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Lithofacies, diagenesis, and depositional history of the Wata Formation (Turonian) at Wadi Abu Risha, west of Wadi Araba, Eastern Desert, Egypt.

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ABSTRACT

Petrographic studies of the different rock types revealed that the limestones comprise lime mudstone, sandy wackestone, bioclastic packstone, sandy Oolitic grainstone. Dolostones are composed of dolomicrite and dolosparite. The sandstones are represented by quartz arenite.

Dolomitization is the most important diagenetic process affecting the different studied rock types. They are: Cementation, recrystallization and dedolomitization processes on the basis of chemical analysis and carbon and oxygen isotopes, the dolomites were formed under mixed (marine-meteoric) waters.

The depositional patterns of the Turonian of Wata Formation lithofacies were probably deposited in shallow water (subtidal to intertidal). Salinity varies from normal to somewhat higher very moderate marine circulation. Water conditions are favorable for organisms.

INTRODUCTION

Wadi Abu Risha lies in the northwestern side of Wadi Araba (south of the northern Galala) between lat. 29° 02′- 29° 15′N and long. 31° 40′ – 31° 53′E of the Eastern Desert, Egypt (Fig. 1). In Sinai and in the western side of the Gulf of Suez, the Turonian represented by two distinct formations; the Abu Qada Formation at the base and the Wata Formation at the top (Said, 1990). Moreover, the facies of the Wata Formation changes northwards at Gabal Ataqa, it consists essentially of dolostone such facies named Maghra El- Hadida Formation, (El-Akkad and Abdallah, 1971).

The Wata Formation measures 102m thick, at its type locality at Wadi Wata, while it measures about 86.8m thick. at the studied area. It consists exclusively of intercalation of dolostone and limestone with thin bed of sandstone at the middle part. The age assignment of the wata Formation dated back to Late Turonian (Ghorab, 1961, Cherif et al., 1989 and Orabi, 1992).

The present work aims at studying the petrography, diagenetic changes and the chemical composition of the Wata Formation at Wadi Abu Risha. Stable oxygen and carbon isotopic analyses especially for dolomite rocks were undertaken in order to discuss the origin of dolomites, depositional environment and the geologic history.

METHODS AND MATERIALS OF STUDY

A total of 61 rock samples were collected from the different rock types of the Wata Formation and about seventy thin sections have been prepared and examined petrographically. Some of thin sections were stained with Alizarin Red S and Potassuim Ferricyanide using the procedures developed by Dickson (1966) to differentiate between carbonate minerals. Dunham's terminology (1962) is used here to describe the petrographic texture of the limestones. Terminology proposed by Friedman and Sanders (1978) is also used to describe the petrographic textures of dolostones. However, the classification proposed by Pettijhon et al., (1972) is used to describe the petrography of sandstones.

Chemical analysis of 32 samples for major oxides and some trace elements were carried out in order to throw some light on the chemical nature of the studied rocks. The chemical analyses were carried out in the laboratories of the Nuclear Materials Authority. Oxygen and carbon isotopic analyses were carried out for the dolomite rocks in the laboratory of environment studies, Debrecen, Hangary, to discuss the origin of these dolomites and the geological history is discussed.

LITHOSTRATIGRAPHY

In the study area the Wata Formation conformably overlies the Cenomanian Galala Formation of base unexposed and unconformably underlies

Fig. (1): Location Map of the studied area. (after Conoco, 1987).

the Senonian Matulla Formation.

Dolomites and dolomitic limestones represent the main rock types of the Turonian Wata Formation at Wadi Abu Risha with shales and sandy limestones. It is well exposed as isolated hills with thickness of about 86.8 meters; the basal part is marked by the occurrence of an "ammonite bed". Lithological description of the stratigraphic sequence is given in (Fig. 2).

