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Editor

FRANCES L. PARKER

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146. THE CONTRIBUTIONS OF JEAN LE CALVEZ TO THE STUDY OF THE FORAMINIFERA[1]

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The sudden death of the French biologist Jean Le Calvez in August, 1954, brought to a premature end the career of one of the outstanding students of foraminiferan biology. The scope of his researches was almost as broad as the field itself, although his primary concern was with life cycles and cytology. The present review is an attempt to summarize from the French literature some of his biological contributions that may be of interest to the paleontologist.

Le Calvez' major studies have been detailed in three papers (1938b, 1950, and 1953) and it is with these that this review primarily deals, but in an effort to give the reader an idea of the scope of his observations upon these organisms, all the published foraminiferal works are briefly treated in chronological order. His complete bibliography, including foraminiferal and non-foraminiferal papers, has recently been published in a brief memorial by Debourle (1955) and indicates the breadth of his interests and experience in other fields of biological research. Twenty-two of his 40 publications were devoted to the Foraminifera, the remainder to the morphology, genetics and cytology of various invertebrates.

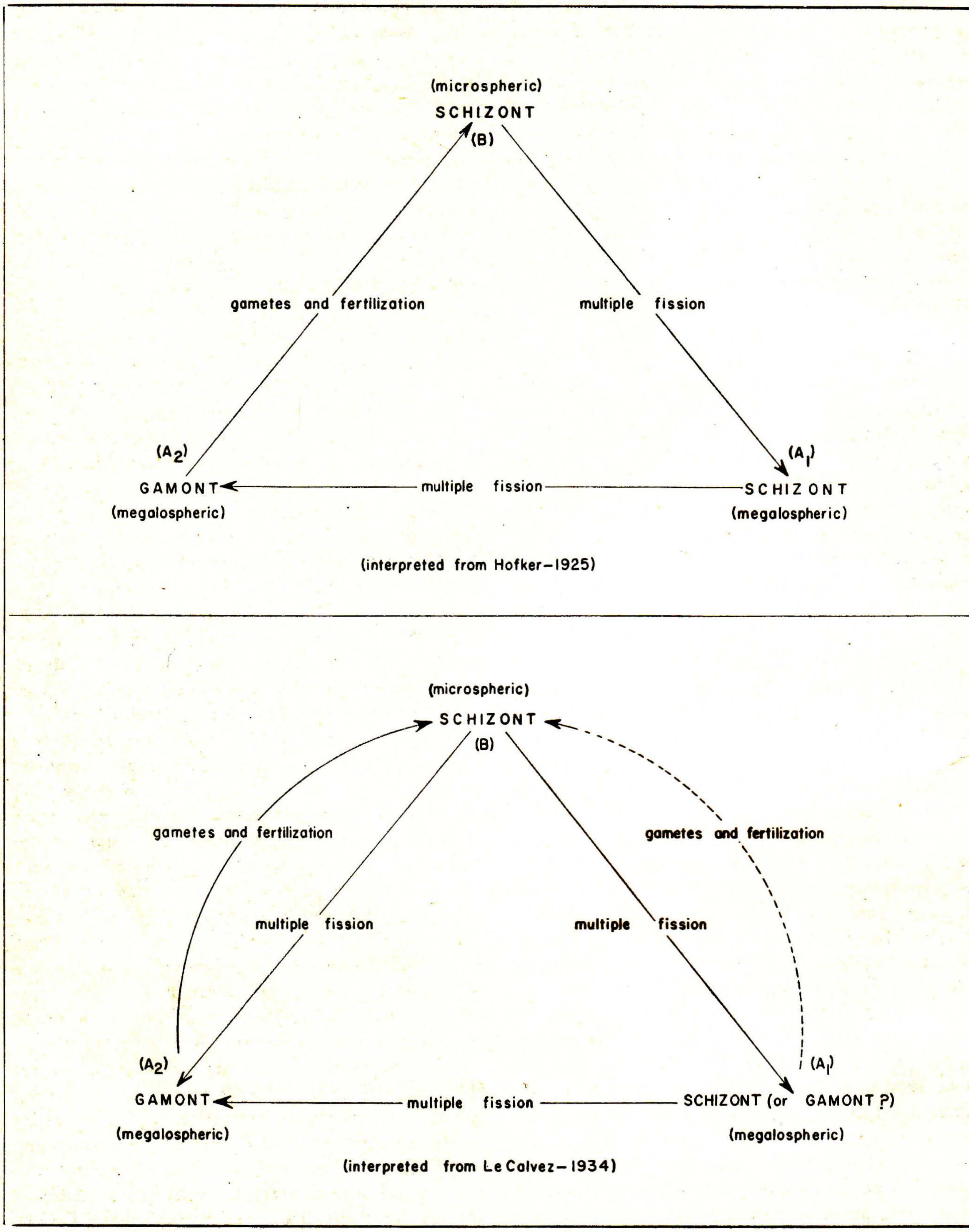
His first publication on the Foraminifera (1934) contains a comprehensive morphological description of the test and protoplasmic elements of *Planorbulina mediterranensis* Orb., together with a discussion of the development of asexually-produced young within the parent test and of their emergence as five-chambered individuals at the conclusion of their incubation period. His data concerning the occurrence of three forms distinguishable on the basis of prolocular diameters are in general agreement with Hofker's (1925) but refute the latter's claim that the sequence from form B (microspheric) to A_1 and then to A_2 is inalterable. Le Calvez observed the production of A_1 from B at one time, but at another the production of A_2 from B rather than from A_1 (Text Figure 1), terming this, appropriately enough, "labile trimorphism".

In his second paper (1935a) he described the following new living species from Villefranche (Maritime Alps) and Banyuls-sur-Mer: *Astrorhiza vermiculata, Bathysiphon humilis, Iridia serialis, Rhabdammina inaequalis, Rhizonubecula adherens, Saccammina fragilis, Webbinella crassa.* He added valuable supplementary observations on the following species: *Ammobaculites tenuimargo* (Brady), *Astrorhiza arenaria* (Norman), *Rhynchosaccus immigrans* (Rhumbler), *Webbinella hemisphaerica* (Jones, Parker and Brady). His description of the test of these forms is, in several cases, augmented by observations on the protoplasmic elements (including the nuclei), together with remarks on observed ecological and distributional relationships.

A second paper appearing late in the same year (1935b) is a short note on the gametes of no less than ten different species: *Iridia lucida* Le Calvez, *I. diaphana* Heron-Allen and Earland, *Iridia serialis* Le Calvez, *Triloculina rotunda* Orb., *Quinqueloculina suborbicularis* Orb., *Orbulina universa* Orb., *Discorbis bertheloti* Orb., *Tretomphalus bulloides* Orb., and *Planorbulina mediterranensis* Orb. The gametes of only two species, *Peneroplis pertusus* and *Elphidium crispum,* were previously known. The gametes are minute (2-3 microns) spherical or elongated bodies bearing two flagella of unequal length.

His next work (1936a) consists of a detailed description of the new species *Iridia lucida* and a comparative study of the reproduction and development of this and two other species within the genus, namely, *lucida, serialis* and *diaphana.* The description of the new species includes not only an account of the normal life activities, such as feeding, locomotion, gamete-formation and asexual reproduction, but also of the organization of the nucleus and surrounding cytoplasm. Relationships within the genus were emphasized through comparable observations on the other two species. He observed asexual reproduction by

[1] A contribution from the Museum of Paleontology of the University of California at Berkeley.



TEXT FIGURE 1

The life cycle of *Planorbulina mediterranensis* as proposed by Hofker (above) and modified by Le Calvez (below).

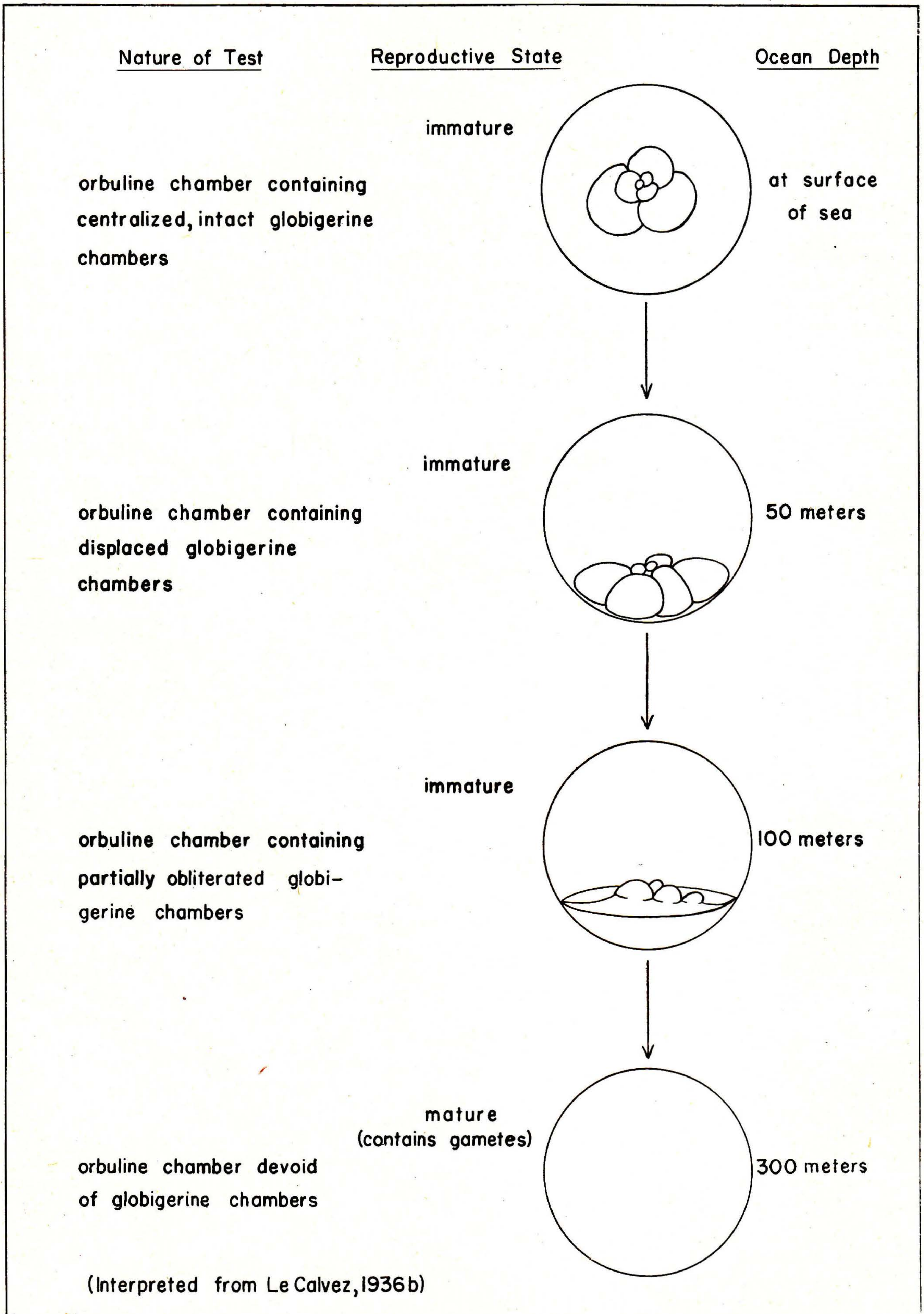
multiple fission and suggested the possible occurrence of a short-lived pelagic stage in the early development of the asexually-produced offspring of *I. diaphana* and *I. serialis.* He discovered good evidence for the occurrence of morphologically similar (but biologically different) generations, representing a sexual and an asexual phase of the life cycle, but carefully refrained from assuming an alternation between the two. Le Calvez pointed out the inapplicability of the classic concept of test dimorphism within such unilocular species as these, in which the tests are identical and the proloculus, the basis for such distinctions, is not differentiated.

The above work was followed by a study on test modifications occurring in association with the reproduction of the pelagic species *Orbulina universa* Orb. and *Tretomphalus bulloides* Orb. (1936b). His observations on living species indicate that empty *Orbulina* tests result from the destruction of the contained globigerine chambers before gamete formation (a fact quoted by Glaessner, 1945, and included in his description of the genus) and therefore, represent the megalospheric (gamont) or sexually-reproducing form. After the gametes escape through the large perforation in the wall of the spherical chamber the latter is *"absolument libre de tout résidu ou fragments de loges"* (p. 128). A study of the vertical distribution of specimens taken in plankton tows at Villefranche-sur-Mer indicated a strong correlation between depth and progressive destruction and disappearance of the globigerine chambers contained within the spherical chamber of *Orbulina universa* gamonts (Text Figure 2). He was unable to discover the true microspheric form and postulates that it may be a small bottom-dwelling type. The species would then be hemipelagic like *Tretomphalus bulloides.* Studies on the latter enabled him to refute Kemna's earlier hypothesis (1903) that benthonic rotaliform individuals form float chambers and repeatedly rise to the surface to reproduce. His observations on the reproductive activities of numerous species enabled him to point out, with conviction and emphasis, that the life of a parental foraminifer ends with the production of young by either multiple fission or sexual processes. He was able to follow the development of flagellated gametes from the parental protoplasm, their passage through the "balloon chamber" and their liberation through the large pores on its lower surface. He concluded that the float chambers of both species are primarily related to reproductive processes and possibly serve as protective structures for the gamete-producing parents. Le Calvez reminds the reader, in passing, that although the large terminal chamber of *Orbulina* undoubtedly aids in flotation, the earlier globigerine chambers are also of a form which has proven to be a successful adaptation for a planktonic existence within the genus *Globigerina.*

A second paper on *Planorbulina mediterranensis* (1937a) contains further details of the process of asexual reproduction of this species. In this account Le Calvez stressed the fact that individuals which are to reproduce asexually may be either microspheric or megalospheric, corresponding, therefore, to types B and A_1 of Hofker. The reproductive process is similar in either case, however, and results in the production of five-chambered young which have employed portions of the parental protoplasm and test during their own formative stages. The elaborate transformation of degenerating maternal protoplasm into living embryonal protoplasm, and the utilization of maternal test materials in mineralizing the "chitinous" walls of the young animal's test are considered to be quite different from the simple fragmentation observed in lower Foraminifera. To the more complicated procedure he prefers to apply the term "incubation'. In a similar vein, he prefers the term "embryo" for the young animals rather than "spore", since he feels they are structurally far more complicated than mere spores.

In the same year (1937b), Le Calvez published a short note on the structure of the chromosomes of *Patellina corrugata* in which were disclosed, for the first time, double spirals of the type which characterize the chromosomes of many plants and higher animals, this as supplementary evidence in support of Myers' earlier observations (1935) concerning the basic resemblance of the chromosomes and chromosomal activities of the Foraminifera to those of the Metazoa and Metaphyta.

Le Calvez' description of the large living foraminifer *Bathysiphon filiformis,* with emphasis on the nucleus and cytoplasmic elements, is a valuable supplement to the observations of earlier workers. The author here described the interesting process whereby a debris-laden section is periodically amputated from one end of the test, ridding the animal of accumulated waste products and thereby solving a problem which is particularly serious for those limicolous forms which are too sluggish to remove their waste materials by pseudopodial activity. The paper also contains a description of two different types of nuclei and the suggestion that these may correspond to two different phases in the life cycle, although the



TEXT FIGURE 2
The correlation between depth and progressive loss of globigerine chambers in *Orbulina universa.*

suggestion is tempered with Le Calvez' usual precautionary comment that direct proof of any such relationship is still wanting.

The French student's first attempt to synthesize knowledge within the general field of foraminiferan biology appeared in 1938. The introduction to this work contains a brief discussion of the author's own technical methods in the study of living Foraminifera and a useful historical review of the field. The first half of the paper is concerned with the cytology and general biology of *Iridia lucida* Le Calvez, *Planorbulina mediterranensis* Orbigny and *Patellina corrugata* Williamson, and though more voluminous than the second or general section, is probably of less interest to paleontologists.

The treatment of *Iridia lucida* is much more elaborate and detailed than that accorded the species in his earlier (1936a) survey of the genus. The assignment of this species to the Saccamminidae is a bit disturbing, and Le Calvez (personal communication, 1953) expressed concern over the problem before his death, but additional cytological investigation will be required before any valid systematic readjustments should be attempted. The brief description of the animal's habitat and its appearance in life are little more than a revision of similar sections of the earlier paper; but the discussion of nuclear cycles, division processes, reproduction and development is a valuable addition to the first outline. The general documentation of his cytological observations is convincing, though some of his illustrations of chromosomes are highly diagrammatic. Certain aspects of the nuclear division cycle, however, require further investigation in this and related species before their true significance can be understood. This is particularly true of meiosis in the light of Le Calvez' later (1946, 1950) studies of this process in *Patellina corrugata* and *Discorbis vilardeboanus,* but it is also true to a lesser degree of schizogonic mitosis. Concerning the life cycle, he was able to state that the gamonts produce biflagellated gametes which copulate to form new individuals, some of which are probably gamonts. Schizonts were very rare in his collections, but produced mononucleated young whose fate remained undetermined.

Le Calvez' treatment of *Planorbulina mediterranensis* in this study also represents more than a mere synthesis of previous reports (1934 and 1937a), since it is documented with detailed, though still disappointingly incomplete (because of the refractory nature of the material), cytological information. The species' test morphology has been carefully described, but the main emphasis is on the life cycle. Although the cytological documentation of nuclear cycles is as unreassuring to the reader as the exceptionally uncompromising materials must have been discouraging to Le Calvez himself, the account of the actual reproductive and developmental phenomena is most convincing, because throughout the presentation Le Calvez' characteristic intellectual honesty is maintained.

The development and asexual reproduction of the multinucleate microspheric form (form B) is described in great detail, as is the incubation of pentaloculine young and their development into either schizonts (A_1) or gamonts (A_2). Although microspheric forms are invariably multinucleate, the megalospherics were found by Le Calvez to have either one nucleus, in the case of gamonts (A_2), or two, in the case of schizonts (A_1), a condition similar to that observed by Lister (1895), Winter (1907), and Rhumbler (1911), long before Hofker (1925, 1930) launched his oft-assailed "trimorphism" concept. This nuclear difference constitutes cytological trimorphism or trimorphism at the *nuclear* level of organization.

The section devoted to *Planorbulina* is closed with a description of the development of the A_1 form (schizonts), the production of gametes by the A_2 forms (gamonts) and the occurrence of "polyvalent" or twinned animals in a phenomenon not related to plastogamy (the association of individuals for the exchange of gametes).

