

ON THE VARIABILITY OF SOME RECENT AND FOSSIL "CLAVULINA" SPECIES (FORAMINIFERA).

by

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With 3 figures and 5 plates

ZUSAMMENFASSUNG

In einem synoptischen Diagramm wird ein Überblick über die verschiedenen Gattungen der Clavulinen gegeben. Die Variabilität der rezenten Clavulinen, *Clavulina angularis* d'ORBIGNY, und fossiler Clavulinen, *Clavulinoides trilatera* CUSHMAN, *C. selectiva* HAGN und *C. gaultina* (MOROZOVA), wird vorgestellt und die Formen werden auf 5 Tafeln abgebildet.

Das Artkonzept wird kurz erläutert. Hervorgehoben wird, daß die Kontroverse Biospezies/Morphospezies nur ein Scheinproblem darstellt. Es gibt noch eine Reihe weiterer Artkonzepte, die auf die Foraminiferen angewandt werden.

Um ein nomenklatorisches Chaos in naher Zukunft zu vermeiden, werden drei Vorschläge unterbreitet: Selbstbeschränkung bei der Aufstellung neuer Taxa, Untersuchung großer Stückzahlen gleicher oder ähnlicher Arten und Studium rezenter Foraminiferen.

ABSTRACT

The variability of Recent *Clavulina angularis* d'Orbigny and fossil *Clavulinoides trilatera* Cushman, *C. selectivus* Hagn, and *C. gaultinus* (Morozova), is presented and figured on five plates. A review on the different clavulinid genera is given in a synoptical diagram.

The species concept is reconsidered. Study of large suites of specimens and study of living foraminifera are vital to taxonomic work in micropaleontology.

INTRODUCTION

Many recently established generic and subgeneric taxa seem to be the result rather of sophisticated thinking in paleontology than actually of intensive study of the fossil material.

One of the most fascinating phenomena of micropaleontology, in particular foraminiferology, is the vast material the scientist can deal with. But it is a pity that many specialists neglect this advantage. A careful study of large suites of

specimens shows that there is considerable morphological variation of phenotypic forms in each foraminiferal stock. Evolutionary thinking in paleontology in recent decades has been hindered by a tendency to hide this variability of foraminifera in new taxonomic criteria.

The present author would like to explain his ideas on these problems. The variability of some Recent and fossil "*Clavulina*" species will serve as an example.

Material studied:

Sample 1: Recent; Red Sea, shore sample approximately 20 km south of Hurghada, Egypt; courtesy of Paul Romul, Neusäß (Germany).

Sample 2: Late Cretaceous, Middle Maastrichtian (*Globotruncana gansseri* zone); Corsicana Marl from original sample of Cushman (1946: sample 29); courtesy of James Mello, Dept. of Paleobiology, U.S. National Museum of Natural History, Washington, D.C. (U.S.A.).

Sample 3: Late Cretaceous, Middle Maastrichtian (*Globotruncana gansseri* zone); Arkadelphia Marl from original sample of Cushman (1946: sample 72); courtesy of James Mello.

Sample 4: Late Cretaceous, lower part of Late Campanian (*Globotruncana ventricosa* zone); "Grünsand-Übergangsschicht" of Imkeller (1896) (equivalents of Pinswang beds, Hagn 1953a, 1953b; Stackelberg 1960); Stallau Creek, elevation approximately 800 m, south of Bad Heilbrunn, Upper Bavaria (Germany).

Sample 5: Early Cretaceous, lower part of Late Albian; Tannheim beds, forest road cut (Neuer Illingstoa-Weg), elevation 930 m, east of Ohlstadt, Upper Bavaria (Germany), (Weidich 1982, p. 375).

Deposition of material:

Figured specimens and thin sections are deposited in the micropaleontological collection of the Bayerische Staatssammlung für Paläontologie und historische Geologie (BSP) in Munich (Germany):

Foraminiferal cells: 6038-6048,

Thin sections (76 x 26 mm): 1053-1100 a/86.

TAXONOMY OF "CLAVULINAS"

D'Orbigny established the genus *Clavulina* in his "Tableau méthodique de la classe des Céphalopodes" in 1826. His short description adequately defined the morphotype as at that time similar genera were unknown. But d'Orbigny did not designate a type species.

The taxonomic concept of the early foraminiferal workers did not always take into account the fine structure of the walls and aperture.

Carpenter *et al.* (1862, p. 192) went so far as to conceive the genus *Clavulina* d'Orbigny as "clavuline varieties of *Valvulina* and *Verneuilina*".

In 1863 Parker and Jones chose *Clavulina angularis* d'Orbigny, 1826, as type species and they emended the diagnosis so that in the genus *Clavulina* the aperture is without a tooth.

Cushman (1911, p. 72) on the other hand, took *Clavulina parisiensis* d'Orbigny, 1826, as type species, and this species was thought to have a tooth in its aperture. He wrote: "aperture in early chambers with a valvular tooth; in the later portion aperture central or nearly so, rounded, and with or without a tooth". So, we must hold that in the youngest chambers a tooth may sometimes be missing.

Cushman also described the species *Clavulina bradyi* Cushman 1911, a new name for *Clavulina cylindrica* Brady, 1884 (non *C. cylindrica* d'Orbigny, 1826) as "usually with a single valvular tooth" and "having the single valvular tooth or sometimes none" (Cushman 1911, p. 74).

Though this species later became type species of *Cylindroclavulina* Bermudez and Key, 1952, because of its cylindrical initial part, one can see that a certain variation in the formation of a tooth had been observed much earlier in time.

Considering that fossil foraminifera may preserve poorly due to diagenesis, the presence or absence of a tooth can be a morphological character hardly to be recognized as such. Additionally the functional morphology of a tooth is not understood and the presence or absence of a tooth during ontogeny is not at all clear.

In the following years, Cushman and other foraminiferologists observed several morphotypes differing from the original *Clavulina* with chamber arrangement 3-1 (triserial followed by uniserial part; compare figure 1), and test shape, triangular in early stages and cylindrical in adult specimens.

Furthermore the composition and formation of the chamber wall and of the septa (labyrinthic, canaliculate, non-caliculate, solid), as well as the formation of the chambers themselves (internally subdivided), were other criteria for establishing new taxa, [see also Coleman (1980); Banner and Pereira (1981)]:

Clavulinella Schubert, 1920

Martinottiella Cushman, 1933

Pseudoclavulina Cushman, 1936

Clavulinoides Cushman, 1936

Cylindroclavulina Bermudez and Key, 1952

Clavulinopsis Banner and Desai, 1985

Figure 1 shows a synopsis of several clavulinas and their morpho-characters. The distinguishing characters between the genera are indicated by bold lines. One can see that nearly all morpho-character classes served as generic criteria. There was no rank of characters.

