

CHEMICAL AND ORGANIC DEPOSITS OF THE SEA ¹

BY THOMAS WAYLAND VAUGHAN

(Presented before the Society December 29, 1916)

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INTRODUCTION

As the discussion of this subject is necessarily brief, no attempt will be made to review the classification of organic and chemical deposits advanced by Murray and Renard in the *Challenger* reports, and I will immediately pass to the consideration of some of the results obtained from researches made during the past ten years. My remarks will be for the most part confined to the discussion of deposits formed in water less than 100 fathoms deep, because recent investigation has been chiefly directed to these and because the geologist usually encounters relatively shallow-water sediments in his field-work. However, in places accumulations of pelagic foraminifera, of radiolarian earths, and of certain particular kinds of manganese nodules above present sealevel indicate that some ancient deep-sea deposits have been elevated from several thousand feet below the surface of the ocean and now form parts of dry-land areas; but the areas occupied by such deposits are relatively small in comparison with the enormous extent of sediments of shallow-water origin.

¹ This is the sixth of a series of papers composing a "Symposium on the Interpretation of Sedimentary Rocks."

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AUTHOR'S NOTE.—The short paper herewith presented is to some extent an abstract of a larger paper by myself in collaboration with J. A. Cushman, M. I. Goldman, M. A. Howe, and others, entitled "Some shoal-water bottom samples from Murray Island, Australia, and comparisons of them with samples from Florida and the Bahamas," Carnegie Institution of Washington Pub. 213, 1917, pp. 235-297. The accompanying tables are taken from the larger paper, but the illustrations on plates 47 and 48 are published for the first time. It is published by permission of the President of the Carnegie Institution of Washington and of the Director of the U. S. Geological Survey.

In order to make an application of the results procured from a study of modern sediments to the interpretation of the conditions under which the older were formed, samples must be collected and studied, and all obtainable information regarding the conditions under which they were deposited should be gathered. This information should include the relations of the deposit to land areas, the configuration of the sea-bottom, the velocity and direction of winds and currents, and the depth, temperature, and salinity of the water. Air temperature, rainfall, and surface run-off and sediment from adjacent land areas, where there are such, should also be known; and it is desirable to know the chemical composition of the water discharged into the sea and that of the rocks over which or through which it passes.

Each sample should be divided into four parts, unless the quantity of the material is large. One part should be preserved intact, the second used for a chemical analysis, the third for a mechanical analysis and petrologic study, and the fourth for a detailed list of the important organisms entering into its composition.

Although complete analyses of selected samples are needed, the analyses usually are only partial, because of the impracticability of having an indefinite amount of chemical work performed. SiO_2 , Fe_2O_3 , Al_2O_3 , CaO , MgO , P_2O_5 , and SO_3 are determined in as many samples as practicable, while CaO and MgO and insoluble residue after ignition are determined in a larger number. The ratio of MgO to CaO (or of the hypothetical combinations MgCO_3 to CaCO_3) is highly important, as will later be made clear.

Mechanical analyses have been sufficiently discussed by Mr. Shaw in the immediately preceding paper.

CHEMICAL DEPOSITS

As the chemical deposit of greatest geologic importance in the shoal waters of the ocean is calcium carbonate, attention will be confined to it. No argument is needed to show that to understand the relative saturation of the ocean with reference to CaCO_3 is of prime importance. Fortunately the subject has recently been attacked by a number of investigators.

As a part of a discussion of the formation of atoll rims, I summarized the results obtained up to 1914 as follows:²

“(1) All the bays, sounds, and lagoons within the Florida reef and key region are filling with sediment; (2) Drew's investigations of denitrifying bacteria show that chemical precipitation of calcium carbonate is taking place in the lagoons; (3) the chemical examination by R. B. Dole of samples of sea

² Wash. Acad. Sci. Jour., vol. 4, Jan. 19, 1914, pp. 27-28.

water flowing into and out of the Tortugas lagoon show that although both carbonate and bicarbonate radicles are in solution, uncombined carbon dioxide is not present, and that the water possesses no capacity for further solution of calcium carbonate by virtue of its content of free carbon dioxide; (4) the determinations by Dole of the salinity of the water within the Tortugas lagoon and at the southern end of Biscayne Bay show a higher concentration than that in the open sea-water on the outside, indicating that concentration by evaporation is taking place. As the results of these lines of inquiry are so positive, the formation of lagoons by submarine solution may be definitely eliminated from consideration."