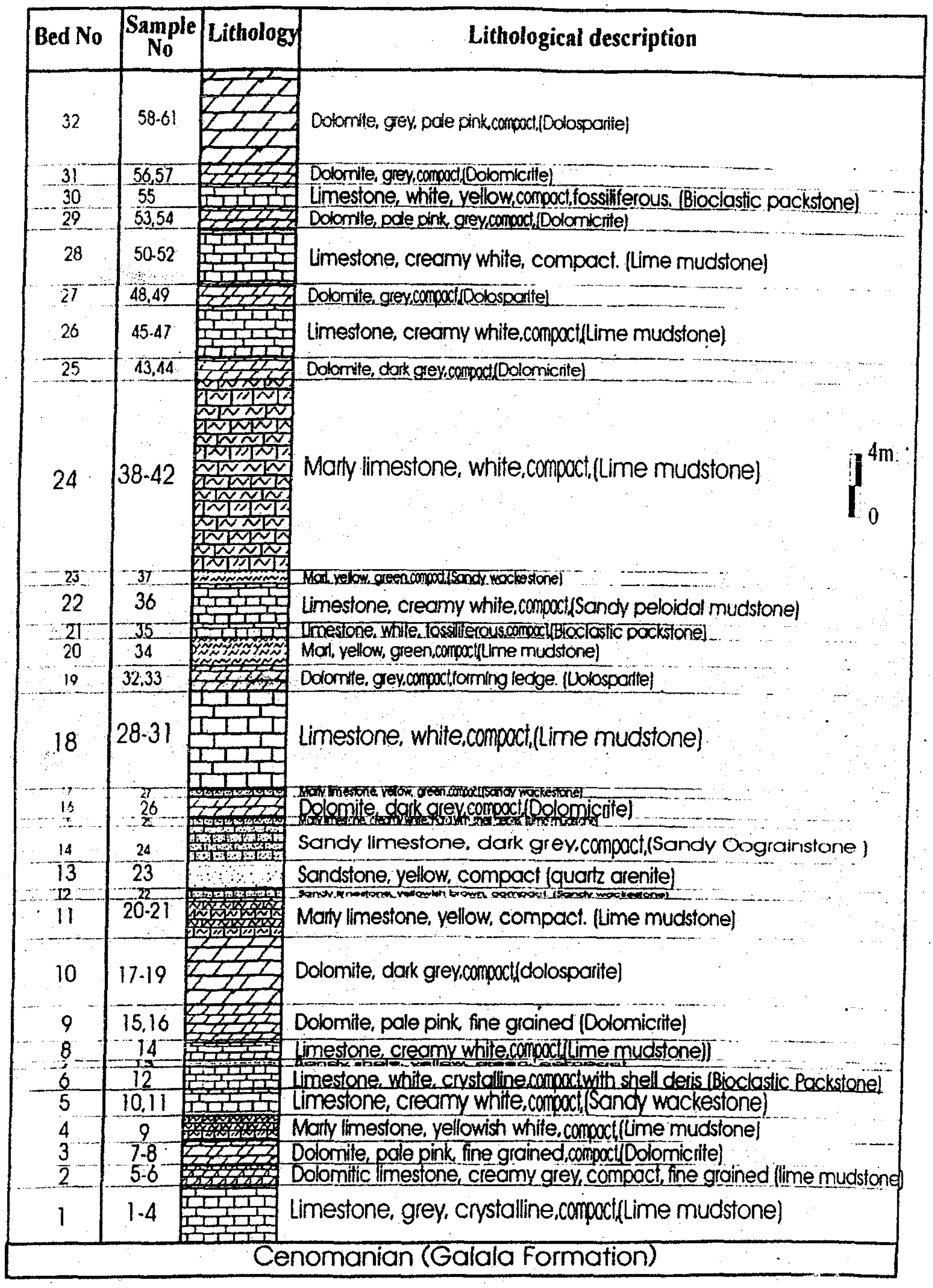
The Wata Formation is characterized by shallowing upward cycle appear in the upper part that consists of white, yellow limestone or marl at the base capped by pale pink, gray, dolomite at the top. A cycle of another type that appear in the lower part of this succession consists of limestone, clayey at the base, creamy white, pale pink dolomitic limestone or white to yellow marly limestone at the middle and capped by pale pink dolomite or yellow sandstone at the top (Fig. 2).

LITHOFACIES

The petrographic investigations of these rocks have been carried out to interpret the environmental conditions of deposition and understand the diagenetic processes affecting the consolidated rocks. These lithofacies are lime mudstone, sandy peloidal mudstone, sandy wackstone, bioclastic packstone, sandy oolitic grainstone, dolomicrite, dolosparite and quartz arenite.

Lime mudstone

This type comprises a greyish to yellowish brown micritic mudstone, which is recrystallized in some parts to clear patches of microsparite. In this lithofacies the lime mudstone often changes into microsparry calcite as a result of recrystallization, which increases in some places to give rise to pseudospar (aggreding neomorphism, Fig. 3). The iron oxides have been spread outwards along the margins of the microsparry crystals during the recrystallization. Very fine quartz grains (<2%) (XSiO2 = 1.52%) are scattered randomly within the lime mud (80–90µm). Also, very fine-zoned dolomite rhombs (3-4%) are dispersed. Some foraminiferal tests, bivalve shells, gastropod, algae and shell fragments are observed. Most of these bioclasts were underwent a recrystallization that distorted their original structure. The presence of various kinds of fossils, glauconite and



