# CONTRIBUTIONS
# FROM THE
# CUSHMAN FOUNDATION
# FOR
# FORAMINIFERAL RESEARCH

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## Contents

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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# 210. PLANKTONIC FORAMINIFERA IN THE DANIAN OF DENMARK

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## ABSTRACT

Planktonic Foraminifera, since they form 50-100% of the total foraminiferal populations, indicate that the type Danian of Denmark is a deep-sea sediment. Globigerines, especially **G. daubjergensis** Brönnimann, **G. pseudobulloides** Plummer and **G. triloculinoides** Plummer, show distinct orthogenetic changes during Danian time. These orthogenetic developments can be checked by the orthogenetic increase of pore diameters of **Gavelinopsis involuta** Reuss. The total gradual change in the whole planktonic assemblage, including **Guembelina, Stainforthia (Chiloguembelina)** and **Guembelitria,** during the Danian stage is also striking. At the boundary between Wind's zones III and IV, discontinuities in the orthogenetic changes were distinguished and lead to the conclusion that shifting of the deep-sea bottom took place. A short analysis of **Chiloguembelina** shows that it should be incorporated in the genus **Stainforthia** (Hofker, 1956c). The same stages of development of **Globigerina daubjergensis** and **G. pseudobulloides** in the Maestrichtian Chalk Tuff and during the Danian of Denmark show that the type Maestrichtian of Dumont can be correlated with the Danian of Denmark.

The samples used are stored at the Geologisch Bureau, Heerlen, Holland; the faunas and species described are stored in the foraminiferal collections of the Geologische Dienst (Geological Survey) at Haarlem, Holland.

## INTRODUCTION

After the finding of planktonic Foraminifera (globigerines) in a sample of the coral limestone of Faxe by Reichel (1953) and the short description of some globigerines found in two samples from Daubjerg and from Hjerm by Brönnimann (1953), Troelsen (1957) gave an account of some planktonic Foraminifera of the type Danian. He found that in the various zones of the Danian planktonic globigerines are distributed in varying frequencies (Troelsen, 1957, p. 127, fig. 24) so that there is already an indication that the different species (*G. daubjergensis* Brönnimann, *G. pseudobulloides* Plummer, *G. triloculinoides* Plummer, *G. compressa* Plummer) have developed independently during the Danian.

The author sampled many outcrops of the Danian in Denmark, covering all the zones. By using a new method of washing (decanting the floating foam of each sample) nearly all the samples from Jutland and Seeland yielded large quantities of planktonic specimens contrarily to what was found by Troelsen (1957, p. 126). Thus, in all the Danian zones and at most localities, the planktonic Foraminifera form 50-90% of the total foraminiferal population. Moreover, the benthonic Foraminifera give the impression that the Danian sea of Denmark was a deep one, which is contrary to what has been believed hitherto, since many species and genera occur which are typical of deep water (1000 m. or more). The ostracod fauna strengthens this view since such genera as *Bythocypris, Bythoceratina, Bythocythere, Cytheropteron,* and many others which are typical of deep water (Van Morkhoven, personal communication) are found. The only coral found, *Corallium becksi,* is very close to *C. rubrum* from the Mediterranean, also a deep-sea species. The high frequencies of the planktonic populations point to the presence of a deep and open sea. Often ½ kg. of raw material yields more than 10,000 globigerines.

Troelsen (*loc. cit.*) and Loeblich and Tappan (1957a, 1957b) are of the opinion that the type Danian must be "lower Paleocene" on the basis of the planktonic Foraminifera since they believe that the Danian contains an assemblage typical of that part of the Paleocene. However, they did not compare the different horizons of the Danian with other known Paleocene horizons nor did they observe the striking fact that in the various horizons of the Danian the constituents of the faunas were not the same except that Troelsen (*loc. cit.*) showed that *G. triloculinoides* and *G. compressa* occurred only in the upper horizons. Much more striking and significant is the fact that the species already mentioned, together with *Guembelina, Guembelitria* and *Chiloguembelina,* not only are not constantly present in the horizons but that several of them also gradually change in character so that a single biologic unit can be found in three or even four successive stages of development, known as different species during the Danian. They may even pass through different generic stages as well. These orthogenetic changes at once show that the Danian stage was not as short as was suggested by Loeblich and Tappan. This is further emphasized by the fact that only at the end of the Danian can be found stages of development which seem to be more or less identical with Midway species.

I will now give a brief description of the development stages which were found in the samples of different zones of the Danian. These zonations have been given by Odum (1926) and Wind (1953). These are based on macrofossils such as echinids and brachiopods but, since species can be induced by changes in the surrounding sea, a chronology based on orthogenetic changes, especially of planktonic organisms, is always to be preferred. This is because we are independent of benthonic guide fossils as such (see especially Table 1).

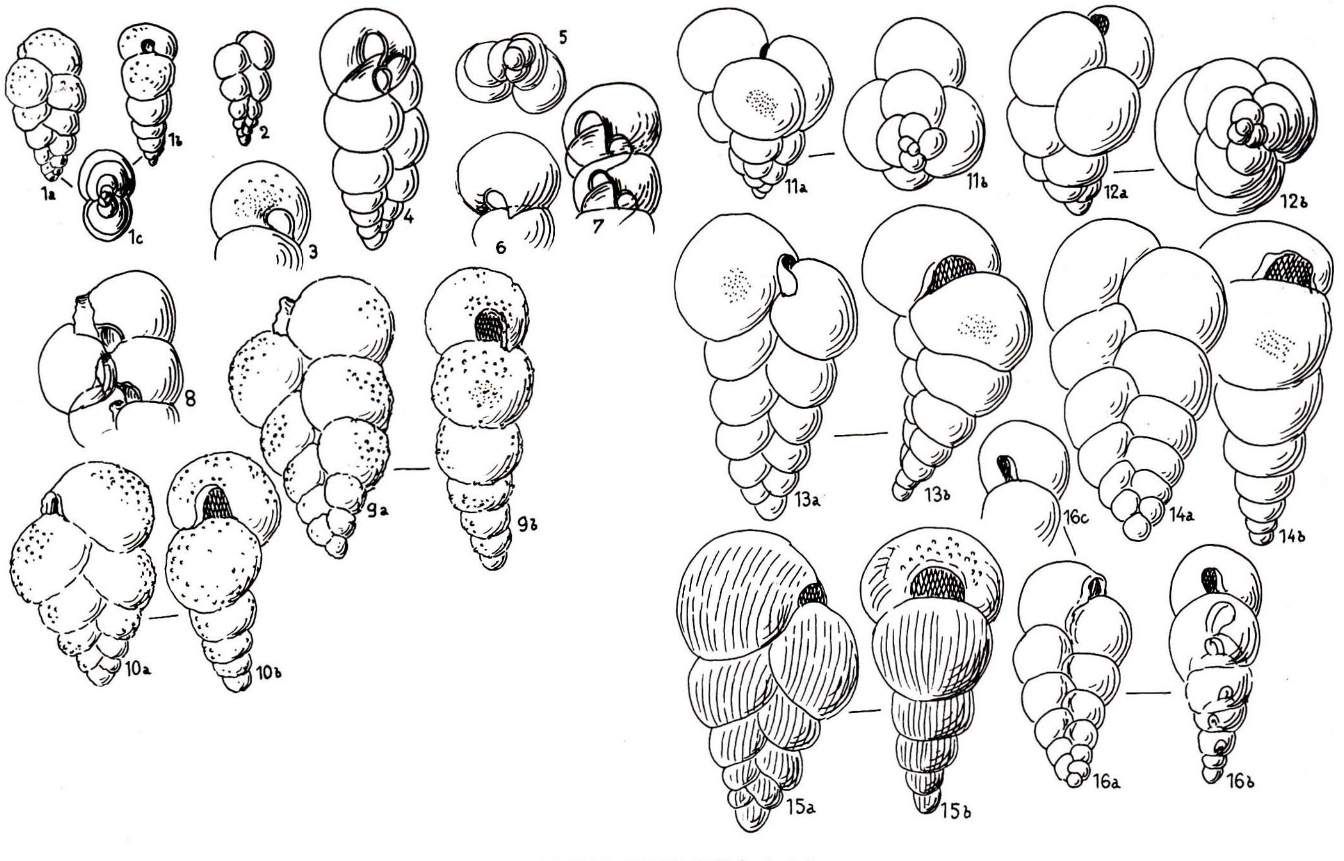
### *GLOBIGERINA DAUBJERGENSIS* BRÖNNIMANN GENS

Text figures 29-34

In the lowest part of the Danian, resting on the typical zone (called the "Fiskeler") between the Skrivekridt (uppermost Maestrichtian, *Pseudotextularia* zone) and the Danian up into the lowest Paleocene (greensand covering the white Danian), we find a group of forms characterized by a more or less spinose outer wall (in which the spines, in most cases observed, are separated from one another), very fine, densely placed pores (often hardly visible), a more or less highly trochoid spire beginning with a rather large (for planktonic Foraminifera) proloculus, nearly globular chambers which increase rapidly in size, and a final whorl with 3 or 4 large globular chambers. The aperture, situated at the usually closed ventral umbilicus, is rounded and peculiarly small.

The gens begins in the uppermost white chalk below the Danian with very small specimens, mostly with 3 chambers in the last-formed whorl. Gradually during the Danian the test diameters increase; beginning with the appearance of tests with larger diameters (0.06-0.12 mm.) the gens has the species characteristics which caused Brönnimann (1953) to distinguish several "species," such as *G. primitiva* Finlay and *G. linaperta* Finlay (see Table 4).

In the middle Danian continued orthogenesis results



TEXT FIGURES 1-16

Figs. 1-10, *Stainforthia* (*Chiloguembelina*) *morsei* (Kline); Hofker sample 1003, lower upper Danian, Helligkilde Quarry. 1, × 57. 2, much smoother specimen, × 57. 3, apertural face showing the loop-shaped aperture; × 160. 4, specimen from ad-apertural face, in oil; the last-formed chamber is seen within, from behind, to show the part of the border of the aperture which, in reality, is a reduced toothplate attached to the border of the aperture of the previous chamber; × 160. 5, as in 1c, an individual is seen from its initial end, which is "twisted" and triserial (not observed by Beckmann, 1957); × 160. 6, aperture loop-shaped; × 160. 7, specimen in edge view, with transparent chamber walls, showing the alternation of the position of the apertures, as in *Bolivina* and *Stainforthia;* × 160. 8, transparent specimen, from the side, with the alternating toothplates visible from within; × 160. 9, specimen from two sides, × 160. 10, a smaller specimen, × 160.

Figs. 11, 12, *Guembelitria mauriciana* (Howe and Roberts), × 160. 11, Vigsö-Bjerre, sample 971; a, side view, b, initial end. 12, Stevns Klint, sample 1053; a, side view, b, initial end.

Figs. 13, 14, *Stainforthia* (*Chiloguembelina*) *midwayensis* (Cushman), × 160. 13, Stevns Klint, sample 1053, zone I; from two sides, a twisted specimen. 14, Stevns Klint, sample 1055, zone II; from two sides.

Figs. 15, *Guembelina wilcoxensis* Cushman and Ponton, × 160. Stevns Klint, sample 1055, zone II; the apertural face shows typical pustules around the aperture.

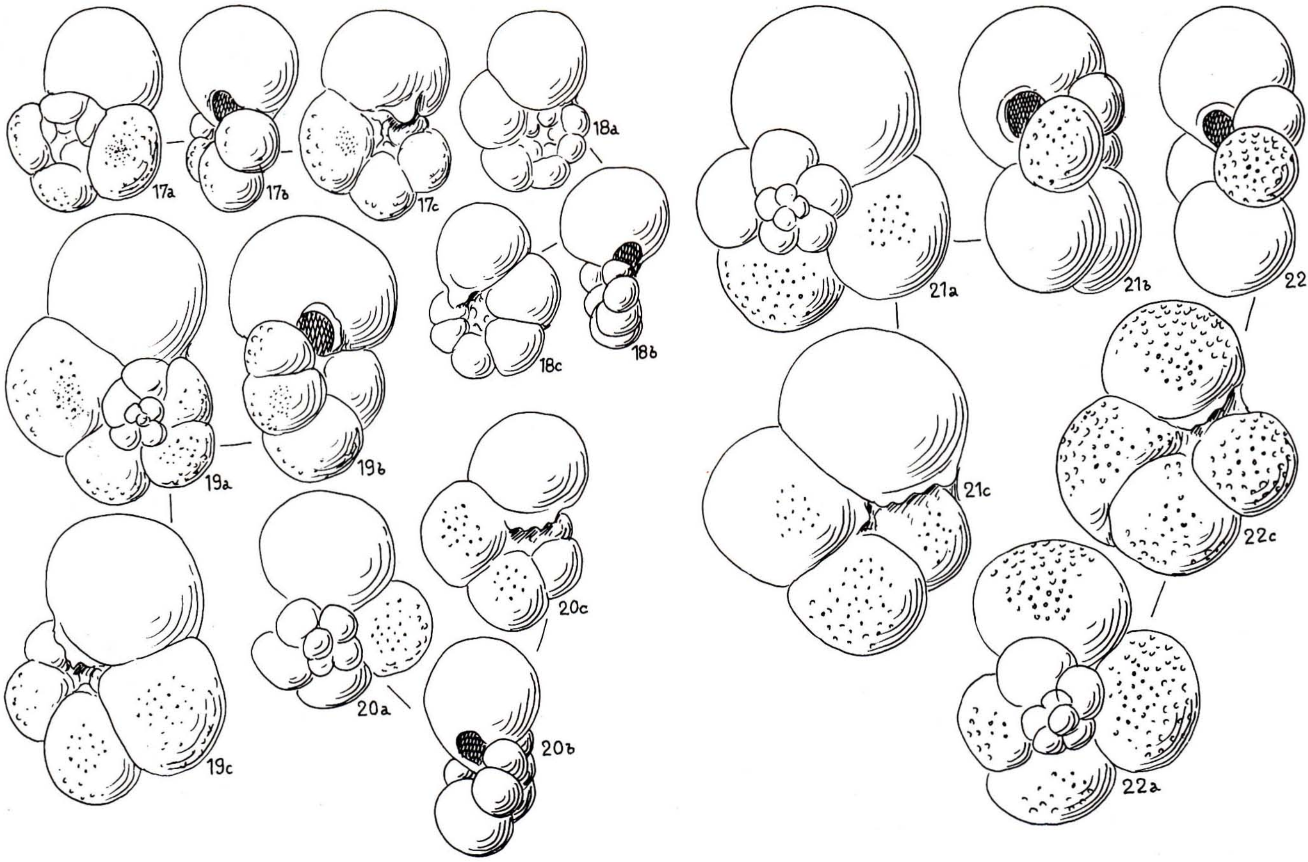
Fig. 16, *Stainforthia* (*Chiloguembelina*) *parallela* Beckmann, × 160. Sevel Chalk Works, Sample 1020; zone III or lower IV; a, side view, b, edge view with alternating foramina and toothplates drawn in, c, aperture of another specimen.

in forms with larger diameters (0.09-0.16 mm.) averaging 0.12-0.13 mm. At this level, for the first time, tiny openings appear in the wall of the last-formed chambers when these chambers are large enough to surround two chambers of the previous whorl. These openings appear just at the junction of the suture between these two chambers of the previous whorl and the spiral suture of the outer one. They gave Loeblich and Tappan (1957b, p. 184) cause to place the species in the genus *Globigerinoides* although a comparison with the type species of *Globigerinoides* shows that the location of these small openings in *Globigerina daubjergensis* differs from that of the secondary apertures of *"Globigerinoides."* Moreover, it is unlikely that a single species would slip from one genus into another gradually.

In the upper Danian the forms continue to increase in size and the occurrence of the dorsal openings becomes more and more frequent. In the uppermost Danian the average diameter reaches 0.19 mm., with variants from 0.12-0.27 mm. Moreover, in the highest levels and in the Paleocene just above (greensands) a third characteristic develops: the last-formed chambers become very voluminous, many of them covering the whole umbilical region and the visible aperture (*Catapsydrax* character). In addition, the density of the spinose projections diminishes on the walls of the last-formed chambers so that they are only detectable with high magnifications; with lower magnification the chambers seem very smooth.

In this *G. daubjergensis* gens we observe, especially in the later development stages, many specimens which would be identified as *G. chascanona* Loeblich and Tappan (1957b, pl. 49, figs. 4, 5) from the Hornerstown formation and *"Catapsydrax" echinatus* Bolli (1957, pl. 37, figs. 2-5) from the Navet formation of Trinidad. This may be observed from an examination of the figures of these species.

The continuous changes in the characteristics of *G. daubjergensis,* especially in the diameter of the test, enable us to use them as tools in working out the detailed stratigraphy of the Danian stage, since it was found that in quite different lithological facies the change in this planktonic organism continues without



TEXT FIGURES 17-22

All figures × 160; a, dorsal side, b, apertural face, c, ventral side.

Figs. 17-20, 22, *Globigerina pseudobulloides* Plummer. 17, 18, Vigsö-Bjerre, sample 971, zone I; the specimens are nearly planispirally built, the pores fine, and small pustules cover the surface. 19, Stevns Klint, sample 1053, zone I; this specimen already shows a more advanced stage, the pores are larger and more distinct, with pustules between. 20, Stevns Klint, sample 1055. zone II; specimens show a more trochoid test. 22, Skillingbro, sample 947, zone III; here the first forms with "pitted" surface appear; the pores are larger yet no real honeycomb structure is formed.

Fig. 21, *Globigerina triloculinoides* Plummer. Stevens Klint, sample 1053, zone I; specimen which stands between this species and *G. pseudobulloides;* pores are more distinct, pustules are lacking; it is the form with 4-5 chambers in the last-formed whorl.

interruption. We find large quantities of this species in calcilutite, bryozoan chalk, fine coccolithic chalks, glauconitic chalks and greensands. They are, as planktonic forms, undisturbed by bottom conditions; even at those levels which are considered by some authors to be transgression formations, the quantity of these tiny planktonic tests does not decrease, apparently indicating that these layers of boulders are not true transgressional zones but have been laid down in a continuously deeper sea (which also is indicated by the amount of coccolithophorids).

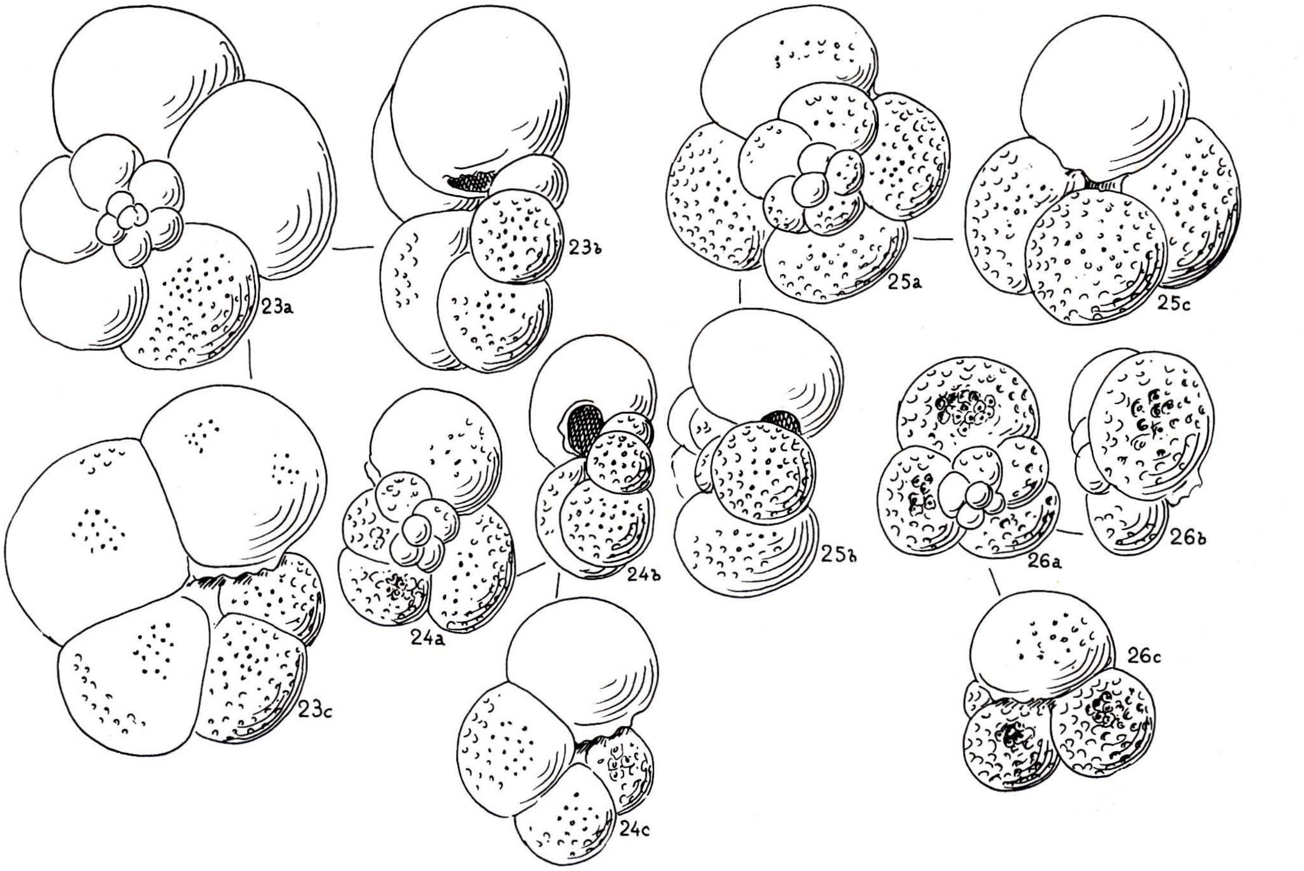
Forms of *G. daubjergensis* without dorsal openings have been figured by Loeblich and Tappan (1957b) from the Pine Barren and McBryde formations in North America; these may be of lower Danian age. Forms such as *G. chascanona* and *"Catapsydrax" echinatus* (which may be merely forms of *Globigerina daubjergensis*) are described from much higher Paleocene levels of North America. These species are found abundantly in the highest levels of the type Danian so that the American formations containing them might be correlated with the uppermost part of the Danian. But one also might suppose that these forms occurred earlier than these American formations and that they are not characteristic of these particular formations or else that they are similar development stages of other species.

## *GLOBIGERINA TRILOCULINOIDES* PLUMMER GENS

Text figures 21, 24-28

In Wind's zone II, or Odum's zone B, we find large specimens usually with 4-5 chambers in the last-formed whorl. These chambers are very globular and cover large parts of both sides of the tests, thus, giving them the appearance of *"Globigerinella."* The aperture, near the strongly rounded periphery, is crescent-shaped, often widely opened, mostly at one side (ventral), and provided with a distinct rim. The thin wall is very smoothly finished and shows distinct pores which are more or less scattered over the surface.

