ABSTRACT: Conorbitoides, n. gen., Ctenorbitoides, n. gen., and Aktinorbitoides, n. gen., conical and stellate pseudorbitoid genera, are described from the late Upper Cretaceous of Cuba. These forms are associated with encrusting foraminifera which, together with Rhodophyta, play an important role as reef builders. A key to the genera of the Pseudorbitoididae is also presented.

New Pseudorbitoididae from the Upper Cretaceous of Cuba, with remarks on encrusting foraminifera

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INTRODUCTION

In probably late Campanian or early Maestrichtian beds of reefal to fore-reefal facies there occur in Cuba, in addition to Vaughanina Palmer, three new pseudorbitoid genera, Aktinorbitoides, n. gen. (genotype Aktinorbitoides browni, n. sp.), Ctenorbitoides, n. gen. (genotype Ctenorbitoides cardwelli, n. sp.), and Conorbitoides, n. gen. (genotype Conorbitoides cristalensis, n. sp.). These new genera have been encountered in subsurface samples from Camagüey Province, Cuba, and Ctenorbitoides cardwelli has also been found in a surface sample from Habana Province, Cuba. A representative of Aktinorbitoides that is probably different from Aktinorbitoides browni is also reported from a surface sample from southern British Honduras. In the type material, the two conical forms, Ctenorbitoides cardwelli and Conorbitoides cristalensis, are associated. The stratigraphically slightly older stellate form, Aktinorbitoides browni, has not been found together with either of the conical pseudorbitoids. Two of the genera, Aktinorbitoides and Ctenorbitoides, are, as far as the internal organization is concerned, related to Vaughanina Palmer (Bronnimann, 1954). Conorbitoides, on the other hand, is a conical pseudorbitoid derived from Sulcoperculina Thalmann.

Two species of encrusting foraminifera are also described, Acravulina cenomaniana (Seguenza) and Placopsilina sp. ex gr. cenomanana d’Orbigny – longa Tappan, both of which intergrow in layers with Archaeolithothamnium sp. and Solenopora piai Keijzer. Together with these Rhodophyta, they play an important role as reef builders in the late Upper Cretaceous of Cuba.

KEY TO THE GENERA OF THE PSEUDORBITOIDIDAE

The definition of a genus does not need to be, and often cannot be, restricted to a single character. In the early stages of a taxonomic study, an apparently satisfactory generic grouping may be achieved by the use of a single distinguishing feature. In the later stages, as the group of forms becomes better known, a single character is frequently no longer diagnostic. Additional features, usually of a more general nature than those used in the beginning, have to be introduced into the generic definitions, which then become more complex. The Globoturcanicidaceae furnish a good example of this trend in taxonomic work (Bronnimann and Brown, 1956). In the Pseudorbitoididae, the genera already known have been defined on the basis of the elements of the equatorial layer alone. After having studied the conical and aktinate pseudorbitoids, it is the writer’s opinion that the overall shape of the test is also an important taxonomic criterion. It is of a more general nature than the internal structure of the equatorial layer, and can be used in the definition of taxa of higher than generic rank. The following key is therefore based on both of these criteria:
Test lenticular:
  Outline aktinate. ..........  
  Outline circular:
    Equatorial layer with annular walls ............ Aktinorbitoides
    Equatorial layer without annular walls: Vaughana
      Neanic stage with radial rods: 
        Two sets of radial rods . . Sulcorbitoides
        More than two sets of radial rods . . Rhabdorbitoides
      Neanic stage with radial plates:
        Single set of radial plates, as a rule not interconnected laterally . . . . . . . . . . . . . . . . . Pseudorbitoides
        Single set of radial plates, irregularly interconnected laterally, and with incipient radii and interradii . Historbitoides

Test conical:
  Apex pointed, neanic stage sulcoperculinoid . . . . . . . . . . Conorbitoides
  Apex comb-like, neanic stage vaughaninoid . . . . . . . . . . Ctenorbitoides

ORIGIN OF MATERIAL

The new pseudorbitoids and encrusting foraminifera described here occur in a dark gray, hardfragmental limestone in two cores taken from 2789–2808 feet and from 2808–2838 feet in Cuban American Cristales well no. 1A. The well is situated in central Camagüey Province, Cuba, about 4 km. northeast of the town of Majagua (see text-fig. 1).

TEXTURE OF THIN SECTIONS AND ENVIRONMENT

Thin sections from both cores show organic fragments, predominantly of algal origin but also angular fragments of mollusks and remains of echinoderms and encrusting and other benthonic foraminifera, embedded in a dark gray microcrystalline matrix. Sulcoperculinas, pseudorbitoids and encrusting foraminifera are common. Planktonic foraminifera have not been seen in the thin sections. However, in the top portion of a slightly shallower core, from 2703–2721 feet, of essentially the same fragmental texture as the cores from 2789–2838 feet, rare specimens of Globotruncan a fornicata Plummer, Globotruncan a sp. ex gr. arae (Cushman), “Globigerina” sp. ex gr. cretacea d’Orbigny, and Pseudo guembelina sp. have been encountered in residues of washed material. Texture and organic composition suggest fore-reef environment for these fragmental limestones.

AGE

Two different pseudorbitoid faunules are recognized. The upper one, from 2789–2808 feet, is characterized by Ctenorbitoides cardwelli and Conorbitoides cristalensis, and the lower one, from 2808–2838 feet, by Aktinorbitoides browni. Because of the absence of planktonic foraminifera in the cores from 2789–2838 feet, the age of the two pseudobritoid faunules cannot be determined in terms of the Globotruncan a zonation. The associated benthonic assemblage is the same for both faunules, and consists of:

  Vaughanina sp. cf. V. barkeri Bronnimann
  Sulcoperculina globosa de Cizancourt
  Sulcoperculina sp. cf. S. vermunti (Thiadens)
  Acervulina cenomaniana (Seguenza)
  Placosilina sp. ex gr. cenoman d’Orbigny – longa
  Tappan
  Solenopora piai Keijzer
  Archaeolithothamnium sp.
The age significance of this assemblage is rather vague, both Maestrichtian and Campanian age assignments being possible on the basis of Vaughanina Palmer and Sulcoperculina Thalmann. The occurrence of a Vaughanina close to if not identical with Vaughanina barkeri Bronnimann suggests a pre-Vaughanina cubensis age, i.e., older than upper Maestrichtian.