Bed No	Sample No	Lithology	Lithological description
32	58-61		Dolomite, grey, pale pink,compact,(Dolosparite)
31	56,57		Dolomite, grey,compact,(Dolomicrite)
30	55		Limestone, white, yellow,compact,fossiliferous. (Bioclastic packstone)
29	53,54		Dolomite, pale pink, grey,compact,(Dolomicrite)
28	50-52		Limestone, creamy white, compact. (Lime mudstone)
27	48,49		Dolomite, grey,compact,(Dolosparite)
26	45-47		Limestone, creamy white,compact,(Lime mudstone)
25	43,44		Dolomite, dark grey,compact,(Dolomicrite)
24	38-42		Marly limestone, white,compact,(Lime mudstone)
23	37		Marl, yellow, green,compact,(Sandy wackestone)
22	36		Limestone, creamy white,compact,(Sandy peloidal mudstone)
21	35		Limestone, white, fossiliferous,compact,(Bioclastic packstone)
20	34		Marl, yellow, green,compact,(Lime mudstone)
19	32,33		Dolomite, grey,compact,forming ledge. (Dolosparite)
18	28-31		Limestone, white,compact,(Lime mudstone)
7	27		Marly limestone, yellow, green,compact,(Sandy wackestone)
16	26		Dolomite, dark grey,compact,(Dolomicrite)
[illegible]	25		Marly limestone, creamy white, [illegible] with shell [illegible] (lime mudstone)
14	24		Sandy limestone, dark grey,compact,(Sandy Oograinstone)
13	23		Sandstone, yellow, compact (quartz arenite)
12	22		Sandy limestone, yellowish brown, compact. (Sandy wackestone)
11	20-21		Marly limestone, yellow, compact. (Lime mudstone)
10	17-19		Dolomite, dark grey,compact,(dolosparite)
9	15,16		Dolomite, pale pink, fine grained (Dolomicrite)
8	14		Limestone, creamy white,compact,(Lime mudstone))
7	13		Sandy shale, yellow, green, compact
6	12		Limestone, white, crystalline,compact,with shell deris (Bioclastic Packstone)
5	10,11		Limestone, creamy white,compact,(Sandy wackestone)
4	9		Marly limestone, yellowish white, compact,(Lime mudstone)
3	7-8		Dolomite, pale pink, fine grained,compact,(Dolomicrite)
2	5-6		Dolomitic limestone, creamy grey, compact, fine grained (lime mudstone)
1	1-4		Limestone, grey, crystalline,compact,(Lime mudstone)
Cenomanian (Galala Formation)			

Fig.(2): Columnar section of the Wata Formation (Turonian) at Wadi Abu Risha

very fine quartz grains indicate a subtidal marine environment below the wave base.

Sandy peloidal mudstone

This lithofacies mainly consists of micrite matrix (CaO= 36.05%, table, 1) with considerable proportion of allochems (up to 10%). However few grains of algae are present in bed no. (22). The non-skeletal carbonate grains are represented by homogeneous pellets that are well rounded and embedded in micrite matrix (Fig. 4). The terrigneous material are very fine quartz, silt and clays (SiO2= 8.5 %&Al2O3=6.37%). Very minute dolomite rhombs are scattered in matrix. The absence or scarcity of bioclastic grains associated with the micrite matrix indicates deposition in shallow subtidal zone under high energy of dominant normal salinity. The terrigneous material in the form of clay present in a considerable amount can be attributed to increase in silt and clay amount delivered into the site of deposition either by running water, fluctuation of sea level or as a result of the lack of strong currents and turbulence of water.

Sandy wackestone

This lithofacies is made up of quartz grains {XSiO2= 12.44 % & Al2O3= 2.54%) embedded in micrite (XCaO= 34.17%) in addition to 2% of pellets, 8% of shell fragments and < 1% of glauconite with disseminated dolomite (XMgO= 1.20%). Partial recrystallization of micrite to microsparite and more recrystallization give blocky calcite (Fig. 5). Quartz grains in this lithofacies are usually moderately sorted, subrounded to rounded in shape. They are of monocrystalline type, but a few grains are polycrystalline type and have fine sand size (70–90µm). A few very small rounded. Pellets and greenish yellow, rounded glauconite in addition to 3% fragments of echinoids plates and bivalve are noticed in the groundmass. These consider that this lithofacies was deposited under shallow marine in the shallower part of the intertidal zone.

Bioclastic packstone

This lithofacies comprises micritic matrix (XCaO= 52.47%) with considerable proportion of allochems (more than 10%). Shell fragments of gastropods and bivalves, algae and calcispheres, represent the bioclastic carbonate grains. The non–skeletal grains are generally scarce represented by pellets. Dolomitization (XMgO= 1.48%), has partially affected the miritic matrix producing scattered dolomite rhombs in matrix (Fig. 6). Clays are the terrigenous material in this lithofacies (XSiO2= 2.36% & XAl2O3= 0.95%). This lithofacies most probably deposited under shallow marine environment as proved by 1- The presence of fossil tests (gastropods and bivalves) and shell fragments 2- The presence of drusy calcite filling the internal structure of fossil tests (intraporosity) (Flügel, 1982). The presence of algae associated with calcisphers (fruiting case of algae) favors the shallow marine depositional environment where sunlight was still available for photosynthesis of algae. Under these shallow marine conditions micrite can be formed either by direct inorganic precipitation of aragonite (suspended masses of aragonite needles known as whitings) or caused by strong bottom currents stirring up fine sediments (Blatt. et al., 1980).

Sandy Oolitic grainstone

The rock is composed of micrite matrix (XCaO= 43.81%) with considerable proportion of allochem. Algae represent the skeletal grains, while, ooids and peloids represent the non-skeletal grains. Terrigenous material is presented as fine sand, and silt (XSiO2= 18.32% & XAl2O3= 1.55%) (Fig. 7). The oolites are of the suprficial type and consist of concentric lamellae of micrite around organic fragments. Some of them are radial and their diameter is less than 0.5mm. They coat the bioclasts belonging to different type of organisms. Presence of oolites with rounded bioclasts may suggest high agitation of water at the end of shallowing upward cycles. The oolites need warm condition and shallow depth to be formed (Wilson, 1975 and Flügel, 1982). Also, the high-agitated water produced the fragmented bioclasts that occur as a nucleus to the oolites. The presence of agitated currents associated with elevated temperature might be sufficient to bring carbonate precipitation on nuclei and to form ooids. It is clear that the lithofacies was deposited under normal marine conditions in the shallower part of intertidal zone.