Le Calvez' observations on *Patellina corrugata* corroborated Myers' (1953) study of the life cycle of this species, but the French protozoologist's interest in matters cytological has led him to unveil additional structural and mechanical details of considerable importance to the cytologist in an evaluation of the nuclear division processes. Le Calvez' study confirmed Myers' major conclusions, but his greatest contribution, the discovery of the pre-schizogonic position of meiosis (1946), was delayed for a decade.

The second, or general, portion of this *magnum opus* is a comprehensive summary of the status of biological knowledge of the Foraminifera in 1938. The section begins with a discussion of the ecto- and endo-plasmic elements of the organism's protoplasmic body and is followed by a short discussion of the process of protoplasmic purification and cyst formation. The body of this section, however, is concerned with life cycles, reproduction and nuclei. Nuclear morphology and structure are first treated, followed by a discussion of typical and atypical nuclear divisions, from which the important processes of meiosis is conspicuously absent.

Le Calvez divides the Foraminifera into four main groups (on the basis of the processes of nuclear multiplication during the schizogonic phase of the life cycle).

The forms occurring in the first three groups also have a gamogonic phase and maintain their group similarity in gamogonic matters, but those of the fourth group, as the group name implies, lack this entire generation. The following tabulation summarizes the significant features of the groups designated in Le Calvez' textual account.

Group	*Representative Species*	*Schizogonic Generation* (asexual)	*Gamogonic Generation* (sexual)
Primitive	*Iridia lucida*	Mononucleate. Nuclear multiplication toward end of vegetative period.	Forms with flagellated gametes
Higher	*Planorbulina mediterranensis*	Multinucleate. Nuclear activity throughout vegetative period.	
Plastogamic	*Patellina corrugata*	Tetranucleate. Two divisions, at beginning of vegetative period. Two divisions at end of vegetative period.	Forms with amoeboid gametes
Apogamic	*Discorbis orbicularis*	Mononucleate. A few divisions, at end of vegetative period.	No gamogonic generation known

of empty tests without knowledge of their biological origin or protoplasmic contents. He suggested that the scarcity of microspheric individuals of certain species in both Recent and fossil assemblages might be attributable to the fact that multiple fission occurs within the parental test and is accompanied by its partial or complete destruction (as in *Planorbulina mediterranensis*, for example), a condition contrary to that found in species whose young are produced outside the parental test (as in *Elphidium crispum*). The French biologist concluded that the trimorphism hypothesis must be modified in the direction of Rhumbler's (1911)

Toward the end of his discussion of sexual reproductive processes, Le Calvez summarized the status of information on the highly controversial (at that time) gametes of the Foraminifera, strongly refuting the hypothesis that the supposed flagellated gametes were merely parasitic flagellated Protozoa which had invaded the foraminiferan tests. His own observations are convincing proof of the existence of true flagellated gametes in some members of this order, and subsequent workers have confirmed the correctness of his conclusions.

Le Calvez, in a rather extensive treatment of the concept of trimorphism, clearly demonstrated the absence of test trimorphism in *Planorbulina mediterranensis* and seriously questioned Hofker's (1925, 1930) idea that the life cycle of such species invariably involves three morphologically distinct forms. With his usual candor, he called attention to the fact that in an earlier publication (1934) he had reported the occurrence of three morphologically different test types in this species. The study of a larger and statistically adequate sample now enabled him to disprove the earlier conclusions and also to disclose other pitfalls lying in the path of students who would analyze groups

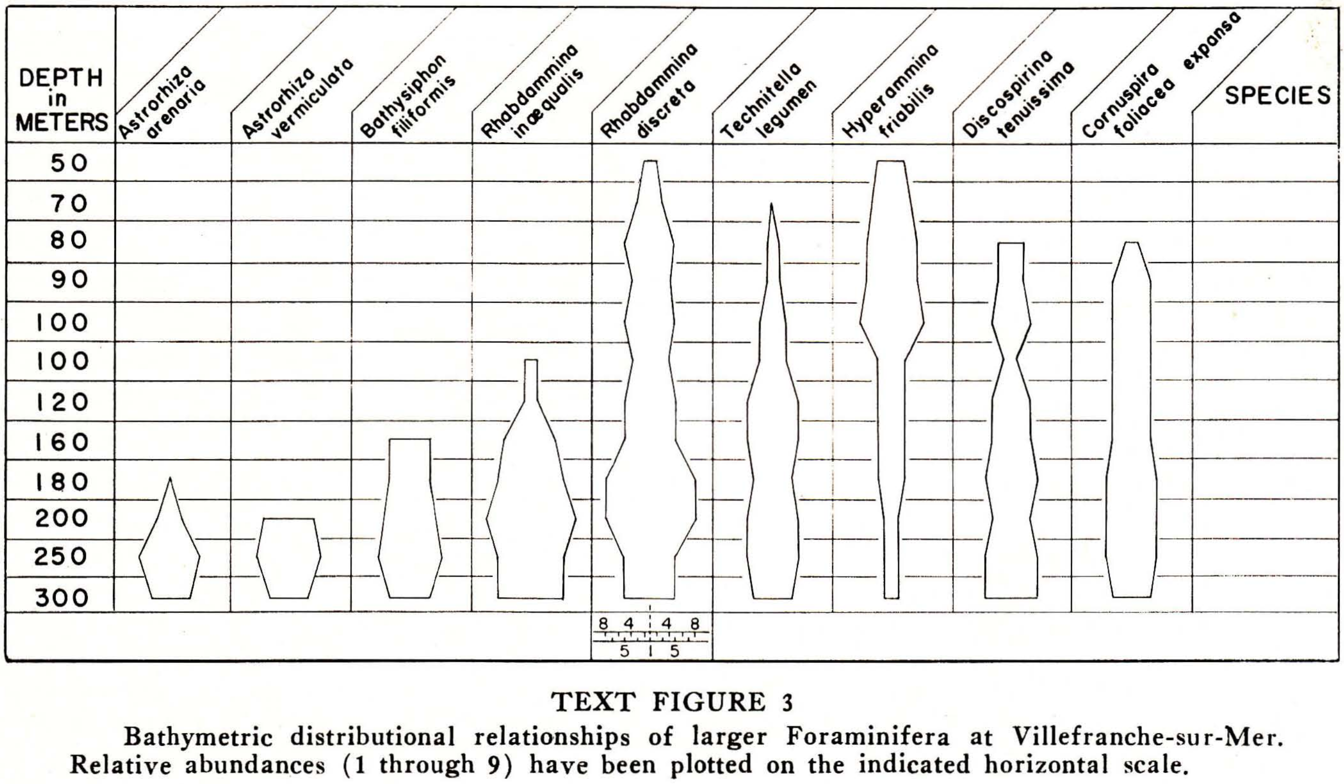
earlier suggestion that there is simply a possibility of finding three *biologically*—not morphologically— distinct individuals for each species: microspheric schizonts, megalospheric schizonts, and megalospheric gamonts. Le Calvez' criticism of Hofker's misconception and misapplication of this basic idea seems biologically sound.

Just before the final summary of his conclusions for the 1938 study, Le Calvez devoted a few pages to a general statement concerning the elements and duration of the life cycle, together with a general and morphological interpretation of the available data relating thereto. In the course of this, he referred to the possible effect of seasonal and latitudinal gradients upon the ratio of schizonts to gamonts, a relationship of possible interest and value to the paleoecologist if a positive means of distinguishing the two biologically different (but often morphologically similar) forms can ever be developed.

The principal concern of almost half the conclusions from this his largest publication on the Foraminifera is with the degree of correlation existing between test dimorphism and the alternation of sexual and asexual generations, or, to phrase it differently, the correlation betwen morphological and biological duality. An additional complication, the number of nuclei, should also be taken into consideration, as he indicates, to make the picture complete. The classical concept of the life cycle, largely the result of the studies of Lister (1895) and Schaudinn (1895), involved a strict correlation between morphological and biological types, in that the megalospheric individual was believed to represent the sexually-reproducing and the microspheric the asexually-reproducing animal. The essential features of these and other pertinent relationships are presented in the following interpretation of the major conclusions from his 1938 synthesis:

1. Test dimorphism occurs in only a few higher species and is completely absent in others.
2. The degree of correlation between morphological and biological duality is highly variable throughout the order and not obligatory.
3. An alternation between sexual and asexual generations is by no means imperative in all species, since supernumerary asexual generations (megalospheric individuals) may occur and the sexual generation may be completely lacking.
4. The correlation between prolocular size and nuclear number is also variable, since megalospheric individuals of certain higher Foraminifera may be multinucleate and both schizonts of numerous lower Foraminifera are mononucleate throughout their vegetative life.
5. The notion of morphological dimorphism (more paleontological than biological) should be abandoned, or at least related, wherever possible, to the reproductive potential (*i.e.*, whether they are schizonts or gamonts) of the individuals to which it is applied.
6. Schizogony is the ubiquitous phase of the cycle throughout the order. A well-defined nucleus is always present, and the young, produced inside or outside the maternal test, have from 1 to 5 chambers at birth.
7. The shape of the young is due solely to its own protoplasm, which models the chambers and secretes the test in the midst of the surrounding maternal protoplasm.
8. Gamogony is less constant in its occurrence (may even be lacking) and more variable in its details.
9. Gametes may be amoeboidal or flagellated.

Le Calvez' final publication of this year (1938c) dealt with the distribution of the larger Foraminifera living in the bay at Villefranche-sur-Mer. The data from his frequency chart have been summarized in Text Figure 3, but his original literal frequency symbols have been assigned numerical values which could be plotted in scaled columns to facilitate their interpretation. Le Calvez' sym-



TEXT FIGURE 3

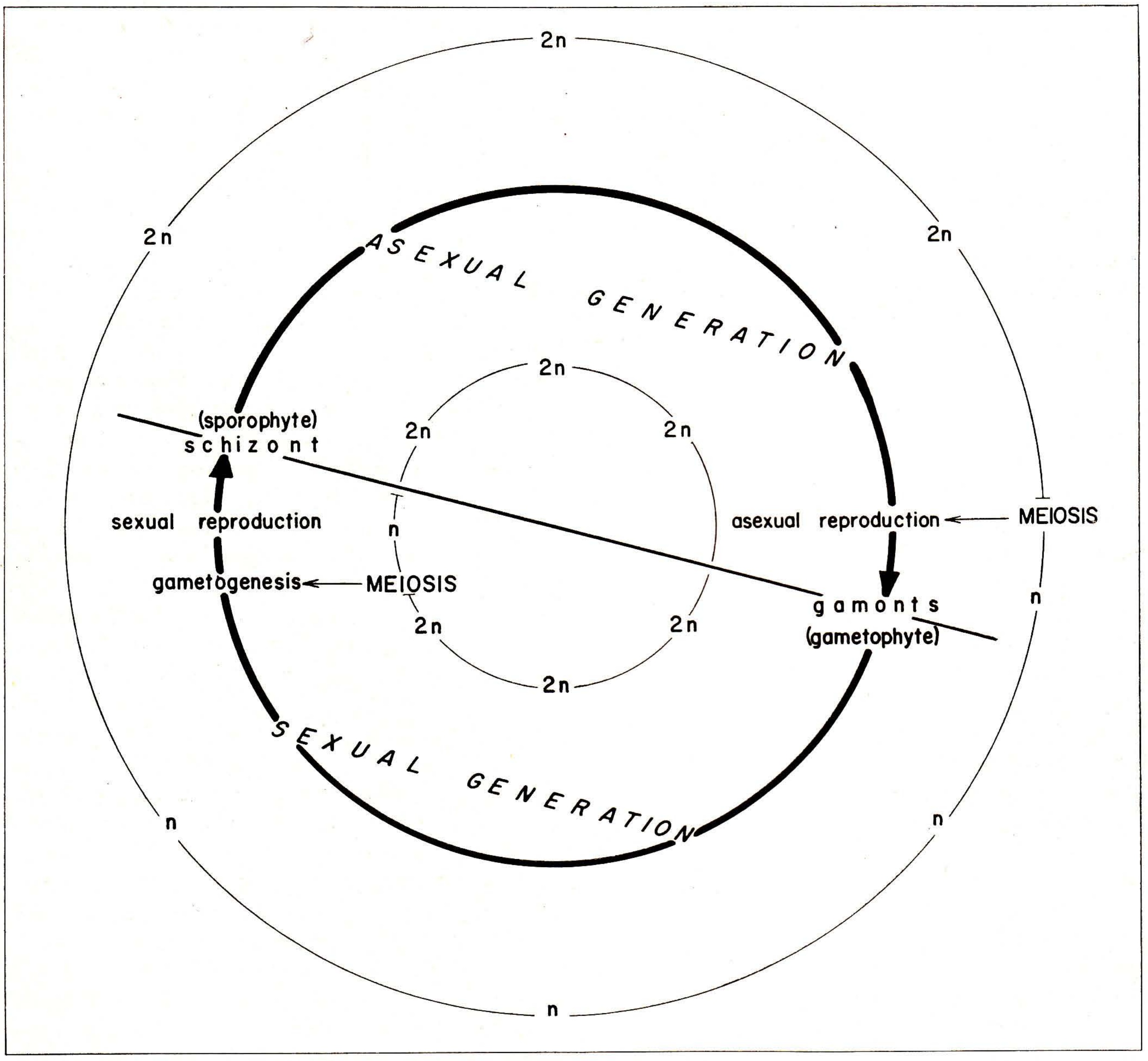
Bathymetric distributional relationships of larger Foraminifera at Villefranche-sur-Mer. Relative abundances (1 through 9) have been plotted on the indicated horizontal scale.

bols, the descriptive phrases for which they stood, and the numerical values assigned them by the reviewer are as follows:

TR (*très rare*)	=1	CO (*commun*)	=6
RA (*rare*)	=2	TC (*très commun*)	=7
AR (*assez rare*)	=3	AB (*abondant*)	=8
PC (*peu commun*)	=4	TA (*très abondant*)	=9
AC (*assez commun*)	=5		

Le Calvez considers that the association of the nine indicated species and their grouping around the 200-meter isobath comprises a distinct facies dominated by *Rhabdammina,* and that the several species have moved upward from the continental slope to occupy the continental shelf.

The next paper published by Le Calvez (1939a) was the second of three containing descriptions of Recent foraminiferal faunas. The first (1935a) has already been mentioned. The second is a briefly annotated listing of the species comprising a characteristic Indo-Pacific, subreef fauna from the vicinity of Nhâ-Trang on the southeast coast of Indo-China. The third (1951a), the only paper published jointly with his wife, Yolande, will be discussed in its proper chronological sequence.



TEXT FIGURE 4

The position of meiosis in the foraminiferan life cycle. The outermost circle indicates the chromosome cycle (alternation between the diploid, 2n, and the haploid, n, condition) determined by Le Calvez (1946) when he discovered meiosis in association with asexual reproduction, as it occurs in most land plants. The innermost circle indicates the chromosomal cycle which would result if meiosis occurred in association with gametogenesis, as is the case for most animals and as was formerly believed to be the case for the Foraminifera. The dark circle is a composite generalized representation of the corresponding life cycles.

Early in 1939, there also appeared the first in a series of three papers devoted to the study of foraminiferan parasites. Two of these appeared before the war, while the third (to be described in its proper chronological sequence in a later paragraph) appeared shortly after its close. All three are valuable contributions not only for the student of the Foraminifera, but for protozoologists and parasitologists generally. The first (1939b) is a detailed account of the morphology, development and reproduction of an unusual sporozoan (Protozoa) within the test of *Planorbulina mediterranensis,* together with observations on the effect of each member of the association upon the other. The second (1940) is an equally detailed account of parasitic amoeba which, peculiarly enough, appear to invade *Discorbis mediterranensis* only when the individual gamonts are paired during sexual reproduction.

Le Calvez' first foraminiferal paper published after the war was a short preliminary note (1946) announcing a discovery which most students consider highly significant. For many years it has been assumed that the Foraminifera, following the pattern well established in the animal kingdom, reduce the number of chromosomes from the normal diploid complement to the halved, or haploid, number at the time of gamete formation (Text Figure 4). According to this procedure, the diploid complement would then be restored at the time of the pairing and fusion of gametes following their liberation from two different parents; but the cytological evidence which supported this inferred conformity with the norm has long been considered inadequate. Le Calvez, after re-examining his pre-war preparations of *Patellina corrugata* and studying new ones of *Discorbis vilardeboanus,* found fairly convincing cytological evidence of the occurrence of chromosome reduction in a position in the life cycle which bears greater resemblance to the pattern observed in land plants than that found in animals. His evidence showed that the reduction occurred prior to multiple fission, (*i.e.,* prior to asexual reproduction) and that the individuals so produced contained the haploid number of chromosomes throughout their life, since there was no opportunity for gametic pairing and the restoration of the diploid complement until gametes were formed and fertilized at the end of vegetative life. The nuclear divisions which immediately preceded the formation of gametes were found to be normal duplicative divisions (mitoses), and no reduction in chromosome number (meiosis) occurred at this point, contrary to earlier opinions (including his own). The original diploid complement is restored with the formation of gametes (now haploid, of course, although this condition was attained a full generation earlier than was formerly supposed) which subsequently fuse in pairs to form new zygotes.

In the same paper Le Calvez managed to fan the flickering flame of trimorphism by citing a mechanism whereby a third *biologically* distinctive form could be produced. If chromosome reduction fails to occur prior to asexual reproduction, diploid rather than haploid schizonts are produced. These are morphologically identical with haploid megalospheres (gamonts), since they have large proloculi, but they have the diploid chromosomal complement which characterizes true microspheric schizonts.

