STABLE ISOTOPIC COMPOSITION, STOICHIOMETRY AND ORIGIN OF SILICEOUS DOLOMITE OF NAQB SIWA MEMBER BAHARIYA OASIS, EGYPT

By

H. HOLAIL* and K. K. C. LOHMANN**

* Department of Geology, Faculty of Science, University of Qatar, Doha, Qatar
** Department of Geological Sciences, The University of Michigan, Ann Arbor, MI. 48109, USA.

تركيب النظائر الثابتة وأصل الدولوميت السليسي
الواحـات البحريـة – مصــر

حنـفي هليــل   و   كيجــر لومـــان

يتناول هذا البحث دراسـة تتابع الدولومـيت السلـيسي لعصر الكامبـاني السـفلي بالواحات البحرية – مصر . حيث يحتوي الدولوميت على عقد ودرنات من الشيرت وكذلك عدسات يملؤها معدني الكوارتز والكالسيت . وقد وجد أن الدولوميت قد تكون نتيجة إحلال لصخور الكربونات الأصلية ، مع وجود نسبة بسيطة من الدولوميت كمادة لاحمة . وقد أثبـتت تحـاليل النظائـر الثابتـة للأكـسـجين والكربون وكـذلك عنصـري الصـوديوم والاسترانشيوم أن عملية الدلتة قد تمت في وجود محاليل خليط من المياه البحرية والمياه الجوية بينما عكست نفس التحاليل وجـود محاليـل بحريـة ممثلـة في تكون بلورات الدولوميت داخل عقد الشـيرت .

وقد أوضـحت هذه الدراسـة وجـود خـمـسة عمليات ثانوية أثرت بالتتـابع على هذه الصخور وهي : دلتة جزئية لصخور الكربونات الأصلية بواسطة محاليل بحرية ، تسلكن أولي وإحلال لصخور الكربونات الأصلية ، دلتة كاملة لصخور الكربونات بواسطة محاليل خليط (بحرية + جوية) ، تكون مادة لاحمة من السليكا والدولوميت ، وأخيراً تكون بلورات الكالسيت من محاليل جوية .

Key Words: Stable isotope, Chert, Dolomite, Bahariya Oasis, Egypt.

ABSTRACT

The Lower Campanian Naqb Siwa member exposed near Bahariya Oasis, Egypt, is a shoaling-upward dolomite sequence that hosts chert nodules and lenses and cavity fillings of quartz and calcite. Dolomite is dominantly replacive, but also includes pore-filling cement. Slightly negative $\delta^{18}O$ compositions (average -2.2 ‰ PDB), and oxygen covariation with Na and Sr contents, reflect dolomitization in the presence of variable meteoric-marine fluid mixtures. However, isotopic and trace element values of dolomite rhombs in chert nodules reflect the signature of marine conditions. $MgCO_3$ contents correlate positively with $\delta^{18}O$ and negatively with Sr contents.

A sequence of five diagenetic events is recorded by relations between various authigenic phases. These are: 1) partial dolomitization by marine fluids; 2) early silicification and replacement of original carbonate sediments; 3) complete dolomitization of the carbonate sediments in mixed marine-meteoric fluids; 4) silicification and dolomite cementation; and 5) precipitation of void-filling meteoric calcite (mean $\delta^{18}O$ = -9.6 ‰ PDB).

INTRODUCTION

Detailed studies of ancient and recent dolomites have yielded many new insights into the occurrence and formation of various dolomitic sediments. After more than three decades of research, however, the meaning of these insights is still a matter of dispute. This is especially true of epicontinental dolomites that host nodular chert [1-3]. These cherts show fundamental differences in their diagenetic history from those recovered from deep sea sediments [4-6].

Many studies of nodular chert in dolomitic sediments have focused on their petrography and paragenesis, and indicate an origin through the replacement of evaporite minerals that were formed from hypersaline fluids , under arid conditions, at low latitudes [3, 7, 8]. In addition, the presence of dolomite crystals in the chert prompts the problem of dolomite-chert diagenesis. Previous discussion has been focused on the question whether dolomitization process proceeds [9], is simultaneous with [10] or postdates [11] the silicification process. Alternating periods of dolomitization and silicification have also been described. ·

It has also been suggested that the chert associated with dolomite may be characteristic of mixing zone (meteoric-marine) environments, where dolomite rhombs in chert should show isotopic signatures characteristic of precipitation from meteoric water [12]. In this paper, we present and discuss petrographic and geochemical characteristics of co-occurring chert and dolomite from the Lower Campanian sequence at Bahariya Oasis in Egypt, examine their diagenetic origin and evaluate the environment for a dolomite-chert association.