Dolomicrite

The rock is essentially made up of fine-grained dolomite rhombs (70-85 µm) with *micritic* to microsparitic calcite crystals (8%) (Fig. 8). The rhombs are closely packed exhibiting xenotopic and hypidiotopic texture with an equigranular fabric. Most of these rhombs contain a dark core of opaque iron oxides with thin clear outer rim (Fig. 9). Sometimes the rhombs exhibit a cloudy surface. The dolomite rhombs in some parts of this lithofacies are partially recrystallized to calcite (dedolomitization process) giving a poikilotopic texture (Fig. 9).

Dolosparite

This lithofacies is composed essentially of dolomite (70–90%), blocky calcite (10-20%), quartz grains (1-3%), shell fragments <4%, and iron oxides (Fig. 10). Two types of dolomite rhombs can be noticed. The first is fine-grained (120–160µm), that shows dark brown patches in the rock. These rhombs are hypidiotopic to xenotopic in texture and with an equigranular fabric. The cores that constitute the main bulk of rhombs are stained with iron oxide, whereas their outer peripheries are rimmed with clear zone (Fig. 10). The second type is coarse-grained (240–320µm), having hypidiotopic to idiotopic texture with inequigranular fabric. The zonal structure of the dolomite rhombs consists of dark core iron oxide scattered with random orientation, and clear outer rim some of these rhombs show a cloudy surface without any core (Fig. 11). Also, the iron oxides associated with fine-grained dolomite (Fig. 10) are expelled away and precipitated as dark patches in different parts of the rock. Some of them resulted from the coalescence of two adjacent dolomite rhombs (Fig. 11). The calcite crystals replacing the periphery of the rhombs usually invaded inside the core of the rhombs. Sometimes, the calcite replacement (dedolomitization process) proceeds along fissures and cracks, which represent the pathway of fresh water, so that most of the dolomite rhombs in this fissure were completely replaced by calcite (Fig. 10).

Quartz arenite

The rock is the only clastic rock in the Wata Formation, it is thickness is about 1.6m. The rock is made up of quartz grains (85-90%), dolomite rhombs (2%), glauconite <1% with iron oxides and micrite cement. Rounded to subrounded, well-sorted quartz grains ranging in size from 220 to 280μm is recorded. The majority of the grains are monocrystals having straight to slightly undulose extinction. A few grains are of polycrystalline type giving undulose extinction (Fig. 12). Dolomite rhombs are hypidiotopic in texture and inequigranular fabric. Zoning is expressed by the presence of small core of iron oxide. Glauconite grains are green to yellowish green.

Diagenetic Processes

The main diagenetic processes that affected the Wata Formation at Wadi Abu Risha are 1- Cementation (overgrowth syntaxial type) 2- Recrystallization, 3- dolomitization and 4- dedolomitization.

1- Syntaxial calcite overgrowth cement

This cement is common in sandy wackestone where it contains echinoid plates. The echinod fragment is surrounded by thin crust of syntaxial calcite rim cement (Fig. 13), which indicates an early cementation under subsurface diagenesis (Flügel, 1982). As the echinoderms consist of low Mg-calcite and have one-calcite crystals so, the precipitated calcite takes the same orientation. However, due to their highly porous calcareous plates they are more easily affected by diagenesis (Dullo, 1990).

2- Recrystallization

Recrystallization affected the matrix and even the particles especially in the facies rich in unstable (high Mg-Calcite) skeletal grains. Neomorphism of these shallow marine sediments could take place in meteoric environment during early stages of their diagenesis (Longman, 1977). The lime mud matrix inbetween the grains in the studied lithofacies have been suffered from aggrading neomorphism where it is converted into microspar. In more advanced stage of recrystallization, all the microspars changed into coarse pseudospar (Fig. 14). In the studied lithofacies, the molluscan particles are the most extensively recrystallized. In some cases, the recrystallization begins from the periphery and continues towards the center of shell (Fig. 15). In advanced stages of recrystallization, the whole particles have been changed into pseudospar and consequently its original morphology is hardly recognizable. The origin of both partial and complete aggrading neomorphism of matrix and skeletal particles may be resulted from the effect of a thin solution film of circulating fresh water moved through them dissolving the early formed carbonate (usually aragonite and high Mg–cacite) in front and precipitating low Mg–calcite behind without change in the fabric of skeletal particles (Bathurst, 1975).