Johnston and Williamson have recently paid particular attention to the solubility-product constant $[Ca^{++}] [CO_3=]$, the concentration of H_2CO_3 , the effect of temperature on H_2CO_3 concentration, and the relation of the solubility-product constant to rise in temperature, and say:

"We believe therefore that the surface layers of the ocean, except in the polar regions and within currents of cold water—in other words, the warmer portions of the ocean—are substantially saturated with $CaCO_3$; but the truth of this belief can not be regarded as established until trustworthy determinations of the several quantities concerned have been made."

The latest contribution to the subject is by R. C. Wells in an article entitled "The solubility of calcite in sea-water in contact with the atmosphere and its variation with temperature."⁴ His experiments were conducted with water from Fowey Rocks Light, Florida, collected between July 19 to 25, 1915. He says:

"In other words, sea-water appears to contain so much carbonate that in contact with the atmosphere at 1° C. it neither has nor acquires an appreciable solvent action on calcite. At higher temperatures it undergoes a slow diminution in its content of carbonates on being agitated in contact with outdoor air."

The evidence appears to me conclusive that ocean water, except at great depths and probably on the surface in polar regions, is saturated with $CaCO_3$. If this conclusion is granted, it is obvious that any agency that increases the $CaCO_3$ concentration or that diminishes the capacity of the water to hold $CaCO_3$ in solution will produce precipitation.

Are there precipitating agencies? There are, and they are both inorganic and organic. Of the inorganic agents there are three, as follows: (1) Increased concentration due to evaporation. (2) Loss of CO_2 into the atmosphere where the CO_2 content of the atmosphere is below the amount necessary for equilibrium with that of the water. The loss of CO_2 under such conditions will be hastened by surface agitation of the water. (3) Loss of CO_3 by increase in temperature. Of the organic

³ Jour. Geol., vol. 24, Dec., 1916, p. 735.

⁴ Carnegie Inst. Washington Pub. 213, 1917, pp. 316-318.

agents, bacteria appear to be the most important. As the result⁵ of the investigations of Drew and of Kellerman on dentrifying bacteria are now generally known, it is here only necessary to say that these organisms evolve ammonia which may take up CO_2 from bicarbonates or may react with calcium sulphate, producing an excess of CaCO_3 , which consequently is precipitated. Any other ammonifying bacteria will produce the same result, and green plants by robbing the water of CO_2 may bring about precipitation.

An evaluation of the work done by inorganic and organic agencies has not yet been made, and it is exceedingly difficult, if not actually impossible, to make it. For instance, off the west side of Andros Island, Bahamas, opposite South Bight, where the deposit is largely a chemical precipitate, the salinity of a spot sample of water was 38.86 parts per thousand, while that of the tongue of the ocean east of Andros Island was about 36.50 parts per thousand, and that of the water at Fowey Rocks, Florida, is about 36 parts per thousand. The increased concentration would necessarily cause precipitation. At the same locality there is surface agitation of the water; and as there is an enormous submarine flat, having a width east and west of 60 sea miles and a maximum depth of only about 18 feet below mean low-tide level, the temperature during the hotter months of the year would naturally be higher than in the open ocean. Therefore all three inorganic agencies are operative. At the same locality Drew found "160,000,000 dentrifying bacteria per 1 cubic centimeter,"⁶ and thought the actual number probably greater. The problem is complex and needs further investigation.

Although the criteria for recognizing chemical precipitates in bottom samples have not yet been worked out in the desired detail, some of them may be mentioned. Among them are spherulites, separate aragonite needles, and aggregates of aragonite needles into the globular, ovoid, or ellipsoidal bodies known as oolite grains. Illustrations of these are given on plate 47, figures 1 to 7, and plate 48, figures 1 to 3 (see page 944).

For purposes of comparison, besides mounts of such objects as are shown on plates 47 and 48, those of us engaged in these studies have many preparations of artificial and natural precipitates. The paper by Messrs. Johnston, Merwin, and Williamson, entitled "The several forms of calcium carbonate,"⁶ is of great value in this connection.

With reference to the chemical composition of deposits of the kind under consideration, it will be said that they are almost pure calcium carbonate. Excluding silica, the elevated oolites of Florida and the Ba-

⁵ Carnegie Inst. Washington Pub. No. 182, 1914, pp. 41-43.

