

## MINERALOGY AND GEOCHEMISTRY OF CORAL REEF IN IRAQI MARINE ENVIRONMENT IN THE NORTH PART OF ARABIAN GULF

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### ABSTRACT

Coral reef area in northwest of the Arabian Gulf was investigated for mineralogy and geochemistry to throw lights on such unique Iraqi Marine Environment; six specimens of two main species of coral reefs, *Platygyra pini* and Octocoral *Menella* were collected at two sites. While eight samples of the surrounding sediments are chosen from other two sites. The mineralogy is determined by XRD, and reveals that calcite, low magnesium-calcite, and aragonite are the main minerals that comprise the Octocoral *Menella* in site 1, whilst aragonite and calcite are dominate in the *P. pini* coral reef at site 4.

The non-carbonate fractions indicate that these coral reefs contain quartz, anorthite feldspare, halite, and gypsum; the highest content of aragonite was observed in the *P. pini* compared to calcite. The abundance of carbonate minerals (92.1%) in the *P. pini* is in contrast to (73.1%) in the *Menella*. The main minerals in the sediments of site 2 are represented by chlorite and talc, whereas quartz and phengite are the most prominent minerals that diagnose in sediments of site 3; phengite mineral is a first discovery in the sediments of Arabian Gulf, whilst talc is a first detection in Iraqi marine sediments.

The concentration of CaO is the most abundant oxide in all the analyzed specimens of the coral reef followed by SiO<sub>2</sub>. There are high proportions of calcium oxide in *P. pini* Chevalier coral (56.65 %) than the *Menella* (48.81%). There are some special pattern of distribution for major and trace elements in coral reef area based on calcium content. Most of the silica came from quartz, phengite and clay minerals; the highest concentrations of Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, K<sub>2</sub>O, Na<sub>2</sub>O, MgO, SiO<sub>2</sub>, TiO<sub>2</sub>, V<sub>2</sub>O<sub>5</sub>, Cr, Ni, Cu, Rb and Zr are found in the sediments of site 2 as opposed to the other sites. These results could affect the association of these elements with clay minerals through adsorption or absorption, the highest content of P<sub>2</sub>O<sub>5</sub>, Ga, W and As in the sediments of site 3 may reflect the adsorption of these elements on surface of the quartz and phengite; from the other hand, the highest concentrations of Sr, Zn, Br, Sn, Ta, and Pb in the *P. pini* may indicate the relative effects of the environmental variation within the studied area.

Keywords: Arabian Gulf, Coral Reefs, Iraq, *Menella*, *Platygyra pini*.

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### INTRODUCTION

Coral reefs are among the greatest keys to unlock our understandings of a marine ecosystem (Perkol – Fenkel and Banayahu, 2007); this organism lives within exclusive temperature conditions and the sea water varieties survive between 14 to 34 °C (Coles and Fadlallah, 1991). Coral reefs of the Arabian Gulf and Oman Sea are serious habitats of cultural, socio-economic, and scientific importance. The seven countries surrounding the Arabian Gulf – Bahrain, Kuwait, Iran, Iraq, Qatar, Saudi Arabia and the United Arab Emirates – share a valuable ecosystem. Corals particularly in the Arabian Gulf are exposed to great summer sea temperatures compared with other tropical regions, with temperatures above 34°C for several months annually and summer maxima rising above 36°C (Coles and Riegl, 2013; Burt *et al.*, 2015).

Salinity in the Arabian Gulf is also very high, generally between 35- 46 ppt in Iraqi marine environments (Al-Dabbas and Al-Jaberi, 2015) , while in the shallow waters between Bahrain and Qatar, salinity often exceeds 50 ppt; these waters have the potential to offer important insights into how corals respond to temperature and salinity stress (Smith *et al.*, 2017). Arabian Gulf reefs are relatively geographically isolated from the Indian Ocean by the narrow (42 km wide) Strait of Hormuz, yet are relatively young current shorelines (reached ~6000 years ago) (Lambeck, 1996); however it is unclear whether there has been enough isolation to support genetic adaptation to the local environment. Around the world, reefs grow at temperatures of about 28°C and above a certain threshold, the corals start expelling the algae from their tissue in a phenomenon known as coral bleaching. Bleached corals can sometimes recover, but, in many cases, die. In Australia, corals start to bleach if the water reaches 31°C. However, in the Arabian Gulf, bleaching starts at 35 to 36°C . In most areas of the Arabian Gulf, corals do not form true reefs, but are better described as ‘coral carpets’, where separate colonies raise on exposed rocky substrates rather than building on older dead coral skeletons (Burt *et al.*, 2015).

Seasonal changes in the intimate environment of coral reefs cause a physiological effect on these organisms ( Eghtesadi- Araghi, 2011); Arabian Gulf coral groups are on average, smaller in size relative to their counterparts living in more benign conditions outside the area (Burt, 2013); the lack of larger sized colonies within the Arabian Gulf indicates that most individual colonies may not survive for the lengths of time they do in areas outside of the Gulf, as a result of the harsh nature of the Gulf environment (Riegl and Purkis, 2012).

The Arabian Gulf coral reef communities can be classified according to place of growth in the water, (a) offshore deep water reefs and (b) near shore shallow water reefs Burt *et al.* (2015) distinguishes two types of coral reef communities in Qatar, shallow communities (600 m from the shore) at a depth of 3 m, and deep communities (40 km from the shore) at a depth of 25 m. Pilcher *et al.* (2000) refers to the depth of near shore coral reefs in Kuwait as ranging between 10 to 15 m, while the offshore coral reefs are surrounded by a 30 m depth.