If the planktonic faunas with Globotruncana fornicata Plummer, Globotruncana contusa (Cushman), forms transitional between Globotruncana fornicata and Globotruncana contusa, Globotruncana rosetta (Carsey), Globotruncana stuarti (de Lapparent) and Globotruncana sp. ex gr. lapparenti Brotzen found in the core from 2703-2721 feet (top) are in situ, and if the cores from 2031-2838 feet represent a normal stratigraphic succession, then the age of the two pseudorbitoid faunules is late Campanian or early Maestrichtian. Because the stratigraphic succession is not certain, however, the age significance of these planktonic faunas from the shallower cores is problematical. In the writer’s opinion, there is little doubt that they are autochthonous and that the stratigraphic sequence is undisturbed. It will also be noted that the age determination afforded by the planktonic faunas does not conflict with the pre-upper Maestrichtian age indicated by Vaughanina sp. cf. V. barkeri. The age of the two pseudorbitoid faunules is therefore tentatively regarded as late Campanian or early Maestrichtian.

ACKNOWLEDGMENTS

The writer wishes to thank W. H. Cardwell, chief geologist of the Cuban American Oil Company, Dallas, for having made the well samples available and for permission to publish this note. He is also indebted to Ing. G. A. Seiglie, geologist with the Comisión de Fomento Nacional, Havana, for isolated specimens of the conical pseudorbitoids and for information on the planktonic assemblages collected in the well samples; to P. Norton, of the Cuba California Oil Company, Havana, and to N. K. Brown, Jr., of the Gulf Oil Corporation, New York, who kindly showed the writer comparative pseudorbitoid material and who discussed the manuscript with him; and to G. A. Cooper, of the United States National Museum, who obligingly had the holotypes of the conical pseudorbitoids drawn by a National Museum staff artist.

The holotypes of the new species, together with all other figured specimens, will be deposited in the collections of the United States National Museum, Washington, D. C.
Aktinorbitoides browni Bronnimann, n. sp.

Plate 1, figures 1–9; plate 2, figures 1–10; text-figures 2–6

Holotype: Aktinorbitoides browni Bronnimann, n. sp., pl. 1, fig. 5. The specimen is from thin section no. 9 of core from 2808–2838 feet in Cuban American Cristales well no. 1 A (for location see text-fig. 1). The maximum diameter of the holotype is 0.64 mm. measured interradially, and 0.9 mm. across opposite radii. The species is named for N. K. Brown, Jr., who first recognized the new pseudorbitoid.

Exterior: Specimens of Aktinorbitoides browni could not be extracted from the hard limestone. Random cuts indicate a small, strongly umbonate lenticular pseudorbitoid with aktinate periphery. Radii and interradii apparently are not differentiated in the form of ridges and grooves on the surface of the tests. The short radii are irregularly distributed. Adjoining radii may run parallel and almost touch each other, or they may be divergent and far apart. A typical specimen, represented by the holotype (pl. 1, fig. 5), has seven radii. About one-half of the total length of a radius projects outside the test proper. The radii are covered by lateral layers except for their extreme tips, where the vertical radial plates of the equatorial structure are exposed. The peripheral portions of the radii are broad and compressed in a lateral direction, not pointed as in Asterorbis or Asterocyclina, and their maximum width at the periphery varies considerably in the same specimen. Those of the holotype have a maximum width of 102μ, 128μ, and 153μ, and an average length of about 260μ, measured from the pointed initial end at the juvenarium to the periphery.

In other specimens, the radii are 170μ to 600μ in length. Oblique sections tangential to the umbos expose thick-walled lateral chambers, and vertical sections occasionally display strong central pillars. The scatter-diagram (text-fig. 2) shows little variation in the dimensions of the tests, which are not grouped into smaller A-forms and larger B-forms, reflecting a primitive uniserial juvenarium. The diameter of tests ranges from 0.5 mm. to about 1.00 mm., measured interradially, and the thickness from 0.5 mm. to 0.7 mm. Aktinorbitoides browni is one of the smallest lenticular pseudorbitoids found to date. The dimensions of the tests come closest to those of topotypes of Pseudorbitoides israeliskyi Vaughan and Cole. The schematic model of the test (text-fig. 3) is useful for the orientation of random cuts observed in thin sections. Two characteristic vertical cuts are shown in the model, one across opposite radii and one across interradius and radius. Surface features have not been indicated on the model.

Interior: Random cuts are adequate for the interpretation of the internal organization with the exception of that of the juvenarium, which preferably should be based on centered sections. Perfectly oriented sections have not been found, however, and the following description of the juvenarium is the result of the analysis of more or less centered, somewhat oblique equatorial and vertical cuts. The structure of the characteristic aktinate margin of the test is illustrated by the oblique equatorial cuts of figures 2 and 5–9 of plate 1 and the oblique vertical cuts of figures 1–4 of plate 2. The relationship between juvenarium and aktinate
structure, which is confined to the neanic stage, is shown by the drawings of text-figures 4a-c and 5a-d. Centered vertical sections across interradius and radius expose only lateral chambers on the interradial side of the juvenarium (pl. 2, figs. 1, 3). On the radial side of these vertical sections, the equatorial layer can be seen, covered on both sides by layers of lateral chambers. This difference between the radial and interradial sides, which at first glance is puzzling, is explained by the restriction of the radial vertical plates to the radii. The lateral chambers not only form the normal lateral layers on both sides of the equatorial layer, but they also grow across the interradial portions of the juvenarium. Lateral chambers thus form a protecting cover over the juvenarium and equatorial structures, with a general tendency to produce a lenticular form of test.