⁶ Am. Jour. Sci., vol. 41, 1916, pp. 473-512.

hamas contain over 99 per cent CaCO_3 and only traces of MgCO_3 ; in the oolitic muds, however, MgCO_3 usually ranges from about 2.7 to about 3 per cent, this larger percentage probably being due to the presence of alcyon arian epicules and of foraminiferal shells and other organic tests that contain MgCO_3 . The oolites, both those elevated and those submarine, seem uniformly to contain a little CaSO_4 , which, according to Messrs. Johnston, Merwin, and Williamson, is probably necessary for the formation of aragonite at ordinary sea temperatures.

Chemical Analyses of Oolite and bottom Samples from Florida and The Bahamas

(By W. C. Wheeler)

	Oolite, Boca Grande Key, Florida.	Oolite, Ever- glades, Miami, Florida.	Oolite Sharp Point, Andros Island.	Bottom sample ⁷ (98), east side Marquesas Lagoon, Florida.	Bottom sample ⁸ (87), 1 mile west of west end of South Bight, Bahamas.
Chemical Analyses					
	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>	<i>p. ct.</i>
SiO_2	0.03	8.23	0.07	1.13	0.28
Al_2O_3.....	.18	.00	.00	.14	.03
Fe_2O_3.....	.22	.21	.13	.21 (total Fe)	.11 (total Fe)
MgO	Trace.	Trace.	Trace.	1.31	1.25
CaO	53.77	51.60	54.57	51.04	52.30
Na_2O}.....	.90	.11	.14	.....	.....
K_2O	Trace.	Trace.	Trace.	.....	.....
H_2O	1.21	.17	1.72	2.03 (and organic)	3.16 (and organic)
CO_2	42.34	40.11	43.07	41.50	42.45
P_2O_5	Trace.	Trace.	Trace.	.....	.....
SO_3.....	.28	Trace.	.14	.....	.....
Cl	1.02	.08	.03	.....	.....
Soluble.....	.....	.....	.....	¹⁰ 2.21	.....
Total.....	99.95	100.51	99.87	99.57	99.58

Reduced analysis (hypothetical combination); H_2O , organic matter, and soluble salts rejected; silica not essential.

SiO_2	0.03	8.19	0.07	1.18	0.29
$(\text{Al}, \text{Fe})_2\text{O}_3$.....	.42	.21	.13	.37	.15
MgCO_3	Trace.	Trace.	Trace.	2.88	2.72
CaCO_3	99.05	91.60	99.56	95.57	96.84
$\text{Ca}_3\text{P}_2\text{O}_8$	Trace.	Trace.	Trace.	.....	.....
CaSO_4.....	.50	Trace.	.24	.....	.....
Total.....	100.00	100.00	100.00	100.00	100.00

⁷ Samples washed and dried over H_2SO_4 .

⁸ Sample filtered, washed, and dried over H_2SO_4 .

⁹ Twenty-five per cent soluble SiO_2 ; the rest of the silica appears to be white sand.

¹⁰ Saline salts not washed out by water in the preparation of the sample.

Conditions are most favorable for the precipitation of calcium carbonate and for the accumulation of the precipitated material, which at first is in a very finely divided state, where the temperature of the sea is high and where there are relatively shallow bodies of water that are protected from heavy seas and strong currents. On actual coral reefs there seems to be no chemically precipitated calcium carbonate, and there is but little of it along the channels through lagoons. The amount of material of such an origin in specific localities is graded in accordance with the character and strength of winds and local currents.¹¹

ORGANIC DEPOSITS

In the investigation of organic deposits, after the mechanical analysis has been made, the separates are studied to determine the proportion of each of the ingredients composing each separate. In order to facilitate the recognition of the ingredients, a reference collection of coccolithophoridæ, diatoms, calcareous algæ, radiolaria, foraminifera, madreporarian and alcyonarian corals, echinoids, bryozoa, mollusks, crustacea, bones, etcetera, is necessary. The skeletons of the larger organisms are prepared for study as thin sections and mounted crushed fragments. The tables of the analyses of the skeletons of marine invertebrates and of calcareous algæ, recently prepared by F. W. Clarke and W. C. Wheeler, make possible estimating the proportion of the chemical constituents contributed by each group of organisms that takes part in the formation of the deposit. The following are estimates by Dr. M. I. Goldman of the averages for the composition of the marine invertebrates and calcareous algæ at Murray Island, Australia, using the Clarke and Wheeler tables as the basis of his estimates. Two tables of analyses, one of calcareous algæ and one of foraminifera, are here presented. It seems probable that Doctor Goldman's estimate of the MgCO_3 content of the *Corallinaceæ* is a little too high.