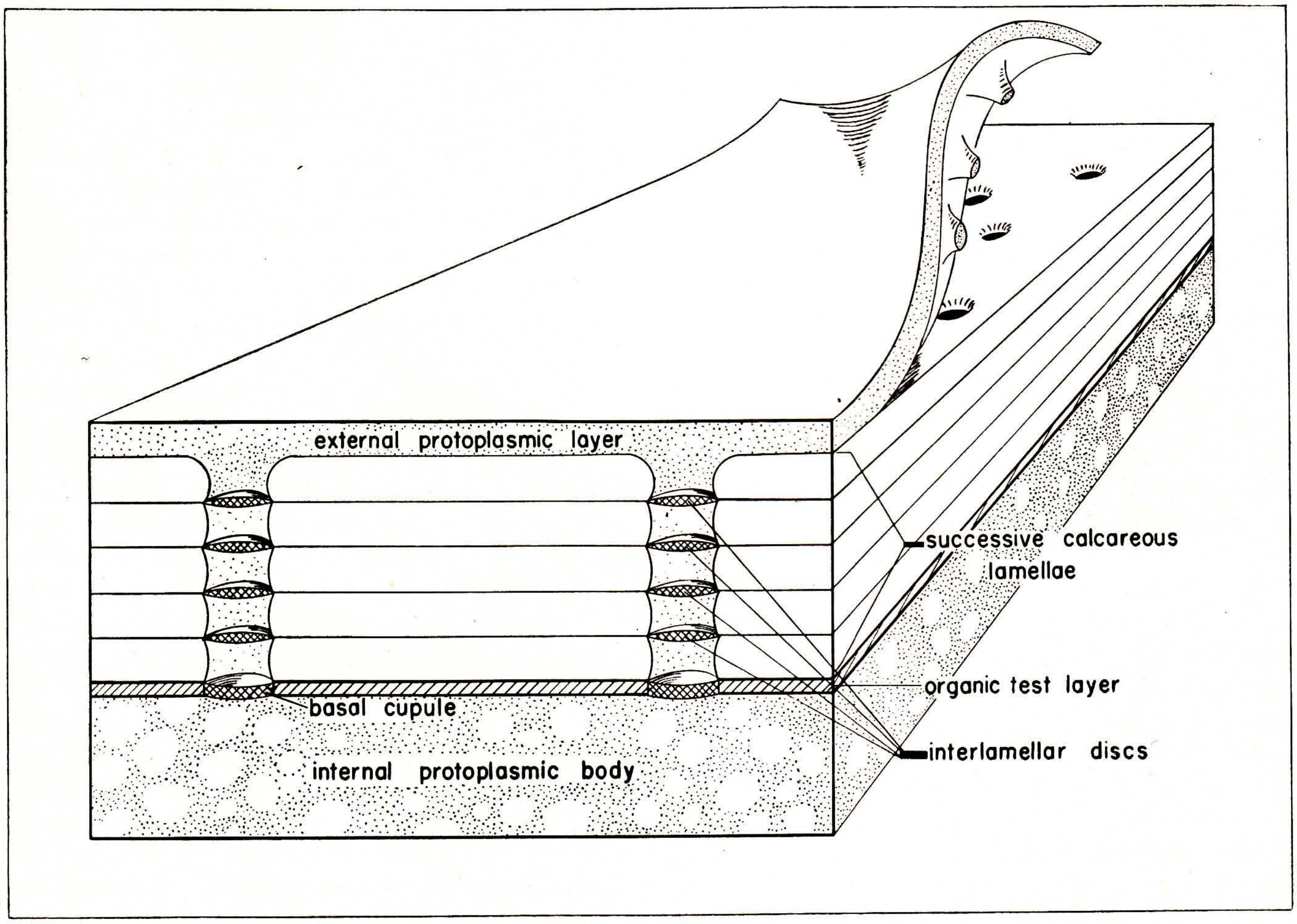
Le Calvez' third paper on foraminiferal parasitology (1947a) contains a description of a foraminifer *Entosolenia marginata,* which lives on the outer surface of *Discorbis vilardeboanus* and feeds by short-circuiting particles from the latter's food-laden protoplasmic envelope into its own mouth. The ectoparasitic *Entosolenia* is apparently closely adapted to this mode of existence and dies if *D. vilardeboanus* is not present in laboratory cultures. Le Calvez offered the interesting suggestion that the close relationship between the two species may severely restrict the size of *Entosolenia* populations and may explain their usual scarcity in the fossil record. The parasite reproduces only by asexual means, a fact which the French cytologist believed may explain the marked polymorphism within the species, since no gametic union occurs to preserve specific morphological types. In the asexual process he outlined, the entosolenian tube dissolves prior to multiple fission, a phenomenon of possible interest in the interpretation of the fossil remains of the animal.

During the same year, Le Calvez published the results of his observations on the nature of the test wall and pore structure in *Discorbis erectus.* This study has shown that thickened extensions of the underlying organic layer ("basale chitinoide") of the test lie at the base of the test perforations, possibly preventing the flow of protoplasm through the pores to the outside. As successive lamellae are added to the test, discoidal structures are deposited at corresponding intervals by the extralocular protoplasmic sheath which extends down into the pores from the outside (Text Figure 5).

The French protozoologist's next published work (1948) was an abstract of an address presented before the Thirteenth International Zoological Congress in which he summarized recent contributions, principally his own, to the knowledge of foraminiferan nuclei, life cycles and sexuality.

A detailed account of his observations on sexual differentation and on the position of meiosis (chromosome reduction) in the life cycle appeared in 1950. In this well-documented account he elaborated upon the occurrence of meiosis just prior to multiple fission in the asexual phase of *Patellina corrugata's* life cycle and presented strong evidence of a similar condition in *Discorbis vilardeboanus.* The paper is of cytological interest because of the author's valuable observations on such processes and features as the passage of nuclear materials into the cytoplasm, the development of chromosomal spirals during meiosis, and the formation of tetrads. The following generalizations concerning the nuclear cycles of dimorphic Foraminifera are of particular interest to students of the group:

1. The gamont is mononucleate and haploid.
2. Gamogonic divisions are:
   a. either low and fixed in number (plastogamic species with amoeboid gametes),
   b. or high and intermediate (hologamic and plastogamic species with flagellated gametes).
3. The copulation of two gametes produces the diploid zygote which, after growth and development, will become the schizont.
4. All diploid post-zygotic divisions occur at the beginning of the schizont's life. These are either few in number (two or, rarely, three), as in plastogamic species with amoeboid gametes, or more numerous (three to five), as in hologamic species and plastogamic species with flagellated gametes.
5. The nuclei remain at rest throughout the entire vegetative life of the schizont.
6. A sexual reproduction of the schizont begins with two successive schizogonic divisions; the first is reductional, the second, equational. It therefore produces four times as many mononucleate haploid embryos (future gamonts) as there are nuclei in the old schizont.



TEXT FIGURE 5
Diagrammatic representation of the test of *Discorbis erectus,* based upon Le Calvez' two-dimensional illustration (1947b).

The tabulation below represents the reviewer's own attempted synthesis of Le Calvez' conclusions concerning the differences which he has observed between the schizont and the gamont:

Character	*Schizont*	*Gamont*
Volume	Greater	Smaller
Season of predominance	Winter	Summer
Relative longevity	Extended	Short
Shell contour (of plastogamic discorbids)	Flattened	Conical
Direction of coiling	Generalizations not yet possible	
Phototropism (littoral species)	Negative, or only slightly positive	Often positive

The second portion of this 1950 paper deals principally with the results of an experimental study of the pairing responses observed in the gamonts of *Discorbis mediterranensis.* Pairing experiments have led Le Calvez to the conclusion that these organisms, whose sexuality he believes to be genotypically determined, secrete a chemical which induces pairing between members of different sexes.

In a final section he reviewed the nature of certain species [such as *Discorbis orbicularis* and *Fissurina* (*Entosolenia*) *marginata*] which have no sexual cycle, saying that such apogamic forms, because of their uninucleate condition, minute size and relatively simple tests, may be considered to represent gamonts which have lost their potential for sexual reproduction.

Le Calvez generally published alone, but his third study on foraminiferal faunas (1951a) was conducted in conjunction with his wife, Yolande, a micropaleontologist in her own right. Their study of the brackish-water Foraminifera from two large lagoons on the Mediterranean coast of southeastern France have shown that here, as in similar environments elsewhere, the number of species represented is small but the number of individuals of a given well-adapted species may be quite large. They conclude that the nature of the bottom seems to regulate this abundance, but that variations in salinity influence the average size attained by the tests. A full English summary of this paper has been recently published by Arnal (1955).

Later the same year (1951b) Le Calvez confirmed earlier observations of the presence of iron compounds in foraminiferal protoplasm and suggested that the excessive precipitation of these compounds within the living protoplasm of *Planorbulina mediterranensis* and *Rotalia beccarii* might well be a preliminary step toward organic pyritization within the test at or following the death of the animal if external conditions are otherwise chemically favorable.

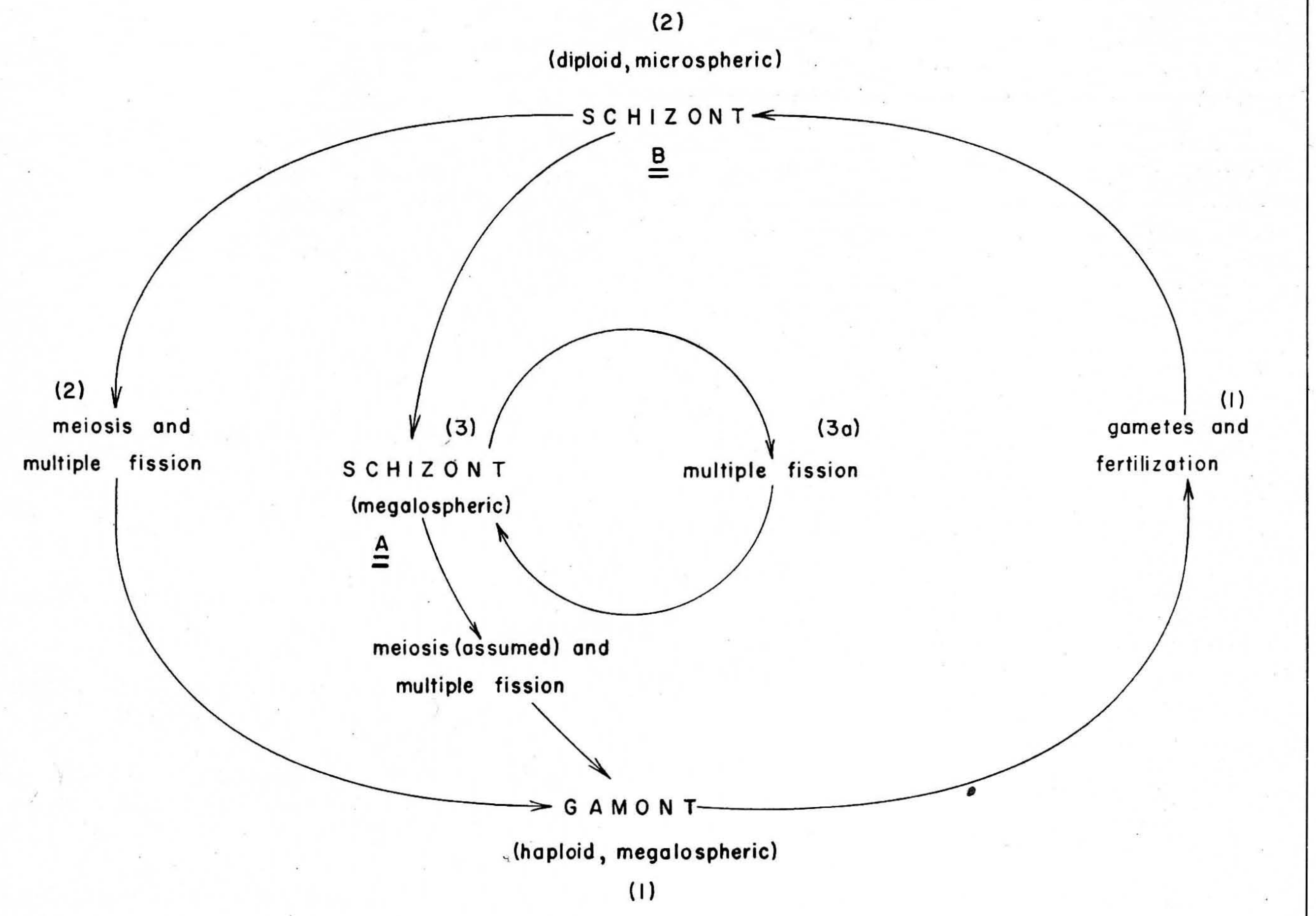
The study of cytological preparations and living specimens of certain Mediterranean rotalids has shown (1952) that *Discorbis patelliformis* (Brady) represents the asexual phase and *D. erectus* (Sidebottom) the sexual phase of a single species, for which Le Calvez proposed the designation *Discorbis patelliformis* (Brady) *erectus* (Sidebottom). He recognized certain general morphological differences between the tests of species which pair during sexual fertilization (plastogamic species) and those which do not (hologamic species) and indicated that a comparative study of these features in other discorbids should aid in unraveling additional complications in discorbid taxonomy.

In his final publication on the Foraminifera, a textbook account, Le Calvez (1953) has combined his own previous contributions with those of other students to produce a composite picture which, from a biological viewpoint, is probably the most complete and up-to-date one available. It gives a final glimpse of the French biologist's own knowledge of the group and contains his conclusions concerning several problems of great importance to students of foraminiferan biology, such as the nature and mechanism of sex differentiation, the time and position of meiosis in the life cycle, and the degree of correlation between morphological and functional duality in the cycle.

Slightly less than half of the superbly illustrated 115-page account is devoted to a systematic survey of the families, a section based largely upon Cushman's (1948) treatment of the subject, although some of the Allogromiidae are removed to the Thecamoebae and the residue are dubbed Lagynidae in the sense of Galloway. The first part of the non-systematic section treats the foraminiferan test and is a compilation of observations by micropaleontologists and other students of foraminiferan biology (including Rhumbler and Hofker); but the remainder is devoted to the protoplasmic elements and the biological activities of the Foraminifera, the realm in which Le Calvez' own contributions have had their greatest impact. Text Figure 6 is an attempted synthesis of Le Calvez' principal conclusions and generalizations concerning the foraminiferan life cycle, based upon his 1938 and 1953 publications, but since the remainder of his account of the biology of the

Foraminifera is largely a summary of observations already reviewed, further discussion of it seems unnecessary.

Jean Le Calvez was a competent scientist and teacher with a broad experience in several fields of biological investigation. His interest and re-



1-2-1 = dimorphic cycle *(Patellina corrugata)*
1-2-3-1 = holotrimorphic cycle *(Rotalia beccarii flevensis)*
1-2-3-1; 1-2-1; 3-3 = paratrimorphic cycle *(Planorbulina mediterranensis* and *Elphidium crispum)*
3-3 = apogamic cycle *(Discorbis orbicularis)*

STEPS	TYPICAL EXAMPLE	OTHER SPECIES WITH ANALOGOUS CYCLES	SEXUAL CHARACTERISTICS		NUCLEAR NUMBER		EXCEPTIONAL FEATURES
			Fertilization	Gametes	Schizont	Gamont	
1-2-1	*Iridia lucida*	*I. diaphana, I. serialis, Webbinella hemisphaerica*	monogamic	biflagellate	1	1	no micro-megalo-spheric differentiation
	Discorbis patelliformis	*D. pulvinata, D. ornatissima, D. parisiensis D. opercularis, D. mediterranensis*	plastogamic	triflagellate	multiple	1	
	Spirillina vivipara	*Patellina corrugata*	plastogamic	amoeboid	3 or 4	1	
1-2-1 and occasionally 1-2-3-1	*Elphidium crispum*	*Nubecularia lucifuga, Quinqueloculina seminulum, Q. suborbicularis, Triloculina circularis, T. rotunda, Peneroplis pertusus, Discorbis vilardeboanus, D. berthеloti, Planorbulina mediterranensis, Rotalia beccarii, Cibicides lobatulus, Cyclocibicides vermiculatus, Eponides repandus, Tretomphalus bulloides*	monogamic	biflagellate	multiple	1	position of meiosis still undetermined for all but D. vilard.
3-3a	*Discorbis orbicularis*	*Entosolenia marginata*	*(no sexual phase)*		these are biologically schizonts, but, like gamonts, are mononucleate		

(Interpreted from Le Calvez – 1938 and 1953)

TEXT FIGURE 6
Diagram of the various types of life cycles exhibited by the Foraminifera.

search in the field of genetics made him particularly well qualified to open this important frontier in foraminiferan biology, but his untimely death has dimmed our hopes and expectations for such a conquest. His contributions to our knowledge of the biology of the Foraminifera have enabled us to advance along a broad front toward a better understanding of the complex life patterns exhibited by these creatures, and his observations will continue to furnish stimulation and guidance to foraminiferologists, be they students of the test or the paleontologically unmentionable "soft parts."

GLOSSARY OF BIOLOGICAL TERMS

Apogamy — the production of an asexually reproducing organism from what is normally a sexually reproducing form, without the formation and fusion of gametes. Le Calvez applies this term to species which have lost their sexual phase completely, such as *Fissurina* (*Entosolenia*) *marginata* and *Discorbis orbicularis.*

Diploid — the fundamental somatic (vegetative) or zygotic number of chromosomes. This is usually indicated by the symbol "2n" and is double the haploid, or gametic, number.

Gametogenesis — the process whereby gametes are formed.

Gamete — germ or sex cells which fuse during fertilization to produce a zygote.

Gametophyte — the haploid, gamete-producing plant in species exhibiting an alternation of sexual and asexual generations.

Gamont—an animal destined to produce gametes.

Haploid — the reduced number of chromosomes produced after meiosis and typically exhibited by gametes. This is usually indicated by the symbol "n" and is one-half the diploid number.

Meiosis — the process whereby the diploid chromosome complement is reduced to the haploid condition.

Mitosis — the process by which a nucleus gives rise to two morphologically equivalent nuclei *without* the reduction in chromosome number which characterizes meiosis.

Monogamy — as used by Le Calvez, this term is contrasted with "plastogamy" and refers to sexual reproduction without physical contact between mating gamonts.

Plastogamy — term originally applied to cytoplasmic fusion as opposed to nuclear fusion karyogamy), but applied by Le Calvez to Foraminifera which actually associate in pairs for the exchange of gametes (*e.g., Patellina corrugata*).

Somatic — relating to the non-reproductive (vegetative) cellular or nuclear elements as opposed to the reproductive (germinal) elements.

Sporophyte — the diploid, asexually reproducing plant in species exhibiting an alternation of sexual and asexual generations.