1) **Juvenarium:** The uniserial juvenarium starts with a subspherical protoconch, followed by fourteen to seventeen spiral chambers, which increase in size gradually as added. The final chamber or chambers, however, may be smaller than the preceding ones. The walls of the early chambers of the juvenarium are thicker than those of the later ones. The spire consists of two to three volutions. The outer diameter of the initial chamber including the walls, which are about 10μ thick, ranges from 50μ to 65μ. The spiral chambers communicate by basal stolons. The stolon from protoconch to deuteroconch seems to be centrally located. Connections to the lateral chambers are by fine pores. The septa of the spiral chambers consist of two lamellae, which enclose fissural lumina. A true canal system appears to be developed, as in *Sulcoperculina* Thalmann (Brown and Bronnimann, 1957, p. 30, text-fig. 1).

The maximum diameter of the juvenarium is from 300μ to 400μ. The juvenarium is relatively large compared with the interradial diameter of the tests (text-figs. 4 and 5). The three specimens illustrated in text-fig. 4a-c show the following ratios (3) between the diameter of the juvenarium in microns (1) and the interradial diameter of the test in microns (2):

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-figure 4a</td>
<td>325</td>
<td>559</td>
<td>0.58</td>
</tr>
<tr>
<td>Text-figure 4b</td>
<td>325</td>
<td>533</td>
<td>0.61</td>
</tr>
<tr>
<td>Text-figure 4c</td>
<td>390</td>
<td>520</td>
<td>0.75</td>
</tr>
</tbody>
</table>

The form of the juvenarium is perfectly spiral and does not indicate the later aktinate structure of the test. None of the spiral chambers shows elongation in the direction of the radii. Radii and interradii are structures of the neanic stage. In vertical section, the thick-walled juvenarium is distinctly trochoid, sulcoperculinoid. The spiral chambers are somewhat compressed in a lateral direction and peripherally provided with well developed connections to the lateral chambers.
Aktinorbitoides browni Bronnimann, n. sp., x ca. 270: a, vertical section across late nepionic chambers; b, arrangement of radial plates and lateral chambers; c, d, e, vertical sections across radii; d, vertical section across radius close to the juvenarium.

sulci. Comparison of the sulcus of Aktinorbitoides, as illustrated in text-figure 6a, with that of Vaughanina (Bronnimann, 1954, pl. 10, fig. 10) clearly demonstrates the postulated affinity between these genera also in the formation of the nepionic peripheral indentation. Centered juvenaria are illustrated in figures 2 and 9 of plate 2. They show the following dimensions in microns:

<table>
<thead>
<tr>
<th></th>
<th>Pl. 2, fig. 2</th>
<th>Pl. 2, fig. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of juvenarium</td>
<td>390</td>
<td>380</td>
</tr>
<tr>
<td>Height of juvenarium</td>
<td>156</td>
<td>195</td>
</tr>
<tr>
<td>Inner diameter of protoconch</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>Height of sulcus</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Radial diameter of largest spiral chamber</td>
<td>78</td>
<td>91</td>
</tr>
<tr>
<td>Thickness of dorsal wall of early portion of juvenarium</td>
<td>39</td>
<td>90</td>
</tr>
<tr>
<td>Thickness of dorsal wall of later chamber of juvenarium</td>
<td>ca. 6</td>
<td>ca. 6</td>
</tr>
</tbody>
</table>

2) Neanic stage: The neanic stage consists of the structurally different radii and interradii. The radii are formed by elements of the equatorial and lateral layers, whereas the interradii contain lateral chambers only. This is very different from the structure of Historbitoides Bronnimann or of any of the Tertiary Aktinocyclinas or Asterocyclinas. To demonstrate this structural differentiation between radii and interradii, two characteristic vertical cuts have been selected in the schematic model (text-fig. 3). The first section goes across two opposite radii, the large sulcoperculinoid juvenarium, and the equatorial layer, which in both radii are covered on both sides by lateral chambers. The second cut goes across interradius and radius, showing only lateral chambers in the interradius to the left, but equatorial layer and lateral layers in the radius to the right. Vertical sections across interradii alone are illustrated in figures 2 and 4 of plate 2. In both sections only lateral chambers occur in the interradii. In one of the thin sections (pl. 2, fig. 4), the initial chamber is cut slightly tangentially, but otherwise the juvenarium is perfectly represented. The section goes exactly through the interradii, made up of lateral chambers. The other thin section (pl. 2, fig. 2) is not quite centered, and on the right side cuts at first across the early portion of a radius, as indicated by roof and floor of the equatorial layer; then it remains completely within the lateral chambers of the interradius. Vertical sections across radii or across radius and interradius are illustrated in figures 1 and 9 of plate 2 and by figure 3 of plate 1.

The equatorial layer of the radii is fan-shaped, the pointed initial end touching the juvenarium and the broad end forming the periphery of the radius. The pointed inner ends of the radii are always situated between adjoining spiral chambers. The distal openings of the septal canals in the sulcus appear to be directly related to the formation of the radii. The equatorial layer of the radii is single throughout. It develops from the sulcus at the periphery of the juvenarium and increases in height gradually toward the periphery. The equatorial layer is clearly delimited from the lateral chambers by roof and floor, as in Vaughanina. In some instances, transverse (annular) walls have been noted. Cross sections of the radii are rounded near the juvenarium and strongly compressed in a lateral direction at the periphery.