CHARACTER GENUS	test shape		chamber wall	septa	chamber	chamber arrangement	aperture					
	early stages	adult specimen	canaliculate (c) noncanaliculate (nc)	solid (s)	internally subdivided		shape rounded (r) elongate slit (e)	number single (s) multiple (m)	tooth (t)	tooth plate (p)	position in early portion	position in adult specimen
<i>Clavulina</i> D'ORB. 1826	tri. ³	cyl.				3-1 ⁶		s				term.
<i>Clavulina</i> D'ORB. EMEND. PARKER & JONES	tri.	cyl.				3-1		s	-			
<i>Clavulina</i> D'ORB. IN CUSHMAN 1948	tri.	cyl.				3-1	r or lobed	s	t			term.
<i>Pseudoclavulina</i> CUSHMAN 1936	tri.	cyl.				3-1	r	s	-			term. ¹⁵ neck
<i>Clavulinoides</i> ¹ CUSHMAN 1936	tri.	cyl.				3-(2)-1 ⁷	r or ¹¹ radiate	s	-			term.
<i>Clavulinoides</i> CUSH. EMEND. BANNER & DESAI			c	s		3-1	r	s	-	interio- marg. ¹⁴		term.
<i>Clavulinopsis</i> BANNER & DESAI 1985			c	s		3-1		(s or m) m ¹²	-	areal	areal	
<i>Tritaxilina</i> CUSHMAN 1911	cyl. ⁴	cyl.	c		+	5/4/3-2-1 ⁸	r	s	t	interio- marg.		term.
<i>Clavulinella</i> SCHUBERT 1920	cyl.	cyl.	c		+	3-1		s				
<i>Martinottiella</i> CUSHMAN 1933	± cyl.	cyl.			-	5/4-3-2-1 ⁹	e			lip ¹³		term.
<i>Cylindroclavulina</i> BERMUDEZ & KEY 1952	cyl.	cyl.			-	3-2-1		s	t			term. ¹⁶ neck
<i>Valvulina</i> D'ORBIGNY 1826	tri.	tri.			-	3		s	t			interio- marg.
<i>Tritaxia</i> REUSS 1860 EMEND. BANNER & DESAI	tri.	tri./ ⁵ compress.	nc	s		3(-1) ¹⁰	r	s	p	areal	areal	
<i>Marieita</i> ² LOEBLICH & TAPPAN 1964	tri.	tri.	labyrinthic					m				areal

Fig. 1.

Synoptical diagram of several clavulinas and their morphocharacters. Only characters mentioned in the type descriptions are noted.

- 1) LOEBLICH & TAPPAN (1964, p. C272) consider *Clavulinoides* CUSHMAN, 1936, as a junior synonym of *Tritaxia* REUSS, 1860.
 - 2) *Marieita* LOEBLICH & TAPPAN (1964, p. C294).
 - 3) tri. = triangular.
 - 4) cyl. = cylindrical.
 - 5) tri./compress. = "triangular in section in early stage, later portion uniserial and commonly triangular, more rarely compressed" (LOEBLICH & TAPPAN, 1964, p. C272). This description of *Tritaxia* REUSS, 1860, is an emended definition as REUSS (1860, pp. 227-228) has not mentioned a uniserial adult part.
 - 6) 3-1 = triserial followed by uniserial part.
 - 7) 3-(2)-1 = "earliest portion triserial, triangular, frequently with an early biserial stage following the triserial portion,, adult uniserial" (CUSHMAN, 1948, p. 126).
 - 8) 5/4/3-2-1 = "early stage with as many as five chambers in the first whorl, then successively reducing to four, three, two, to a rectilinear series in the adult" (CUSHMAN, 1948, p. 138).
 - 9) 5/4-3-2-1 = "early stages a trochoid spire with several chambers, usually five in the first whorl of the microspheric form, and keeping four or five for several whorls, later becoming uniserial abruptly" (CUSHMAN, 1948, p. 138); "early chambers trochospiral with 4 or 5 to whorl, progressively reduced to triserial, biserial, and uniserial, adult with relatively elongate uniserial development (LOEBLICH & TAPPAN, 1964, p. 282).
 - 10) 3(-1) = "initially or wholly triserial, sometimes abruptly adding one, two or three final chambers in rectilinear uniseries" (BANNER & DESAI, 1985, p. 85).
 - 11) r or radiate = aperture rounded or with radiating portions.
 - 12) (s or m) m = aperture of triserial part single or multiple, uniserial part with multiple aperture.
 - 13) lip = with bordering lip.
 - 14) interiomarginal = aperture interiomarginal.
 - 15) terminal neck = aperture terminal often with neck.
 - 16) terminal neck = aperture terminal on distinct neck.
- To *Pseudoclavulina*: HOFKER (1967a: *Pseudoclavulina anglica* CUSHMAN, and 1976a: *Pseudoclavulina clavata* CUSHMAN) did some work on the fine structure of the chamber walls of species of this genus. He recognized solid walls on both species.

VARIABILITY OF SOME "CLAVULINA" SPECIES

Beginning with the intensive study of foraminifera for applied micropaleontology in the last few decades, the sudden increase of different forms made new names necessary. The morpho-species concept was strictly applied to Recent and fossil

foraminifera. However, other taxonomic concepts also (see next chapter) brought forward an avalanche of names.

As with the genera of the clavulinas, no observation of any strong ranking of morpho-characters in the species can be made. Some specialists use cross sections, sutures and shapes of tests, while others

like to dwell upon special agglutination preferences and size of tests.

Insufficient material led to some poor descriptions of taxa. Only a few examples exist where large suites of specimens were the material basis of the discussion of new species.

Clavulina angularis d'Orbigny, 1826

Figure 2, plates 1 and 2

The present author received some hundred clavulinas gathered by Paul Romul from one Recent sample from the Red Sea (sample 1). It was difficult to assign these forms to species well established in the literature (e.g. Cushman 1910, 1918; Bock *et al.* 1971; Calvez 1977¹). Those species are:

Clavulina angularis d'Orbigny, 1826

C. nodosaria d'Orbigny, 1839

C. tricarinata d'Orbigny, 1839

C. angularis d'Orbigny var. *difformis* Brady, 1884

C. humilis Brady var. *mexicana* Cushman, 1922

C. pacifica Cushman, 1924

It is easy to gather few specimens and then label them with a specific name. But it was impossible to do so with all those specimens transitional between the six taxa listed above.