Rezai and Savari (2004) asserts that coral cover in the Gulf of Oman is typically 30-40% at depths of 4-12 m; the only significant population of living coral in Bahrain is surrounded by 40 m deep sea water; comparatively coral reef communities in offshore and near- shore in Iran range at 3 to 15 m (Rezai and Savari, 2004) . Total coral reef area coverage in the UAE which occurs primarily as shoals and which localises around the numerous offshore islands, ranges at less than 20 m deep (Riegl, 2002). Most coral reefs communities in the Arabian Gulf are near-shore shallow water reefs; coral reefs use calcium carbonate (CaCO<sub>3</sub>) from sea water

to synthesize a hard and protective marine shells (Kleypas *et al.*,1999; Langdon *et al.*, 2000; Falter *et al.*, 2001).

In the ocean, where aragonite saturation decreases, the effect will tend to favor organisms that create the more stable forms of calcium carbonate, such as calcite and high magnesium calcite; aragonite-creating organisms, like corals, will in turn be subject to more dissolution and bio-erosion, calcification of all groups, however; is negatively affected by the decrease in the carbonate saturation of sea waters (Feely *et al.*, 2004). Coral reefs in the northern and northwestern territories of the Arabian Gulf are exposed to a very heavy load of particles that derive their input from the Shatt Al-Arab River of Iraq; nine species of coral reefs we are discovered in the Iraqi marine environment between September of 2012 and May of 2013 by Marine Science Center (MSC) of Basrah, Iraq and Scientific Diving Center (SDC) of Freiberg ,Germany (Pohl *et al.*,2014).

This investigation aims to describe the mineralogy and geochemistry of Iraqi coral reefs and the surrounding marine sediments.

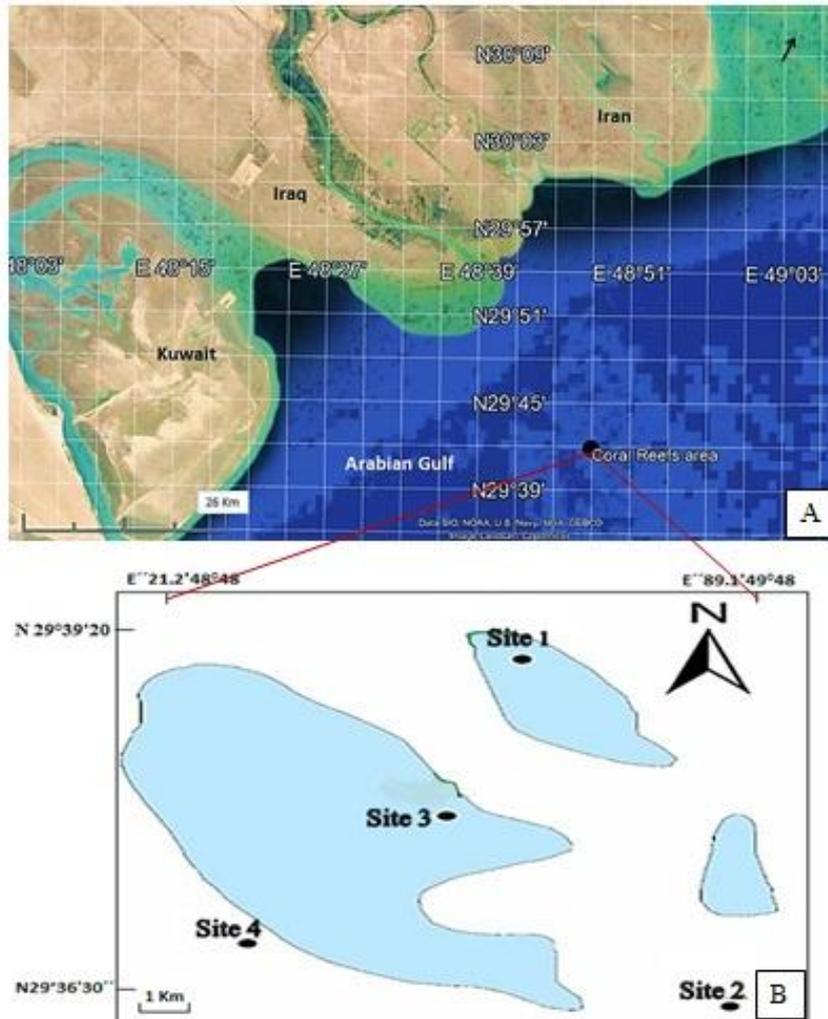
### MATERIALS AND METHODS

Iraqi coral reefs are offshore, distributed within a space of approximately 28 km<sup>2</sup>, at depths ranging between 7-20 m (Pohl *et al.*, 2014) (Map 1). The study area is located in the northwest Arabian Gulf between 29°36'30" N - 29°39'20.94" N latitude and 48°48'21.2" E - 48°49'89.1" E longitude (Map 2, Tab. 1). This investigation aims to describe the mineralogy and geochemistry of Iraqi coral reefs and the surrounding marine sediments.



**Map (1):** Modified map of coral reefs distribution according to Burt *et al.* (2015), with illustrating the Iraqi coral reefs

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Map (2): (A) Regional map of the coral reefs area, (B) magnified map of the coral reef area illustrating the position of research Sites.

Table (1): Site coordinates of the study area

Site	Coordinates	
1	29°39'20.94''N	48°49'30.6''E
2	29°36'30''N	48°49'89.1''E
3	29°38'02.8''N	48°49'12.4''E
4	29°36'59.0''N	48°48'21.2''E

Fourteen specimens from coral reefs and marine sediments are selected in four sites in the Iraqi coral reefs area; all the specimens were collected by experienced scientific divers from MSC in University of Basrah. Six from them represent different two species of coral reefs. Three specimens collected from the *Menella* species and another three from *P. pini* (Sites 1 and 4). Eight specimens are collected from the surrounding marine sediments in the coral reefs area (Sites 2 and 3), four specimens from site 2, and four from site 3 as shown in Map (2 b); specimens were taken in plastic boxes and transported to the geology laboratory in Basrah University.