This form might be taken for a large and aberrant *Globigerina pseudobulloides* and may be identical with *Globorotalia pseudobulloides* trans. *G. uncinata* Bolli (1957, pl. 17, figs. 16-18) from the lower Lizard Springs formation of Trinidad.



TEXT FIGURES 23-26

All figures × 160; a, dorsal side, b, apertural face, c, ventral side.

Fig. 23, *Globigerina pseudobulloides* Plummer. Hvallöse, sample 863, zone IV; though the surface is largely "pitted," the ridges between the pores never fuse to give rise to the honeycomb structure as found in the Midway of Plummer's localities.

Figs. 24-26, *Globigerina triloculinoides* Plummer. 24, Rigstrup, sample 871, zone III; here the first traces of a real honeycomb structure go hand in hand with a decrease to four chambers in the final whorl. 25, Skillingbro, sample 944, zone II; test with 4-5 chambers in the last-formed whorl and a pitted wall structure. 26, Helligkilde, sample 1004, zone IV; small test with distinct honeycomb structure and 3 chambers in the last-formed whorl.

Gradually during the middle Danian of Denmark this form changes. Already in the upper part of zone II and frequently in zone III (zone C) we find specimens which show a more and more trochoidal test, always with four chambers in the last-formed whorl. These chambers are highly globular and an increasing number of ridges appear on the surface surrounding the distinctly placed pores so that in the end the test wall has a true honeycomb structure. In zone IV (zone D) the chambers become so large that at the end of the development range only 3 chambers can find place in the final whorl, thus, giving rise to that form which occurs so commonly and typically in the Midway formation of Texas, described by Plummer (1926) as *G. triloculinoides.* In the uppermost Danian this form is much rarer than *G. daubjergensis.* It is commonest in some levels of zone IV where it may form the bulk of the planktonic fauna.

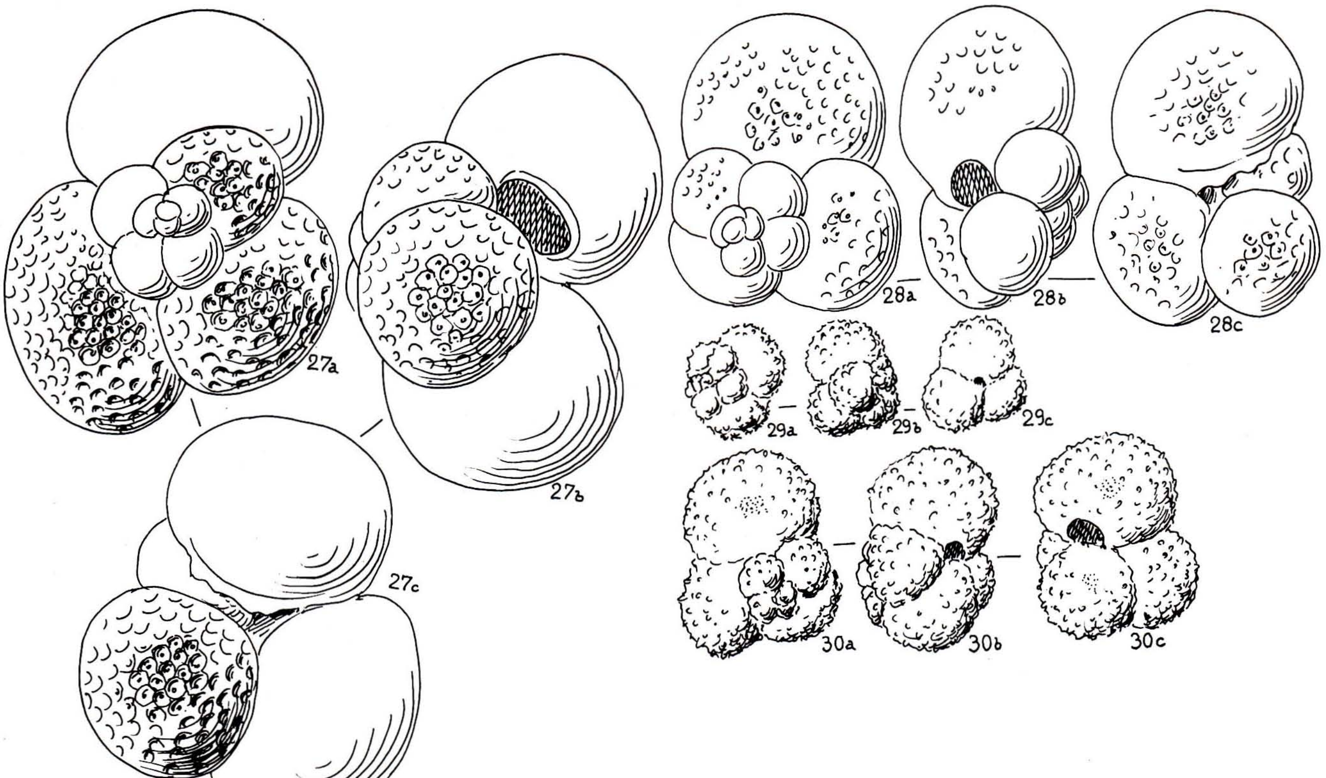
The honeycomb structure of the test wall, though typical of the later stages of development, is not typical for the gens as a whole but develops gradually. Moreover, the number of chambers in the last-formed whorl diminishes during that development from 5 towards 3. Yet these changes cannot be put into distinct "measurements" and thus only can be used in addition to the measurable diameter of *G. daubjergensis*:

| *G. daubjergensis* average diameters | *G. triloculinoides* |
|---|---|
| 0.06-0.11 mm. | 5 chambers, surface smooth |
| 0.12-0.13 mm. | 5/4 chambers, traces of honeycomb |
| 0.14-0.19 mm. | 3 chambers, distinct honeycomb |

## *GLOBIGERINA PSEUDOBULLOIDES* PLUMMER GENS

Text figures 17-20, 22, 23, 36-38

This gens is already present in the lowest Danian (Wind's zone I, Odum's zone A) and in the uppermost white chalk beneath the Danian. Here it consists of small specimens having a very flat, more or less trochoidal to nearly planispiral test, usually 5 chambers in the last-formed whorl, and very fine pores with small knobs between them. The aperture usually has the typical flap or rim at its ventral side and protrudes slightly over the umbilical hollow. In the next zone the tests may be somewhat larger but show the typical structure of the wall described above. In the middle Danian the species is not common and begins to de-



TEXT FIGURES 27-30

All figures × 160; a, dorsal side, b, apertural face, c, ventral side.

Figs. 27, 28, *Globigerina triloculinoides* Plummer. 27, Helligkilde, sample 1004, zone IV; large specimen with distinct honeycomb structure and 3 chambers in the last-formed whorl. 28, Daubjerg, sample 1022, zone III-IV. The test shows 3-4 chambers in the last-formed whorl and the beginning of honeycomb structure.

Figs. 29, 30, *Globigerina daubjergensis* Brönnimann. 29, Vigsö-Bjerre, sample 971, zone I; specimen in the *linaperta* stage, without dorsal openings. 30, Stevns Klint, sample 1053, zone II; already a larger specimen.

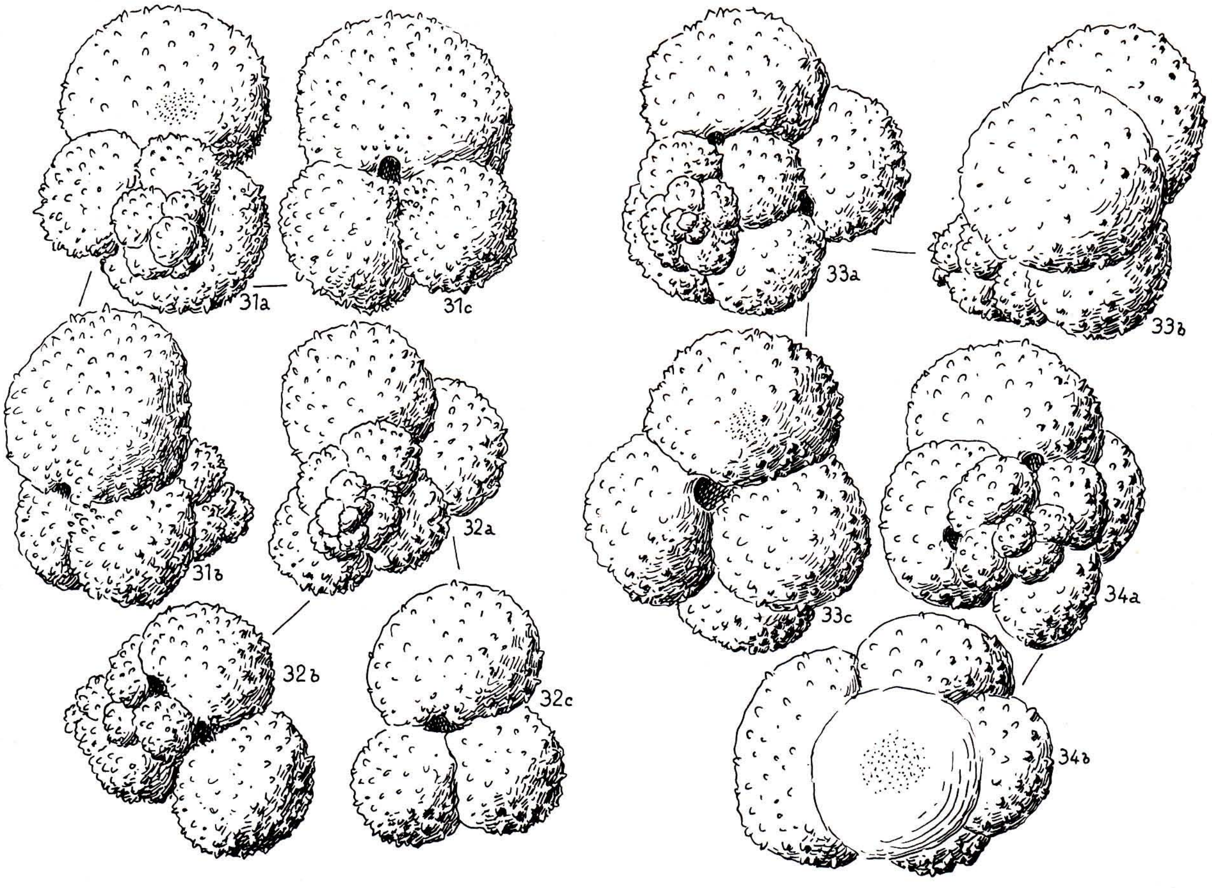
velop larger pores or, more precisely, pores ending in narrow pits on the surface with small pustules between, especially on the ventral side of the earlier chambers. In the upper Danian the gens becomes more and more rare and here the wall has the typical honeycomb structure with the pits close together and also visible on the dorsal side of the test. The tests are no larger than those of the middle Danian. A real honeycomb structure such as is found at the type locality of the species, the Midway formation of Texas, is not found in the uppermost part of the Danian, in Denmark, but in the Paleocene above (especially typical in the Montian clays above the greensand).

*G. pseudobulloides* is the only species which also is found in the clay layers above the greensands as they occur at Hvallöse. In sample 841, Egsmark, where a very typical Paleocene fauna was found in the clay, a form was abundant which is identical with *G. pseudobulloides* of the Midway formation (Plummer station 174-T-27). Here the honeycomb structure is found in all chamber walls and is very typical. So this species, beginning in the uppermost white chalk (Skrivekridt) with knobs between the fine pores, gradually changes its wall structure through the Danian from a pitted one towards a strongly honeycombed one in the Paleocene clays above the greensand, indicating that those clays are of the same age as the Midway Paleocene. Table 5 gives this orthogenesis of the wall structure for *G. pseudobulloides* through the sequence of zones.

### *GLOBIGERINA COMPRESSA* PLUMMER

Text figure 35

This form is found only in the upper part of the Danian. There is a strong belief that the species developed at this time from one of the earlier forms of *G. pseudobulloides*. The number of chambers is still 5 in the last-formed whorl; the pores are fine; the test wall is completely smooth, without pustules such as are found in *G. pseudobulloides;* the rims of the apertures are absent or only slightly developed. Fine pores also are found at the somewhat compressed periphery so that there can be no reason to call this species a *Globorotalia,* since the type of that genus has a dis-



TEXT FIGURES 31-34

All figures × 160; a, dorsal side, b, apertural face, c, ventral side.

*Globigerina daubjergensis* Brönnimann. 31, Skillingbro, sample 947, zone III; specimen without dorsal openings but having the high spire which is typical of specimens of *G. chascanona* Loeblich and Tappan. 32, Daubjerg, sample 1022; zone III-IV; such specimens were very common here; they show the *chascanona* characters, together with the first small dorsal openings typical of real *daubjergensis;* the species was first described from this locality. 33, Hvallöse, sample 863, zone IV; typical specimen with distinct dorsal openings. 34, Hvallöse, sample 861; the latest stage of development, in which *"Catapsydrax"* closing chambers are formed over the umbilical hollow; dorsal openings are present; the specimens strongly resemble *"Catapsydrax" echinatus* Bolli; such forms also occur in the lower Paleocene of Holland.

tinctly poreless and sharp periphery. *Globigerina compressa* was not found in any of the numerous samples of lower and middle Danian analyzed; it seems to appear in the upper part of the Danian (Wind's zone IV, Odum's zone D).

### *GUEMBELINA WILCOXENSIS*
### CUSHMAN AND PONTON

Text figure 15

A very typical species of *Guembelina,* having fine but distinct, rounded costae on the entire wall of each chamber, a wide crescent-shaped aperture with a distinct border, and fine pustules on the apertural face of the last-formed chamber, may be identical with Cushman and Ponton's species. It is found in the lower and (rarely) middle Danian and may have been reworked from the underlying upper Maestrichtian since similar forms occur in the Danish upper Skrivekridt. It is almost identical to *G. striata* Ehrenberg.

### *GUEMBELITRIA MAURICIANA*
### (HOWE AND ROBERTS)

Text figures 11, 12

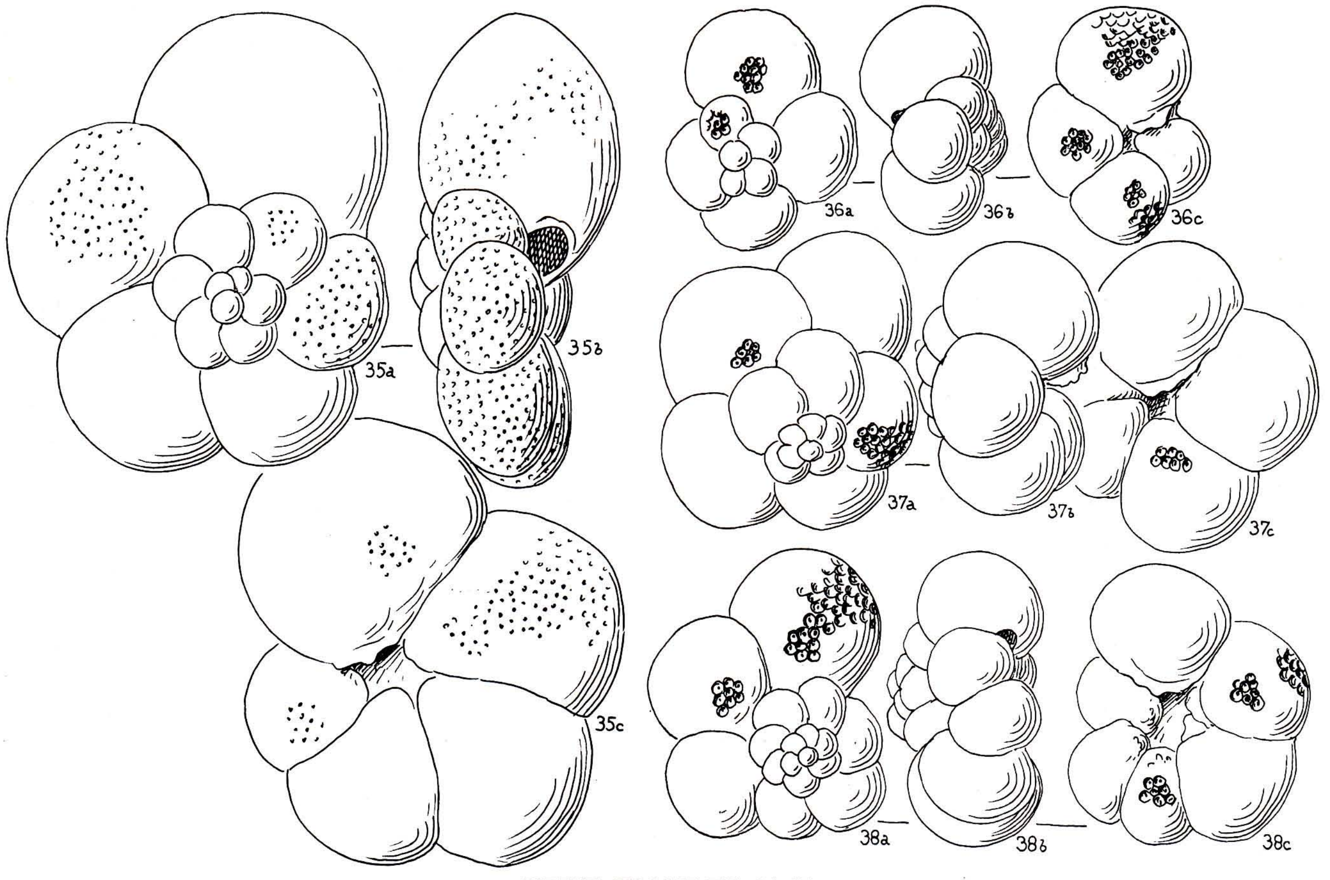
A small but very typical *Guembelitria* is very common in the lower zones of the Danian of Denmark. There is no difference between these specimens and those described by the author (Hofker, 1957a) from the upper part of the Maestrichtian Chalk Tuff of Holland. It may be Howe and Roberts' species or a form of *G. cretacea* Cushman.

### *STAINFORTHIA (CHILOGUEMBELINA)*

Text figures 1-10, 13, 14, 16

There are at least three different species of *"Chiloguembelina"* in the Danian of Denmark. In the lowest Danian a relatively large species is found having smoothly finished walls and a widely opened, though mostly slightly asymmetrical, aperture. It may belong to a form intermediate between *C. midwayensis* (Cushman) and *C. crinita* (Glaessner); some specimens show a slightly pustulose surface. Another species is found in the upper Danian, also very commonly. It has the loop-shaped aperture of *C. parallela* Beckmann and may be referable to that species. Analysis of this species gives rise to the following ideas.

The genus *Chiloguembelina* was erected for Tertiary forms which resemble *Guembelina* Egger (Loeblich and Tappan, 1956, p. 340). Previously, Hofker (1956c,



TEXT FIGURES 35-38

All figures × 160; a, dorsal side, b, apertural face, c, ventral side.

Fig. 35, *Globigerina compressa* Plummer. Mygind, sample 868, zone IV; specimens always show pores on the peripheral side, as do those from Plummer's type localities; such forms cannot belong to the genus *Globorotalia* since the type of that genus always has a poreless periphery.

Figs. 36-38, *Globigerina pseudobulloides* Plummer. 36, 37, Egsmark, sample 841, clayish marl; Paleocene. 36, specimen showing honeycomb structure. 37, overgrown specimen showing the honeycomb structure of the wall. 38, Plummer sample 174-T-27, Midway formation, Texas, U.S.A.; here also the honeycomb structure is fully developed.

pp. 908-910) published data concerning one of the species included by Loeblich and Tappan in their genus, placing this species, *Guembelina venezuelana* Nuttall, in his new genus *Stainforthia.* We must bear in mind that this publication appeared in July, 1956, whereas that of Loeblich and Tappan appeared in November, 1956.

Beckmann (1957) gave an account of *Chiloguembelina* from Trinidad, referring to a note by Hofker (1954) on *Guembelina venezuelana* but omitting any reference to Hofker's (1956c) more complete analysis of the species. Beckmann's description of the finer structure is superficial but he mentions the mostly asymmetrical aperture and the twisting of the tests, often typical of *Stainforthia;* he denies the triserial arrangement of the initial chambers.

In the Danian of Denmark, species of *Chiloguembelina* are common; one species from that formation was referred by Loeblich and Tappan (1957b, p. 179) to *C. morsei* (Kline) though in the Danian specimens the hispid surface of the last-formed chambers is mostly lacking. The species is found only in the middle and upper Danian.

The author was able to study numerous specimens of this species from the Danian of Denmark and concluded that *Chiloguembelina* must be considered a junior synonym of *Stainforthia* in which the toothplate is existent though highly reduced. When studied in oil it can be seen that each protruding apertural lip, always poreless, extends over the aperture and then bends inward, attaching itself to the border of the previous aperture, which is in the reverse position; this also is the case in *Bolivina* and *Stainforthia.* It is obvious that the protruding lip mentioned by Loeblich and Tappan and by Beckmann is merely a reduced toothplate and does not differ from the structure described by the author (Hofker, 1956c) for *Stainforthia venezuelana* (Nuttall).

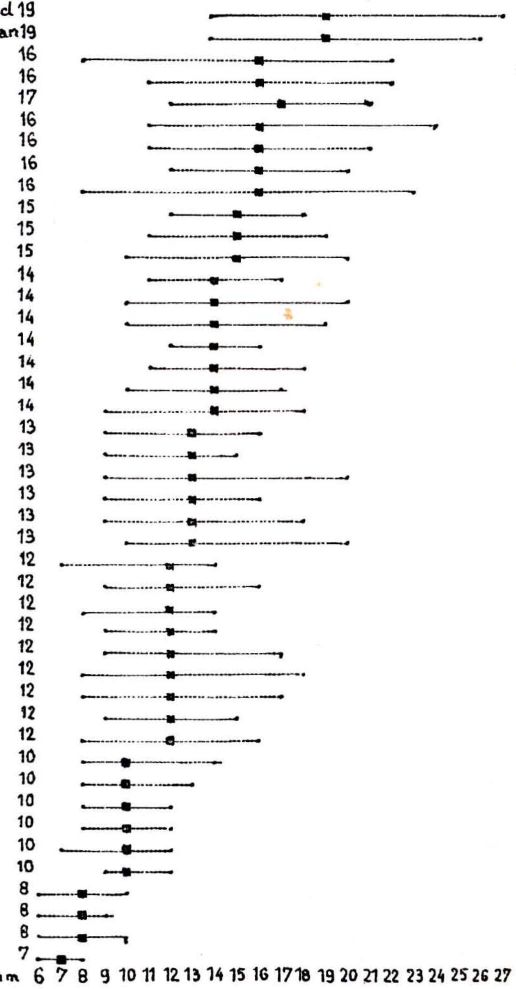
Thus, it is obvious that *Chiloguembelina* Loeblich and Tappan is a synonym of *Stainforthia* Hofker and that the whole group belongs, with many other species, to the hyaline forms formerly included in *Virgulina* and later gathered together into the genus *Stainforthia.* It may be that these small, probably planktonic forms should be separated from the main group as a subgenus *Stainforthia* (*Chiloguembelina*). The genus is found throughout the Tertiary to Recent times; other representatives are *Bolivina garretti* Cushman from the Oligocene, together with several other Oligocene species, and Recent *"Guembelina."* All these species have the loop-shaped aperture, the alternation of the structural peculiarities of the successive apertures, and the subglobular chambers. They all have toothplates, often greatly reduced, and frequently the tendency to have a triserial initial portion, at least in the microspheric generation where the twisting tendency is residual. *Stainforthia* (*Chiloguembelina*) is not related to *Guembelina* or *Heterohelix.* It is the character of the aperture which makes the difference between these genera for the lack of a coiled initial portion is not conclusive, as suggested by Beckmann. Only late Cretaceous forms of the *Guembelina* group from North America and the Tethys region sometimes show the coiled initial portion, as pointed out by Loeblich and Tappan as well as by Montanaro Gallitelli (1957). In Europe, the extremely common species *Guembelina striata* (Ehrenberg), occurring from the Turonian to the uppermost Maestrichtian, is not represented by a single specimen with a coiled initial portion (see Hofker, 1957b, pp. 418-426). *Chiloguembelina midwayensis* and *C. crinita* were described from the lower Lizard Springs formation of Trinidad, *C. parallela* from the upper Lizard Springs. This coincides strikingly with the situation in the Danian of Denmark where the first two species are found only in the lower Danian, the last only in the upper. *C. morsei* is most common in the middle Danian.