To get a better idea of the variability of these clavulinas, the material was split into five

morphogroups taking into consideration the form of the chambers and the contact of the chambers of the uniserial part of the test:

Group 1:

Globular to subglobular chambers, sutures strongly depressed and straight; very rare, mostly broken (transitional forms to Group 2 frequent; compare figure 2 and morphotypes of Group 2 of figure 2 and plate 2, figures 9-11,13).

Group 2:

Chambers like little barrels, sutures distinctly to slightly depressed and straight; frequent; (plate 2, figures 9-14).

Group 3:

Chambers columnar, sutures slightly depressed and straight; frequent; (plate 2, figures 4-5).

Group 4:

Chambers similar to Group 3, but with an overlap on the preceding chambers, sutures slightly or distinctly depressed and curved; abundant; (plate 1, plate 2, figures 1-3).

Group 5:

Like Group 4, but additionally with overlapping chambers at the edging looking like spines; rare to common; (plate 2, figures 6-8).

One can also establish five groups, if the cross section is chosen as the distinguishing character: rounded, ellipsoidal or bicarinate, tricarinate, quadricarinate, and quinquecarinate.

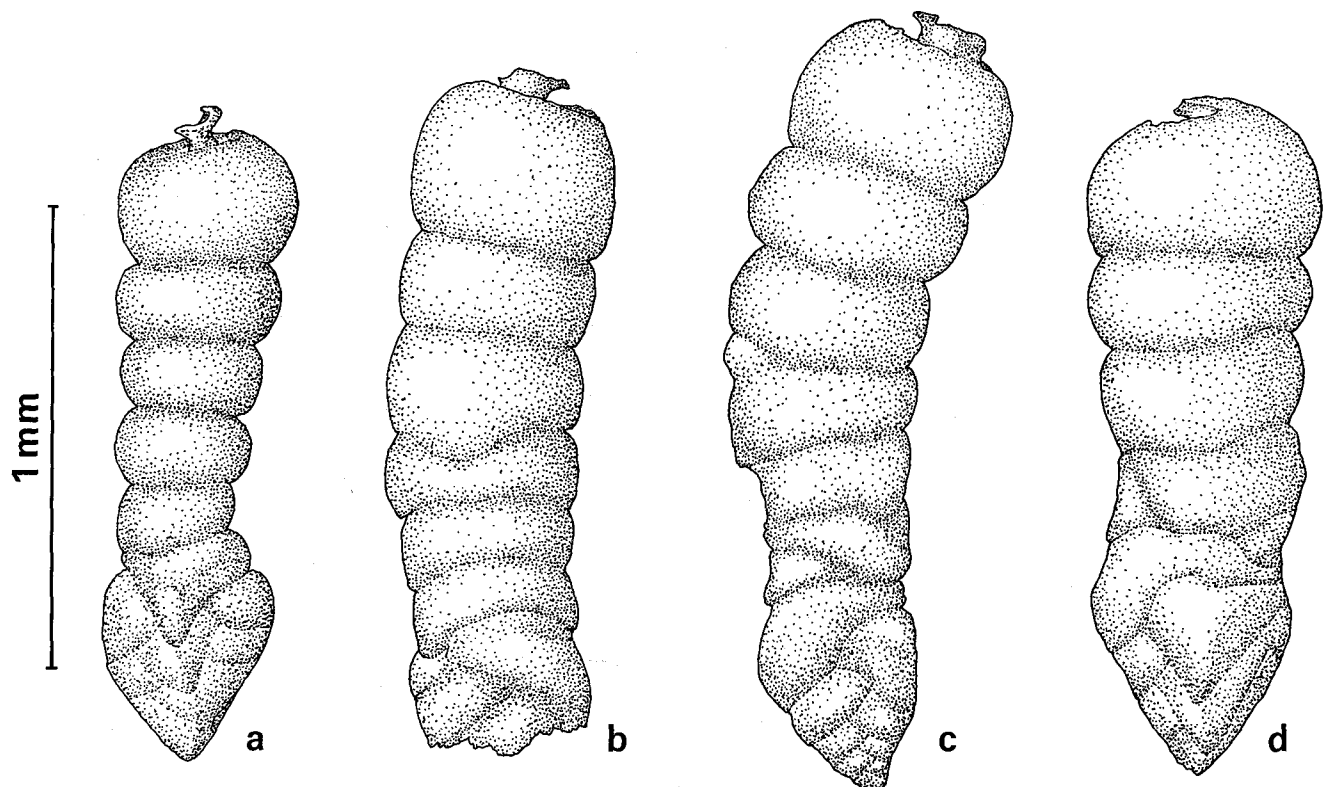


Fig. 2. Variability of *Clavulina angularis* d'ORBIGNY. Recent sample, Red Sea (sample 1).

a = Morphotype 1; b-d = Morphotype 2. Note irregular growth of the first uniserial chambers in specimens c and d.

Most of the specimens belong to Group 4 with a great variability in cross-section. But except for the dwarfed specimens (plate 2, figures 15-20) and Group 1, which are rare, all other groups are quite frequent. They can be seen as transitional forms to Group 4 (e.g. initial part of uniserial portion angular, later part rounded in cross-section or sutures curved in the early part, later straight).

Unfortunately the proloculus is broken in the vast majority of the specimens, so that the few complete specimens were not sectioned for measurements of the proloculus. Measurement of the proloculus diameter as made in oil or water is vague and it would be insufficient to give any of those values.

Some sectioned specimens show side walls which are canaliculate as did Toksvad and Hansen (1983, p. 160, plate 1, figure 2), in their "*Clavulina pacifica*" and "*Clavulina nodosaria*".

Clavulina angularis is known worldwide from Recent tropical to warm temperate shallow seas. Probably Tertiary morphotypes similar to the Recent specimens can be labelled with the same name.

From the frequent transitional forms, it was concluded that all morphotypes probably form one "species" only. Therefore the oldest name was chosen as valid: *Clavulina angularis* d'Orbigny 1826.