¹¹ This subject is discussed in considerable detail in the larger paper referred to in the footnote on page 933.

Average Composition of the Skeletons of marine Invertebrates and of Calcareous Algae, estimated for Murray Island, Australia

	CaCO ₃	MgCO ₃	CaSO ₄	Ca ₃ P ₂ O ₈
Corallinaceæ.....	80.00	19.00	1.00	.....
Halimeda.....	99.00	.50	.50	.....
Mean alga.....	89.50	9.75	.75	.....
Madreporaria.....	99.30	.70	.....	.....
Alcyonaria.....	75.00	15.00	.....	8.00
Mollusks.....	99.75	.25	.....	.....
Tinoporus.....	89.00	11.00	.....	.....
Amphistegina.....	95.20	4.80	.....	.....
Orbitolites.....	89.40	10.60	.....	.....
Polytrema.....	88.75	11.25	.....	.....
Approximate average foraminifera.....	89.50	10.50	.....	.....
Crustacea:				
(1) Malacostraca and ostracods.....	77.00	12.50	1.25	8.75
(2) Balanus.....	98.50	1.50	.....	.....
Sea-urchin spines.....	90.00	9.00	1.00	.....
Worm-tubes.....	91.00	8.00	.....	1.00

Chemical Composition of Corallinaceæ from Murray Island and Cocos-Keeling Islands

(By Alfred A. Chambers)

Chemical analyses of calcareous algae

	<i>Goniolithon frutescens</i> Fosl., Cocos-Keeling Islands.	<i>Goniolithon orthoblastum</i> (Heyd.), M. A. Howe, Murray Island Australia.	<i>Lithophyllum kaiseri</i> Heyd., Cocos-Keeling Islands.
Loss on ignition.....	46.70	50.97	45.72
SiO ₂ +Fe ₂ O ₃ +Al ₂ O ₃.....	.07	.11	.28
CaO.....	46.16	42.39	45.92
MgO.....	6.29	5.71	7.09
P ₂ O ₅	Present.	Present.	Present.
SO ₃	None.	None.	None.
Total.....	99.22	99.18	99.01
CO ₂ needed.....	43.19	39.59	43.88

Reduced analyses (hypothetical combinations)

SiO ₂ , (Al, Fe) ₂ O ₃	0.07	0.12	0.29
MgCO ₃	13.80	13.66	15.33
CaCO ₃	86.13	86.22	84.38
Ca ₃ P ₂ O ₈	Trace.	Trace.	Trace.
CaSO ₄.....	.00	.00	.00
Total.....	100.00	100.00	100.00

Chemical Analyses of Foraminifera important as Contributors to Deposits in Coral-reef Areas

- (1) *Tinoporos baculatus* (Montfort) Carpenter, from Murray Island.
- (2) *Polytrema mineaceum* (Linn.), from Cocoanut Point, Andros Island, Bahamas.
- (3) *Orbiculina adunca* (Fichtel and Moll), from Key West, Florida.
- (4) *Orbitolites marginalis* (Lam.), from south of Tortugas, depth 17 fathoms.
- (5) *Quinqueloculina auberiana* d'Orbigny, from south of Tortugas, depth 17 fathoms.

Analyses of 1, 2, 3, 4 by W. C. Wheeler; of 5 by Alfred A. Chambers

Chemical analyses of foraminifera

	(1) Tinoporos.	(2) Polytrema.	(3) Orbiculina.	(4) Orbitolites.	(5) Quinqueloculina.
SiO ₂	0.03	} 0.02 {	0.11	0.30	} 0.54
(Al, Fe) ₂ O ₃ ..	.18		.09	.13	
MgO.....	5.03	5.09	4.64	4.93	4.32
CaO.....	27.35	47.35	48.79	48.92	49.02
P ₂ O ₅.....	.00	(?)	Trace.	Trace.	(?)
Ignition ¹² ...	46.57	46.24	45.56	45.20	45.54
Total...	99.16	98.70	99.09	99.48	98.42

Reduced analyses (hypothetical combinations)

	(1) Tinoporos.	(2) Polytrema.	(3) Orbiculina.	(4) Orbitolites.	(5) Quinqueloculina.
SiO ₂	0.03	} 0.02 {	0.11	0.31	} 0.56
(Al, Fe) ₂ O ₃ ..	.19		.09	.13	
MgCO ₃	11.08	11.22	10.04	10.55	9.33
CaCO ₃	88.70	88.76	89.76	89.01	90.11
Ca ₃ P ₂ O ₈.....	.00	(?)	Trace.	Trace.	(?)
Total...	100.00	100.06	100.00	100.00	100.00
	Murray Id.	Bahamas.	Key West.	Tortugas.	Tortugas.

