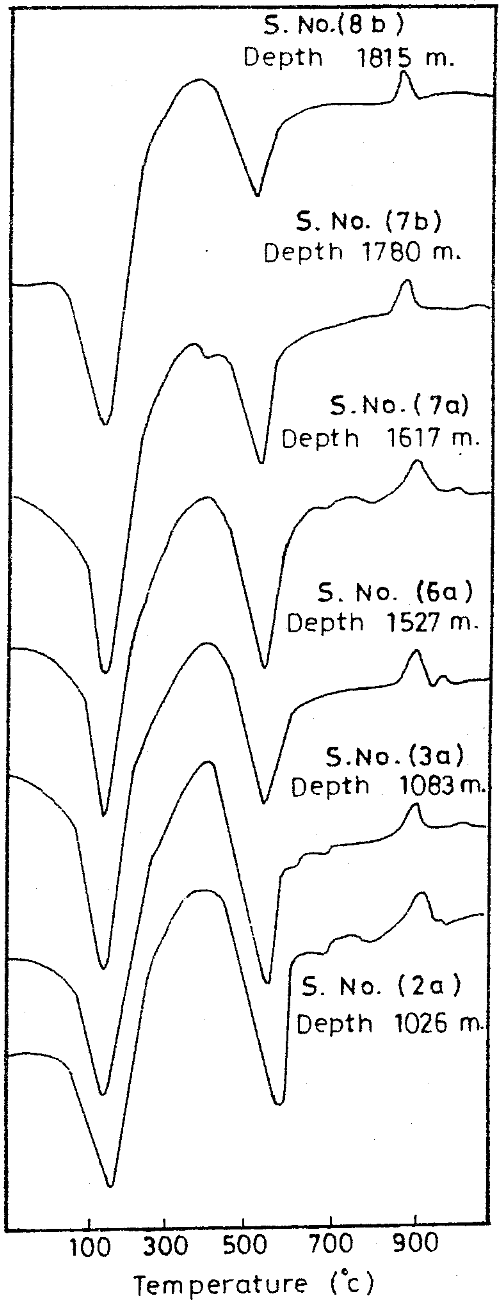


Fig.(11): DTA of the studied samples from Misri- 1 well, northeastern Sinai, Egypt.

carbonaceous matter. The presence of endothernic peak at the temperature 530 ° C - 560 °C indicates loss of structural water from Kaolinite. The presence of sharp exothermic effect at 890 - 925 °C confirms the presence of Kaolinite (Bazek, 1973).

CHEMICAL AND GEOCHEMICAL CHARACTERISTICS :

The core samples have been subjected to complete chemical analysis. The following major and minor constituents have been determined : SiO_2, Al_2O_3, TiO_2, Fe_2O_3,

SO^{--}_3, Cl^- and Sr. Acid insoluble residue (A.I.R.) and Loss on ignition were also determined. The results of the chemical analysis of the core samples understudy is shown in Table 2.

From the vertical distribution of the major and minor chemical constituents (Fig. 12) it can be concluded that : SiO2 % and A. I. R contents are relatively high especially at depth 1617m reflecting the sandy and shaly character of the beds. Moreover some samples are characterized by relative high content of CaO and MgO content in some parts which may indicate the dolomitization of some parts of the calcareous material. The scarcity of SO_3^{--} and Cl^- content in the middle and lower part the of this well indicate the deposition of open morine environment with normal salinity and not evaporational (Mason, 1971, Pettijohn, 1975). The high concentration of Al_2O_3 content, and K_2O content reflect the presence of clay minerals such as kaolinite and illite as detected by x-ray analysis.