At the periphery of average specimens, the pseudorbitoidal vertical radial plates are 5μ to 7μ thick and about 25μ apart. They are straight, and composed of two lamellae. The boundary between the lamellae is indicated by dark lines. Minute irregularities along the sides appear to connect adjoining plates. This impression of irregular transverse connections may be caused by poor preservation of the delicate plates. In the model (text-fig. 9), they are tentatively represented as in Vaughanina, although it is realized that this interpretation may have to be changed. The transverse connections occur over short distances only, across two or more vertical plates. They are about 15μ apart. Occasionally they seem to be somewhat longer, but they can rarely be followed across a complete radius (pl. 1, figs. 5, 7, 9). The subcircular cross sections of radii near the juvenarium exhibit coarse radial plates or rods arranged perpendicular to the axis of the radius (pl. 2, figs. 6, 10). Cross sections near the periphery of the test show two sets of more or less alternating radial plates separated from each other by a narrow median gap. In some instances, the
plates develop bifurcated inner ends, a feature previously noted in Vaughanina (text-fig. 6c). The equatorial structures are sheathed by low primary lateral chambers.

**Lateral layers:** In average specimens, about seven lateral layers occur on both sides over the juvenarium. They are also formed across the interradii and over the radii. The rather low and long chambers are arranged in regular tiers. They are connected by basal stolons and by fine pores. Strong pillars may occur over the center of the test. Lateral chambers and pillars of average specimens have the following dimensions: Length ca. 64μ; height ca. 25μ; thickness of wall ca. 5μ to 10μ; diameter of pillars at periphery 20μ to 65μ. In oblique sections close to the surface, the lateral chambers appear as thick-walled polygons with an inner diameter of 50μ to 70μ.

**Genus Ctenorbitoides** Bronnimann, *new genus*

**Definition:** Ctenorbitoides cardwelli Bronnimann, n. sp.

**Definition:** The base of the cone-shaped test is flat to slightly umbonate, the flanks are distinctly concave. The apex of the cone, which is on the ventral side of the test, is not pointed but is comb-like, compressed. Lateral chambers and small pillars cover the flanks and base of the cone. The pseudorbitoidal elements consist of two systems of alternating vertical plates, separated by a narrow median gap, and transverse (annular) walls, perforated by radial stolons. The vertical plates radiate from the centrally situated juvenarium to the periphery of the cone, so that they themselves are arranged on the surface of a low cone with the juvenarium at its apex. Vertical plates also project fan-wise to the periphery of the ctenoid apex. The juvenarium tends to be situated in the center of the cone, equidistant from flanks and base. It is uniserial, distinctly trochosorial and sulcoperculinoid. From additional, probably sulcus-bearing nepionic chambers on its ventral side, the pseudorbitoidal structures of the ventral fan-like extension develop.

**Comparisons:** Ctenorbitoides differs in the cone-like test and in the development of an apical comb from Vaughanina Palmer, to which it is closely related in having the same arrangement of pseudorbitoidal plates. From the cone-shaped Conorbitoides Bronnimann it is distinguished by the Vaughanina-like internal structure and by the apical comb. The pointed apex of Conorbitoides is formed by a protruding pillar-like calcite needle, whereas the apex of Ctenorbitoides is formed by pseudorbitoidal plates.

**Relationships:** Ctenorbitoides is structurally closely related to Vaughanina. It was probably derived from primitive forms of Vaughanina with a strongly trochosorial juvenarium, such as those represented by Vaughanina Barkeri Bronnimann, by modification of its ventral part, from which the cone-like portion of the test developed.

**Occurrence:** Cuba.

**Age:** Upper Cretaceous, probably late Campanian or early Maestrichtian.
Ctenorbitoides cardwelli Bronnimann, n. sp., dimension diagram.

The juvenarium is a morphologically significant feature of orbitoidal foraminifera in general. The equidistant position of the juvenarium influences the arrangement of the pseudorbitoidal elements. They are situated in an equatorial layer in normal lenticular pseudorbitoids, but are on the surface of a low cone in Ctenorbitoides cardwelli, the height of which is determined by the distance from the embryo to the center of the surface of the basal umbo. The term “equatorial layer,” which is conveniently and correctly used in all lenticular orbitoidal tests, can therefore no longer be applied in the cone-like Ctenorbitoides, and is replaced by the term “conical layer.” In the following discussion, all sections perpendicular to the axis of the cone are designated as horizontal sections, and all those parallel to the axis of the cone are designated as vertical sections. Centered horizontal or vertical sections cut across the protoconch.

1) **Juvenarium:** The juvenarium is uniserial. Oblique horizontal sections (pl. 4, figs. 2, 4; pl. 5, fig. 10; text-fig. 9) expose a subspherical protoconch about 65 μ in diameter, including the walls, followed by twelve to fifteen spiral chambers, which increase in size gradually as added. The ultimate spiral chambers may be smaller than the preceding ones. The radial diameter of one of the largest spiral chambers is about 130 μ. The stolons between the nepionic chambers are at the base of the septa. The main stolon from protoconch to deuteroconch could not be seen. Communications with the lateral chambers are by means of fine pores. The septa of the spiral chambers are composed of two lamellae, and, as in the juvenaria of other pseudorbitoids, true canals seem to occur. The maximum diameter of the juvenarium is from 250 μ to 360 μ. Vertical sections show a triangular juvenarium (pl. 3, figs. 3–6; pl. 5, figs. 8, 11, 13; text-fig. 8), with distinct trochosorial arrangement of the spiral chambers, which are provided with peripheral sulci. The sulci of the early spiral chambers are larger than those of the later ones. In some of the sections a sulcus or sulcus-like indentation seems to occur on the ventral side of the trochosorial (text-fig. 8; pl. 3, fig. 5; pl. 5, fig. 11). The ventral fan-like system of pseudorbitoidal plates starts from this indentation. The following dimensions, in microns, are taken from the vertical sections illustrated in text-figure 8:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Text-fig. 8a</th>
<th>Text-fig. 8b</th>
<th>Text-fig. 8c</th>
<th>Text-fig. 8d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of cone</td>
<td>720</td>
<td>1090</td>
<td>800</td>
<td>—</td>
</tr>
<tr>
<td>Height of cone</td>
<td>486</td>
<td>770</td>
<td>605</td>
<td>—</td>
</tr>
<tr>
<td>Diameter of juvenarium</td>
<td>358</td>
<td>260</td>
<td>258</td>
<td>295</td>
</tr>
<tr>
<td>Height of juvenarium</td>
<td>192</td>
<td>154</td>
<td>166</td>
<td>205</td>
</tr>
<tr>
<td>Diameter of protoconch, including walls</td>
<td>64</td>
<td>64</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Thickness of dorsal wall of juvenarium</td>
<td>64</td>
<td>40</td>
<td>—</td>
<td>38</td>
</tr>
</tbody>
</table>

