CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

VOLUME I, Parts 1 and 2
August, 1950

Contents

WASHINGTON, D. C., U. S. A.
1950

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Editor

Alfred R. Loeblich, Jr.

The CONTRIBUTIONS, the official organ of the Cushman Foundation for Foraminiferal Research, publishes original papers on any phase of foraminiferal study and short reviews of recent literature. The CONTRIBUTIONS will be issued quarterly.

Manuscripts may be submitted by any worker on the Foraminifera. Contributors should consult recent numbers of the CONTRIBUTIONS for the style to be used in manuscripts as regards arrangement of title, subheads, synonymy, footnotes, tables, bibliography, legends for illustration and other matter. Manuscripts should be typewritten, doubled spaced. Plates should be arranged for publication at the size of 5½ x 8 inches, exclusive of margins, heading and title. Communications in regard to manuscripts should be addressed to Alfred R. Loeblich, Jr., U. S. National Museum, Washington 25, D. C.

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* * * * * *

To all those who are making it possible to continue the Contributions for Foraminiferal Research, through their efforts in establishing the Cushman Foundation for Foraminiferal Research, Inc., we wish to express our heartfelt appreciation and to extend our best wishes for its success.

Frieda B. Cushman
Alice E. Cushman
Ruth Cushman Hill
Robert W. Cushman

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DORR'S PRINT SHOP, BRIDGEWATER, MASSACHUSETTS, U. S. A.

CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

VOLUME I, Parts 3 and 4
November, 1950

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PLATES

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DORR'S PRINT SHOP, BRIDGEWATER, MASSACHUSETTS, U. S. A.

1. CERTIFICATE OF INCORPORATION OF THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH, INC.

We, the undersigned, all of whom are of full age and citizens of the United States, and a majority of whom are citizens of the District of Columbia, desiring to associate ourselves as a corporation for the purposes set forth in paragraph 3 hereof in accordance with Title 29 of Chapter 6, of the District of Columbia Code (1940), do hereby state:

1. The name by which the corporation shall be known is the "Cushman Foundation for Foraminiferal Research, Inc."
2. The term for which the corporation is organized is perpetual.
3. The purposes of the corporation shall be the promotion and conducting of research in the paleontology and biology of the Foraminifera and allied organisms, and the publication of the results of such research.
4. The number of its directors for the first year of the existence of the corporation shall be as follows: until the first annual meeting of the directors, seven; thereafter, twelve.

IN WITNESS WHEREOF we have hereunto set our hands and seals.

G. Arthur Cooper
Alice E. Cushman
Frieda Billings Cushman
Robert W. Cushman
Lloyd G. Henbest
Ruth Cushman Hill
Edwin Kirk
J. Brookes Knight
Alfred R. Loeblich, Jr.
Helen Tappan Loeblich
John B. Reeside, Jr.

BY-LAWS

ARTICLE I

Name, Purposes and Seal

SEC. 1. *Name.* The name of this Corporation is the "Cushman Foundation for Foraminiferal Research, Inc.," hereinafter referred to as the "Foundation."

SEC. 2. *Purpose.* The purpose of the Foundation shall be the promotion and conducting of research in the paleontology and biology of the Foraminifera and allied organisms, and the publication of the results of such research.

SEC. 3. *Seal.* The corporate seal of the Foundation shall represent the form of a foraminifer, or group thereof, and shall bear the name of the Foundation and any other device approved by the Board of Directors.

ARTICLE II

SEC. 1. *Kinds of membership.* The membership of the Foundation shall consist of Fellows and Patrons. Fellows and Patrons may be persons, groups of persons, or institutions.

SEC. 2. *Fellows.* Fellows shall be persons, groups of persons, or institutions, who pay annual dues of ten dollars ($10.00).

SEC. 3. *Patrons.* Patrons shall be persons, groups of persons, or institutions, who contribute two hundred fifty dollars ($250.00) or more at any one time.

SEC. 4. *Subscribers.* Subscribers shall be persons, groups of persons, or institutions who pay the subscription fee of the "Contributions," the quarterly journal of the Foundation, hereinafter described.

SEC. 5. *Payment of dues.* All dues shall be payable in advance on or before January the second of each year.

SEC. 6. *Arrears.* No Fellow or subscriber who is in arrears shall receive the publications of the Foundation, nor exercise any of its privileges.

SEC. 7. *Currency.* All dues or obligations to the Foundation shall be paid in terms of United States money.

ARTICLE III
Directors

SEC. 1. *Number and qualifications.* After its first annual meeting, the Board of Directors (elsewhere referred to as the "Board") shall consist of twelve persons, of recognized standing as paleontologists, biologists, geologists or oceanographers, interested in the foraminifera. At least two shall be members of the Smithsonian Institution, one of whom shall represent the Department of Zoology and one the Department of Geology. At least one other Director shall be a member of the United States Geological Survey. Three members shall be chosen from the oil, or other industries that use foraminifera, and three shall be chosen from representatives of research and educational institutions, but this provision may be suspended by majority vote of the Board of Directors.

SEC. 2. *Election of Directors.* Directors shall be chosen by the Board from the Fellows of the Foundation.

SEC. 3. *Term of office.* The term of office for Directors shall be three years. At the first annual meeting of the Board, four Directors shall be chosen for a term of three years, four for two years, and four for one year.

SEC. 4. *Duties and powers.* The Directors shall have the control and management of the property and affairs of the Foundation. The Directors shall in all cases act as a Board regularly convened. In the transaction of business, the act of a majority of a quorum present at a meeting duly assembled shall be the act of the Board. The Directors shall elect the officers of the Foundation as hereinafter provided, and shall fill any vacancies occurring in the office of Director during any term. They may employ, discharge, and fix the salaries of employees of the Foundation as they may deem proper. The Board may adopt such rules and regulations for the conduct of their meetings and the management of the Foundation as they may deem proper, not inconsistent with law or these By-laws.

SEC. 5. *Meetings.* The Annual Meeting of the Board of Directors shall be held at such time and place as may be fixed from time to time by the Board. Special meetings may be called at any time by the President by giving advance written notice of at least two weeks, which notice shall specify the purpose and place of the meeting.

SEC. 6. *Quorum.* At any meeting of the Board, five members shall constitute a quorum.

SEC. 7. *Voting.* A vote resulting in a tie shall require a second vote. This shall be taken and, if a tie continues, the chairman shall cast the deciding vote. Directors unable to attend may vote by submitting their vote in writing to the Board before the vote is taken.

SEC. 8. *Order of business.* The order of business at the Annual Meeting shall be as follows:

(1) Call to order
(2) Reading of minutes of previous meeting
(3) Old or unfinished business
(4) Reading of the Secretary's, Treasurer's, and Editor's reports
(5) New business
(6) Adjournment

SEC. 9. *Committees.* The Board may, consistent with these By-laws and in its discretion, appoint and prescribe the power, duty and authority of such committees of Directors or Fellows or both, as it deems necessary for the administration of the affairs of the Foundation.

SEC. 10. *Attendance at meetings.* Failure to attend two or more annual or special meetings in succession, or to submit a written vote in accordance with section 7 of this article, without justifiable reason, shall be regarded as constituting resignation from the Board.

ARTICLE IV
Officers, their Duties and Executive Authority

SEC. 1. *Officers.* The officers of the Foundation shall consist of a President, a Vice President, and a Secretary-Treasurer. The president shall be a specialist of recognized standing in foraminiferal science.

SEC. 2. *Election and term of officers.* The Board shall elect the said officers from its own membership at its first annual meeting and each year thereafter at its annual meetings. The new officers shall assume duty immediately after the first annual meeting, and at the beginning of the calendar year following the succeeding annual meetings.

SEC. 3. *Duties of officers.* The duties and powers of the officers shall be as follows:

A. President
  1. The President shall preside at all meetings of the Board.
  2. He shall sign and execute all contracts in the name of the Foundation, and all notes, drafts, deeds, or other documents and papers necessarily or properly to be executed.
  3. He shall enforce these By-laws and perform all the duties incident to this office and which are required by law, and generally he shall supervise the corporate affairs of the Foundation.

B. Vice President
  1. During the absence or incapacity of the President, the Vice President shall perform the duties of that office, and when so acting he shall have all the powers and be subject to all the responsibilities of the office of President.

C. Secretary-Treasurer
  1. The Secretary-Treasurer shall keep minutes of the meetings of the Board and of the Foundation.

2. He shall attend to the serving of notices of all meetings of the Board and of the Foundation.
3. He shall be the custodian of the records and seal of the Foundation.
4. He shall attend to all correspondence and present to the Board of Directors at their meetings all official communications received by him.
5. He shall perform all the duties incident to the office of Secretary of a corporation as prescribed by law.
6. The Secretary-Treasurer shall have the care and custody of and be responsible for all the funds and securities of the Foundation, and shall deposit such in the name of the Foundation in such banks or trust companies as the Board of Directors may designate.
7. He shall make, sign and endorse in the name of the Foundation all checks, drafts, notes and other orders for the payment of money, and pay out and dispose of such, all under the direction of the President.
8. He shall keep correct books of account of all its business and transactions and shall exhibit his books and accounts to any Director upon request.
9. He shall render a report of the condition of the finances of the Foundation at each regular meeting of the Board of Directors and at such other times as shall be required of him, and he shall make a full financial report at the annual meeting of the Board.
10. He shall further perform all duties incident to the office of Treasurer of a corporation, as prescribed by law.
11. He shall give such bond as the Board shall determine appropriate for the faithful performance of his duties. The premium for said bond shall be paid by the Foundation.

SEC. 4. *Vacancies.* Vacancies among the officers and Directors shall be filled at the next regular or special business meeting of the Board for the remainder of the unexpired term.

ARTICLE V
Publications and Editors

SEC. 1. *Publication.* The Foundation shall publish a journal quarterly or as often as the Board shall deem appropriate, which journal shall be called "Contributions from the Cushman Foundation for Foraminiferal Research," elsewhere herein referred to as the "Contributions." The Foundation may, at the discretion of the Board, publish special papers or monographs.

SEC. 2. *Distribution.* One copy of each issue of the Contributions shall be distributed to each patron, fellow and subscriber. All other publications shall be offered for sale at a price or on a special subscription basis determined by the Board of Directors.

SEC. 3. *Management.* The Contributions and all other publications shall be managed by a Staff of Editors consisting of an Editor, two Assistant Editors, and such other Associate Editors as the Board shall determine.

SEC. 4. *Appointment of Editors.* The Editors shall be appointed by the Board of Directors and shall be selected for special competence in the use and study of Foraminifera. All terms shall be for three years and reappointment for like term. The Editor, Assistant Editors, and Associate Editors may not serve concurrently as members of the Board of Directors.

SEC. 5. *Editor.* The Editor shall determine, subject to authority from the Board of Directors, what papers shall be published and all matters dealing with format and composition of the various publications. He shall submit and certify to the Secretary-Treasurer the statements and bills of costs incurred.

SEC. 6. *Assistant Editors.* The Assistant Editors shall be termed senior and junior and in that order shall act in the absence of the Editor.

SEC. 7. *Associate Editors.* The Associate Editors shall cooperate with the Editor in obtaining papers in their special fields and submit them to the Editor for approval. They shall also cooperate with the Editor as scientific critics of papers and advise the Editor in their special fields. Two-fifths of the Associate Editors shall represent foreign countries.

SEC. 8. *Reports.* The Editor shall submit an annual report to the Board of Directors.

ARTICLE VI
Amendments to the By-Laws

SEC. 1. *Amendments.* Amendments to these By-laws may be made at any regular or special meeting of the Board of Directors by a two-thirds vote provided that a notice of the intent to amend the By-laws indicating the time and place of the meeting for said purpose and a copy of the proposed amendment or amendments shall have been sent by registered mail to each officer and member of the Board at least three months in advance of said meeting.

A meeting of the Incorporators of the Cushman Foundation for Foraminiferal Research, Inc., was held at 4 P.M., June 27, 1950, in the room devoted to the Cushman Collection in the United States National Museum, Washington, D. C., to elect Trustees and appoint an Editor for the remainder of the following year.

The following scientists were elected as Trustees with official positions as indicated, to serve in accordance with the By-Laws for the remainder of the current fiscal year of the Foundation:

James A. Waters as Trustee and President
G. Arthur Cooper as Trustee and Vice President
Margaret Ruth Todd as Trustee and Secretary-Treasurer
Carl O. Dunbar as Trustee
Lloyd G. Henbest as Trustee
John B. Reeside, Jr., as Trustee
Waldo L. Schmitt as Trustee

Alfred R. Loeblich, Jr., was appointed to serve as Editor for the remainder of the current fiscal vear.

According to the By-Laws, the above Trustees are obliged to complete the organization of the Foundation by electing a full staff of twelve permanent Trustees, and a complete staff of Editors. The selection of the Board of Trustees and appointment of the Board of Editors will be made with a view of representing all fields of the study of Foraminifera, including commercial micropaleontology.

The Foundation gratefully acknowledges legal services and advice of Mr. Harry M. Edelstein, Solicitor, United States Department of the Interior, which were given by the Department without obligation as a contribution to science. The organizers sought the advice of Dr. W. E. Wrather, Director of the United States Geological Survey, on many questions. His valuable counsel is gratefully acknowledged. Notarial service was given by Mr. Thomas F. Clarke of the Smithsonian Institution, also as a contribution to science.

2. ADDITIONAL FORAMINIFERA FROM THE NORTHERN RED SEA

RUSHDI SAID
Cairo, Egypt

ABSTRACT—The systematic descriptions of thirty species of Foraminifera observed in the northern Red Sea are presented. These species supplement those previously recorded by the author from the same area (1949).

Listed and described below are some additional species of Foraminifera that were observed in some bottom samples dredged from the northern Red Sea on board the R. R. S. *Mabaheth* in 1934-5. These together with the species described previously (Said 1949) bring the total number of species and varieties observed in the northern Red Sea to one hundred and eighty. Only five of these are pelagic: *Globigerina bulloides* d'Orbigny, *Globigerinoides sacculifera* (H. B. Brady), *Globigerinella aequilateralis* (H. B. Brady), *Orbulina universa* d'Orbigny and *Tretomphalus bulloides* (d'Orbigny).

SYSTEMATIC DESCRIPTIONS

Family REOPHACIDAE

Genus **Reophax** Montfort, 1808

Reophax sp. (Pl. 1, fig. 1)

Test elongate, consisting of four to six chambers arranged in a straight line, increasing in size as added; chambers indistinct; wall built of coarse sand grains and mica flakes finished smoothly.

A few specimens of this species were found at station 58 in the Red Sea proper (depth: 596 m.).

Family TEXTULARIIDAE

Genus **Textularia** Defrance, 1824

Textularia carinata d'Orbigny (Pl. 1, fig. 2)

Textularia carinata d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, No. 23.—H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 360, pl. 42, figs. 15, 16.—Egger, Abhandl. k. bay. Akad. Wiss., Muenchen, Cl. 11, vol. 18, 1893, p. 270, pl. IV, figs. 39-41.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 17, figs. 26, 27.—Ikari, The Suisangaku Zasshi, No. 30, 1927, p. 3, pl. 1, fig. 5.

A few typical specimens of this species are found in the Gulf of Aqaba and the Red Sea proper. Depth: 265-596 m.

This is a Mediterranean species which has been recorded in various areas ranging from off Japan to West Africa.

Textularia pseudotrochus Cushman (Pl. 1, fig. 7)

Textularia trochus H. B. Brady (not d'Orbigny), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 366, pl. 43, figs. 15, 16, 18.—Egger, Abhandl. k. bay. Akad. Wiss. Muenchen, Cl. II, vol. 18, 1893, p. 273, pl. 6, figs. 37, 38.—Cushman, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 124, pl. 25, fig. 1.

Textularia pseudotrochus Cushman, Bull. 104, U. S. Nat. Mus., pt. 3, 1922, p. 21, pl. 5, figs. 1-3.

Textularia orbica Lalicker and McCulloch, Allan Hancock Pacific Exped., vol. 6, No. 2, 1940, p. 136, pl. 15, fig. 17.

This tropical Pacific species occurs in appreciable numbers in the Red Sea at few stations of shallow water depths. Depth: 24-433 m.

The synonymy of this species is not clear. *T. orbica* includes in synonymy the same figures of Brady that *T. pseudotrochus* includes, and it is probable that these two species are the same.

Textularia ornatissima Said, n. sp.
(Pl. 1, fig. 6a, b)

Test of small size for the genus, compressed, fan shaped, ovate in top view; peripheral margin acute, siphonate; chambers distinct, broader than high, increasing in breadth rapidly, hence the fan shaped appearance of the test, extending laterally into siphons, increasing in thickness gradually; sutures distinct, depressed, oblique; wall smoothly finished; aperture a narrow slit located at the base of the inner margin of the last chamber. Length: 0.17 mm; breadth 0.25 mm.

Holotype (Cushman Coll. No. 59637) from station 49, Mabaheth Expedition 1934-35, Gulf of Aqaba, Lat.

28° 27′ 24″ N., Long. 34° 30′ 18″ E. Depth: 265 m.

This species is characterized by its small size, fan shaped test which is ovate in top view. The periphery is ornamented by rather lengthy siphons. It differs from *T. floridana* Cushman in its small size and in the rapid increase in breadth and thickness of the chambers.

This species occurs sporadically in small numbers at several stations of the Red Sea proper and the Gulf of Aqaba. Depth: 265-596 m.

Textularia pseudorugosa Lacroix (Pl. 1, fig. 4)

Textularia pseudorugosa Lacroix, Bull. Instit. Oceanographique, No. 582, 1931, p. 11, fig. 3 (in text).—Colom, Instit. Español. Oceanografía, Notas y Resúmenes, ser. 2, No. 108, 1942, p. 9, pl. 11, figs. 210-212, 215.

This Mediterranean species occurs in small numbers at various stations in the Gulf of Aqaba and the Red Sea proper. Depth: 265-512 m.

Textularia rugosa (Reuss) of Lalicker and McCulloch (Pl. 1, fig. 5)

Textularia rugosa Lalicker and McCulloch, Allan Hancock Pacific Exped., vol. 6, No. 2, 1940, p. 138, pl. 16, fig. 21.

This species occurs in the Red Sea proper where it is seen to attain large size, about 3 mm in length. The taxonomic position of this species is not clear due to the fact that most Recent records assigned to this species are different from Reuss's *Plecanium rugosum* which was described from the Oligocene of Gaas. Moreover, most Recent records were removed from the genus *Textularia* to *Gaudryina* (see Cushman, Special Publ. 7, Cushman Lab. Foram. Res., 1937, p. 84). The nearest record to my material is that of Lalicker and McCulloch although my specimens are larger. This species occurs in the shallow reef areas of the Red Sea. Depth: 24-102 m.

Genus **Siphotextularia** Finlay, 1939

Siphotextularia concava (Karrer) (Pl. 1, fig. 3)

Textularia concava Goes, Bull. Mus. Comp. Zool., vol. 29, 1896, p. 42.—Millett, Journ. Roy. Micr. Soc., 1898, p. 559, pl. 7, fig. 5.—Flint, Ann. Rep. U. S. Nat. Mus., 1897 (1899), p. 283, pl. 28, fig. 5.—Fornasini, Mem. Accad. Sci. Istit. Bologna, ser. 5, vol. 10, 1903, p. 10, pl. 10, fig. 11.—Sidebottom, Mem. Proc. Manchester Lit. Philos. Soc., vol. 49, No. 5, 1905, pl. 1, fig. 11.—Heron-Allen and Earland, Trans. Zool. Soc., London, vol. 20, 1915, p. 624.—Cushman, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 119.—Lacroix, Bull. Instit. Oceanographique, No. 591, 1932, p. 14, figs. 10-12 (in text).—Lalicker and Bermudez, Torreia, No. 8, 1941, p. 10, pl. 3, fig. 1.

Siphotextularia concava Palmer, Mem. Soc. Cubana Hist. Nat., vol. 15, 1941, p. 303.—Bermudez, Special Publ. 25, Cushman Lab. Foram. Res., 1949, p. 66, pl. 2, figs. 72-74.

Specimens of this cosmopolitan species are found in small numbers at different stations of the Red Sea proper and the Gulf of Aqaba. They differ from typical specimens in that the aperture is elongated at right angles, rather than parallel to the suture between the last two chambers. Depth: 265-433 m.

Family MILIOLIDAE

Genus **Quinqueloculina** d'Orbigny, 1826

Quinqueloculina parkeri (H. B. Brady) (Pl. 1, fig. 8)

Miliolina parkeri H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 177, pl. 7, fig. 14.

Quinqueloculina parkeri Cushman, Bull. 71, U. S. Nat. Mus., pt. 6, 1917, pl. 15, fig. 3.—Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 25, pl. 6, figs. 3, 4.