Clavulinoides trilatera (Cushman, 1926)
Plate 3

Morphotypes attributed to this species by the present author have been assigned to the Recent proloculus

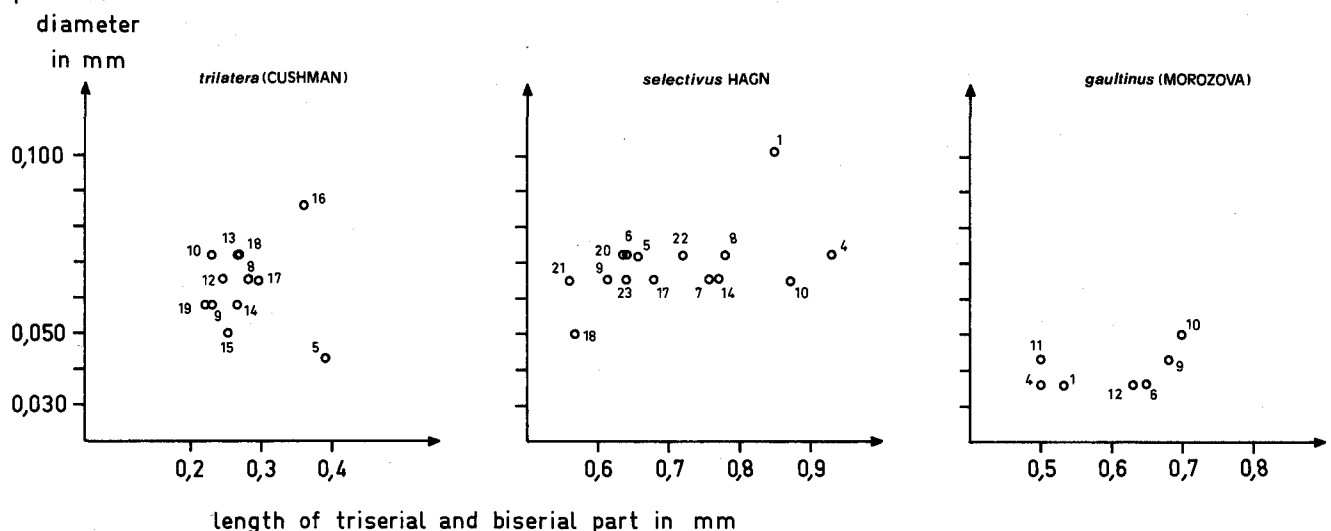


Fig. 3. Diagrams of proloculus diameter vs. length of triserial and biserial part of the tests of *Clavulinoides trilatera* CUSHMAN, *C. selectivus* HAGN, and *C. gaultinus* (MOROZOVA). All measurements with aid of an ocular micrometer from thin sections. Numbers refer to figured specimens on plates 3, 4 and 5 respectively.

species *Clavulina angularis* d'Orbigny, 1826, in some early papers on Late Cretaceous foraminifera (e.g. Plummer 1926).

Clavulinoides trilatera is perhaps one of the most variable "*Clavulina*" species. If one picks out these forms from samples rich in clavulinas (samples 2 and 3), the enormous variation is quite striking. Plate 3 gives only a few examples of this phenomenon to prove that there are intermediate forms at least between seven species, subspecies and varieties published so far. These taxa are:

- Clavulina trilatera* Cushman, 1926
- C. trilatera* Cushman var. *aspera* Cushman, 1926
- C. compressa* Cushman, 1928
- C. trilatera* Cushman var. *concava* Cushman, 1931
- C. insignis* Plummer, 1931
- C. aspera* Cushman var. *whitei* Cushman and Jarvis, 1932
- C. plummerae* Sandidge, 1932

Specimens triangular in cross-section as well as specimens asymmetrically triangular to plano-convex in cross-section apparently made up the bulk of the Late Cretaceous samples. Specimens with concave sides (tricarinate or quadricarinate) are the extreme variants on the one end of the scale of form variation, while thin concave-convex types form the other end.

The proloculus diameter of the sectioned specimens plotted in a diagram (figure 3) against length of triserial and biserial part of the test form a conglomeration of dots from which it is difficult to draw conclusions about a dimorphism with microspheric and megalospheric forms. From observations of thin sections, side walls are found to be canaliculate, as was recently shown by SEM photomicrographs by Banner and Desai (1985).

The stratigraphic range seems to be Santonian to Maastrichtian in northern America and Europe.

Clavulinoides selectivus Hagn, 1953
Plate 4

Test elongate, strongly developed triserial initial part, slightly concave sides, peripheries well rounded. Biserial stage indistinct, only visible in clarified specimens, little developed. Uniserial part short as seen from the specimens available, consisting of 3 chambers, cross-section triangular and rounded. Early chambers indistinct, in the uniserial part more distinct, slightly tumid. Sutures indistinct, in particular in the early part, later slightly depressed. Test material finely arenaceous, surface matt, with much calcareous cement; characterized by small, laminated, black grains, which are incorporated in the test, and may be of biotite. Aperture terminal, rounded, with small neck.

The above description follows Hagn (1953b, p. 17), to which can be added:

Triserial part in some specimens rounded, in other specimens more acute,

Uniserial part consists of up to 5 chambers,

Cross-section of uniserial part very variable, rounded to ellipsoidal, tricarinate or quadricarinate with slightly concave sides (compare plate 4).

There is only a weak correlation between proloculus diameter and length of triserial and biserial part of the test (figure 3). Specimens with larger triserial and biserial parts seem to have a larger proloculus too.

A sexual dimorphism with microspheric and megalospheric specimens was not observed.

In the side walls of the sectioned specimens no pores (probably due to diagenetic cementation) could be observed with the exception of two specimens where parts of side walls show some vague darker lines, perpendicular to the surface, which could be interpreted as pores.

The species was obtained from the lower part of the Late Campanian of southern Germany (Pinswang beds and "Grünsand-Übergangsschichten" of the Helvetikum unit).

No similar species has so far been found in the literature.

Clavulinoides gaultinus (Morozova, 1948)
Plate 5

Morozova (1948, p. 36) described a new species of apparent relationship to the *Clavulina plexus* with

an elongated-pyramidal triangular triserial part and a pronounced uniserial part which is round in cross-section. Compared with the figure of the holotype, the following morpho-character should be added: early chambers of the uniserial part somewhat angular.

Although placed in the genus *Clavulina* d'Orbigny, 1826, so far no other colleague has been able to observe a tooth in the aperture, nor did Morozova mention presence or absence of a tooth.

Agalarova (in Dzhafarov et al. 1951, p. 73) established the new species *Clavulina brevis*, which may be a juvenile specimen of *Clavulinoides gaultinus* (Morozova). Agalarova explicitly pointed out the round and terminal aperture without any lip-like projection².

In 1951 Noth placed the species *gaultinus* in the genus *Clavulinoides* Cushman, but did not mention whether he had seen a biserial stage or not. His figures (plate 2, figures 12-13 and plate 4, figure 8) are not quite clear in this detail, while the specimen of figure 7 on plate 4 is of the type 3-1. Noth (1951) distinguished three morphotypes concerning the form of the uniserial chambers, but was reserved in establishing new taxa.