3- Dolomitization

The dolomitization process of the Wata Formation at Wadi Abu Risha is based on several factors (a) petrographic characteristics of dolomite rhombs. (b) the stratigraphic position of the former carbonates. (c) geochemical analyses of major oxides and trace elements and. (d) carbon and oxygen isotopes.

a- Petrographic characteristics

The studied dolostone and dolomitic limestone are characterized by two phases of dolomitization, the first phase is early producing, fine–grained dolomite, while the second phase is late producing coarser dolomite rhombs. The first type is fine-grained (25-100μm) which is characterized by xenotopic to hypidiotopic texture and equigranular fabrics. They show zoning expressed by small brown core of iron oxides surrounded by clear outer rims (Fig. 16). Usually the first type of dolomites overlies lime mudstone, lithofacies. The second type of rhombs is coarser than the first type ranging in size from 160–320μm. this type is more abundant that overlies the first type of dolomite rhombs and occasionally present together in one bed. Two aspects express the zoning. One of them is characterized by limpid clear calcian core while the several is a small dark brown spot of iron oxide surrounded by successive clear calcite zones.

Lee and Friedman (1987) used the crystal size of dolomite to differentiate early diagenetic dolomitization from late one. They stated that the finer sized dolomite crystals belong to the earlier phase of dolomitization, while the coarser size of dolomite, may belong to the late phase of dolomitization, Recently, Gregg et al., (1992) suggested that dolomite recrystallization occurs in the first few centimeters below the sediment–water interface by surface energy–deriven dissolution–reprecipitation, as inferred from the textures observed: dolomicrite and dolosparite.

b- Geochemical analyses

mMg/mCa (molar ratios) ratio for dolostones varies from 0.89 to 0.99 this reflects the deviation from ideal (1:1) stoichiometry of dolomite (Table. 1).

i- Distribution of Sodium and Strontium

The bulk sodium content in the various facies is related to the diagenetic history of carbonate rock. The precipitation of NaCl cement, derived from evaporation of marine water, could supply Na+ ions during dolomitization. Therefore, in the partially dolomitized samples, Na+ concentration is high but the low Na+ content can characterize the completely dolomitized samples and those that were affected by meteoric diagenesis. In the present work, concentration of Na+ in the dolostone ranges from 127 to 1100 ppm. This indicates that the dolomitization process was less saline than sea water because Na+ concentration for recent dolomites deposited in a marine environment is generally 1000-3000ppm (Randazzo et al., 1987). The low Na+ values suggest mixing of saline waters with fresh water. Mixing of sea water with fresh water was needed to cause undersaturation with respect to CaCO3 and oversaturation with respect to dolomite.

Strontium is the most useful trace element in evaluating the salinity of dolomitizing fluids owing to the nature of the partitioning between dolomite crystals and the waters from they precipitate (Randazzo et al., 1987). The Sr2+ content of dolostones of Wata Formation ranges between 69 and 312ppm. Mitchel et al., (1987) suggested that the marine dolomite attains Sr2+ content of about 500-800ppm. They found that hypersaline evaporatic dolomites contain Sr2+ of about 600-900ppm. It is noticed that sodium and strontium concentrations in the fine and coarse dolomites are low values than those of the Holocene marine and supratidal dolomites. This suggests that dolomitization processes may have taken place in a mixed saline with fresh water medium.

Table (1): Chemical analysis of different rock types of Wata Formation at Wadi Abu Risha

Bed no.	CaO %	MgO %	mMg/ Mca	SiO_2 %	Fe_2O_3 %	Srppm	Nappm	Mnppm	δC^{13}	δO^{18}
32	31.85	20.41	0.89	0.09	0.11	97	649	388	-0.39	0.09
31	30.12	20.65	0.96	0.07	0.13	89.1	220	155	1.64	0.11
30	54.11	0.00	-	0.72	0.46	151	860	600	-	-
29	30.13	21.30	0.98	0.26	0.19	86.9	138	620	-0.36	0.19
28	54.26	0.09	0.002	-	0.41	125	420	200	-	-
27	30.14	21.33	0.99	-	0.23	71.2	130	620	-0.31	0.21
26	29.76	21.51	0.98	-	0.18	77.0	599	233	-	-
25	30.18	21.53	0.98	-	0.27	69.0	127	620	0.30	0.18
24	50.22	0.62	0.02	2.41	1.06	218	860	300	-	-
23	28.33	1.14	0.08	14.58	6.48	138	512	400	-	-
22	36.05	1.12	0.04	8.50	3.05	242	960	300	-	-
21	51.8	1.26	0.007	6.07	1.84	151	1311	900	-	-
20	48.99	2.23	0.06	3.15	0.58	108.6	3104	465	-	-
19	31.92	19.17	0.91	-	0.32	170	1100	288	1.55	1.21
18	51.50	0.65	0.02	0.38	0.89	225.6	984	543	-	-
17	27.50	3.27	0.25	19.36	4.69	178	438	0.00	-	-
16	30.02	20.97	0.97	0.33	1.06	89.4	315	698	-0.57	1.01
15	39.70	8.69	0.30	1.31	3.35	66.9	1812	233	-	-
14	43.81	3.37	0.10	18.32	1.86	192	790	1100	-	-
12	38.33	1.14	0.20	7.58	6.48	138	766	400	-	-
11	40.1	1.33	0.05	2.93	0.62	248.5	1365	698	-	-
10	30.42	20.66	0.92	0.10	0.23	109.7	599	388	0.71	-0.20
9	28.88	21.10	0.89	-	0.11	312	286	333	1.53	1.21
8	51.45	0.57	0.03	-	0.71	360	1263	310	-	-
6	51.50	1.69	0.04	0.30	2.16	175	1008	300	-	-
5	42.51	1.20	0.05	8.24	2.83	189	750	2500	-	-
4	37.52	1.09	0.03	1.33	0.84	332.1	431	310	-	-
3	31.92	19.17	0.91	-	0.32	170	522	265	1.55	0.82
2	28.36	17.4	0.86	3.51	0.58	108.5	310	465	-	-
1	42.04	2.4	0.08	1.10	1.93	269.4	2462	620	-	-