Mineral identification of the specimens took place with X-ray diffraction patterns obtained by means of a D-5000 X-ray diffractometer, using CuK $\alpha$  sources in wavelength,  $\lambda$  being 1.54056Å at 40 kV and 30 mA between 5-65°. Geochemical analyses for the major and trace elements were calculated by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) method for major oxides (Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, CaO, MgO, Fe<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, P<sub>2</sub>O<sub>5</sub>, TiO<sub>2</sub>, V<sub>2</sub>O<sub>5</sub>, MnO, and SrO), and Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) method for trace elements (Ni, Cu, Zn, As, Ga, Br, Rb, Zr, Mo, Sn, Ta, W, Pb, and Cr) at the ALS Laboratories in Spain.

## RESULTS AND DISCUSSION

### (A) Mineralogical Analysis

Coral contains the carbonate minerals from the coral skeleton, but also contains many minerals that are a natural chelate due to the zooxanthellae that grows on the coral (Devnita, 2009); calcite, aragonite and dolomite create more than 90 % of carbonate minerals of coral reefs (Scherer, 1986). They form as grains and cements in the body of corals (Tucker and Hollingworth, 1986); besides those minerals, there are also other minerals, which build coral reefs as minor components (Schroeder and Purser, 1986), the mineralogical composition of sediments around coral reefs is derived from the reef itself (Devnita, 2009); the composition of the specimens in the studied sites has been recognized by X-ray diffraction analyses.

The bulk mineral components and the relative abundance of each mineral have been considered on the basis of peak high measurements of a 100% reflection peak; the data attained are summarized in Table (2) and selected X-ray diffractograms are provided in Diagrams (1, 2, 3, and 4); carbonate minerals obtained in the *Menella* sp.1 (Site 1) are calcite, low Mg-calcite, and aragonite. Calcite recorded here dominates over aragonite; the non – carbonate fractions show that the *Menella* contain quartz, anorthite feldspar, and halite. However, these minerals are not the dominant minerals normally found in these reefs (Tab. 2).

Aragonite and calcite could be the main carbonate minerals of the *P. pini* in site 4, it formed more than 92% from the total minerals of this reef, and recorded here dominates over calcite, quartz and halite are recorded at lower constituents regarding this species of coral reef. The abundance of carbonate minerals (92.1%) in the species of *P. pini* is in contrast to volumes present in the Octocoral *Menella* species (73.1%). The content of carbonate minerals in Iraqi coral reefs are seemingly higher than the adjacent coral reefs in Kuwait and Saudi Arabia (Al-Langawi, 2013; Basyoni, 1999). Non-carbonate minerals attributed to these corals may indicate that rock fragments within the coral reef area stems not only from the origin of the reef, but also from other sources, since feldspar and quartz arise from igneous rocks. Major minerals in the sediments of site 3 are quartz, phengite, and gypsum. The clay minerals, chlorite and talc comprise more than 96% of the total minerals in the sediments of site 2 (Tab. 2). The Phengite is the first recorded mineral in sediments of the Arabian Gulf, while talc has been the first detected in Iraqi marine sediments. Phengite is similar to muscovite,

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but with the addition of magnesium, iron and an overall high silica content (Mookherjee and Redfern, 2002).

Cibin *et al.* (2008) proposes that phengite is an aluminum true mica which contains a high amount of tetrahedral co-ordinated silica; most of the phengite have a fluorine content that uses an indicator for metamorphosed sediments (Iiu *et al.*, 2009). Talc is a hydrous silicate composed of magnesium, silica and water that is relatively pure in composition, but can contain small amounts of aluminum, iron, manganese and titanium; it ore from within the deposit originates from hydrothermal alteration processes involving of magnesium minerals, mainly olivine and orthopyroxenes, but may also occur from a process of regional metamorphism or contact with magnesium calcareous or ultrabasic rocks (Pontes and Almeida, 2005). This occurrence is associated with a mineral presence of biotite, chlorite, serpentine and carbonates (Machado, 2016). In subduction zone metamorphism that leads to continuous reduction of water stored, hydrous minerals in metapelites are evident as potassic mica (phengite), whereas other important hydrous phases in subduction zones are talc and chlorite as shown by Schmidt and Poli (2014).

Chen *et al.* (2017) mentioned the phengite is a critical carrier of water and potassium (K) in sediment as well as in the basaltic layers of subducted slabs; the data herein provides sufficient conclusions that the source of discovering the phengite, talc and chlorite in the sediments of coral reefs in the study area may be derived from metamorphic rocks that formed during subduction processes between Arabian and Persian plates.

**Table (2):** Minerals are recognized within the research sites

Sites	Mineral	Chemical Formula	Percentage %
Site 1	Calcite	CaCO <sub>3</sub>	31.8
	Mg-Calcite	Ca <sub>0.9</sub> Mg <sub>0.1</sub> CO <sub>3</sub>	20.7
	Aragonite	CaCO <sub>3</sub>	20.6
	Quartz	SiO <sub>2</sub>	16.6
	Anorthite feldspar	Al <sub>2</sub> Ca <sub>0.2</sub> O <sub>8</sub> Si <sub>2</sub> Sr <sub>0.8</sub>	7.3
	Halite	NaCl	3
Site 2	Chlorite	Al <sub>0.865</sub> Fe <sub>0.255</sub> H <sub>4</sub> Mg <sub>2.292</sub> O <sub>9</sub> Si <sub>1.588</sub>	80
	Talc	H <sub>2</sub> Mg <sub>3</sub> O <sub>12</sub> Si <sub>4</sub>	16.5
	Gypsum	CaH <sub>4</sub> O <sub>6</sub> S	3.5
Site 3	Quartz	SiO <sub>2</sub>	57.5
	Phengite	Al <sub>9.12</sub> Fe <sub>1.12</sub> F <sub>0.16</sub> H <sub>8</sub> K <sub>2</sub> MgNa <sub>0.1</sub> O <sub>48</sub> Si <sub>13</sub>	35
	Gypsum	CaH <sub>4</sub> O <sub>6</sub> S	7.5
Site 4	Aragonite	CaCO <sub>3</sub>	63.8
	Calcite	CaCO <sub>3</sub>	28.3
	Quartz	SiO <sub>2</sub>	5
	Halite	NaCl	2.9