This Indo-Pacific species occurs in appreciable numbers at a few stations of the Red Sea proper. Depth: 17-24m.

Quinqueloculina striatula Cushman (Pl. 1, fig. 9)

Quinqueloculina striatula Cushman, Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 27, pl. 7, figs. 3, 4.

This species recorded from the tropical Pacific is found in small numbers at a few stations of the Red Sea proper. Depth: 17-24 m.

Genus **Miliolinella** Wiesner, 1931

Miliolinella labiosa (d'Orbigny) (Pl. 1, fig. 10)

Miliolina labiosa H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 170, pl. 6, figs. 3-5.

Miliolinella labiosa Wiesner, Deutsche Sud-Polar Exped., vol. XX, Zool., 1931, p. 108, pl. 15, figs. 181-182.—Rhumbler, Kieler Meeresforschung, vol. 1, 1936, p. 227, text figs. 213-218.

A few typical specimens of this species are observed at several stations of the Red Sea proper. Depth: 92-433 m.

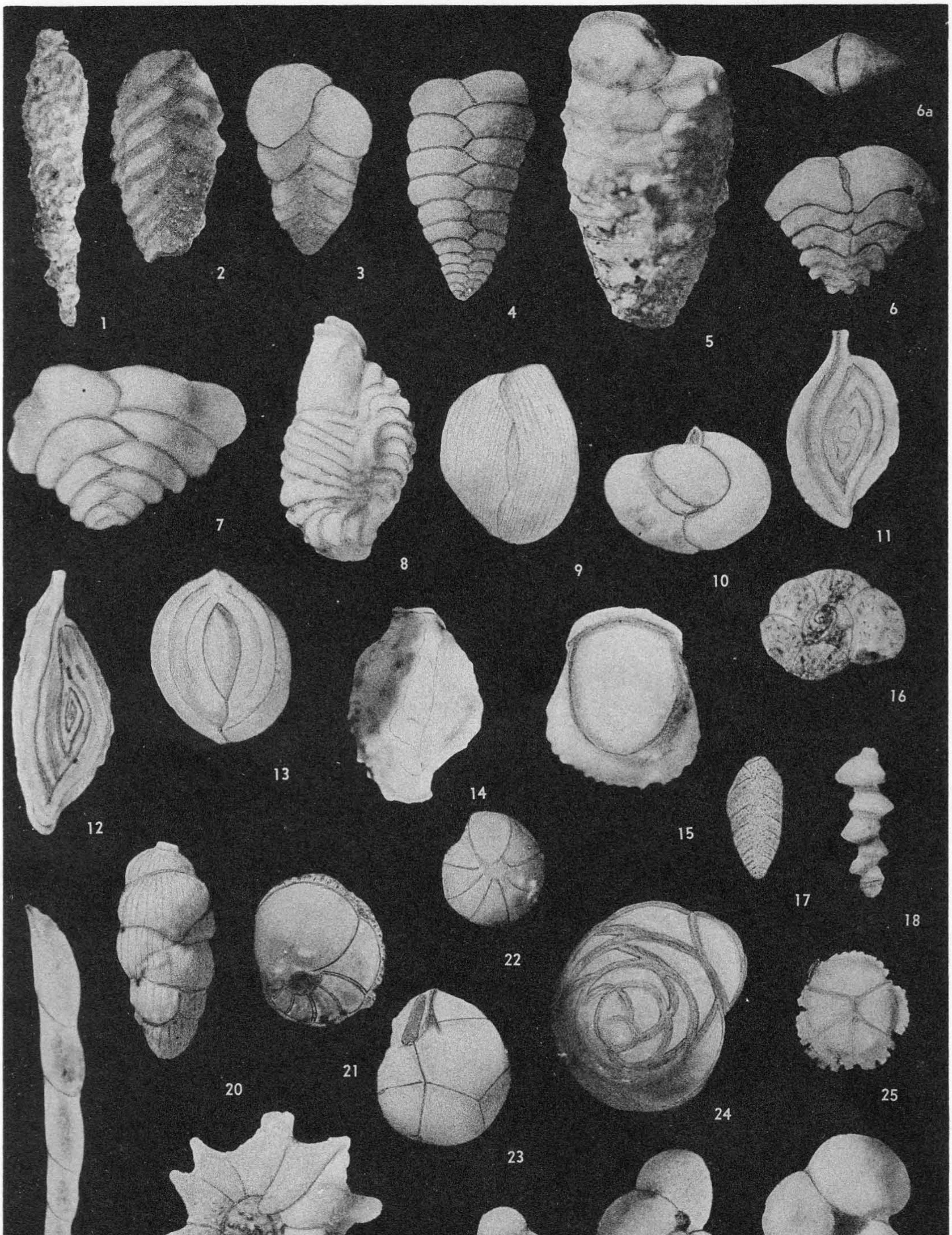
Genus **Spiroloculina** d'Orbigny, 1826

Spiroloculina clara Cushman (Pl. 1, fig. 11)

Spiroloculina clara Cushman, Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 40, pl. 10, figs. 4, 5.—Cushman and Todd, Special Publ. 11, Cushman Lab. Foram. Res., 1944, p. 59, pl. 8, figs. 18, 19.

Typical specimens of this tropical Pacific species occur at the deeper water stations of the Gulf of Aqaba and the Red Sea. Depth: 596-1128 m.

EXPLANATION OF PLATE 1



Said, Red Sea Foraminifera

Spiroloculina pellucida Said, n. sp. (Pl. 1, fig. 12)

Test very much compressed, periphery acute, keeled; chambers numerous, narrow, the central portion thin and translucent, the sides slightly thick and opaque; sutures distinct, not depressed, very slightly limbate; wall smooth; aperture at the end of a tapering neck, compressed with no lip or tooth. Length 0.60 mm; breadth 0.22 mm.

Holotype (Cushman Coll. No. 59645) from Station 58, Mabaheth Expedition 1934-35, Red Sea, Lat. 27° 51′ 30″ N., Long. 34° 38′ 12″ E. Depth: 596 m.

This species is very distinct and could be easily separated from *S. clara* Cushman with which it is usually associated by the fact that it is larger in size, has an acute and keeled edge rather than a truncated one, and by its slender neck. This species occurs in appreciable numbers in the deep water stations of the Gulf of Aqaba and the Red Sea proper. Depth: 596-1128 m.

Genus **Sigmoilina** Schlumberger, 1887

Sigmoilina edwardsi (Schlumberger) (Pl. 1, fig. 13)

Sigmoilina edwardsi Heron-Allen and Earland, Trans. Zool. Soc., London, vol. 20, 1915, p. 584, pl. 45, figs. 19-21.—Martinotti, Atti Soc. Ital. Sci. Nat., vol. 59, 1920, p. 276.—Cushman, Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 45, pl. 11, fig. 9.—Contr. Cushman Lab. Foram. Res., vol. 22, pt. 2, 1946, p. 39, pl. 6, figs. 11-13.

This species which was previously recorded from the Suez Canal occurs in small numbers at several Red Sea stations. Depth: 14-24 meters.

Genus **Triloculina** d'Orbigny, 1826

Triloculina cf. **bassensis** Parr (Pl. 1, fig. 14)

Triloculina bassensis Parr, Proc. Roy. Soc. Victoria, vol. 56 (n. ser.), pt. 2, 1945, p. 198, pl. 8, figs. 7a-c.

A few specimens close to this species originally described from Barwon Heads, Victoria, Australia occur at several stations of the Red Sea proper. Depth: 21-24 m.

Genus **Pyrgo** Defrance, 1824

Pyrgo denticulata (H. B. Brady) (Pl. 1, fig. 15)

Biloculina ringens var. *denticulata* H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 143, pl. 3, figs. 4, 5.

Pyrgo denticulata Cushman, Bull. 104, U. S. Nat. Mus., pt. 6, 1929, p. 69, pl. 18, figs. 3, 4.—Bull. 161, U. S. Nat. Mus., pt. 1, 1932, p. 62, pl. 14, figs. 1-9.—Parr, Proc. Roy. Soc. Victoria, vol. 56 (n. ser.), pt. 2, 1945, p. 199.

This cosmopolitan species occurs in small numbers at only a few stations of the Red Sea proper. Depth: 14-24 m.

Family TROCHAMMINIDAE

Genus **Trochammina** Parker and Jones, 1859

Trochammina rotaliformis J. Wright (Pl. 1, fig. 16)

Trochammina rotaliformis Heron-Allen and Earland, Proc. Roy. Irish Acad., vol. 31, pt. 64, 1913, p. 52, pl. 3, figs. 11-13.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 2, 1920, p. 77, pl. 16, figs. 1, 2.—Cushman and Parker, Proc. U. S. Nat. Mus., vol. 80, Art. 3, 1931, p. 6, pl. 2, fig. 5.—Cushman, Mem. 111, Instit. Royal Sci. Nat. Belgique, 1949, p. 20, pl. 3, fig. 8.

A very few specimens of this species were noticed at only one station in the Red Sea proper. Depth: 596 m.

Family LAGENIDAE

Genus **Dentalina** d'Orbigny, 1826

Dentalina filiformis (d'Orbigny) (Pl. 1, fig. 19)

Nodosaria filiformis H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 500, pl. 63, figs. 3-5.

Dentalina filiformis Norvang, Zoology of Iceland, vol. 2, pt. 2, Foraminifera, 1945, p. 15.—Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, No. 6, p. 314, pl. 40, fig. 17.

A very few specimens of this species occur at all three stations of the Gulf of Suez. Depth: 59-64 m.

Family BULIMINIDAE

Genus **Bolivina** d'Orbigny, 1839

Bolivina variabilis (Williamson) (Pl. 1, fig. 17)

Textularia variabilis Williamson, Ray Society, London, 1858, p. 76, figs. 162, 163.

Bolivina variabilis Heron-Allen and Earland, Trans. Zool. Soc., London, vol. 20, 1915, p. 647.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 3, 1922, p. 49, pl. 4, fig. 3; Special Publ. 9, Cushman Lab. Foram. Res., 1937, p. 158, pl. 16, figs. 6, 12-14.

This widely distributed species occurs at several stations of the Red Sea proper. Depth: 468-512 m.

Genus **Bitubulogenerina** Howe, 1934

Bitubulogenerina sp. (Pl. 1, fig. 18)

Test elongate, slender throughout, rounded in cross section; chambers numerous, attenuate, distinct, alternating along an axis; sutures indistinct; wall-thin, finely perforate; aperture slightly elliptical.

A very few specimens of this species have been observed at station 48 in the Gulf of Aqaba. It is an elongate form with attenuated chambers. The presence of this Eocene-Miocene genus in the Recent is notable. Depth: 265 m.

Genus **Uvigerina** d'Orbigny, 1826

Uvigerina tenuistriata Reuss (Pl. 1, fig. 20)

Uvigerina tenuistriata H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 574, pl. 74, figs. 4-7. —Chapman, Proc. Zool. Soc. London, 1895, p. 35.—Cushman, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 259, pl. 55, fig. 2.—Hanna and Church, Journ. Pal., vol. 1, 1928, p. 201.

A very few specimens of this species occur at station 34 in the Red Sea proper. Depth: 80-433 m.

Family ROTALIIDAE

Genus **Lamarckina** Berthelin, 1881

Lamarckina ventricosa (H. B. Brady) (Pl. 1, fig. 21)

Discorbina ventricosa H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 654, pl. 9, fig. 7.

Lamarckina ventricosa Cushman, Bull. 104, U. S. Nat. Mus., pt. 8, 1931, p. 34, pl. 7, fig. 5.

Typical specimens of this species have been observed in numerous stations of the Gulf of Aqaba and the Red Sea proper. This species attains its greatest abundance at a depth of 300 meters, but is found at depths as great as 770 meters.

This species was originally described by H. B. Brady from *Challenger* dredgings off Bermuda, 435 fathoms. In addition he recorded it from Gomera, Canaries, 620 fathoms; and off Raine Island, 155 fathoms. The appearance of this species in the Red Sea is therefore of interest.

Genus **Gyroidina** d'Orbigny, 1826

Gyroidina soldanii d'Orbigny (Pl. 1, fig. 22)

Gyroidina soldanii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 278, No. 5.—Parker, Jones and Brady, Ann. Mag. Nat. Hist., ser. 4, vol. 8, 1871, p. 176, pl. 12, fig. 151.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 8, 1931, p. 38, pl. 8, figs. 3-8.

This species occurs in large numbers at numerous stations of the Gulf of Aqaba and the Red Sea proper. It attains its greatest numbers at depths of 200 meters, although it is seen to occur as deep as 1128 m. Specimens are smaller than typical.

Genus **Eponides** Montfort, 1808

Eponides berthelotianus (d'Orbigny) (Pl. 1, fig. 24)

Pulvinulina berthelotiana H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 701, pl. 106, fig. 1.

This species occurs abundantly at station 58 in the Red Sea proper. Depth: 596 m.

Genus **Siphonina** Reuss, 1860

Siphonina tubulosa Cushman (Pl. 1, fig. 25)

Siphonina tubulosa Cushman, Publ. 342, Carnegie Instit., 1924, p. 40, pl. 13, figs. 1, 2; Proc. U. S. Nat. Mus., vol. 72, Art. 20, 1927, p. 10, pl. 1, figs. 3, 5.—Heron-Allen and Earland, Journ. Roy. Micr. Soc., vol. 50, 1930, p. 188, pl. 4, figs. 62-64.

A very few specimens of this species were observed at station 58 in the Red Sea proper. Depth: 596 m.

Family CALCARINIDAE

Genus **Calcarina** d'Orbigny, 1826

Calcarina defrancii d'Orbigny (Pl. 1, fig. 26)

Calcarina defrancii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 267, No. 3, figs. 5-7.—H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 714, pl. 108, fig. 6.—Chapman, Journ. Linn. Soc., Zool., vol. 28, 1900, list p. 209.—Cushman, Bull. 100, U. S. Nat. Mus., vol. 1, pt. 6, 1919, p. 365, pl. 44, fig. 2.

Specimens resembling d'Orbigny's original figures of this species were observed from station 20c in the Red Sea proper. Depth: 17-21 m.

Family CASSIDULINIDAE

Genus **Cassidulina** d'Orbigny, 1826

Cassidulina subglobosa H. B. Brady (Pl. 1, fig. 23)

Cassidulina subglobosa H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 430, pl. 54, fig. 17.—Chapman, Proc. Zool. Soc. London, 1895, p. 25; Flint, Ann. Rep. U. S. Nat. Mus., 1897 (1899), p. 293, pl. 38, fig. 4.—Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 98, fig. 152.—Proc. U. S. Nat. Mus., vol. 56, 1919, p. 606.—Bull. 104, U. S. Nat. Mus., pt. 3, 1922, p. 127, pl. 24, fig. 6.

This species described from the *Challenger* material at depths to 2950 fathoms and which is considered as a characteristic deep water species occurs in the Red Sea in very large numbers at comparatively shallower depths. It is abundant at numerous stations, but particularly plentiful at station 34. Depth: 80-433 m.

Family GLOBIGERINIDAE

Genus **Globigerina** d'Orbigny, 1826

Globigerina bulloides d'Orbigny (Pl. 1, fig. 27)

Globigerina bulloides d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 277, No. 1.—Rhumbler, Nordische Plankton, pt. 14, Foraminiferen, 1901, p. 21, text figs. 24-26.—Cushman, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, 1941, p. 38, pl. 10, figs. 1-13.

This species occurs in small numbers at all deeper water stations of the Gulf of Aqaba and the Red Sea proper. Depth: 265-1393 meters.

Genus **Globigerinoides** Cushman, 1927
Globigerinoides sacculifera (H. B. Brady)
(Pl. 1, fig. 28)

Globigerina sacculifera H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 604, pl. 80, figs. 11-17.—Cushman, Amer. Journ. Sci., vol. 239, 1941, pl. 3, fig. 1.

This species builds about 90% of the "Globigerina oozes" observed in this collection. It is the most abundant pelagic species found. Depth: 265-1393 m.

Genus **Globigerinella** Cushman, 1927
Globigerinella aequilateralis (H. B. Brady)
(Pl. 1, fig. 29)

Globigerina aequilateralis H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 605, pl. 80, figs. 18-21.

Globigerinella aequilateralis Cushman, Amer. Journ. Sci., vol. 239, 1941, pl. 2, fig. 1.

This species occurs in small numbers at the deeper stations of the Gulf of Aqaba and the Red Sea proper. Depth: 265-1393 m.

Genus **Orbulina** d'Orbigny, 1839
Orbulina universa d'Orbigny

Orbulina universa H. B. Brady, Rep. Voy. *Challenger,* Zoology, vol. 9, 1884, p. 608, pl. 78 and pl. 81, figs. 8-26, pl. 82, figs. 1-3.—Fornasini, Mem. Accad. Sci. Istit. Bologna, ser. 5, vol. 7, 1899, p. 12, pl. 4, figs. 7-11.

This cosmopolitan species occurs in appreciable numbers at deeper water stations in the Gulf of Aqaba and the Red Sea proper. Depth: 265-1393 m.

REFERENCE

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Manuscript received May 3, 1950

3. THE DISTRIBUTION OF FORAMINIFERA IN THE NORTHERN RED SEA

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ABSTRACT—The following paper is an attempt to decipher the ecologic factors that determine the distribution of Foraminifera in the northern Red Sea. Fifty samples were treated quantitatively and the results of the counts of the different species were presented using a new method.

The three areas which constitute the northern Red Sea, namely the Gulf of Suez, the Gulf of Aqaba and the Red Sea proper which are different from each other with regard to bottom topography, chemistry of water and type of sediment were found to support different foraminiferal populations. The constancy of the characters of the Gulf of Suez is reflected in the fact that the Foraminifera of this Gulf are uniform. In the case of the Red Sea proper, four overlapping zones of benthonic foraminiferal populations governed by depth were noticed. The reason for this zonation is not temperature regulation as has previously been held to be the case in other parts of the world.

The origin of the Red Sea Foraminifera is discussed and a possible reason for the almost complete absence of Mediterranean species from the area is given.

A gross relationship between the total numbers of benthonic Foraminifera and the nitrogen percentage was found. This relationship is not absolute since many other factors are believed to exert control over these numbers. The topographic position from which the sample was procured and the median diameter of the sediment are probably among the important factors that determine the concentration of Foraminifera, while oxygen does not seem to play an important role.

INTRODUCTION

The following paper records the distribution of Foraminifera in the northern Red Sea and attempts to decipher the ecologic conditions which control the distribution of the different species in the area.

In a previous publication the author (1949) listed and described the Foraminifera of the northern Red Sea. As more samples became available for study, some further species were noted. These additional species, together with the pelagic species recorded in the area, are described in the preceding paper.

The material upon which this study is based was collected during the Egyptian Preliminary Expedition to the northern Red Sea on board the R. R. S. *Mabahetli* in 1934-5. Fifty samples were examined, of which ten are cores and forty are grab samples. In the case of the cores, only the top parts were examined. The localities of the different sampling stations are given in a previous publication (Crossland 1939, table, p. 77). For ease of reference and for compilation of all data regarding the samples, table I has been prepared. This table shows the position, the calcium carbonate, the nitrogen and the organic carbon percentages, the ratio between carbon and nitrogen, the median diameter, the sorting coefficient, the surface and bottom temperatures, and the surface and bottom salinities of the different samples.