The asymmetrical juvenarium leaves no doubt concerning the orientation of the cone. The umbonate base of the cone represents the dorsal, and the centoid apex the ventral side of the test. The juvenarium occupies a position virtually equidistant from the surfaces of the flanks of the cone and from the center of the surface of the base of the cone.

2) **Neanic stage:** The pseudorbitoidal structure, i.e., vertical plates and annular walls, are as in Vaughanina. They have been described in detail in a previous note, to
UPPER CRETACEOUS PSEUDORBITOIDIDAE

TEXT-Figure 9
Ctenorbitoides cardwelli Bronnimann, n. sp., oblique centered section exposing lateral chambers, juvenarium, and part of conical layer, x ca. 117.

which the reader is referred (Bonnimann, 1954, pp. 100-102). Distinct roofs and floors delimit the layers with pseudorbitoidal structures from the lateral layers. Because of the equidistant position of the juvenarium, the vertical plates radiating to the periphery of the base of the cone are no longer in an equatorial plane, but are on the surface of a low cone with the juvenarium at its apex, here termed “conical layer.” In a typical specimen, almost forty radial plates have been counted per quadrant, as against thirty-two to thirty-six in Vaughanina cubensis (Bonnimann, 1954, p. 100). The pseudorbitoidal elements extending ventrally, fan-wise, to the periphery of the ctenoid apex are a characteristic additional feature of the neanic stage. In this fan-like extension their arrangement is the same as in the conical layer, at least in the final stage.

Dimensions of some of the neanic features measured in three of the illustrated thin sections are listed below:

1) Specimen illustrated in figure 1 of plate 3 (an almost centered vertical section with oblique fan-like ventral extension): Diameter of test 0.97 mm.; height 0.65 mm. Thickness of conical layer near periphery, including roof and floor, 40µ. Thickness of roof and floor of conical layer at periphery 10µ. Thickness of annular walls less than 10µ. Average distance between annular walls 12µ.

2) Specimen illustrated in figure 3 of plate 3 (a centered vertical section): Thickness of conical layer near periphery, including roof and floor, 50µ.

3) Specimen illustrated in figure 1 of plate 6 (a vertical section close to the periphery of the base of the cone): Thickness of conical layer, including roof and floor, 40µ. Thickness of vertical plates 5-12µ. Distance between vertical plates 5-25µ.

Lateral chambers: The lateral chambers cover flanks and base of the cone-shaped test in regular tiers. They are rather low, thick-walled, and polygonal in oblique section. In a typical centered vertical section, illustrated by figure 6 of plate 3, lateral chambers occur in eight to nine layers over the juvenarium toward the flanks and the base of the test. On the dorsal side they form a distinct umbo; on the flanks they are in slightly concave layers. The diameter of the figured specimen is 1.02 mm., the height 0.85 mm., and the width of the comb-like apex 0.16 mm. The surface of the umbo and of the flanks of the cone are all 0.22 mm. from the triangular juvenarium. The following dimensions are taken from the above-mentioned vertical section, and refer to average lateral chambers: Length 40µ to 70µ; height ca. 12µ; thickness of walls 10µ to 12µ.

Communications are by means of basal stolons and fine pores. Pillars are from 20µ to 60µ in diameter. Horizontal sections between juvenarium and apex show that the lateral chambers are arranged in concentric layers around the axis of the test.

Genus Conorbitoides Bronnimann, new genus
Genotype: Conorbitoides cristalensis Bronnimann, n. sp.

Definition: Conorbitoides cristalensis Bronnimann is the base of the cone-shaped test, or the dorsal side, is flat to very slightly umbonate. The flanks of the cone are straight to concave. The apex of the cone, on the ventral side of the test, is pointed. Juvenarium and neanic stage are uniserial, trochospiral and sulcoperculinoid. The protoconch tends to be equidistant with respect to the surfaces of base and flanks. A thin calcite needle, which gradually increases in thickness to form the protruding pointed apex of the test, occurs in an axial position, on the ventral side of the juvenarium.

Comparisons: Conorbitoides differs from the likewise cone-shaped Ctenorbitoides Bronnimann in the Sulcoperculinoid-like character of the juvenarium and neanic stage, and in the pointed instead of ctenoid apex. Conorbitoides differs from the lenticular Sulcorbitoides Bronnimann in the cone-shaped test.

Relationships: Conorbitoides is closely related to Sulcoperculinina Thalmann. It was probably derived, later than and independently of Sulcorbitoides, from a Sulcoperculinina ancestor by the development of an asymmetrical cone-shaped test. It is remarkable that the two cone-shaped
Upper Cretaceous pseudorbitoids are associated. The sulcoperculinoid Conorbitoides may represent a less advanced genus standing between Sulcoperculina and Ctenorbitoides, which is Vaughanina-like in its neanic stage.