Zygote — a cell formed by the fusion of gametes during fertilization.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

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147. RECENT FORAMINIFERA FROM SHORE SANDS OF WESTERN INDIA

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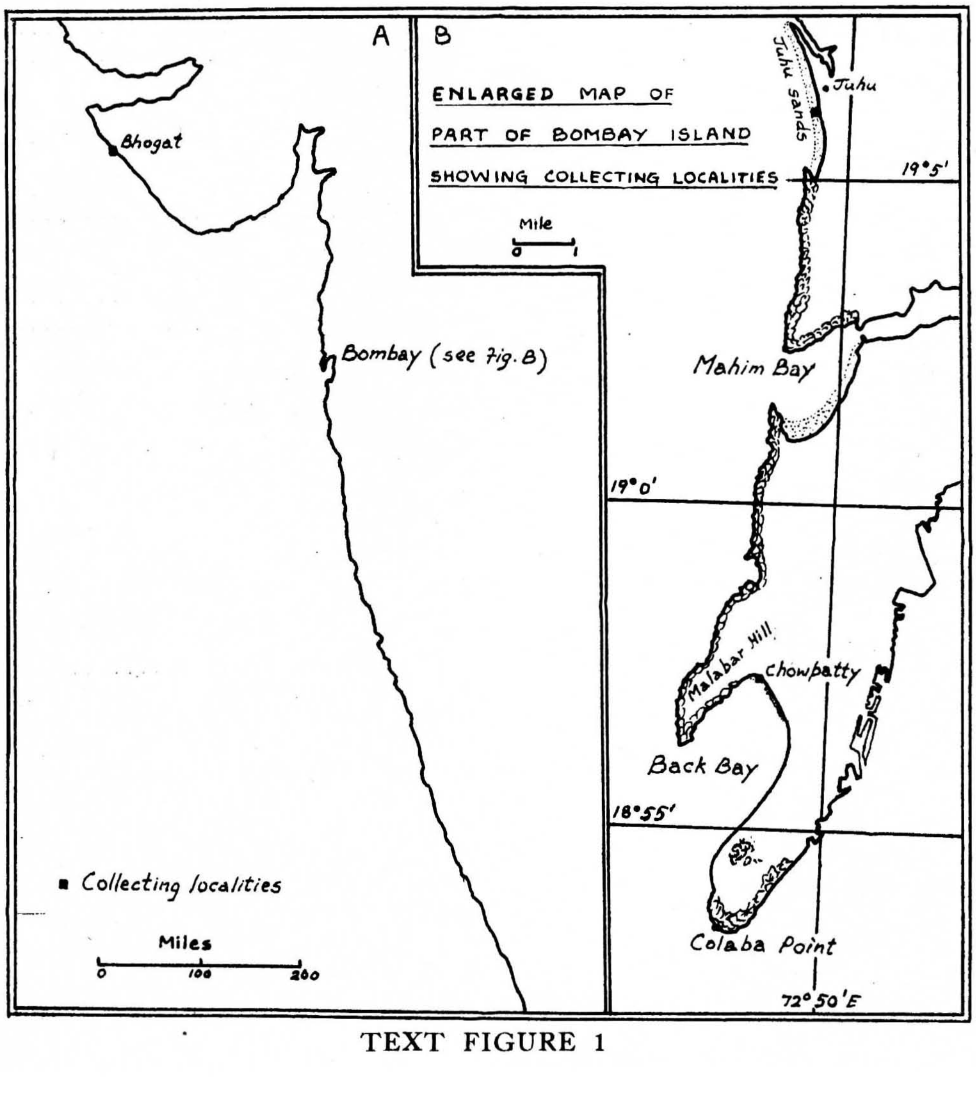
ABSTRACT—Recent Foraminifera from three beach samples from Western India are recorded and illustrated. There are 46 species and varieties, the great majority of which are characteristic Indo-Pacific forms.

INTRODUCTION

This paper records results of investigations carried out by the writer on foraminiferal assemblages from several beach samples from Western India. Of the three samples investigated for this study, two were from places in and near Bombay (Chowpatty beach 18°57′15″ N.: 72°49′00″ E. and Juhu beach 19°06′00″ N.: 72°49′30″ E.) while the third sample was from shore sand near Bhogat (21°58′00″ N.: 69°12′30″ E.) in Saurashtra. The samples from Bombay area were collected by the writer in January, 1955, while the sample from Bhogat beach was collected by Mr. Krishna Mohan during the field-season 1953-54 and subsequently handed over to the writer for foraminiferal study. Forty six species and varieties are recorded from these localities. All the forms are illustrated. The occurence of each species is shown in the accompanying distribution table. The collecting localities are shown in Text Fig. 1.

The writer wishes to take this opportunity to express his sincere thanks to J. Hofker, The Hague, Holland, for his valued opinion concerning the identification and taxonomy of certain 'Rotalids' and to S. R. N. Rao, Department of Geology, Lucknow University, for his many use-



TEXT FIGURE 1

ful suggestions during the progress of the work and for reading the manuscript. The writer is also grateful to the Director, Geological Survey of India, Calcutta, for library privileges.

PREVIOUS WORK

A survey of the literature shows that little detailed work has been done on the exceedingly rich microfauna from coasts of Western India. Perhaps the earliest reference is by Parker and Jones (1865) who described a few Foraminifera from anchor mud, Bombay Harbour. Chapman (1895) recorded some Foraminifera from near Laccadive Islands, in the Arabian Sea. Cushman (1936) described *Elphidium indicum* from Bombay shore sand, while *Spiroloculina indica* was described by Cushman and Todd (1944) from Recent shore sand, Karachi (now in Pakistan). Kurian (1951, 1953) recorded certain Foraminifera from off the Travancore coast. Recently Chaudhury and Biswas (1954) have published a list of perforate Foraminifera from the Juhu beach, Bombay.

FAUNAL DISTRIBUTION

The great majority of forms recorded herein are typically Indo-Pacific although certain species are cosmopolitan in distribution. Fifteen species are identical with those described by Said (1949, 1950) from the Northern Red Sea.

Of the 46 species and varieties recorded, 11 are common to the three localities.

Juhu beach (*Bombay*).—A total of 34 species and varieties were found. Assemblage is dominated by species belonging to the genus *Streblus*, some of which occur in super-abundance. The family Miliolidae is abundant in the number of species, though not in the number of individuals. Two species—*Siphogenerina raphanus* (Parker and Jones) and *Poroeponides lateralis* (Terquem)—also occur abundantly in the Juhu beach material.

Chowpatty beach (*Bombay*).—A total of 12 species and varieties were found. Assemblage is dominated by *Streblus annectens* (Parker and Jones), *Poroeponides lateralis* (Terquem), *Elphidium indicum* Cushman, and several species of *Quinqueloculina*. The fauna from this locality is poor in the number of species as compared to that from the Juhu beach, which is only 10 miles to the north. This may probably be attributed to the more protected nature of the Back Bay which is shut off on the north by the Malabar Hill and on the south by Colaba Point (see Text Fig 1), and to the predominantly rocky substratum in the immediate vicinity of the beach.

Bhogat beach (*Saurashtra*).—A total of 30 species and varieties were found. Assemblage is dominated

LIST OF SMALLER FORAMINIFERA FROM WESTERN INDIA

Foraminifera	Collecting Localities		
	Juhu	Chowpatty	Bhogat
Textularia conica Orbigny			R
Textularia foliacea Heron-Allen and Earland			R
Quinqueloculina crassa Orb. var. **subcuneata** Cushman	R	R	R
Quinqueloculina lamarckiana Orbigny	A	F	F
Quinqueloculina cf. mosharrafai Said			R
Quinqueloculina seminulum (Linnaeus)	A	F	F
Quinqueloculina undulose-costata Terquem	F	F	R
Quinqueloculina venusta Karrer	F		R
Miliolinella cf. **labiosa** (Orbigny)	R		
Spiroloculina excavata Orbigny	R	F	
Spiroloculina eximia Cushman	F		
Spiroloculina indica Cushman and Todd	A		R
Triloculina cf. **rotunda** Orbigny	F		R
Triloculina aff. **rupertiana** (Brady)	R		
Triloculina terquemiana (Brady)			R
Triloculina tricarinata Orbigny	R	R	R
Triloculina sp. indet.	R		
Vertebralina sp. indet.			R
Robulus sp. indet.			R
Nonion scapha (Fichtel and Moll)	F		
Elphidium advena (Cushman)	R	F	R
Elphidium cf. **craticulatum** (Fichtel and Moll)			R
Elphidium crispum (Linnaeus)			F
Elphidium indicum Cushman	R	F	R
Elphidium simplex Cushman	R		
Elphidium sp. indet.	R		
Bulimina marginata Orbigny	R		
Bolivina cf. **pseudoplicata** Heron-Allen and Earland	R		
Bolivina striatula Cushman	R		
Bolivina variabilis (Williamson)	R		
Bolivina sp. indet.			F
Loxostomum limbatum (Brady)	R		R
Chrysalidinella dimorpha (Brady)	R		
Siphogenerina raphanus (Parker and Jones)	A	R	R
Discorbis sp. indet.	R		
Eponides cf. **praecinctus** (Karrer)			R
Eponides sp. indet.	R		
Streblus annectens (Parker and Jones)	A	F	F
Streblus dentatus (Parker and Jones)	F		R
Streblus papillosus (Brady)	F		F
Streblus ? aff. **audouini** (Orbigny)			F
Poroeponides lateralis (Terquem)	A	F	F
Cancris auricula (Fichtel and Moll)	R		
Cibicides lobatulus (Walker and Jacob)			R
Cibicides sp. indet.	F		R

R = Rare = 1-4 specimens

F = Frequent = 5-14 specimens

A = Abundant = Over 15 specimens

by several species belonging to the genus *Streblus,* some of which occur in super-abundance. Other species which are common are *Quinqueloculina seminulum* (Linnaeus), *Q. lamarckiana* Orbigny, *Elphidium crispum* (Linnaeus) and *Poroeponides lateralis* (Terquem). The assemblage is further characterized by the presence of arenaceous forms—*Textularia conica* Orbigny and *T. foliacea* Heron-Allen and Earland. No arenaceous forms were found in the Bombay localities.

SYSTEMATIC DESCRIPTIONS

Family TEXTULARIIDAE

Genus **Textularia** Defrance, 1824

Textularia conica Orbigny

Plate 1, figure 2

Textularia conica Orbigny, 1839, De la Sagra, Hist. Fis. Pol. Nat., Cuba, Foraminiferes, p. 143, pl. 1, figs. 19, 20; Cushman, 1932, U.S. Nat. Mus., Bull. 161, Pt. 1, p. 11, pl. 2, figs. 8-10: pl. 3, figs. 1, 3 (*et syn.*).

This is a cosmopolitan species. Rare specimens were found in the Bhogat material.

Textularia foliacea Heron-Allen and Earland

Plate 1, figure 1

Textularia foliacea Heron-Allen and Earland, 1915, Trans. Zool. Soc. Lond., vol. 20, p. 628, pl. 47, figs. 17-20; Cushman, 1932, U.S. Nat. Mus., Bull. 161, p. 8, pl. 1, figs. 6-10.

This characteristic Indo-Pacific species occurs abundantly in the sample from Bhogat beach.

Family MILIOLIDAE

Genus **Quinqueloculina** Orbigny, 1826

Quinqueloculina crassa Orbigny var. **subcuneata** Cushman

Plate 2, figure 7

Quinqueloculina crassa Orbigny var. *subcuneata* Cushman, 1921, U.S. Nat. Mus., Bull. 100, vol. 4, p. 423, pl. 89, figs. 4a-c.

This is a widely distributed species in the Indo-Pacific and also extends into the Atlantic. Rare specimens were found at each of the three localities.

Quinqueloculina lamarckiana Orbigny

Plate 2, figure 10

Quinqueloculina lamarckiana Orbigny, 1839, De la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminifères, p. 189, pl. 11, figs. 14-15; Cushman, 1932, U.S. Nat. Mus., Bull. 161, Pt. 1, p. 24, pl. 6, figs. 2a-c (*et. syn.*).

This cosmopolitan species occurs abundantly at the three localities.

Quinqueloculina cf. **mosharrafai** Said

Plate 2, figure 11

Quinqueloculina mosharrafai Said, 1949, Cush. Lab. Foram. Res., Spec. Publ. No. 26, p. 10, pl. 1, fig. 23.

A single specimen which may be questionably referred to this species from the Red Sea, was found in the Bhogat material. The wall is thick and covered with numerous small pustules.

Quinqueloculina seminulum (Linnaeus)

Plate 2, figure 9

Serpula seminulum Linnaeus, 1758, Systema Naturae, 10th Ed., p. 786.

Quinqueloculina seminulum (Linnaeus) d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 303, No. 44; Cushman, 1917, U.S. Nat. Mus., Bull. 71, Pt. 6, p. 44, pl. 11, fig. 2.

This widely distributed species occurs abundantly in all the samples.

Quinqueloculina undulose-costata Terquem

Plate 2, figure 8

Quinqueloculina undulose-costata Terquem, 1882, Mem. Soc. Geol. France, p. 185, pl. 20, figs. 18, 19.

Specimens referable to this Tertiary species were found in all the samples. Rare to frequent in occurence.

Quinqueloculina venusta Karrer

Plate 2, figure 6

Quinqueloculina venusta Karrer, 1868, Sitz. Akad. Wiss. Wien, vol. 57, p. 147, pl. 2, fig. 6; Cushman, 1921, U.S. Nat. Mus., Bull. 100, vol. 4, p. 420, pl. 91, figs. 2a-c (*et. syn.*).

This is a widely distributed species, both in the fossil state and in the Recent seas. Occurs in the Juhu and Bhogat beach samples.

Genus **Miliolinella** Wiesner, 1931

Miliolinella cf. **labiosa** (Orbigny)

Plate 1, figure 15

Triloculina labiosa Orbigny, 1839, De la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminifères, p. 178, pl. 10, figs. 12-14.

Miliolinella labiosa (Orbigny) Wiesner, 1931, Deutsch. Sud-Polar Exped., vol. 20, Zool., p. 108, pl. 15, figs. 181-182.

Rare specimens which may be doubtfully referred to this species were found in the material from Juhu beach.

Genus **Spiroloculina** Orbigny, 1826

Spiroloculina excavata Orbigny

Plate 1, figure 13

Spiroloculina excavata Orbigny, 1846, Foram. Foss. Bass. Tert., Vienne, p. 271, pl. 16, figs. 19-21; Cushman and Todd, 1944, Cush. Lab. Foram. Res., Spec. Publ. No. 11, p. 23, pl. 4, figs. 12-16 (*et. syn.*).

Typical specimens of this cosmopolitan species were found in samples from Juhu and Chowpatty beaches.

Spiroloculina eximia Cushman

Plate 1, figure 14

Spiroloculina eximia Cushman, 1922, Carnegie Inst Washington, Publ. 311, p. 61, pl. 11, fig. 2; 1929, U.S. Nat. Mus., Bull. 104, Pt. 6, p. 42, pl. 8, figs. 7a,b.

A few specimens referable to this Indo-Pacific species were found in the material from Juhu beach.

Spiroloculina indica Cushman and Todd

Plate 2, figure 5

Spiroloculina indica Cushman and Todd, 1944, Cush. Lab. Foram. Res., Spec. Publ. No. 11, p. 71, pl. 9, figs. 32a,b.

This species was originally described from the Recent shore sand, Karachi, and is so far known only from the Arabian Sea. Fairly typical specimens were found in the Juhu and Bhogat beach samples.

Genus **Triloculina** Orbigny, 1826

Triloculina cf. **rotunda** Orbigny

Plate 2, figure 1

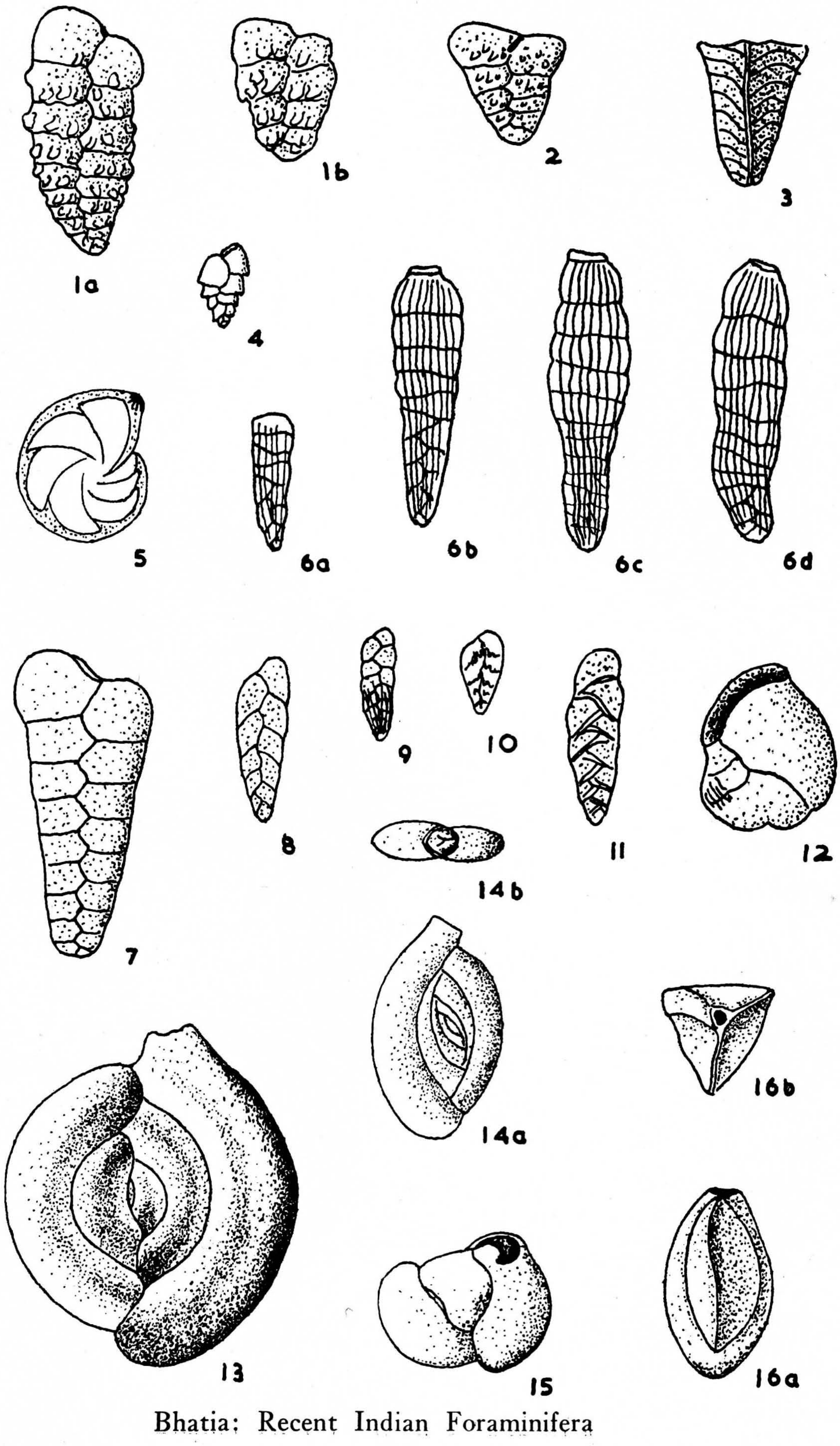
Triloculina rotunda Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 229, No. 4; Cushman, 1929, U.S. Nat. Mus., Bull. 104, p. 59, pl. 14, figs. 3a-c.