ii- Iron and Manganese

Fe2O3 and Mn2+ in the studied dolomite have low concentrations. The Fe2O3 content ranges from 0.11 to 1.06, with mean value of 0.30% while Mn2+ content ranges from 155 to 698 Mn, with a mean value 438ppm. This suggests that the dolomitization may be probably occurred in an oxidizing environment (surface dolomitization). This may refer to that the pore-waters were depleted is Mn-Fe and Fe2+ and Mn2+ were locked up as oxide/hydroxide compounds (Tucker, 1990).

C- Carbon and Oxygen isotopes

The isotopic composition of the dolostones depends on the isotopic composition of the precursor carbonate rock and that of the solution that caused the dolomitization. Loukina and Abu El-Anwar, (1994) and Given and Wilknson (1987) deduced that dolomites with negative oxygen isotope indicates low Sr2+ concentrations which was probably formed in low-salinity meteoric water, as the meteoric water is unstable to provide sufficient Mg for dolomitization. This suggests that dolomitization had occurred in mixed sea water (mixed-zone).

The mean δ18O value in dolomites of the Wata Formation 0.50 (varies between 1.21 and –0.2‰ δ 18O PDB), while, δ13C ranges between is -0.57 and 1.64‰. Low positive δ13C (0.57‰ mean) suggests derivation of most C in the CO32- from the replaced primary CaCO3, while the δ13C of modern carbonate sediment ranges between about +4 and –2‰ on the PDB scale (Gross, 1964).

From the foreign data the light δ18O and δ13C values immediately exclude any dolomitization mechanism involving hypersaline water. The occurrence of δ18O values higher than 2.5‰ are characteristic of dolomites forming at present time in sabkhas, at tidal flats and areas with active circulation of marine waters (Land, 1985). Mattes and Mountjoy (1980) deduced a relation between crystal size of dolomite and δ18O composition. According to them the increasing dolomite crystal sizes will the δ18O value decrease.

The hypersaline model can't be applied to the Wadi Abu Risha dolostones for the following reasons: (1) Dolomitization was induced by evaporation would result in an increase in the Mg/Ca ratio (range from 2.5-27), high Na and Sr contents in the dolomites. This is not the case in the studied dolostones. (2) The isotopic composition (δ18O and δ13C) of dolomite formed under the hypersaline brine model is distinctly "heavy" whereas the studied dolomites are distinctly light.

Petrographic and geochemical evidence indicate that the mixing–zone of dolomitization was needed for the lowering of Mg/Ca ratio (near stiochiometric dolomite) in the dolomitizing solutions by mixing fresh water with sea water. However this depends on the rate of mixing of both waters. Lower Na, Sr and Mn co-precipitating with the dolomites implies mixing of marine–meteoric dolomitizing solution. So, the dilution aspect in the mixing–zone will cause depletion in isotopic elements especially 818C. Vahrenkamp & Swart (1994) stated that mineral systems of fine–grained dolomite has a faster rate of precipitation that usually resulted in a lighter isotopic composition. Coarse-crystalline textures are as mature or immature as fine- crystalline textures. In general, all the described dolomite textures were probably formed at near–surface conditions.

4- Dedolomitization

Varol and Magaritz (1992) used the term early diagenetic dedolomite for incomplete dedolomitization and late diagenetic dedolomite for the completely calcitized dolomite associated with the generation of redolomite. The pertrographic investigation aided by stainning with Alizarin Red S (Dickson, 1966), provided the partial dedolomitization process cannot give clear blocky calcite, but the whole dolomite zones can be changed into calcite that are psedomorphs after dolomite that observed with some remnants of dolomite within calcite (Fig. 17), giving a poikilotopic fabric. In general the replacement is initiated from the outer periphery of dolomite rhombs. In farther advance of dedolomitization crystals are more frequent than dolomite along cracks. In this case, the replacing calcite crystals coalesce together and constitute the bulk of the rock,

GEOLOGICAL HISTORY

The geological history and the depositional environment of the Wata Formation at Wadi Abu Risha are based on synthesis of the field and stratigraphic data together with petrographic and geochemical configuration before and during deposition. During the Cretaceous and Early Tertiary, the Northeastern Desert was subjected to the Syrian Are movements. This tectonics was most probably responsible for the variation in the vertical and laterial facies changes of the Upper Cretaceous rock units from Gabal Ataqa in north to El-Galala El-Qibliya in the south.

The prevailing rock types are show great variety of the depositional textures from grainstone to mudstone with much pelleting of micrite matrix. The Turonian (Wata Formation) lithofacies depositional pattern represents sediments of shallow water, generally a few to tens of meters deep. Salinity varies from essentially normal to somewhat higher marine circulation is very moderate and water conditions are favorable for organisms.