GEOLOGIC SETTING

Dolomite forms Naqb Siwa, the lower member in the Campanian El Hefhuf Formation at Bahariya Oasis, Egypt (Fig. 1). This sequence was deposited in a shallow marine environment and lacks evidence for associated evaporites [13-15]. The Naqb Siwa member is overlain by interbedded shale, sandstone, and dolomite of the middle and upper members of the El Hefhuf Formation, and is underlain by ferroan dolomite of the El Heiz Formation (Upper Cenomanian). The Naqb Siwa member is completely dolomitized and includes grayish-white chert nodules and lenses which show sharp contacts with the dolomite host rock. These nodules are: (1) evenly distributed with no concentration along selective horizons; (2) uneven in size with no internal compositional banding; and (3) inclusion-rich, with dolomite rhombs comprising up to 30 percent of an individual sample. Late coarse-grained calcite fills open spaces and is a common accessory mineral associated with dolomite. Examination of this type of calcite within the entire Upper Cretaceous sequence has demonstrated that it was formed during infiltration of meteoric water during regional erosion,coincident with the development of an Upper Cretaceous-Lower Tertiary unconformity [16].
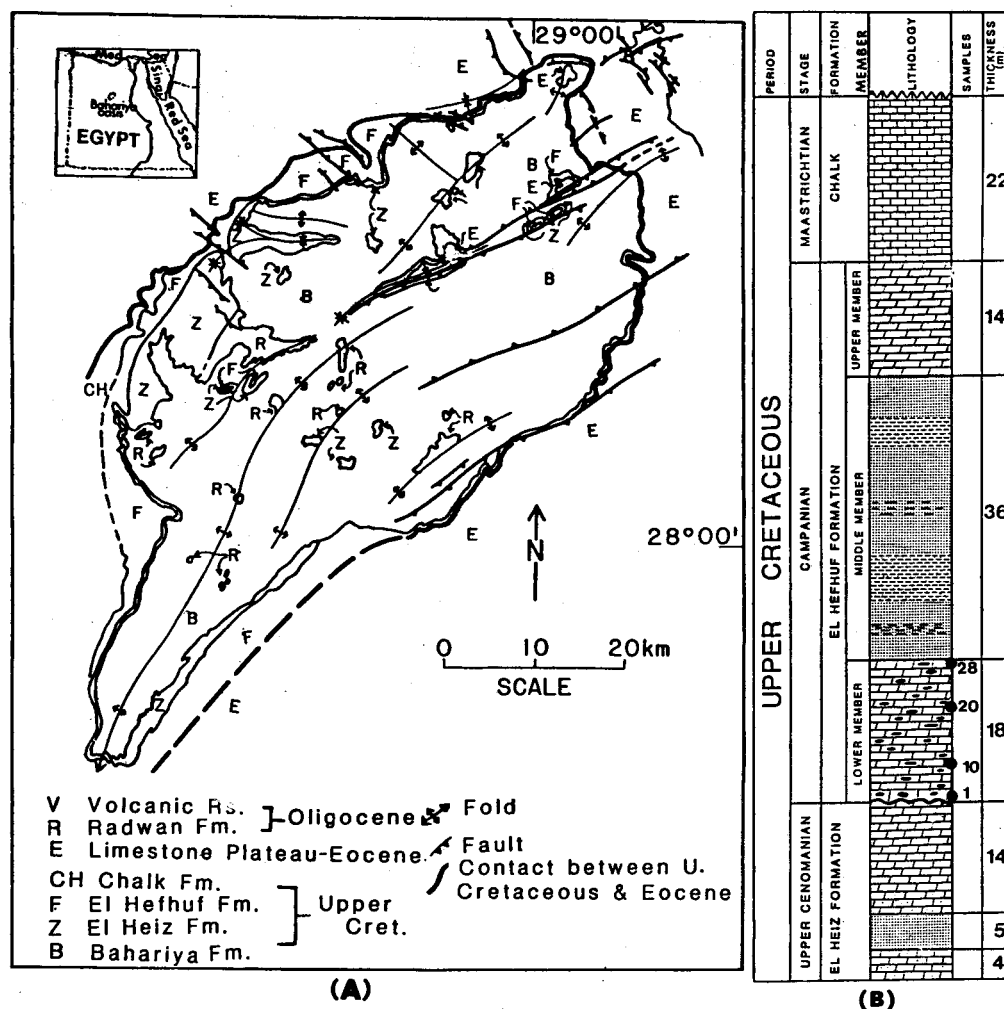

Fig. 1. A- Location map of the Bahariya Oasis. Modified from Said and Issawi [25]. B- Stratigraphic section of the Upper Cretaceous sequence at Bahariya Oasis.

METHODS

Forty dolomite samples were investigated. Textural relations among component phases were examined in polished and stained (Alizarin Red-S and potassium ferricyanide) thin sections. Microstructures were examined in thin sections and by scanning electron microscopy (SEM) of broken surfaces. Polished thin sections were also examined by cathodoluminescence.

All samples were analyzed by X-ray diffraction to determine carbonate mineralogy and dolomite stoichiometry. Ca, Mg and Fe contents were determined by electron probe microanalysis (EPMA). Trace element (Sr, Na and Mn) concentrations were determined by atomic absorption at the University of Michigan.