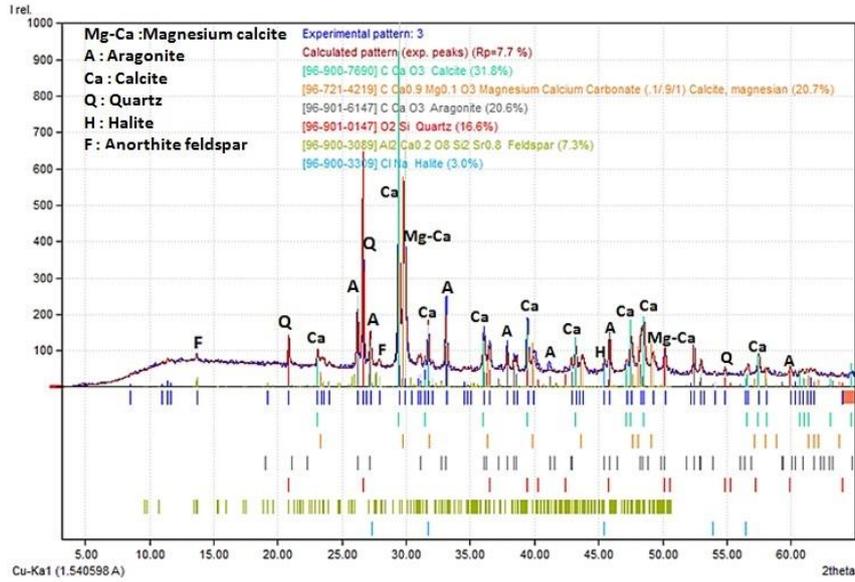


Diagram (1): XRD of Octocoral *Menella* coral reef in Site 1.

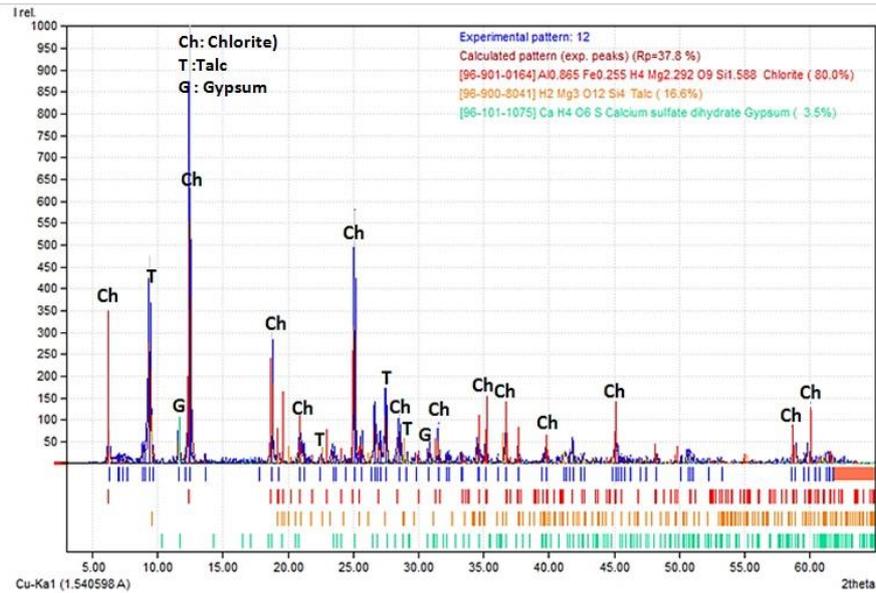


Diagram (2): XRD of marine sediments in Site 2.

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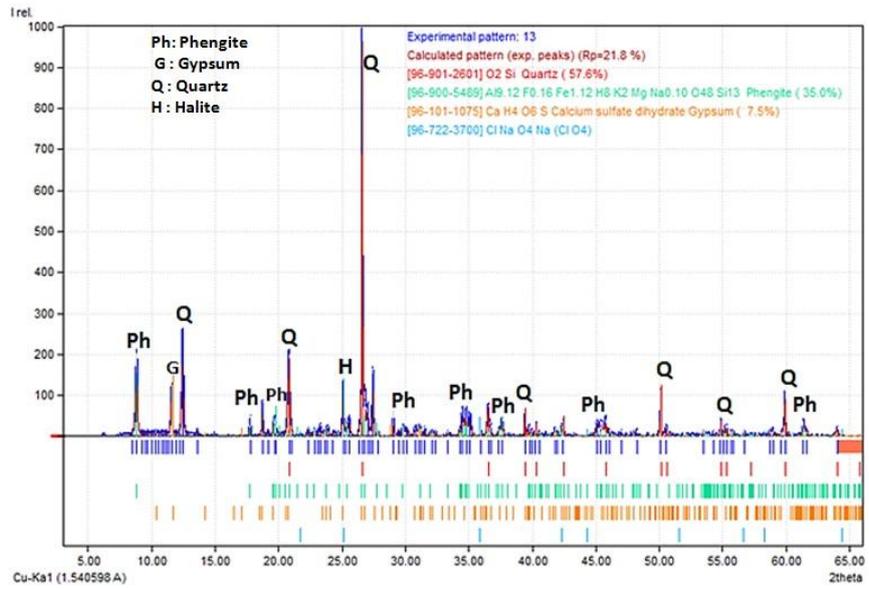


Diagram (3): XRD of marine sediments in Site 3.