From the point of view of its hydrography and biology, the Red Sea represents today one of the least understood bodies of water. Few oceanographic expe-

TABLE I

1—Gulf of Suez

No. of Sample	University No.[1]	Station No.	Position		Median Diameter (in mm)	Sorting Coefficient	Ca Co_3 %	Nitrogen %	Organic C %	Ratio C/N	Surface Temperature (C°)	Bottom Temperature (C°)	Surface Salinity (o/oo)	Bottom Salinity (o/oo)	Depth	Remarks
			Latitude N ° ′ ″	Longitude E ° ′ ″												
1	8503	1	29 23 30	32 37 00	.044	4.02	60.77	.050	.35	7.0	20.72	21.00	42.48	42.74	62	Core
2	8504	2	29 08 15	32 45 30	.020	3.42	57.27	.055	.45	8.2	20.73	21.00	42.34	42.50	59	Core
3	8505	3	28 46 45	32 57 15	.064	3.46	73.02	.049	.38	7.8	21.24	21.50	41.82	42.30	64	Core

2—Gulf of Aqaba

No. of Sample	University No.	Station No.	Latitude N	Longitude E	Median Diameter	Sorting Coefficient	Ca Co_3 %	Nitrogen %	Organic C %	Ratio C/N	Surface Temperature	Bottom Temperature	Surface Salinity	Bottom Salinity	Depth	Remarks
4	8506	57	28 11 54	34 32 12	.010	4.33	71.11	.033	.15	4.5					1128	Grab
5	8507	48	28 47 42	34 32 00	.034	2.00									365	Grab
6	8508	49	28 27 24	34 30 18	.200	2.37	77.20	.024	.06	2.5					265	Grab
7	8509	52b	28 32 00	34 40 12	.018	3.99	42.20	.023	.08	3.5					1113-1143	Grab
8	8510	52b	28 32 00	34 40 12	.030	3.14									1113-1143	Grab
9	8511	54	28 40 30	34 42 18	.014	3.98	58.62	.024	.11	4.6	22.65	>21.00	40.60		1161	Grab
10	8512	55	28 49 12	34 39 12	.005	2.25	57.65	.025	.12	4.8					442	Grab

3—Red Sea proper

No. of Sample	University No.	Station No.	Latitude N	Longitude E	Median Diameter	Sorting Coefficient	Ca Co_3 %	Nitrogen %	Organic C %	Ratio C/N	Surface Temperature	Bottom Temperature	Surface Salinity	Bottom Salinity	Depth	Remarks
11	8513	43	27 52 00	34 27 24	.018	3.70	76.52	.041	.21	5.1	23.35	21.50	40.37		1147	Grab
12	8514	41a	27 54 57	34 37 38	.260	1.58	95.17	.044	.09	2.0	23.32		40.41		24	Grab
13	8515	58	27 51 30	34 38 12	.022	2.88	78.47	.055	.20	3.6					596	Grab
14	8516	42	27 49 30	34 39 30	.015	2.45	77.13	.032	.12	3.8	23.45		40.34		741	Grab
15	8517	45a	27 29 30	34 23 30	.200	2.06	75.21	.016	.09	5.6	23.35		40.40		960	Grab
16	8518	40	27 34 36	34 00 51	.022	2.26	80.32	.086	.22	2.6	23.47		40.41		941	Core
17	8519	7	27 30 40	34 03 30	.029	2.70	81.27	.049	.31	6.3	24.23		40.32		731	Core
18	8520	26	27 27 48	33 45 18	.200	1.94	83.62	.041	.11	2.7					236	Grab
19	8521	32a	27 17 00	33 52 06	.640	2.52	89.09	.058	.24	4.1					30-102	Grab
20	8522	32c	27 17 00	33 52 06	.710	2.16									30-102	Grab
21	8523	21a	27 26 42	33 45 33	.035	2.28	84.70	.091	.35	3.8					73	Grab
22	8524	20j	27 21 51	33 46 30	.570	2.26									17-21	Grab
23	8525	20c	27 21 51	33 46 30	.570	2.26	96.96	.029	.19	6.6					17-21	Grab

24	8526	15a	27 20 48	33 47 48	.780	2.25									20-53	Grab
25	8527	27	27 27 48	33 54 00	.340	1.93									203	Grab
26	8528	14a	27 19 39	33 48 06	.370	1.95	92.26	.029	.13	4.5					66-70	Grab
27	8529	14c	27 19 39	33 48 06	.500	1.91									66-70	Grab
28	8530	18a	27 19 18	33 48 48	.035	2.51	91.28	.042	.15	3.6					66-70	Grab
29	8531	19	27 17 54	33 50 12	.059	2.36	88.33	.052	.39	7.5					102	Grab
30	8532	34h	27 23 24	33 56 30	.240	1.73	92.53	.024	.09	3.8					80-433	Grab
31	8533	34	27 24 21	33 55 48	.290	1.45									80-433	Grab
32	8534	34c	27 24 21	33 55 48	.580	1.69									80-433	Grab
33	8535	34a	27 23 24	33 56 30	.320	1.97	94.86	.030	.11	3.7					80-433	Grab
34	8536	34	27 23 24	33 56 30	.320	1.63									80-433	Grab
37	8539	34	27 23 24	33 56 30	.550	1.82									80-433	Grab
38	8540	34	27 23 24	33 56 30	.220	1.75									80-433	Grab
39	8541	37	27 24 48	33 59 15	.024	2.30	80.52	.039	.19	4.9	23.42		40.32		366	Core
42	8544	22a	27 16 12	33 51 24	.025	1.93					23.55		40.43		102	Grab
43	8545	23c	27 18 24	33 52 36	.300	1.86	95.43	.025	.11	4.4					93	Grab
44	8546	33	27 17 00	33 52 06	.085	2.45									22-51	Grab
45	8547	67	27 08 42	34 10 00	.027	2.07	75.77	.031	.18	5.8	23.20		40.44		814	Core
48	8550	75	27 03 18	34 12 24	.050	2.45						21.65			486	Grab
49	8551	69	27 03 18	34 12 24	.380	3.00						21.70		40.60	92-400	Grab
50	8552	74	27 03 18	34 12 24	.170	1.39										Grab
51	8553	76	26 57 36	34 23 36	.011	2.94	69.45	.030	.15	5.0	23.13	21.65	40.43	40.65	951	Core
52	8554	77	27 05 24	34 37 00	.005	2.61	78.27	.023	.13	5.7	23.28	<21.70	40.41	40.65	127	Core
53	8555	78	27 13 21	34 50 12	.024	3.69	77.52	.019	.11	5.8	23.55	<21.70	40.28	40.65	1148	Core
56	8558	87a	On slopes of Brothers' I.		.760	1.83					23.17		40.53		94-198	Grab
60	8562	102c	24 55 15	35 51 27	.820	1.66									183	Grab
62	8564	103	24 55 20	35 51 00	.280	1.28									512	Grab

1. Refer to numbers of specimens as housed in the Geology Dept., Cairo, Egypt.

ditions have had the investigation of the Red Sea as their sole purpose. Most expeditions have made only a casual study to supplement data on other seas. The basis of our present knowledge of the oceanography of the Red Sea is largely provided by the results of the Austrian Expedition on the *Pola* in 1895-6 and 1897-8 (Luksch 1898, 1901; Natterer 1898, 1901). However, oceanographic instruments at that time were imperfect, and the *Pola* observations lack the accuracy desirable in modern oceanography. More recently two Italian expeditions on board the *Magnaghi* carried out an extensive program of oceanographic investigations in the Red Sea in 1923-4 and 1929 (Picotti 1927; Vercelli 1925, 1927, 1931). The results of these expeditions have in general amplified our knowledge of the physical oceanography of the Red Sea and have in particular thrown abundant light on the regime of currents in the strait of Bab el-Mandab, as well as on the tides and currents in the Gulf of Suez. Unfortunately not only were these investigations restricted to certain regions, but they did not deal with the chemistry or the sedimentation of the Red Sea waters. Later came the observations of the *Snellius* Expedition (Van Riel 1932) and of the John Murray Expedition in 1933-4 in the southern half of the Sea (Sewell 1935). Finally the Fouad I University, Cairo, Egypt, undertook a six weeks' cruise in the northern Red Sea in the R. R. S. *Mabaheth* in 1934-5. Interesting results have emerged from the work of this expedition (Crossland 1936, 1939; Mohamed 1940, 1949; Shukri and Higazy 1944).

Extending between lat. 12° N and 30° N, the Red Sea fills a long and narrow basin, which at the northern end is closed except for the communication through the Suez Canal and at the southern end is separated from the Gulf of Aden by a shallow sill. The total length of the Red Sea is nearly 1800 kms and the width 270 kms. Information regarding the bottom topography, chemistry, hydrography and sedimentation will be presented in the discussion which follows when dealing with the distribution of the Foraminifera of the northern part of the Sea.

Previous Work on the Ecology of Foraminifera

As Cushman (1942, p. 60) points out, our present knowledge of the ecology of Foraminifera is meager indeed. Myers, in a series of papers (1941-1948) published the results of his observations in the Dutch East Indies and Plymouth, England, and contributed substantially to our understanding of the factors that determine the distribution of Foraminifera in the sea. Unfortunately his studies were carried out on a qualitative basis and his observations were so scattered that concrete and complete study of a particular area or of a particular assemblage was not presented.

Norton (1930) studied fifteen samples from many localities and recorded the characteristic families of Foraminifera found at different depths. His studies showed that the percentages of the different families of which his samples were composed differed with depth. His approach to the study of the ecology of Foraminifera was an improvement on earlier work, but the number of samples studied was very small and they came from widely separated localities. Moreover, this author used qualitative methods, and recorded any species, irrespective of its numbers, in his histograms. His lumping together of species into families is another point of weakness as it is known that species of one family and even of one genus behave differently under varying ecological conditions.

Schott's work (1935) on the samples of the equatorial Atlantic was a marked advance. His extensive work on a well spaced grid in the area, together with the quantitative methods, gave interesting results. This author confirmed quantitatively earlier observations that benthonic Foraminifera are concentrated in the coastal regions. His charts of distribution of the different species in the area are the first of their kind. His work, however, involved the study of the vertical distribution of Foraminifera in the cores, the pelagic forms of which were found to be more useful in determining the Pleistocene history. He therefore paid much more attention to the pelagic forms inasmuch as they are clues to the stratigraphical problem with which he was primarily concerned. Phleger's treatment of the Foraminifera of the submarine cores of the continental slope (1942), the cores of the North Atlantic Basin (1946) and the cores of the Caribbean Sea (1948) made an advance both in the methods of study and in the presentation of data. He took advantage of the long cores obtained by Stetson, using the older type of coring tube, and by Pettersson using a piston type of coring tube, and attempted to build a complete stratigraphic section of the Pleistocene. He used Foraminifera as indices of climate with remarkable success. In recent years he extended his work on the spatial distribution of Foraminifera in extremely well sampled areas. In the Gulf of Mexico some species of Foraminifera show patterns of distribution which throw light on their origin.[1] As will be shown later, the methods which he used are subject to criticism, and some of his conclusions open to doubt.

Parker (1948) studied the areal distribution of the Foraminifera of the continental shelf and proved quantitatively Norton's earlier thesis (1930) of the presence of zonations limited by temperature regulations. She listed the characteristic species of each zone, and contributed substantially to our understanding of the ecology of Foraminifera.

Höglund (1947) in an extremely careful study on the Foraminifera of the Gullmar Fjord and the Skagerak used sounder methods of representation of his

1. Oral communication. The work on the Gulf of Mexico will be published shortly by the Geological Society of America.

quantitative data and arrived at forty-eight types of bathymetric distribution curves for the different species recorded in the areas studied.

Method of Study

There is no standard method for the quantitative study of Foraminifera. Each author uses the technique which he finds most suitable for his purpose. The following review of literature shows that the use of such a large variety of methods has made it difficult for various workers to correlate their results. Moreover, many of the methods fail to show the true relationships of the different species in space or in time.

In any study which involves the tracing of the fluctuations of the number of species of Foraminifera vertically or laterally, the different samples which are to be analyzed must be equal either in weight or volume. It is obvious that no correlation is possible between counts on unequal parts. Although this is of fundamental importance, many authors did not take this into consideration (for example, Oinomikado and Stach 1948).

Authors who realized the importance of analyzing equal parts of the different samples, used different sizes or weights which made the total counts of Foraminifera of little value in correlation. Schott (1935) counted the total number of Foraminifera (both pelagic and benthonic) in one gram dry weight of the fraction on the 0.2-2 mm sieve. He recognized the importance of separating benthonic and pelagic species and calculated the percentage of the benthonic fraction in the sample. Parker (1948) counted the total number of specimens in 100 c.c. of the whole sample. Phleger (1942) and Höglund (1947) recorded the total numbers of specimens in parts of their cores. Although neither mentioned the weight or volume of the sample which made the starting point of their investigation, it is implied from their work that they used equal volumes. Morishima (1948) started with 30 c.c. of his samples and recorded total number of populations.

Most workers discard the finer fractions and do not incorporate them in their studies. Few authors state the size of the fractions which were analyzed, although this is of fundamental importance since total numbers of species and the occurrences of many species depend on the fractions analyzed. To demonstrate this fact, the writer has analyzed sample No. 3 of the Gulf of Suez and counted the total number of Foraminifera in one gram of sediment of which only fractions coarser than 0.2 mm were used in one case, and in the same sediment but using fractions coarser than 0.1 mm in the second case. The results of these counts were as follows:

Total number of specimens counted in fractions coarser than 0.2 mm — 180/gr.

Total number of specimens counted in fractions coarser than 0.1 mm — 600/gr.

It is apparent therefore from these counts that the total number of specimens differ appreciably according to the fractions analyzed.

The only author, as far as the writer is aware, who specifically described the fractions used in his study is Schott (1935). He used fractions between 0.2-2 mm. Unfortunately the size limits which he used are coarse. This is due to the fact that the sediments which made the basis of his study were, to a large extent, *Globigerina* oozes with high median diameter and that smaller Foraminifera were of no importance to his study. Since many smaller Foraminifera are important ecological indicators in the Red Sea, counts of fractions coarser than 0.1 mm are considered to be more representative. It is true, however, that even these counts are not complete. The best result would be obtained by counting Foraminifera in all fractions, but since most Foraminifera that pass through the 0.1 mm sieve are young specimens which are difficult to identify, it is believed that if these are left out of account, the relative numbers of the adult population will be approximately correct.

Presentation of data:

Most authors represent their counts of the different species by using percentages (Phleger, Parker and Schott). Other authors record the actual counts of the species (Höglund, Oinomikado and Stach), found in the different samples.

The disadvantages of the percentage method of representation become obvious when the frequencies of the different species are traced from one locality to another. This is due to the fact that total number of specimens in all samples are reduced to 100 irrespective of whether the sample is rich or poor in Foraminifera. Thus small numbers of one species in a poor sample will be a high percentage, while a large number of the same species in a rich sample will be a low percentage. An example of this is demonstrated by the percentage and number (in one gram dry weight of the sample in fractions coarser than 0.1 mm) of *Uvigerina ampullacea* H. B. Brady in the sediments of the Gulf of Aqaba and the Red Sea proper:[2]

No. of sample	%	Actual Number
4	54	11
13	14	32

The best that the percentage method can do is to give a picture of the relative numbers of the different species in one sample, but it fails completely to provide a basis for correlation of the numbers of specimens in two different samples. As can be seen from the above table, the true distribution of the species has been

2. The term Red Sea as usually employed includes the Gulf of Suez and the Gulf of Aqaba. In the following pages the term Red Sea has been used in this sense and the phrase "Red Sea proper" to denote this Sea excluding the Gulf areas.

completely reversed by the percentage method. In many cases a species has a wide bathymetric range and occurs in small numbers at the different depths, but in some depths the influx of numerous other species will alter percentages substantially. Conclusions drawn from percentages may be thus false, and records such as these have to be treated with caution.

Authors who used actual counts instead of percentages for the presentation of their data do not completely convey the true picture, because none of them mentioned the weight or the volume of the sample from which the counts were obtained. Numbers like these can not be correlated.

Proposed method of study:

In the following paragraphs, a method is described in which an attempt has been made to avoid the discrepancies of the methods of presentation already discussed, and to standardize methods for the quantitative study of Foraminifera.

The method used in this study involves the use of twenty-five grams of each sample which were dried, disaggregated and sieved. Fractions finer than 0.1 mm were discarded. Coarser fractions were then treated by the carbon tetrachloride method devised by Cushman and Ozawa for the separation of Foraminifera from the sediment. In some cases it was found that some of the forms did not float due to the thickness of the wall. In such cases the residues were examined separately and the numbers of each species observed were recorded with those of the floated sample. In all cases these figures did not materially alter the relative numbers already determined from the floated fraction.

In counting the specimens, flotations under 0.1 c.c. in volume were used in their entirety and total counts made. For larger volumes, division of the sample was accomplished by means of a simple splitting device designed by Parker (1948, pp. 218-9). This apparatus consists of a small tray divided into two sections by a knife edge in the middle of a V-shaped trough inclined at approximately 45°. With this apparatus it is possible to make numerous divisions of the flotations and obtain a representative fraction of the entire sample. Some 200 species were identified from all the samples studied, but of these only about eighty-four were found to be of value in deciphering the nature of populations in the areas studied and were the only species counted separately. Other species were not identified but were counted under "miscellaneous," and in no instance did these species exceed 6% of the total. In most cases they constituted a smaller fraction. Methods of counting were those that were used by Phleger (1942, p. 1078).

Total population counts were approximated to the nearest whole number since figures obtained by this procedure are subject to error. Percentages of the different species were calculated by exactly the same method used by Phleger. The percentages of the different species were then converted into actual total numbers as they occur in the whole sample. Numbers obtained by this method are approximate.

For purposes of standardization and future use by other investigators who need to correlate their quantitative studies with those of the area under consideration, the total numbers thus calculated were divided by twenty-five (original weight of sediment used) to give the total number of species of Foraminifera in one gram dry weight of sediment in which fractions coarser than 0.1 mm only are used. The total number of all species in one gram will be called the Foraminiferal number. The term "Foraminiferal number" was proposed by Schott (1935). In this work the term is redefined and extended to meet the problems of spatial distribution of Foraminifera. Pelagic and benthonic species should be separated and their totals recorded as the benthonic and pelagic numbers.

Since numbers obtained by this method are subject to error, block representation of the data was preferred to tabular presentation in the distribution tables. Actual numbers might convey to the reader an appearance of accuracy which is inherently impossible.

It must be emphasized that the aim of the whole procedure is to obtain counts of Foraminifera in one gram dry weight of sediment. This could be obtained by numerous methods. One could begin with equal weights or volumes, as found more feasible, proceed with counts and finally convert them to the unit of the gram. In other words, if an investigator is concerned with the study of the Foraminifera of a core, he could use equal volumes as usual, count the different species and total numbers of the population, and calculate percentages. Finally it is proposed that he should weigh his material and calculate the foraminiferal number in one gram.

Table II shows the distribution of the more important species of Foraminifera occurring in the Red Sea in terms of numbers of specimens in one gram of sediment, together with the benthonic, pelagic and foraminiferal numbers.

It is hoped that other workers will find this procedure useful and much more representative of the true distribution of Foraminifera. Such a method will also permit results from different areas of the world to be compared and correlated.

Limitations of the quantitative study of Foraminifera:

1. *Living and dead specimens:*

The present investigation was carried out on tests separated from samples which were dredged from the bottom. It is obvious that many of the tests represent dead specimens. The assemblages thus described do not necessarily represent living assemblages at any one time, either on the bottom at the position of the samples or in the column of water directly above them.

Undoubtedly each sample represents an accumulation over some time, and is not necessarily a true population for any given instant. Foraminifera found in any one sample may be: (1) those living on the bottom at the time of the collection of the sample; (2) tests of adult forms that were discarded in the process of reproduction; (3) excretions of predators upon Foraminifera; or (4) transported there by currents. Of the four possibilities, that of transportation by currents is probably the main cause of deviation from the living assemblage. Phleger (1942, p. 1078) was aware of this problem, but he assumed without any further study that his conclusions were not affected.

This problem can be attacked only in the field. As the samples are dredged from the bottom of the Sea the contents of the tests should be examined by a staining medium (e. g. methyl eosin-green according to Rhumbler 1893, 1935) to make sure that the contents are really living protoplasmic material. As the materials here studied were not treated in this way, we have to accept the fact that mixing of living and dead forms did occur. It is to be noted however, that, as will be shown from the following discussion, there is a distribution pattern of the different species which cannot be explained by mixing and current action alone. It is, for example, of significance to note that the Gulf of Suez contains a characteristic foraminiferal fauna which is different from that of the Red Sea proper in spite of the fact that there is a strong bottom current from the Gulf to the Red Sea proper. Thus the foraminiferal faunas described appear to represent true faunas. A similar observation has been made by Phleger and Walton (1950) in their study of Barnstable Foraminifera, where they found that the harbor species do not appear in the bay in spite of that fact that a strong tidal current passes out of the harbor twice a day. These two instances indicate that, in spite of the fact that mixing of species by current action occurs, it seems safe to assume that the mixing does not alter distributions appreciably.

This conclusion has also been reached by Murray of the *Challenger* Expedition (1897). In a discussion of planktonic Foraminifera he found that no tests of Foraminifera occurred in the bottom samples when the living forms were absent from the plankton. Murray concluded that the rate of fall of the tests of Foraminifera after death is rapid, and that bottom currents do not alter the distribution of dead tests.

This conclusion is puzzling and can only be explained by assuming that foraminiferal tests do not stand abrasion by transportation over the bottom. In fact many foraminiferal tests disintegrate under rigorous treatment by a brush under the binocular, and it seems warranted to believe that tests do not stand appreciable transportation. In this study broken and heavily abraded specimens were not counted in order that as much as possible, the products of transportation might be eliminated. These represent only a small fraction and did not materially affect the counts. It is concluded therefore that although mixing of faunas takes place, this does not seriously alter the conclusions reached from the type of bottom samples used. It is to be noted that the following investigation is not a purely biological problem, and the work has been carried out as an attempt to decipher the factors that determine the distribution of faunas in the hope that it might help in paleoecologic studies.