A microscope-mounted drill assembly was employed to extract 0.2 to 0.5 mg of powdered dolomite or calcite from polished slabs for carbon and oxygen isotope analyses at the University of Michigan. These were roasted under vacuum at 380°C for 1 hour and then reacted at 55°C with phosphoric acid. Dolomite samples were reacted off-line for 4 to 6 hours; calcite samples were reacted in an extraction line coupled directly to the inlet of a mass spectrometer. Isotopic enrichments were corrected for ^{17}O contributions [17]; no correction for the difference in calcite vs. dolomite phosphoric acid fractionation factors was applied. Precision, better than 0.07 per mil for both carbon and oxygen determinations, was monitored through daily analyses of NBS-20.

Fourteen chert samples were analyzed for their oxygen isotopic composition. Chert was separated after crushing by hand picking. Samples were then crushed to fine powder, washed with 20 % HCl to remove carbonate, sieved and oven dried. Oxygen was liberated from chert with bromine pentafluoride [18].

RESULTS

Petrography

Petrographic examination indicates that Naqb Siwa dolomites exhibit distinctive vertical textural variations. At the base is a uniform mosaic of dolomite crystals that contains no clue regarding the identity of the precursor carbonate sediment. Original sediment has been completely replaced by medium crystalline, nonferroan, subhedral dolomite with normal extinction. This type of dolomite is associated with nodular chert and with traces of detrital quartz and pyrite (Fig. 2A). Original sedimentary components, especially foraminifers, are typically well preserved in chert nodules after silicification.

In the upper part of the sequence, dolomite crystals are euhedral and occur in association with fine to coarse-grained quartz cement and nodular chert (Figs. 2B and 3A). Dolomite rhombs vary in size, with intercrystalline material consisting of iron oxide, clay minerals, pyrite and dark-colored amorphous organic matter. Euhedral dolomite crystals illustrated sharp and well-defined terminations (Fig. 3A). Individual crystals exhibit a range of physical and chemical characteristics. Some are clear and inclusion-free with nearly perfect crystal faces, while others are cloudy and contain one or two

petrographically distinct zones (Figs. 2B and 4A). Euhedral, unzoned dolomite crystals within nodular chert through the entire sequence are fine to medium-crystalline (Figs. 2A and 3B).

In general, Naqb Siwa dolomites exhibit alternating red and dull luminescent zones surrounding dull to non-luminescent cores. The occurrence of bright cream-colored dolomite as a cement and as patches in dolomite cores can be observed under high magnification (Fig. 4A). These patches exhibit a complex mottled texture reflecting brightly luminescent dolomite intermixed with nonluminescent dolomite rhombs. Dolomite rhombs in chert nodules show textures indicative of partial dissolution of dolomite crystals (Fig. 4A).

Petrographic and mineralogical analyses of siliceous nodules in the Naqb Siwa dolomite demonstrate significant variation in their form and distribution (Fig. 2). Chert nodules locally contain well-preserved skeletal fragments and forms which are completely silicified. There are no relict evaporite inclusions within the chert nodules.
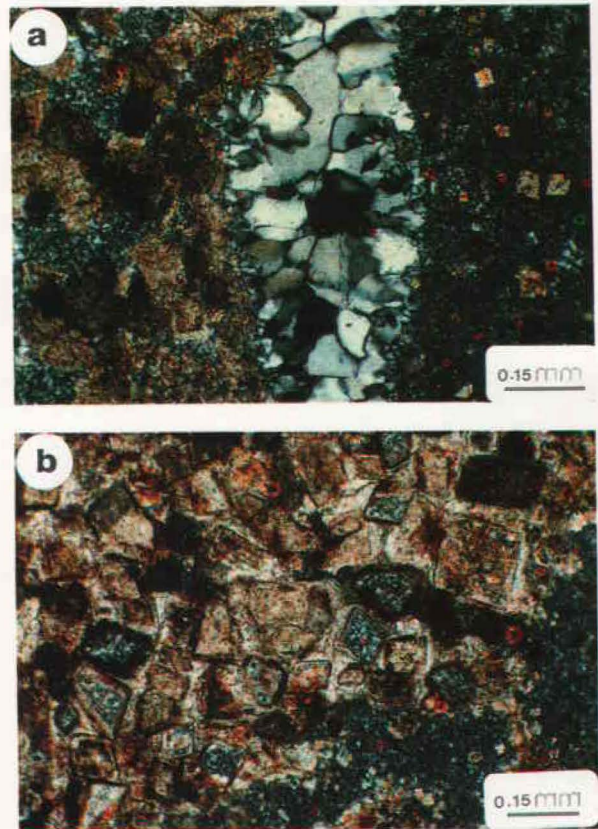
Fig. 2. Photomicrographs of Naqb Siwa carbonate in which original limestone has been replaced by dolomite (Crossed polarized light). A- Basal mosaic dolomite crystals associated with nodular chert. Note the difference in size and shape between dolomite crystals in the chert nodule and the grains of the host dolomite. Two principal cement crystal forms are present, an early diagenetic microcrystalline quartz and a later diagenetic drusy cement. B- Zoned dolomite crystals with two distinct clear zones surrounding dark cores. This texture characterizes dolomite from the upper part of

the sequence. Partial to complete replacement of some dolomite rhombs by microcrystalline quartz is also observed.