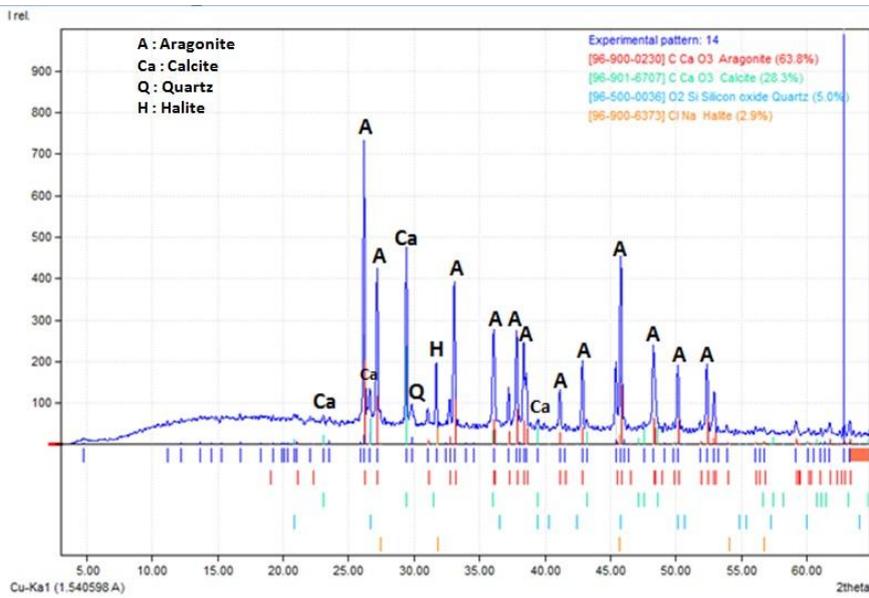


Diagram (4): XRD of *Platygyra pini* coral reef in Site 4

**(B) Geochemical Analysis**

The mineralogical composition of coral reefs depends upon the organisms which composed them (Schroeder and Purser, 1986); coral reefs which are built by carbonate sedimentary rocks are comprised more than 50 % of carbonate minerals and these minerals contain  $\text{CO}_3^{2-}$  with one or more cations of calcium, magnesium and also iron (Kerans *et al.*, 1986). Elements distribution in marine sediments reflects the range of chemical, oceanographic, and sedimentary controls on their supply to their distribution (Clavert and Pederson, 1993).

The concentration of the major oxides ( $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{P}_2\text{O}_5$ ,  $\text{TiO}_2$ ,  $\text{V}_2\text{O}_5$ ,  $\text{MnO}$ , and  $\text{SrO}$ ) and trace elements (Ni, Cu, Zn, As, Ga, Br, Rb, Zr, Mo, Sn, Ta, W, Pb, and Cr) have been measured in the collected samples, and its data are presented in Tables (3 and 4); the purpose of chemical analysis of the coral reef area is to identify the chemical variations in coral composition and surrounding marine sediments, calcium oxide is the most abundant oxide in all of the analyzed coral reef area followed by silica oxide. At site 4 reefs were found to contain higher proportions of calcium oxide in the *P. pini* (56.65 %) than the Octocoral *Menella* coral species (48.81%) at site 3, that actually confirmed the mineralogy study as mentioned in Table 2. The interesting in the geochemical analysis of marine sediments in coral reef area is the larger percentages of calcium oxide than the other calcium contents in Iraqi marine sediments; Al-Jaberi (2015) gave important information about the content of major and trace elements in Iraqi marine sediments; stated that calcium oxide range in these sediments between 13.1-23%. Whilst, the content of calcium oxide in the sediments of study area ranges between 35.22-39.61% as shown in Table (3), which reflect the important role of coral reefs to provide the marine sediments at the studied area by carbonate minerals. However, there were some special pattern of distribution for major and trace elements in coral reef areas based on CaO content; the distribution of major oxides and trace elements are listed in Diagrams (5, 6, 7, 8, 9, 10); CaO is increase in studying sites with decrease  $\text{SiO}_2$  (Diag. 5), which indicates that silica oxides, mostly come from non- carbonate minerals represented by quartz, phengite and clay minerals in the sediments of the coral reef area. Also, the relation between CaO and MgO is belong to this group as well (Diag. 5, 6).

Basyoni (1999) mentioned that the negative correlation between CaO and MgO in coral reefs may be attributed to acid soluble carbonate ( $\text{CaCO}_3$ ) fractions and the mineralogical composition of the sediments; the largest values of major constituents:  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{TiO}_2$ ,  $\text{V}_2\text{O}_5$  and  $\text{MnO}$ , and trace elements (Ni, Cu, Cr, Rb, and Zr) associated with clay minerals (chlorite and talc) are evident at site 2 as shown in Diagrams (5, 6, 7, 8, 9, 10). On the other hand, the content of CaO in this site is the lowest compared with the other sites; these results can be explained by the presence of these elements in the non-carbonate constituents of clay minerals. Alumina and silica in the sediments of this site can be considered as main constituents in the chemical composition of clay minerals; physio-chemical exploration of marine sediments may provide a vision of a possible mechanism of trace elements accompanied with clay minerals, revealing adsorption on the surface or inclusion in the crystal lattice (Kahn *et al.*, 1992).

In the site 3, sediments were found to contain a high proportion of silica oxide (20.25 %), and most of this oxide may relate to the content of quartz and phengite minerals. The highest  $\text{P}_2\text{O}_5$ , Ga, W, and As concentrations were also encountered in this site (Diag. 7, 8, 9), as a result of their adsorption on the surface of the quartz and phengite. The content of the SrO in *P. pini* was higher than the *Menella* sp. (Tab. 3, Diag. 6). Bathurst (1975) emphasized that the aragonite and calcite can hold some strontium level. The free energy of mixing of the strontium  $\text{Sr}^{2+}$  in the aragonite is greater than in the calcite, thus preferring the aragonite

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(Basyoni , 1999); Deer *et al.* (1992) states that a major control on trace and minor elements in either calcite or aragonite is crystallochemical .