**Occurrence:** Cuba.

**Age:** Upper Cretaceous, probably late Campanian or early Maastrichtian.

**Conorbitoides cristalensis** Bronnimann, new species

Plate 5, figures 5(?), 9(?), 14–16; plate 7, figs. 5–6; text-figs. 10–11

**Holotype:** *Conorbitoides cristalensis* Bronnimann, n. sp., pl. 7, figs. 5–6. The specimen is from core at 2789–2806 feet in Cuban American Cristales well no. 1 A (for location see text-fg. 1). The diameter of the holotype is 0.53 mm., the height 0.4 mm. The new species is named after the well location Cristales, northeast of Majagua, Camagüey Province, Cuba.

**Exterior:** The exterior of the new species could be studied in well preserved isolated specimens. The cone-shaped tests are small for pseudorbitoids. The diameter ranges from 0.4 mm. to 0.65 mm., and the height from 0.37 mm. to 0.5 mm. The height of the cone is usually less than the diameter. The largest specimens correspond in dimensions to the smallest specimens of *Ctenorbitoides cardwelli* Bronnimann. The dimension diagram (text-fg. 10), although based on only a few specimens and therefore not conclusive, does not show any grouping into smaller A-forms and larger B-forms. The absence of dimorphism suggests a primitive, uniserial juvenarium. The flat base of the cone, which actually represents the dorsal (spiral) side of the test, may show a few lateral chambers. The holotype (pl. 7, figs. 5–6) has no lateral chambers on the flat dorsal side, or at least none that can be seen from the outside. The flanks of the test, excepting the extreme marginal area toward the peripheral sulcus and the protruding axial spine, are covered by large, polygonal, thick-walled lateral chambers. They are in slightly concave layers. No pillars have been seen. The sulcus along the periphery of the base of the cone is very thin, but well developed. Occasionally, short radial plates can be seen in the sulcus.

**Interior:** The centered horizontal section (text-fg. 11c), which is practically identical with the horizontal section of a small *Sulcoperculina*, shows a spire of two and one-half volutions. It is composed of a subspherical protoconch 60µ to 90µ in diameter, including the walls, and about nineteen spiral chambers, which increase gradually in size. The largest spiral chambers have a radial diameter of 100µ to 120µ, including the outer wall. They are connected by basal stolons. Lateral chambers, indicating the orbitoidal nature of the form, can be seen in this type of section. The centered vertical section, as illustrated by figures 14–16 of plate 5 and by text-figure 11a–b, exhibits low lateral chambers on the flanks and occasionally also on the base of the cone. The *Sulcoperculina*-like portion is strongly asymmetrical and trochospiral. The sulcus of the final whorl is thin and deeply incised. Lateral chambers on the flanks of
the cone are arranged in irregular concave layers. They may also occur on the base of the cone, producing a very slight umbonal thickening (text-fig. 11b). The axial calcite needle starts as a very thin ventral projection of the umbilical plug.

The following measurements, in microns, are taken from the centered vertical sections illustrated in text-fig. 11a–b:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Text-fig. 11a (without lateral chambers on dorsal side of test)</th>
<th>Text-fig. 11b (with lateral chambers on dorsal side of test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of test</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>Height of test</td>
<td>364</td>
<td>400</td>
</tr>
<tr>
<td>Maximum diameter of apical spine</td>
<td>78</td>
<td>90</td>
</tr>
<tr>
<td>Diameter of protoconch, including walls</td>
<td>—</td>
<td>90</td>
</tr>
<tr>
<td>Thickness of dorsal wall of juvenarium</td>
<td>ca. 65</td>
<td>50–70</td>
</tr>
<tr>
<td>Thickness of radial rods</td>
<td>ca. 10</td>
<td>ca. 10</td>
</tr>
<tr>
<td>Length of sulcus of peripheral spiral chamber</td>
<td>90</td>
<td>80</td>
</tr>
</tbody>
</table>

Superfamily ROTALIICAE

Family PLANORBULINIDAE Cushman

Genus ACERVULINA Schultze, 1854

**Acervulina cenomaniana** (Seguenza)

Plate 6, figures 3–5


The following description is based on random cuts found in thin sections from core at 2789–2808 feet in Cuban America Cristales well no. 1 A (for location see text-fig. 1).

**Description:** The calcareous, chambered, generally dish-shaped test is either free or attached to a substratum on which it may spread or which it may envelop. The diameter of typical large specimens is from about 2 mm. to 3.6 mm.; the height is about 0.2 mm. As a rule, the test consists of a single layer of large open-arcuate chambers, similar to those of the equatorial layers of *Orbitoides* d’Orbigny. Individual chambers or small groups of chambers may grow over the early chambers of the first-formed layer. Occasionally, additional irregular chambers may be formed at the periphery of the test. Attached tests are distinctly asymmetrical, the attached side being flat and thin-walled and the opposite free side being formed by the convex, thick and coarsely perforate outer walls of the chambers. Unattached tests, on the other hand, may be symmetrical in vertical section, both sides being similarly developed, with thick, coarsely perforate, convex outer walls. The symmetry or asymmetry of the tests manifests itself in the individual chambers. Stolons are close to the flat side, but are not completely basal in attached forms, and are centered in symmetrical free specimens. The embryo has been seen in vertical sections only, where it appears to be represented by two subglobular chambers, of practically equal dimensions, separated by a straight wall. It is not known whether the nepiont is spirally arranged. The primary wall of the chambers is a thin, dark, opaque layer, which doubles back at the apertures and forms the dark points so well known in vertical sections of the septa of rotaliids. The secondary wall of the test is a thin hyaline-radiate calcite layer inside and outside of the layer. As in other rotaliids, additional calcite layers are deposited outside of the test, the number, of which corresponds with the number of growth stages. Accordingly, early chambers of the test have a thinner outer wall than later-formed chambers. Communications between chambers are by means of large, circular stolons. Oblique horizontal sections show that the stolons are irregularly distributed. Pillars are not developed.