From Fig. 13, a reversible correlation fields is observed (r = -

Table (2) : Results of chemical Analyses of the major and minor constituents of Misri-1 well

sample No	depth (m)	SiO_2 %	Al_2O_3 %	TiO_2 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	H_2O %	L.O.I %	SO_3^{-} %	Cl^{-} %	O=Cl %	A.I.R %	Ca/Mg ratio	Sr ppm	$MgCO_3$ %	$CaCO_3$ %	$CaSO_4$ %	NaCl %	calite %	dolomit %
1a	815	4.22	tr	tr	0.06	39.17	1.15	6.32	0.41	1.95	39.12	0.22	6.18	2.42	9.35	40.55	895	2.42	69.66	0.37	7.54	67.25	4.83
1b	870	6.15	tr	tr	0.04	40.97	0.46	5.03	0.34	1.84	34.29	0.34	6.11	2.39	10.17	77.00	850	0.97	72.73	0.58	8.51	71.76	1.58
2a	1000	46.12	15.16	0.56	0.62	11.19	0.93	0.51	0.22	4.13	18.12	0.28	1.91	0.75	49.82	14.27	245	1.95	19.63	0.48	0.61	17.68	3.91
2b	1026	45.49	14.49	0.76	0.52	7.13	0.55	0.39	0.58	5.42	17.58	0.30	0.69	0.27	51.99	15.42	230	1.16	12.36	0.51	1.13	11.20	2.32
3a	1083	3.63	tr	tr	0.13	49.65	0.18	0.87	0.22	1.60	37.58	0.29	2.35	0.93	6.73	322.36	889	0.38	88.30	0.49	3.87	87.92	0.76
3b	1130	2.18	tr	tr	0.18	51.05	0.18	0.35	0.15	1.16	42.15	0.36	0.29	0.11	3.12	331.45	915	0.38	90.71	0.61	0.42	90.33	0.76
4a	1155	6.41	tr	tr	0.15	28.50	17.66	0.56	0.26	2.28	37.69	0.43	1.02	1.59.	8.18	1.92	515	37.09	50.35	0.73	1.68	13.26	74.18
4b	1295	6.13	tr	tr	0.08	26.18	18.15	0.93	0.61	1.22	42.22	0.41	0.99	0.39	8.11	1.72	505	38.12	46.24	0.69	1.11	8.12	76.23
5a	1374	2.35	tr	tr	0.07	25.95	19.85	1.98	0.98	2.50	44.03	0.47	1.08	0.43	3.74	1.56	510	41.69	45.77	0.79	1.78	4.08	83.38
5b	1485	5.12	tr	tr	0.11	25.15	18.12	1.11	0.99	1.15	42.29	0.24	1.90	0.74	6.32	1.65	495	38.05	44.61	0.41	1.32	6.56	76.10
6a	1527	32.05	15.61	0.82	0.37	13.28	4.58	1.05	0.52	1.86	23.51	0.34	2.47	0.98	35.52	3.45	120	9.62	23.28	0.58	3.15	13.66	19.24
6b	1580	38.12	9.12	0.23	0.19	17.12	3.15	1.05	0.72	2.12	24.12	0.67	1.19	0.47	40.12	6.47	185	6.62	29.73	1.14	1.25	23.12	13.23
7a	1617	39.16	5.05	0.19	0.28	15.51	6.75	1.11	0.51	1.90	25.06	0.67	1.55	0.62	41.98	2.74	140	14.18	26.85	1.14	2.55	12.67	28.36
7b	1680	42.12	12.15	0.21	0.32	14.13	3.12	0.53	0.12	2.12	21.19	0.54	1.39	0.54	49.15	5.39	120	6.55	24.55	0.92	0.63	18.00	13.10
8a	1800	43.15	15.10	0.56	0.28	12.15	0.18	0.28	0.18	2.14	22.90	0.32	1.01	0.39	45.12	78.91	125	0.38	21.30	0.54	0.34	20.92	0.76
8b	1815	49.18	14.70	0.92	0.39	7.67	0.18	0.36	0.54	3.42	21.19	0.67	1.32	0.52	50.47	49.82	132	0.38	12.85	1.14	2.18	12.47	0.76
9a	1944	27.54	10.18	tr	0.06	25.64	0.55	0.25	0.38	2.40	29.03	1.18	1.01	0.40	29.23	55.48	614	1.16	44.31	2.01	1.66	43.15	2.32
9b	8000	28.08	9.12	0.32	0.08	26.12	1.02	0.92	0.52	2.19	25.13	0.89	1.04	0.41	30.12	29.62	505	2.21	46.15	1.51	1.09	43.95	2.41
10a	2080	28.19	11.92	0.48	0.52	20.64	2.12	0.53	0.49	1.15	28.15	0.72	1.11	0.43	39.18	11.61	160	4.45	35.96	1.22	0.58	31.51	8.90
10b	2145	32.30	11.23	0.79	0.49	15.55	0.09	0.54	0.49	2.86	26.37	0.38	2.49	0.99	38.17	55.00	154	0.19	27.29	0.65	4.10	27.10	0.38