## STRATIGRAPHIC DATA FROM PLANKTONIC SPECIES

Forty-four samples from many localities in Denmark and from different zones of the Danian have been fully analyzed. When arranged in a series (Table 1) with the continuous sequence of enlarging diameters of *Globigerina daubjergensis* from 0.07 to 0.19 mm., this series is also more or less arranged in the sequence of zones, as developed from macrofossils by Odum and Wind. In the highest zones especially, there is better agreement with the zones indicated by Odum than those indicated by Wind (Mygind, Bredstrup Klint). There is, as will be shown, a great possibility that in both these localities a discontinuity (shifting by floor gliding) occurs.

In all samples where *Gavelinopsis involuta* (Reuss, 1862) was found, the diameter of the pores of that species were measured also. In the sequence given by *Globigerina daubjergensis* these pore diameters increased in an orthogenetic series. This emphasizes the truth of this arrangement.

In addition, in all these samples the frequencies of the planktonic species were calculated. These show a much greater variability than in the six samples analyzed by Troelsen (1957) but still they do show that the *linaperta* form of *G. daubjergensis* more or less disappears toward the youngest Danian whereas the first typical form with the dorsal openings appears from the middle Danian on and the *Catapsydrax* form appears in the highest Danian. *Globigerina pseudobulloides* which is very common in zone I gradually disappears in zone III as a smooth form and continues in the upper half of the Danian as a form with a pitted surface (ending with a honeycomb structure). *G. triloculinoides,* with 4-5 chambers and a strongly pitted surface, is found in zone II, where it is often



| Samples from Denmark arranged according to diameter of Glob. daubjerg. and diameter of pores of Gavelinopsis involuta. | Largest diameters of the Globigerina daubjargensis gens in 1/100 mm Variation breadth and average diameter | Pore-diameters of Gavelinopsis involuta Averages in μ | Variation numbers | Percentages planktonic species: Glob. daubjergensis (linaperta)<br>Glob. pseudobulloides (smooth)<br>Chilogümbelina midwayensis<br>Gümbelitria mauriciana<br>Gümbelina wilcoxensis<br>Glob. triloculinoides (5 chambers)<br>Chilogümbelina morsei<br>Glob. triloculinoides (4 chambers)<br>Glob. pseudobulloides (pitted)<br>Glob. daubjergensis (typica)<br>Chilogümbelina parallela<br>Glob. compressa<br>Glob. daubjergensis (catapsydrax) | Specimens analysed | Approximate percentages planktonic specimens in whole fauna | Odum's zonation 1926 | Wind's zonation 1953 |
|---|---|---|---|---|---|---|---|---|
| 861 Hvallöse Greensand | 19 | 5,6 | 3 11 12 40 14 1 3 | _ _ _ _ _ _ _ 1 3 90 _ 1 5 | 334 | 50 | Pal. | Pal. |
| 862 Hvallose highest Dan | 19 | 5,9 | 2 6 9 18 7 2 | _ _ _ _ _ _ _ _ 5 80 _ 3 12 | 152 | 50 | D | V |
| 851 Bredstrup Klint | 16 | 5,7 | 4 12 22 33 3 | 21 _ _ _ _ _ 1 1 9 65 1 _ 3 | 460 | 95 | D | III(IV? |
| 867 Mygind | 16 | 5,6 | 12 9 16 24 11 2 | 23 _ _ _ _ _ _ 3 12 61 1 | 296 | 80 | D | III |
| 850 Bredstrup Klint | 17 | 5,3 | 1 12 18 17 31 4 | 12 _ _ _ _ _ _ 1 17 70 | 421 | 90 | D | III (IV?) |
| 863 Hvallöse | 16 | 5,2 | 1 10 15 15 24 7 | _ _ _ _ _ _ _ 1 2 95 1 1 | 1225 | 80 | D | IV |
| 1004 Helligkilde | 16 | 5,3 | 12 18 20 29 8 1 | 10 _ _ _ _ _ 5 23 _ 58 3 1 | 257 | 60 | C? | IV |
| 852 Bredstrup Klint | 16 | 5,2 | 2 17 25 16 18 3 | 11 _ _ _ _ _ 1 3 16 69 | 312 | 80 | D | III(IV?) |
| 869 Mygind | 16 | 5,1 | 6 25 28 11 21 | 21 _ _ _ _ _ 1 12 10 54 2 | 416 | 85 | D | III |
| 1002 Helligkilde | 15 | | | _ _ _ _ _ _ _ 70 _ 30 | 38 | 40 | C? | IV |
| 868 Mygind | 15 | 4,9 | 2 47 32 9 6 | 36 _ _ _ _ 3 _ 10 23 25 2 1 | 196 | 80 | D | III |
| 875 Völdum | 15 | | | 7 _ _ _ _ _ _ 3 4 86 | 139 | 90 | D | IV |
| 1006 Helligkilde | 14 | 5,0 | 11 28 38 22 11 | 30 _ _ _ _ _ 7 28 _ 35 | 129 | 70 | C? | IV |
| 1000 Helligkilde | 14 | 4,9 | 13 24 22 5 7 | 69 _ _ _ _ _ 3 19 _ 9 | 167 | 80 | C? | IV |
| 1003 Helligkilde | 14 | 4,9 | 7 31 16 10 5 | 55 _ _ _ _ _ 5 13 _ 27 | 210 | 50 | C? | IV |
| 1007 Helligkilde | 14 | | | 10 _ _ _ _ _ 8 70 _ 12 | 46 | 50 | C? | IV |
| 865 Mygind | 14 | 4,3 | 63 45 9 3 | 58 _ _ _ 1 4 _ 3 31 3 | 107 | 90 | D | III |
| 855 Krogsager | 14 | 4,5 | 18 26 17 3 | 89 _ _ _ _ _ 1 _ 2 8 | 321 | 90 | | IV |
| 846 Bredstrup Klint | 14 | 4,1 | 8 27 17 3 1 | 75 _ _ _ _ _ 3 _ 3 16 3 | 119 | 90 | D? | III |
| 873 Völdum | 13 | | | 53 3 _ _ 1 _ 7 7 5 13 10 | 148 | 95 | C? | III |
| 871 Rigtrup | 13 | | | 64 - - - - _ 4 _ 17 14 1 | 139 | 95 | C | III |
| 1008 Helligkilde | 13 | | | 60 _ _ _ _ _ 1 39 | 98 | 70 | C? | III |
| 1022 Daubjerg | 13 | | | 99 _ _ _ _ _ _ 1 | 883 | 98 | C | |
| 1001 Helligkilde | 13 | 4,0 | 7 19 36 19 3 1 | 98 _ _ _ _ _ 2 | 528 | 80 | C? | III |
| 857 Krogsager | 13 | 4,2 | 6 36 23 5 2 | 80 1 _ _ _ _ 2 1 1 14 1 | 324 | 50 | | III |
| 1020 Sevel | 12 | | | 44 6 _ 3 _ _ 19 2 4 23 | 138 | 80 | D | |
| 848 Bredstrup Klint | 12 | 4,3 | 46 28 5 | 50 1 _ _ _ _ _ 1 3 45 | 171 | 60 | D? | III |
| 882 Purhus | 12 | | | 54 2 _ _ _ _ 3 2 _ 39 | 56 | 100 | C? | III |
| 1045 Faxe | 12 | 4,3 | 9 8 14 4 | 70 10 _ _ _ 3 3 7 7 | 119 | 95 | C | III |
| 944 Skillingbro | 12 | | | 70 _ _ 1 _ 11 1 _ 20 | 115 | 70 | C | II |
| 854 Karlby Klint | 12 | 4,0 | 7 16 35 11 | 49 3 1 1 _ 31 1 _ 16 | 98 | 90 | B | II |
| 1067 Karletrup | 12 | 4,0 | 1 4 35 10 | 35 26 _ 4 _ 34 1 | 77 | 60 | | II |
| 943 Rebild | 12 | 3,6 | 3 13 57 9 2 | 75 17 1 3 _ 4 | 160 | 40 | | II |
| 947 Skillingbro | 12 | 3,5 | 5 17 20 35 1 | 65 24 5 _ _ 6 | 86 | 80 | B | III |
| 1047 Faxe | 10 | | | 60 28 12 | 54 | 99 | C? | III |
| 1055 Stevns Klint | 10 | 3,9 | 1 13 36 3 | 34 50 8 1 3 3 1 | 152 | 90 | | II |
| 916 Nyvang Gaard | 10 | | | 50 27 9 14 | 44 | 90 | | II |
| 1011 Hjerm | 10 | 4,0 | 8 26 13 3 | 40 27 13 9 _ _ 1 10 | 91 | 80 | D | |
| 1013 Hjerm | 10 | | 4 17 24 15 | 28 19 18 12 _ 6 2 | 71 | 80 | D | |
| 915 Nyvang Gaard | 10 | 3,3 | 2 13 16 17 9 | 77 15 _ _ _ 8 | 26 | 20 | | I |
| 881 Raastedt | 8 | 3,5 | 1 10 15 18 8 2 | 56 21 3 3 2 14 1 | 80 | 100 | B | II |
| 959 Kjölby Gaard | 8 | 3,4 | 2 8 12 16 6 | 14 37 9 1 9 | 55 | 80 | A | I |
| 990 Vigsö-Bjerre | 8 | | | 8 62 24 7 2 | 114 | 80 | | I |
| 971 Vigsö-Bjerre | 7 | 3,1 | 3 11 23 9 | 31 36 21 11 1 | 161 | 80 | | I |
| | | μ 3 3,5 4 4,5 5 5,5 | 2 2,5 3 3,5 4 4,5 5 5,5 6 6,5 7 7,5 | | | | | |

TABLE 1. Planktonic Foraminifera during the Danian stage; orthogenetic development of *Gavelinopsis involuta*.

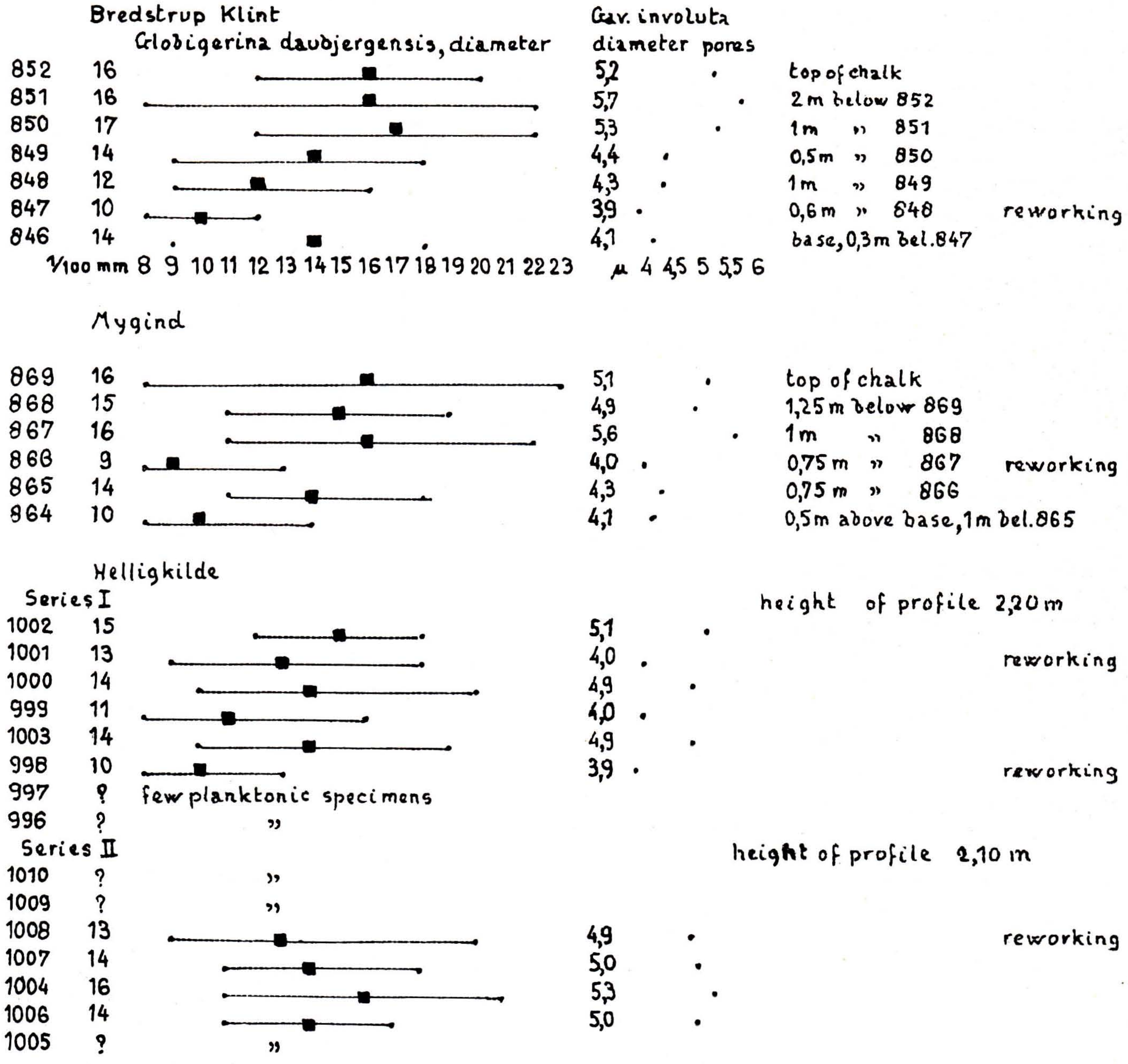


TABLE 2. Orthogenetic disturbances in the boundary interzone III-IV in the Danian.

one of the commonest forms, and from zone III on changes into the typical form (with 3-4 chambers), being commonest in zone IV; in the highest zones it becomes rare. *Chiloguembelina midwayensis* is found in zones I and II, more commonly in the former; it is absent in all higher zones. *C. morsei* is common in zones III and IV and disappears in the highest levels. *C. parallela* appears in zone III and is never common. *Globigerina compressa* is found only in zones IV, V, and the lowest Paleocene (?); it never becomes common. *Guembelitria mauriciana* is found only in zones I and II, rarely in zone III. *Guembelina wilcoxensis* is always relatively rare, occurring in all samples of zone I, with scattered specimens up into zone III.

It is obvious that a division of the Danian by means of planktonic forms is possible. There are few samples from which they are absent.

It was possible to take several continuous series of samples through the boundary between zones III and IV, at Bredstrup Klint, Mygind, and probably Helligkilde. At that boundary, often indicated by a conglomeratic aspect of the rock, a very typical abnormality in the occurrence and orthogenesis of *Globigerina daubjergensis* and *Gavelinopsis involuta* can be detected (Table 2). At the base of Bredstrup Klint we find a discontinuity both in the diameter of *G. daubjergensis* and the pore diameter of *G. involuta;* in sample 847 many specimens show marked signs of reworking (glauconite filled, broken) and the data point to zones II and III. From sample 850 upward there is a sudden jump in the orthogenetic data and here all the characteristics of the planktonic forms found point to Zone IV. Quite a similar phenomenon is found in the outcrop at Mygind. In the two series of samples taken in the quarry at Helligkilde, many reworked specimens are found together with a strong advance in diameter size.

Nevertheless, in all the samples from these three localities, where planktonic specimens are found they are abundant. Deep-sea ostracods are common as are coccoliths, and benthonic species typical of zone IV occur throughout the entire sequence of samples.

Rosenkrantz (1937, p. 201) postulates an abrasion zone between zones III and IV; he believes that at that time the sea bottom emerged and the presence of the conglomeratic layer was due to a period of dryness which was followed by a transgression of the sea. This seems impossible in view of the available fauna. The sea at the time of zones III and IV was distinctly a deep one, estimated to be a least 1000 m. deep. The total emergence of the sea floor would have caused considerable changes not only in the planktonic fauna but also in the lithological facies of the rock. Such changes, however, cannot be detected; a conglomeratic structure of the same chalky rock along with discontinuities in the orthogenetic sequence are the only things found. In Helligkilde only, where no real conglomerate could be found, did some samples (always consisting of hard rock) yield an insufficient number of planktonic specimens although such specimens were never completely absent.

The phenomena described here must be caused by disturbances other than transgressions. They can be explained by postulating sliding or slumping of the soft sea floor. Such phenomena have been reported in Recent deep seas and may be caused by a slight inclination of the floor or by rising coast lines. By such sliding mechanisms the deposition of boulders, the covering of younger layers by older ones etc., would be common and both these phenomena have happened in the case in question where layers with older, badly preserved fossils, overlie younger ones and the deposition of boulders gave rise to Rosenkrantz's "conglomerates." Wind (personal communication) tells me that, at the boundary between zones III and IV at some localities, parts of the surface of zone III clearly were incorporated into the lowest part of zone IV. This is exactly the kind of phenomenon brought about by slipping and it is shown in Bredstrup Klint, Mygind and Helligkilde by the discontinuities in the orthogenetic data.

That an abnormality of sequence, as shown by the series of samples at these localities (and it may be that the series at Hjerm also belongs to this group), occurs is clearly seen when we compare the series taken in the 7 m. of Danian in the quarry at Dalbyovre which goes through undisturbed zone III (zone C). Here, all the samples (which yield a very poor benthonic fauna) contain the planktonic fauna of that

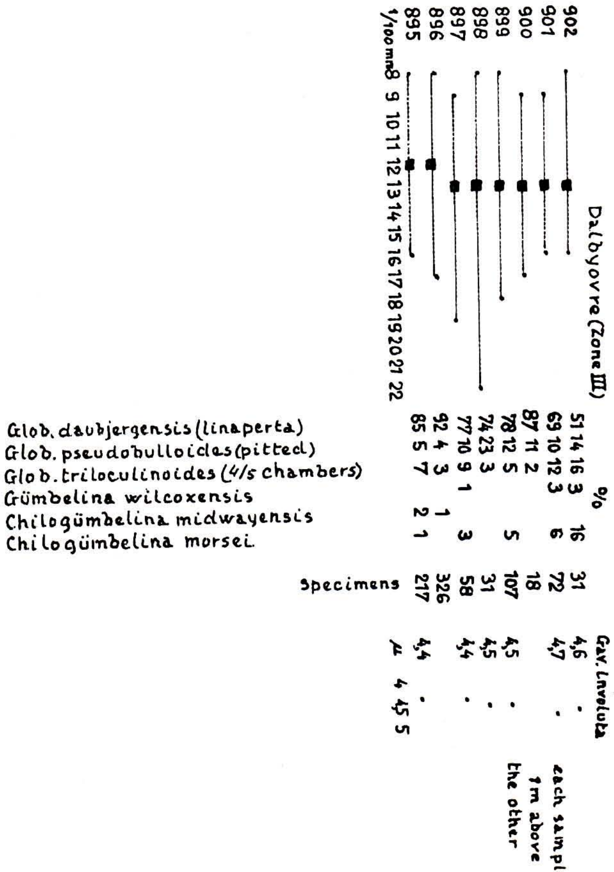


TABLE 3.

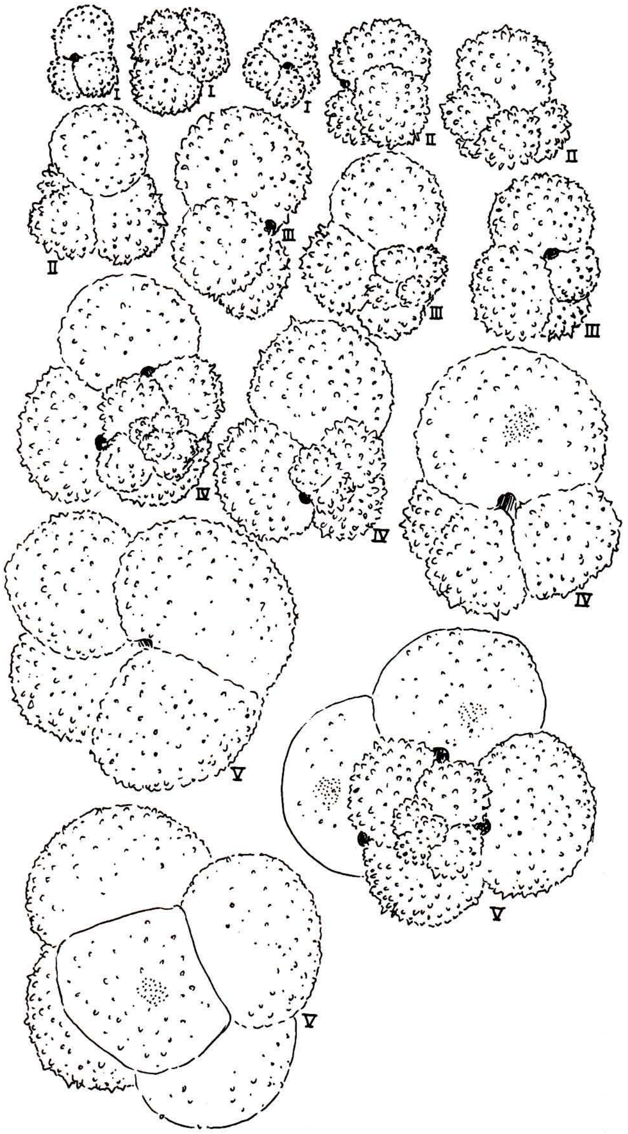


TABLE 4. The orthogenetic change of *Globigerina daubjergensis* during the Danian stage in Denmark. Roman numerals indicate Wind's zones. × 110.

zone and there is a very gradual, continuous change in the *G. daubjergensis* series and in the orthogenesis of *Gavelinopsis involuta*. In addition, the frequencies of the total planktonic population are those of zone III (Table 3).