Doctor Goldman undertook at my request a study of two bottom samples from Murray Island, Australia, and endeavored to correlate the chemical composition of each sample as deduced from the organic remains composing it with the chemical composition of the entire sample as determined by actual analysis.

¹² Equals organic matter + CO₂ + H₂O.

*Summary of Analysis of organic Composition of Sample No. 27337, from
Murray Island, Australia*

I. Numbers of grains of different organisms counted

	Algae.	Corals.	Mollusks.	Tinoporos.	Amphistegina.	Orbitolites.	Undifferentiated foraminifera.	Crustacea.	Balanus.	Worm-tubes.	Total.
Fine gravel....	39	31	29	5	4	2	..	..	..	..	110
Coarse sand....	56	58	20	2	1	1	3	2	..	1	144
Medium sand..	11	20	5	..	..	1	1	..	..	1	39
Fine sand.....	21	20	9	..	..	..	2	..	1	..	53
Very fine sand.	6	11	2	..	..	..	..	..	..	..	19
Total...	133	140	65	7	5	4	6	2	1	2	365

II. Calculated percentage by weight of different organisms present

Fine gravel....	9.4	6.3	6.5	0.8	0.5	0.2	..	..	..	..	..
Coarse sand....	19.3	13.3	3.3	.4	.1	.3	0.6	0.4	..	0.1	..
Medium sand..	3.8	6.2	1.5	..	..	.3	.2	..	..	.1	..
Fine sand.....	9.8	8.4	3.8	..	..	..	.7	..	0.6	..	..
Very fine sand.	.2	.4	.1	..	..	..	..	..	..	..	..
Total...	42.5	34.6	15.2	1.2	.6	.8	1.5	.4	.6	.2	97.6

III. Calculated percentage chemical composition by organisms

CaCO ₃	38.0	34.4	15.2	1.0	0.6	0.7	1.3	0.3	0.6	0.2	92.3
MgCO ₃	4.2	.2	.0	.2	.0	.1	.2	.1	.0	.0	5.0
CaSO ₄.....	.3	..	..	..	..	..	..	..	..	..	.3
Ca ₃ P ₂ O ₈.....	..	..	..	..	..	..	..	..	..	..	..

IV. Calculated percentage chemical composition by size portions

	Per cent present.	CaCO ₃ .	MgCO ₃ .	CaSO ₄ .	Ca ₃ P ₂ O ₈ .
Fine gravel.....	23.6	22.40	1.10	0.3	....
Coarse sand.....	37.9	35.55	2.20	....	Tr.
Medium sand.....	12.2	11.70	.50	....	Tr.
Fine sand.....	23.2	22.00	1.15	....	....
Very fine sand.....	.7	.65	.05
	97.6	92.3	5.00	0.3	Tr.
Silt.....	.7	1.7	Tr.
Clay.....	1.2	1.7	Tr.
Total.....	99.5	98.7	5.0	0.3

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Chemical Composition of Samples from Murray Island, Australia, as calculated from their organic Ingredients and as determined by chemical Analysis

Specimen No. 27353a, 1,600 feet from shore

	CaCO ₃ .	MgCO ₃ .	CaSO ₄ .	Ca ₃ P ₂ O ₈ .	SiO ₂ and (Al, Fe) ₂ O ₃ .
Calculated.....	94.3	4.6	0.2	Tr.	.60
Observed.....	93.6	5.8	Tr.	...	.60

	CaCO ₃ .	MgCO ₃ .	CaSO ₄ .
Revised.....	93.0	5.8	0.2
Observed.....	93.6	5.8	Tr.