2. *Taxonomy:*

The basis of any areal distribution study of Foraminifera, or in understanding the zoogeography of one species, is sound taxonomic work. As Höglund (1947) pointed out, comparison of the population of any one area with any other is questionable owing to "the taxonomic confusion and the doubtfulness of synonymy." All identifications were carried out in the Cushman Laboratory and were compared with its excellent collections. However, there are many transitional stages between different species, and many minute new mutations occur so that "lumping" of variant forms was reluctantly made in some instances. *Bulimina marginata* and *Spiroloculina aperta* counts are subject to some correction due to the fact that some slightly different forms, which probably belong to different species, were incorporated in the counts of these species. Some species are very difficult to separate from each other and some error has occurred thereby in the counts. This is true in the cases of *Quinqueloculina bradyi* and *Q. samoaensis;* and *Cibicides refulgens* and *C. tenuimargo.*

3. *Counting methods:*

These are inherently inaccurate. Every care was taken however, to assure proper splitting of flotations, of picking the areas along the tray from which the counts were conducted, but certainly some errors have occurred. It is, however, said with certainty that although the counting methods were not one hundred per cent correct, yet by using block representations in the table of distribution, the picture is true.

Discussion of Results

1. *Gulf of Suez:*

The Gulf of Suez is different from the Gulf of Aqaba and the Red Sea proper with respect to bottom topography, chemistry of water, and type of sediment. The Gulf of Suez is flat bottomed with a depth of thirty to forty fathoms. At its mouth the Gulf descends to a depth five times greater than its own, and is thus a shallow shelf filled with the surface water of the Red Sea. The exchange of water between the Gulf of Suez and the Mediterranean which takes place through the Suez Canal, is of no importance to the water and salt budget of the Red Sea (Sverdrup et al, p. 688). In all seasons but July to September, the surface water flows from the Gulf to the Mediterranean because the sea level is higher at Suez than at Port Said. The highly saline bottom water of the Bitter Lakes through which the Canal is cut flows towards the Mediterranean in all seasons, and from July to December an additional outflow of this water towards the Red Sea also takes place. The whole picture is complicated by the fact that this route of exchange is subject to great salinity variations because it passes through the saline Bitter Lakes where the salinity of the water is about 50 o/oo at the surface and as high as 55 o/oo at the bottom. This salinity variation and the insignificant amount of water that is actually exchanged, suggest a probable reason for the almost complete absence of any intermingling of faunas between the two seas during the last eighty years since the establishment of the Suez Canal. Cooke (1886) noted the remarkable difference between the molluscan faunas of the two seas — a contrast also noted by the present writer (1949) in the foraminiferal faunas.

The exchange of water between the Gulf of Suez and the Red Sea proper has been investigated by the Egyptian Preliminary Expedition (Mohamed 1940). Temperature and salinity variations in the Gulf suggest the inflow of a warm, less saline surface current from the Red Sea proper into the Gulf of Suez and the outflow of a bottom current, more saline and less warm. The efflux of the latter into the Red Sea, on both sides of Shadwan Island, was clearly indicated by temperature and salinity observations of the Expedition in the southern approaches of the Gulf. Moreover, the analysis of the correlation curves of these observations has suggested that the water of this bottom current mixes at the edge of the Gulf with the water in the upper strata in the Red Sea proper, the resulting admixture sinking down and contributing to the formation of the Red Sea bottom water.

In the Gulf of Suez the oxygen content is generally high through the water column and shows but slight variations with depth. This contrasts with the conditions of the Gulf of Aqaba and the Red Sea proper where much lower percentages prevail.

The variation of temperature with depth in the shallow Gulf of Suez varies from one region to another. The vertical distribution of temperature along the medial line of the Gulf is shown in figure 1A, reproduced from Mohamed's paper (1940, p. 309). Towards the south there is a marked increase in temperature. Figure 1B shows the vertical distribution of salinity along the medial line of the Gulf (after Mohamed 1940).

The sediments of the Gulf of Suez are, like the sediments of the Gulf of Aqaba and Red Sea proper, rich in carbonates, although those of the Gulf of Suez are slightly poorer than those of the Red Sea proper. The organic matter present in the sediments of the Gulf of Suez, as measured by the nitrogen content, does not exceed 0.055%, but is relatively higher than other parts of the Red Sea. The silica content of the sediments of the Gulf of Suez varies from 14.07% to 23.33%. The total iron content is higher in the Gulf of Suez than other parts of the Red Sea. The magnesia content does not vary widely in the three areas.

According to Shukri and Higazy (1944) the topography of the bottom seems to exert its influence on the physical constitution of the sediments. The deposits of the shallow and smooth Gulf of Suez show but little variation in the statistical data, in contradistinction to the deposits of the irregular bottom of the Red Sea proper. The sediments of the Gulf of Suez are in fact comparable to those of continental shelves.

Distribution of Foraminifera:

Table II shows the distribution of the benthonic Foraminifera in the three different areas of the Red Sea, while figure 1 shows diagrammatically the fluctuations of the numbers of the more common species of benthonic Foraminifera in the Gulf of Suez.

The Foraminifera of the Gulf of Suez are unique both in uniformity and in the nature of the assemblage. The fact that the conditions of the Gulf are more or less constant throughout and are different from those of the Sea has contributed to this observation. More than fifty per cent of the fauna is composed of three species: *Bulimina marginata, Bolivina hebes suezensis* and *Virgulina pauciloculata*. It is of interest to point out that these three species are almost exclusively confined to the Gulf of Suez. *Bulimina marginata* occurs in small numbers in the Red Sea proper and in the Gulf of Aqaba, but the other two species are confined to the Gulf and occur in appreciable numbers. Among the arenaceous Foraminifera only the Textulariidae are recorded. Representatives of this family fluctuate in numbers between 14 and 50 in one gram of sediment (never more than 8% of the total numbers of benthonic Foraminifera). These numbers can not be correlated with any factor. There is a tendency, however, for larger numbers to accumulate in coarser sediments and at shallower depths.

Representatives of the family Miliolidae fluctuate between 90 and 120 (in one gram of sediment) in the Gulf of Suez. These numbers are comparable with those in many shallow water samples of the Red Sea proper, but the species noted in both areas are different. *Quinqueloculina sclerotica* is restricted to the Gulf, while *Q. laevigata* occurs in larger numbers in the Gulf than in any other area.

With regard to total numbers, it is noticed that the Gulf possesses a very rich benthonic foraminiferal fauna, the numbers ranging from 380 to 600 in one gram of sediment and averaging 498. These total numbers are only exceeded in a few samples procured from the approaches of the Gulf of Suez in the Red Sea proper. It is of interest to point out that this may be

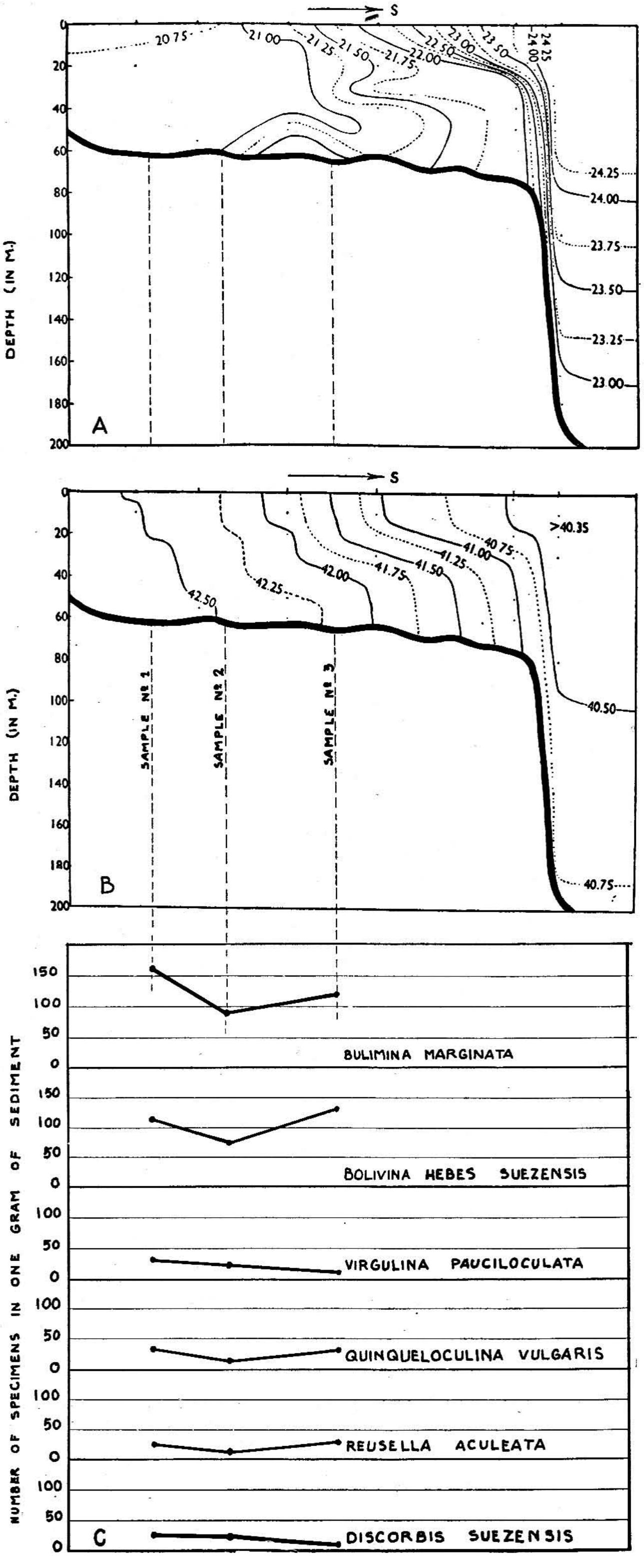

Fig. 1 A-C: Frequency of the more common benthonic Foraminifera in the Gulf of Suez. A and B (after Mohamed, 1940) are depth profiles along the medial line of the Gulf showing respectively temperature (in C°) and salinity distribution in the water of the Gulf.

correlated with the fact that the Gulf possesses the highest organic content of the three areas with the exception of some samples from the approaches of this Gulf in the Red Sea proper (Mohamed 1949). Although a study of the total numbers of benthonic Foraminifera in the samples of the three parts of the Red Sea shows a gross relation to the total organic content of the samples, it must be emphasized that numbers are not simple functions of the organic content of sediments. There are many other factors which play an important role in determining the total numbers of benthonic Foraminifera. In other words, although the organic production of the Gulf of Suez is higher than other areas, and the total numbers of benthonic Foraminifera are high, the relation is not absolute. It seems that the size distribution of the sediment plays an important role. The size distribution is one of the important factors that controls the organic content of sediments (Trask and Patnode 1942) and is a function of the topography (Shukri and Higazy 1944, p. 68). Coarser and better sorted sediments are characteristic of shallow or sloping bottoms, or those collected from near land masses including submarine ridges. In the Red Sea coarser sediments have been noticed to accumulate more calcium carbonate particles relative to organic matter. Finer sediments accumulate organic matter which is observed to be greatest in sediments with median diameters between 0.04 and 0.02 mm.

The Foraminifera of the Gulf of Suez are different from those of the Mediterranean and the Red Sea proper, and thus can be considered as an isolated community. This isolation may be due to the regime of currents which connects this area with the adjacent seas. Bottom currents leave the Gulf and only surface waters move in. Since benthonic Foraminifera do not pass through a planktonic stage in their life cycle (Myers 1948), it is quite possible that no exchange of benthonic Foraminifera could take place between the Gulf and adjacent seas. The conclusion that the Gulf possesses an isolated benthonic foraminiferal fauna may afford an explanation of the fact that out of the twenty-three new species of Foraminifera recorded in the Red Sea, seven are either confined to the Gulf exclusively or occur in large numbers in the Gulf and in small numbers in areas outside the Gulf. The species that are confined to the Gulf are: *Textularia aegyptica, Spiroloculina communis convexa, S. elegantissima, S. nummiformis, Bolivina hebes suezensis;* while *Quinqueloculina multimarginata* and *Discorbis suezensis* have been noted in small numbers outside the Gulf.

Although the present regime of currents permits but little exchange of benthonic Foraminifera between the Gulf of Suez and adjacent seas under consideration, it must always be kept in mind that the present regime is a function of the present-day climate. In the recent past the climate has fluctuated greatly. In fact, the latitudes in which the Red Sea lies have enjoyed a cooler and probably wetter climate during the ice advance in the Northern Hemisphere. Such a climate will alter densities and hence currents. Also any advance of the ice will affect the wind system which determines the direction of currents. Furthermore, there is evidence that the Pliocene and Pleistocene eustatic fluctuations of sea level were of such a nature as to permit a free flow of waters between the Mediterranean and the Gulf of Suez. This former connection, together with the changes in the regime of currents, could explain the origin of the benthonic Foraminifera of the Gulf of Suez.

In a previous publication, the writer (1949) noted that the majority of the Red Sea Foraminifera is Indo-Pacific. This is true, but it must be emphasized that the Gulf of Suez contains more cosmopolitan and Mediterranean species than any other area in the Red Sea.

It is concluded that the Gulf of Suez is inhabited by a foraminiferal population which is unique to the Gulf, and that the characters of this population are constant throughout due to the uniformity of the physical characters of the Gulf. The nitrogen percentage coupled with the median diameter offer a possible explanation of the fluctuations of the total numbers of benthonic Foraminifera present.

2. *Gulf of Aqaba:*

The Gulf of Aqaba, the most desolate sea in the world, has an irregular bottom of an average depth of 700 fathoms. It is separated from the Red Sea proper by the sill of Tiran of 140-170 fathoms depth, outside which the bottom is at a depth of 500-600 fathoms. Near the eastern side of the Gulf troughs as deep as 1000 fathoms occur and the contrast is great when we compare these depths with the heights of the mountains bordering the eastern side of the Gulf. The depth of the Gulf of Aqaba is nearly equal to the greatest depth of the Red Sea which is about ten times as broad, although the Red Sea itself is remarkable for its great depth in proportion to its breadth. Along the beaches of the Gulf of Aqaba the mountains rise abruptly. Except in the south, there is no counterpart of the maritime plain which is so characteristic of the true Red Sea coast.

The mode of exchange of the water masses between the Gulf of Aqaba and the Red Sea proper across the shallow sill of Tiran has been worked out by the Egyptian Preliminary Expedition (Mohamed 1940). During the winter a surface current from the Red Sea to the Gulf has been observed, while a bottom current moves from the Gulf to the Red Sea proper and contributes to the bottom waters of the Red Sea proper. This pattern is similar to the water exchange between the Red Sea and the Gulf of Aden in the same season.

It is interesting to note that an adiabatic increase in temperature takes place in the deeps of the Gulf of Aqaba. The temperature after reaching a minimum of ca. 21.20°C at a depth between 300 and 400 m, increases slowly and steadily towards the bottom. The observed gradient of this increase amounts to 0.20°C for 1000 m in depth.

The vertical distribution of oxygen in the Gulf of Aqaba is strikingly different from that of the Red Sea proper in two respects. In the first place, the minimum oxygen mid stratum which is consistently observed in the Red Sea proper is non-existent; and secondly, the oxygen content of the deep water is much higher than the Red Sea proper.

The phosphate content in the Gulf of Aqaba increases until a depth of 700 m is reached; below this the concentration does not show any significant variation with depth, but remains relatively constant at ca. 23 mg. phosphate per cubic meter, a concentration which is much lower than that of the deep water of the Red Sea proper. Although the latter contains as much phosphate as any other oceanic basin in the world, the Gulf of Aqaba deeper waters are impoverished in phosphate.

The carbonate content of the sediments of the Gulf of Aqaba is lower than that of the Red Sea proper, but it is high compared to other areas.

The organic content of the sediments of the Gulf of Aqaba is extremely low, never exceeding 0.025%.

In harmony with the roughness and irregular configuration of the bottom, the results of the mechanical analyses vary greatly. Shallower samples are more sorted than deeper sediments. The samples studied were procured from waters ranging between 265-1393 m depth. Of the seven samples three (Nos. 5, 6 and 10) are nearer the shore than the remaining four which were procured from deeper waters and are located in the mid sea.

Distribution of Foraminifera:

The total numbers of benthonic Foraminifera recorded in the Gulf are low, ranging from 8 to 270 in one gram of sediment and averaging 69. This observation is in perfect harmony with the fact that the Gulf sediments possess the lowest nitrogen content and are very fine grained. The median diameter ranges from 0.005 to 0.200 and averages 0.044 mm. The highest total number of benthonic Foraminifera was noticed in the near shore sample (No. 6) which is characterized by having the coarsest median diameter. The conclusion already stated, that the total number of benthonic Foraminifera is dependent on the nitrogen percentage and median diameter among other factors, seems to hold true in the case of the Gulf of Aqaba. It is of interest to point out that although the Gulf of Aqaba possesses the highest values of oxygen, the total numbers of benthonic Foraminifera are small and it seems that the amount of oxygen does not exert an influence on the numbers of Foraminifera. The oxygen content, however, is inversely proportional to the amount of the nitrogen content of marine sediments. It has been remarked previously that nitrogen accumulates in finer sediments. Although the sediments of the Gulf of Aqaba are fine grained, the amount of nitrogen is low. This low value might be related to the high oxygen values.

The Foraminifera of the Gulf of Aqaba differ greatly from those of the Gulf of Suez and the Red Sea proper. Characteristic are high percentages of *Uvigerina ampullacea* and *U. shukrii,* the numbers varying from 3 to 112 in one gram of sediment. These two species make over 50% of the total benthonic Foraminifera in the samples. *Cibicides mabahethi* and *C. wuellerstorfi* are very characteristic and make from 4 to 40% of the total number of benthonic Foraminifera. Among the Miliolidae, *Spiroloculina aperta* is abundant. The Textulariidae are represented by few specimens and seem to be concentrated in coarser near-shore sediments. On the whole the total numbers of benthonic Foraminifera are small and the samples are impoverished in species.

There are some samples from the Red Sea proper, particularly the deeper water samples which were procured from the approaches of the Gulf of Aqaba, that have a foraminiferal content similar to that of the samples of the Gulf of Aqaba. It is therefore impossible to say without further evidence that the Gulf of Aqaba is characterized by the foraminiferal assemblage just described or whether or not this assemblage is characteristic of deeper water areas of both the Gulf and the Red Sea proper. However, relatively shallow samples of the Gulf (Nos. 5 and 6) do not correspond in their foraminiferal assemblages to the samples procured from similar depths in the Red Sea proper. These two samples contain the characteristic species of the Gulf of Aqaba and although few other species appear, the total number of benthonic Foraminifera is low and the number of species is limited.

Samples 5 and 6 are collected outside Wasit and are located on a slope, and although the two samples have the same physical constitution, the deeper one has higher total numbers of benthonic Foraminifera, due probably to accumulation under gravity.

Representatives of the family Globigerinidae are numerous in the Gulf. The total number of pelagic Foraminifera ranges from 400 to 1850 and averages 733 in one gram of sediment. According to classical ideas about the definition of the *Globigerina* oozes these should be termed as such. However, Correns, in a recent work (1937) on the sediments of the equatorial Atlantic, has defined *Globigerina* ooze as a sediment with a foraminiferal number greater than 6000, which would indicate that at least one quarter of the sediment consists of unbroken foraminiferal tests in the size grade of diameters between 0.2 and 2 mm. Such samples would contain more than 60% calcium carbonate. Although the sediments of the Gulf of Aqaba contain high quantities of calcium carbonate, the foraminiferal number even in the sense described in this work (including fractions coarser than 0.1 mm) is much lower than Correns' (1937) minimum number for a *Globigerina* ooze. It is concluded therefore that, although the sediments of the Gulf of Aqaba and the Red Sea proper contain high numbers of the Globigerinidae, there are no true oozes in either area. The fact that the Red Sea contains much lower numbers of pelagic Foraminifera is in harmony with the conclusions of Mohamed (1949) that the organic production of the area under consideration is low. Although no planktonic studies were carried out on the Sea in any of the expeditions that worked the area, this conclusion was arrived at from the fact that the Sea sediments contain a much lower organic content than other oceanic basins. The observation that the pelagic Foraminifera, and consequently the phytoplankton, are lower in the Sea is one of the first counts to confirm this view.

The total numbers of benthonic Foraminifera in the Gulf of Suez and the Red Sea proper are comparable to other areas. For example, Parker's total numbers in 100 c.c. of sediment in the continental shelf (1948) were taken, and the foraminiferal numbers calculated by converting the volume to weight (assuming that the specific gravity of the sediment is 2.5) and dividing the numbers by total weight. The resultant foraminiferal numbers are very approximate, but probably are sufficiently accurate for correlation. It was found that the benthonic Foraminifera in the Red Sea compare with those of the North American Atlantic shelf, but the pelagic numbers showed that the Red Sea possesses a poor pelagic assemblage both in species and in numbers. No comparison was possible between the benthonic foraminiferal numbers of the Red Sea and those of the equatorial Atlantic as worked out by Schott (1935). The total numbers of Schott are low, but this is probably due to the fact that Schott took into consideration only fractions coarser than 0.2 mm.