The author (Hofker, 1958, 1959a, b, c) has indicated the correlation of the Danish Danian with the Dutch Maestrichtian Chalk Tuff (Maestrichtian *s.s.* of Dumont). Several planktonic species were described from the latter which can be grouped in the earlier or later stages of the *Globigerina daubjergensis* gens (*G. linaperta,* Hofker 1956a, fig. 11; *G. primitiva,* Hofker 1957a, fig. 5; *G. daubjergensis,* Hofker, 1956a, figs. 19, 20) and of *G. pseudobulloides* (Hofker, 1956a, fig. 4; 1959c). The specimens referred by the author to *G. linaperta* and *G. primitiva* undoubtedly belong to the *G. daubjergensis* gens in its primitive stage of development; they are found throughout the Maestrichtian Chalk Tuff. In the Paleocene above the Md in Holland and Belgium, the stage of *G. daubjergensis* is that of the highest Danian (zone V of Wind) and the overlying Paleocene greensand in Denmark. In addition, specimens of *G. pseudobulloides* (Hofker, 1959c) in the Maestrichtian Chalk Tuff (Mb, lower Mc) show the same stage of development as is found in zones I-III in the Danish Danian. In the Mc and Md of the Maestrichtian Chalk Tuff, moreover, abundant specimens of *Guembelitria* are found which continue in the Me and which do not differ from those found in the Danish Danian.

This strongly points to a correlation of at least part of the Maestrichtian Chalk Tuff with the Danish Danian (also suggested by Wind, 1953) and of the overlying Paleocene with Zone V or the greensand Paleocene of Denmark. It also was shown by the author (Hofker, 1956b, 1959b) that *Gavelinopsis involuta* has quite the same orthogenetic development during the Maestrichtian Chalk Tuff as is shown here for the Danian of Denmark. It may be that the Lizard Springs formation of Trinidad also is of Danian age; a more detailed study of the planktonic forms of this formation is needed to establish this. However, the structure of *Globigerina pseudobulloides* in the lowest Lizard Springs is that of the Paleocene and not that of the Danian in Denmark.

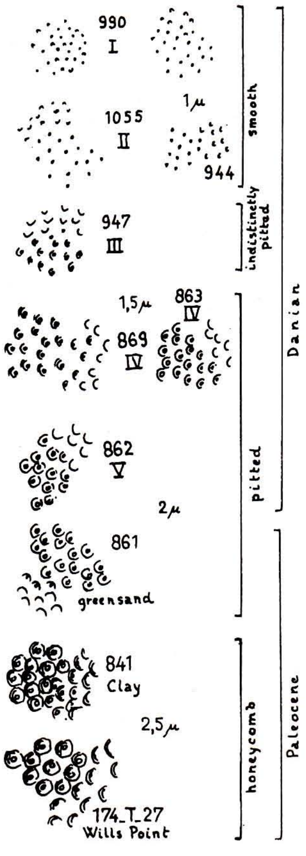


TABLE 5.* Structure of walls of *Globigerina pseudobulloides* during the Danian and the overlying Paleocene, and comparison with the type locality of *G. pseudobulloides,* the Midway formation of Texas, U.S.A. (Plummer station 174-T-27). The pores gradually increase in size, ranging from 1 μ diameter to 2.5 μ. Together with this increase, the smooth wall becomes pitted and finally attains the honeycomb structure which also is found at the type locality. In the first stages of the development series, small tubercles can be found between the pores. The series forms a true gliding orthogenesis. All figures, × 210.

* In Table 5 "Midway" should be substituted for "Wills Point."

## CONCLUSIONS

1. Planktonic species in the type Danian show many orthogenetic changes which must be considered when comparing other formations with it. For the first time a well-established orthogenesis of a planktonic form (*Globigerina daubjergensis*) has been demonstrated; it corresponds with a similar rectilinear orthogenesis of another foraminifer of quite a different character (*Gavelinopsis involuta*). In addition, it has been shown that during such an orthogenesis within a single gens, three different "species" belonging to three different "genera" were traversed. This shows that those genera and species are artificial and should be eliminated. The pores of globigerines do not change their diameters during the development of species.

2. During the course of the type Danian of Denmark, the whole planktonic fauna gradually changes which might lead to the conclusion that a zonation of the Danian is more or less artificial; there is a continual and gradual change perhaps due to orthogenetic changes as well as to climatological influences. Small jumps in orthogenesis in the interzonal "conglomerates" may be caused by short interruptions in sedimentation, with shifting phenomena on the sea bottom.

3. During the whole Danian, the amount of the planktonic population is considerable, from 50-100% of the total population. This together with the fact that many of the benthonic species of Foraminifera are typically deep-sea species (large Lagenidae, large number of arenaceous forms) and that a fauna of deep-sea ostracods and deep-sea corals was found leads to the conclusion that the sediments of the type Danian were deep-sea sediments.

4. Inasmuch as during the conglomeratic "abrasion" interzones between the zones of the type Danian a decrease of planktonic and deep-sea species can hardly be found, these interzones are not transgressional zones. In three instances, in the larger "transgressional" interzone between Wind's zones III and IV, great irregularities in the orthogenetic sequence of both *G. daubjergensis* and *Gavelinopsis involuta,* both in the same sense, were observed. These phenomena lead to the conclusion that the "transgressional" zones

or abrasion interzones are caused by shifting of the deep-sea floor during Danian time. There are no indications of "uplifts" or large regressions during the Danian of Denmark.

5. A closer study (using high magnifications and the immersion of specimens in oil) of the planktonic species found in the so-called "Danian" deposits throughout the world may lead to a better understanding of the stratigraphic position of these sediments. Each superficial identification of a species invariably will lead to errors in this respect.

6. In the Maestrichtian Chalk Tuff of Holland (type Maestrichtian of Dumont), in which coastal formation scattered specimens of the species in question are found, and in the overlying lower Paleocene in Holland, the *G. daubjergensis* gens and the *G. pseudobulloides* gens show the same stages of development as those found in the Danian and lower Paleocene of Denmark; this is also true of the developmental stages of several benthonic Foraminifera. The conclusion is that the Maestrichtian Chalk Tuff and the overlying lower Paleocene in Holland and the Danian stage and overlying lower Paleocene in Denmark are of the same age.

Brotzen (1959) points out that the Danian of Sweden and Denmark is strongly Cretaceous in character; he states that in all localities the Danian is found overlying the Maestrichtian. But we must bear in mind that Brotzen's "Maestrichtian" is the white Chalk (*Pseudotextularia* zone) which, in its foraminiferal fauna and evolutionary stages of Foraminifera, is of the age of the Cr 4 in Holland which there is covered by the Maestrichtian Chalk Tuff, the type of Dumont's "Maestrichtian." Thus, the observation by Brotzen that the Danian always overlies the "Maestrichtian" in Sweden and Denmark does not contradict the correlation in time of the Danian stage with the Maestrichtian Chalk Tuff. Both show the same orthogenetic stages and development of Foraminifera and both overly "white Chalk" which, contrarily to the original definition of Dumont, nowadays is considered to belong to the Maestrichtian also. The whole sequence of the units mentioned in this paper may be shown in the following table:

| | | *Denmark* | | *Holland* | |
|---|---|---|---|---|---|
| | Paleocene | Clays<br>Greensands | Paleocene | Montian<br>Limestone<br>Lowest Paleocene<br>(limestone with glauconite) | |
| | indurated surfaces with holes | | | | |
| | D A N I A N deep sea formations | Wind Odum zone V | type MAESTRICHTIAN riffal or coastal formations | Me | |
| | | zone IV (or D) | | Md | planktonic forms of "Danian" types |
| | | zone III (or C) | | Mc | |
| | | zone II (or B) | | | |
| | | zone I (or A) | | Mb | |
| planktonic faunal break | Fish Clay (Fiskeler) | | | Ma-layer | (regression-transgression layers) |
| | Cretaceous | White Chalk<br>(*Pseudotextularia* zone)<br>(Skrivekridt) | Cretaceous | White Chalk<br>(Upper Gulpen Chalk or Cr 4) | planktonic forms of "Cretaceous" types |

In the deeper and colder Danian sea, ammonites and belemnites had already disappeared whereas their latest representatives found their last development in the warmer coastal and riffal sea of South Limburg, Holland. Foraminifera from underlying formations, from the type Maestrichtian and Danian, and from the overlying formations in Holland and Denmark strongly suggest a time identity of the Maestrichtian Chalk Tuff and the Danskekalk. Thus, the fact that Brotzen termed the white chalk, below the Danian, as of Maestrichtian age does not mean that this chalk is of the same age as the type Maestrichtian.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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# 211. TWO NEW SPECIES OF FORAMINIFERA FROM THE WEST COAST OF THE UNITED STATES

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ABSTRACT

Examination of shallow water samples collected from northern California and Oregon coasts disclosed two new species of Foraminifera: **Massilina crescentensis** and **Trichohyalus orfordensis.**

## INTRODUCTION

Twenty samples were collected by the author in the intertidal zone of northern California and Oregon. Subsequent examination disclosed two new species of Foraminifera.

The samples were collected in pint jars. Rose Bengal in ethyl alcohol was immediately added as an organic stain. Some of this stain is apparent in the photographs as darker areas.

The scope of this paper is not to discuss the associated Foraminifera and their environment but only to bring the new species to the attention of other students. A future paper will report in detail the associated Foraminifera, their environment, and the possible latitudinal limitations of the new species.

The figured types are deposited in the United States National Museum. The photographs are by the author.

## SYSTEMATICS

### Family MILIOLIDAE

### Genus **Massilina** Schlumberger, 1893

### **Massilina crescentensis** Hamlin, n. sp.

Plate 14, figures 1, 2

*Description.*—Test free, imperforate, smooth. Early stages quinqueloculine, later stages planispirally coiled. Chambers somewhat inflated, increasing in size as added, periphery subround to subacute; large specimens may be keeled and the initial portion of the final chamber flattened. Antepenultimate chamber visible on the periphery. May or may not have protruding chamber on one side. Aperture generally oval with a lip and plate-like or wedge-shaped tooth; large specimens may have secondary tooth extending down from the top of the aperture. Four or five chambers visible on one side, five or six visible on the other side. Sutures distinct, depressed.

| *Dimensions.*— | Max. Diameter | Min. Diameter | Thickness |
|---|---|---|---|
| Holotype (Fig. 1) | 0.62 mm | 0.46 mm | 0.29 mm |
| Paratype (Fig 2) | 0.96 mm | 0.70 mm | 0.40 mm |

*Type Level.*—Recent, Intertidal.

*Locality of Holotype.*—At the natural tunnel at the base of the west side of Battle Rock, Port Orford, Oregon.

*Locality of Paratype.*—300 feet west of the south end of "A" Street, Crescent City, California.

*Depository.*—Holotype (Fig. 1), USNM 627596; Paratype (Fig. 2), USNM 627597.

*Discussion.*—Since this species occurred most abundantly at Crescent City, California, it was named for that town.

*M. crescentensis* differs from *M. pulchra* Cushman and Gray by being inflated rather than compressed. While *M. crescentensis* has a smooth surface, *M. pulchra* is ornamented with costae.

*M. crescentensis* differs from *Pateoris hauerinoides* (Rhumbler) in apertural characteristics. Whereas *M. crescentensis* has an oval-shaped aperture in both the young and the adult, *P. hauerinoides* has a low, arched aperture which becomes narrow and almost slit-like in the later stages. *M. crescentensis* has an apertural tooth, a feature absent in the genus *Pateoris.*

### Family ROTALIIDAE

### Genus **Trichohyalus** Loeblich and Tappan, 1953

### **Trichohyalus orfordensis** Hamlin, n. sp.

Plate 14, figures 3-5

*Description.*—Test free, trochoid, initial stages biconvex, becoming planoconvex in the adult, periphery subacute; all whorls visible dorsally, chambers increasing in size as added, becoming lobulate in later stages; perforate, smooth. Dorsal sutures limbate, curving backwards, flush to slightly raised in the young, becoming depressed in the adult. Peripheral keel, some specimens tending to lose the keel in later stages. Ventral side partially obscured with secondary test material. The vesicular growth creates nodes and pustules of various sizes, with the largest concentration occurring in the umbilical region and along the ventral sutures. Adult specimens show an irregular serration along the periphery, due to the nodes and pustules extending slightly beyond the margins of the test. Where not obscured by secondary growth, the areas between sutures show pores communicating with the interior of the test. In the last two or three chambers of some specimens the ventral sutures curve gently and then bend sharply toward the umbilicus, creating a re-entrant angle. Striations are found on the apertural face and on the ventral side of the last two or three chambers. Six or seven chambers may be detected on the ventral side. The aperture is a small opening usually obscured by the secondary growth, about ¾ ventral from the periphery. Wall calcareous, hyaline.

| *Dimensions.*— | Max. Diameter | Min. Diameter | Thickness |
|---|---|---|---|
| Holotype (Fig. 3) | 0.74 mm | 0.70 mm | 0.31 mm |
| Paratype (Fig. 4) | 0.75 mm | 0.70 mm | 0.30 mm |
| Paratype (Fig. 5) | 0.60 mm | 0.50 mm | 0.24 mm |

*Type Level.*—Recent, Intertidal.

*Type Locality.*—At the natural tunnel at the base of the west side of Battle Rock, Port Orford, Oregon.

*Depository.*—Holotype (Fig. 3), USNM 627598; Paratype (Fig. 4), USNM 627599; Paratype (Fig. 5), USNM 627600.

*Discussion.*—This species is named for the type locality; Port Orford, Oregon.

*T. orfordensis* differs from *T. bartletti* (Cushman) in having a sharper periphery, greater inflation of the later chambers, and more deeply depressed sutures. The ventral side of *T. orfordensis* shows sparse secondary growth on the chamber areas, the greatest concentration occurring in the umbilical region and along the sutures where it forms nodes and pustules. The ventral side of *T. bartletti* is thickly covered with nodes and pustules of secondary tissue. *T. orfordensis* has a peripheral keel which is lacking in *T. bartletti.*

*T. orfordensis* differs from *T. pustulata* Loeblich and Tappan by being plano-convex rather than biconvex in shape, and in having a margin which is slightly, instead of strongly, serrated. Less vesicular growth, depressed sutures, a peripheral keel and lobulate chambers also distinguish *T. orfordensis* from *T. pustulata.*

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Ellis, B. F. and Messina, A. R., 1940, Catalogue of Foraminifera: Spec. Publ., Am. Mus. Natural History, New York.

Loeblich, A. R. and Tappan, H., 1953, Studies of Arctic Foraminifera: Smithsonian Misc. Coll., vol. 121, no. 7, 150 pp.

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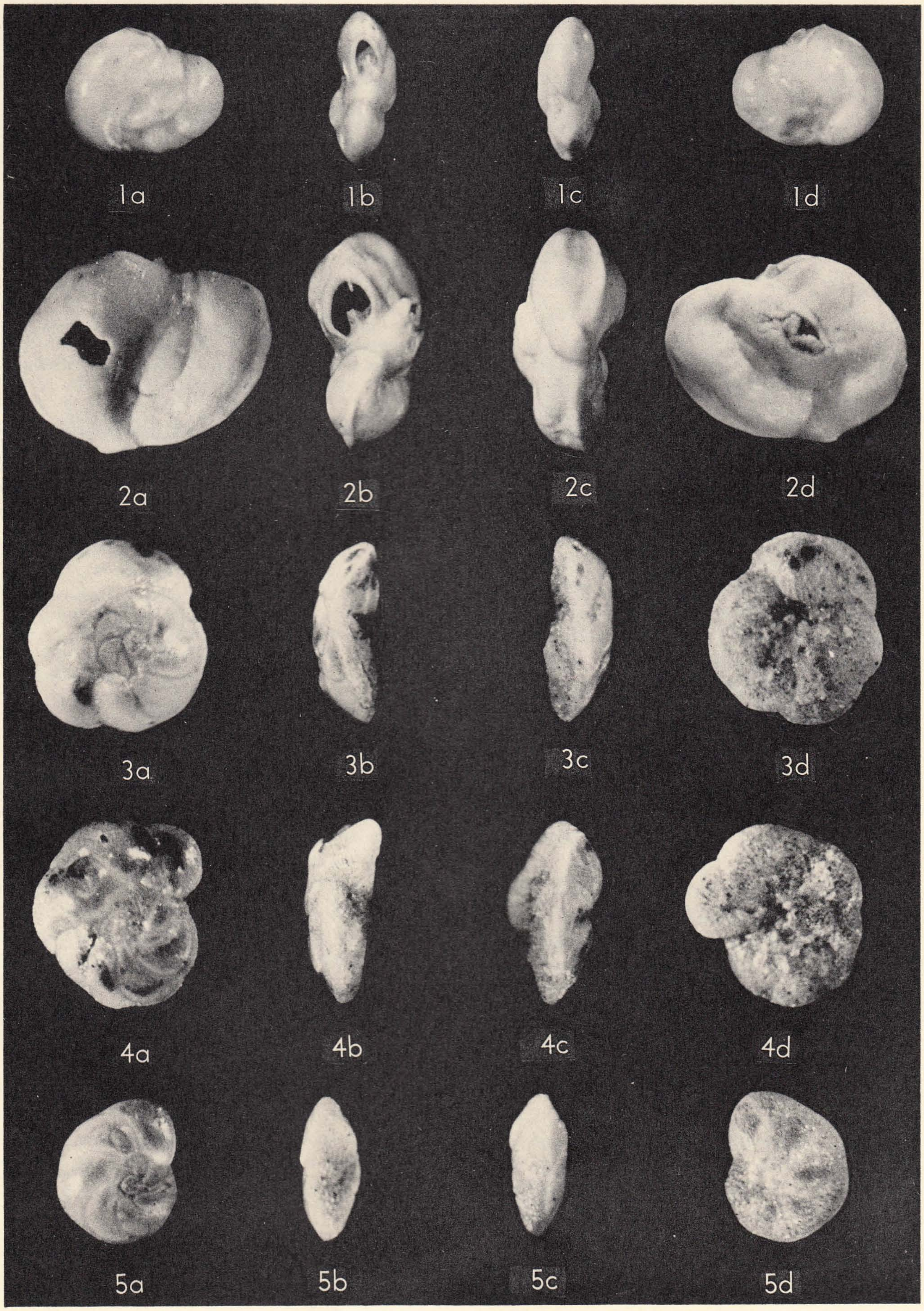
## EXPLANATION OF PLATE 14

Unretouched Photographs

Figures approx. × 38

| Figs. | | Page |
|---|---|---|
| 1, 2. | *Massilina crescentensis* Hamlin, n. sp. ……<br>1. Holotype, (USNM 627596). 2. Paratype, (USNM 627597). 1a, 2a. Side views. 1b, 2b. Apertural views. 1c, 2c. End views (opposite aperture). 1d, 2d. Side views. | 87 |
| 3, 4, 5. | *Trichohyalus orfordensis* Hamlin, n. sp. ……<br>3. Holotype, (USNM 627598). 4. Paratype, (USNM 627599). 5. Paratype, young specimen, (USNM 627600). 3a, 4a, 5a. Dorsal views. 3b, 4b, 5b. Apertural views. 3c, 4c, 5c. Edge views (opposite aperture). 3d, 4d, 5d. Ventral views. 4c and 4d. Oriented with respect to each other. | 87 |



Hamlin: New Species, West Coast of United States

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XI, PART 3, JULY, 1960

# 212. THE SIGNIFICANCE OF VARIABILITY IN *PRAEGLOBOTRUNCANA GAUTIERENSIS* (BRÖNNIMANN), 1952, FROM THE CRETACEOUS EAGLE FORD GROUP OF TEXAS

JAMES I. JONES
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ABSTRACT

1. The establishment of a preferred dextral coiling direction is demonstrated for the species **Praeglobotruncana gautierensis** (Brönnimann) from Texas Cretaceous strata ranging in age from lower Cenomanian to middle Campanian.

2. The morphologic characters height and width of test, and height and width of chambers one and four, as here defined, may be used to demonstrate minor morphologic variability by utilizing the techniques of this study.

3. A high degree of correlation exists between variation in the benthonic index as here defined and test morphologic variability as measured by the coefficient of variation in the species **P. gautierensis** from the Texas Cretaceous.

4. The coefficient of relative dispersion about the reduced major axis and the standard deviation of the total dispersion about the reduced major axis may be effectively used to measure minor morphologic variation in the species **P. gautierensis.**

## INTRODUCTION

The planktonic Foraminifera have been found useful in stratigraphic correlation due to their wide distribution, general abundance, and occurrence independent of sedimentary facies. These same factors make this group an excellent one to study for paleoecologic purposes if it first can be shown that they are useful as environmental indicators. Studies of this type are generally lacking, a situation in part due to the basic simplicity of many of the forms which often exhibit little morphologic change over limited temporal sequences.

This study investigates the species *Praeglobotruncana gautierensis* (Brönnimann), 1952, from a limited stratigraphic sequence within the Eagle Ford group of the Texas Cretaceous, and shows how this species may be used to indicate paleoecologic variation through this interval. A number of quantitative techniques have been employed to measure the morphologic variability of these species. Resulting data are then analyzed for possible paleoecologic significance.

## ACKNOWLEDGEMENTS

The writer is grateful to Dr. Roger L. Batten for his inspiration and guidance throughout this study. Dr. Alfred R. Loeblich, Jr., the United States National Museum, and Mr. William Schell have contributed to various aspects of the study. The writer is indebted to the Wisconsin Alumni Research Foundation for providing the funds which made this study possible.

## PROCEDURES

### *Collecting*

Two sections of the Britton formation of the Eagle Ford group were sampled. Locality "A" is 3.6 miles S81°W of Cedar Hill, Dallas County, and 7.4 miles N89°30′E of Mansfield, Tarrant County, Texas, just north of Mansfield Road along a bank of an unnamed tributary of Mountain Creek. Locality "B" is located on the Elm Fork of the Trinity River, Dallas County, Texas, below the railroad trestle where the Chicago, Rock Island and Pacific Railroad crosses Elm Fork, approximately two and three-eighths miles S85°W of the intersection of U.S. Highway 77 and Texas Highways 114, 183 and Loop 12. These localities were provided by Mr. William Schell (Unpublished master's thesis, Southern Methodist University). Section "A" is stratigraphically higher than section "B." Samples were collected at levels showing lithologic change and at five-foot intervals where no change was apparent. Tables 1 and 2 give the measured sections at localities "A" and "B" respectively, and indicate which strata were sampled.