Neagu (1962) also observed a considerable variability of the species *gaultinus*. He found morphotypes with chamber arrangement 3-1 and 3-2-1 (triserial followed by uniserial part and triserial followed by biserial and uniserial part (see figure 1), and therefore chose *Clavulinoides* as the correct genus. Considering the form of the uniserial chambers, Neagu established two new subspecies: *gaultinus carinatus* and *gaultinus intermedius*, in addition to *Clavulinoides gaultinus gaultinus* (Morozova).

Apparently this species is highly variable when considering the arrangement and form of the chambers, and it will be sufficient to use one name for this mid-Cretaceous and worldwide distributed species:

Clavulinoides gaultinus (Morozova, 1948)

1948 *Clavulina gaultina* sp. nov. - Morozova, p. 36, plate 1, figure 4 (Western Caucasus Mts., USSR).

1948 *Pseudoclavulina californica* Cushman and Todd, n. sp. - Cushman and Todd, pp. 92-93, plate 16, figure 6a-b (California, U.S.A.)

1951 *Clavulina brevis* Agalarova, 1951. - Agalarova, p. 73, plate 11, figures 5-6 (Azerbaijan, USSR) [after Ellis & Messina].

1951 *Clavulinoides gaultinus* (Morozova). - Noth, pp. 36-37, plate 2, figures 12-13; plate 4, figures 7-8 (Austria).

1961 *Clavulina gaultina* Morozova, 1948. - Scheibnerova, p. 35, plate 2, figure 1a-b (Carpathian Mts., USSR).

1962 *Clavulinoidea gaultinus gaultinus* (Morozova) 1948, *Clavulinoidea gaultinus carinatus* n. ssp., *Clavulinoidea gaultinus intermedius* n. ssp. - Neagu, pp. 419-425, plate 40 (Rumania).
v 1969 *Pseudoclavulina gaultina* (Morozova, 1948). - Risch, pp. 73-74, plate 1, figure 2 (southern Germany).
1973 *Clavulina gaultina* Morozova. - Dailey, p. 47, plate 3, figure 9 (California, U.S.A.).

Although the chamber arrangement is often 3-1, 3-2-1 types are rather rare, and the chamber walls of the sectioned specimens are found to be non-canalicate (perhaps due to diagenesis), the present author recommends the genus *Clavulinoidea* in this case, nonetheless.

THE SPECIES CONCEPT IN FORAMINIFEROLOGY

The presented examples of various clavulinas clearly demonstrate the high variability of foraminiferal species. Several other cases of considerable variation could be produced within the benthics, e.g. *Valvulineria/Gyroidina* in the Early Cretaceous, *Gaudryina* and *Spiroplectammina* in the Late Cretaceous, as well as within the planktonics, e.g. *Rotalipora cushmani* (Morrow) Weidich, 1984.

Problems of assignment to certain genera or species arise only if large suites of specimens are considered. As seen from older and more recent literature the practice of using large suites of specimens is neglected. That is the reason why many poorly defined "new" taxa are established and differential diagnosis are not given.

The species concept in fossil foraminifera species as well as in nearly all Recent species is based on test morphology.

Therefore the biospecies/morphospecies controversy seems to be a fictive problem only, because the biospecies concept cannot be applied to fossil foraminifera. The biospecies concept is rarely applied to Recent foraminifera. Looking critically at the old and new papers on foraminiferal taxonomy, it is obvious that there are some other species concepts within the literature, including:

Statistical species;

Geographical species : e.g. Boreal and Tethyan foraminifera, though morphologically identical, belong to different species;

Regional-value species: a certain morphological variety in a region is split off for its local stratigraphic value and is raised to specific rank;

Geochronological species: a morphologically identical form is split off because the total range of the morphotype is interrupted by a gap of (known at

the time) non-existence for several millions of years;
Cladistic species;

Lineage species;

Lost-material species: type material of a species was lost and a new species is established instead of revising and establishing a neotype;

High-tech species: a new species is established after SEM or TEM studies, whilst morphologically similar and well known species have been studied in the past by light-microscopy only.

CONCLUSIONS

In the author's opinion three proposals can be made to simplify taxonomy, rather than complicate it: 1) Self-restriction in establishing new taxa: The editors of scientific journals are asked to reject poorly defined and figured new taxa based on insufficient material, and missing differential diagnosis. 2) Study of large suites of specimens, horizontally and vertically, to check the variability of fossil and Recent foraminifera. 3) Study of living foraminifera in the sea and in culture to check physico-chemical and biological parameters which are responsible for the observed variability of foraminifera.

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FOOTNOTES

1) Calvez (1977) in her revision of the d'Orbigny Collection put *tricarinata*, *difformis*, and *pacifica* into synonymy of *Clavulina angularis* d'Orbigny.

2) At that time, and later, Russian authors mostly did not distinguish between "Clavulina with tooth" (= *Clavulina*) and "Clavulina without tooth" (= *Pseudoclavulina*) or in Rauser-Chernousova and Fursenko (1959, p. 224) they placed *Pseudoclavulina* as a subgenus into *Clavulina*.