3. *The Red Sea proper:*

The Red Sea proper possesses an exceedingly irregular bottom. It has a characteristic maritime plain of some twenty miles breadth. The descent to its great depths is by a series of steps, except in places along the coast of Arabia where there are abrupt falls to 400 or 500 fathoms. The greatest of all depths recorded is 1000 fathoms. These great depths cannot be compared with oceanic deeps, but are rift features and approach in their topography longitudinal narrow valleys. Some of these deep valleys extend for long distances. The Red Sea proper is characterized by such an irregular topography that some of the summits of the submarine pinnacles rise from the depth of the water sheer to the surface forming in some instances small islets, the most important of which are the Brothers Islets and the Daedalus Reef. The Brothers Islets rise abruptly from water about 700 m deep on the western side, and 1100 m on the eastern side and are nearer to the middle of the Sea than to the African shore (Shukri 1944). These islets are fringed by corals and they must be tectonic in origin for no coral growth could produce them from such depths, and in fact the corals have added but little to their bulk. There are some reefless coasts along the Sea even in the north. The reason for this lack of reefs is not fully understood as the environment of the Sea is favourable for coral growth.

The Red Sea is located in a region which is characterized by such an arid climate that evaporation from the water surface exceeds greatly the small precipitation. The adjacent lands have no runoff and no rivers enter the Red Sea. Along the entire length the prevailing winds blow consistently from the north north-west during the summer season, but during the winter season, the north north-west winds reach only as far south as lat. 21° or 22° N, and south of this the wind direction is reversed, south south-east winds dominate.

The climatic conditions and the prevailing winds determine the character of the exchange of waters of the Red Sea and the Gulf of Aden across the shallow sill which separates them. Owing to excessive evaporation the surface salinity of the water in the northern part of the Red Sea reaches values between 40 and 41%. In summer the temperature reaches more than 30°, but in winter the temperature falls to 18° C. The lowering of temperature in winter, together with the intense evaporation in that season, leads to the formation of a deep water mass that fills the entire basin of the Red Sea below the sill depth and has a salinity between 40.5 o/oo and 41 o/oo and a temperature between 21.5° and 22° C. The formation of this deep water is further facilitated by the character of the currents, which are related to the prevailing winds. The surface current flows towards the north north-west (into the Red Sea) from November to March, with transitional stages in April, May and October. During the winter, when the surface current flows in, the velocity is less in the northern half of the Sea where the flow is directed against the wind than it is in the southern half. For this reason a convergence develops which facilitates the formation of deep water. Superimposed upon the longitudinal flow are cross currents which are probably due to irregular eddies.

The oxygen content of the deep water is very low in spite of the sinking of surface water in winter. According to Thompson (1939), the oxygen content shows an annual variation, values higher than 2.0 ml/L being observed at the end of the winter, whereas at the end of the summer most values were lower than 1 ml/L. Thompson attributes these low oxygen values and the annual variation to a very rapid consumption of oxygen, which at depths between 350 and 600 m appears to amount to about 2 ml/L/year. This rate of oxygen consumption is by far the highest which has been found at such depths, but appears reasonable in view of the very high water temperature (about 22° C). The observations of the John Murray Expedition in September and in April-May both indicate the existence of a region of minimum oxygen content in the central portion of the Red Sea at depths between 300 and 500 meters. Thompson attributes this to a vertical rotational movement, which in winter is related to the sinking of surface water in the northern part of the Red Sea and rising of deep water inside of the sill. This feature of the presence of an intermediate zone of minimum oxygen content has been observed throughout the Red Sea proper; the observations of the John Murray's Expedition are supplemented by those of the Egyptian Preliminary Expedition in the northern parts (Mohamed 1940).

The exchange of water between the Red Sea and the Gulf of Aden is subject to annual variation which is related to the change in the direction of the prevailing winds in winter and summer. In winter when south south-east winds blow in through the Straits of Bab el Mandab, the surface layers are carried from the Gulf of Aden to the Red Sea, and at greater depths highly saline waters of the Red Sea flow across the sill. In summer when north north-west winds prevail, the surface flow is directed out of the Red Sea by the wind. At shallower depths water from the Gulf of Aden flows in, having a lower salinity and lower temperature than the outflowing surface water. At still greater depths highly saline Red Sea water appears to flow out over the sill, but it is probable that this outflow is much reduced as compared to the outflow in winter.

The variations of temperature with depth in the Red Sea proper agrees, in its characteristic features, with that in the Gulf of Aqaba. From its high values in the upper stratum, the temperature decreases to a minimum value of ca. 21.60° C (i.e. 0.50° C higher than the corresponding values in the Gulf of Aqaba) at a depth of about 500-600 m, below which it increases adiabatically with increase of depth. The vertical distribution of temperature in the northern regions of the Red Sea (across the section Safaga Mowela) is shown in figure 2A (reproduced after Mohamed 1940), and accompanied by graphs showing the distribution of the more common benthonic foraminiferal species occurring in this section.

The temperature and salinity observations of the Egyptian Preliminary Expedition, when plotted to give the velocity profiles of the currents normal to the traverses studied, showed the striking feature of the alternation in the direction of flow across each section, a feature which has suggested the existence of vortex movements. These movements probably cause the abnormal values of temperature which have been recorded in some stations of the Red Sea. Cyclonic and anticyclonic vortices probably are the cause of these movements. The system of currents in the Red Sea proper is thus complicated.

The phosphate content of the waters of the Red Sea proper varies from 0 to 6 mg. phosphate per cubic meter in the surface layer, below which it increases to a maximum concentration of 64 to 69 mg. phosphate per cubic meter at intermediate depths, usually between 400 and 600 m. With increasing depths the phosphate decreases to 800 meters, below which a concentration (34 to 39 mg. phosphate per cubic meter) is usually present. The deep water of the Red Sea proper is enriched with phosphate and the values are comparable to those in other oceanic basins, in contradistinction to the conditions prevailing in the Gulf of Aqaba.

The sediments of the Red Sea proper are richer in calcium carbonate than the sediments of the Gulf of Suez or the Gulf of Aqaba. The organic matter found in these sediments is very low compared with that of other marine sediments. The highest content is found in the sediments obtained from the southern approaches of the Gulf of Suez in the Red Sea proper, where organic residues transported by the outgoing current are likely to accumulate.

The mechanical constitution of the sediments is found to vary in accordance with the very irregular nature of the bottom topography.

The conditions of the Red Sea are more uniform than those prevailing in many other ocean basins, particularly with regard to salinity. No rivers flow into the Sea and hence no drastic changes in salinity take place.

Distribution of Foraminifera:

It has been previously stated that the foraminiferal fauna of the Red Sea is Indo-Pacific (Said 1949), and it is obvious that the path of migration is the Strait of Bab el Mandab. Under the present regime of currents, and taking into consideration the fact that benthonic Foraminifera do not have a planktonic stage in their life cycle, it is difficult to believe that the Indian Ocean benthonic Foraminifera would move along the sill against the outgoing current to the Red Sea. Although it is true that some forms can probably move in shallower or tidal flats from the Indian Ocean to the Red Sea, it is very hard to believe that under the present conditions, the deep water species can migrate freely. One must assume that the origin of the benthonic foraminiferal fauna occurred during climatic conditions different from those prevailing at the present day, and in which the regime of currents was reversed. It is well known that currents are functions of salinity and temperature differences, as well as the direction of wind which is known to have fluctuated during the Pleistocene. It must be emphasized, however, that with our present knowledge of the ways by which Foraminifera move and migrate, together with our meager knowledge of the depth toleration of many species, it is difficult to come to any conclusion regard-

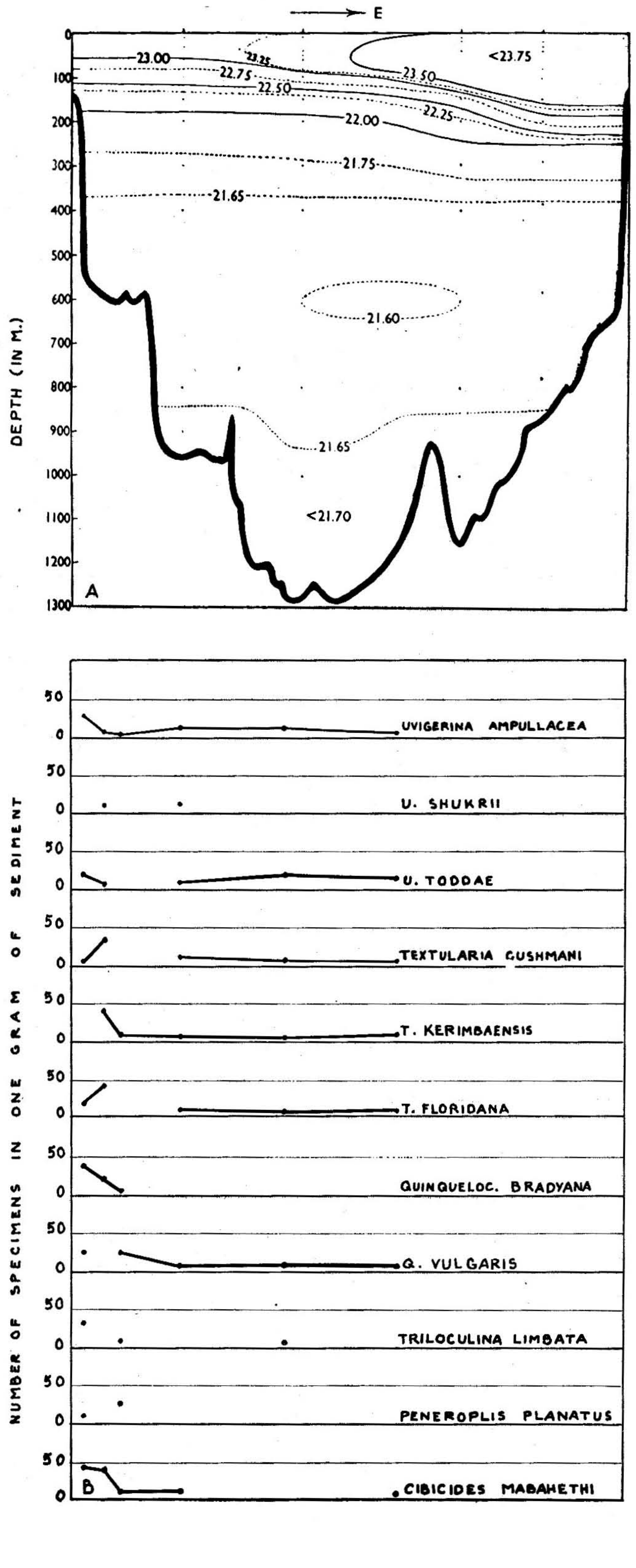

Fig. 2 A-B: Frequency of some benthonic Foraminifera along section Safaga-Mowela in the Northern Red Sea. A (after Mohamed, 1940) is a depth profile showing temperature distribution in the water along this section.

ing the time of migration of the Red Sea benthonic foraminiferal fauna or the nature of the exchange of benthonic Foraminifera between the two water masses.

The Foraminifera of the Red Sea proper are different from those of the Gulf of Suez and the Gulf of Aqaba. The Sea is characterized by an abundance of representatives of the families Textulariidae and Miliolidae. There are three types of assemblages noticed in the Sea. The first, characteristic of depths between 21 and 73 m, is composed almost entirely of representatives of these two families, although few representatives of the families Peneroplidae and Anomalinidae occur. This type is characterized by an abundance of Miliolidae over Textulariidae, proportions running as high as 3½ : 1. The Miliolidae and Textulariidae make from 54 to 77% and average 66% of the total benthonic Foraminifera of the samples. The benthonic foraminiferal numbers in these samples are high. It ranges from 110 to 475 in one gram of sediment and averages 283.

The second assemblage, characteristic of depths between 70 and 300 m, is also characterized by an abundance of representatives of the families Textulariidae and Miliolidae which range from 34 to 75% and average 47% of the total benthonic Foraminifera of the samples. In this assemblage, representatives of the family Textulariidae are more abundant than those of Miliolidae. There are more representatives of the family Anomalinidae in this assemblage. The benthonic foraminiferal numbers are high and range from 22 to 910 and average 312 in one gram of sediment.

The third assemblage, characteristic of sediments deeper than 500 m, is distinct. It is composed of the three species of *Uvigerina* known from the Red Sea together with a few representatives of the family Anomalinidae. *Spiroloculina aperta* is common in this assemblage. It is to be noted that the benthonic Foraminifera recorded from the deep water samples dredged from the approaches of the Gulf of Aqaba are nearer in their constitution to those of this Gulf than to those of the deeper water of the Red Sea proper.

Between the second and third assemblages, there is a fourth assemblage which is intermediate in character, composition and numbers. This assemblage overlaps both the second and the third and might be considered to be characteristic of depths between 300 and 500 m.

The Red Sea has a very irregular bottom topography, and there are exceptions to these characteristic assemblages at the different depths mentioned. Such exceptions have been mentioned in the literature. Norton (1930) records a shallow water fauna from a depth of 825 fathoms eight miles east of Andros Island in a narrow oceanic channel that has suffered intense faulting. The occurrence of this assemblage at this depth was attributed to mixing. Considerable up and down movement has taken place in the Red Sea during Tertiary time, and it is understandable therefore that no clear demarcation exists of the different benthonic foraminiferal assemblages. Sample No. 16 (941 m deep) consists of typical shallow water species together with a small percentage of deep water forms. The Red Sea can by no means be compared with a smoothly sloping continental shelf.

The family Anomalinidae is represented by a greater variety of species in the mid depth samples than in the deeper water samples, although the total numbers are the same.

Bathymetric distribution curves of some of the more common benthonic Foraminifera found in the Red Sea proper were prepared by plotting the number of species in one gram of sediment against depth. These curves are drawn in figure 3. It is of interest to point out that the curve for *Bulimina marginata* is like that given by Höglund (1947, p. 294), which he made on more or less similar lines. The main difference is that this species is less abundant at depths between 100 and 300 m in the Red Sea, but the type figure compares well with Höglund's figure for the Skagerak. The three species of *Uvigerina* recorded from the Red Sea appear in large numbers at three different depths. Large numbers of *Uvigerina ampullacea* appear at depths between 300 and 700 m, while in the case of *U. shukrii* large numbers are recorded from depths between 300 and 400 m. *U. toddae* is concentrated at depths between 100 and 300 m.

Clavulina angularis is a shallow water species which appears only at depths between 20 and 160 m. *Textularia kerimbaensis* has a wide bathymetric range, although it seems to be concentrated at depths between 50 and 300 m. *T. cushmani* is recorded up to depths of more than 1100 m, but seems to congregate at shallow depths. *Gaudryina arenaria* and *Cibicides rhodiensis* are concentrated at depths between 100 and 200 m. *Cibicides gibbosa* occurs in greatest numbers at depths between 100 and 150 m. The Miliolidae are shallow water species as can be seen from the curves of *Quinqueloculina vulgaris* and *Q. lamarckiana*. *Gyroidina soldanii* appears suddenly at depth of 200 m and the numbers are reduced progressively in deeper water.

The present study has confirmed the findings of the *Pola* and the Egyptian Preliminary Expedition of the presence of a deep water fauna in the Red Sea. Sewell (1934), writing about the results of the John Murray Expedition in the southern parts of the Red Sea, emphasized the absence of life in the deeper parts of the Sea (between 55 and 1167 m). The trawling and dredging of this Expedition in the deeper parts of the Red Sea produced surprisingly negative results. Mortensen (1939) described two new echinoderms from the Gulf of Aqaba and the Red Sea proper at depths as great as 1260 m, while the present study shows the presence of a teeming life at depths even greater than those previously recorded.

Globigerinidae are concentrated in the deeper water samples and range in numbers from 1 to 1800 in one

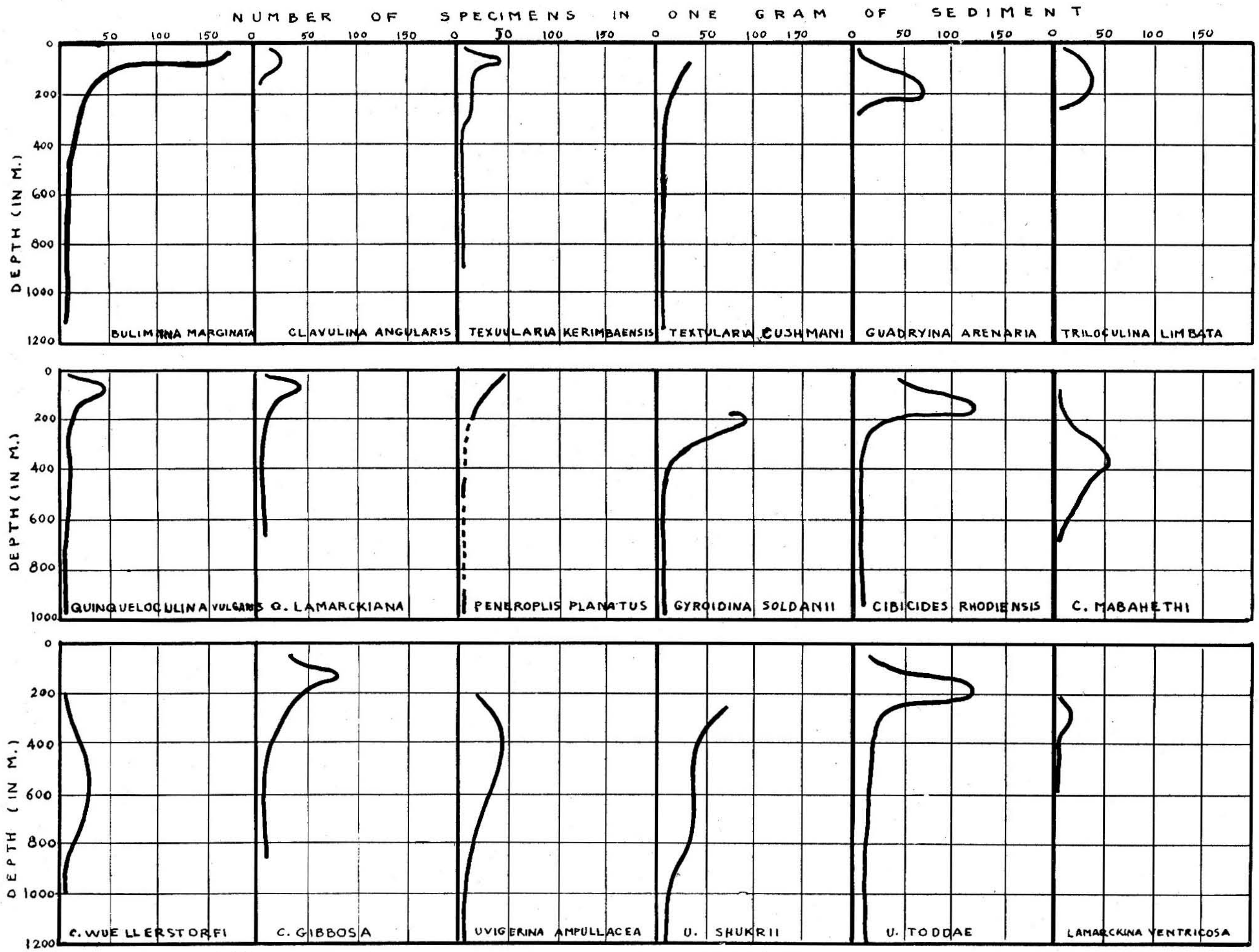

FIG. 3: BATHYMETRIC DISTRIBUTION CURVES OF SOME BENTHONIC FORAMINIFERA OCCURRING IN THE NORTHERN RED SEA

gram of sediment. Following Correns, none of the sediments can be considered a genuine *Globigerina* ooze. The shallowest samples from which Globigerinidae have been observed are 66 to 70 m deep. In these samples the numbers of the Globigerinidae are very low, between 1 and 3 in one gram of sediment. Large numbers of Globigerinidae accumulate between depths 700 and 1200 m.

Figure 4 shows the concentration of benthonic Foraminifera in the different areas of the Sea. It is to be noticed that the areas of the Red Sea proper that are rich in benthonic Foraminifera are also rich in organic content, and the general picture could be correlated with the concentration of the nitrogen content. As has been previously stated, this correlation is not absolute, the nitrogen content not being the only factor in question. The position of the sample is of importance. The samples richest in numbers are those procured from the tops of submarine hills (samples Nos. 31 and 42). Another important factor is the texture of the sediment, the coarser sediments (up to median diameter .200 mm) being more likely to contain a greater number of benthonic Foraminifera.