### *Sampling and measuring techniques*

Twelve samples from locality "A" and seventeen from locality "B" were prepared and examined. Standard preparation techniques were employed. A 0.25 gram fraction of each sample was picked of all Foraminifera and counts made to determine the relative abundance of planktonic forms present (see Table 3). Eleven samples from localities "A" and "B" were chosen for detailed quantitative study of the species *Praeglobotruncana gautierensis.* This species was selected because of its general abundance throughout the interval sampled, in which it is the most common planktonic species, and because it is well represented in other Upper Cretaceous strata. Random sample populations of thirty individuals of this species were picked from each sample for detailed morphologic study and measurement (see Figure 1). The measurements were made with a binocular microscope in combination with a traveling micrometer ocular. Table 4 gives the measurements for sample B1-1. The detailed measurements and other quantitative information have been included for only a single sample. The

TABLE 1. Stratigraphic section at Locality "A."

[*, foraminiferal population sample; †, population sample of *Praeglobotruncana gautierensis* (Brönnimann)]

| *Feet* | | |
|---|---|---|
| 55— | | Soil zone, top of section. |
| — | A1 | |
| — | A2-1* | Clay shale, waxy, tan to orange, some small darker discontinuous areas, orange weathered zones to 2″ thick, most is finely laminated. |
| — | | |
| — | | |
| 50— | A2-2-1*† | |
| — | | |
| — | A2-2-2* | |
| — | | |
| — | | |
| 45— | A2-3* | Claystone concretions. |
| — | | |
| — | | |
| — | | |
| — | | |
| 40— | | |
| — | A2-4* | Clay shale, chocolate brown to tan, becoming massively bedded with beds to 1″ thick, some finely laminated beds present, abundant selenite crystals on joints and fractures. |
| — | | |
| — | | |
| — | | |
| 35— | | |
| — | A3-1 | Claystone nodules ½″ to 1″ thick, laterally continuous. |
| — | A4-1* | Gray clay shale about 1′ thick, many selenite crystals, grading downward to blue, maroon weathering clay shale, some claystone concretions. |
| — | A5 | |
| — | A-6-1*† | |
| 30— | A6-2*, A7-1, A8, A9-1, A10, A11, A12-1* | Alternating layers of maroon, dark blue and dark gray clay. |
| — | | |
| — | A13-1* | Clay shale, dark blue. |
| — | | |
| — | | |
| 25— | A13-2-1*† | Clay shale, dark blue. |
| — | | |
| — | | |
| — | A13-2-2* | |
| — | | |
| 20— | | |
| — | | |
| — | | |
| — | | |
| — | A14-1 | Irregular discontinuous claystone concretions, 2½″ to 4″ thick, maroon weathering. |
| 15— | | |
| — | | |
| — | | |
| — | | |
| — | | |
| 10— | A15-1* | |
| — | | Clay shale, dark blue. |
| — | | |
| — | A15-2-1*† | |
| — | | |
| 5— | | |
| — | A15-2-2* | |
| — | | |
| — | | |
| — | | |
| 0— | | |

data for all samples are on file in the Main Library of the University of Wisconsin (Jones, J. I., Unpublished master's thesis [1959]).

## QUANTITATIVE CONSIDERATIONS

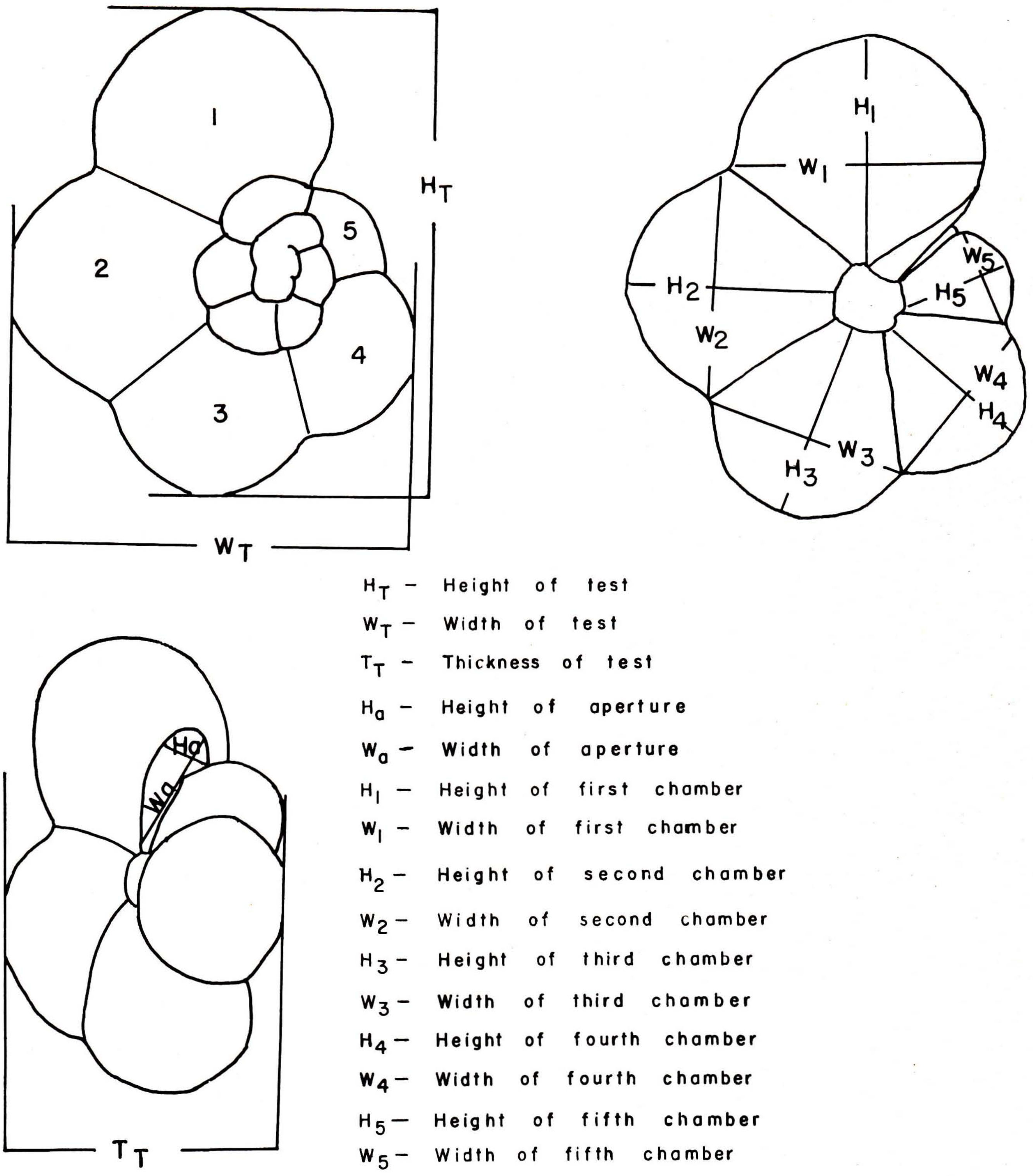
### *Benthonic Index*

The percent of benthonic Foraminifera in the total foraminiferal population for any given sample is here defined as the benthonic index. This index is thought to be related to water depth in a stable, shelf-type marine environment. The present study considers the variation in the benthonic index through a limited stratigraphic sequence as indicative of changing environmental conditions. With present knowledge it is impossible to determine which factors may have caused changes in the benthonic index.

TABLE 2. Stratigraphic section at Locality "B."

[*, foraminiferal population sample; †, population sample of *Praeglobotruncana gautierensis* (Brönnimann)]

| *Feet* | | |
|---|---|---|
| 70— | | Soil zone, top of section. |
| — | B1-1*† | |
| — | | |
| — | | |
| — | | |
| 65— | | Clay shale, tan to chocolate brown, some claystone concretions which are laterally continuous, ledge forming, some thin limestone flags. |
| — | | |
| — | | |
| — | | |
| — | | |
| 60— | | |
| — | | |
| — | | |
| — | | |
| — | | |
| 55— | | |
| — | B1-2 | Limestone, white flaggy, 2″ thick. |
| — | | |
| — | | |
| — | B2-1* | Base of tan to brown clay shale, contact is gradational with underlying blue clay shale. |
| 50— | | |
| — | | |
| — | B3-1*† | Top of blue clay shale unit. |
| — | | |
| — | | |
| 45— | | |
| — | | |
| — | B3-2*† | Blue clay shale. |
| — | | |
| — | | |
| 40— | | |
| — | | |
| — | | |
| — | B3-3* | |
| — | B4-1 | Limestone, medium-gray, dense, fine-grained, weathers buff to maroon, 4″ thick. |
| 35— | | |
| — | | |
| — | B5-1* | Blue clay shale. |
| — | B6-1* | Claystone concretions, ledge-forming, 1½″ thick. |
| — | | |
| 30— | | |
| — | | |
| — | | |
| — | B7-1* | Blue clay shale. |
| — | | |
| 25— | | |
| — | B8-1 | Claystone concretions, ledge-forming. |
| — | B9-1* | |
| — | B10-1 | Claystone concretions. |
| — | | |
| 20— | | Blue clay shale. |
| — | | |
| — | | |
| — | B11-1* | |
| — | B12-1* | Claystone concretions. |
| 15— | | Blue clay shale. |
| — | | |
| — | B13-1* | Blue clay shale. |
| — | B14-1 | Claystone concretions, ledge-forming. |
| — | B15-1*† | Blue clay shale. |
| 10— | | |
| — | B16-1 | Claystone concretions. |
| — | B17-1, B18-1 | Blue clay shale over thin ledge of claystone concretions. |
| — | | |
| — | B19-1* | Blue clay shale. |
| 5— | B19-2* | |
| — | B19-3* | Blue clay shale. |
| — | B19-4*† | |
| — | | |
| — | | |
| 0— | | |



$H_T$ – Height of test

$W_T$ – Width of test

$T_T$ – Thickness of test

$H_a$ – Height of aperture

$W_a$ – Width of aperture

$H_1$ – Height of first chamber

$W_1$ – Width of first chamber

$H_2$ – Height of second chamber

$W_2$ – Width of second chamber

$H_3$ – Height of third chamber

$W_3$ – Width of third chamber

$H_4$ – Height of fourth chamber

$W_4$ – Width of fourth chamber

$H_5$ – Height of fifth chamber

$W_5$ – Width of fifth chamber

Chambers are numbered 1 through 5 with the final chamber number 1 and proceeding consecutively towards the older chambers.

Fig. 1 Measured morphologic characters and their abbreviated terminology.

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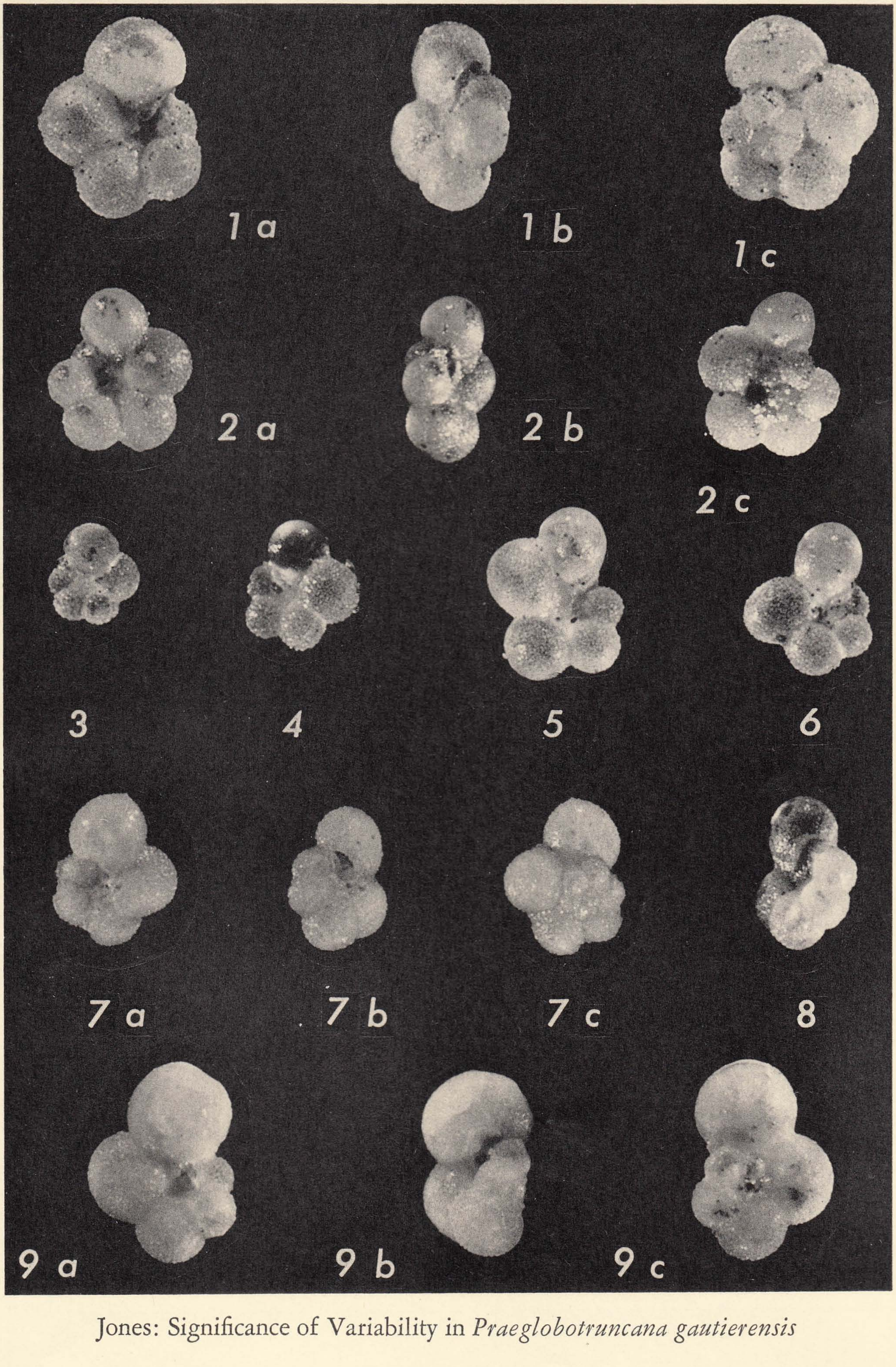
EXPLANATION OF PLATE 15

All figures approximately × 70.

FIGS. PAGE

1-7. *Praeglobotruncana gautierensis* (Brönnimann, 1952). .......... 102

1a-c, typical specimen, locality B3-1; a-umbilical, b-apertural, c-spiral. 2a-c, typical specimen, locality A15-2; a-umbilical, b-apertural, c-spiral. 3-6, range of variation in test and chamber shape; locality A15-2; all views are umbilical. 7a-c, average specimen, locality A2-2; a-umbilical, b-apertural, c-spiral. 6, apertural variant, showing high, wide aperture; locality B3-1; apertural view. 7a-c. specimen showing thickened final chamber, locality 119-19 (Grayson fm.); a-umbilical, b-apertural, c-spiral.



Jones: Significance of Variability in *Praeglobotruncana gautierensis*

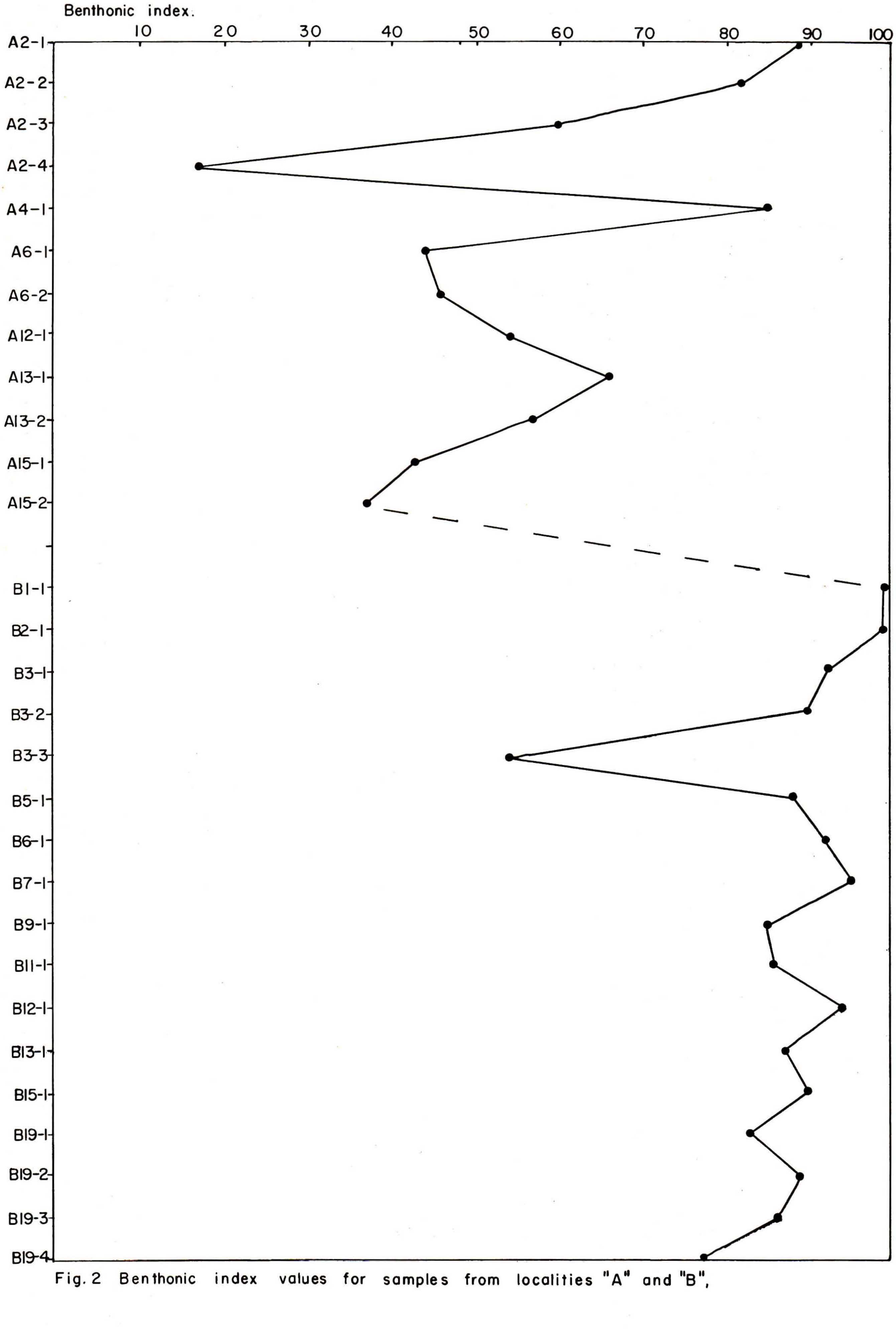


Fig. 2 Benthonic index values for samples from localities "A" and "B",

Several investigators have used relative percentages of planktonic and benthonic Foraminifera for stratigraphic and general paleoecological purposes (Tromp, 1949 and Polski, 1959). These and other studies indicate the usefulness of planktonic and benthonic ratios. The benthonic index, when plotted against stratigraphic position, show changes that are here assumed to be indicative of environmental fluctuation. Figure 2 shows the benthonic index values for successive vertical samples from localities "A" and "B." The samples from locality "B" generally exhibit consistently high benthonic index values, except at sample B3-3. Locality "A" shows more variation and generally lower values. Sample A2-4 in particular shows an extremely low comparative value. This sample exhibited a high percentage of broken and worn specimens indicating secondary transportation and deposition. Since the specimens in the remainder of the samples appear fresh and unworn it is assumed that depositional factors are primarily responsible for this particularly low benthonic index value.