(Tr) : Trace (L.O.I) : Loss on ignition (A.I.R) : Acid Insoluble residue

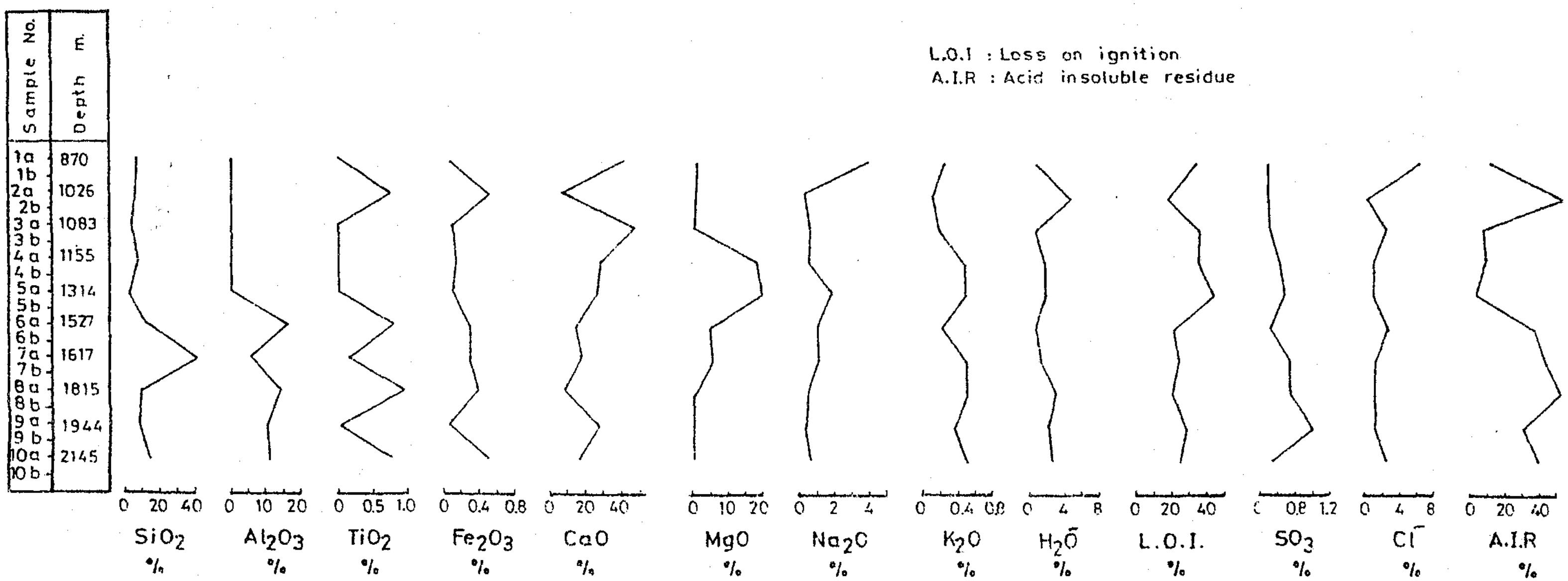


Fig.(12): Vertical distribution of the major and minor chemical constituents at the rock samples from Misri - 1 well, northeastern Sinai, Egypt.