In the upper part of the Naqb Siwa sequence, diagenetic quartz occurs as a cement in inter-rhomb pores and also as a replacive phase. In many larger voids drusy fabric is common and consists of an outer void-lining generation of elongate crystals normal to the void wall, and an inner void-center generation of larger, more equant crystals. In some dolomite rhombs, partial to complete replacement by microcrystalline quartz crystals has occurred though the former rhombic shape and outer zones of the dolomite rhombs are still recognizable (Fig. 2B). Such preferential replacement of dolomite rhomb cores may reflect difference in original composition and chemical stability of dolomite crystals [19].

Late, sparry, void-filling calcite was formed after dolomitization and silicification. This exhibits a distinct cathodoluminescent zonation in which bright zones alternate with dull and non-luminescent ones (Fig. 4B).

Geochemistry

Major elements: EPMA analyses for Ca, Mg and Fe and show that the dolomite in the upper part of the sequence and in chert, is nearly stoichiometric (Tables 1 and 2). In contrast, basal dolomite averages 45.80 mol% $MgCO_3$ (Fig. 5). In general, $FeCO_3$ content for Naqb Siwa dolomite is less than 1 mol%.

Trace elements: Trace element composition varies persistently between host dolomite and dolomite rhombs in chert. Sodium values for Naqb Siwa dolomite average 420 ppm for basal dolomite and 175 ppm for dolomite from the upper part of the sequence. Sodium values for dolomite rhombs in chert are relatively high with an average of 630 ppm.

Strontium mean value for Naqb Siwa basal dolomite (120 ppm) is in the range of mixing-zone dolomites, whereas strontium values for dolomite from the upper sequence (average 70 ppm) are slightly lower than those typical of mixing-zone origin. Strontium values of the dolomite rhombs in chert are relatively high with an average of 240 ppm.
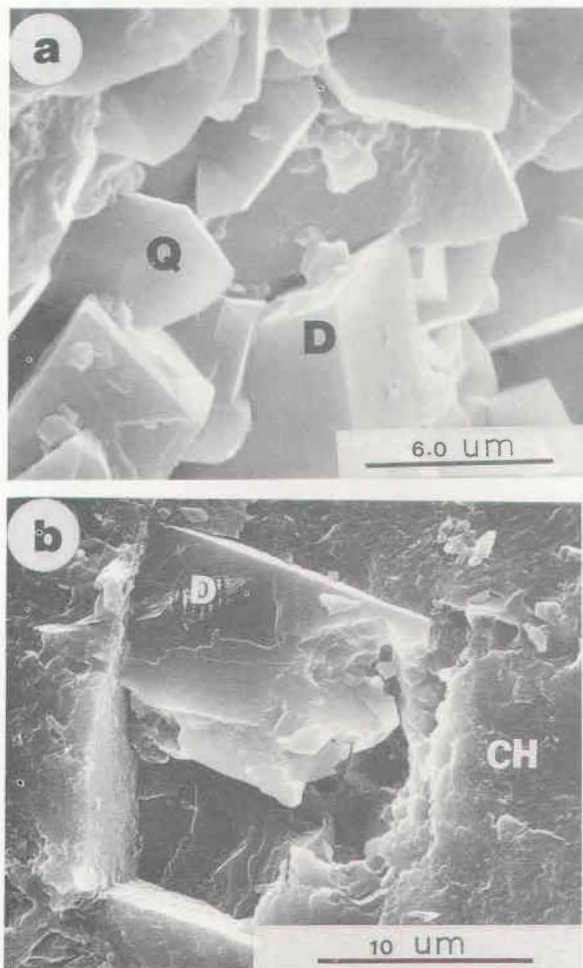

Fig. 3: Scanning electron micrographs of dolomite crystals from the Naqb Siwa Member. A- Well developed faces on dolomite crystals (D). Note quartz (Q) as a late diagenetic cement in the inter-rhomb pores. B- Partly dissolved dolomite crystal (D) in nodular chert (CH) from the lower part of the sequence.