A few specimens which may be questionably referred to this species were found in samples from Juhu and Bhogat beaches.

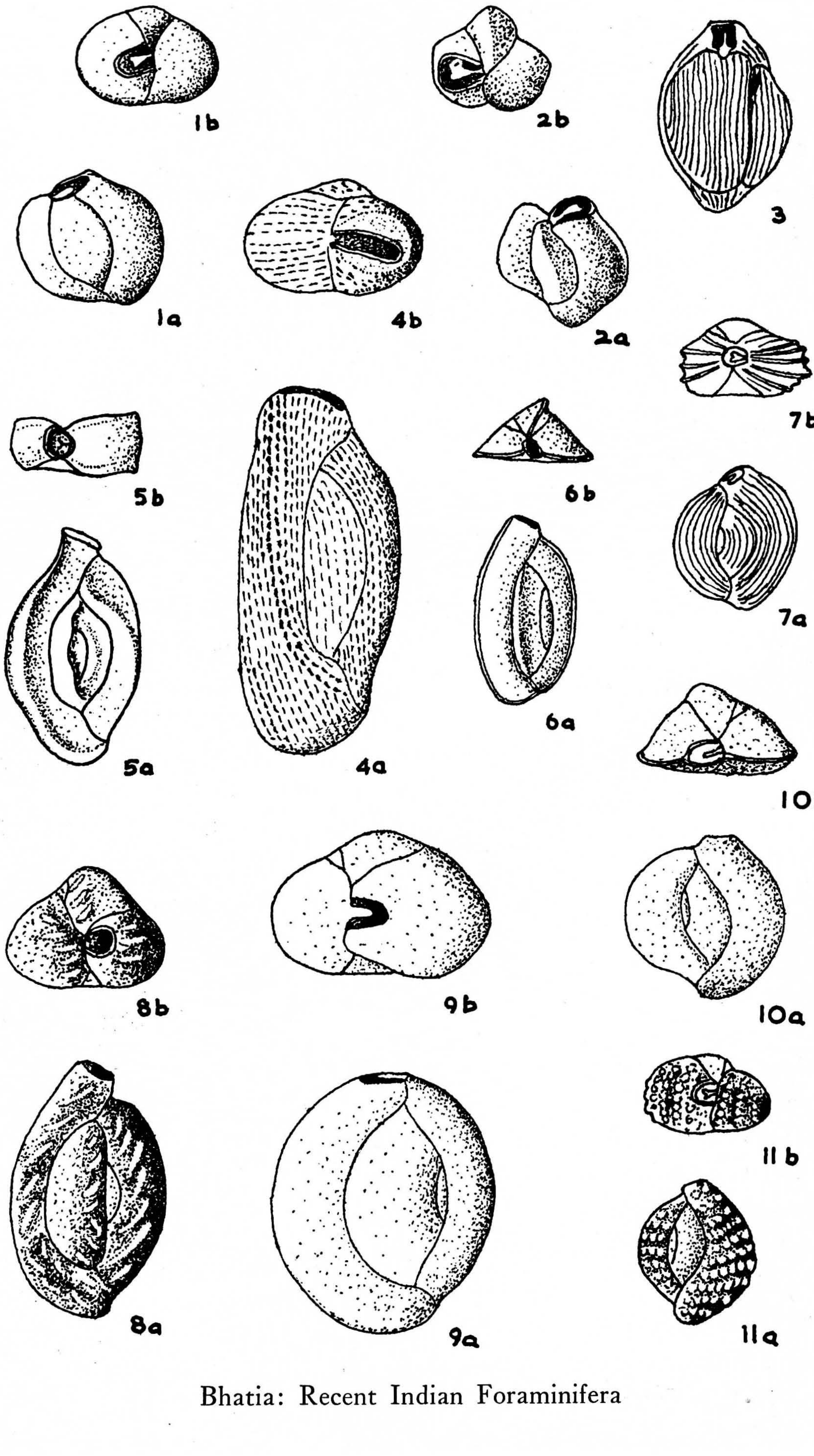
EXPLANATION OF PLATE 1

All figures X 40

Figs.		Page
1.	*Textularia foliacea* Heron-Allen and Earland. a, microspheric form; b, megalospheric form. Loc. Bhogat	17
2.	*Textularia conica* Orbigny. Loc. Bhogat	17
3.	*Chrysalidinella dimorpha* (Brady). Loc. Juhu	21
4.	*Bulimina marginata* Orbigny. Loc. Juhu	20
5.	*Robulus* sp. indet. Loc. Bhogat	19
6.	*Siphogenerina raphanus* (Parker and Jones). a,b, microspheric forms; c,d, megalospheric forms. Loc. Juhu	21
7.	*Bolivina* sp. indet. Loc. Bhogat	21
8.	*Bolivina variabilis* (Williamson). Loc. Juhu	21
9.	*Bolivina striatula* Cushman. Loc. Juhu	21
10.	*Bolivina* cf. *pseudoplicata* Heron-Allen and Earland. Loc. Juhu	20
11.	*Loxostomum limbatum* (Brady). Loc. Bhogat	21
11.	*Loxostomum limbatum* (Brady). Loc. Bhogat	21
12.	*Vertebralina* sp. indet. Loc. Bhogat	19
13.	*Spiroloculina excavata* Orbigny. Loc. Chowpatty	18
14.	*Spiroloculina eximia* Cushman. a. side view; b. apertural view. Loc. Juhu	18
15.	*Miliolinella* cf. *labiosa* (Orbigny). Loc. Juhu	17
16.	*Triloculina tricarinata* Orbigny. a. side view; b. apertural view. Loc. Juhu	19



Bhatia: Recent Indian Foraminifera



Bhatia: Recent Indian Foraminifera

Triloculina aff. **rupertiana** (Brady)
Plate 2, figure 4

Miliolina rupertiana Brady, 1884, *Challenger Rept.*, Zool., vol. 9, pl. 7, figs. 7-12.

A few specimens which are very close to this species were found at Juhu beach. The chamber arrangement is triloculine and the surface of the test is striato-punctate.

Triloculina terquemiana (Brady)
Plate 2, figure 3

Miliolina terquemiana Brady, 1884, *Challenger Rept.*, Zool., vol. 9, p. 166, pl. 114, figs. 1a,b.

Rare specimens of this species were found at Bhogat beach.

Triloculina tricarinata Orbigny
Plate 1, figure 16

Triloculina tricarinata Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 229, No. 7; Cushman, 1929, U.S. Nat. Mus., Bull. 104, Pt. 6, p. 56, pl. 13, figs. 3a-c.

This widely distributed species was found at each of the three localities.

Triloculina sp.indet.
Plate 2, figure 2

A single speciment of this indeterminate species was found at Juhu beach.

Family OPHTHALMIDIIDAE
Genus **Vertebralina** Orbigny, 1826
Vertebralina sp. indet.
Plate 1, figure 12

A single specimen of this indeterminate species was found in the material from Bhogat beach.

Family LAGENIDAE
Genus **Robulus** Montfort, 1808
Robulus sp. indet.
Plate 1, figure 5

A few specimens of this indeterminate species were found in the sample from Bhogat beach.

Family NONIONIDAE
Genus **Nonion** Montfort, 1808
Nonion scapha (Fichtel and Moll)
Plate 5, figure 15

Nautilus scapha Fichtel and Moll, 1798, Test. Micr., p. 105, pl. 19, figs. d-f.

Nonion scaphum (F. & M.) Cushman, 1930, U.S. Nat. Mus., Bull. 104, Pt. 7, p. 5, pl. 2, figs. 3,4; Marks, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, pt. 2, p. 49, pl. 5, figs. 16a,b (*et. syn.*).

Frequent specimens of this species occur in the sample from Juhu beach. Forms referred to as *N.pizarrensis* Perry by Chaudhury and Biswas (1954, p. 31) from the Juhu beach probably belong here.

EXPLANATION OF PLATE 2

All figures × 40

a. Side view; b. Apertural view

Figs.		Page
1.	*Triloculina* cf. *rotunda* Orbigny. Loc. Juhu	18
2.	*Triloculina* sp. indet. Loc. Juhu	19
3.	*Triloculina terquemiana* (Brady). Loc. Bhogat	19
4.	*Triloculina* aff. *rupertiana* (Brady). Loc. Juhu	19
5.	*Spiroloculina indica* Cushman and Todd. Loc. Juhu	18
6.	*Quinqueloculina venusta* Karrer. Loc. Juhu	17
7.	*Quinqueloculina crassa* Orbigny var. *subcuneata* Cushman. Loc. Juhu	17
8.	*Quinqueloculina undulose-costata* Terquem. Loc. Juhu	17
9.	*Quinqueloculina seminulum* (Linnaeus). Loc. Juhu	17
10.	*Quinqueloculina lamarckiana* Orbigny. Loc. Juhu	17
11.	*Quinqueloculina* cf. *mosharrafai* Said. Loc. Bhogat	17

Genus **Elphidium** Montfort, 1808

Elphidium advena (Cushman)

Plate 5, figure 9

Polystomella advena Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 56, pl. 9, figs. 11, 12.

Elphidium advenum Cushman, 1930, U.S. Nat. Mus., Bull. 104, Pt. 7, p. 25, pl. 10, figs. 1,2; 1939, U.S.G.S. Prof. Paper 191, p. 60, pl. 16, figs. 31-35 (*et syn.*).

Widely distributed in the Western Atlantic and the Pacific Ocean. Rare to frequent specimens were found in all the three localities.

Elphidium cf. **craticulatum** (Fichtel and Moll)

Plate 5, figure 10

Nautilus craticulatus Fichtel and Moll, 1798, Test. Micr., p. 51, pl. 5, figs. h-k.

Elphidium craticulatum (F. & M.) Cushman, 1933, U.S. Nat. Mus., Mull. 161, Pt. 2, p. 48, pl. 11, figs. 5a,b; 1939, U.S.G.S. Prof. Paper 191, p. 56, pl. 15, figs. 14-17 (*et syn.*).

A single specimen which may be questionably referred to this species was found in the sample from Bhogat beach.

Elphidium crispum (Linnaeus)

Plate 5, figure 11

Nautilus crispus Linnaeus, 1758, Systema naturae, Edn. 10, 709; Edn. 13 (Gmelin), p. 3370.

Polystomella crispa (Linnaeus) Lamarck, 1822, Histoire des animaux sans vertèbres, vol. 7, p. 625.

Elphidium crispum (Linnaeus) Cushman and Grant, 1927, San Diego Soc. Nat. Hist. Trans., vol. 5, p. 73, pl. 7, figs. 3a,b; Cushman, 1939, U.S.G.S. Prof. Paper 191, p. 50, pl. 13, figs. 17-21 (*et syn.*).

This cosmopolitan species was found only in the sample from Bhogat beach. Frequent in occurrence.

Elphidium indicum Cushman

Plate 5, figure 12

Elphidium indicum Cushman, 1936, Contr. Cush. Lab. Foram. Res., vol. 12, p. 83, pl. 14, figs. 10a,b; 1939, U.S.G.S. Prof. Paper 191, p. 62, pl. 17, fig. 16.

This species has so far been recorded only from the western coast of India, the type being from Bombay shore sand. Typical specimens were found in all three localities.

Elphidium simplex Cushman

Plate 5, figure 13

Elphidium simplex Cushman, 1933, U.S. Nat. Mus., Bull. 161, Pt. 2, p. 52, pl. 12, figs. 8, 9; 1939, U.S.G.S. Prof. Paper 191, p. 62, pl. 17, fig. 10.

This characteristic Indo-Pacific species was found only at Juhu beach. Rare in occurrence.

Elphidium sp. indet.

Plate 5, figure 14

This indeterminate species occurs only in the Juhu beach sample. The species is probably the same as *E. tikutoensis* (Chaudhury and Biswas, 1954, p. 31, *non* Nakamura).

Family BULIMINIDAE

Genus **Bulimina** Orbigny, 1826

Bulimina marginata Orbigny

Plate 1, figure 4

Bulimina marginata Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 269, pl. 12, figs. 10-12; Cushman and Parker, 1947, U.S.G.S. Prof. Paper 210-D, p. 119, pl. 28, figs. 5-6.

A single specimen referable to this species was found in the sample from Juhu beach.

Genus **Bolivina** Orbigny, 1839

Bolivina cf. **pseudoplicata** Heron-Allen and Earland

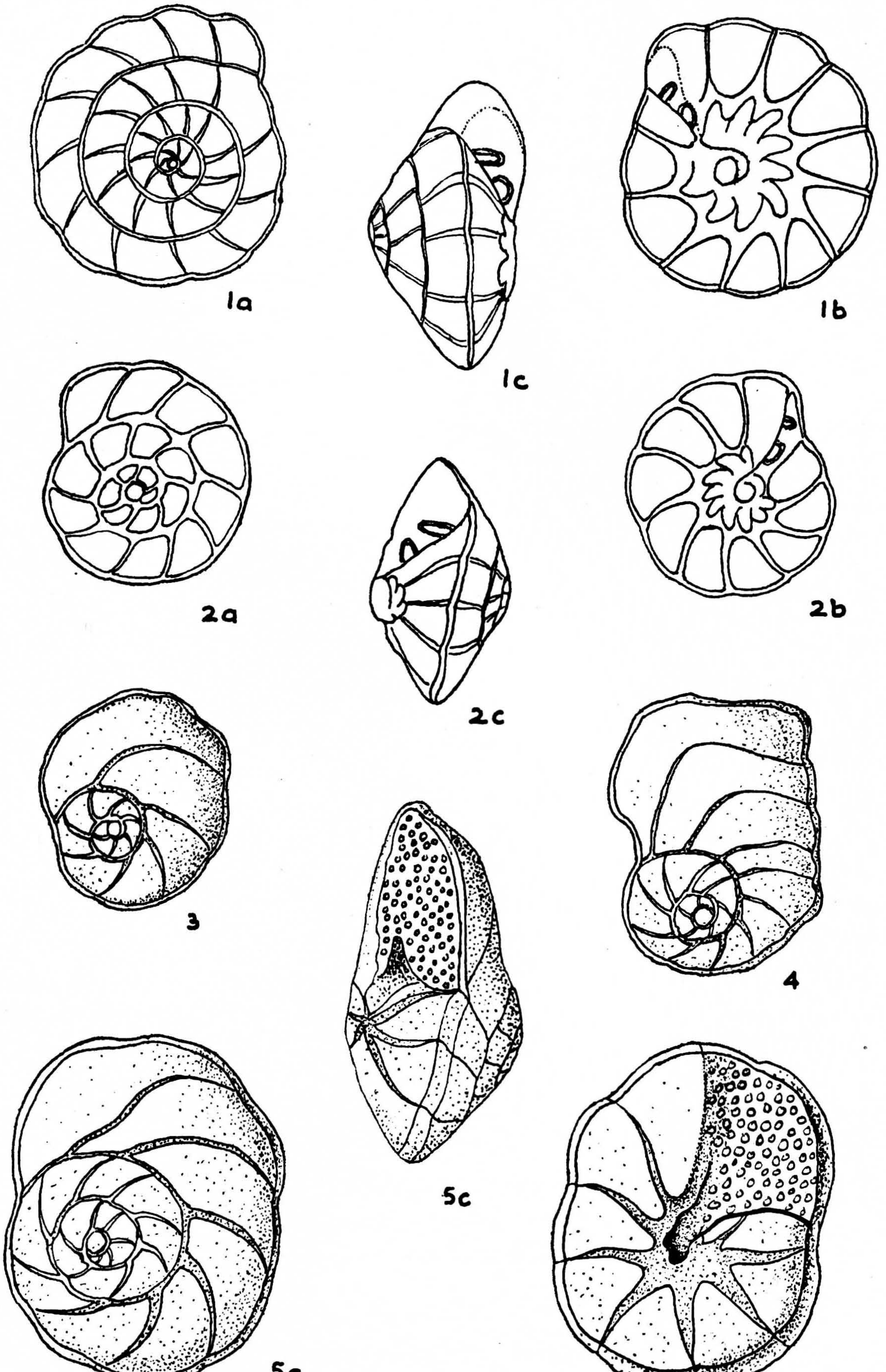
Plate 1, figure 10

EXPLANATION OF PLATE 3

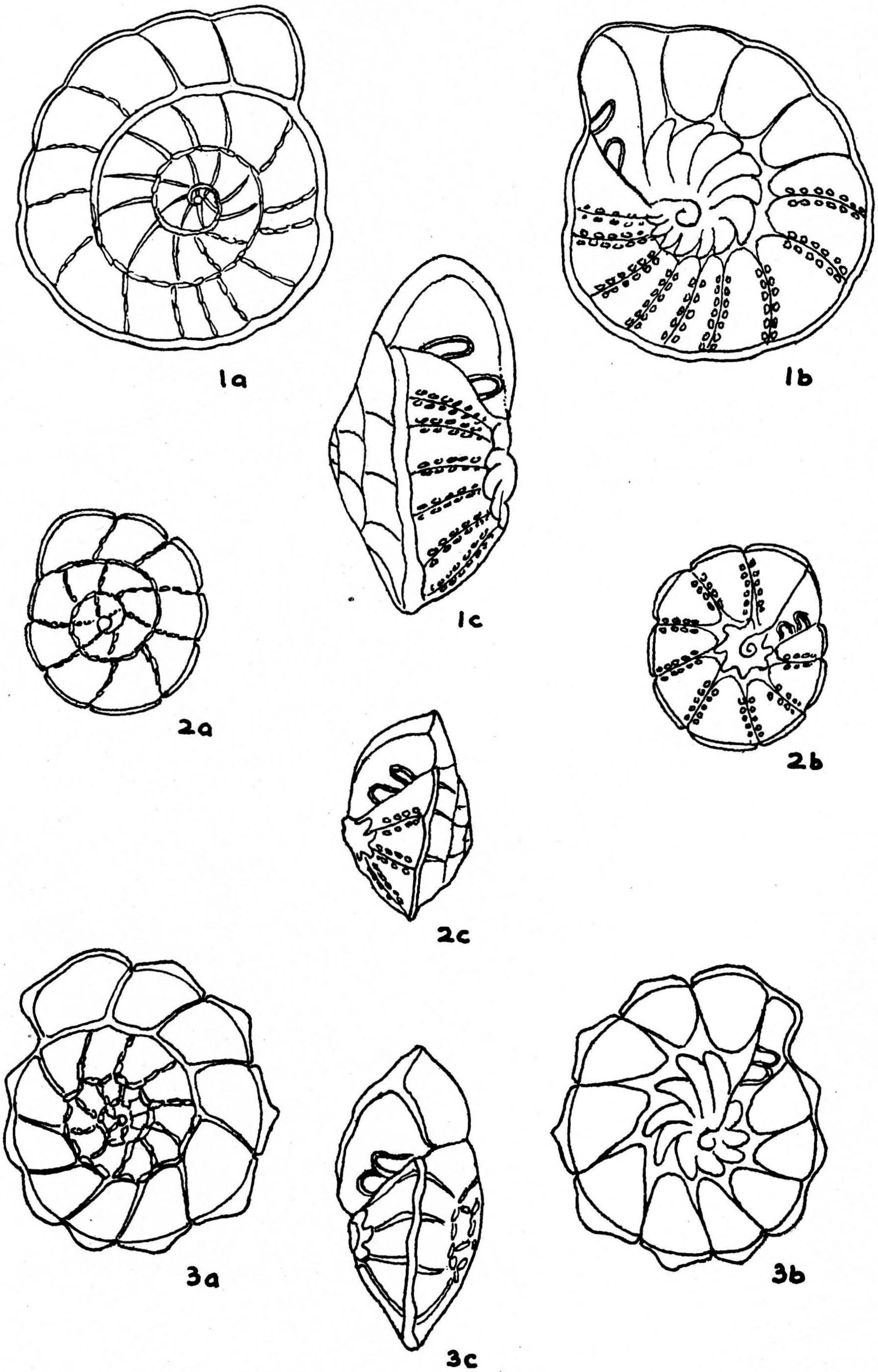
All figures × 40

a. Dorsal view. b. Ventral view. c. Peripheral view

FIGS.		PAGE
1.	*Streblus annectens* (Parker and Jones). Microspheric form. Loc. Juhu	22
2.	*Streblus annectens* (Parker and Jones). Megalospheric form. Loc. Juhu	22
3-4.	*Poroeponides lateralis* (Terquem). Juvenile specimens. Loc. Juhu	23
5.	*Poroeponides lateralis* (Terquem). Adult specimen. Loc. Juhu	23