0.89) indicating the increase of SiO_2 on the expense of the total carbonates in the studied section. The ternary diagram Fig. 14, indicates that most samples (60%) are related to field (A), the category of sandy shale and 40% are related to field (B) the category of limestone and dolostone where diagenetic dolomitization is possible. The triangular diagram (Fig. 15) show that most samples are located between $CaCO_3$, $MgCO_3$ and $CaCO_3$- A.I.R Sides of the triangle. This reflects that these rocks vary between pure limestone, dolomitic limestons, dolostone and shaly rocks rich in clay minerals and other terrigenous components.

From the inter-element correlations (Fig 16), the geochemical significance shows that :

Calcium content forms a strong negative correlation with acid insoluble residue (Fig 16 a) where ($r = -0.86$). Potasium content forms a moderatly positive correlation with acid insoluble residue ($r = +0.64$) in Fig 16 b. Strontium content forms a strong positive correlation with calcium ($r = + 0.79$) in Fig 16 c and strong negative correlation with acid insoluble residue ($r = -0.82$) in Fig 16 d.

Diagenesis

The limestones of the subsurface Certaceous core samples of Misri-1 Well were subjected to a number of diagenetic processes; most important of these are neomorphism; dolomitization and silicification.

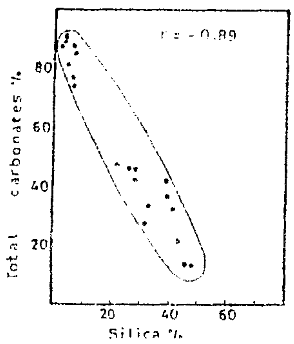


Fig.(13): Scatter diagram of total carbonates versus silica % in the studied rock samples.

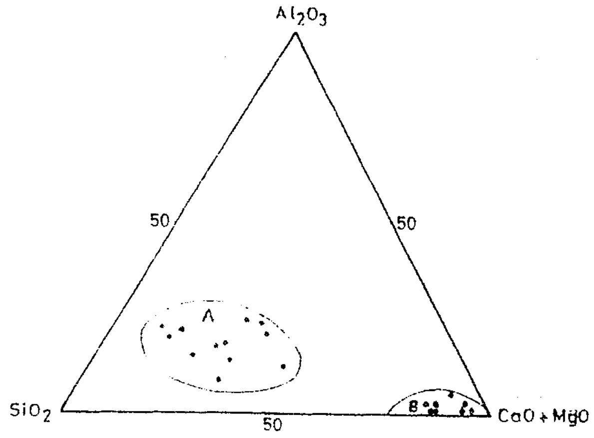


Fig.(14): Ternary diagram of SiO_2, Al_2O_3 and (CaO+MgO) in the rock samples.

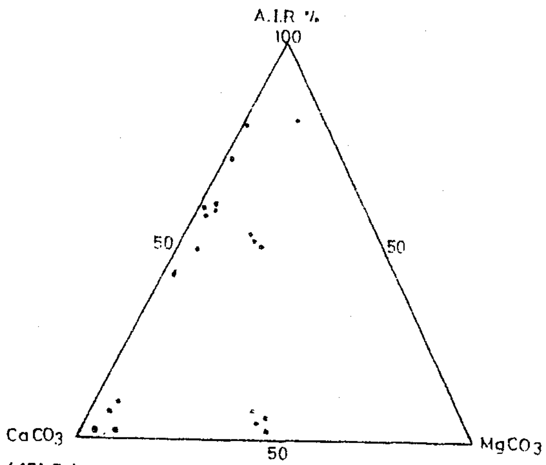


Fig.(15): Triangular diagram on the basis of $CaCO_3$, $MgCO_3$ and A.I.R in the studied samples.