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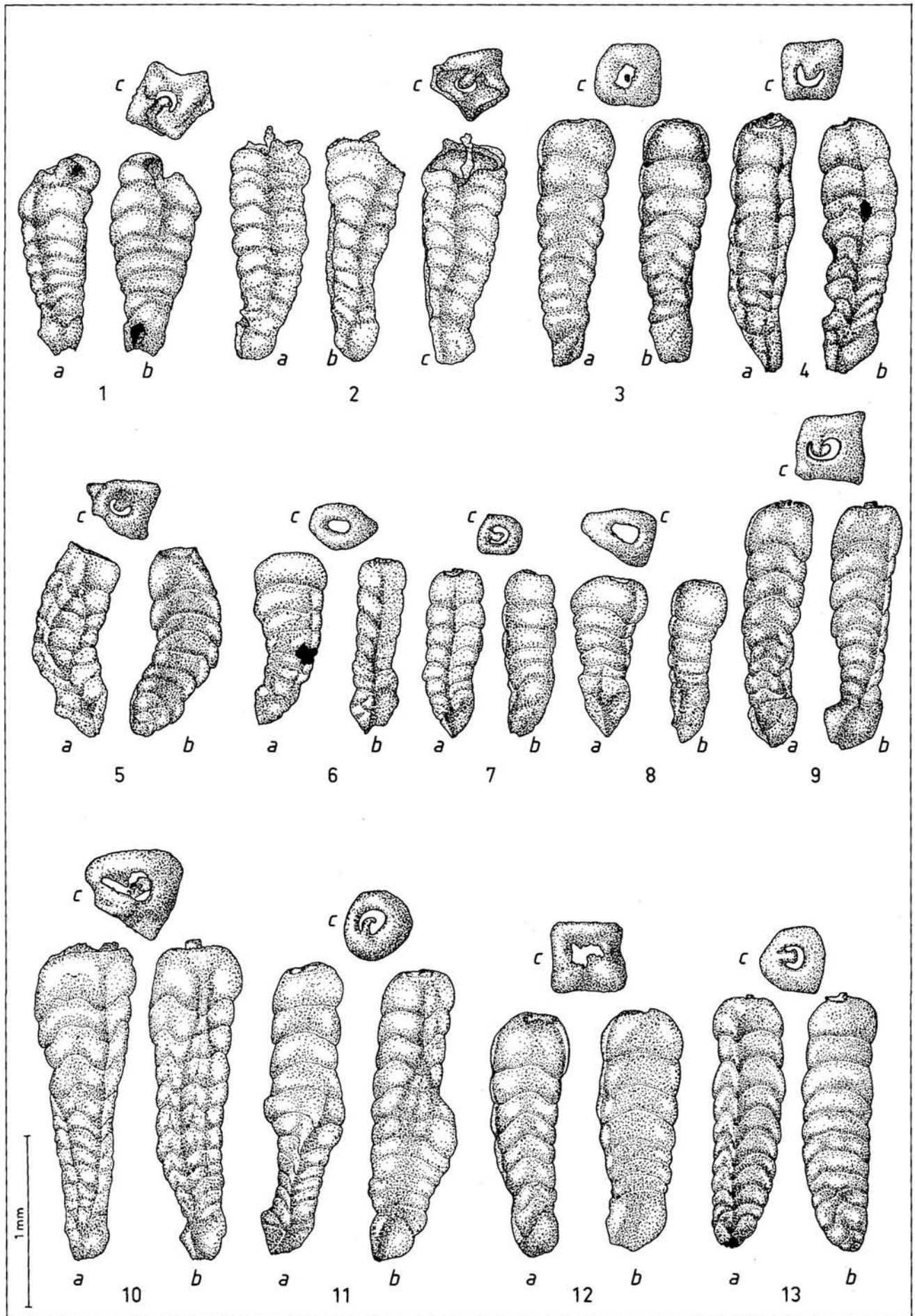
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PLATE 1

Variability of *Clavulina angularis* d'Orbigny
Recent sample, Red Sea (sample 1).

- Figures 1-2 Morphotype 4, quinquecarinate.
Figures 3-12 Morphotype 4, adricarinate.
Figure 13 Morphotype 4, tricarinate.

The plates are *camera lucida* drawings by the author.



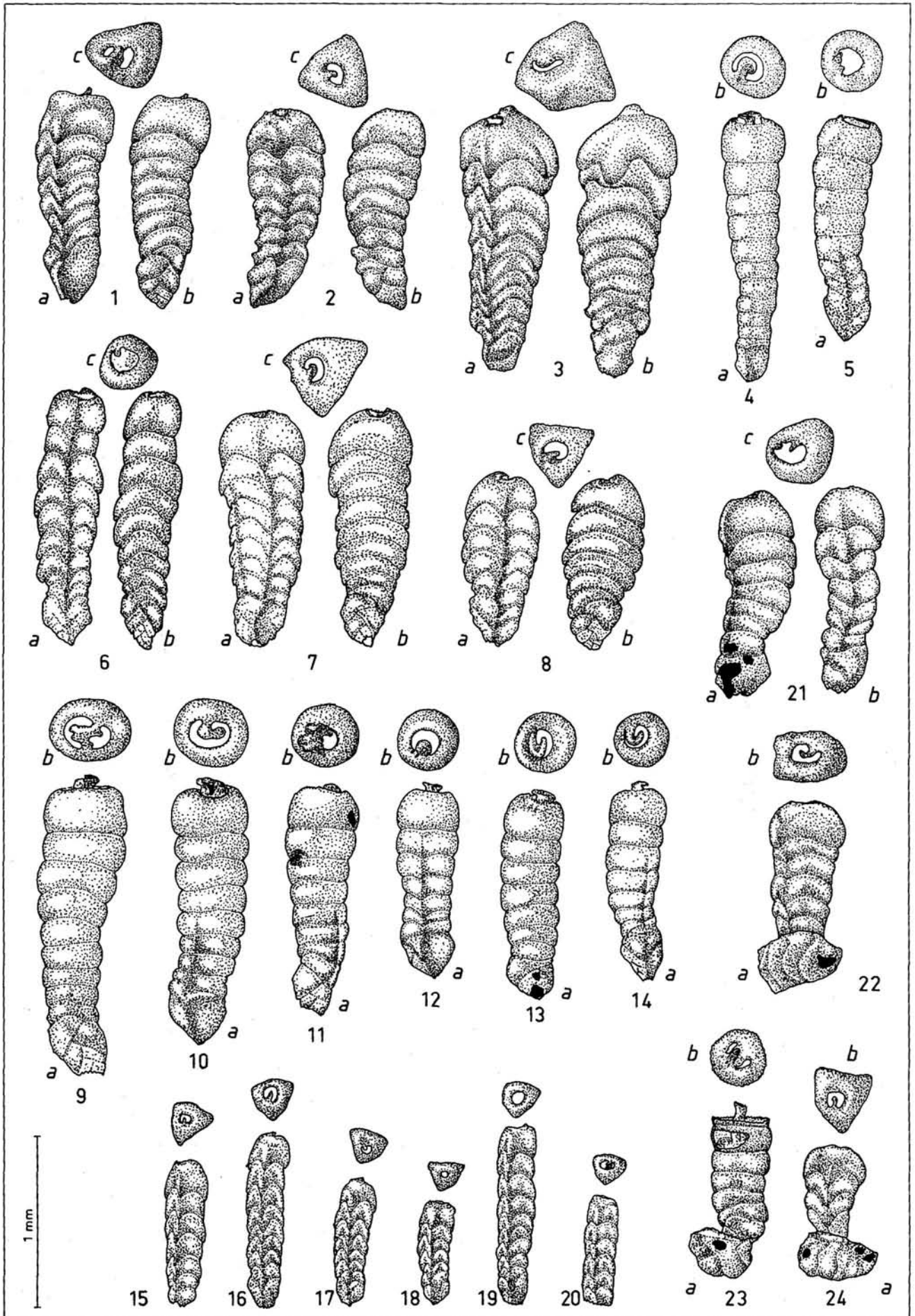


PLATE 3

Variability of *Clavulinoides trilatera* (Cushman).
Late Cretaceous, North America (samples 2 and 3).