Bhatia: Recent Indian Foraminifera



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Bolivina pseudoplicata Heron-Allen and Earland, 1930, Journ. Roy. Micr. Soc., vol. 50, p. 81, pl. 3, figs. 36-40.

Rare specimens which may be questionably referred to this Atlantic species were found at Juhu beach.

Bolivina striatula Cushman

Plate 1, figure 9

Bolivina striatula Cushman, 1922, Carnegie Inst. Washington, Publ. 311, p. 27, pl. 3, fig. 10.

A few specimens of this cosmopolitan species occur in the material from Juhu beach.

Bolivina variabilis (Williamson)

Plate 1, figure 8

Textularia variabilis Williamson, 1858, Recent Foram. Great Britain, p. 76, pl. 6, figs. 162, 163.

Bolivina variabilis (Williamson) Chaster, 1890-91 (1892), First Rept. Southport Soc. Nat. Sci., p. 59, 69; Cushman, 1937, Cush. Lab. Foram. Res., Spec. Publ. No. 9, p. 158, pl. 16, figs. 6, 12-14.

Typical specimens of this widely distributed species were found in the Juhu beach material.

Bolivina sp. indet.

Plate 1, figure 7

Frequent specimens of this indeterminate species were found in the Bhogat beach material. The test is of medium size, coarsely perforate, and with straight sutures.

Genus **Loxostomum** Ehrenberg, 1854

Loxostomum limbatum (Brady)

Plate 1, figure 11

Bolivina limbata Brady, 1881, Quart. Journ. Micr. Sci., vol. 21, p. 57; 1884, *Challenger Rept.*, Zool., vol. 9, p. 419, pl. 52, figs. 26-28.

Loxostomum limbatum (Brady) Cushman, 1937, Cush. Lab. Foram. Res., Spec. Publ. No. 9, p. 186, pl. 21, figs. 26-29.

Rare specimens of this widely distributed species were found in samples from Bhogat and Juhu beach.

Genus **Chrysalidinella** Schubert, 1907

Chrysalidinella dimorpha (Brady)

Plate 1, figure 3

Chrysalidina dimorpha Brady, 1881, Quart. Journ Micr. Sci., vol. 21, p. 54; 1884, *Challenger Rept.*, Zool., vol. 9, p. 388, pl. 46, figs. 20-21

Chrysalidinella dimorpha (Brady) Cushman, 1945, Contr. Cush. Lab. Foram. Res., vol. 21, p. 52, pl. 8, figs. 21, 22.

A single specimen referable to this species was found in the Juhu beach material.

Genus **Siphogenerina** Schlumberger, 1883

Siphogenerina raphanus (Parker and Jones)

Plate 1, figure 6

Uvigerina (Sagrina) raphanus Parker and Jones, 1865, Philos. Trans., p. 364, pl. 18, figs. 16, 17.

Siphogenerina raphanus (P. & J.) Cushman, 1942, U.S. Nat. Mus., Bull. 161, Pt. 3, p. 55, pl. 15, figs. 6-9 (*et syn.*).

This is a widely distributed species. It occurs abundantly in the Juhu beach material and rarely in the Chowpatty and Bhogat beach samples. This species has probably been erroneously recorded as *Rectobolivina multicostata* by Chaudhury and Biswas (1954, p. 31).

Family ROTALIIDAE

Genus **Discorbis** Lamarck, 1804

Discorbis sp. indet.

Plate 5, figure 4

Rare specimens of this indeterminate species occur in the Juhu beach material. Specimens are too minute to allow any specific identification.

Genus **Eponides** Montfort, 1808

Eponides cf. praecinctus (Karrer)

Plate 5, figure 2

Rotalia praecincta Karrer, 1868, Sitz. Akad. Wiss. Wien, vol. 58, p. 189, pl. 5, fig. 7.

Truncatulina praecincta (Karrer) Cushman, 1915, U.S. Nat. Mus., Bull. 71, Pt. 5, p. 39, pl. 26,

EXPLANATION OF PLATE 4

All figures × 40

a. Dorsal view b. Ventral view c. Peripheral view

FIGS.		PAGE
1.	*Streblus papillosus* (Brady). Microspheric form. Loc. Juhu	23
2.	*Streblus papillosus* (Brady). Megalospheric form. Loc. Juhu	23
3.	*Streblus dentatus* (Parker and Jones). Microspheric form. Loc. Juhu	22

fig. 2.

A few specimens which may be questionably referred to this species were found in the sample from Bhogat beach.

Eponides sp. indet.

Plate 5, figure 3

This is an indeterminate species of which rare specimens were found in the Juhu beach material.

Genus **Streblus** Fischer, 1817

Streblus annectens (Parker and Jones)

Plate 3, figures 1, 2

Rotalia beccarii (Linnaeus) var. *annectens* Parker and Jones, 1865, Philos. Trans., vol. 155, p. 387, 422, pl. 19, figs. 11a-c.

This well-known Indo-Pacific species occurs frequently to abundantly in all three samples. Hofker (personal communication) suggests the maintenance of the generic name *Streblus* for this and the following two species. His suggestions are adhered to in this paper. These species belong to Hofker's suborder Deuteroforaminata. The apertural apparatus in all these species consists of a protoforamen and a deuteroforamen.

Both the megalospheric (fig. 2) and the microspheric (fig. 1) generations were recognized. In the former, the test is minute, with 2½ whorls visible on the dorsal side; in the latter, the test is large, stout, and with 3½-4 whorls on the dorsal side.

Chaudhury and Biswas (1954, p. 31) recorded two species of *Rotalia* [*R. beccarii* (Linnaeus) and *R. nipponica* Asano] from the Juhu beach. The writer has so far failed to obtain any specimen which could be assigned to either of these two species. Since these records are without any descriptions or figures, the identifications may be taken as doubtful. Although there are many records of *R. beccarii* from widely separated regions, most of them are not the same as the Adriatic species.

Streblus dentatus (Parker and Jones)

Plate 4, figure 3

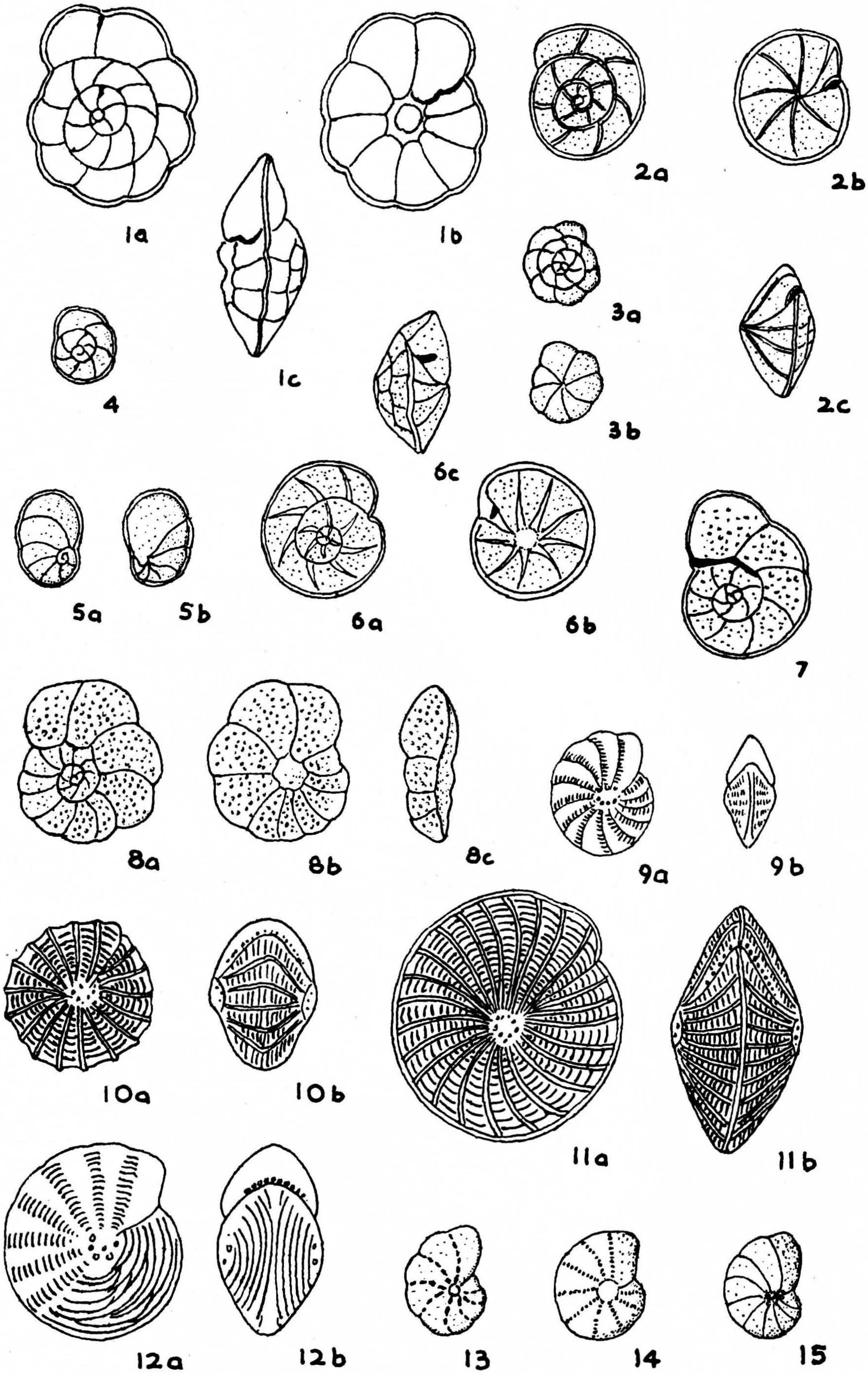
Rotalia beccarii (Linnaeus) var. *dentata* Parker and Jones, 1865, Philos. Trans., vol. 155, p. 387, 422, pl. 19, figs. 13a-c.

EXPLANATION OF PLATE 5

All figures × 40

FIGS. PAGE

1. *Streblus* ? aff. *audouini* (Orbigny). a, dorsal view; b, ventral view; c, peripheral view. Loc. Bhogat 23
2. *Eponides* cf. *praecinctus* (Karrer). a, dorsal view; b, ventral view; c, peripheral view. Loc. Bhogat 21
3. *Eponides* sp. indet. a, dorsal view; b, ventral view. Loc. Juhu 22
4. *Discorbis* sp. indet. Dorsal view. Loc. Juhu 21
5. *Cancris auricula* (Fichtel and Moll). a, dorsal view; b, ventral view. Loc. Juhu 23
6. *Rotorbinella* sp. indet. a, dorsal view; b, ventral view; c, peripheral view. Loc. Bhogat 23
7. *Cibicides lobatulus* (Walker and Jacob). Dorsal view. Loc. Bhogat 24
8. *Cibicides* sp. indet. a, dorsal view; b. ventral view; c, peripheral view. Loc. Juhu 24
9. *Elphidium advena* (Cushman). a, side view; b, peripheral view. Loc. Chowpatty 20
10. *Elphidium* cf. *craticulatum* (Fichtel and Moll). a, side view; b, peripheral view. Loc. Bhogat 20
11. *Elphidium crispum* (Linnaeus). a, side view; b, peripheral veiw. Loc. Bhogat 20
12. *Elphidium indicum* Cushman. a, side view; b, peripheral view. Loc. Chowpatty 20
13. *Elphidium simplex* Cushman. Side view. Loc. Juhu 20
14. *Elphidium* sp. indet. Side view. Loc. Juhu 20
15. *Nonion scapha* (Fichtel and Moll.) Side view. Loc. Juhu 19



Bhatia: Recent Indian Foraminifera

The species is closely related to *S. annectens* and differs from it in having a peripheral spine in each chamber. The sutures on the dorsal side are occasionally beaded. Only the microspheric generation was recognized. Rare to frequent specimens were found in Juhu and Bhogat beach samples.

The type of this species was from Recent anchor-mud, Bombay Harbour. The species is restricted to the Indo-Pacific region.

Streblus papillosus (Brady)

Plate 4, figures 1, 2

Rotalia papillosa Brady, 1884, Challenger Rept., Zool., vol. 9, p. 708, pl. 106, fig. 9 (*et auctorum*).

Rotalia papillosa Brady var. *compressiuscula* Brady, 1884, *ibid.*, p. 708, pl. 107, fig. 1, pl. 108, figs. 1a-c. (*et auctorum*).

Rotalia annectens (Parker and Jones) var. *concinna* Millett, 1904, Jour. Roy. Micr. Soc. London, Pt. 16, p. 505, pl. 10, figs. 7a-c. (*et auctorum*).

The species is characterized by the strongly biconvex test, highly sculptured and beaded sutures on the dorsal side, and the double row of beading along the sutures on the ventral side. There are supplementary chambers in the umbilical region.

Both the microspheric and the megalospheric generations were recognized. In the microspheric forms, the test is large, with 3½ whorls visible on the dorsal side and 13-15 chambers in the final whorl. The megalospheric forms are small with 2½ whorls visible on the dorsal side and 8-10 chambers in the final whorl.

R. papillosa var. *compressiuscula* and *R. papillosa* var. *concinna* appear to be generations of *S. papillosus* and come within its range of variation.

This is a typically Indo-Pacific species and has been recorded from as distant places as Red Sea and China Sea. The species occurs frequently in the Juhu and Bhogat beach samples.

Streblus ? aff. audouini (Orbigny)

Plate 5, figure 1

Rotalia audouini Orbigny, 1850, Prodrome de Paléontologie vol. 2, p. 407; Fornasini, 1906, Mem. R. Accad. 1st. Bologna, ser. 6, vol. 3, pl. 2, figs. 9-10.

This species may questionably be referred to the Tertiary species from the Paris Basin. Rare to frequent specimens were found in all three localities.

Genus **Rotorbinella** Bandy, 1944

Rotorbinella sp. indet.

Plate 5, figure 6

Frequent specimens of this indeterminate species were found in the Bhogat material.

Genus **Poroeponides** Cushman, 1944

Poroeponides lateralis (Terquem)

Plate 3, figure 3-5

Rosalina lateralis Terquem, 1878, Mem. Soc. Geol. France, ser. 3, vol. 1, p. 25, pl. 2, fig. 11.

Pulvinulina lateralis (Terquem) Brady, 1884, Challenger Rept., Zool., vol. 9, p. 689, pl. 106, figs. 2, 3.

Poroeponides lateralis (Terquem) Cushman, 1944, Cush. Lab. Foram. Res., Spec. Publ. No. 12, p. 34, pl. 4, fig. 23.

There are many records of this species which has a world-wide distribution. Recent specimens of the so-called *'Eponides repandus'* (*auctorum, non* Fichtel and Moll) should be ascribed to the genus *Poroeponides*. Most of the authors seem to have accepted Brady's figures (1884, pl. 104, fig. 18) which has many small pores on the apertural face on the ventral side (*vide etiam* Uchio, 1952, p. 157). Brady's species has been given a new name —*Poroeponides cribrorepandus*—by Asano and Uchio (*vide* Uchio, *loc.cit.*)

In the present material, the writer has found a complete transition between the so-called *P. cribrorepandus* and *P. lateralis*. Since there is considerable confusion about the morphology and the taxonomy of *'Eponides' repandus* (Fichtel and Moll), the writer has preferred to assign all the specimens to *P. lateralis* (Terquem).

Abundant to frequent specimens were found in all three localities.

Genus **Cancris** Montfort, 1808

Cancris auricula (Fichtel and Moll)

Plate 5, figure 5

Nautilus auricula Fichtel and Moll, 1798, Test. Micr., p. 108, pl. 20, figs. a-c; var. B, pl. 20, figs. d-f.

Pulvinulina auricula (F & M.) Parker and Jones, 1865, Philos. Trans. vol. 155, p. 393.

Cancris auricula (F. & M.) Cushman, 1931, U.S. Nat. Mus., Bull. 104, Pt. 8, p. 72, pl. 15, figs. 1a-c (*et syn.*).