It has been assumed that an abundance of planktonic Foraminifera suggests a deep-water, open-ocean environment while an abundance of the benthonic forms indicates shallow-water, near-shore conditions. It is understood that an interpretation of environment based on the benthonic index must be of a general nature. A significant correspondence will be shown, however, between variation in this characteristic and

TABLE 3. Number of total specimens and the percent of benthonic specimens in 0.25 gram of prepared sample.

| *Sample* | *Total* | *%benthonic* |
|---|---|---|
| A2-1 | 145 | 89 |
| A2-2 | 260 | 82 |
| A2-3 | 229 | 60 |
| A2-4 | 23 | 17 |
| A4-1 | 202 | 85 |
| A6-1 | 193 | 44 |
| A6-2 | 106 | 46 |
| A12-1 | 138 | 54 |
| A13-1 | 165 | 66 |
| A13-2 | 287 | 57 |
| A15-1 | 265 | 43 |
| A15-2 | 183 | 37 |
| B1-1 | 94 | 99 |
| B2-1 | 242 | 99 |
| B3-1 | 130 | 92 |
| B3-2 | 355 | 90 |
| B3-3 | 307 | 54 |
| B5-1 | 221 | 88 |
| B6-1 | 53 | 92 |
| B7-1 | 427 | 95 |
| B9-1 | 87 | 85 |
| B11-1 | 78 | 86 |
| B12-1 | 18 | 94 |
| B13-1 | 253 | 87 |
| B15-1 | 89 | 90 |
| B19-1 | 250 | 83 |
| B19-2 | 396 | 89 |
| B19-3 | 382 | 86 |
| B19-4 | 86 | 77 |

TABLE 4. Complete data for sample B1-1 Measurements (in microns) of morphologic characters investigated on *Praeglobotruncana gautierensis* (Brönnimann).

| No. | $H_t$ | $W_t$ | $T_t$ | $H_1$ | $W_1$ | $H_2$ | $W_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 332 | 275 | 151 | 167 | 184 | 146 | 142 |
| 2 | 267 | 239 | 149 | 150 | 149 | 128 | 136 |
| 3 | 139 | 120 | 90 | 73 | 88 | 59 | 63 |
| 4 | 306 | 242 | 153 | 166 | 155 | 124 | 128 |
| 5 | 186 | 154 | 86 | 82 | 84 | 90 | 89 |
| 6 | 282 | 223 | 122 | 130 | 135 | 115 | 117 |
| 7 | 113 | 92 | 69 | 50 | 62 | 47 | 42 |
| 8 | 111 | 85 | 70 | 61 | 69 | 41 | 43 |
| 9 | 325 | 281 | 158 | 176 | 158 | 147 | 157 |
| 10 | 251 | 201 | 107 | 123 | 120 | 112 | 115 |
| 11 | 332 | 259 | 174 | 173 | 189 | 142 | 135 |
| 12 | 356 | 282 | 176 | 163 | 154 | 119 | 112 |
| 13 | 289 | 246 | 135 | 142 | 158 | 132 | 138 |
| 14 | 282 | 267 | 150 | 143 | 154 | 130 | 155 |
| 15 | 197 | 144 | 97 | 96 | 96 | 82 | 73 |
| 16 | 278 | 250 | 167 | 143 | 166 | 108 | 174 |
| 17 | 232 | 211 | 138 | 107 | 132 | 89 | 112 |
| 18 | 351 | 282 | 190 | 186 | 170 | 147 | 144 |
| 19 | 123 | 104 | 68 | 68 | 72 | 59 | 54 |
| 20 | 275 | 200 | 128 | 146 | 135 | 105 | 105 |
| 21 | 244 | 217 | 124 | 126 | 130 | 113 | 109 |
| 22 | 321 | 259 | 169 | 150 | 173 | 112 | 123 |
| 23 | 204 | 176 | 101 | 100 | 101 | 89 | 80 |
| 24 | 174 | 150 | 115 | 90 | 90 | 72 | 78 |
| 25 | 128 | 100 | 66 | 59 | 63 | 46 | 36 |
| 26 | 355 | 278 | 204 | 176 | 176 | 132 | 143 |
| 27 | 159 | 138 | 89 | 76 | 76 | 66 | 69 |
| 28 | 257 | 236 | 143 | 113 | 153 | 109 | 134 |
| 29 | 316 | 246 | 151 | 171 | 169 | 134 | 142 |
| 30 | 298 | 270 | 139 | 143 | 131 | 135 | 115 |

| No. | $H_3$ | $W_3$ | $H_4$ | $W_4$ | $H_5$ | $W_5$ | $H_a$ | $W_a$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 115 | 123 | 103 | 116 | 95 | 100 | 38 | 76 |
| 2 | 100 | 107 | 93 | 86 | 81 | 77 | 32 | 70 |
| 3 | 47 | 53 | 39 | 36 | 39 | 36 | — | — |
| 4 | 117 | 111 | 88 | 86 | 82 | 95 | 14 | 30 |
| 5 | 77 | 62 | 59 | 58 | 41 | 39 | 18 | 51 |
| 6 | 92 | 86 | 81 | 101 | 70 | 81 | 27 | 65 |
| 7 | 42 | 42 | 27 | 28 | 26 | 22 | — | — |
| 8 | 34 | 32 | 27 | 30 | 24 | 20 | 14 | 28 |
| 9 | 117 | 111 | 116 | 103 | 109 | 115 | 32 | 74 |
| 10 | 86 | 78 | 73 | 70 | 78 | 57 | 24 | 66 |
| 11 | 116 | 119 | 90 | 96 | 69 | 62 | 35 | 59 |
| 12 | 122 | 119 | 138 | 127 | 104 | 104 | — | — |
| 13 | 103 | 112 | 90 | 100 | 55 | 49 | 36 | 61 |
| 14 | 115 | 103 | 96 | 92 | 70 | 66 | 24 | 76 |
| 15 | 73 | 76 | 89 | 65 | 50 | 62 | 19 | 42 |
| 16 | 89 | 105 | 84 | 88 | 88 | 66 | 27 | 57 |
| 17 | 103 | 101 | 73 | 84 | 61 | 55 | — | — |
| 18 | 130 | 127 | 120 | 127 | 109 | 108 | 23 | 50 |
| 19 | 41 | 32 | 32 | 31 | 35 | 34 | — | — |
| 20 | 80 | 81 | 81 | 88 | 76 | 77 | 35 | 55 |
| 21 | 88 | 95 | 76 | 82 | 77 | 81 | 32 | 63 |
| 22 | 100 | 88 | 117 | 96 | 89 | 89 | 28 | 63 |
| 23 | 84 | 73 | 65 | 62 | 57 | 47 | 28 | 51 |
| 24 | 66 | 70 | 46 | 57 | 47 | 39 | 14 | 100 |
| 25 | 55 | 50 | 42 | 41 | 42 | 39 | 14 | 35 |
| 26 | 147 | 136 | 138 | 109 | 95 | 89 | 30 | 73 |
| 27 | 39 | 45 | 53 | 53 | 41 | 41 | 20 | 43 |
| 28 | 108 | 115 | 86 | 78 | 57 | 80 | 24 | 59 |
| 29 | 113 | 108 | 108 | 97 | 82 | 69 | 26 | 58 |
| 30 | 130 | 117 | 108 | 116 | 97 | 108 | 27 | 81 |

TABLE 4. Complete data for sample B1-1 (Continued)

Mean (**M**), standard deviation (s), observed range (OR), and coefficient of variation (V) values for morphologic characters measured on *Praeglobotruncana gautierensis* (Brönnimann). Measurements are in microns.

| | M | s | OR | V |
|---|---|---|---|---|
| $H_t$ | 249 | 78 | 111-356 | 31 |
| $W_t$ | 209 | 64 | 85-282 | 31 |
| $T_t$ | 129 | 39 | 66-204 | 30 |
| $H_a$ | 26 | 7 | 14-36 | 26 |
| $W_a$ | 59 | 14 | 28-100 | 24 |
| $H_1$ | 125 | 41 | 50-186 | 33 |
| $W_1$ | 130 | 39 | 62-189 | 30 |
| $H_2$ | 103 | 34 | 41-147 | 35 |
| $W_2$ | 109 | 36 | 36-157 | 35 |
| $H_3$ | 91 | 29 | 34-147 | 32 |
| $W_3$ | 89 | 28 | 32-136 | 32 |
| $H_4$ | 81 | 31 | 27-138 | 38 |
| $W_4$ | 80 | 29 | 28-127 | 36 |
| $H_5$ | 68 | 25 | 24-109 | 35 |
| $W_5$ | 67 | 27 | 20-115 | 40 |

Correlation coefficient (r) and growth ratio (a) values for character combinations measured *Praeglobotruncana gautierensis* (Brönnimann).

| Character combination | r | a |
|---|---|---|
| $H_t$-$W_t$ | .969 | 1.216 |
| $H_t$-$W_t$ | .937 | .498 |
| $H_a$-$W_a$ | .719 | 2.063 |
| $H_1$-$H_a$ | .629 | 5.176 |
| $H_1$-$W_1$ | .945 | 1.043 |
| $H_2$-$W_2$ | .950 | .931 |
| $H_3$-$W_3$ | .956 | 1.039 |
| $H_4$-$W_4$ | .935 | 1.093 |
| $H_5$-$W_5$ | .937 | .909 |

Values of the total dispersion about the reduced major axis ($s_d$) and coefficient of relative dispersion about the reduced major axis ($D_d$) for selected character combinations on *Praeglobotruncana gautierensis* (Brönnimann).

| Character combination | $s_d$ | $D_d$ |
|---|---|---|
| $H_t$-$W_t$ | 25 | 8 |
| $H_1$-$W_1$ | 19 | 10 |
| $H_4$-$W_4$ | 15 | 13 |

variation in values which are based entirely upon test morphology. It has been suggested (Emiliani, 1950) that a relationship exists between test variability and environmental variation. The correspondence between the benthonic index and measures of test variability may thus indicate the existence of a closer correspondence than has previously been assumed between environment and test morphology.

### *Coiling Ratio*

The ratio of dextral to sinistral coiling in population samples of a planktonic species has been suggested as an indication of the stage of evolution attained by that species (Bolli, 1950, 1951, 1957). Coiling ratio changes have also been used as a stratigraphic correlation aid (Nagappa, 1957). Variation in the coiling ratios of *Globorotalia truncatulinoides* (d'Orbigny) has been determined to be a reliable criterion for deep-sea core correlation in the equatorial Atlantic (Ericson and Wollin, 1956).

In the present study coiling ratios of the species *Praeglobotruncana gautierensis* have been determined for 14 population samples of 30 individuals each, from five localities. The samples examined are from the Texas Cretaceous and range in age from lower Cenomanian to middle Campanian. Sample 119-19 is from the lower Cenomanian Grayson formation and was collected in Denton County at Grayson Bluff from Tappan's Zone 1 of this locality (Tappan, 1940). Sample 119-20 is from the Austin Chalk and was collected north of Howe, Grayson County. The Taylor sample is from locality 226-T-7 of the Bureau of Economic Geology of the University of Texas (Plummer, 1931). These samples were chosen to observe the coiling ratio of *Praeglobotruncana gautierensis* over a larger stratigraphic interval than that afforded by the Eagle Ford alone. Figure 3 shows the coiling ratios for these samples. A general trend may be observed in which the percentage of dextrally-coiled specimens increases in progressively younger strata. This may be the trend observed by Bolli which results in the establishment of a preferred coiling direction in the relatively younger population samples of a planktonic species. A considerable fluctuation in the coiling ratio values is apparent in the Eagle Ford "A" and "B" sections. This may be interpreted as the result of changing environmental conditions influencing the preferred coiling direction, as has been observed by Ericson and Wollin (1956) in a study of Recent forms. More probably it is a reflection of the more detailed sampling of these localities. The primary significance of Figure 3 is the clearly defined establishment of a preferred coiling direction over the interval examined.

### *Univariate Analysis*

The observed range, arithmetic mean and standard deviation are used in this study to characterize population samples. Confidence intervals of the arithmetic mean have been established using a probability level of 0.025. The confidence interval has been determined from the formula:

Confidence interval of **M** = **M** ± ts**M**

where **M** = arithmetic mean

$$s\mathbf{M} = - \text{ standard error of the mean } = \frac{\text{standard deviation}}{\sqrt{N}}$$

N = number of observations

Values of *t* for the desired probability level may be obtained from a statistical text, as may the method of determination of **M** and s**M**.

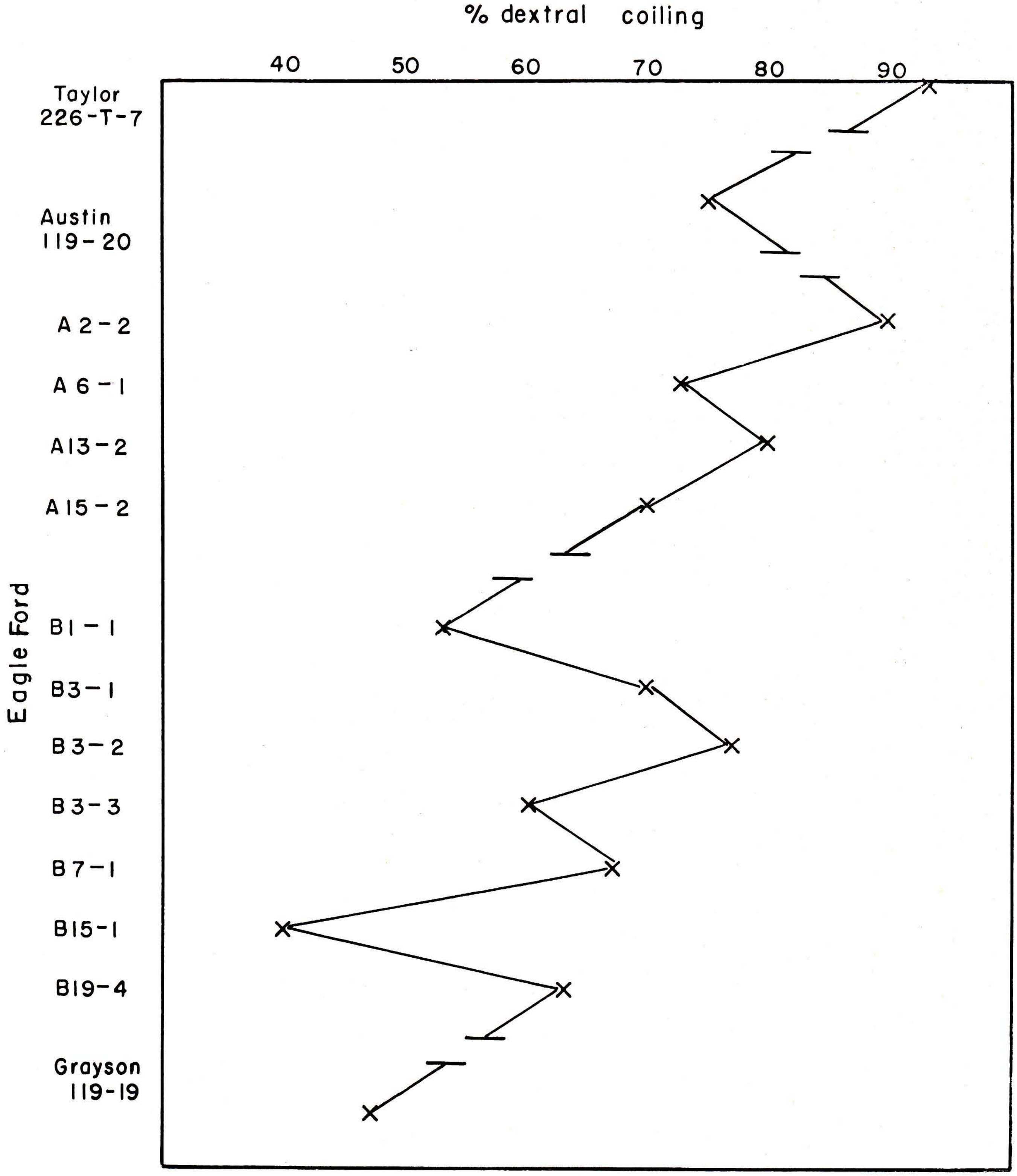


Fig. 3 Coiling ratios of Praeglobotruncana gautierensis (Bronnimann) from five Texas Cretaceous localities.

Figure 4 illustrates the variation in these statistics within the stratigraphic interval investigated.

*Coefficient of Variation (V)*

The coefficient of variation is computed from the formula:

$$V = \frac{100 \text{ standard deviation}}{\text{Mean}}$$

Emiliani (1950) has suggested that a relationship exists between environmental conditions and total morphologic variability as measured by this statistic. In near-optimum environmental conditions morphologic variability is expected to be smallest. Deviations from this may be reflected by changes in the morphologic variability of the organism investigated.

In the present study the coefficient of variation is

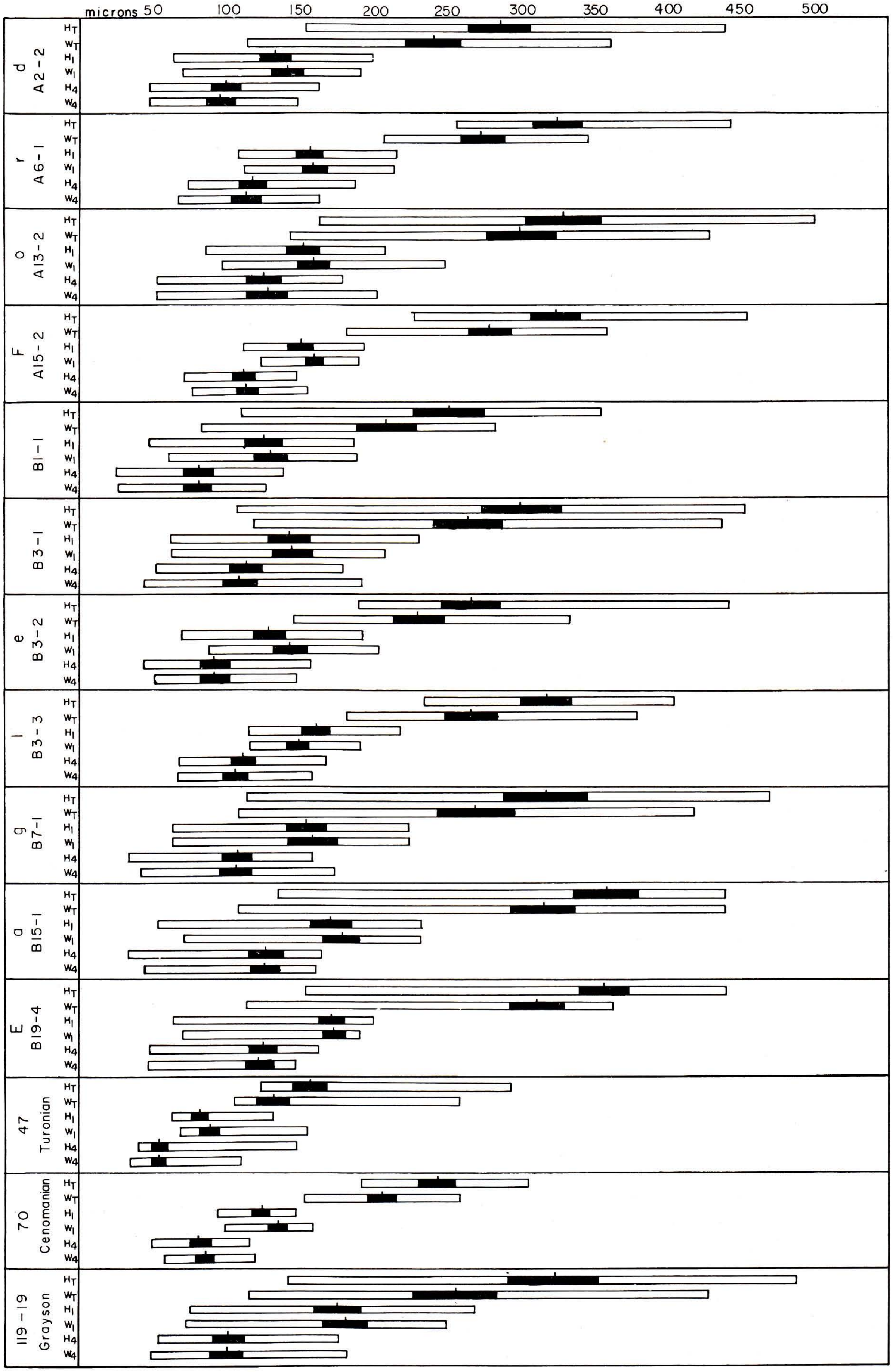


Fig. 4 Observed range, arithmetic mean, and confidence interval of the mean computed for a probability level of 0.025 for population samples of <u>Praeglobotruncana gautierensis</u> (Bronnimann). The total length of each bar represents the observed range, the vertical line the arithmetic mean, and the shaded portion the confidence interval for the arithmetic mean.

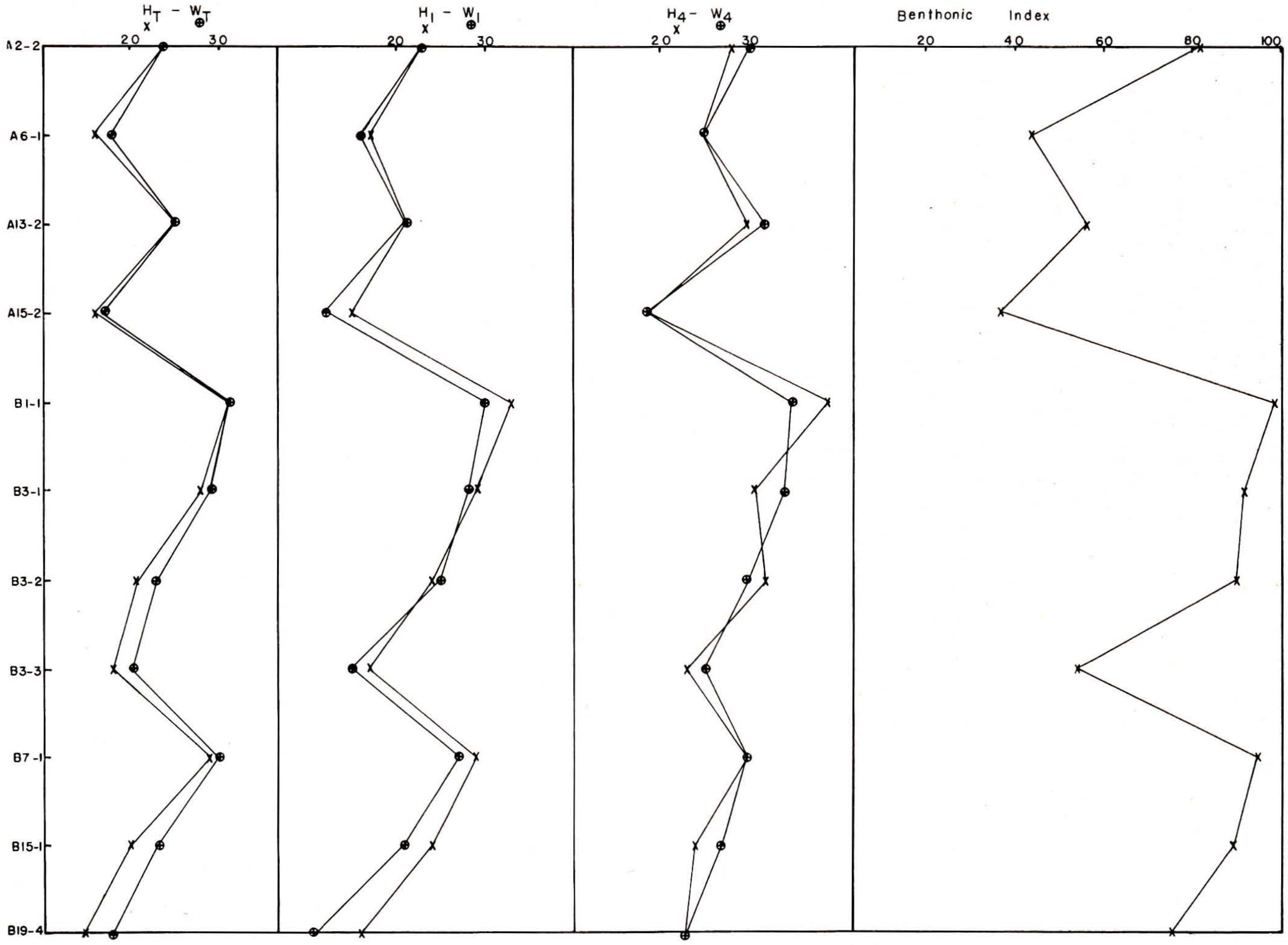


Fig. 5 Coefficient of variation values for six morphologic characters measured on specimens of *Praeglobotruncana gautierensis* (Bronnimann) from localities "A" and "B". The benthonic index values for these localities are also graphed, showing the high degree of correlation of these curves.

utilized to indicate changing environment, on the premise that a changing environment will affect the variability of the morphology of the organism. The V-values were calculated for fifteen morphologic characters measured on population samples from locality "B." These are the characters shown in Figure 1. Six characters — $H_t$, $W_t$, $H_1$, $W_1$, $H_4$, and $W_4$ were chosen to be measured on specimens from other population samples. Figure 5 illustrates the variation in V-values for the six selected characters measured on specimens from localities "A" and "B." Changes in the V-values for successive population samples may be interpreted as a reflection of environmental modification, if it is first considered that some changes in the environment are, in part, reflected by changes in the morphologic variability of the organisms investigated. A test of the validity of this assumption is a comparison of the V-values with fluctuations in other population parameters which are non-dimensional and respond to environmental changes independently of morphologic test features. One such parameter is the benthonic index. Figure 5 demonstrates the close correlation of the coefficient of variation and benthonic index curves. This suggests that the variation observed in the V-values may indeed be the result of a changing environment acting upon test morphologic features, and that these or related environmental changes are also responsible for the fluctuations observed in the benthonic index values.

It is generally thought that the percentage of planktonic forms increases with increasing water depth and distance from shore. As these two factors are usually related it may be assumed that the benthonic index generally varies inversely with distance from shore and water depth. Fluctuation in this value may therefore be considered a broad measure of change in these two factors.