Fig. 4: Photomicrographs showing cathodoluminescent zonation and textures in dolomite crystals of Naqb Siwa Member Formation. A- The euhedral crystal cores of dolomite in chert are retained despite extensive solution. B- Cathodoluminescent image of late void-filling equant calcite.
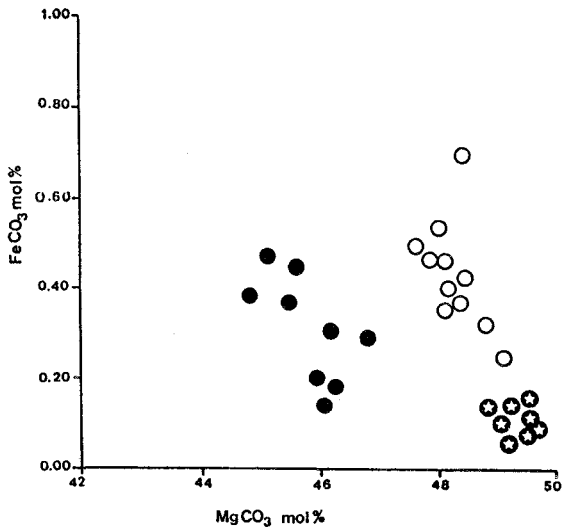
Fig. 5. Relation between mol % $MgCO_3$ and mol % $FeCO_3$ in Naqb Siwa dolomite. Solid circles are basal dolomite, open circles are dolomites from the upper part of the sequence and stared circles are dolomite rhombs in chert nodules.

The Fe^{2+} concentration of Naqb Siwa dolomite is low relative to the underlying El Heiz dolomite [20]. Mn values, as expected, follow Fe values and both show a variation trend opposite to those of Na and Sr due to their distribution coefficients (D_{Fe} and $D_{Mn}>1$). Like Na and Sr, the Mn values are consistently different among the various dolomite types. Mn values in dolomite from the upper part of the sequence are high relative to Mn values in the basal dolomite (Fig. 6).

Carbon and oxygen isotopes of dolomite $\delta^{18}O$ values for basal dolomite of Naqb Siwa member and those from the upper part of the sequence are distinctly different, while their $\delta^{13}C$ values are similar (Tables 1 & 2; Fig. 7). Dolomite from the upper part of the sequence are enriched in ^{18}O relative to those in its basal part. The $\delta^{13}C$ values of Naqb Siwa dolomite are similar to those estimated for marine calcite of Late Cretaceous age [20], with an average of +2.5‰ PDB. This suggests that the Naqb Siwa dolomite did inherit the CO_3^{2-} ions of the precursor. Moreover, the relatively homogeneous $\delta^{13}C$ suggests that the $\delta^{18}O$ compositions of dolomite are controlled by dolomite-water equilibrium fractionation [21].

Naqb Siwa dolomite shows a strong correlation between $\delta^{18}O$ values and $MgCO_3$ content (Fig. 8). Dolomite from the upper part of the sequence shows a near stoichiometric composition, and is distinctive in $\delta^{18}O$ (average -1.9 ‰ PDB) and Sr content (average 70 ppm), compared to the basal calcian dolomites which have low $\delta^{18}O$ (average -2.8 ‰ PDB) and are enriched in Sr (average 120 ppm) (Figs. 8 and 9).
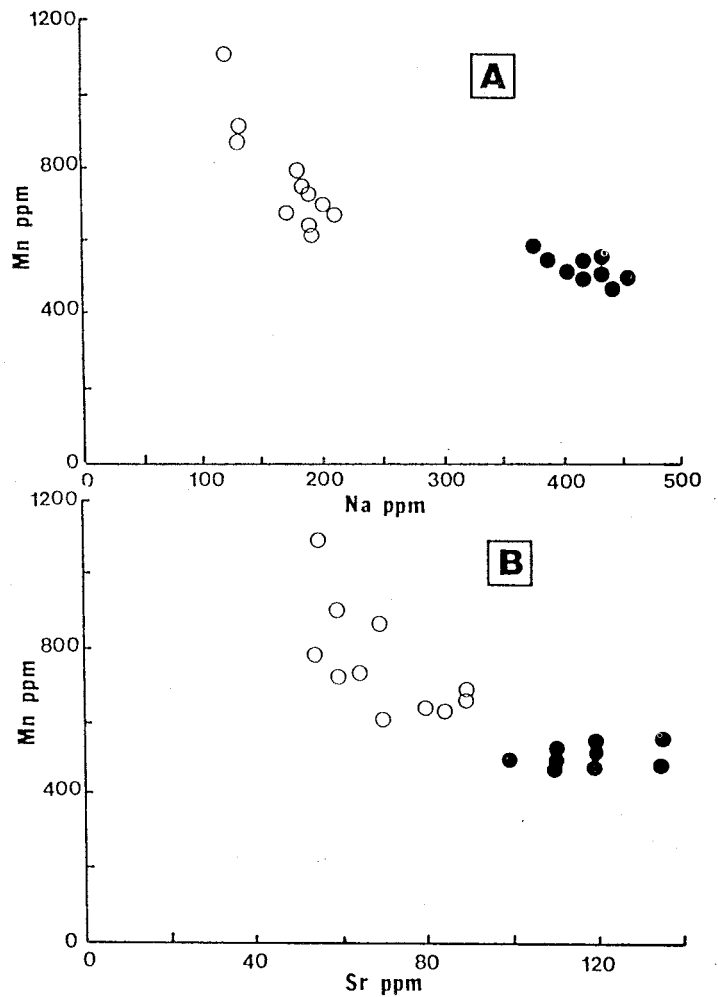