A single specimen of this cosmopolitan species was found in the Juhu beach material.

Family ANOMALINIDAE

Genus **Cibicides** Montfort, 1808

Cibicides lobatulus (Walker and Jacob)

Plate 5, figure 7

Nautilus lobatulus Walker and Jacob, 1798, Adams Essays, Kanmacher's Ed., p. 642, pl. 14, fig. 36.

Cibicides lobatulus (W. & J.) Cushman, 1931, U.S. Nat. Mus., Bull. 104, Pt. 8, p. 118, pl. 21, fig. 3 (*et syn.*).

Rare specimens of this cosmopolitan species were found in the Bhogat beach sample.

Cibicides sp. indet.

Plate 5, figure 8

Frequent to rare specimens of this indeterminate species occur in samples from Juhu and Bhogat beach.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME VII, PART 1, JANUARY, 1956

148. DATE OF ERECTION OF THE GENUS *KILIANINA* PFENDER

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In a recent paper, W. Maync (1955, footnote 1, p. 107) emphasized the existence of a confusion as to the exact date of the erection of the genus *Kilianina* by the late Juliette Pfender. With the exception of the "Catalogue of Foraminifera" by Ellis and Messina, which gives the year 1933, other works devoted to Foraminifera (Glaessner, Pokorny, Sigal) commonly accept the year 1936. In order to settle this question, we offer the following details:

The genus was published for the first time in 1933 in "Annales de l'Université de Grenoble, nouvelle série, section Sciences et Médecine, tome X, Nos. 1 et 2, (ler et 2éme trimestre), 1933." The original pagination is: pp. 243-252, plates I and II. At the foot of page 245 the number of the leaflet (signature) is 17.

The reprint which W. Maync received from Miss Pfender comes from this publication as the pagination (243-252) and the number 17 of the leaflet attest. Apparently Miss Pfender ordered more reprints later which were marked with the year 1935.

Pfender's original publication of 1933 was again reprinted, as is the case with other geological papers, published in the "Annales de l'Université de Grenoble" in "Travaux du Laboratoire de Géologie de l'Université de Grenoble, vol. XVIII, 1934-1935," published in 1936, where the pagination was changed to pp. 121-130, with the leaflet or signature marked as 9, but under the same title and with the same disposition of text figures and plates as in the original 1933-edition.

The date of erection of the genus *Kilianina* is, therefore, the year 1933.

REFERENCE

Maync, W., 1955, *Coskinolina sunnilandensis*, n.sp., a Lower Cretaceous (Urgo-Albian) species. Contr. Cushman Found. Foram. Research, vol. 6, pt. 3, pp. 105-112, pls. 16, 17.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME VII, PART 1, JANUARY, 1956

149. *AULOTORTUS*, A NEW GENUS OF FORAMINIFERA FROM THE JURASSIC OF TYROL, AUSTRIA.

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In 1950, the writer published a paper on the Jurassic microfauna and flora of the Sonnwend Mountains of Tyrol, Austria, in which a new genus of the family Ophthalmididae was described and illustrated. At that time neither the genus nor the species was formally named. In the present paper this fossil is redescribed and a new generic and specific name, *Aulotortus sinuosus* Weynschenk, n.gen. and n.sp., is proposed.

Family OPHTHALMIDIDAE

Genus **Aulotortus** Weynschenk, n.gen.

Generic type.—*Aulotortus sinuosus* Weynschenk n.gen., n.sp.

Description.—Test calcareous, imperforate, tubular in a twisted spiral coil, the tube being crescent shaped in cross section, the crescent lengthening in the outer whorls to give the test a greater thickness. There are no partitions in the test, the wall having irregular sinuses and varying thickness. Early whorls are close coiled; outer whorls become increasingly loosely coiled, but do not uncoil as in *Ammobaculites*. Aperture can not be seen clearly but appears to be a simple opening at the end of the tube. There is a chalky filling on both sides of the early coils so that the fossil is lens shaped.

Discussion.—According to Bornemann's descrip-

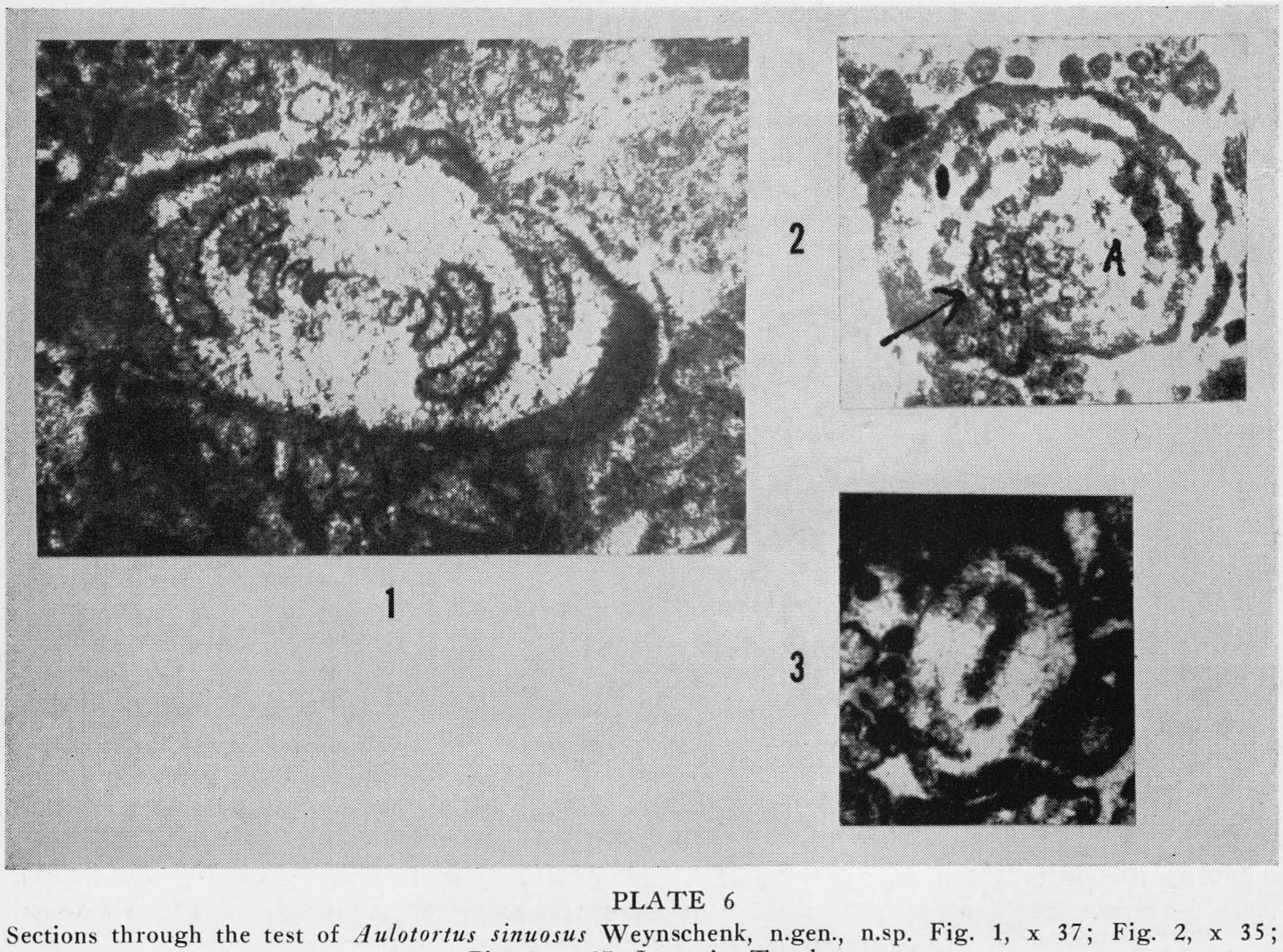

PLATE 6

Sections through the test of *Aulotortus sinuosus* Weynschenk, n.gen., n.sp. Fig. 1, x 37; Fig. 2, x 35; Fig. 3, x 27. Jurassic, Tyrol tion (1874, pp. 713-24, pl. 18, figs. 1-3. pl. 19, figs. 1-7) *Involutina liasica* (Jones) differs from *Aulotortus* in that the whorls of the latter are twisted, the early whorls tightly coiled, while later whorls are more loosely coiled. Phylogenetically *Aulotortus* may derive from *Involutina liasica* (Jones). (See also Macfadyen, pp. 17-23)

Aulotortus sinuosus Weynschenk, n.sp.

Plate 6, Figs. 1-3; Text Figs. 1, 2

1950. Genus ?, species ?, Weynschenk, Die Jura-Mikrofauna und -flora des Sonnwendgebirges (Tirol). Schlern-Schriften no. 83, Univ. Verl. Wagner, Innsbruck, pp. 15, 16, pl. 1, figs. 5, 6, 7.

1 2

TEXT FIGURES 1 AND 2

Fig. 1. The crescent-shaped sections of the last and earlier whorls (in a vertical section) show the thickenings and irregular sinuses of the wall of the tube, as well as the increase in length of the crescentic section toward the outer whorls. The openness of the coiling in these outer whorls is apparent. Details of holotype; X37 approximately. Fig. 2. A vertical section of another specimen, showing the twisted sections of the tubular chamber, and the point on the margin of the fossil, X27, approximately.

Holotype.—Thin section no. 70 in the collection of the Geologic Institute of the University of Innsbruck, Austria. (Pl. 1, fig. 5 of above reference.) Fig. 1 of present paper gives some detail of fig. 5.

Paratypes.—Thin sections nos. 185 and 102 in the collection of the Geologic Institute of the University of Innsbruck, Austria. (Pl. 1, figs. 6 and 7 of the above reference). Fig. 2 is drawn from pl. 1, fig. 7.

Type locality.—Holotype and paratypes are from chert breccia of the Sonnwend Mountains, Tyrol, Austria, the holotype from near Gassenhütte, and the paratypes from near Bettlersteig, and from the west side of Spieljoch.

Type horizon.—Middle Dogger-Upper Dogger (Jurassic).

Description—A species of the genus *Aulotortus* Weynschenk, 1955, with the following characteristics: Chamber, tubular, crescent-shaped in cross section, coiled in a plane spiral in early whorls, twisted in later whorls; test of 4 to 7 whorls. One specimen was found which showed a rather uniform wall, without thickenings of the tubular chamber except in the last adult coil, the test is smooth, but towards the middle, as is shown in fig. 2, there is a protruding point.

Dimensions.—In the original paper, the following dimensions were given. Plate 1, fig. 5, was a vertical cross section of a large adult 1.89 mm. wide, 0.98 mm. high, and the diameter of the proloculus was 0.15 mm. This figure showed the twisting of the coiled test. Figure 1 of the present paper gives some of the details of the irregularities of the wall of this specimen. Plate 1, fig. 6, was a horizontal section with a diameter of 1.2 mm. Plate 1, fig. 7, was a vertical section of another individual with a breadth of 0.67 mm. and height of 0.36 mm. Some detail of this individual is shown in fig. 2.

Ecology.—The habitat of *Aulotortus sinuosus* was in very shallow, littoral waters, in the detritus of the rocks of the adjacent shore forming the near-shore breccia now called "hornstone-breccia". Later, during very early Malm, the relatively steep shoreline shifted to the northeast, as compared to its position during the middle and upper Dogger periods. During this portion of the Dogger, coral reefs tended more and more to occur in the hornstone-breccia areas, resulting in finegrained limestones with detrital fragments. This shallow water environment with warm, oxygen-rich waters not over ten meters deep, as indicated both by the fauna and a petrologic study of the consolidated sediments, with its calcareous muds, was the favored habitat of *Aulotortus sinuosus* and of abundant Miliolidae, Textulariidae, and Lagenidae, as well as of algae.

Elsewhere in this coastal region, the first Peneroplidae and Ventrolaminidae appeared, but they preferred the finegrained bottom areas, where there was a greater circulation of the water, rather than the calcareous muds preferred by *Aulotortus*.

This study of the micropaleontology and ecology is based on the sedimentary rocks of the Sonnwend Mountains, of the Austrian Tyrol.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME VII, PART 1, JANUARY, 1956

150. *AMMOBACULITES*, MIGRANT OR RECENT INTRODUCTION TO CALIFORNIA?

GEORGE L. HARRINGTON
Stanford University

In the June, 1930, Micropaleontology Bulletin J. B. Bush published an article on the Foraminifera of Tomales Bay, California, listing seven species from the brackish waters of that bay.

In an excellent but unpublished paper on the Recent Littoral Foraminifera of the Central California Coast, dated June, 1933, Frank B. Tolman critically discussed the occurrence and synonymy of 77 species and varieties of Foraminifera some of the latter being described as new. He listed three collecting localities in Tomales Bay, finding but three species, but his stations did not include those from which Bush had obtained most of his species.

A 1953 paper by Bandy on the distribution of Recent Foraminifera off the coast of California dismisses the fauna of the brackish shallow water zone by mentioning one species, *Rotalia beccarii.*

During the past ten years the writer has collected beach and tide flat sediments along the California coast as opportunity presented. In April, 1946, a sample of mud from the edge of the tideflat, a short distance northwest of Inverness on Tomales Bay (near one of Tolman's stations), contained a number of specimens of an *Ammobaculites,* together with a single specimen of *Trochammina* and some worn *Elphidium.* This *Ammobaculites* was also found in mud from the tide flat three miles north of Eureka, California, in August, 1946. At about the same time a few specimens of this species were found in a sample dredged near the mouth of Noyo Inlet, a short distance south of Fort Bragg, California. A search through the pages describing *Ammobaculites* in the Ellis and Messina catalogue of Foraminifera led to the belief that our species might be *A. formosensis* Nakamura. In reply to a query whether our specific identification was correct, Miss Ruth Todd very kindly replied that the specimen resembled *A. exiguus* Cushman and Bronnimann, and that since no specimens of *A. formosensis* were available for direct comparison, no statement as to identity with this latter species could be made. In April, 1955 a comparison of our species with an extensive series of *A. exiguus* from the Gulf of Mexico in the collection of Dean Milow (then a graduate student at Stanford University) demonstrated that our specimens were well within the range of variation of *A. exiguus* but were usually more regular than Cushman and Bronnimann's type figure, and had up to ten chambers in the straight, uncoiled portion of the test. (The type figure of *A. formosensis* shows only five chambers in the uncoiled portion of the specimen.)

In November, 1950, *A. exiguus,* as well as a form closely resembling *A. dilatatus* Cushman and Bronniman, together with an arenaceous miliolid resembling *Quinqueloculina fusca* H. B. Brady (of Cushman, 1948, pl. 3, figs. 16 and 17) were collected from a sample of mud at the eastern end of Bolinas Bay, which lies along the same structural depression of the San Andreas fault as Tomales Bay. These three foraminiferal species which were not mentioned by Bush and Tolman, were also found in samples from the tidal mudflats northwest of Inverness on Tomales Bay in 1952 and in 1955. In June, 1955, samples from the north side of the bay, at or near Bush's collecting stations, also contained these three arenaceous Foraminifera. *A. exiguus* and *Q."fusca"* have also been found at the Palo Alto yacht harbor at the south end of San Francisco Bay. The two species of *Ammobaculites* are present in muds, rarely if at all in fine sandy sediments.

At present, the two species of *Ammobaculites* are so common in the mud of Tomales Bay that it is difficult to believe that they were present and were overlooked by Bush and Tolman. If they were absent in 1930, their presence during the recent sampling can only be accounted for by their migration or introduction. In either case a source of origin or an explanation of the manner of their introduction must be sought. One is inclined to be sceptical if it is proposed that they may have migrated attached to ships from the warm waters of the Gulf of Mexico or the Caribbean to the colder waters of the northern California coast. In discussing this with Miss Myra Keen, she pointed out that seed oysters were imported from northern Japan in the middle thirties and planted in several bays along the Pacific Coast from California northward. The "oyster farms" of Tomales Bay probably derived their oysters from this source. It is known that at least two species of mollusks (*Modiolus* sp. and *Tapes japonica*) were introduced with the oysters and are present in considerable numbers in some California bays. It appears quite possible that some Foraminifera were introduced at the same time and, finding a suitable habitat, increased rapidly.

Papers at hand on the Recent Foraminifera of northern Japan do not list any of the three species under discussion, but Supplement No. 1 of the catalogue of Japanese Tertiary smaller Foraminifera by Asano lists *Ammobaculites formosensis* Nakamura and *A. catenulatus* Cushman and McCulloch. As already pointed out, the first of these resembles somewhat *A. exiguus* and the figure of the latter in the Supplement is somewhat similar to our *A. "dilatatus"*, but without type material in hand for comparison, our species cannot be identified with any Japanese species known to us.

Since the three species of arenaceous Foraminifera from Tomales Bay were not found in the sediments of the bay in the studies by Bush and by Tolman and, so far as known, were not found elsewhere on the Pacific Coast from northern California to Puget Sound prior to 1933, it is believed to be a reasonable assumption that they were introduced with the seed oysters from Japan, about 1936 and in following years.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME VII, PART 1, JANUARY, 1956

RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

AKERS, W. H. Some planktonic Foraminifera of the American Gulf Coast and suggested correlations with the Caribbean Tertiary.—Journ. Pal., vol. 29, No. 4, July 1955, pp. 647-664, pl. 65, text figs. 1-3.—Twenty-three species (4 new), 2 subspecies, and 1 new variety, are discussed. Ranges and lower limits of certain species are concluded to be synchronous between the "Miocene" of the Gulf Coast and the "upper Oligocene" of the Caribbean.

APPLIN, ESTHER R. A biofacies of Woodbine age in southeastern Gulf Coast region.—U. S. Geol. Survey Prof. Paper 264-I, June 23, 1955, pp. 187-197, pls. 48, 49, text fig. 41 (map).—In this subsurface "Barlow fauna," a new biofacies of the lower member of the Atkinson formation, are recorded 23 species and varieties, 5 new, most of them illustrated.

ARANA, TRINIDAD DEL PAN. Algunos géneros y especies de microforaminiferos miocénicos de La Pañoleta (Sevilla).—Bol. Real Soc. Española Hist. Nat., sec. Geol., Tomo 51, Ano 1953, 1954, pp. 107-130, text figs. 1-17.

BHATIA, S. B. The foraminiferal fauna of the late Palaeogene sediments of the Isle of Wight, England.—Journ. Pal., vol. 29, No. 4, July 1955, pp. 665-693, pls. 66, 67, text figs. 1-7, tables 1-5.—Over 100 samples from 5 sections of one series of middle and two series of lower Oligocene age yielded 57 species (4 new) and 5 varieties (2 new).