The stratigraphic interval sampled at localities "A" and "B" is one of essentially similar lithologies. The sediments deposited during this interval indicate relatively stable sedimentary conditions and the changes which do occur represent only minor environmental shifts. No pattern is apparent from a study of the sediments of this interval. The fluctuations observed in both the benthonic index and the coefficient of variation thus assume importance as possible indicators of more subtle changes than can be determined from a study of the sediments alone. The V-values vary directly with the benthonic index values and are thought to reflect the same or related environmental changes. Obviously there are other factors which could be considered in this analysis but at the present time these are not recognized from a study of the fossils or their enclosing sediment.

### *Correlation Coefficient (r)*

A high degree of linear correlation exists between quantitative expressions of related morphologic features such as the height and width measurements of a single chamber. The test height and width correlation values are also high as would be expected from two such generalized and related features. The aperture is one of the more variable characters examined. Highly variable apertural measurements may be due in part to measuring errors since the method of measuring is more subjective than others used in this study.

Studies of reduced major axes and relative and absolute dispersion about the reduced major axes are dependent upon a high degree of correlation between the variables investigated. The character combinations $H_t$-$W_t$, $H_1$-$W_1$, and $H_4$-$W_4$ all show high correlation coefficient values and have been chosen for more complete statistical treatment. The method of determination of *r* is explained in standard statistical texts.

### *Reduced Major Axis*

The reduced major axis is the growth line which best represents a dispersion of points plotted on a bivariate scattergram. This growth line makes no assumption of independence for the variables investigated and is considered the most useful for paleontologic work (Imbrie, 1956). Three factors are involved in the determination of the reduced major axis: (1) the position of the joint means of the two variables, which establishes a point on the line, (2) the slope, which is determined from the value of the growth ratio (a), and (3) the absolute length of the line as based upon the values of the observed ranges of the variables.

The growth ratio (a) is an expression of the difference between two growth rates. It is computed by the formula:

$$a = \frac{s_y}{s_x}$$

where $a$ = growth ratio
$s_y$ = standard deviation of y-variable
$s_x$ = standard deviation of x-variable

The value of *a* is equal to the tangent of the angle of slope of the reduced major axis. The reduced major axis may be constructed by determining a point, as established by the joint means of the two variables, and the angle of slope as determined from the value of *a*.

The reduced major axis was plotted for the character combinations $H_t$-$W_t$, $H_1$-$W_1$, and $H_4$-$W_4$ for all population samples of *Praeglobotruncana gautierensis*. Each of these character combinations generally shows a high degree of linear correlation. It is thought that the reduced major axis for the character combinations analyzed may be considered representative of the population sample. Slope differences for these combinations were generally not statistically significant. Positional differences were found to be more significant. The reduced major axis does not appear to be a critical measure of the morphologic variability of the species *Praeglobotruncana gautierensis* for the interval investigated, but for well-correlated character combinations of this species it is useful as a means of population representation.

The spread, or deviation of points about the reduced major axis is of critical importance in the analysis of minor morphologic variation within this species. The reduced major axis may be considered analagous to the arithmetic mean in that both express an average value for a group of variables. The amount of dispersion from this average value is a measure of population morphologic variability. Two methods of measuring this variability have been employed, one absolute and the other relative.

The total (absolute) dispersion about the reduced major axis may be expressed as the standard deviation ($s_d$) of the sums of the vector distances that each point is from the reduced major axis (Imbrie, 1956, p. 239; also Kermack and Haldane, 1950) and is computed by the formula:

$$s_d = \sqrt{2(1-r)\ (s_x^2 + s_y^2)}$$

where $r$ = correlation coefficient
$s_x$ = standard deviation of x-variable
$s_y$ = standard deviation of y-variable

Changes in the $s_d$ values indicate different amounts of absolute variation in the characters tested. It has been shown that variation in some morphologic features of the test (as measured in terms of the coefficient of variability) is well correlated with benthonic ratio variation, and that the same or related environmental factors may have influenced the variability of both these parameters. It is here postulated that a change in the degree of dispersion of points about the reduced major axis as measured by $s_d$ may likewise be used to indicate changing environment. Figure 6 illustrates the variation in these values. The curves show no correlation with curves of other population parameters investigated, excepting those of the $D_d$-value, as discussed below.

A relative value of the dispersion of points about the reduced major axis is more desirable paleontologically than an absolute value. The relative value minimizes the effect of the absolute size of the organism being investigated. The coefficient of relative dispersion about the reduced major axis ($D_d$) is such a value (Imbrie, 1956, p. 241). It is an expression of the amount of shape variation as a proportion of the average sample shape and is computed from the formula:

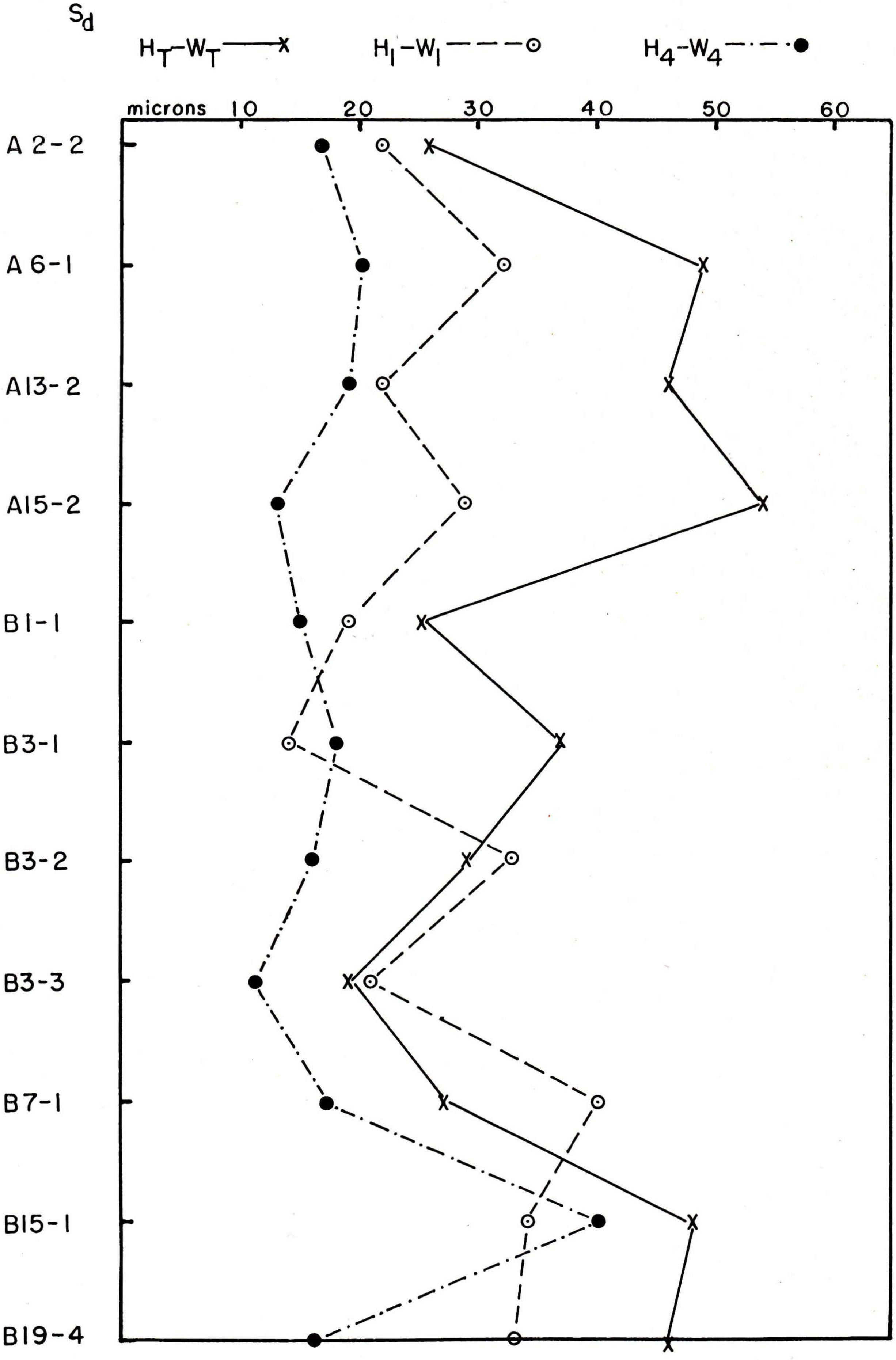


Fig. 6 Standard deviation of the total dispersion about the reduced major axis ($S_d$) values for population samples of Praeglobotruncana gautierensis (Bronnimann) from localities "A" and "B".

$$D_d = 100 \frac{2(1-r)\ (s_x^2 + s_y^2)}{x^2 + y^2}$$

where $r$ = correlation coefficient
$s_x$ = standard deviation of x-variable
$s_y$ = standard deviation of y-variable
$x$ = arithmetic mean of x-variable
$y$ = arithmetic mean of y-variable

This statistic is the most sensitive measure of morphologic variability to be analyzed in this study. Figure 7 illustrates the variation in the $D_d$ values for the character combinations tested in population samples of *Praeglobotruncana gautierensis* from localities "A" and "B." $H_t$-$W_t$, a measure of the totality of test variation, is probably less sensitive to environmental variation than is $H_1$-$W_1$ which measures final chamber variation and is more apt to be influenced by fluctuation in minor environmental factors. There is a general correlation of the curves for $s_d$ and $D_d$ for similar character combinations, as would be expected for two related values. These curves show no correspondence to curves of the other parameters analyzed in this study. $D_d$ and $s_d$ measure extremely small variations in test morphology, while the other values measure more gross aspects of the successive fossil populations. It has been shown that a high degree of correlation exists between the coefficient of variation values and the benthonic index, a parameter which may in part be environmentally controlled and which is apparently unrelated to test morphology. It follows that the variation observed in $s_d$ and $D_d$ may also be a measure

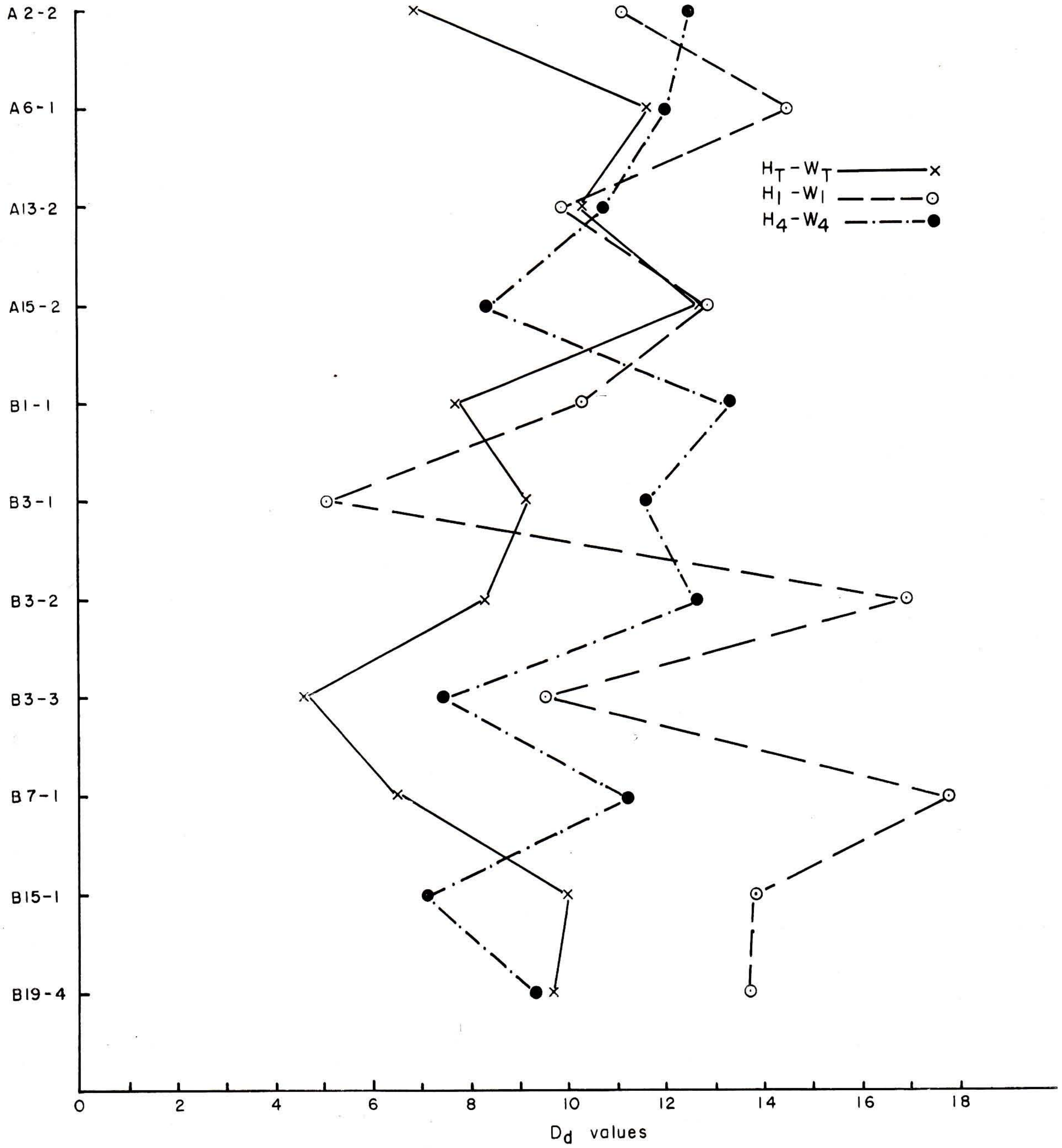


Fig. 7 Coefficient of relative dispersion about the reduced major axis ($D_d$) values plotted against stratigraphic position for three character combinations ($H_T$-$W_T$, $H_1$-$W_1$, $H_4$-$W_4$) measured on population samples of Praeglobotruncana gautierensis (Bronnimann) from localities "A" and "B"

of morphologic expression of environmental fluctuation, but of a degree that the environmental variance is reflected in neither the enclosing sediment nor in gross characteristics of the foraminiferal assemblage itself. Even though it is problematical that the variations in these two population parameters may be correlated with any variable found in an assemblage of fossil Foraminifera or the enclosing sediment, these measures of morphologic variation should not be disregarded. It is possible that detailed studies of living pelagic foraminiferal populations and their environments may aid in the recognition of the environmental factors causing such variations. If these factors could be isolated it would provide a method for paleoecologic determination. A continuation of the present study is in progress in which living pelagic foraminiferal assemblages and their environments are being studied in an attempt to gain more understanding of the fundamental relationships which may exist between environmental variation and morphologic variability.

## SYSTEMATIC PALEONTOLOGY

### Order FORAMINIFERA

### Family GLOBOROTALIIDAE Cushman, 1927

### Genus **Praeglobotruncana** Bermúdez, 1952

### **Praeglobotruncana gautierensis** (Brönnimann), 1952

Plate 15, figures 1-7

*Globigerina gautierensis* Brönnimann, 1952, Bull. Amer. Paleontology, vol. 34, no. 140, p. 11-14, pl. 1, figs. 1-3, text fig. 2.

*Globigerina cretacea* d'Orbigny. Tappan, 1940 (not of d'Orbigny) Jour. Paleontology, vol. 14, no. 2, p. 121-122, pl. 19, figs. 11a-c. Tappan, 1943, (not of d'Orbigny) Jour. Paleontology, vol. 17, no. 5, p. 512, pl. 82, figs. 16-17.

*Praeglobotruncana gautierensis* (Brönnimann). Bolli, 1959, Bull. Amer. Paleontology, vol. 39, no. 179, p. 265-266, pl. 21, figs. 3-6.

*Praeglobotruncana* cf. *gautierensis* (Brönnimann). Bolli, 1959, Bull. Amer. Paleontology, vol. 39, no. 179, p. 266, pl. 21, figs. 7-8.

*Diagnosis.*—Test free, trochospiral, biconvex, umbilicate, periphery rounded; no adult keel, rarely an incipient keel in early chambers; surface smooth, rarely pitted or hispid, early chambers may be hispid with final two or three becoming smooth; 10 to 12 chambers, spherical to ovate, extreme variations becoming clavate, arranged in two to three whorls with five to seven rapidly expanding chambers in final whorl; sutures depressed, radial; open, broad umbilicus; relatively high aperture, interiomarginal, extraumbilical-umbilical, bordered above by a simple lip which may broaden towards and extend slightly into umbilicus, relict lips may extend a short distance into umbilicus.

*Stratigraphic Range.*—Lower Cenomanian to middle Campanian in the Texas Cretaceous. Originally reported from the Upper Cretaceous of Trinidad.

*Discussion.*—This species was described from the Upper Cretaceous Gautier formation of Trinidad where it ranges from the Cenomanian to the Maestrichtian. Material examined from the Texas Cretaceous indicates a minimum range of lower Cenomanian (Grayson formation) to middle Campanian (middle Taylor marl). The writer had originally referred this form to the species "*Globigerina*" *cretacea* d'Orbigny but the lectotypic description of this species, if interpreted correctly, by Banner and Blow (1960) has shown this assignment probably invalid. Material from Tappan's Grayson locality (Tappan, 1940) was examined. The form which she has assigned to *Globigerina cretacea* d'Orbigny was found to be conspecific with *Praeglobotruncana gautierensis* from the Eagle Ford. In addition, samples were examined from the Austin chalk and Taylor marl in which *Praeglobotruncana gautierensis* was present. Although this form varies in abundance in the several samples examined, it is generally the most abundant planktonic species present.

The characteristic features and range of variation observed in *Praeglobotruncana gautierensis* are shown in Plate 15. The figured specimens are all from localities "A" and "B" of the Eagle Ford Britton formation, excepting figures 9a-c, which are from the Grayson formation. The apertural opening varies in height and width, but remains constant in position. Figures 1b, 2b, 7b, 8, and 9b illustrate the observed variation in this characteristic. Figures 3 through 6 show the range of variation in chamber shape and indicate a possible trend toward clavate chambers in one line of development. This morphocline has not been observed in a study of successive population samples. An apertural lip is often developed, varying from slight to broad and usually thickening toward the umbilicus. Figures 1a, 2a, 3, 4, 5, 6, 7a, and 9a illustrate this feature. Occasional specimens show relict lips from previous chambers.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XI, PART 3, JULY, 1960

# RECENT LITERATURE ON THE FORAMINIFERA

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

ALLARD, P. L., et al. Les Foraminifères et le Crétacé Supérieur Français. Mise au point et Données Nouvelles.—84^e^ Congrès des Soc. Savantes de Paris et de Départments, Sec. des Sci., 1959, p. 591-660, 2 maps, table 1.—Lists of species from many localities in Aquitaine, Provence, Alpes, Bresse, Jura, and Paris Basin.

ANDRUSOV, DIMITRIJ. Geologia Ceskoslovenskych Karpat.—Bratislava, 1959, 375 p., 84 pls., 34 text figs., 10 tables.—Foraminifera, mostly planktonic, are used between Lower Cretaceous and Danian.

AYALA-CASTANARES, AGUSTIN. Estudio de Algunos Microfosiles Planctonicos de las Calizas del Cretacico Superior de la Republica de Haiti.—Univ. Nac. Autonoma Mexico, Paleontologia Mexicana No. 4, 1959, p. 1-41, pls. 1-12, text figs. 1, 2 (map, distrib. table).—Twenty-six species, only 14 specifically identifiable, recorded and illustrated in section.

BANNER, F. T., and BLOW, W. H. The taxonomy, morphology, and affinities of the genera included in the subfamily Hastigerininae.—Micropaleontology, v. 6, No. 1, Jan. 1960, p. 19-31, text figs. 1-11.—Five species described and illustrated; three in **Hastigerina**, one in **Hastigerinella**, and one in **Globorotalia**. **Hastigerinella** is distinguished from **Hastigerina** by streptospiral coiling and by bifurcation of the later chambers, sometimes preceded by bifocal concentration of spines. **Beella**, new subgenus of **Globorotalia** (type species **Globigerina digitata** Brady, 1879 [partim], emended Banner and Blow 1959), is erected.

BARNARD, TOM. Some species of **Lenticulina** and associated genera from the Lias of England.—Micropaleontology, v. 6, No. 1, Jan. 1960, p. 41-48, pls. 1-7, text fig. 1 (range chart).—Nine variable species groups are defined as Forms A to I and their variants are illustrated. The groups are compared with named species and their ranges indicated within the ammonite zonation of the Lias. Gradation between lenticuline and flabelline stages is demonstrated.

BARTENSTEIN, HELMUT. Neue mikropaläontologische Beobachtungen zu den Tertiärvorkommen des Reinhardswaldes und des benachbarten Bramwaldes.—Notizbl. hess. L.-Amt Bodenforsch., Band 87, June 5, 1959, p. 367-375, pl. 21, text fig. 1 (map).—Illustrations of arenaceous Foraminifera from the upper Oligocene.

BERGGREN, W. A. Some planktonic Foraminifera from the lower Eocene (Ypresian) of Denmark and northwestern Germany.—Acta Univ. Stockholm., Stockholm Contrib. in Geol., v. 3, Jan. 30, 1960, p. 41-108, pls. 1-13, text figs. 1-12 (maps, correlation tables, pore patterns, drawings).—Fifteen species, one new and two indeterminate, belonging in the genera **Globigerina**, **Hastigerina**, and **Globorotalia**, are described and illustrated. Pore size and pore patterns appear to be of taxonomic value at the species level. Possibility is discussed that the assemblage may be transitional between Paleocene and Eocene.

BETTENSTAEDT, FRANZ. Art- und Gattungsbildung. Eine Untersuchung an fossilen Foraminiferen.—Natur und Volk, Bericht Senckenberg. Naturforsch. Gesellschaft, Band 89, Heft 11, Nov. 1, 1959, p. 367-379, text figs. 1-7.—Evolution of **Spiroplectinata** from **Gaudryina**.

BLANC-VERNET, LAURE. Les milieux sédimentaires littoraux de la Provence occidentale (côte rocheuse). Relations entre la microfaune et la granulométrie du sédiment.—Bull. Instit. Océanographique, Monaco, No. 1112, Feb. 15, 1958, p. 1-45, text figs. 1-8 (maps, graphs).—Quantitative analyses of granulometry and Foraminifera assemblages (as families) from environments of brackish ponds, beaches, clusters of marine phanerogams, floors of passes, submarine grottoes, and muddy sands of the circumlittoral zone (depths from 0 to 80 meters). Many species are listed.

BOLLI, HANS M. Planktonic Foraminifera as index fossils in Trinidad, West Indies, and their value for worldwide stratigraphic correlation.—Eclogae Geol. Helvetiae, v. 52, No. 2, 1959 (Jan. 29, 1960), p. 627-639, table 1.—Summary of current zonation between Lower Cretaceous and Miocene and tentative correlations with Gulf Coast and Europe.