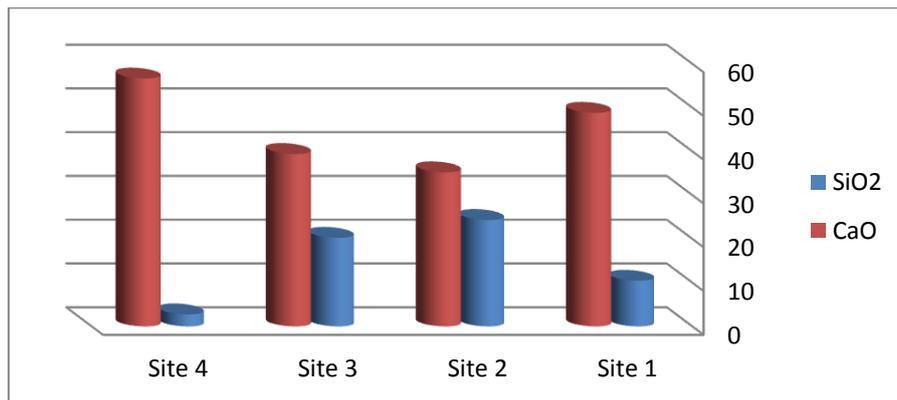
The calcite structure accommodates Ca<sup>2</sup> (ionic radius 1.00 Å) as well as minor and trace elements having an ionic radius less than or equal to 1.00 Å, the aragonite structure accommodates Ca<sup>2</sup> together with minor and trace elements having radii close to or greater than 1.00 Å; Al-Dabbas and Al-Jaberi (2015) confirm that elements which have ionic radii close to or more than 1 Å are visible at higher concentrations in aragonite than in the calcite layer. This conclusion may probably enhance the results in Table (3), which can be used to explain the highest content of Sr, Zn, Br, Pb, Ta, and Sn in the *P. pini* at site 4 compare to others; these elements have obvious positive relationships with calcium oxide as shown in Diagrams (6, 8, 9,10). While, a high content of Mo with Octocoral *Menella* coral reef ( Diag. 10) is reflect the presence of this element in calcite layer.

**Table (3):**Range and mean values of major oxides in studied sites.

Element %	Site 1		Site 2		Site 3		Site 4	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Al <sub>2</sub> O <sub>3</sub>	1.125 - 2.0	1.56	3.08-3.12	3.1	2.027-2.05	2.03	0.348-0.35	0.349
SiO <sub>2</sub>	10.43 – 10.56	10.45	24.32-24.5	24.41	20.25-20.32	20.28	2.75-2.81	2.78
CaO	48.81 – 49.12	48.96	35.22-35.27	35.24	39.41-39.61	39.51	56.65-56.67	56.66
MgO	2.0- 2.2	2.1	2.82-2.9	2.86	2.41-2.5	2.455	0.74-0.79	0.76
Fe <sub>2</sub> O <sub>3</sub>	1.242-1.25	1.24	1.989-1.99	1.989	1.608-1.62	1.61	0.259-0.27	0.26
Na <sub>2</sub> O	1.96 – 2.1	2.03	3.82-3.86	3.84	1.77-1.8	1.78	2.413-2.43	2.42
K <sub>2</sub> O	0.239-0.242	0.24	0.644-0.67	0.667	0.409-0.42	0.41	0.073-0.075	0.074
P <sub>2</sub> O <sub>5</sub>	0.104-0.106	0.105	0.1007-0.1009	0.1008	0.142-0.15	0.146	0.044-0.05	0.047
TiO <sub>2</sub>	0.127-0.13	0.128	0.266-0.27	0.26	0.179-0.21	0.194	0.034-0.042	0.038
V <sub>2</sub> O <sub>5</sub>	0.0043-0.0047	0.0045	0.0095-0.0098	0.0096	0.0074-0.0082	0.0078	0.0067-0.0072	0.0069
MnO	0.0294-0.03	0.0297	0.056-0.058	0.057	0.0399-0.043	0.041	0.00636-0.0068	0.0065
SrO	0.233-0.25	0.241	0.077-0.079	0.078	0.0968-0.098	0.097	0.841-0.871	0.865
L.O.I	33.5-33.54	33.52	27.39-27.44	27.41	31.46-31.52	31.49	35.73-35.82	35.77

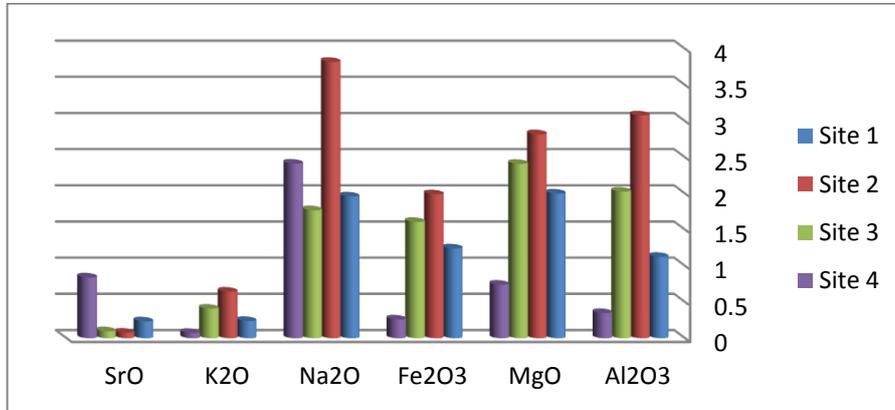
**Table (4):** Range and mean values of trace elements in studied sites.