Specimen No. 27337, 200 feet from shore

	CaCO ₃ .	MgCO ₃ .	CaSO ₄ .	Ca ₃ P ₂ O ₈ .	SiO ₂ and (Al, Fe) ₂ O ₃ .
Calculated.....	93.7	5.0	0.3	Tr.	0.63
Observed.....	93.85	5.5	Tr.	.00	.63

	CaCO ₃ .	MgCO ₃ .	CaSO ₄ .
Revised.....	93.15	5.5	0.3
Observed.....	93.85	5.5	Tr.

The relative importance of organisms in the samples from Murray Island is as follows: 1,600 feet from shore, madreporarian corals, 41.9 per cent; calcareous algæ, 32.6 per cent; foraminifera, 12.4 per cent; mollusca, 10.2 per cent. At 200 feet from shore the order is: Calcareous algæ, 42.5 per cent; madreporarian corals, 34.6 per cent; mollusca, 15.2 per cent; foraminifera, 4.1 per cent.

The next two tables will bring out the similarity between the material from behind the reef at Murray Island and that from behind the reef at Coconut Point, Andros Island, Bahamas.

Percentages of Particles of Silt and Clay Size in bottom Samples from the Reefs at Murray Island, Australia, and at Cocoanut Point, Andros Island, Bahamas.

Murray Island		Cocoanut Point	
	Per cent	Sample	Per cent
200 feet from shore.....	1.9	190.....	1.5
600 feet from shore.....	2.8	191.....	1.8
1,200 feet from shore.....	.9	192.....	1.7
1,600 feet from shore.....	1.4	193.....	1.9
Average.....	1.75	Average.....	1.725

REMARKS.—It should be noted that as fine and medium sand are predominant in the Cocoanut Point samples, they average finer than the Murray Island specimens.

Percentage of $MgCO_3$ (hypothetical Combination) in Samples considered in preceding Table

Murray Island		Cocoanut Point	
	Per cent		Per cent
200 feet from shore.....	5.52	Composite of samples 190	
600 feet from shore.....	5.95	to 193.....	5.24
1,200 feet from shore.....	5.76		
1,600 feet from shore.....	5.83		
Average.....	5.745	Average.....	5.24

Material such as that on and behind the coral reefs at Murray Island, Australia, and Cocoanut Point, Bahamas, are predominantly composed of the remains of madreporarian corals and calcareous algæ; in some places the remains of one, in other places the remains of the other, group of organisms predominating. Grains derived from these two sources form between 74 and 76 per cent of the material across the Murray Island reef, while, roughly, from 20 to 23 per cent is due to mollusca and to shoal-water, bottom-living foraminifera. There is very little pelagic material, although it should be mentioned that coccolithophoridae are invariably present at each locality in separates of silt and clay size. There is an important difference between the Murray Island and Cocoanut Point samples in that those from Murray Island contain no alcyonarian spicules, while there are many such spicules in the material from Cocoanut Point.

Deposits of the kind just described are dependent on definite, areally limited, ecologic conditions; and, according to present information, they cover relatively small areas. In other areas molluscan remains predominate; in others tests of foraminifera, while in others there are relatively few organic remains and the material is mostly a chemical precipitate. Large deposits of calcium carbonate formed by the secreting activities of organisms, as well as those deposits formed by chemical precipitation, are

found in the warmer parts of the ocean, or at least where the surface temperature is high.

CONCLUSION

The investigations outlined comprise ascertaining the physical and chemical characters of a deposit, analyzing it to discover the source of each constituent, evaluating each constituent, and classifying the deposit according to the source of its constituents. The physico-chemical conditions that determine the presence of the responsible depositing agencies in each particular spot must be ascertained and deposits formed under different physico-chemical conditions must be compared. By following such a procedure we may hope to understand what is now happening in the sea, and the knowledge thus gained may enable us to make dependable deductions regarding the history of the sediments that engage our attention in our geologic researches.

EXPLANATION OF PLATES

PLATE 47.—*Artificial Spherulites and Oolites*

FIGURE 1.—Spherulites bacterially formed in water from Great Salt Lake. $\times 100$. (Preparation by K. F. Kellerman.)

FIGURE 2.—Spherulites bacterially formed from calcium acetate in water from Great Salt Lake. $\times 50$. (Preparation by K. F. Kellerman.)

FIGURE 3.—Zonal spherulite inorganically formed in sea-water from Florida. $\times 350$.

FIGURE 4.—Zonal spherulites inorganically formed in sea-water from Florida. $\times 700$.