Fig. 6: A- Relation between Na and Mn content of Naqb Siwa host dolomite. B- Relation between Sr and Mn content of Naqb Siwa host dolomite. Solid circles are basal dolomite and open circles are dolomites from the upper part of the sequence.
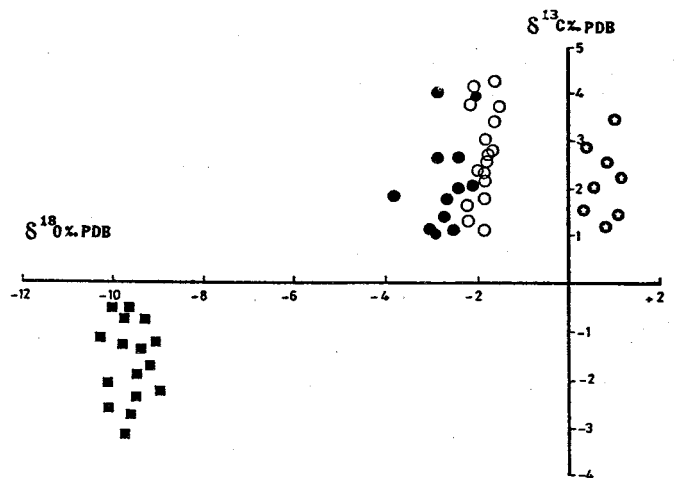

Fig. 7: Isotopic composition of Naqb Siwa dolomite and late void-filling calcite. Solid circles are basal dolomites, open circles are dolomites from the upper part of the sequence, stared circles are dolomite rhombs in chert nodules and solid squares are late void-filling meteoric calcites.

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Table 1
Naqb Siwa Dolomite Composition

Sample	CaCO$_3$	MgCO$_3$ (mol %)	FeCO$_3$	Sr	Na ppm	Mn	δ^{18}O ‰ PDB	δ^{13}C
28	51,73	47.85	0.47	70	128	870	-2.2	+4.0
25.1	-----	-----	-----	----	----	-----	-1.8	+2.6
25	51.58	48.12	0.36	60	130	900	-1.9	+1.8
22	50.84	48.79	0.30	55	120	1100	-1.7	+3.4
20.1	-----	-----	-----	----	----	-----	-1.9	+2.2
20	50.68	49.12	0.24	80	180	645	-1.6	+3.7
18	51.11	48.44	0.43	90	200	690	-1.7	+4.2
15	51.40	48.30	0.37	65	185	740	-1.7	+2.7
14.1	-----	----	-----	----	----	-----	-2.0	+2.4
14	51.76	47.60	0.50	60	190	730	-2.2	+1.7
13.1	-----	-----	-----	----	----	-----	-1.8	+1.2
13	51.38	48.21	0.39	55	180	790	-1.8	+3.0
12	51.33	48.05	0.47	70	190	615	-1.9	+2.0
11	51.50	47.93	0.54	85	195	635	-2.2	+1.4
10.1	-----	-----	-----	----	----	-----	-2.1	+2.1
10	51.03	48.37	0.70	90	210	670	-1.7	+2.9
9	52.86	46.83	0.30	100	410	500	-2.5	+2.7
8	53.88	45.95	0.20	110	415	490	-2.8	+1.4
7.1	-----	-----	-----	----	----	-----	-2.2	+3.8
7	53.86	46.09	0.14	120	420	510	-2.7	+1.8
6.1	-----	-----	-----	----	----	-----	-3.1	+1.2
6	53.45	46.24	0.18	135	380	560	-2.5	+1.2
5	54.78	44.88	0.39	120	435	485	-3.0	+1.1
4.1	-----	-----	-----	----	----	-----	-3.8	+1.9
4	54.30	45.13	0.47	110	440	470	-2.9	+2.6
3	54.26	45.48	0.37	135	455	480	-2.9	+4.1
2.1	-----	-----	-----	----	----	-----	-2.4	+2.0
2	53.50	46.16	0.30	120	390	540	-2.5	+2.0
1	53.96	45.61	0.45	110	430	530	-2.8	+1.4