The measurements, in microns, listed below refer to the specimen illustrated in figure 4 of plate 6. Diameters of chambers are inner diameters, without the outer walls.

- Diameter of protoconch: 121
- Thickness of wall of protoconch: 19
- Thickness of wall between protoconch and deuteroconch: 2
- Length of chambers: 50–200
- Height of chambers: 50–130
- Thickness of outer wall near embryo: 20–40
- Diameter of coarse pores in outer walls: 6–15
- Diameter of stolons: 15–25

Other specimens show dimensions similar to those listed above for the illustrated form. However, stolons may be found with diameters up to 50μ, exceptionally up to 70μ.

**Remarks:** The forms assigned here with some reservation to *Acervulina cenomaniana* (Seguenza) are practically identical with those described as *Archaecyclus mid-orientalis* by Eames and Smout (1955) from Campanian porous chalky limestones found in Kuwait Oil Company’s Umm Gudair well no. 1, in Kuwait, at 4078, 4126, and 4130 feet. At the type locality, *Archaecyclus mid-orientalis* is associated with *Pseuddomia complanata* Eames and Smout, *Siderolites skourensis* (Pfender), *Cuneolina cylindrica* Henson, *Cuneolina pavonia* d’Orbigny, and *Globotruncana*...
of the linneiana-lapparenti group. In the writer's opinion, there is little doubt that Acervulina cenomaniana (Seguenza) and Archaecyclus mid-orientalis Eames and Smout are the same form. The generic assignment, on the other hand, needs to be re-examined. The only other Cretaceous acervulinid, Acervulina cretae Marsson, from the island of Rügen, northern Germany, occurs as small, grumous, enveloping bodies, whereas Acervulina cenomaniana is generally a flat attached or free disc. Acervulina cenomaniana has been noted in many thin sections of late Cretaceous fragmental limestones. In the present material it occurs mainly in the attached form, either on a substratum or intergrowing with Archaeolithothamnium sp., Solenopora piai Keijzer, and Placopsilina sp. ex gr. cenomana d’Orbigny – longa Tappan. Attached and free forms can be regarded as variants. Gradations can be seen from one to the other, and for this reason they are treated as growth-types and not as separate taxa.

Occurrence: Italy, Kuwait, and Cuba.

Age: Upper Cretaceous.

Superfamily LITUOLICAE

Family PLACOPSILINIDAE Cushman

Genus PLACOPSILINA d’Orbigny, 1850

Placopsilina sp. ex gr. cenomana d’Orbigny – longa Tappan
Plate 6, figures 1, 2, 6

The following description is based on random cuts of this encrusting foraminifer in thin sections of hard, dark gray limestone in core from 2789-2808 feet in Cuban American Cristales well no. 1 A (for location see text-fig. 1).

Description: The large, coarsely arenaceous, chambered test is invariably attached to a substratum. The diameter of the coiled portion of the specimen illustrated in plate 6, figure 1, is 1.3 mm. Other fragments of the test measure up to 4 mm. The large early chambers are coiled, about four or five making up a volution. The early portion of the test shows about two volutions, the later portion appears to be spreading in linear series. The interior of the chambers is simple. The walls are coarsely arenaceous. No floors of the type of the ordinary arenaceous chamber wall are developed on the attached side of the test, except perhaps a thin chitinous film. The apertures are large, elongate oval, and not quite basal. A diameter of 325μ and a height of 117μ have been measured in a fragment of a large specimen.

The following measurements, in microns, are taken from the specimens illustrated in plate 6, figure 1 (specimen no. 1) and in plate 6, figure 6 (specimen no. 2). Diameters of chambers are inner diameters, without walls.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. 1</td>
<td>no. 2</td>
</tr>
<tr>
<td>(coiled early portion of test)</td>
<td>(fragment of later portion of test with large chambers)</td>
</tr>
<tr>
<td>Diameter of test ..........</td>
<td>1300</td>
</tr>
<tr>
<td>Length of chambers ......</td>
<td>300–600</td>
</tr>
<tr>
<td>Height of chambers ......</td>
<td>100–220</td>
</tr>
<tr>
<td>Thickness of chamber wall</td>
<td>20–40</td>
</tr>
<tr>
<td>Diameter of apertures .....</td>
<td>40–60</td>
</tr>
</tbody>
</table>

Remarks: d’Orbigny’s original specimen of Placopsilina cenomana is not available. The present form shows affinities to Placopsilina cenomana as figured by Reuss (1854, pl. 28, figs. 4–5) from the Turonian of the Gosau Valley, eastern Alps, and to Placopsilina longa Tappan (1940, pl. 15, figs. 9–10), from the Lower Cretaceous Grayson formation of Texas. The inner structure of both of these forms is unknown. The Cuban specimens, on the other hand, are available only in thin sections. It appears that Placopsilina cenomana and Placopsilina longa are representatives of a closely related group of attached Cretaceous foraminifera, to which the Cuban form seems to belong. Placopsilina sp. ex gr. cenomana-longa is a common component of the layered algal-foraminiferal associations composed of Archaeolithothamnium sp. (pl. 6, fig. 7), Solenopora piai Keijzer, and Acervulina cenomaniana (Seguenza). It has been encountered in many thin sections of Upper Cretaceous fragmental limestones of fore-reef type.

Occurrence: Cuba, Texas, and Europe.

Age: Upper Cretaceous.

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REUSS, A. E.

TAPPAN, H.
UPPER CRETACEOUS PSEUDORBITOIDIDAE

EXPLANATION OF PLATES

PLATE 1

All figures of *Aktinorbitoides browni* Bronnimann, n. sp., from core at 2808–2838 feet (middle) in Cristales well no. 1A; all × ca. 73.