BIELECKA, WANDA, and WITWICKA, EMILIA. Z Terminologia Stosowana Przy Opisie Otwornic (Foraminifera).—Przeglad Geologiczny, Zeszyt 9, Rok 1955, pp. 447-448, 20 text figs.—Illustrated definitions in Polish, English, French, and German.

CITA, M. B. Studio della microfauna contenuta in un campione di fondo raccolto dal batiscafo "Trieste" nel mare di Capri.—Atti Soc. Ital. Sci. Nat. Milano, vol. 94, fasc. 2, 1955, pp. 209-221, pl. 13.—Qualitative and quantitative analysis of a bottom sample obtained by the bathyscaphe from 85 meters.

COPELAND, MURRAY J., and KESLING, ROBERT V. A new occurrence of **Semitextularia thomasi** Miller and Carmer, 1933.—Contr. Mus. Paleo., Univ. Michigan, vol. 12, No. 7, June 15, 1955, pp. 105-112, pl. 1.—A Middle Devonian occurrence in western New York and notes on structure and systematic position of the species.

CUMMINGS, ROBERT H. **Nodosinella** Brady, 1876, and associated Upper Palezoic genera.—Micropaleontology, vol. 1, No. 3, 1955, pp. 221-238, pl. 1, text figs. 1-10.—A revision of Brady's material leading to emendations, a new family, Earlandiidae, and 3 new genera: **Earlandinella** (type species **Nodosinella cylindrica** Brady), **Earlandinita** (type species **Nodosinella perelegans** Plummer), and **Lugtonia** (type species **Nodosinella concinna** Brady). Thirteen species, 6 new, classified in 7 genera, are described and illustrated.

DROOGER, C. W., KAASSCHIETER, J. P. H., and KEY, A. J. The Microfauna of the Aquitanian-Burdigalian of southwestern France. Parts 1 and 2, General remarks and Miogypsinidae by C. W. DROOGER; Part 3, Smaller Foraminifera by J. P. H. KAASSCHIETER; and Part 4, Ostracoda by A. J. KEY.—Verhandl. Kon. Nederl. Akad. Weternschappen Natuurk., Eerste Reeks, Deel 21, No. 2, 1955, pp. 1-136, pls. 1-20, text figs. 1-11, 4 tables.—Six miogypsinids, none new are recognized. The stratigraphic interpretation of the Aquitaine basin is made on their occurrence. Evidence of their probable ecology is reviewed. In the section on smaller Foraminifera, 87 species and varieties, none new, are recorded and illustrated. The faunas indicate warm shallow water conditions, probably near a calcareous reef.

DUNNINGTON, H. V. Close zonation of Upper Cretaceous globigerinal sediments by abundance ratios of **Globotruncana** species groups.—Micropaleontology, vol. 1, no. 3, July 1955, pp. 207-219, text figs. 1-8, table 1.—In Iraq the ratio between individuals showing one peripheral keel and individuals showing two or more keels in randomly oriented thin sections is a constant for any horizon, is unaffected by facies, and varies progressively with age in a stratigraphic sequence. The ratio thus can provide a precise key to stratigraphic position.

D'YAKONOVA-SAVEL'EVA, E. N. Genezis I Stratigraficheskoe Polozhenie Krasnots-vetnoi Tolshchi Severnogo Kavkaza V Svyazi S Nakhodkoi Vysshikh Fuzulinid.—Trudy Leningrad. Obsh. Est., Otdel. Geol. Min., vol. 68, No. 2, 1951, pp. 102-149, pl. 1, text figs. 1-16, geol. sections.—Eleven species (4 new and 3 indeterminate) and one new variety are described and illustrated in an appendix by G. A. DUTKEVITCH.

EMILIANI, CESARE. The Oligocene microfaunas of the central part of the northern Apennines.—Paleontographica Italica, vol. 48 (n. ser. vol. 18), Anni 1952-53 (1954), pp. 77-184 [1-108], pls. 21-25 [1-5], text figs. 1-3, tables 1-20.—Two hundred fifty-five species (of which 17 are new, 2 have new names, and 83 are indeterminate) and 11 varieties (of which 2 are new and 2 indeterminate) are recorded from 5 localities and many are illustrated. Statistical analyses of various features of the 5 faunas are presented: number of specimens, species, etc.; predominant forms (in % of specimens); ecologic interpretation; similarity indexes; and time-space distribution.

FUJIMOTO, HARUYOSHI, and IGO, HISAYOSHI. **Hidaella**, a new genus of the Pennsylvanian fusulinids from the Fukuji district, eastern part of the Hida mountainland. central Japan.—Trans. Proc. Palaeont. Soc. Japan, n. ser., No. 18, June 20, 1955, pp. 45-48, pl. 7.—**Hidaella** (genotype **H. kameii**, n.sp.) an aberrant descendant of **Fusulinella.**

FUJITA, Y. On the foraminiferal fauna in the Fiyata formation.—Studies from the Geol. and Min. Instit., Tokyo Univ. of Education, No. 2, March 30, 1953, pp. 17-24, text fig. 1, tables, graphs, map (Japanese with English abstract).—From the small fauna a new (unnamed) variety of **Elphidium craticulatum** is described.

GANDOLFI, ROLANDO. The genus **Globotruncana** in northeastern Colombia.—Bull. Amer. Pal., vol. 36, No. 155, Sept. 13, 1955, pp. 1-118, pls. 1-10, text figs. 1-12.—This important paper describes 16 species (3 new and 1 new name and 24 subspecies (20 new), assigning them to the subgenus **Globotruncana;** and 11 species (3 new) and 11 subspecies (all new), assigning them to the subgenus **Rugoglobigerina** as slightly modified and placed under **Globotruncana.** These Colombian species are organized into 4 groups, based on morphological similarities. The groups are subdivided into 16 branches believed to constitute evolutionary lines. Range charts and evolution diagrams are included. Stratigraphic considerations in Colombia are discussed, as well as evolutionary connections between **Globigerina** and **Globotruncana.** A key for determination of subgenera, species, and subspecies is set up.

A **Globotruncana** fauna from the Pecan Gap chalk of Texas.—Micropaleontology, vol. 1, no. 3, July 1955, pp. 257-259, text figs. 1-9.—Study of apertural characteristics of **"Globorotalites,"** and possible evolutionary connections.

GEROCH, S. **Saccamminoides** n.gen. (Foraminifera) from the Eocene in the Flysch Carpathians.—Ann. Soc. Geol. Pologne, vol. 23, Annee 1953 (1955), pp. 53-63, pl. 5, text figs. 1a, b.—**Saccamminoides** (genotype **S. carpathicus,** n.sp.) in the Saccamminidae from the lower Eocene Flysch.

HAGN, HERBERT. Geologisch-paläontologische Untersuchungen im Helvetikum und Flysch des Gebietes von Neubeuern am Inn (Oberbayern).—Geol. Bavarica, No. 22, 1954, pp. 1-136, text figs. 1-26, geol. map.—A few Foraminifera are illustrated in thin section and numerous species listed.

Paläontologische Untersuchungen am Bohrgut der Bohrungen Ortenburg CF1001, 1002 und 1003 in Niederbayern.—Z. deutsch. geol. Ges., Jahrg. 1953, Band 105, Teil 3, 1955, pp. 324-359, pl. 10, text figs. 1-4.—The wells penetrate strata from Helvetian to Santonian and many species are listed from the various levels. A few Foraminifera, 1 new, are described and illustrated from some of the Tertiary beds.

HILTERMANN, HEINRICH, and KOCH, WILHELM. Biostratigraphie der Grenzschichten Maastricht/Campan in Lüneburg und in der Bohrung Brunhilde, 2 Teil: Foraminiferen.—Geol. Jb., Band 70, Aug. 1955, pp. 357-383, pls. 27-29, text figs. 5-7. —Species of **Bolivinoides** and **Neoflabellina** are the chief fossils used in zoning these beds.

ISOMI, H. The Carboniferous and Permian formations and fusulinid fossils found in the area of upper reaches of the River Hino, Fukui Prefecture.—Bull. Geol. Survey Japan, vol. 6, No. 1, Jan. 1955, pp. 19-22, text fig. 1 (geol. map).—Fusulinids listed from Pennsylvanian and Permian.

KANTOR, VIERA, and KANTOR, JAN. Beitrag zur kenntnis der Markasitvererzung bei Teplicany nördlich von Kaschau.—Geol. Sbornik Slovak. Akad. Wissen., Jahrg. 6, heft 1-2, 1955, pp. 81-103, pls. 10-13, distrib. chart 3 (German summary, pp. 99-103).—Helvetian fauna recorded in well material.

KLINGLER, WOLFGANG. Mikrofaunistische und stratigraphisch-fazielle Untersuchungen im Kimmeridge und Portland des Weser-Aller-Gebietes.—Geol. Jb., Band 70, Jan. 1955, pp. 167-246, pls. 6-22, text figs. 1-7.—In this ostracod paper, one foraminifer, **Valvulina meentzeni** n.sp., is described from the lower middle Kimmeridgian.

KNIPSCHEER, H. C. G., and MARTIN, G. P. R. Eine neue Art der Gattung **Bolivinoides, Bolivinoides concinna,** n.sp., aus dem Helvet der süddeutschen Molasse.—Geol. Jb., Band 70, Aug. 1955, pp. 261-263, text figs. 1a-g.

LISZKA, S. Foraminifera of the Lower Senonian in the vicinity of Cracow.—Ann. Soc. Géol. Pologne, vol. 23, Année 1953 (1955), pp. 165-190, pls. 12, 13, distrib. tables.—Forty-nine species and varieties, none new, are recorded and a few of them illustrated.

LUCZKOWSKA, E. Tortonian Foraminifera from the Chodenice and Grabowiec beds in the vicinity of Bochnia.—Ann. Soc. Géol. Pologne, vol. 23, Année 1953 (1955), pp. 77-156, pls. 6-10, text figs. 1-4, distrib. table.—Forty-three species (6 new) and 9 varieties (3 new) are described and illustrated.

MATSUNAGA, TAKASHI. **Spirosigmoilinella,** a new foraminiferal genus from the Miocene of Japan.—Trans. Proc. Palaeont. Soc. Japan, n.ser., No. 18, June 20, 1955, pp. 49, 50, text figs. 1, 2.—**Spirosigmoilinella** (genotype **S. compressa,** n.sp.) of the Silicinidae.

MAYNC, WOLF. On some erroneous or questionable determinations of **Choffatella.**—Micropaleontology, vol. 1, no. 3, July 1955, pp. 269-272.—Four examples of erroneous identifications, plus additional pertinent comments.

MOORE, D. G. Rate of deposition shown by relative abundance of Foraminifera.—Bull. Amer. Assoc. Petr. Geol., vol. 39, No. 8, Aug. 1955, pp. 1594-1600, text figs. 1-4.—Assuming constant production of Foraminifera, rate of deposition is inversely proportional to percentage of Foraminifera. Six long cores from San Antonio Bay, Texas, with levels dated by Carbon-14, show deposition ratio between 0.2 and 4.7 feet per century with a maximum at 6900 years ago.

MORIKAWA, S., and KAWADA, S. Fusilinidae from the Maemonkura Valley, west of Chichibu Mine.—Bull. Chichibu Mus. Nat. Hist., No. 3, March 1953, pp. 61-64, 2 text figs. (maps). (Japanese with English abstract).—A few species indicating lowermost Permian.

NAGAHAMA, H., and SUZUKI, T. On the Foraminifera from the Karatsu and the Sasebo Coal Fields in Kyushu.—Bull. Geol. Survey Japan, vol. 6, No. 1, Jan. 1955, pp. 69-72, text fig. 1 (geol. map).—Smaller Foraminifera are listed, including 5 new names (nomina nuda).

NAKKADY, S. E. The stratigraphical implication of the accelerated tempo of evolution in the Mesozoic-Cenozoic transition of Egypt.—Journ. Pal., vol. 29, No. 4, July 1955, pp. 702-706, text figs. 1-5. —Numerous examples of evolution from species to species, and even across family and generic lines, are listed and illustrated.

OBRADOVIC, SULTANA. Kurzer Rückblick auf die Schichten eines teils der bohrung Velika Greda 21 auf grund mikropalaontologischer untersuchungen.—Yugoslavia Geol. Instit. "Jovan Zujovic," Belgrade, Zbornik radova, vol. 7, 1954, pp. 229-234 (pp. 232-234 German summary), pl. 1.

PHLEGER, FRED B. Ecology of Foraminifera in southeastern Mississippi Delta area.—Bull. Amer. Assoc. Petr. Geol., vol. 39, No. 5, May 1955, pp. 712-752, text figs. 1-40 (distrib. maps), tables 1-11.—Living and total populations are calculated for facies from marsh to offshore. About 40 species are involved.

POKORNY, VLADIMIR. **Cassigerinella boudecensis,** n.gen., n.sp. (Foraminifera, Protozoa) from the Oligocene of the Zdanice Flysch.—Vestnik UUG, roc. 30, 1955, pp. 136-140, text figs. 1-3.—A globigerinid with cassiduline chamber arrangement, probably originated from **Globigerinella.**

REDMOND, C. D. A new **Siphogenerinoides** from the Coniacian of Colombia.—Micropaleontology, vol. 1, no. 3, July 1955, pp. 247-249, text figs. 1-5.—**S. bentonstonei,** n.sp., the oldest known species of the genus, showing primitive characteristics.

SANDER, N. J. An apparatus for photographing Foraminifera and other small objects.—Micropaleontology, vol. 1, no. 3, July 1955, pp. 251-256, pl. 1, text figs. 1, 2.

SMOUT, ALAN H. Reclassification of the Rotaliidae (Foraminifera) and two new Cretaceous forms resembling **Elphidium.**—Journ. Washington Acad. Sci., vol. 45, No. 7, July 1955, pp. 201-210, text figs. 1-10, chart.—**Fissoelphidium,** n.gen. (type species **F. operculiferum,** n.sp.) and **Pseudosiderolites,** n.gen. (type species **Siderolites vidali** Douvillé, 1907) both in the Miscellaneidae. **Elphidiella** is also included in the Miscellaneidae and a new Maestrichtian species of it described. Probable phyllogeny and family characteristics of the nine families of the superfamily Rotaliidea are discussed.

TAPPAN, HELEN. Foraminifera from the Arctic slope of Alaska, Part 2, Jurassic Foraminifera.—U. S. Geol. Survey Prof. Paper 236-B, June 29, 1955, pp. 21-90, pls. 6-28, text figs. 3-9, chart 1.—**This** important paper, including the first Liassic Foraminifera discovered in the Western Hemisphere, describes and illustrates 111 species, of which 35 are new, 5 are given new names, and 4 are indeterminate. Correlations with European Jurassic strata are discussed.

TINOCO, IVAN DE MEDEIROS. Nota sobre a microfauna do Calcareo Cretaceo da Ilha de Itamaraca, Estado de Pernambuco.—Div. Geol. Min., Rio de Janeiro, Notas Prelim. Estudos, No. 91, 1955, pp. 1-12, pls. 1-3.—Fourteen species, all but one indeterminate, are described and illustrated.

TOMIC-DZODZO, RADOJKA. Microfauna from well-drilling Ce 1—Sumecani.—Yugoslavia Geol. Instit. "Jovan Zujovic," Belgrade, Zbornik radova, vol. 7, 1954, pp. 201-227 (pp. 226-227 English summary), pls. 1-4.—About 49 Foraminifera, none new, are recorded from Tortonian and Sarmatian strata.

TOMIC-DZODZO, R., and VELJKOVIC-ZAJEC, K. Paleontoloshki Prikaz Mikrofaune, in Le Composé Géologique et la strukture tectonique d'une partie de Ovce Pole et de Tikves avec documentation paléontologique.—Bull. Instit. Geol. Republique Macedonienne, fasc. 4, 1954, pp. 71-90 [Pt. I, Foraminifera], pls. 1-12.—Forty-seven species, none new, are discussed and most of them illustrated.

VASICEK, MILOSLAV. Vyznam Foraminifer ve vede a v praxi.—Casopis, Narodniho Musea, Roc. 120, cislo 2, 1951 (1952), pp. 138-147, text figs. 1, 2.

VASSILENKO, V. P. Anomalinidae, in Fossil Foraminifera of USSR. (in Russian)—Neftianoi geologo-razvedochnyi institut, Leningrad, Trudy, n.s., vyp. 80, 1954, pp. 1-282, pls. 1-36, text figs. 1-42, table 1.—About 151 species, subspecies, varieties, and new names are included and illustrated. Stratigraphic ranges for each are indicated on a chart. The Anomalinidae are classified in 3 genera and 8 subgenera as follows: **Anomalina** subgenera: **Anomalina,** 23 **species** (3 new and 2 new names) and 2 varieties (1 new); **Gavelinella,** 7 species (1 new) and 3 subspecies (2 new); and **Pseudovalvulineria,** 23 species (3 new and 1 new name) and 10 subspecies and varieties (4 new). **Cibicides** subgenera: **Cibicides,** 13 species (2 new) and 9 subspecies and varieties (3 new); **Anomalinoides,** 9 species (6 new) and 2 subspecies (1 new); **Cibicidoides,** 34 species (9 new) and 4 varieties (1 new); **Gemellides** n. subgenus (type **G. orcinus** n.sp.), 10 species (3 new); and **Planulina,** 1 species. **Karreria,** 1 species. Many of the new specific, subspecific and varietal names are credited to 14 additional authors besides VASSILENKO, particularly MJATLIUK, BYKOVA, MOROSOVA, and AISENSTAT.

VELJKOVIC-ZAJEC, KATARINA. A contribution to the knowledge of mikrofauna from the village Zubetinac (East Serbia).—Yugoslavia Geol. Instit. "Jovan Zujovic," Belgrade, Zbornik radova, vol. 7, 1954, pp. 247-257 (pp. 255-257 English summary), pls. 1-3.—Sixteen Foraminifera, none new, were recorded and most of them illustrated from Upper Cretaceous (Senonian?) strata.

VILLA, FLORIANO. Studi stratigrafici sul terziario subalpino lombardo. Nota IV, Gli affioramenti terziari a sud del lago di Varese.—Riv. Ital. Pal. Stratig., vol. 61, No. 2, 155, pp. 2-28, pls. 8-10, text figs. 1, 2.—Eocene and Oligocene faunas.

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