PLATE 47.—*Natural Precipitates*

FIGURE 5.—Great Salt Lake oolite. $\times 100$.

FIGURE 6.—Aragonite needles out of mud from the west side of Andros Island. $\times 840$.

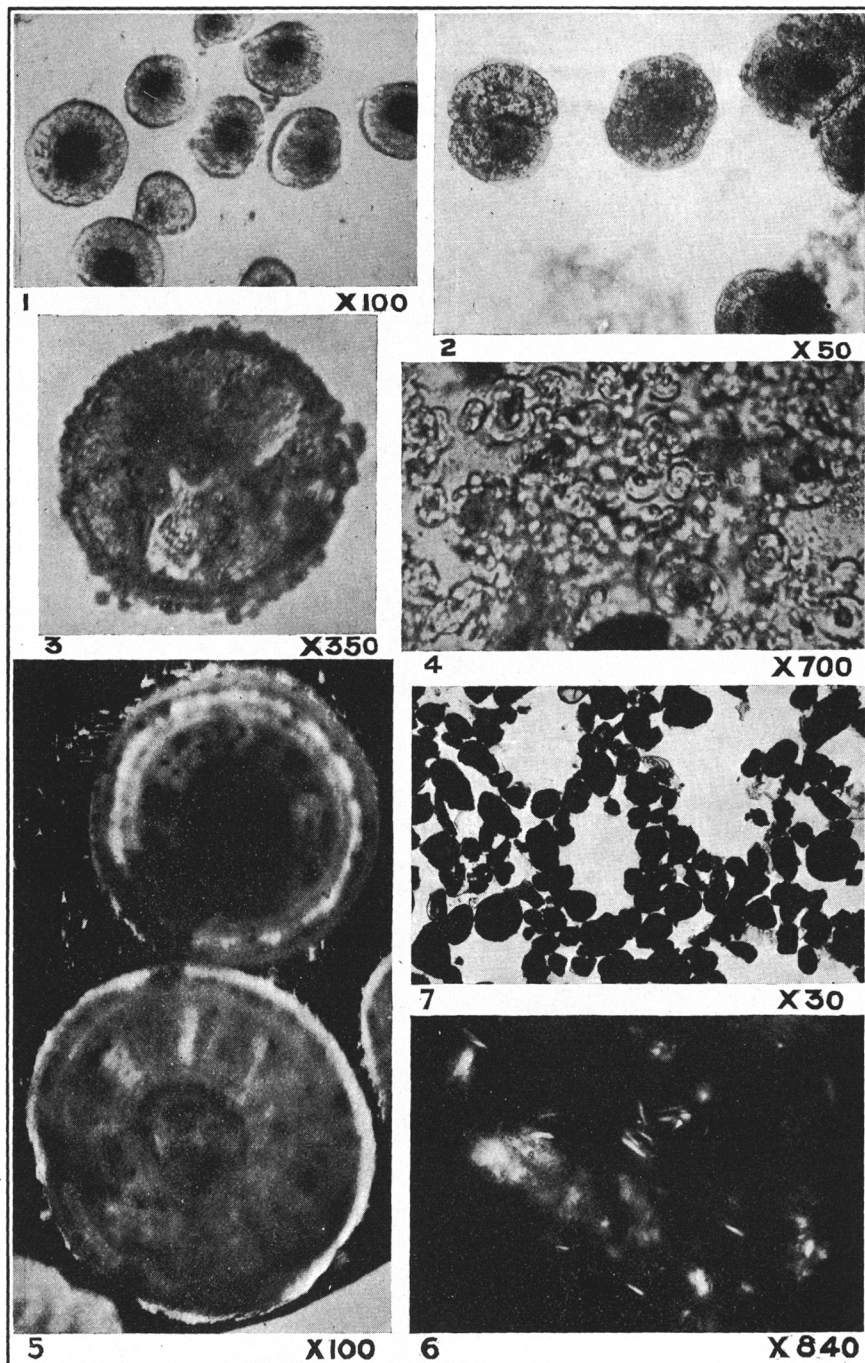
FIGURE 7.—Small oolites out of mud from the west side of Andros Island. $\times 30$.