The relationship between these three factors, namely the nitrogen percentage, the median diameter and the total number of benthonic Foraminifera in one gram of sediment, was worked out along mathematical lines to decipher its nature. In the first place, nitrogen percentage is known to increase with the fineness of the sediment (Trask and Patnode 1942). These two authors have observed that organic material (measured by nitrogen percentage) is likely to accumulate in basins, where texture is expected to be fine grained. Coarse sediments accumulate where strong currents operate which are likely to carry away the buoyant organic material. These two authors therefore postulate a linear relationship between texture and organic content. In the case of the Red Sea, however, such a relation is non-existent. Shukri and Higazy (1944, p. 66) have noted that the nitrogen percentage remains more or less constant irrespective of median diameter except between median diameters 0.04 and 0.02 mm, where samples become conspicuously enriched.

The nitrogen percentage is an indicator of the organic content of the sediment, which is the only source of food for benthonic animals and bacteria (Sverdrup et al, p. 1009). The relation therefore between benthonic foraminiferal numbers and nitrogen percentage is to be expected, but the picture is complicated by the fact that food supply is not the only factor that determines numbers.

If we assume that X_1, X_2 and X_3 stand for the total number of benthonic Foraminifera in one gram of sediment, the nitrogen percentage and the median diameter of the sediment, the correlation coefficients between these three factors could be worked out according to the following formulae (Hoel 1947):

$$r_{12} = \frac{n\sum x_1x_2 - \sum x_1 \sum x_2}{\sqrt{\left[n\sum x_1^2 - (\sum x_1)^2\right]\left[n\sum x_2^2 - (\sum x_2)^2\right]}}$$

$$r_{13} = \frac{n\sum x_1x_3 - \sum x_1 \sum x_3}{\sqrt{\left[n\sum x_1^2 - (\sum x_1)^2\right]\left[n\sum x_3^2 - (\sum x_3)^2\right]}}$$

$$r_{23} = \frac{n\sum x_2x_3 - \sum x_2 \sum x_3}{\sqrt{\left[n\sum x_2^2 - (\sum x_2)^2\right]\left[n\sum x_3^2 - (\sum x_3)^2\right]}}$$

where n stands for the total number of samples analyzed. By using these three correlation coefficients between the three variables, we may proceed as follows:

$$R_{11} = 1 - r_{23}^2$$

$$R_{12} = r_{13}r_{23} - r_{12}$$

$$R_{13} = r_{12}r_{23} - r_{13}$$

$$R_{22} = 1 - r_{13}^2$$

$$R_{33} = 1 - r_{12}^2$$

$$R_{23} = r_{13}r_{12} - r_{23}$$

$$R = 1 + 2\,(r_{12}r_{13}r_{23}) - r_{13}^2 - r_{23}^2 - r_{12}^2$$

By using these formulae we can proceed to obtain the multiple and partial coefficients by using the following formulae:

$$r_{1.23} = \sqrt{1 - \frac{R}{R_{11}}}$$

$$r_{13.2} = \frac{R_{13}}{\sqrt{R_{11}R_{33}}}$$

$$r_{23.1} = \frac{R_{23}}{\sqrt{R_{22}R_{33}}}$$

$$r_{12.3} = \frac{R_{12}}{\sqrt{R_{11}R_{22}}}$$

If these coefficients approach 1.00, the relation may be safely postulated as a plane whose equation would be:

$$\frac{R_{11}}{S_1}X_1 + \frac{R_{12}}{S_2}X_2 + \frac{R_{13}}{S_3}X_3 = 0$$

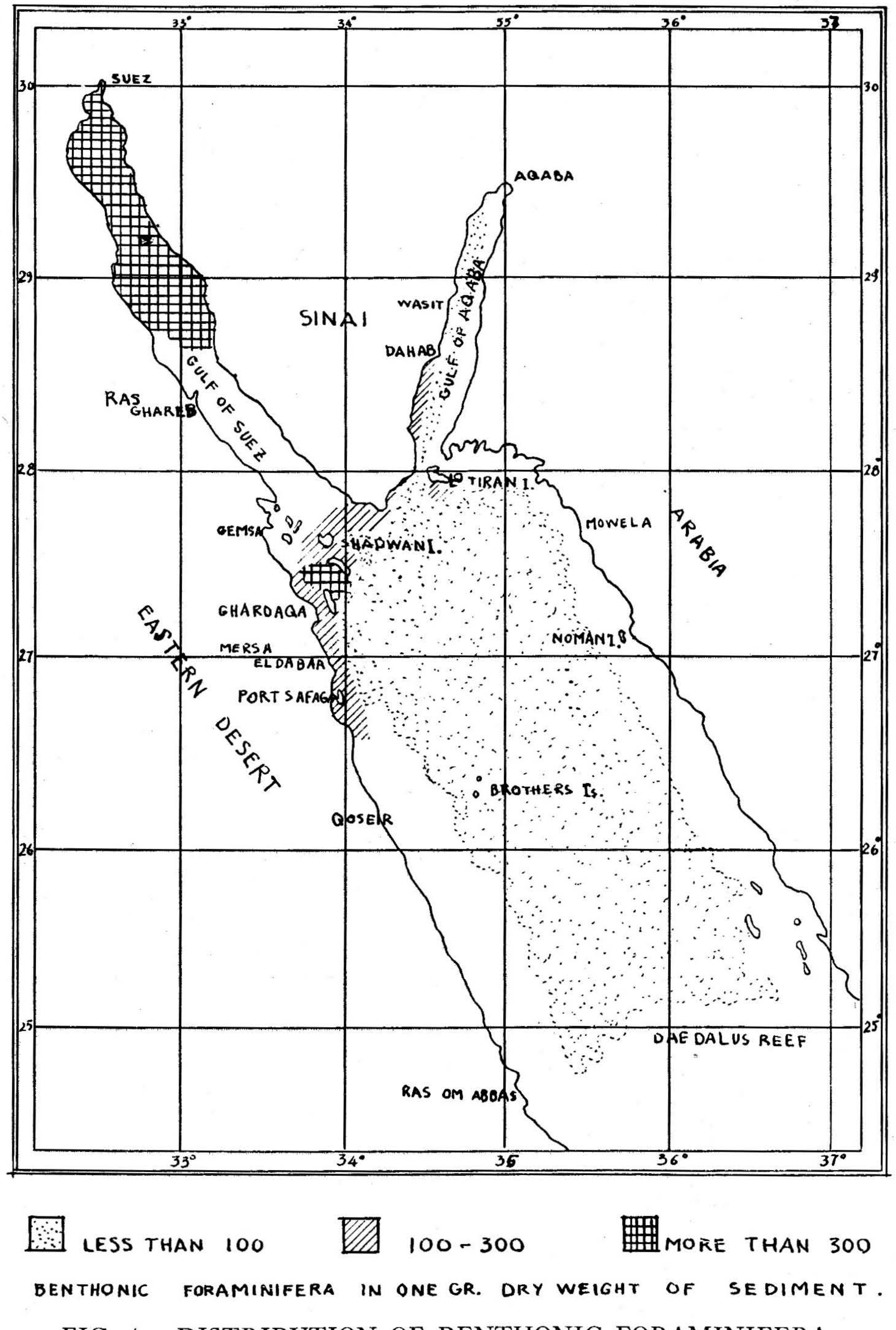

FIG. 4: DISTRIBUTION OF BENTHONIC FORAMINIFERA IN THE NORTHERN RED SEA

where S_1, S_2 and S_3 stand for the standard of deviation which could be obtained as follows:

$$S_1 = \sqrt{\frac{\Sigma(x_1 - \bar{x}_1)^2}{n}}$$

$$S_2 = \sqrt{\frac{\Sigma(x_2 - \bar{x}_2)^2}{n}}$$

$$S_3 = \sqrt{\frac{\Sigma(x_3 - \bar{x}_3)^2}{n}}$$

where $\overline{X}_1$, $\overline{X}_2$ and $\overline{X}_3$ are the arithmetic averages of the three factors in question.

The results of the calculations made on 27 samples is presented in the following table:

r_{12}	0.38
r_{13}	0.30
r_{23}	—0.15
R	0.73
R_{11}	0.98
R_{12}	—0.42
R_{13}	—0.35
R_{22}	0.91
R_{23}	0.26
R_{33}	0.86
S_1	189.80
S_2	0.02
S_3	0.18
$r_{1.23}$	0.49
$r_{12.3}$	—0.45
$r_{13.2}$	—0.39
$r_{23.1}$	0.30

These results point out to the possibility of a multiple relation between the three variables; the benthonic foraminiferal number, the nitrogen percentage and the median diameter. This relation may be represented by the following equation: $0.005X_1 - 21X_2 - 2X_3 = 0$. The physical meaning of these coefficients is that total numbers of benthonic Foraminifera in a sample are directly proportional to the nitrogen percentage and the median diameter. It must be emphasized that the number of samples studied is small and that the Red Sea sediments are unique in showing, as far as our present knowledge goes, no linear relationship between texture and nitrogen percentage. The above equation should remain, therefore, tentative and it would be of interest to test it in other areas of the world.

Summary and Conclusions

This paper deals with the ecologic factors that determine the distribution of Foraminifera in the northern Red Sea. Fifty samples were treated quantitatively and the results of the counts of the more common species in these samples are presented in table II using a new method. This method is believed to be more useful than the percentage method of presentation hitherto used in such studies. The percentage method presents the relative abundance of the different species in one particular sample and does not convey the true picture of abundance when the distribution is traced laterally or vertically. The new method involves the counting of the different species in one gram dry weight of sample. Equal weights of the different samples are used and the counts may be converted easily to represent numbers present in one gram of sediment. This method offers a way of standardization in quantitative studies of Foraminifera, so that correlation of the results from the different parts of the world will be possible.

It was found that there is a gross relationship between the concentration of benthonic Foraminifera in the different parts of the area under consideration and the nitrogen percentage. This latter is an indication of the organic content of the sediment which is the ultimate source of food for benthonic animals in the sea. This relationship is demonstrated diagrammatically in figure 4. It was also noted that this relationship is not absolute, since many other factors enter the picture. The texture of the sediment seems to exert some control, the coarser the sediment the more the concentration of benthonic Foraminifera. The topographic position of the sample is also of importance; samples collected from submarine hills are more likely to contain more benthonic Foraminifera. There are undoubtedly many other factors which determine the number of benthonic Foraminifera in the sample, but it seems that nitrogen percentage and median diameter have a relationship to the benthonic foraminiferal number. A mathematical treatment of the interdependence of these quantities has shown that there is a likelihood of interrelationship between them. This relationship is represented by a plane. The equation of this plane is given, and a check of this equation showed that the theoretical values obtained from the equation tend to deviate radically from the actual numbers in deeper water samples and are larger. This could be explained by the operation of other factors which are probably more important in the deeper water than at other depths. Theoretical numbers obtained from the equation for shallower samples are lower than actual numbers. In mid depths, however, the equation deviates but little except when the sample is procured from a position which favors the accumulation of benthonic Foraminifera. The foregoing shows that the equation has a limited value.

It was also found that with an increase in the oxygen content of the water there is not necessarily an increase in the numbers of benthonic Foraminifera. Areas with higher quantities of oxygen are in fact more impoverished in benthonic Foraminifera. This is probably due to the fact that oxygen affects the organic content negatively; the higher the oxygen the less organic content.

The constancy of the characters of the Gulf of Suez is reflected in that the Foraminifera of this Gulf are uniform. In the case of the Red Sea proper where the conditions are varied, the foraminiferal composition of the different samples is variable.

The conclusions already reached by previous workers that the three areas which constitute the Red Sea are different in their environmental conditions is manifested by the fact that these three areas support very different populations of Foraminifera. Each area is seen to contain forms which do not flourish in other areas.

In the case of the Red Sea proper, it was found that there are four overlapping zones of benthonic foraminiferal assemblages governed by depth. The reason for this zonation is not temperature regulation as has previously been held to be the case in other parts of the world (Parker 1948). Temperature changes in the Red Sea water column are so little (2°C difference between top and bottom waters of the Red Sea proper) that it is hard to believe that such a small variation in temperature could alter the benthonic foraminiferal assemblage appreciably. The zonation is probably due to organic content and size of sediment and to various other factors rather than temperature.

Benthonic Foraminifera congregate in coastal regions irrespective of depth. Deeper water samples and offshore samples are poor in benthonic Foraminifera.

The Red Sea possesses exceptionally low organic content as compared with other oceans of the world. This is probably due to lower organic production of the Sea (Mohamed 1949). This conclusion has been confirmed by the counts of pelagic species of Foraminifera in the deposits of the Sea (for example, Schott's lists and numbers of the equatorial Atlantic). In fact the pelagic foraminiferal numbers are so low that no sediment in the Red Sea could be regarded as true *Globigerina* ooze. On the other hand, the benthonic foraminiferal numbers are comparable to other areas (for example, Parker's lists and counts of the western Atlantic continental shelf).

The origin of the Foraminifera of the Red Sea is discussed. Most species belong to the Indo-Pacific province and there are very few Mediterranean species in the area despite a connection with the Red Sea through the Suez Canal having existed for over eighty years. The reason for this is believed to be that the exchange between the Mediterranean and the Red Sea is very insignificant in water and salt budgets of both seas and that the exchange is subject to such great salinity variations that the intermingling of faunas is rendered impossible. It must be remembered, however, that the Red Sea possesses two typically Mediterranean Pliocene species: *Cibicides rhodiensis* and *C. gibbosa*. This could be regarded as supporting the suggestion that there was formerly a Pliocene connection between the two seas (Ball 1939, p. 26). However, the fact that few Mediterranean species are present in the modern Red Sea, in spite of this previous connection, might be interpreted as due to the connection not lasting long enough to carry the migration stream to its full extent, or to the oceanographic conditions of the Red Sea, particularly temperature and salinity. Remarkable enough is the presence of a few typical western Atlantic species: *Textularia floridana, Sigmomorphina pearceyi, Nonion sloanii, Sigmoilina arenata,* and *Lamarckina ventricosa.*

The origin of the Red Sea fauna, particularly the deep water forms, is believed to stem from glacial times, since the present day climate produces a flow of currents which cannot account for the origin of the benthonic Foraminifera. It is postulated that the Pleistocene fluctuations of climate altered currents in such a way as to bring a free exchange of benthonic Foraminifera between the Red Sea and the adjacent seas.

The present work has also shown that deep waters of the Red Sea are teeming with life, in contradistinction to the findings of the John Murray Expedition in 1934-5.

The present day regime of currents is shown not to favor the migration of benthonic Foraminifera and in fact favors isolation. This isolation is probably at a maximum in the Gulf of Suez where many of the new species recorded in the area occur.

Owing to the small number of samples studied which were scattered over large areas of the Sea, some of the conclusions reached are tentative and subject to revision when more samples become available. It is hoped that in the future the *Mabaheth* will resume its activities which were cut short by the opening of hostilities between Italy and Ethiopia and succeeding events.

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4. NUMMULITES GIZEHENSIS AS A POSSIBLE INDICATOR OF EOCENE CLIMATE

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ABSTRACT—Irregularities in the spire of **Nummulites** have been repeatedly reported. Some of these irregularities could be attributed to changes in the external environment. The well-known **Nummulites gizehensis** (Forskal) possesses a spire which becomes tighter in the later part of the test. This is believed to be due to a limited food supply during the winter season.

During the course of a study of the *Nummulites* of Egypt, it became apparent that some of the irregularities of the spire in some species are repeated almost consistently through the race. Various authors have reported irregularities without any attempt to decipher their causes (Rozlozsnik 1927). A quantitative study of the spire of one of the species which shows this character beautifully, *Nummulites gizehensis* (Forskal), was attempted.

Five hundred specimens of *N. gizehensis* were split along their equatorial plane by heating the specimens in sand and then plunging them into water. The split specimens were then mounted in glycerine and studied under the binocular. Measurements of the distances between the successive spiral laminae along two perpendicular lines in the equatorial plane were carried out.

The cumulative distances of these measurements, starting from the proloculum out, were plotted along the vertical axis, while the numbers of whorls were plotted along the horizontal axis. The resultant curve, the so-called spiral diagram, shows the path of the spire along the equatorial plane. From these measurements the arithmetical average was calculated, and the spiral diagram of this hypothetical average specimen was plotted. This curve is shown in figure 1. This figure shows that *N. gizehensis* begins its life by a tight spire which soon becomes lax and very regular. In this regular portion the average height of the spiral cavity is 0.38 mm. This portion is followed by another in which the spire becomes tight. The average height of the spiral cavity in this later part is about 0.30 mm. The break in the spiral path comes at about whorl number 26.

This observation has been observed by de la Harpe (1883) in his monograph of Libyan Nummulites (compare for example his figures on pl. 3, figs. 20a, 21, 21a and 23).

Experimental work carried out on Recent larger Foraminifera in the Pacific by Myers (1943) showed that the shape of the chamber is directly dependent on the supply of food. Myers noted that chambers added during seasons of limited food supply became

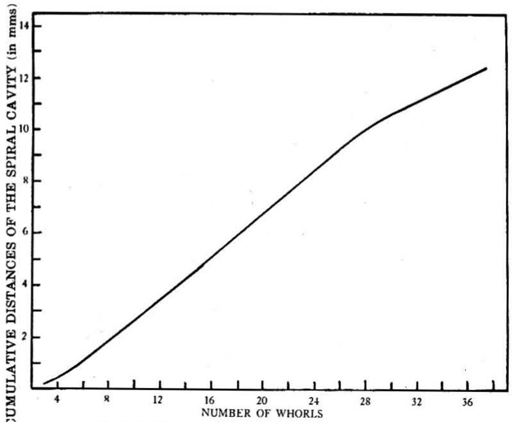

Fig 1· Spiral diagram of a hypothetical specimen of *N gizehensis* based on arithmetical averages of measurements carried on five hundred specimens

"short and narrow compared with those when food was abundant" (*ibid*, p. 27). If it is true that the shape of the chamber is a function of the amount of food available, it follows that classifications and evolutionary lines that are based on the dimensions of the chambers are probably artificial (compare for example Abrard's classification (1928) and Davies' evolutionary lines (1935)).

Applying this observation in the case of *N. gizehensis*, it could be assumed that the tightening of the spire and the reduction of the height and length of the chambers in approximately one quarter of the spire is probably a seasonal affair. This assumption would mean that the Middle Eocene in the Mediterranean had a temperate climate rather than a tropical one, a conclusion which is in harmony with recent paleoclimatological investigations (Brooks 1949). The winter season must have been stormy and cool with the result that the phytoplankton production was low. Temperate regions are known to fluctuate in their organic production as to permit a season of limited food supply. Tropical regions have two maxima a year in their organic production.

N. gizehensis possesses a small aperture and is thus directly dependent on the organic production of the sea. It occurs in large numbers building whole banks for long distances showing that the organic production must have been high. Higher production is known to occur in higher latitudes and in coastal and neritic areas (Sverdrup et al 1942, p. 944). The Middle Eocene Tethys was an epicontinental sea of comparatively shallow depths which favor nutrient renewal.

If it is assumed that the tightening of the spire was a seasonal affair, it follows that the life span of *N. gizehensis* was about one year, which would mean a greater vigor in adding chambers than Recent forms. It seems that a whole whorl of this Nummulite was added in about ten days.

The reproduction of this Foraminifer was stimulated by the winter season and was carried early in spring. The breaking of protoplasm probably produced as many as eight-hundred new agamonts. The highest number of progeny that was recorded by Myers (1943) is about two hundred and twenty-five for *Calcarina, Amphistegina* and *Elphidium.*

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5. SOME NEW SPECIES OF FORAMINIFERA FROM THE DANO-MONTIAN OF ALGERIA

A. TEN DAM AND J. SIGAL

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ABSTRACT—Sixteen new species of Foraminifera are described from the Dano-Montian marls from localities in Eastern Algeria and Tunesia, particularly from a section in the Dano-Montian of Oued Mougras.

During the course of a monographical study of the Foraminifera from the Cretaceous of Algeria by the junior author and a study of Dano-Montian samples from the Oued-Mougras section by the senior author, rich foraminiferal assemblages were obtained from the Algerian Dano-Montian, which are probably contemporaneous with the Lower and Upper Midway of Texas. Some of the more interesting new forms are described in the present paper. Holotypes are deposited in the ten Dam Collection, and paratypes in both the ten Dam and Sigal Collections. A set of paratypes will be deposited in the collection of the U. S. National Museum, Washington, D. C.