Table 2
Chemical Composition of Dolomite Crystals within Nodular Chert

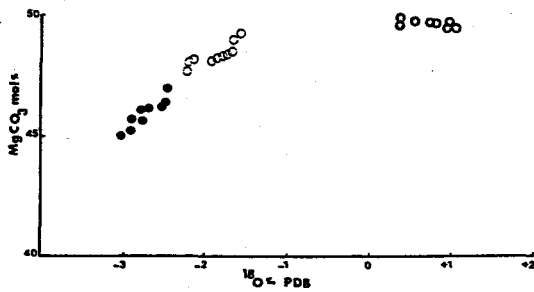| Sample	CaCO$_3$	MgCO$_3$ (mol %)	FeCO$_3$	Sr	Na ppm	Mn	δ^{18}O ‰ PDB	δ^{13}C
1	50.26	49.51	0.1	235	610	42	+0.7	+2.6
2	50.23	49.72	----	210	560	30	+0.3	+2.9
3	50.06	49.45	0.1	210	570	40	+0.3	+2.1
8	50.22	49.64	----	220	580	45	+0.5	+2.1
13	50.75	49.26	----	240	630	28	+1.0	+3.6
17	50.84	48.75	0.1	270	660	30	+1.1	+2.3
25	50.36	49.46	0.1	250	630	35	+0.8	+1.3
28	50.78	49.00	0.1	270	650	30	+1.0	+1.4

Fig. 8: Relation between mol % MgCO₃ and δ¹⁸O values of Naqb Siwa host dolomite. Symbols as in Fig. 5.

The $\delta^{18}O$ values of late void-filling sparry calcite (with low Mg^{2+} content) are consistent throughout the section, ranging from -0.6 to -3.2‰ and from -8.8 to -10.2‰ PDB, respectively (Table 3). Moreover, these are identical to values in calcite veins throughout the Late Cretaceous sequence in Bahariya Oasis [16].

Oxygen isotopes of chert A large fraction of Naqb Siwa chert samples seems to be well preserved according to the criterion of microcrystallinity of the quartz in the chert. Since isotopic exchange is likely to be associated with recrystallization and grain coarsening, microcrystallinity suggests the preservation of original chert. The $\delta^{18}O$ values of chert from silicified dolomites exhibit an average of 32.0 SMOW, with no significant difference through the sequence (Table 4). These values are compatible with $\delta^{18}O$ values of Late Cretaceous cherts from other places [22-24].

Table 3
Stable Isotopic Composition fo Naqb Siwa Late Calcite Cement

Sample	$\delta^{18}O$ ‰ PDB	$\delta^{13}C$ ‰ PDB	Sample	$\delta^{18}O$ ‰ PDB	$\delta^{13}C$ ‰ PDB
20	-10.0	-0.6	20.1	-9.5	-0.7
20.2	-9.8	-0.8	21	-9.6	-2.3
21.1	-9.5	-2.4	23	-9.3	-2.0
23.1	-9.1	-1.8	23.2	-8.8	-2.3
25	-9.7	-3.1	26	-10.2	-2.7
26.1	-10.2	-2.2	27	-9.1	-0.9
27.1	-9.0	-1.3	27.2	-9.3	-1.4
28	-10.2	-1.2	28.1	-9.8	-1.3

Table 4
Oxygen Isotopic Composition of Siwa Chert

Sample	$\delta^{18}O$ SMOW	Sample	$\delta^{18}O$ SMOW
3	32.4	5	32.0
7	32.2	10	32.5
12	31.8	13	31.6
15	32.2	18	31.9
19	32.1	21	32.1
23	31.6	25	32.0
26	32.0	28	31.6

DISCUSSION

In order to explain the origin and diagenesis of the Naqb Siwa silicified dolomites, the following aspects are addressed: 1) environment of deposition; 2) mixing-zone environment for dolomitization and silicification; and 3) timing of diagenesis.

Environment of deposition Numerous studies have described the Late Cretaceous paleogeography and geologic history of Bahariya Oasis [13, 14, 15, 25]. During this time, Egypt was located near the equator and had a subtropical climate [26]. Moreover, the Late Cretaceous shoreline appears to have run fairly close to the present coast [27]. The combination of these features with field observations indicates significant facies changes ranging from shallow marine to a predominantly clastic sequence.

Paucity of fossils in the dolomite may indicate restricted environmental conditions, but absence of either evaporites or traces thereof, and the presence of skeletal fragments and forams in chert nodules indicate that the water within this environment was not hypersaline. The absence of evaporite minerals is consistent with sediment accumulation in a non-sabkha setting.

Mixing-zone environment for dolomitization and silicification An important aspect of diagenesis is the burial history and its control on the maximum temperature of
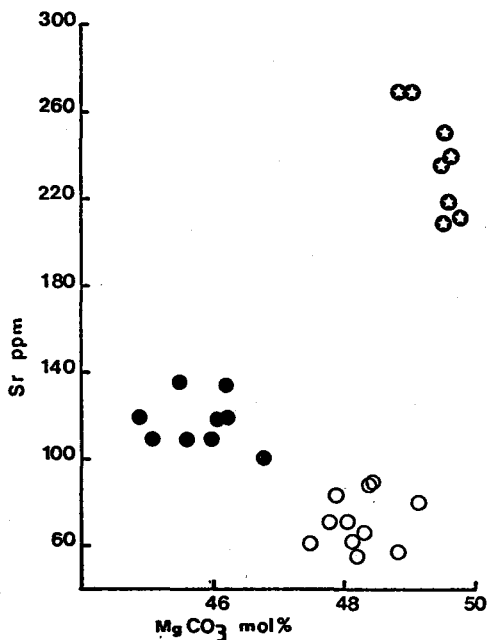