1  Slightly oblique equatorial section showing the large juvenarium and peripheral parts of two radii on the lower side. Radial plates are exposed only in the shorter of the two radii. Thin section no. 6.

2  Almost centered equatorial section with five or six radii. The *Vaughanina*-like structures are exposed in the two largest radii. Thin section no. 11.

3  Vertical cut across interradius, juvenarium and radius. Thin section no. 5.

4  Oblique vertical cut across two radii, juvenarium and radius. Thin section no. 9.

5  Holotype. Thin section no. 9.

6, 8  Oblique tangential cuts across umbo and four radii: 6, thin section no. 7; 8, thin section no. 5.

7, 9  Part of an oblique vertical cut exposing the juvenarium and the internal *Vaughanina*-like structure of a radius: 7, thin section no. 7; 9, thin section no. 5.

PLATE 2

All figures of *Aktinorbitoides browni* Bronnimann, n. sp., from core at 2808–2838 feet (middle) in Cristales well no. 1A; all × ca. 73.

1  Cut across interradius, juvenarium and radius. Thin section no. 6.

2, 4  Cuts across interradius, juvenarium and interradius: 2, thin section no. 10; 4, thin section no. 6.

3, 5, 7–8, 10  Peripheral vertical cuts exposing cross sections of radii: 3, thin section no. 9; 5, thin section no. 8; 7–8, thin section no. 3; 10, thin section no. 8.

6  Perpendicular section across three radii close to the juvenarium, showing the somewhat irregular arrangement of the radial elements and the rounded cross sections. Thin section no. 4.

9  Centered vertical section across radius, juvenarium and radius. Thin section no. 3.

PLATE 3

All figures of *Ctenorbitoides cardwelli* Bronnimann, n. sp., from core at 2789–2808 feet in Cristales well no. 1A. All are vertical sections, × ca. 73, illustrating the central position of the juvenarium and the low cone formed by the equatorial layer.

1, 3–6  Centered, and showing the fan-like ventral development of radial plates: 1, thin section no. 8; 3, thin section no. 6; 4, thin section no. 1; 5, thin section no. 5; 6, thin section no. 9.

2  Oblique, outside the juvenarium and the ventral fan. Thin section no. 2.

PLATE 4

All figures of *Ctenorbitoides cardwelli* Bronnimann, n. sp., from core at 2789–2808 feet in Cristales well no. 1A; all × ca. 73.

1, 3, 5, 7  Oblique cuts tangential to the flanks of the test, in figure 1 almost parallel to the flanks, showing the vertical plates of the conical layer and the vertical plates of the comb-shaped apex; indications of transverse plates can be seen in places; lateral chambers are large, thick-walled polygons: 1, thin section no. 27; 3, thin section no. 30; 5, 7, thin section no. 29.

2, 4  Oblique sections close to the juvenarium: 2, thin section no. 11; 4, thin section no. 28.

6  Vertical section, not quite centered, showing the conical layer, some of the large nepionic chambers, and the structure of the comb-shaped apex. Thin section no. 7.
PLATE 5

1-4, 6-8, *Ctenorbitoides cardwelli* Bronnimann, n. sp., from core at 2789–2808 feet in Cristales well no. 1A. 
10-13 1–2, 4, 6–7, vertical and oblique vertical cuts across the peripheral portion of the base of the cone exposing the *Vaughanina*-like type of pseudorbitoidal structure, × ca. 73: 1, 4, thin section no. 8; 2, thin section no. 3; 6, thin section no. 4; 7, thin section no. 10; 3, vertical section, × ca. 363, of part of the juvenarium, showing the sulcus; same specimen as in pl. 3, fig. 5; thin section no. 5; 8, 11–13, vertical sections of smaller specimens, in part oblique, but almost centered, × ca. 73: 8, 11, thin section no. 27; 12, thin section no. 32; 13, thin section no. 10; 10, oblique cut across center of small specimen, × ca. 73, showing uniserial juvenarium and, on the left side, a portion of the conical layer with *Vaughanina*-like annular walls; thin section no. 15.

5 *Conorbitoides cristalensis* Bronnimann(?), from core at 2789–2808 feet in Cristales well no. 1A. 
Oblique cut across the test, × ca. 73; it is not clear whether or not the sulci show *Vaughanina*-like structure. Thin section no. 16.

9 *Conorbitoides cristalensis* Bronnimann(?), from core at 2789–2808 feet in Cristales well no. 1A. 
Horizontal cut above the juvenarium, × ca. 73; the lateral chambers are arranged concentrically around the central fan or pillar. Thin section no. 22.

14–16 *Conorbitoides cristalensis* Bronnimann, n. sp., from core at 2789–2808 feet in Cristales well no. 1A. 
Vertical sections across the small cone-shaped test, × ca. 73; 14–15, practically centered cuts: 14, thin section no. 1; 15, thin section no. 18; 16, thin section no. 7.

PLATE 6

1–2, 6 *Placopsilina* sp. ex gr. *cenomanana* d’Orbigny – *longa* Tappan, from core at 2789–2808 feet in Cristales well no. 1A; all × ca. 73: 1, initial spire cut almost horizontally; thin section no. 27; 2, 6, vertical cuts across the tests of large specimens; thin section no. 10.

3–5 *Acervulina cenomaniana* (Seguenza), from core at 2789–2808 feet in Cristales well no. 1A; all × ca. 73. Vertical sections: 4–5, centered; 3–4, thin section no. 21; 5, thin section no. 13.

7 *Archaeolithothamnium* sp., from core at 2789–2808 feet in Cristales well no. 1 A; × ca. 73. Thin section no. 18.

PLATE 7

1–4 *Ctenorbitoides cardwelli* Bronnimann, n. sp. 
1–3, holotype; 4, paratype. All × 65.

5–6 *Conorbitoides cristalensis* Bronnimann, n. sp. 
Holotype; × 148.
micropaleontology, volume 4, number 2