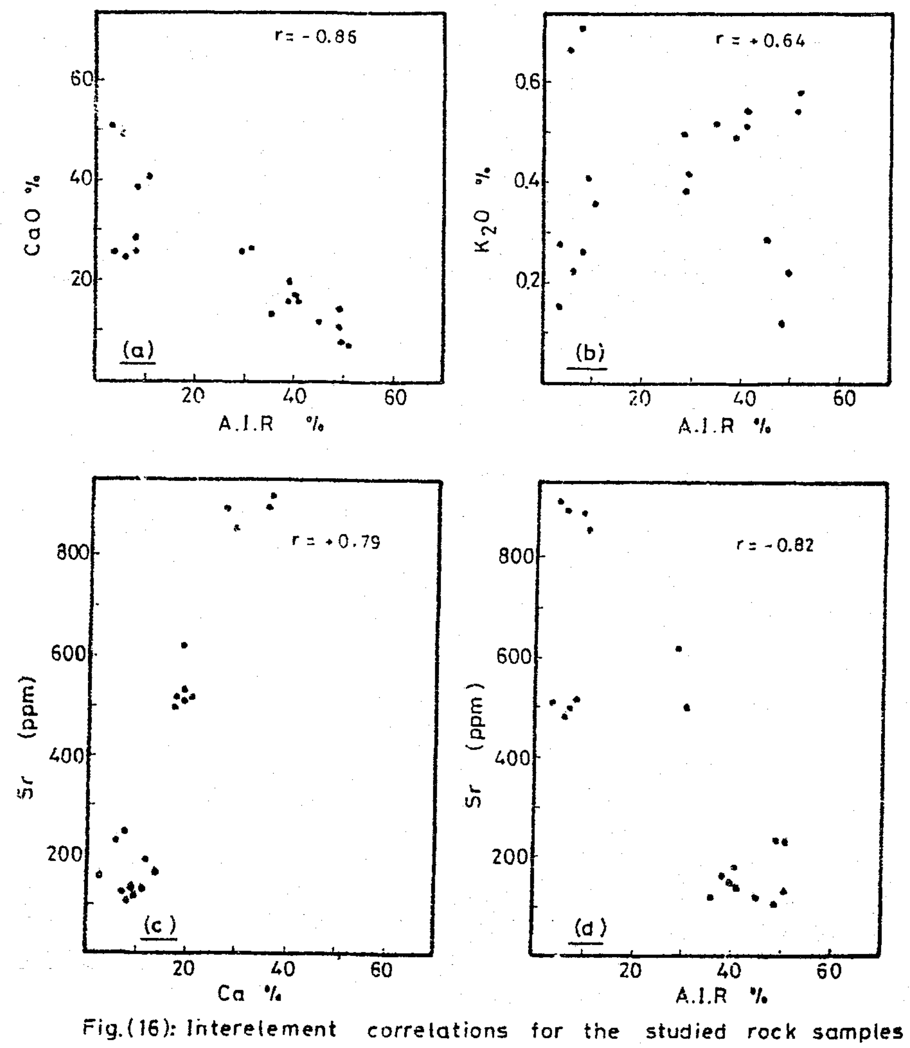


Fig.(16): Interelement correlations for the studied rock samples at Misri - 1 well, northeastern Sinai, Egypt.

1 - Recrystallization as neomorphic process :

The presence of the micrite relicts and the graduation from micrite to microsparite are evidence for the recrystallization process. There are two types affecting the recrystallization of the particles.

a - Aggrading recrystallization and b - Degrading recrystallization.

a) Aggrading Recrystallization :

The particles subjected to this type of recrystallization will be altered into coarsely crystaline calcite more or less merging within the surrounding matter and enclousing them as in sample la (Fig. 3_a). The alteration begins at the margins of the particles and spread inwardly to altering their internal structure. Ghosts within the matrix are observed in thin sections.

b) Degrading Recrystallization :

This type of recrystallization leads to reduction in the grain size of the particles and can be observed in samples 3a, 6a and 9a representing different types of degrading recrystallization including:

1 - High degree of recrystallization leading to complete obleteration of the particles and the matrix into microsparry calcite.