SYSTEMATIC DESCRIPTIONS

Family TEXTULARIIDAE

Subfamily TEXTULARIINAE

Genus **Vulvulina** d'Orbigny, 1826

Vulvulina gracillima ten Dam and Sigal, n. sp.
(Pl. 2, fig. 1)

Test relatively small, elongate, base rounded, maximum breadth of the uniserial portion in its last formed chamber equal to maximum width of the biserial part, compressed especially in the uniserial portion, periphery angled, slightly lobulate in the uniserial portion; earliest chambers planispirally coiled, comprising one-fourth to one-third of the textularian portion of the test, followed by a series of biserial chambers, increasing in size as added, textularian portion one-third to one-fourth of the entire test, uniserial portion well developed, with as many as seven chambers, slightly increasing in size as added; sutures distinct, very slightly depressed, curved slightly backward at the periphery; wall very finely agglutinated, arenaceous, smoothly finished; aperture in the adult terminal, elongate, narrow.

Length 1.3 mm, breadth 0.35 mm, thickness of textularian portion 0.2 mm, thickness of uniserial portion 0.18 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1157 (1); paratypes, ten Dam Coll. No. A 1157 (2) and Sigal Coll. Relatively rare in the Dano-Montian of Kalaat es Snam, Tunesia (type locality), and of Oued Mougras, Algeria.

Remarks.—This species is closely related to *Vulvulina colei* Cushman, but can be distinguished by its better development of the uniserial portion and by the lack of a projecting or spinose basal portion of the test.

Family VERNEUILINIDAE

Genus **Gaudryina** d'Orbigny, 1839

Subgenus **Siphogaudryina** Cushman, 1935

Gaudryina (Siphogaudryina) aissana ten Dam and Sigal, n. sp.
(Pl. 2, figs. 2a, b)

Test elongate, tapering, length two to 2½ times as great as breadth, greatest breadth at the beginning of the biserial portion, early portion triserial, triangular in section, reduced as compared to the well-developed biserial portion, comprising about one-fifth of the entire test, tapering toward the rounded initial end, biserial portion comprising four-fifths of the test, very gradually tapering, the sides frequently almost parallel in the later portion, distinctly quadrangular in section, with more or less rounded angles; chambers indistinct in the triserial portion, only visible in thin section or in etchings, chambers distinct in the biserial portion, eight to ten in number, distinctly inflated, particularly in the lower angle, giving a lobed appearance to the test, but with no overlapping, and with a sinuous median suture; sutures distinct, depressed, particularly on the sides where they are nearly straight, more or less curved upward on the broad sides; wall arenaceous, with small amount of cement, finely arenaceous but somewhat roughly finished, much sculptured by the ornamentation; aperture oval, in a slight re-entrant at the inner margin of the last-formed chamber.

Length 1.9 mm, diameter 0.9 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1010 (7); paratypes, ten Dam Coll. No. A 1010 (1-6, 8-15) and Sigal Coll. Relatively common in the Dano-Montian of Oued-Mougras and Sidi-Aissa (type locality), Algeria.

Remarks.—This species seems closely related to *Gaudryina (Siphogaudryina) rhodiensis* (Cushman), 1936 by its general appearance and ornamentation, but differs in the less well developed triserial portion, smaller number of chambers, greater height of the chambers and more parallel sides.

Gaudryina (Siphogaudryina) rectangularis ten Dam and Sigal, n. sp.

(Pl. 2, figs. 3a-4)

Test elongate, tapering, three to 3½ times as long as broad, greatest breadth obtained by the final chambers, earliest portion triserial, equally triangular in section, with relatively sharp angles and flat sides, reduced in comparison to the well-developed biserial portion, and comprising about one-fifth of the entire test, rapidly tapering from the initial end, biserial portion forming about four-fifths of the test, gradually tapering, distinctly rectangular in section, the broader sides showing the biserial arrangement, with relatively sharp angles; chambers indistinct in the triserial portion, visible only in thin section or etchings, later biserial chambers distinct, nine to ten in number, inflated very slightly or not at all in the beginning, later chambers distinctly inflated; sutures distinct in the biserial portion, in the early part almost flush with the surface or slightly depressed on the narrow sides, gradually becoming more depressed, sutures in the later chambers distinctly depressed on the broad and narrow sides, almost straight, inclined toward the initial end; wall finely arenaceous, with small amount of cement, finely but somewhat roughly finished; aperture in a slight re-entrant at the inner margin of the last formed chamber.

Length 1.45 mm, diameter 0.55 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1062 (4); paratypes, ten Dam Coll. No. A 1062 (1-3, 5-10) and Sigal Coll. Sometimes rather common in the Dano-Montian of Algeria. Type locality at Oued-Mougras, Algeria.

Remarks.—This species is characterized by its distinctly rectangular section, with two broad and two narrow sides, which rarely occurs in other species of this genus. In this character it resembles *Gaudryina (Siphogaudryina) jonesiana* (Wright), 1886, which, however, has more rounded angles and a well developed triserial portion.

Genus **Pseudoclavulina** Cushman, 1936

Pseudoclavulina globulifera ten Dam and Sigal, n. sp.

(Pl. 2, figs. 5-7)

Test elongate, slender, with the early triserial portion more or less sharply triangular in section and comprising about one-sixth of the entire test, uniserial portion about five-sixths of the entire test, rounded in section; chambers of the triserial portion indistinct, only visible in thin sections or etchings, later uniserial ones rounded and inflated, with definite strictures between the chambers; sutures usually obscure; wall arenaceous, with considerable cement, more or less roughly finished; aperture small, rounded, terminal on a short conical or tubular neck.

Length 1.25 mm, diameter 0.27 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 933 (3); paratypes, ten Dam Coll. No. A 933 (1-2, 4-5) and Sigal Coll. It is known only from the Dano-Montian of Oued-Mougras, Algeria (type locality).

Remarks.—This species seems more or less related in its general appearance and slenderness to *Pseudoclavulina mexicana* (Cushman), 1922, from the Gulf of Mexico, but is easily distinguished by the absence of the contracted tubular portions between the adult uniserial chambers and by the less roughly finished wall, without radiating sponge spicules. It differs from the other species of this genus by the distinct constrictions between the uniserial chambers.

Genus **Clavulinoides** Cushman, 1936

Clavulinoides rugulosa ten Dam and Sigal, n. sp.

(Pl. 2, figs. 8-10)

Test elongate, stout, four to five times as long as broad in the adult, sides nearly parallel for most of their length, tapering abruptly at either end, triangular in section throughout, acutely angled margins becoming rounded toward the apertural end, sides slightly convex, triserial portion forming one-fifth of the test, with broadly rounded base; chambers of the early triserial portion indistinct, only visible in thin sections or etchings, later uniserial chambers more or less distinct, very slightly inflated, increasing very slightly in height as added, final chamber often somewhat rounded in section; sutures distinct in the later portion, slightly depressed, somewhat arched centrally; wall coarsely arenaceous with relatively little cement, roughly finished; aperture terminal, rounded, without neck or lip.

Length 1.9 mm, diameter 0.47 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 981 (11); paratypes, ten Dam Coll. No. A 981 (1-10, 12-13) and Sigal Coll. Relatively common in the Dano-Montian of Oued-Mougras (type locality) and Sidi-Aissa, Algeria.

Remarks.—This species, characterized by its broadly rounded initial end and parallel sides is similar to *Clavulinoides cubensis* Cushman and Bermudez, 1937, but may be distinguished by its roughly finished wall and slightly convex sides. It is as roughly finished as *Clavulinoides midwayensis* Cushman, 1936, but differs in general appearance.

Clavulinoides algeriana ten Dam and Sigal, n. sp.

(Pl. 2, fig. 11)

Test elongate, adult forms five to six times as long as broad, sides nearly parallel for most of their length, tapering abruptly toward the apertural end and more slowly toward the initial end, triangular in section in the triserial portion and the first three or four chambers of the uniserial portion, more or less rounded in section in the later uniserial chambers, triserial portion one-fourth of the entire test; chambers of the triserial portion indistinct, visible only in thin sections or etchings, uniserial chambers distinct, the first ones very slightly if at all inflated, the later ones distinctly inflated, very slightly increasing in height as added; sutures in the uniserial portion distinct, very slightly depressed and slightly arched centrally in the first three or four chambers, distinctly depressed in the last three chambers; wall arenaceous, more or less roughly finished; aperture terminal, rounded.

Length 1.64 mm, diameter 0.32 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 692 (6); paratypes, ten Dam Coll. No. A 692 (1-5, 7-11) and Sigal Coll. Relatively common in the Dano-Montian of Oued-Mougras and Sidi-Aissa (type locality), Algeria.

Remarks.—This species is similar in general appearance to *Clavulinoides aspera* (Cushman) var. *whitei* (Cushman and Jarvis), 1932 and *Clavulinoides disjuncta* (Cushman), 1932, but may be distinguished from the first species by its less roughly finished surface and from the latter by its more reduced initial portion.

Genus **Pseudogaudryinella** Cushman, 1936

Pseudogaudryinella compacta ten Dam and Sigal, n. sp.

(Pl. 2, figs. 12a, b)

Test compact, the early portion equally triangular in transverse section, earliest stage triserial, angles acute, sides concave, later biserial, the two sides showing the alternating chambers broader than the third side, the last one or two chambers showing a tendency to become uniserial, rounded in transverse section; triserial portion comprising one-third to one-half of the entire test; chambers in the early portion somewhat indistinct, but easily visible after etching, later distinct and somewhat inflated, particularly in the two last chambers; sutures fairly distinct in the biserial portion and more or less depressed; wall finely arenaceous, with small amount of cement, finely but somewhat roughly finished; aperture in the adult small, terminal, rounded, in a shallow depression at the top of the last formed chamber.

Length 1.34 mm, diameter 0.64 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 717 (2); paratypes, ten Dam Coll. No. A 717 (1, 3-5) and Sigal Coll. Rare in the Dano-Montian of eastern Algeria. Type locality at Oued-Mougras, eastern Algeria.

Remarks.—This species is somewhat similar to *Pseudogaudryinella capitosa* (Cushman), 1937, but differs in lacking the well developed uniserial portion, showing only a slight tendency toward a uniserial structure of the chambers. It is more compact than any other species of the genus.

Family VALVULINIDAE

Subfamily EGGERELLINAE

Genus **Textulariella** Cushman, 1927

Textulariella cushmani ten Dam and Sigal, n. sp.

(Pl. 2, figs. 13a-16)

Test conical, length about twice the breadth, generally almost circular in transverse section, tapering from the acute initial end, early stages with four or five chambers to the whorl, later triserial and finally biserial, biserial stage reduced in comparison with the preceding stages, composed of one or two whorls; chambers comparatively few, increasing rapidly in size as added, the last two comprising about one-third of the entire test, slightly inflated in the final chambers, interior of the chambers with the peripheral portion divided by radiating partitions, shown externally by dark vertical streaks on the chambers, visible in broken or sectioned specimens; sutures indistinct in the early multiserial portion but later distinct and somewhat depressed, particularly in the last chambers; wall finely arenaceous, with considerable cement, rather smoothly

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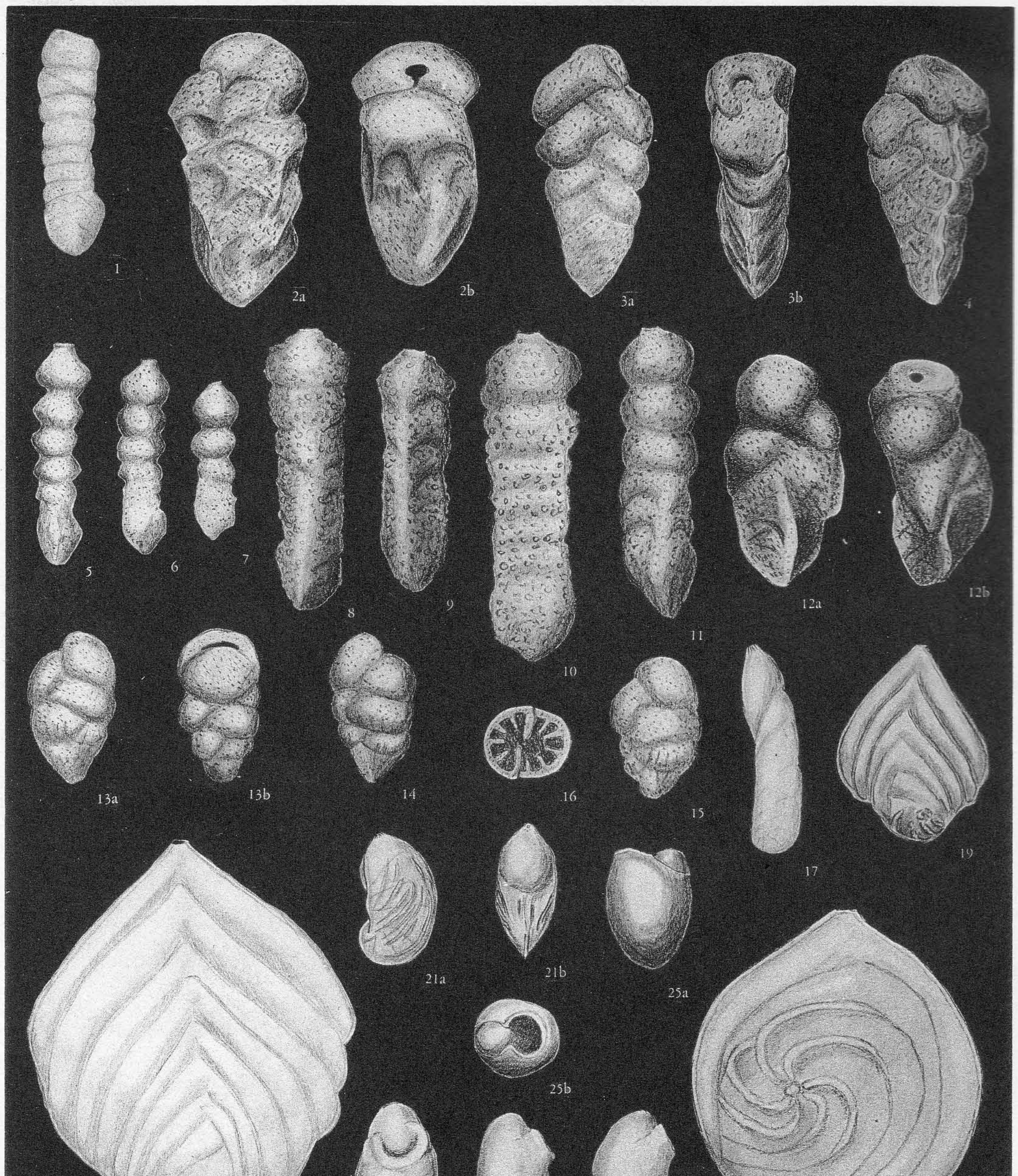

ten Dam and Sigal, Dano-Montian Foraminifera finished; aperture a narrow, elongate slit at the base of the inner margin of the last formed chamber.

Length 0.87 mm, diameter 0.45 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1006 (9); paratypes, ten Dam Coll. No. A 1006 (1-8, 10-15) and Sigal Coll. Locally common in the Dano-Montian of Algeria. Type locality at Oued-Mougras, Algeria.

Remarks.—This typical representative of the genus *Textulariella* is similar to *Textulariella trinitatensis* Cushman and Renz, 1946, but differs in its greater relative length, higher chambers and reduced biserial portion. It differs from *Textulariella trinitatensis* Cushman and Renz var *subcylindrica* Cushman and Renz, 1946, in having an acute initial end.

Family LAGENIDAE

Subfamily NODOSARIINAE

Genus **Vaginulinopsis** Silvestri, 1904

Vaginulinopsis pseudoscitula ten Dam and Sigal, n. sp.

(Pl. 2, fig. 17)

Cristellaria scitula Plummer (not Berthelin), Univ. Texas Bull. No. 2644, 1926, p. 100, pl. 7, fig. 5.

? *Marginulina* cf. *scitula* (Berthelin) Cushman, Contr. Cushman Lab. Foram. Res., vol. 16, 1940, p. 56, pl. 9, figs. 21-22.—Cushman and Renz, l. c., vol. 18, 1942, pp. 5-6, pl. 1, fig. 7.—Cushman and Todd, l. c., vol. 18, 1942, pp. 27-28, pl. 5, fig. 9.

Test elongate, slender, much compressed, dorsal peripheral margin acutely angled, ventral peripheral margin more rounded; early chambers planispirally coiled, the proloculum followed by as many as four to five chambers, chambers in the early portion triangular, gently curved, as many as six later uniserial chambers which are oblique, with greatest height at the dorsal periphery; sutures shown as thin dark lines, not depressed except occasionally very slightly depressed between the last two chambers; wall calcareous, finely perforate, smooth; aperture terminal, marginal, slightly protruding, radiate.

Length 1.22 mm, breadth 0.28 mm, thickness 0.12 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 939 (1); paratypes, ten Dam Coll. No. A 939 (2-3) and Sigal Coll. Rare in the Dano-Montian of Algeria. Type locality at Oued-Mougras, Algeria. Known also from the Upper Midway of Texas, Alabama and Trinidad.

Remarks.—From comparison with the original figures and description of Berthelin, where he states that his *Cristellaria scitula* is an uncoiled form, it is clear that Berthelin's species cannot be identical with *Cristellaria scitula* Plummer, 1926, which is distinctly coiled in its early stage. Plummer also stated that there are differences between her forms and the original species. It is not certain, however, that the species described as *Marginulina* cf. *scitula* by Cushman, Cushman and Renz and Cushman and Todd are entirely identical with Plummer's species, as the latter forms seem to have a greater breadth.

Genus **Palmula** Lea, 1833

Palmula toulmini ten Dam and Sigal, n. sp.

(Pl. 2, figs. 18, 19)

Test large, broadly oval in general outline, much compressed, greatest thickness at the proloculum and coiled initial end, base rounded in outline, periphery broadly rounded, with a tendency to become truncate at the upper limit of the last formed chevron-shaped chamber, sharply angled, sometimes slightly lobulate at the base; early chambers planispirally coiled, about six in number, depressed, gently curved, later chambers bilaterally symmetrical with as many as eight to nine in the adult, narrow, chevron-shaped, straight at the top, gently curved backward at the base; sutures limbate, raised in the early planispiral portion, very slightly depressed in the chevron-shaped portion; wall calcareous, finely perforate, smooth, surface ornamentation composed of the sutural ridges in the early coiled portion; aperture terminal, circular, produced.

Length 2.44 mm, breadth 2.0mm, thickness 0.1 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 957 (2); paratypes, ten Dam Coll. No. A 957 (1, 3-4) and Sigal Coll. Rare in the Dano-Montian of Oued-Mougras, Algeria (type locality).

Remarks.—This species is similar to *Palmula mcglameryae* Toulmin, 1941, but differs in its gently curved coiled chambers, by the sutural ridges of the early coiled portion and slightly depressed sutures between the chevron-shaped chambers.

Palmula sigmoicosta ten Dam and Sigal, n. sp.

(Pl. 2, fig. 20)

Test large, nearly circular in general outline, much compressed in the chevron-shaped chambers and the peripheral part of the planispiral chambers, more or less inflated in the central part of the test, periphery truncate at the upper limit of the last formed chamber, somewhat angled at the base; early planispirally coiled chambers about six or seven in number, depressed, very strongly curved, narrow, the one or two chevron-shaped chambers curved and reaching far backwards toward the base of the test, narrow; sutures of the planispiral portion strongly limbate and elevated in the central part, more or less flush with the surface toward the periphery, sutures of chevron-shaped portion limbate, flush with the surface; wall calcareous, finely perforate, surface ornamentation composed of the sutural ridges in the central part of the coiled portion; aperture terminal, circular.

Length 1.9 mm, breadth 1.75 mm, thickness 0.45 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1154; paratypes in Sigal Coll. Rare in the Dano-Montian of Oued-Mougras, Algeria (type locality).

Remarks.—This very peculiar species is easily distinguished from other species of the genus by the much reduced number of chevron-shaped chambers and by the strongly sigmoid sutures of the coiled portion.

Genus **Saracenaria** Defrance, 1824

Saracenaria tunesiana ten Dam and Sigal, n. sp.

(Pl. 2, figs. 21a, b)

Test relatively short, triangular in section, about twice as long as broad, initial coil comprising about one third of the entire test, dorsal periphery strongly curved, with a sharp and narrow keel, ventral face ovoid, tapering at both ends, laterally bordered by a raised limbate rim; initial coil composed of five chambers, increasing in height as added, followed by four to five uniserial chambers which increase only slightly in size as added, last formed chamber slightly inflated on the ventral face; sutures distinct, flush with the surface in the initial portion, slightly depressed and gently curved in the uniserial part; wall calcareous, perforate, surface ornamented by several sharp, narrow, slightly elevated and limbate costae, curved and almost parallel with the dorsal periphery; aperture terminal, radiate.