Element ppm	Site 1		Site 2		Site 3		Site 4	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Ni	20.1-22	21	53.9-60.7	57.3	34.9-36.2	35.5	14.4-16.2	15.3
Cu	20.3-25	22.6	28-29.8	28.9	25-26.5	25.75	22.7-24.3	23.5
Zn	32.9-35	33.9	46-49	47.5	59.2-60.6	59.9	196-198	197
As	16.6-20.1	18.35	13.5-14.2	13.85	22-24.2	23.1	13-16	14.5
Ga	21.6-22.8	22.2	15-16.3	15.65	28-29.3	28.6	12.3-13.5	12.9
Br	43.4-48.8	46.1	11.6-12.8	12.2	26.8-28	27.4	71.4-72.6	72
Rb	10.1-13.6	11.8	22.3-25.2	23.75	16.5-17.3	16.9	5.5-5.9	5.7
Zr	1.4-2.3	1.85	53.9-55.1	54.5	44.6-45.8	45.2	1.4-2.2	1.8
Mo	17.4-19.6	18.5	7.6-8.9	8.25	4.1-5.3	4.7	5.6-6.3	5.95
Sn	3.7-5.8	4.75	3.9-4.8	4.35	1-2.3	1.65	16.9-18.2	17.5
Ta	115-120	117	84.5-89.5	87	100-105	102.5	177-182	179.5
W	19.4-21.9	20.65	85.8-88.4	87.1	254-256	255	88.4-89.5	88.9
Pb	7-9.5	8.25	9.5-10.4	9.95	8.6-9.2	8.9	13.7-14.5	14
Cr	55-62.5	58.75	200-212	206	178-183	180.5	31.6-33.2	32.4

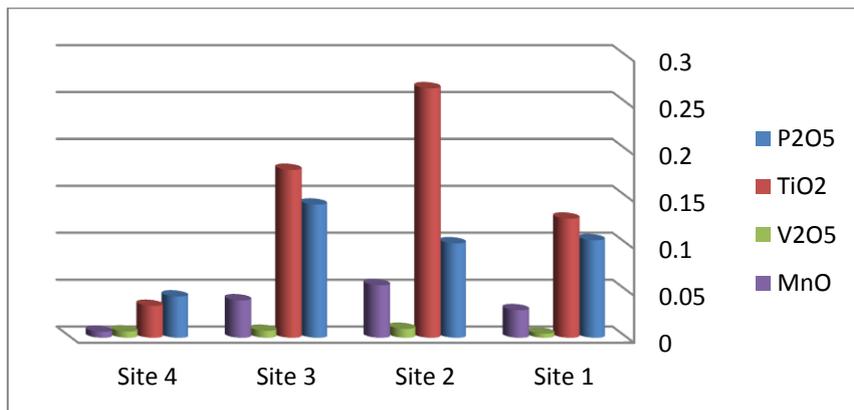


**Diagram(5):** Distribution of SiO<sub>2</sub> and CaO in the studied sites.

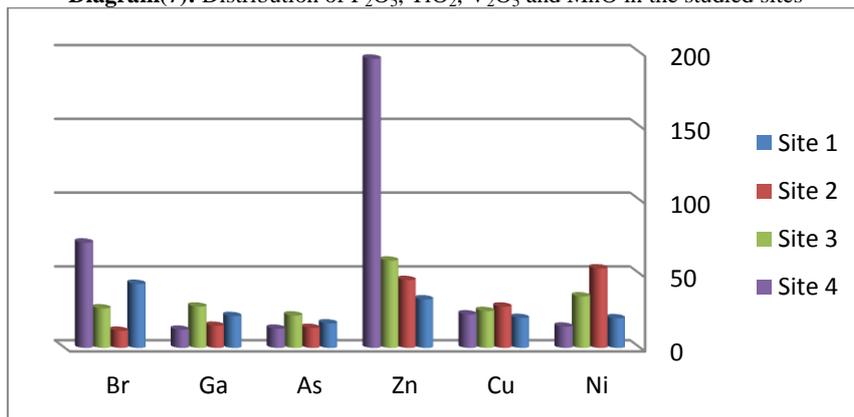
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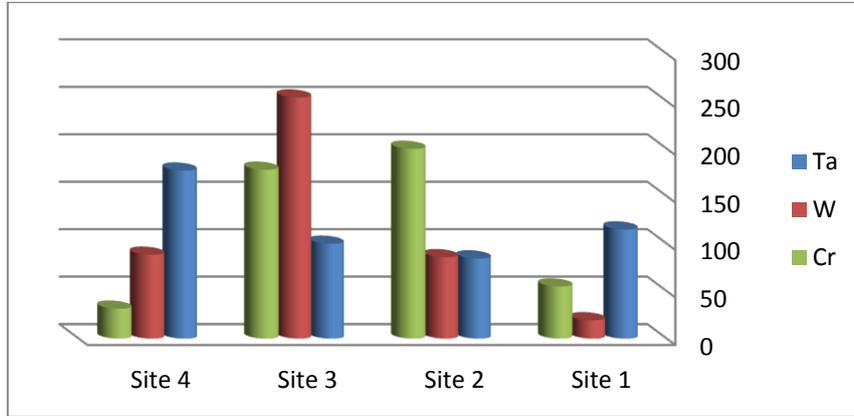
**Diagram(6):** Distribution of Al<sub>2</sub>O<sub>3</sub>, MgO, Fe<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, and SrO in the studied sites.