PLATE 48

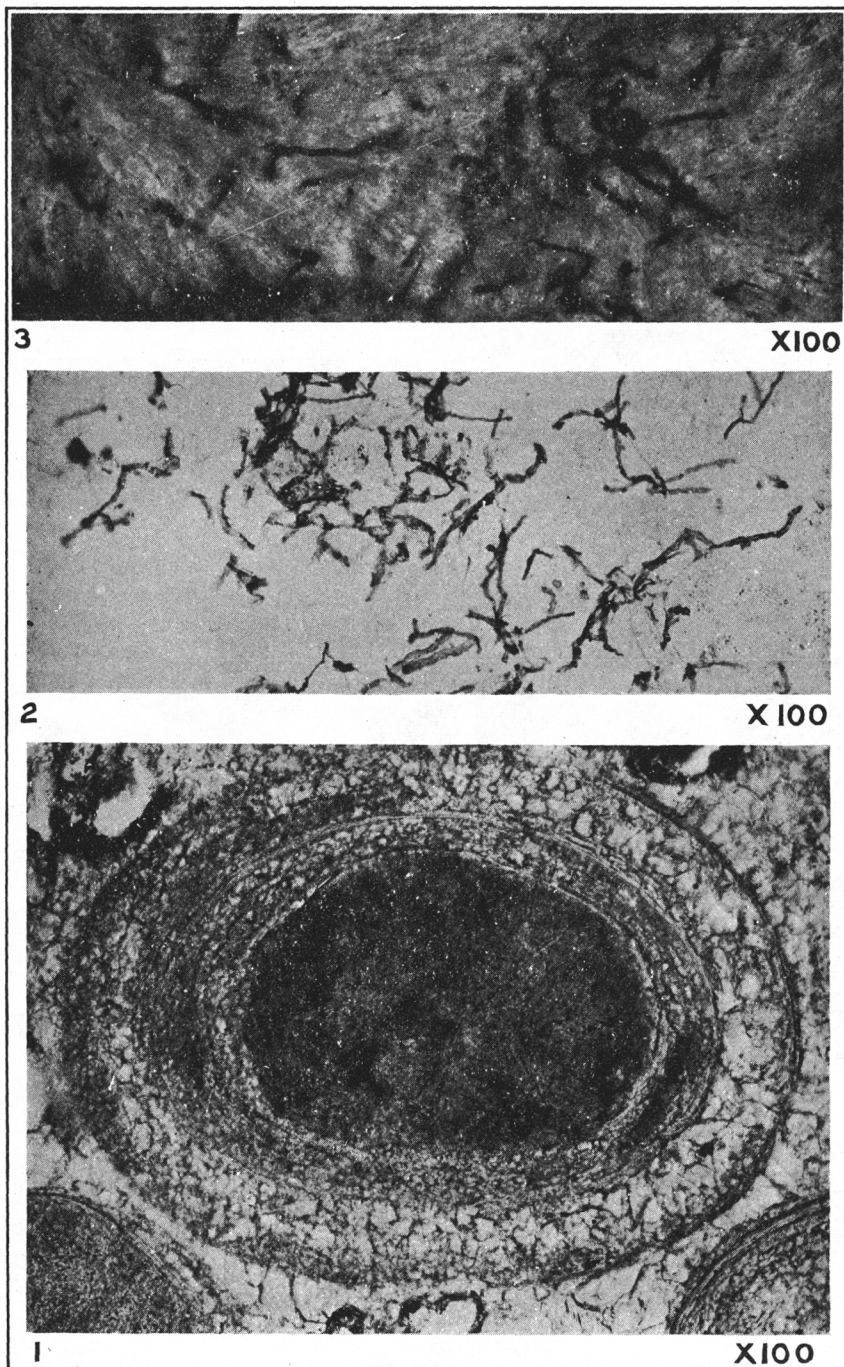
FIGURE 1.—Bahaman elevated oolite. $\times 100$, without traces of filamentous algæ.

FIGURE 2.—Illustrates filamentous algæ left after decalcification of a corallite of *Orbicella cavernosa* (Linn.). $\times 100$.

FIGURE 3.—Thin section of *Orbicella annularis* (Ellis and Solander), with filamentous algæ in place. $\times 100$. The presence of filamentous algæ in oolite grains is adventitious. These organisms bore into any calcium-carbonate structures that lie on the sea-bottom.



ARTIFICIALLY AND NATURALLY PRECIPITATED CALCIUM CARBONATE



FILAMENTOUS ALGAE THAT BORE INTO CORAL SKELETONS AND OOLITE
GRAIN WITHOUT FILAMENTOUS ALGAE

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