Fig. 9: Relation between mol % MgCO₃ and Sr contents of Naqb Siwa host dolomite. Symbols as in Fig. 5.

dolomite formation. The progressive diagenetic history of this sequence shows that these sediments have never been buried deeply [16]. Therefore, lines of evidence derived from paleogeography, burial history, trace elements and isotope data suggest that formation of Naqb Siwa dolomite is inconsistent with models for evaporitic or epigenetic dolomitization. It appears that marine to fresh water solutions can be considered for the origin of Naqb Siwa dolomite.

Estimates of the relationship between the isotopic composition of dolomite, the isotopic composition of the water from which it forms and temperature can be evaluated semiquantitatively using Craig's equation [28] if the limits of these conditions are known. On the basis of the data of Claypool et al. [29] and of Scholle and Arthur [30], it is estimated that, during the Late Cretaceous, the $\delta^{18}O$ value of ocean water was about 0.5-1‰ less than it was immediately before the start of ice cap growth in the Tertiary [31]. The modern local air temperature never drops below 14°C, which is considered to be the lower limit of the temperature range. Based on these factors, the most isotopically enriched $\delta^{18}O$ values of the dolomite rhombs in chert appear to be in isotopic equilibrium with the Late Cretaceous marine fluids. Furthermore, this type of dolomite is generally low in Fe and Mn and high in Na and Sr relative to the host dolomite. This indicates that this dolomite records an early phase of partial marine dolomitization and these trace element and isotopic values were preserved through isolation in chert nodules as a closed system.

The low oxygen isotope compositions, high Fe and Mn, and low Na and Sr concentrations strongly suggest that host dolomite must have formed from fluids depleted in ^{18}O, Sr, and Na and enriched in Fe and Mn relative to seawater. A meteoric water influence has been considered to be the main control in this system. In this study, host dolomite formation has been attributed to mixed seawater and meteoric water.

Whether ^{18}O-depleted dolomite was formed under subsurface conditions, or whether the chemistry reflects later stabilization [32, 33] is difficult to determine, but the present study suggests that dolomite may have formed from pore solutions at low temperatures under shallow-burial conditions in a mixing-zone environment. This is supported by oxygen isotopic values and CL-microfabric which required post-sedimentary fluids, either to form the dolomite initially, or to stabilize a previously formed dolomite [32].

Timing of diagenesis Effects of replacement (dolomitization and/or silicification), neomorphism, leaching of fossil skeletons, and passive precipitation of pore and void-filling quartz and calcite spar are widespread within the studied area. The combination of petrographic and geochemical features indicates specific diagenetic events. Synthesis of the available data allows the construction of the paragenesis of these diagenetic events. The variability in oxygen isotope and trace element values and the preservation of some dolomite rhombs within chert nodules support the interpretation of multiple dolomitization-silicification events. Diagenesis continued as Naqb Siwa sediments passed from the marine to the meteoric-phreatic zone and finally into the vadose zone.

Diagenesis involved a partial replacement of original $CaCO_3$ by dolomite under marine conditions. This early stage of dolomitization most probably affected the original metastable carbonate constituents. Dolomites formed during this early replacement phase are generally low in Fe and Mn and relatively high in $\delta^{18}O$, Na and Sr. Silicification of the original $CaCO_3$ sediments took place after this early stage of partial dolomitization. There is no evidence that the chert nodules replaced evaporite minerals, and isotopic data suggest that these chert nodules kept a marine signature. The silicification process was interrupted or followed by complete dolomitization of the remaining $CaCO_3$ sediment. This stage of complete dolomitization changed the geochemical record of the earlier partial marine dolomite. On the other hand, dolomite rhombs in chert have preserved this geochemical record. Dolomite, quartz and calcite cements were also formed after complete dolomitization. Dolomite and calcite components exhibit signatures ranging from mixing-zone to meteoric environments, suggesting progressive freshening of fluids as the result of a falling sea level.

CONCLUSIONS

1. The petrographic and geochemical data indicate two episodes of dolomitization: a) the earlier stage that was driven by marine fluids, and b) the second stage was driven by the mixing of marine and meteoric waters; this latter dolomite is volumetrically dominant, having replaced both limestone and most pre-existing dolomite.

2. Isotopic and trace element values of dolomite rhombs in chert nodules reflect the signature of marine conditions.

3. The mixing-zone model may explain the bulk chemistry of Naqb Siwa dolomites; however, the isotopic composition of dolomite rhombs in chert nodules argues against a mixing-zone origin for the replacement by the nodular chert.

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