- Figure 1-3 Morphotypes with strongly concave sides (sample 2).
 Figures 1-2 tricarinate form.
 Figure 3 quadricarinate form.
- Figures 4-19 Three different morphotypes with regards to cross-section
 (sample 2):
 Figures 4,8,11-15, 18-19 tricarinate throughout, sides
 concave or slightly convex in the centre.
 Figures 5,9 asymmetric tricarinate, one side plan.
 Figures 6,7,10,16-17 initial part tricarinate, later
 bicarinate. Figure 7 convex-plan. Figure 6 biconvex.
 Figures 10, 16-17 convex-concave.

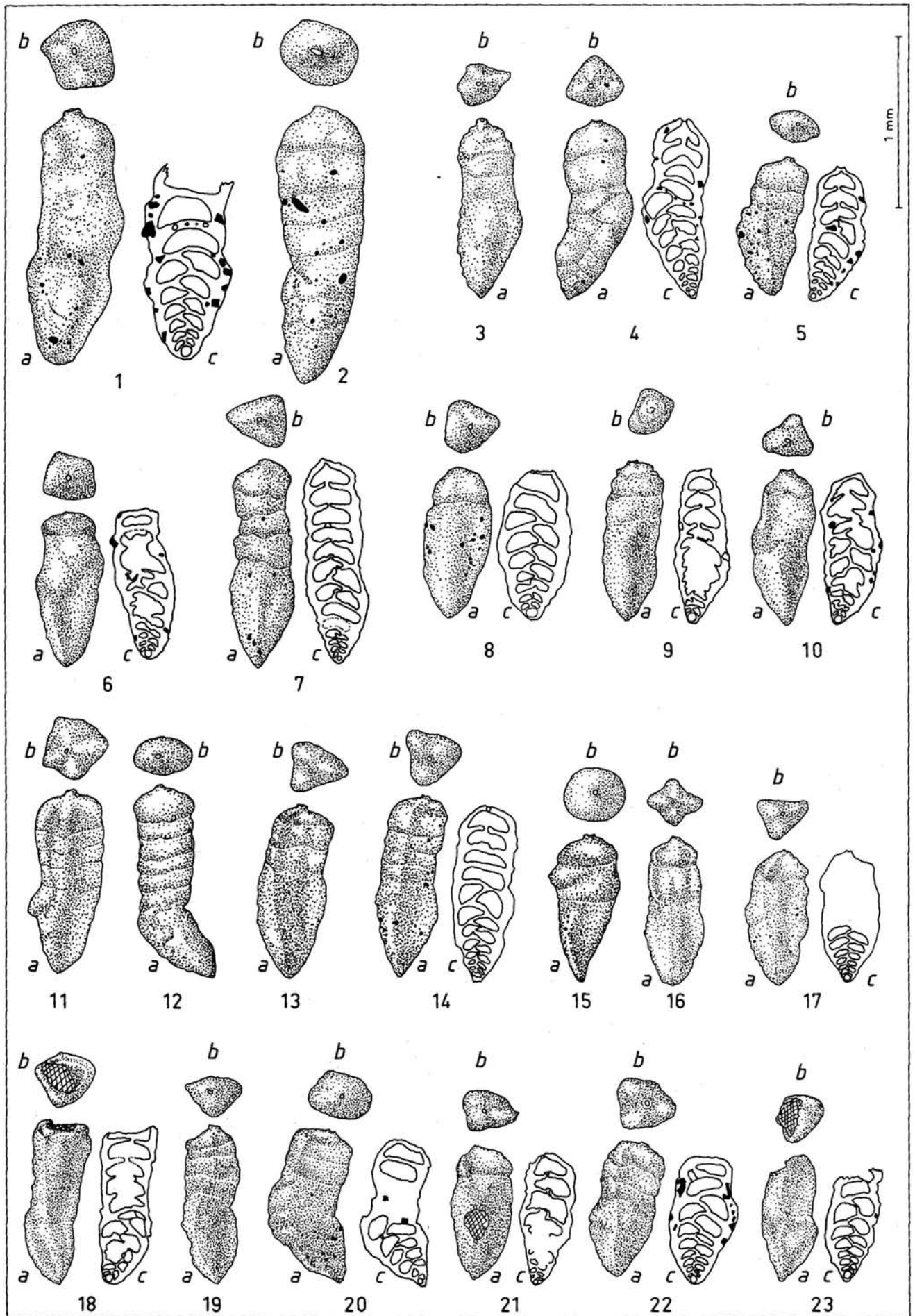


PLATE 4

Variability of *Clavulinoides selectivus* Hagn
Late Cretaceous, southern Germany (sample 4).