The large-scale circulation of near–normal sea–water (Tethys Sea) that covers the northern parts of Egypt especially during the Late Cretaceous and Tertiary induced by an overlying freshwater lens could create a dolomite body. Exposure of carbonate and rain will cause the creation of a fresh water lens within carbonate body. At the interface between fresh and marine waters, diffusion and physical mixing as a result of energy–level variations (i.e. tides, wet/dry seasons, etc.) will create a zone of mixed–salinity water. Hence flow in the mixing zone is from the deepest part of the fresh water lens towards its outer limits parallel to the sea water–fresh water interface. Sea water has to enter the side of carbonate platforms and circulate in the subsurface with a volume equal to half of the mixing–zone discharge into the ocean.

During dolomitization, rocks must be near or below sea level in order to physically ensure that sea water can provide the necessary magnesium ions. Thick sequences of dolomite may be built up as consequence of multiple regression. The dolomite that suffered from dedolomitization process is well developed in several beds throughout the study area. It displays partial and complete replacement of dolomite rhombs producing massive and blocky calcite crystals. Petrographic studies and geochemical analyses showed that the absence of evaporite minerals associated with calcite replacing dolomite indicating that dolomites were not altered by CaSO4 solution. The dedolomitization process of the study lithofacies is favoured by percolation of meteoric water in and around cracks of the exposed surface dolomite rhombs, being deficient in Mg++ ions. The meteoric water was removed the Mg ion from dolomite and inturn calcite crystals can be formed. Hence, the occurrence of dedolomite is a good indication of the supratidal zone which is characterized by intermittent with subaerial weathering where the replacement of dolomite by calcite is accomplished.

SUMMRY AND CONCLUSIONS

The present study deals with geological and sedimentological studies on Wadi Abu Risha that lie in the northwestern side of Wadi Araba (south of the northern Galala) between lat. 29° 02'- 29° 15'N and long. 31° 40' – 31° 53'E. This work is concerned with the stratigraphic sequence, petrography, diagenetic changes, different chemical analyses and depositional conditions that prevailed during the sedimentation of the Turonian age (Wata Formation).

In the study area the Wata Formation conformably overlies the Cenomanian Galala Formation of base unexposed and unconformably underlies the Senonian Matulla Formation. Dolomites and dolomitic limestones represent the main rock types isolated hills with thickness of about 86.8 meters; the basal part is marked by the occurrence of an "ammonite bed".

The petrographic investigations of these rocks revealed that these lithofacies are lime mudstone, sandy peloidal mudstone, sandy wackstone, bioclastic packstone, sandy oolitic grainstone, dolomicrite, dolosparite and quartz arenite. The main diagenetic processes that affected the Wata Formation at Wadi Abu Risha are Cementation (overgrowth syntaxial type), Recrystallization, dolomitization and dedolomitization.

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The depositional environments of the Wata Formation were deposited under deep subtidal and shallow subtidal gave rise the deposition of lime mudstone under calm condition and slight cold water changed to become shallower water, warm water, which led to the flourishing of different type of organisms. While, the dolomitization process was probably due to the mixing of saline sea and fresh water; this based on the distinctly light δ18O isotope

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Fig. (3): Lime mud recrystallized into clear patches as a result of aggreding neomorphism and contains few subrounded quartz grains. (bar scale: 100μm).

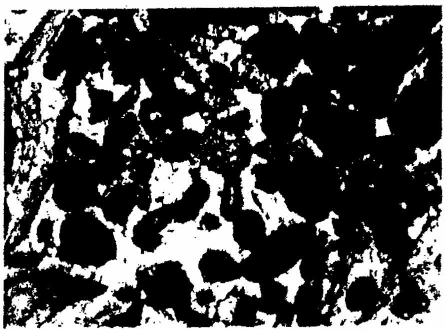


Fig. (4): Moderately sorted pellets of dense lime mud and some of algae debris show partial aggreding neomorphism with a sharp contact in a microsparite matrix. (bar scale: 300μm).

Fig. (5): Monocrystalline, fine–quartz grains and recrystallized fragments of bivalve and echinoids plates are cemented by lime mud that suffered from partial recrystallization into microsparite. (bar scale: 300μm)

Fig. (6): Very dense lime mud cementing bioclast grains represented by algae with gastropods, very fine quartz grains and some shell fragments. (bar scale: 300μm)

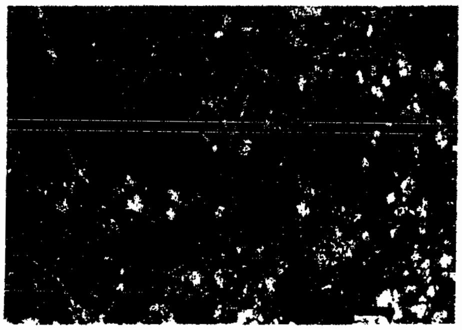


Fig. (7): Superficial, concentric and radial oolites with few bivalve and foraminiferal tests suffering recrystallization. (bar scale: 300μm).