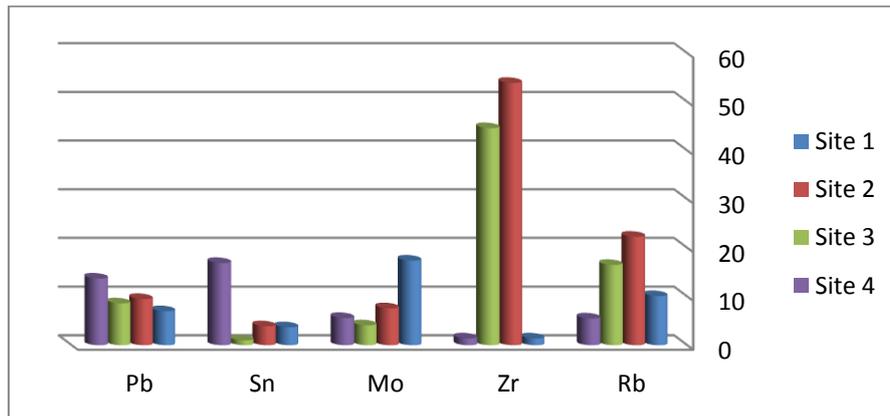
**Diagram(7):** Distribution of P<sub>2</sub>O<sub>5</sub>, TiO<sub>2</sub>, V<sub>2</sub>O<sub>5</sub> and MnO in the studied sites



**Diagram(8):** Distribution of Br, Ga, As, Zn, Cu, and Ni in the studied sites.



**Diagram(9):** Distribution of Ta, W, and Cr in the studied sites.



**Diagram(10):** Distribution of Pb, Sn, Mo, Zr, and Rb in the studied sites.

## CONCLUSIONS

The present study concluded the following:

- 1- Aragonite and calcite are the main minerals in the *Platygyra pini*, the aragonite content at 63.8% higher than that of calcite at only 28.3%.
- 2- Calcite, low Mg- calcite, and aragonite are the dominant minerals observed in the Octocoral *Menella* coral .
- 3- Quartz and phengite are the main minerals within the sediments of the study area at site 3, whereas chlorite and talc are most prominent at site 2.
- 4- Calcium oxide (CaO) is the most abundant oxide in the study area followed by silica oxide (SiO<sub>2</sub>).
- 5- Most proportions of calcium oxides in the sediments of coral reef area are providing from coral reefs itself.
- 6- Most of the silica oxides are obtained from quartz and clay minerals, whereas most calcium oxide observed in the coral reefs.

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- 7- Some major and trace elements associated with non-carbonate minerals are increased with decreased of CaO.
- 8- Strontium and a few trace elements that have radii close to or greater than 1.00 Å, have a preferred presence in aragonite layers especially within the *P. pini*. While Mo preferred presence in a calcite layer of *Menella*.

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معدنية و جيوكيميائية الشعاب المرجانية في البيئة البحرية العراقية في الجزء الشمالي من  
الخليج العربي

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الخلاصة

تم دراسة معدنية وكيميائية منطقة الشعاب المرجانية في شمال غرب الخليج العربي لإلقاء الضوء على هذه البيئة البحرية العراقية الفريدة . جمعت ستة عينات من نوعين رئيسيين من الشعاب المرجانية *Platygyra pini* و *Menella* في موقعين. في حين تم اختيار ثمانية عينات من الرواسب البحرية المحيطة من موقعين آخرين. حددت المعادن عن طريق الأشعة السينية الحادة XRD للشعاب المرجانية والرواسب.

اظهرت الدراسة المعدنية أن calcite و low magnesium calcite و aragonite هي المعادن الرئيسية التي تتألف في *Octocoral Menella* في الموقع 1 ، في حين تهيمن معادن aragonite و calcite في *P. pini* في الموقع 4؛ تشير المكونات الغير الكربوناتيية إلى أن هذه الشعاب المرجانية تحتوي على نسب من quartz و feldspar و halite و gypsum . لوحظ ان أعلى محتوى من aragonite في *P. pini* مقارنة مع وجود calcite. ان نسبة معادن الكربوناييت تصل الى 92.1٪ في *P. pini* مقارنة مع نسبتها في *Octocoral Menella* و هي 73.1٪. تمثل معادن chlorite و talc المعادن في رسوبيات الموقع 2 ، في حين أن quartz و phengite هما من أبرز المعادن في رسوبيات الموقع 3.

ان معدن ال phengite هو أول اكتشاف في رواسب الخليج العربي ، في حين أن talc هو أول اكتشاف في الرواسب البحرية العراقية.

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ان تركيز CaO هو الأكثر وفرة في جميع العينات التي تم تحليلها في منطقة الشعاب المرجانية يليها SiO<sub>2</sub>؛ هناك أعلى نسب من CaO في *P. pini* (56.65%) مقارنة بنسبتها في *Menella* (48.81%). هناك بعض أنماط التوزيع الخاصة للعناصر الرئيسية والعناصر النزرة في منطقة الشعاب المرجانية بناءً على محتوى الكالسيوم؛ جاءت معظم نسب السيليكا من quartz و phengite والمعادن الطينية.

لوحظ هناك تواجد نسب عالية من تراكيز Al<sub>2</sub>O<sub>3</sub> و Fe<sub>2</sub>O<sub>3</sub> و K<sub>2</sub>O و Na<sub>2</sub>O و MgO و SiO<sub>2</sub> و TiO<sub>2</sub> و V<sub>2</sub>O<sub>5</sub> و Cr و Ni و Cu و Rb و Zr في رواسب الموقع 2 مقارنة بالمواقع الأخرى؛ يمكن أن تعزى هذه النتائج إلى ارتباط هذه العناصر بالمعادن الطينية عن طريق الامتصاص أو الامتصاص. ان أعلى محتوى من P<sub>2</sub>O<sub>5</sub> و Ga و W و As وكما في رواسب الموقع 3 قد تعكس امتزاز هذه العناصر على اسطح معادن quartz و phengite. قد تشير التراكيز العالية من Sr، و Zn و Br و Sn و Ta، و Pb في الشعاب المرجانية *Platygyra pini* إلى التأثيرات النسبية للتغير البيئي داخل المنطقة المدروسة.