BOMBITA, GH. L'Ypresien de Varna (French resumé).—Acad. Repub. Pop. Romine, Bul. Stiintific, sec. Geol. Geogr., tom II, 3-4, 1957, p. 625-632, text figs. 1-10.—Correlation based on nummulites.

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BROTZEN, FRITZ. On **Tylocidaris** species (Echinoidea) and the stratigraphy of the Danian of Sweden with a bibliography of the Danian and the Paleocene.—Sver. Geol. Undersökning, ser. C, No. 571, Arsbok 54, No. 2, 1960, p. 1-81, pls. 1-3, text figs. 1-19, tables 1, 2.—Includes list of Foraminifera from a quarry section of Stevnsian (= upper part of Maestrichtian) and Danian. Extensive bibliography (27 pages).

BUTTERLIN, JACQUES, and BONET, FEDERICO. Répartition stratigraphique de **Operculina catenula** Cushman et Jarvis dans le bassin des Caraïbes.—C. R. S. Soc. Géol. France, Jan. 18, 1960, fasc. 1, p. 14, 15.—Range extended throughout lower Eocene.

CHANG, LIN-HSIN. On the occurrence of **Parafusulina rothi** in the Permo-Carboniferous rocks of Hsilingrameng, Inner Mongolia.—Acta Pal. Sinica, v. 5, No. 3, August 1957, p. 453-456, pl. 1.

CIFELLI, RICHARD. Notes on the distribution of English Bathonian Foraminifera.—Geol. Mag., v. 97, No. 1, Jan. 1960, p. 33-42.—Lagenidae is the predominant family. Four faunules, having the same order of superposition, are recognized in different geographic areas. Comparison of species ranges between England and Germany reveal unexplained discrepancies, suggesting that certain species ranged higher in England.

CITA, M. B., FORTI, A., RAFFI, G., and VILLA, F. Jurassic and Cretaceous microfacies from the Prealps and Central Apennines (Italy).—Fifth World Petroleum Congress (New York), 1959, sec. I, Paper 54, p. 1-32, pls. 1-20, text figs. 1-8 (map, stratigraphic sections, correlation table).—Correlation of microfossil zones between four sections. Microfacies are illustrated in thin sections of rocks.

CITA, MARIA BIANCA, and PASQUARÉ, GIORGIO. Studi stratigrafici sul sistema Cretaceo in Italia. Nota IV. Osservazioni micropaleontologiche sul Cretaceo delle Dolomiti.—Riv. Ital. Pal. Stratig., v. 65, No. 4, 1959, p. 385-442, pls. 25-28, text figs. 1-6.—Among six groups of assemblages distinguishable in thin section, one, from Lower Cretaceous, is characterized by globigerinids.

COLE, W. STORRS, TODD, RUTH, and JOHNSON, CHARLES G. Conflicting age determinations suggested by Foraminifera on Yap, Caroline Islands (includes appendix, Larger Foraminifera from Yap by W. STORRS COLE and Smaller Foraminifera from Yap by RUTH TODD).—Bull. Amer. Pal., v. 41, No. 186, March 25, 1960, p. 73-112, pls. 11-13, text fig. 1 (map), tables 1-3.—Fossils from a single sample correlated by larger Foraminifera with Tertiary **f** but by planktonic Foraminifera with Tertiary **d.** Both kinds are illustrated.

DAVIS, EL. Die stratigraphische Gliederung der erdölführenden Schichten der Insel Zante.—Praktika, Akad. Athenon, tom. 34, 1959, p. 120-129, pls. 1, 2, text fig. 1 (columnar section).—Lists and illustrations of nummulites from Lutetian beds and smaller Foraminifera from Miocene and Pliocene beds.

DROOGER, C. W. **Miogypsina** in northwestern Germany.—Proc. Kon. Nederl. Akad. Wetenschappen, ser. B, No. 1, 1960, p. 38-50, pls. 1, 2.—One **Miogypsina** (new) and one **Lepidocyclina** from the classical localities of Astrup and Doberg of Chattian age permit comparison with the Aquitaine basin and indicate the Chattian is older than, and without any considerable time gap from, the typical Aquitanian near Bordeaux.

DURIF, PAUL. Observations micropaléontologiques (Foraminifères) sur le Carbonifère marin du bassin de Fort-Polignac (Sahara oriental).—Bull. Soc. Géol. France, sér. 7, tome 1, No. 2, Dec. 1959, p. 163-165.

EAMES, F. E., BANNER, F. T., BLOW, W. H., and CLARKE, W. J. Mid-Tertiary stratigraphical palaeontology.—Nature, v. 185, No. 4711, Feb. 13, 1960, p. 447-448.—Observations on the Foraminifera assemblages characteristic of the Lattorfian, Rupelian, Chattian, Aquitanian, and Burdigalian and possibility of worldwide correlation. Absence of marine Oligocene in the western hemisphere resulted in reworking of Eocene into basal Miocene beds.

FLÜGEL, ERIK. Statement concerning the types and figured originals from the collections of the **Novara** Expedition in the custody of the Geological-Paleontological Section of the Museum of Natural History, Vienna, Austria (with an appendix by C. A. FLEMING and N. de B. HORNIBROOK, "Notes on the localities of New Zealand fossils collected by the **Novara** Expedition").—New Zealand Jour. Geol. Geophys., Hochstetter Centenary Issue, v. 2, No. 5, Dec. 1959, p. 826-845.—Foraminifera described by Karrer and Stache are present (with a few exceptions) and number of specimens is recorded; those described by Schwager from Kar Nicobar are missing.

FORBES, C. L. Carboniferous and Permian Fusulinidae from Spitsbergen.—Palaeontology (Pal. Assoc. London), v. 2, pt. 2, March 1960, p. 210-225, pls. 30-33, text fig. 1, table 1.—Seventeen species, none new.

GAMBINI, ANDRÉE. Sur la composition de quelques sables coquilliers à Foraminifères des lagons de la Nouvelle-Calédonie.—Bull. Soc. Géol. France, sér. 7, tome 1, No. 4, 1959 (Feb. 1960), p. 431-433, pl. 28, text fig. 1 (map), table 1.—List of species; **Marginopora** predominates.

GREEN, KEITH E. Ecology of some Arctic Foraminifera.—Micropaleontology, v. 6, No. 1, Jan. 1960, p. 57-78, pl. 1, text figs. 1-9 (maps, profile, graphs), tables 1-6.—Quantitative study of species compared with ecologic factors is based on cores and bottom samples taken between 433 and 2,760 meters depth from an area north of northwestern Ellesmere Island. The qualitatively uniform fauna, primarily hyaline and mostly **Globigerina pachyderma,** shows striking quantitative differences with depth, permitting zonation into shelf, slope, apron, and abyssal, with each zone having several indicator species. Displacement by turbidity-flow is recognized in the middle of one core. About 100 species are recorded (five species and one variety new and 28 indeterminate). Few specimens were stained by rose bengal.

HOFKER, J. Foraminifera from the Cretaceous of Limburg, Netherlands. XLII. On the development stage of **Globigerina pseudobulloides** Plummer in the Maestrichtian Chalk Tuff.—Natuurhist. Maandblad, 48<sup>e</sup> Jrg., Nos. 5-6, June 26, 1959, p. 80-83, text figs. 1-5.—Knobs between pores instead of honeycomb structure around pores, and pore diameters of 1 μ instead of 2 μ, show that specimens belong to a more primitive stage of evolution than that shown by type specimens. Equivalence of the Maestrichtian Chalk Tuff with the Danian of Denmark is indicated.

XLIII. Globigerines and related forms in the Cretaceous and Lower Paleocene of South Limburg.—Natuurhist. Maandblad, 48$^e$ Jrg., Nos. 7-8, Aug. 28, 1959, p. 89-95, text figs. 1-9.—Wall rugosities on **Globigerina cretacea** and **G. rugosa** increase in younger strata, thus aiding recognition of reworked Cretaceous specimens in the turbulent water facies of the Maestrichtian Chalk Tuff.

XLIV. The age of the Kunrade Chalk.—Natuurhist. Maandblad, 48$^e$ Jrg., Nos. 9-10, Oct. 30, 1959, p. 121-124, columnar sections.—Determined as an inner shoal deposit of upper Danian age.

XLV. **Dyocibicides kunradensis** nov. spec.—Natuurhist. Maandblad, 48$^e$ Jrg., Nos. 9-10, Oct. 30, 1959, p. 125-126, text figs. 1-4.—Of Dano-Paleocene age.

XLVI. Analysis of the Ma in the type-locality behind the Bicycle-Barn at Enci-quarry.—Natuurhist Maandblad, 48$^e$ Jrg., Nos. 11-12, Dec. 29, 1959, p. 145-148, 1 table.—A thin regression-transgression deposit forming the boundary between uppermost Maestrichtian and lowermost Danian.

Orthogenesen von Foraminiferen.—Neues Jahrb. Geol. Paläont., Abh., Band 108, heft 3, Oct. 1959, p. 239-259, text figs. 1-14.—Examples taken from various characters in the genera **Neoflabellina, Bolivinoides, Stensiöina, Gavelinella,** and **Gavelinopsis.**

Die asterigeriniden Foraminiferen.—Paläont. Zeitschr., Band 33, heft 4, Nov. 1959, p. 247-265, 2 pls., 2 text figs.—Sixteen species (none new) belonging in the genera **Asterigerina, Asterigerinoides, Asterigerinata,** and **Heminwayina** are described and illustrated.

Les Foraminifères des Craies Tuffoïdes de Charente et Dordogne de l'Aquitaine, France du Sud-ouest.—84$^e$ Congrès des Soc. Savantes de Paris et de Départments, Sec. des Sci., 1959, p. 253-368, text figs. 1-214, tables 1-3.—About 100 species, 11 new. Ranges in the Aquitaine are in general longer and begin earlier and end later than in the boreal regions.

Les Foraminifères du Crétacé Supérieur du Cotentin.—84$^e$ Congrès des Soc. Savantes de Paris et de Départments, Sec. des Sci., 1959, p. 369-397, text figs. 1-68.

—Fifty-three species; one new in the genus **Praelacazina** nov. gen. (genotype **Biloculina fragilis** Hofker). Age interpreted as uppermost Maestrichtian.

The Foraminifera of the lower boundary of the Danish Danian.—Medd. Dansk Geol. Forening, Band 14, hefte 3, 1960, p. 212-242, text figs. 1-47.—Five zones based on smaller Foraminifera are recognized across the boundary; two zones in Danian, one zone of reworked specimens in Fish clay regression-transgression deposit, and two zones in upper Senonian. Correlation with Holland is discussed both on the basis of zones and on the basis of orthogenesis of pore diameters in several species. Twenty-eight species and subspecies (four new) are illustrated.

The genus **Truncorotalia** Cushman and Bermudez, 1949. —Micropaleontology, v. 6, No. 1, Jan. 1960, p. 111-115, text figs. 1-10.—**Truncorotalia** ranges from Danian or uppermost Maestrichtian to Recent and may have evolved out of **Globorotalites.** Specimens of its type species show open and closed umbilical cavities from different localities. **Conorotalites** is synonymous with **Globorotalites.**

HOOPER, KENNETH. The genus **Operculina** in Australia, a literature survey: 1826-1958.—Carleton Univ. (Ottawa), Dept. Geology, Geol. Paper 59-1, 1959, p. 1-6 (mimeographed), text fig. 1.

IGO, HISAYOSHI, and OGAWA, KEIZO. Fusulinids from the Funafuseyama limestone, Part 1.—Jubilee Publ. Comm. Prof. H. Fujimoto Sixtieth Birthday, 1958, p. 49-57, pls. 1, 2.—Four species of **Parafusulina,** one new and one indeterminate.

JURKIEWICZ, HENRYK. Microfaunal correlation in the Palaeogene of the eastern part of the Silesian nappe (English summary of Polish text).—Ann. Soc. Geol. Pologne, v. 29, fasc. 3, Année 1959, p. 235-263, pls. 23-26.—Nine distinctive assemblages of smaller Foraminifera are recognized in a section of Paleocene to middle Eocene. Assemblages are illustrated and ranges and abundances of 66 species indicated.

KLAUS, JEAN. Le "Complexe schisteux intermédiaire" dans le synclinal de la Gruyère (Préalpes médianes). Stratigraphie et micropaléontologie, avec l'étude spéciale des Globotruncanidés de l'Albien, du Cénomanien et du Turonien.—Eclogae Geol. Helvetiae, v. 52, No. 2, 1959 (Jan. 29, 1960), p. 753-851, pls. 1-8, text figs. 1-9, tables 1, 2.—About 40 species and subspecies, mostly globotruncanids, recorded and illustrated, with minor revisions of taxonomy. Partly new phylogeny proposed. Seven zones set up between lower Albian-Aptian? and Coniacian-upper Turonian.

LORENZ, C. Les couches à Lépidocyclines de Mollere (près de Ceva, Piémont, Italie).—Revue de Micropaléontologie, v. 2, No. 4, March 1960, p. 181-191, pls. 1-3, text figs. 1-4 (map, sections, range chart).—A rich **Lepidocyclina** conglomerate at the base of a transgression is dated as Aquitanian.

LUCINI, P. Su due microfaune del Flysch del versante tirrenico della Basilicata.—Boll. Soc. Geol. Ital., v. 77, fasc. 3, 1958 (1959), p. 173-181, text figs. 1-4 (microphotographs and range chart).—Photographs of the most significant planktonic elements from two Cretaceous microfaunas, Cenomanian and Campanian-Maestrichtian.

MALAKHOVA, N. P. Turnejskij Jarus Severnogo i Srednego Urala.—Akad. Nauk SSSR, Ural. filial, Trudy Gorno-Geol. Instit., Vyp. 38, 1959, p. 1-104, pls. 1-14.—Paleontologicheskaja Chasty (p. 85-99) includes 24 species (5 new) of Tournaisian Foraminifera.

MARIE, PIERRE. Sur les faciès à Foraminifères du Coniacen subrécifal de la région de Foissac (Gard) et sur le nouveau genre **Sornayina.**—Bull. Soc. Géol. France, sér. 7, tome 1, No. 3, 1959 (Feb. 1960), p. 320-326, pl. 19b, text figs. 1, 2, table 1.—Trochiform agglutinated genus with cribrate aperture. **Sornayina** nov. gen. (genotype **S. foissacensis** n. sp.) and three new species.

MARTIROSJAN, J. A. Globotrunkany iz Verkhnemelovykh Otlozhenij Jugo-Zapadnoj Chasti Armjanskoj SSR.—Akad. Nauk Armianskoi SSR, Izvestia, ser. geol. geogr. Nauk, tom. 11, No. 6, 1958, p. 7-16, pls. 1-4.—Nine species of **Globotruncana,** four new.

MAYNC, WOLF. Bemerkungen zur Systematik der Lituolidae.—Paläont. Zeitschr., Band 33, Nr. 4, Nov. 1959, p. 199-210.—Significance in systematics of type of coiling, aperture, and other morphologic features.

On some larger arenaceous Foraminifera from the Liassic limestone section of Monte Baldo, east of Lago di Garda, Italy.—Riv. Ital. Pal. Stratig., v. 65, No. 4, 1959, p. 367-382, pls. 21-24.—Five species recorded and illustrated in thin section from rocks dated as Domerian (middle Lias).

MOULLADE, M. Sur l'attribution spécifique de Foraminifères appartenant au genre **Trochammina,** découverts dans l'Aptien et l'Albien des Baronnies (Drôme, Hautes-Alpes).—Revue de Micropaléontologie, v. 2, No. 4, March 1960, p. 199-202, pl. 1.—Description of **Trochammina concava** Chapman 1892, var. **vocontiana,** n. var.

PAPP, A. Nummuliten aus dem Untereozän vom Kühlgraben am Fusse des Untersberges (Salzburg).—Verhandl. Austria Geol. Bundesanstalt, heft 2, 1959, p. 163-179, text figs. 1-10.—Ten species of nummulites, five of larger forams, and two planktonics (**Globorotalia**) from a 6-meter section of Ypresian and Paleocene age.

PARR, WALTER J. (edited by LESLIE E. KENT). The Foraminifera of the Bluff Beds, Durban and some other South African calcareous coastal rocks.—Trans. Proc. Geol. Soc. South Africa, v. 61, 1958, p. 103-109. —A few species listed, indicating Pleistocene age.

PESSAGNO, EMILE A., JR. Stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puerto Rico.—Micropaleontology, v. 6, No. 1, Jan. 1960, p. 87-105, pls. 1-5, text figs. 1, 2 (map, evolution diagram), charts 1-3.—Occurrence and abundance of 65 species (six species and one subspecies new) in numerous samples of three Upper Cretaceous formations and one Paleocene-Eocene formation are recorded. The new species and a few of the planktonics are illustrated. Local zonation (two zones, five subzones, and two zonules) is based on ranges of species of **Globotruncana.**

PAVLOVSKY, MELITA. Über **Heterostegina** und ihre fundorte in Kroatien (German summary).—Instit. Recherches Geol. Repub. Pop. Croatie, Bull. Géol., t. 12, 1958 (1959), p. 23-36, pls. 1, 2, text fig. 1 (map), table.—Five species and a subspecies.

SAMYSHKINA, K. G. Foraminifery i stratigrafija Al'bskikh Otlozhenij Dagestana.—Doklady Akad. Nauk SSSR, tom 130, No. 1, 1960, p. 166-169.—Crétaceous Foraminifera listed.

SCHÜTZNEROVA-HAVELKOVA, VENCESLAVA. **Dyocibicides regularis** n. sp. (Foraminifera, Protozoa) aus der bohrung nitkovice im mittelmährischen Helvet (German summary of Czech text).—Vestnik Ustred. Ustavu Geol., roc. 35, cislo 1, 1960, p. 39-42, pls. 1, 2, text figs. 1-3.

SEIBOLD, EUGEN, and SEIBOLD, ILSE. Kalkbankung und Foraminiferen.—Eclogae Geol. Helvetiae, v. 51, No. 3, 1958 (Dec. 30, 1959), p. 729-737, text figs. 1-7 (graphs).—Quantitative relationships between lime content and abundance and size of several species in the lower Malm in southern Germany.

SHENG JING-CHANG. Permian Fusulinids from Liangshan, Hanchung, southern Shensi.—Acta Palaeont. Sinica, v. 4, No. 2, 1956, p. 199-228, pls. 1-8.—Twenty-two species, 10 new.

SMITH, PATSY BECKSTEAD. Foraminifera of the Monterey Shale and Puente Formation, Santa Ana Mountains and San Juan Capistrano Area, California.—U. S. Geol. Survey Prof. Paper 294-M, March 16, 1960, p. 463-495, pls. 57-59, text figs. 155-157 (maps, columnar sections), tables 1-10.—Occurrence and abundance of 98 species and varieties (none new) in four outcrop sections and three wells. Stratigraphic ranges of the 57 more important species indicated between Relizian and Mohnian stages.

STAINFORTH, R. M. Current status of transatlantic Oligo-Miocene correlation by means of planktonic Foraminifera.—Revue de Micropaléontologie, v. 2, No. 4, March 1960, p. 219-230, 1 range chart.—An objective compilation of records of 15 species in the Mediterranean region and comparison with their ranges in America. Discussion of possible explanations for discrepancies in their ranges in the two continents. Evidence supporting existence of Oligocene in America.

TAPPAN, HELEN. Cretaceous biostratigraphy of northern Alaska.—Bull. Amer. Assoc. Petr. Geol., v. 44, No. 3, pt. 1, March 1960, p. 273-297, pls. 1, 2, text figs. 1-7 (maps, facies diagram, zone diagram, correlation tables).—Description of facies and associated Foraminifera and interpretation of depositional environments. Five zones based on Foraminifera cover the interval lower Albian to Senonian. Correlations are made with strata in Canada and United States. Thirteen new species are described and illustrated and one given a new name.

TAVANI, GUIDO. Osservazioni su alcune specie di Foraminiferi del Miocene Superiore.—Atti Soc. Toscana Sci. Nat., ser. A, v. 65, fasc. 1, Anno 1958 (1959), p. 6-14, pl. 1.—Re-description and re-illustration of three already described species. Discussion of paleoecologic significance of variation and abnormal growth.

THALMANN, HANS E., and AYALA-CASTANARES, AGUSTIN. Evidencias Micropaleontologicos sobre la Edad Cretacico Superior de las "Pizarras Necoxtla."—Univ. Nac. Autonoma Mexico, Paleontologia Mexicana No. 5, 1959, p. 1-20, pls. 1-4, text figs. 1, 2 (map, distrib. table).—List and illustrations (in thin section) of planktonic species.

TORIYAMA, RYUZO, and SUGI, TOMOMITSU. Permian Fusulinids from Central Thailand.—Mem. Fac. Sci., Kyushu Univ., ser. D, Geol., v. 9, No. 1, Dec. 20, 1959, p. 17-32, pls. 1-3, map.—Seven species, three indeterminate.

TRUJILLO, ERNEST F. Upper Cretaceous Foraminifera from near Redding, Shasta County, California.—Journ. Pal., v. 34, No. 2, March 1960, p. 290-346, pls. 43-50, text figs. 1-3 (maps, columnar section), tables 1, 2.—Foraminifera from three outcropping shale units (middle Turonian, Coniacian, and Santonian) are described and illustrated; 90 species (22 new).

UCHIO, TAKAYASU. Ecology of living benthonic Foraminifera from the San Diego, California, area.—Cushman Found. Foram. Res., Spec. Publ. 5, April 20, 1960, p. 1-72, pls. 1-10, text figs. 1-18 (maps, graphs), tables 1-9.—Quantitative study based on 157 samples taken from five traverses extending from near shore out to 650 fathoms. Living distribution and abundances reveal seven assemblages with depth boundaries at about 13, 45, 100, 250, 350, and 450 fathoms. Total population counts are generally not indicative of living distributions. Illustrations and occurrence and abundance records are included for 160 species (34 new); for some, descriptions or discussions are also included. **Recurvoidella** n. gen. (type species **R. parkerae** n. sp.) and **Paradentalina** n. gen. (type species **Enantiodentalina muraii** Uchio) are erected.

VORONOV, P. S. Novye Predstaviteli Permskikh Foraminifer Rajona Syndasko na Jugo-vostochnom Poberezh'e Khatangskogo Zaliva.—Nauchno-issl. Instit. Geol. Arktiki, Sbornik Statei paleont. biostrat., vyp. 5, 1957, p. 23-47, pls. 1-3, text figs. 1, 2 (map, columnar section).—Eleven species and three varieties, all new.

YAMAGIWA, NOBUO, and ISHII, KEN-ICHI. **Yabeina** from Omura Island, Shima, Mie Prefecture.—Jubilee Publ. Comm. Prof. H. Fujimoto Sixtieth Birthday, 1958, p. 58-65, pls. 3, 4.—One species and one subspecies, both new.

RUTH TODD