2 - Obliteration of the internal structure of the particles through "micritization" stage according to Bathurst (1975).

3 - The lime mud invades the internal texture and change it

into a mass of lime - mud with only the external shape of the original grains.

2 - Dolomitization :

This process affected the core samples represented by samples 4a,5a and 6a where extensive dolomitization took place especially in samples 4a and 5a. Some twin crystals of dolomite rhomite that resulted from the coalesecnce of two adjacent dolomite rhombs, were observed (Fig. 5a). This may be regarded as a result of the crystallization of some dolomite rhombs. From the petrographic investigation, the presence of line grained dolomite crystals indicates that dolomitization process was active directly after deposition.

3 - Silicification :

This process affected the core samples of Misri -1 Well represented by samples No.6a, 9a, 9b and 10b. The source of silica content may derived from the shaly samples associated with the core samples as endogenic origin. The existence of composite quartz grains showing wavy extinction and the well - sorted crystals showing sutures among the micritic groundmass indicate that the rock was subjected to tectonic stress (Tucker, 1984).

CONCLUSIONS

The petrographical, mineralogical and geochemical studies for the core samples collected from Misri-1 Well have revealed that there are four types of facies from surface to bottom; sparry biomicrite; dolomitized micrite, marly dolomitized sparrymicrite and marly micrite facies. They are mineralogically and chemically different. X-ray analysis has revealed that calcite, dolomite, kaolinite and quartz are the main constituents whereas halite, gypsum and illite minerals are detected as minor minerals. The presence of kaolinite may indicates a typical tropical sediment, derived from feldspars by both hydrothermal alteration and superficial weathering and illite may be present due to incomplete degradation of potash feldspars or to the diagenesis of kaolinite under non-marine environment. A sharp exothermic effect at 890 - 925 °C confirms the presence of kaolinite and the other exothermic effect at 375 - 390 °C suggests the detection of carbonaceous matter. The sparry biomicrite is characterized by high percentage of CaO and Loss on ignition (L.O.I). Dolomitized micrite is characterized by high percentage of CaO, MgO and L.O.I while marly micrite is characterized by high values of SiO_2 and Al_2O_3.

Finally, from the petrographic examination and by the aids of x-ray and chemical analyses three types of diagenetic processes affected the core samples collected from Misri-1 Well, recrystallization of aggrading and degrading types; dolomitization and silicification. The necessary condition for dolomitization had been discussed by many authors Wilson (1957) suggested a slow kinetic process for dolomitization, Teodorovich (1959) showed that dolomite may be formed under a variety of conditions; most of them is due to replacement. Ingerson (1962) suggested a replacement formation for dolomitization. Friedman and Sanders (1967) also agreed with Ingerson for replacement processes of dolomitization. Land et al. (1975) showed that dolomite indicates dolomitization resulting from early meteoric influx into marine carbonate deposits.

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دراسات معدنية وجيوكميائيه على صخور الكريتاوى تحت السطحية
فى بئر مصرى - ١ بشمال سيناء

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يهتم هذا البحث بالدراسات المعدنية بواسطة أشعة أكس والأشعة الحرارية والكميائية للعينات المحمعة من بئر مصرى -١ بشمال شرق سيناء تتكون هذه الصخور من معادن الكالسيت والدولوميت والكاولين والكوارتز كمكون أساس بينما يشكل كل من الأليت والجبس بنسبة ضئيلة وتنقسم هذه الصخور إلى أربعة أنواع مختلفة من الناحية والكميائية.

حجر جيرى نقى . حجر جيرى به نسبة رمل، دولوميت، وطفلة. وقد تعرضت هذه الصخور إلى عملية الإحلال للماغنسيوم بالكالسيوم بتكون الدولوميث ويويعزى هذا الوجود المحاليل المهاجرة من صخور الطفله التى توجد أسفل الدولوميث وأيضا إلى تكون السيليكا. وأن هذه الصخور قد ترسبت فى بيئات مختلفه فمنها Neritic والبحرية الضحله والحافية .