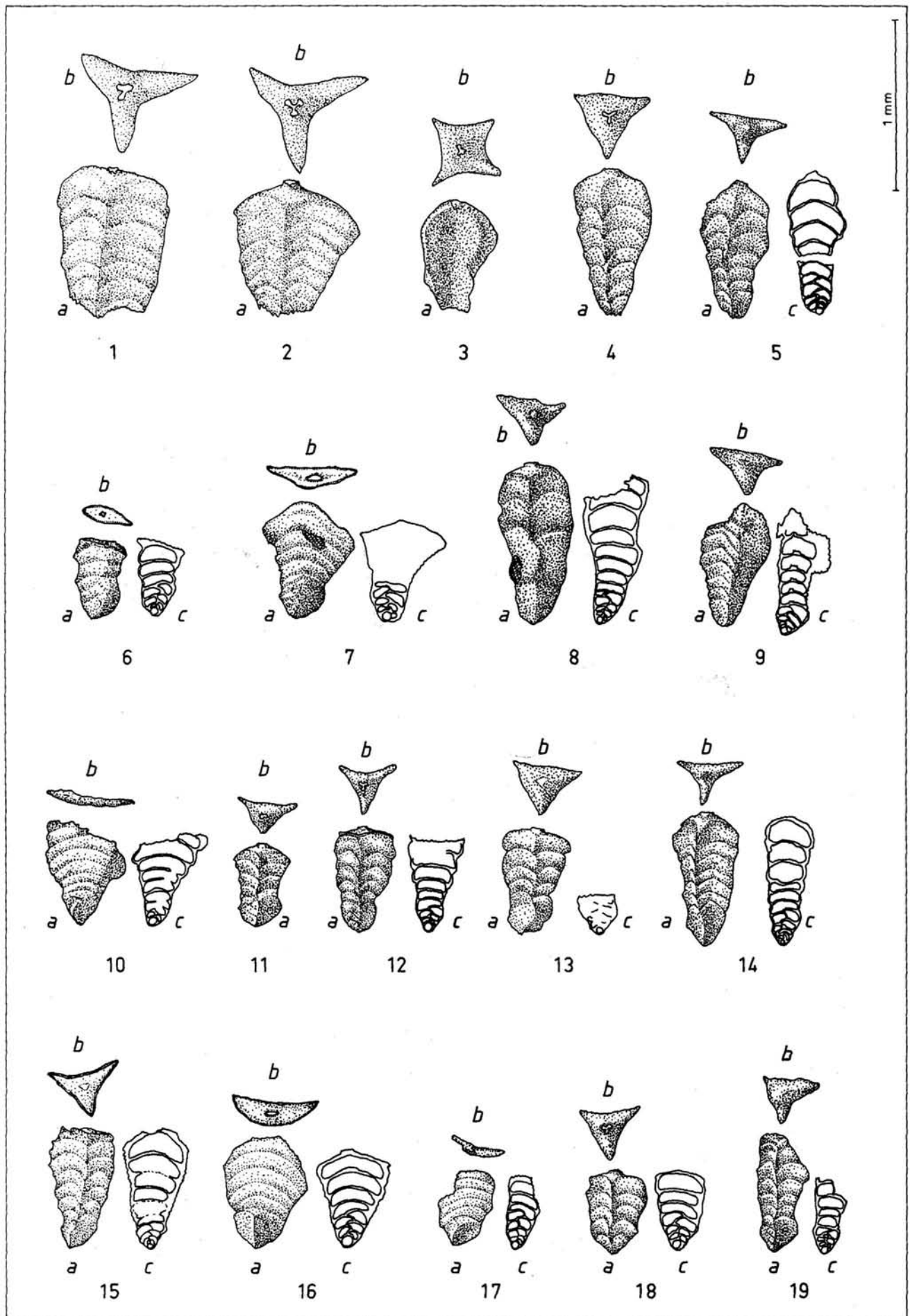
Three morphotopes as regards to cross-section:

Figures 2, 5, 9, 12, 15, 18, 20 rounded or ellipsoidal:

Figures 1, 3-4, 7-8, 10, 13-14, 17, 19, 21-23 tricarinate:

Figures 6, 11, 16 quadrincarinate with slightly concave sides.

Remarks: Larger black dots in the "a" figures are the "black, shiny bodies" of Hagn (1953b, p. 17). Black dots in the "c" figures (thin sections) are larger angular quartz grains.



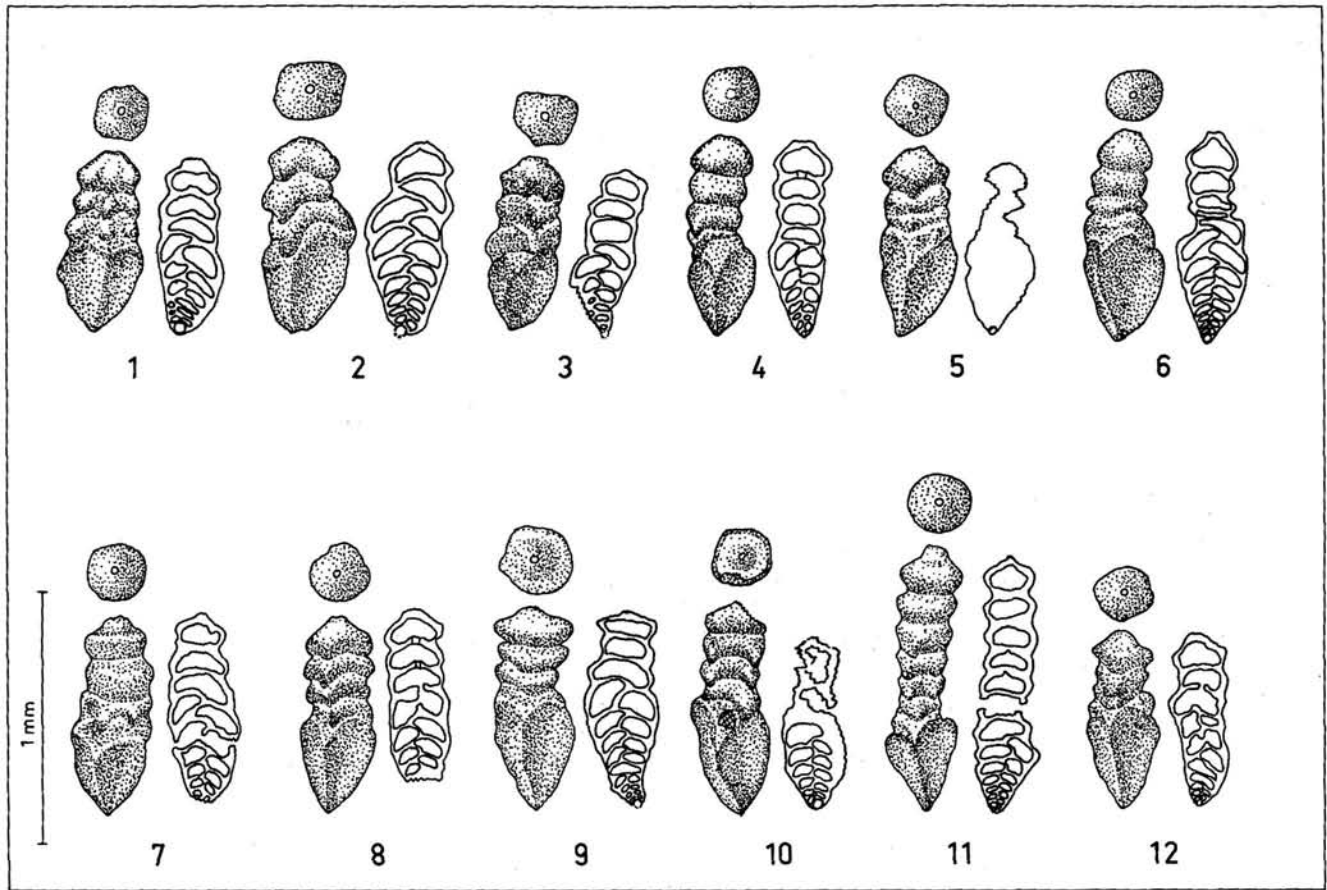


PLATE 5

Variability of *Clavulinoides gaultinus* (Morozova).
Early Cretaceous, southern Germany (sample 5).

Two (three) morphotypes as regards to cross-section and form of chambers:

Figures 1-3, 5, 8, 10, 12 angular:
Figures 4, 7, 11 transitional forms:
Figures 6, 9 rounded.