Length 0.77 mm, breadth 0.36 mm, thickness 0.31 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1156 (1); paratypes, ten Dam Coll. No. A 1156 (2) and Sigal Coll. Rare in the Dano-Montian of Kalaat es Snam, Tunesia (type locality) and of Oued-Mougras Algeria.

Remarks.—This species is distinguished from related forms by its peculiar raised costae, which parallel the dorsal periphery.

Family CHILOSTOMELLIDAE

Subfamily CHILOSTOMELLINAE

Genus **Chilostomelloides** Cushman, 1926

Chilostomelloides plummerae ten Dam and Sigal, n. sp.

(Pl. 2, figs. 22-24)

Test elongate, oval, about twice as long as broad, ends rounded, circular in transverse section, last chamber enveloping about four-fifths of the entire test; sutures indistinct, flush with the surface; wall smooth; aperture semi-circular, distinctly protruding in side view, at the base of the ventral margin of the last formed chamber, with a distinct and strongly thickened lip.

Length 0.9 mm, diameter 0.46 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 1155 (1); paratypes, ten Dam Coll. No. A 1155 (2-5) and Sigal Coll. Locally common in the Dano-Montian of Oued-Mougras, Algeria (type locality).

Remarks.—This species is very similar to *Chilostomelloides eocenica* (Cushman) and *Chilostomelloides cyclostoma* (Rzehak) in general appearance, but is easily distinguished by the semicircular aperture with its strongly thickened lip.

Chilostomelloides macrostoma ten Dam and Sigal, n. sp.

(Pl. 2, figs. 25a, b)

Test short, ovoid, circular in transverse section, broadly rounded at each end; last chamber enveloping about four-fifths of the entire test, revealing only a relatively small portion of the previous chamber; wall calcareous, finely perforate, smooth; aperture at the same level as the top of the test, large, reniform, standing away from the preceding chamber, almost entirely closed in by its own chamber wall, except for a narrow segment formed by the preceding chamber, with a thickened lip.

Length 0.83 mm, diameter 0.50 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 989 (1); paratypes, ten Dam Coll. No. A 989 (2-15) and Sigal Coll. Locally rather common in the Dano-Montian of Algeria, type locality at Oued-Mougras, Algeria.

Remarks.—This species is easily distinguished from other species of the genus by its large and wide reniform aperture, which is at the same level as the top of the test, so that only a very small portion of the preceding chambers is visible. There is no directly or closely related species.

Family VALVULINERIIDAE

Subfamily CIBICIDINAE

Genus **Anomalinoides** Brotzen, 1942

Anomalinoides vanbelleni ten Dam and Sigal, n. sp.

(Pl. 2, figs. 26a-c)

? *Cibicides granosus* van Bellen (not Hantken), Proc. Ned. Akad. Wetenschappen, vol. 44, 1941, p. 1002, fig. 29.

Anomalina grosserugosa ten Dam (not Gümbel), Med. Geol. Stichting, Ser. C-V, No. 3, 1944, pp. 130-131, pl. 5, fig. 2.

Anomalina granosa van Bellen (not Hantken), Med. Geol. Stichting, Ser. C-V, No. 4, 1946, pp. 74-75, pl. 11, figs. 4-6.

Test biconvex, flat, periphery typically broadly rounded, very slightly lobate, umbilical side with an umbilical depression, showing the complete final whorl and a very small part of the previous whorls in the center, spiral side with less marked umbilical depression, showing only slightly more than the last whorl; chambers inflated, as many as seven in the final whorl, rapidly increasing in radial height on the umbilical side, gradually increasing in radial height on the spiral side; sutures distinct, depressed, nearly straight on the umbilical side, slightly curved on the dorsal side; wall calcareous, coarsely perforate, surface roughened by small irregular beads and pustules, particularly on the first chambers of the last whorl on the umbilical side; aperture a slit at the base of the apertural face on the periphery, running down to the umbilical side along the spiral suture, with a very narrow lip (typical interio-marginal and umbilical aperture).

Diameter 0.94 mm, thickness 0.47 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 993 (25); paratypes, ten Dam Coll. No. A 993 (1-24) and Sigal Coll. Locally rather common in the Dano-Montian of Algeria. Type locality at Oued-Mougras, Algeria. Known also from the Montian and from the Lower Eocene of the Netherlands and probably from the Eocene of Dalmatia.

Remarks.—There is much confusion among the Upper Cretaceous, Paleocene and Eocene representatives of the genera *Anomalina* and *Anomalinoides.* This new species is closely related to *Anomalinoides danica* (Brotzen), 1940, but differs in its broadly rounded periphery, in lacking a marked angle between the umbilical side and the periphery and in having straight sutures on the umbilical side. It is also closely related to *Anomalinoides pinguis* (Jennings), 1936, but differs from this species in having fewer chambers in the last whorl and a less involute umbilical side. It does not show any resemblance to *Anomalina grosserugosa* (Gümbel) 1870, which shows much higher chambers and does not have the peculiar ornamentation. From *Anomalina granosa* Hantken, 1875, it differs in having a broadly rounded periphery. It is apparently identical with *Anomalina granosa* van Bellen, 1946 and with *Anomalina grosserugosa* ten Dam, 1944, but not identical with *Anomalina dorri* Cole var. *aragonensis* Nuttall, 1930, which has a much more evolute spiral side and shows still coarser perforations. It seems not certain whether the badly figured *Cibicides granosus* van Bellen, 1941, from Dalmatia, is also a synonym, though it should be according to van Bellen (1946). *Anomalina rubiginosa* Cushman, 1926, shows the same peculiar ornamentation, though to a greater extent, but differs from our species in having the sutures curved on both sides and only indistinctly depressed. From most of these morphologically related species, the true apertural characters have not been described in detail, so that it is not certain whether they belong to either *Anomalina* or *Anomalinoides.* Some of our specimens show remarkably well preserved apertures, so that affiliation with the genus *Anomalinoides* is certain. Often, however, it will be difficult to be certain of the true apertural characters, so that specimens must be compared in general appearance.

Genus **Laticarinina** Galloway and Wissler, 1927

Laticarinina prima ten Dam and Sigal, n. sp.

(Pl. 2, figs. 27a, b)

Test plano-convex, distinctly trochoid, the umbilical side slightly evolute, convex, the spiral side highly evolute, loosely coiled, flattened, composed of two and one-half whorls in the adult, surrounded by a usually transparent keel, a relatively narrow flange forming a carina around the periphery; chambers composed of a larger umbilical portion, extending two-thirds the distance to the periphery from the umbilicus, and a small spiral portion, separated by a thin plate representing a continuation of the keel, seven to eight chambers in the adult final whorl, chambers triangular in appearance on the spiral side, umbilical side showing the seven to eight chambers of the final whorl and a small part of the previous whorls, only very slightly inflated; sutures distinct on both sides; wall calcareous, smooth, finely perforate; aperture indistinct, not clearly visible in our specimens.

Diameter 0.83 mm, thickness 0.2 mm.

Types and occurrence.—Holotype, ten Dam Coll. No. A 699 (1); paratypes, ten Dam Coll. No. A 699 (2-5) and Sigal Coll. Rare in the Dano-Montian of Sidi-Aissa, Algeria (type locality).

Remarks.—It is difficult to classify this new species with certainty in the genus *Laticarinina,* as it shows several characters which differ from the Recent and late Tertiary representatives of the genus. Although the typical characters of transparent keel, subdivision of the chambers and the loosely coiled spire are present, others are lacking: there is a distinct spiral side showing all whorls and an umbilical side which shows only a part of the previous whorls, and the apertural characters are obscured by bad preservation. The authors consider, however, that this new species is a primitive representative of the genus, not yet showing the later typical characters. In these primitive characters it somewhat approaches some keeled species of the genus *Cibicides.*

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RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the foraminifera that have come to hand:

Finlay, H. J. The Foraminiferal Evidence for Tertiary Trans-Tasman Correlation.—Trans. Roy. Soc. New Zealand, vol. 76, pt. 3, July 1947, pp. 327-352.—A full discussion accompanied by a correlation chart.

Crespin, I. Indo-Pacific Influences in Australian Tertiary Foraminiferal Assemblages.—Trans. Roy. Soc. South Australia, vol. 72, (ser. 1), Aug. 23, 1948, pp. 133-142, table I, map.—The "letter" classification is discussed and numerous genera, mostly larger foraminifera, are mentioned.

van Andel, Tj. Some remarks on *Nummulites javanus* Verb. and *Nummulites perforatus* de Montf.—Proc. Konink. Nederl. Akad. Wetenschappen, vol. 51, No. 8, 1948, pp. 1013-1023, text figs. 1-3, tables 1-3.—*Nummulites javanus* is found to be synonymous with *N. perforatus,* and numerous other synonyms are listed.

Silvestri, A. Foraminiferi del Cretaceo della Somalia, Supplemento.—Pal. Ital., Raccolta di Monografie Paleont., vol. 32, suppl. 6, 1948, pp. 63-96 (135-168), pls. 7-9 (15-17).—Ten species, one new, from the families Orbitolitidae, Alveolinidae, Lituolidae, and Orbitoididae, are described and figured.

Hanzawa, Shoshiro. *Borelis philippinensis,* n. sp. from Luzon, P. I.—Jap. Journ. Geol. Geogr., vol. 21, Nos. 1-4, 1949, pp. 155-157, pl. 4.—The form is described and figured from Aquitanian limestone.

Hiltermann, Heinrich. Die wichtigsten Ergebnisse der mikropaläontologischen Arbeiten von Nordwestdeutschland.—"Erdöl und Tektonik in Nordwest-Deutschland," Amt für Bodenforschung, Hannover-Celle, 1949, pp. 326-334, pls. 6-9, text figs. 1-3 (charts).—Charts show vertical distribution of guide foraminifera in the Upper Cretaceous and early Tertiary. Eight typical faunas (from Lias to upper Eocene) are illustrated and named.

Nathan, Hans. Geologische Ergebnisse der Erdölbohrungen im Bayerischen Innviertel.—Geologica Bavarica, No. 1, 1949, pp. 1-68, pl. 1, text figs. 1-5, tables 1-6.—Many foraminifera are mentioned.

Brönnimann, Paul. Pflanzenbewohnende tropische Foraminiferen nebst Beschreibung von *Cymbalopora tobagoensis* n. sp.—Verhandl. Basel Naturforsch. Gesellschaft, vol. 60, 1949, pp. 179-185, text fig. 1.—A discussion of plant-inhabiting tropical foraminifera and description of *C. tobagoensis* from the NW coast of Tobago. Associated foraminifera are listed.

Reedy, Frank, Jr. Stratigraphy of Frio Formation, Orange and Jefferson Counties, Texas.—Bull. Amer. Assoc. Petr. Geol., vol. 33, No. 11, Nov. 1949, pp. 1830-1858, text figs. 1-13.—Foraminifera are listed.

Lowman, S. W. Sedimentary facies in Gulf Coast.—L. c., No. 12, Dec. 1949, pp. 1939-1997, text figs. 1-35.—Foraminiferal families and genera are used in describing biological aspects of facies.

Henson, F. R. S. Recent Publications on Larger Imperforate Foraminifera of the Middle East.—Ann. Mag. Nat. Hist., ser. 12, vol. 2, March 1949, pp. 173-177.—Includes a number of corrections; proposes one new name; assigns *Pseudochrysalidina* to the family Verneuilinidae; points out several generic synonyms; and suggests different phylogenetic relationships for several genera.

Middle Eastern Tertiary Peneroplidae (Foraminifera), with remarks on the phylogeny and taxonomy of the family.—Wakefield, England, Jan. 19, 1950, 70 pp., 10 pls., 3 text figs.—The phylogeny of the group indicates close relationship to the Miliolidae. Taxonomy is discussed, and an artificial key included. Ecology is described and the stratigraphy and distribution of various genera and species in the Middle East are discussed. Twenty-eight species and varieties, 16 new, and 4 undeterminable, are described and figured.

Cretaceous and Tertiary Reef Formations and associated sediments in Middle East.—Bull. Amer. Assoc. Petr. Geol., vol. 34, No. 2, Feb. 1950, pp. 215-238, text figs. 1-14, table 1.—Foraminifera are mentioned.

Cushman, Joseph A. and **Roscoe E.** and **Katherine C. Stewart.** Part VI, Upper Eocene Foraminifera from the Toledo Formation, Toledo, Lincoln County, Oregon.—State of Oregon, Dept. Geol. & Min. Industries, Bull. 36, pts. VI-VIII, October 1949, pp. 125-145, pls. 14-16.—Twenty-seven species and varieties, 2 new, are recorded and figured.

Part VII, Quinault Pliocene Foraminifera from Western Washington.—L. c., pp. 147-163, pls. 17, 18, text fig. 6.—Twenty-three species and varieties, 2 new, are recorded and figured.

Stewart, Roscoe E. and **Katherine C.** Part VIII, Local Relationships of the Mollusca of the Wildcat Coast Section, Humboldt County, California, with related data on the Foraminifera and Ostracoda.—L. c., pp. 165-208, pls. 19-22 (map, charts, and graph), text fig. 7, table 1.—Foraminifera are listed and their range in this Pliocene section indicated on a chart.

Loeblich, Alfred R., Jr., and **Helen Tappan.** North American Jurassic Foraminifera, II: Characteristic western interior Callovian species.—Journ. Washington Acad. Sci., vol. 40, No. 1, Jan. 15, 1950, pp. 5-19, pl. 1, text figs. 1-4.—Twenty-two species, all new, are described and figured.

North American Jurassic Foraminifera: I. The type Redwater Shale (Oxfordian) of South Dakota.—Journ. Pal., vol. 24, No. 1, Jan. 1950, pp. 39-60, pls. 11-16.—Fifty-six species, 52 new and 4 undeterminable, are described and figured. All but 16 belong to the Lagenidae.

Foraminifera from the type Kiowa Shale, Lower Cretaceous, of Kansas.—Univ. Kansas Pal. Contrib., Protozoa, Art. 3, Feb. 24, 1950, pp. 1-15, pls. 1, 2. —Twenty-seven species, 11 new and 5 undeterminable, are described and figured.

Lalicker, Cecil G. Foraminifera of the Ellis Group, Jurassic, at the type locality.—L. c., Art. 2, Feb. 24, 1950, pp. 3-20, pls. 1-4, text figs. 1-5.—Thirty-nine species, all new, and all but 4 in the families Lagenidae and Polymorphinidae, are described and figured. One new genus, *Ellisina* (genotype *E. spatula* n. sp.) is erected. Columnar sections and distribution charts are given.

Zeller, Edward J. Stratigraphic Significance of Mississippian Endothyroid Foraminifera.—L. c., Art. 4, Feb. 24, 1950, pp. 1-23, pls. 1-6.—The evolution of the group is discussed. A new genus, *Plectogyra* (genotype *P. plectogyra* n. sp.) is erected for forms coiling in a 3-dimensional spiral pattern.

Johnson, J. Harlan. A Permian Algal-foraminiferal Consortium from West Texas.—Journ. Pal., vol. 24, No. 1, Jan. 1950, pp. 61, 62, pl. 17.—Description of "algal balls" composed of entwined tubes, foraminiferal (*Nubecularia permiana* n. sp.) and algal.

Spangler, Walter B. Subsurface Geology of Atlantic Coastal Plain of North Carolina.—Bull. Amer. Assoc. Petr. Geol., vol. 34, No. 1, Jan. 1950, pp. 100-132, text figs. 1-11, tables 1-4.—Foraminifera are mentioned and a chart showing ranges of three species is given.

McLean, James D. Jr. Stratigraphic Study of Well at Crisfield, Somerset County, Maryland.—L. c., pp. 133-138, tables 1, 2.—Lists a few guide foraminifera.

Later Tertiary Foraminiferal Zones of the Gulf Coast. —Privately printed, 1950, 20 pp.—A compilation work, listing or mentioning many foraminifera.

Cushman, Joseph A. and **Irene McCulloch.** Some Lagenidae in the Collections of the Allan Hancock Foundation.—Allan Hancock Pacific Expeditions, vol. 6, No. 6, Feb. 23, 1950, pp. 295-364, pls. 37-48.—Seventy-nine species and varieties, 6 species and 4 varieties new and one new name, are described and figured, mostly from the eastern Pacific.

Applin, Esther R., Alfred R. Loeblich, Jr., and **Helen Tappan.** Two new Lower Cretaceous lituolid Foraminifera.—Journ. Washington Acad. Sci., vol. 40, No. 3, March 15, 1950, pp. 75-79, text figs. 1-6. —Two new genera: *Stomatostoecha* (genotype *S. plummerae* n. sp.) and *Phenacophragma* (genotype *P. assurgens* n. sp.) are erected.

Phleger, Fred B., and **William R. Walton.** Ecology of Marsh and Bay Foraminifera, Barnstable, Mass. —Amer. Journ. Sci., vol. 248, No. 4, April 1950, pp. 274-294, pls. 1, 2, text figs. 1, 2 (maps), tables 1-5.—Five subfacies were recognized in three traverses each taken through Barnstable Harbor, across its protecting sand-spit, and out into deep water of Cape Cod Bay. A few significant species are studied quantitatively and their distribution represented by percentages of the total fauna.

White, M. P. A fusulinid slide rule. Journ. Pal., vol. 24, No. 2, March 1950, pp. 123-129, pls. 24, 25, text figs. 1-20.—An exposition of a plan of evolution in the fusulinids.

Bandy, Orville L. Some later Cenozoic Foraminifera from Cape Blanco, Oregon.—L. c., No. 3, May 1950, pp. 269-281, pls. 41, 42, text figs. 1, 2 (map and section).—Twenty-four species and varieties are described and figured, 6 new.

Graham, Joseph J. New Foraminifera from the type Meganos formation (Eocene) of California.—L. c., pp. 282-286, text figs. 1, 2.—Two species are described and figured and numerous associated foraminifera listed.

Elias, Maxim K. Paleozoic *Ptychocladia* and related Foraminifera.—L. c., pp. 287-306, pls. 43-45, text figs. 1, 2.—Recognition of megalo- and microspheric forms, as well as other features, make possible the assignment of the attached genus *Ptychocladia,* formerly considered Bryozoa, to the Foraminifera. A new family, Ptychocladiidae, is erected for this genus and *Chabakovia* and *Bdelloidina.* Seven species and varieties, 5 new, are described and figured in the new family.

Asano, Kiyoshi. Check list of Tertiary Smaller Foraminifera of Japan.—L. c., pp. 307-321, text fig. 1 (map).—This compilation lists 387 forms together with bibliographic references, formation, locality, and repository. Two tables show the Pliocene fauna characteristic of the Japan Sea area as contrasted with that of the Pacific area.

Caudri, C. M. Bramine. The age of the Guaduas formation in Colombia; a correction.—L. c., pp. 388, 389.

Bermudez, Pedro J. Contribucion al estudio del Cenozoico Cubano.—Mem. Soc. Cubana Hist. Nat., vol. 19, No. 3, May 26, 1950, pp. 205-375, correlation table.—Foraminifera are listed from many formations and the stratigraphic ranges of 1511 species and varieties are indicated in a table. A geologic column indicating correlation of the Tertiary formations of Cuba with those of the eastern United States, Mexico, and the Dominican Republic is included.

Hiltermann, H. and W. Koch. Taxonomie und Vertikalverbreitung von *Bolivinoides*-Arten im Senon Nordwestdeutschlands.—Geol. Jahrb. für 1943-1948, vol. 64, 1950, pp. 595-632, text figs. 1-7, tables 1-7.—Charts show visually the evolutionary change in size and shape throughout the Senonian of 3 species and 2 varieties, both new. Three species and 3 varieties are described and figured.

Cederstrom, D. J. Geology and Ground-Water Resources of St. Croix, Virgin Islands.—U. S. Geol. Survey Water-Supply Paper 1067, 1950, pp. 1-117, pls. 1-6, text figs. 1-11, tables 1-13.—Foraminifera are listed.

Cole, W. Storrs. Larger Foraminifera from the Palau Islands.—U. S. Geol. Survey Prof. Paper 221-B, 1950, pp. 21-31, pls. 5, 6, text fig. 1 (map).—Six species, one new and one undeterminable, and one variety are described and figured from the Miocene and Eocene.

Accordi, Bruno. Esame Geologico-Paleontologico della Campionatura di un Pozzo Terebrato a Cartura (Padova).—Mem. Istit. Geol. Univ. Padova, vol. 16, 1950, pp. 1-19, 1 pl., 1 text fig.—The occurrence and frequency of 76 species and varieties in the well are shown in a chart, and 15 of the forms are figured.

Esame Geologico-Paleontologico della Campionatura di un Pozzo Terebrato a ca' Capello (Rovigo).—L. c., pp. 1-17, 1 pl., 1 text fig.—Many foraminifera are listed.

R. T.