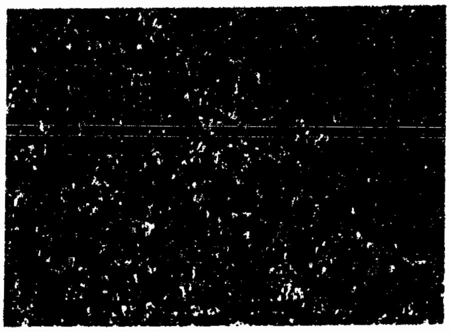


Fig. (8): Inequigranular, hypidiotopic dolomicrite rhombs showing zoning expressed by dark core and clear outer rim. (bar scale: 300μm).

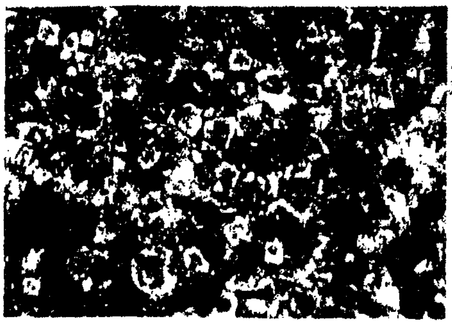


Fig. (9): Inequigranular, hypidiotopic dolosparite in which the iron oxide stained a small dark zone of dolomite rhombs whereas their outer peripheries are rimmed with *clear* zone. (bar scale: 300µm).

Fig. (10): Blocky calcite crystals replacing the zonal, *hypidiotopic* and *idiotopic* dolomite rhombs (dedolomitization process). (bar scale: 300µm).

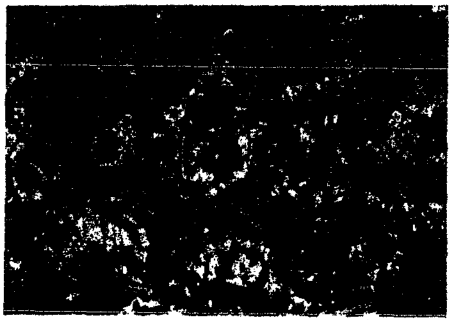


Fig. (11): Hypidiotopic to idiotopic of zonal *dolosparite that* replaced by calcite crystals (dedolomitization process) in center. (bar scale: 300pm).

Fig. (12): Hypidiotopic dolomite rhombs, and subrounded quartz grains binded by microcrystalline micrite. (bar scale: 300µm).

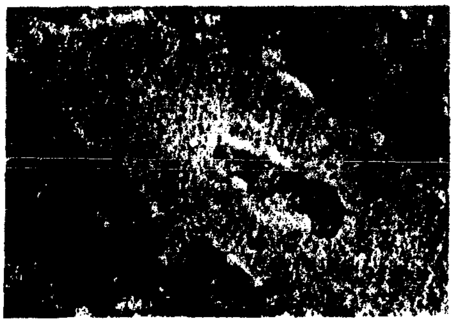


Fig. (13): *Syntaxial overgrowth on echinoderm* fragments. The rim appears to be space-filling *cement, note* neomorphic replacement of the micrite. (bar scale: 300µm).

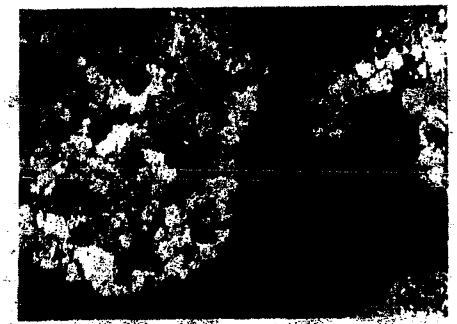
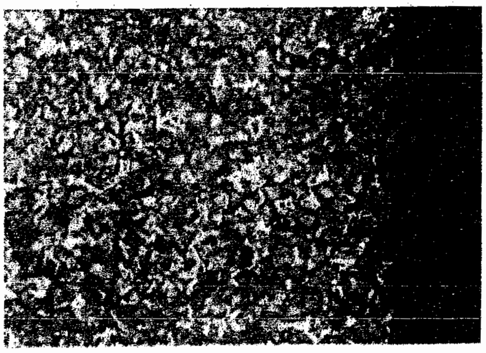


**Fig. (14): A different stages of recrystallization occurring in the lime mud matrix (aggreding neomorphism) begins from microsparite to coarse pseudosparite in a contact with the recrystallization relics of lime mud matrix.
(bar scale: 150µm).**

Fig. (15): Molluscan and foraminiferal tests had susceptible to aggreding neomorphism and its original morphology is hardly recognized. (bar scale: 200µm)

Fig. (16): Photomicrograph showing xenotopic and hypidiotopic dolomite rhombs in a sharp contact with lime mud lithofacies. (bar scale: 150µm).



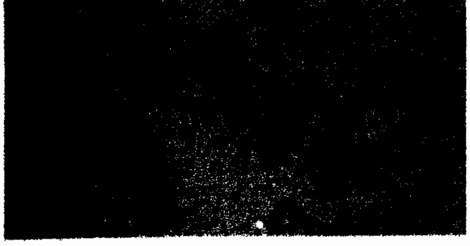


Fig. (17): Photomicrograph showing the dedolomitization process beginning from the outer periphery progressively invading the center of the rhombs (bar scale: 150µm).