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118. UPPER CRETACEOUS AND LOWER TERTIARY
BOLIVINOIDES FROM ISRAEL

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ABSTRACT—Fourteen species and subspecies of **Bolivinoidea** from the Late Cretaceous and Early Tertiary of Israel are recorded and figured. Five of them are described as new. The recorded species and subspecies are divided into three major groups. The stratigraphical ranges of the recorded **Bolivinoidea** are summarized in a range-chart.

INTRODUCTION

Particular attention has been paid in recent years to certain specialized genera of smaller Foraminifera, such as *Neoflabellina*, *Bolivinoidea*, *Stensiöina*, and others. These genera evolve rather rapidly through a succession of short-living, mostly widely-distributed forms and are, therefore, extremely valuable in stratigraphical work, especially as far as Late Cretaceous and Early Tertiary deposits are concerned.

Up to the present detailed research on these genera was restricted to northern and northwestern Europe, where various European authors have investigated the taxonomy, phylogeny and stratigraphic distribution of the species and subspecies belonging to the above-mentioned genera. Relatively little is known on these important forms from other parts of the world.

Detailed studies of the genera *Neoflabellina* and *Bolivinoidea*, carried out at present by the writer in Israel, have already proved the importance of these genera for the Upper Cretaceous and Lower Tertiary stratigraphy of this region.

Some results regarding the occurrence of the species and subspecies of the genus *Bolivinoidea* in the Upper Cretaceous and Lower Tertiary of Israel are given below. These investigations are still in progress because more material will have to be examined in order to solve various problems. Nevertheless, taking into account the scarcity of knowledge regarding the genus *Bolivinoidea* in the Middle East and Mediterranean area in general, and in view of the importance of this genus for the Upper Cretaceous and Lower Tertiary stratigraphy, it seemed useful to publish the results so far obtained in Israel.

As far as known to the writer, no specimen of Upper Cretaceous-Lower Tertiary *Bolivinoidea* has ever been figured from the Middle East region, except by LeRoy (1953) under the name of *Bolivina*. Published records give only generic references (Henson 1938, Tromp 1943, 1949, 1952), except *Bolivinoidea decorata* (Jones) recorded by the writer (1952a, 1952b) from Israel and by LeRoy (1953) from Egypt; *B. rhom-*

boidea (Cushman) recorded by Nakkady (1950) from Egypt; *B. decorata* (Jones) *delicatula* Cushman and *B. draco* (Marsson) recorded by the writer (1952a) from Israel.

For microfaunal evidence of the age of the stratigraphical units of Israel, as given in the accompanying range-chart, reference is made to the writer's (1952a, 1952b) publications. The writer now regards: a) the strata carrying *Globotruncana concavata* (Brotzen) (= *Globotruncana ventricosa* Reiss, 1952a, non White) and *Texanites* as Santonian (lower part of the Santonian-Campanian of Reiss 1952a); b) all strata carrying *Bolivinoidea peterssoni* Brotzen as Upper Maestrichtian (Stevnsian of Brotzen 1945); c) the lower part of the "Dano-Paleocene" (i.e., the *Globigerina*-zone) as Danian; d) and the upper part of the "Dano-Paleocene" (i.e., the *Globigerina-Truncorotalia* zone) as Paleocene. The writer prefers to include the Danian (regarded by him to belong to the Lower Tertiary) and the Paleocene in a "Dano-Paleocene" unit, separated from the Maestrichtian by an unconformity marked in the range chart.

For synonymies and additional references the reader is referred to the publications cited at the end of this paper, especially to Hiltermann and Koch (1950).

The figures are camera-lucida drawings by the writer.

All figured specimens are deposited in the micropaleontological collection of the Geological Institute of Israel, Jerusalem.

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with picking, counting and measuring specimens and to Miss R. Strassburger for drawing the accompanying tables.

SYSTEMATIC PALEONTOLOGY

The discussion of the species and subspecies mentioned here follows the order maintained in the accompanying range-chart and in the table showing the length/breadth index-values.

Genus *Bolivinoidea* Cushman, 1927

Bolivinoidea angulata Reiss, sp. nov.

Plate 28, figures 1-4

Holotype.—Pl. 28, fig. 1a, b, $\times 110$, from the Lower Campanian of Tulkarem, well 6 (Type-locality). No. 2139. Pal. Coll. of Geol. Institute Jerusalem.

Diagnosis.—Test carrot-like to bolt-shaped in outline; section rounded-rectangular, concave towards the medial part of the test; chambers roof-like and angular with rather deep excavations towards the medial part of the test, giving this part of the test a grooved character; ornamentation consisting of prominently raised and elongated lobes of the chambers, forming ribs and knots, mostly obscuring the sutures; length: up to 0.5 mm. (For length/breadth index-values of this and the following species, see accompanying table).

Relationships and remarks.—*B. angulata* is apparently closely related to *B. strigillata strigillata* (Chapman) and to *B. clavata* (Cushman). These latter species have, however, a broadly oval section always with convex sides and rarely rounded-rectangular, and do not have such angular (hence the *derivatio nominis*) or excavated chambers as our species.

Occurrence.—*B. angulata* occurs sporadically at various localities in the country, where it is usually frequent. It seems to be restricted to the Campanian and occurs mainly in the Lower Campanian and only rarely in the deepest layers of the Upper Campanian.

Bolivinoidea decorata decorata (Jones)

Plate 28, figures 5-8, 13

1950. *B. decorata decorata* (JONES) HILTERMANN and KOCH, p. 606, figs. 2-4, No. 14-25, 27-31, 35-38, 42-45 and fig. 5 No. 36, 71.

Remarks.—Specimens of this subspecies occur frequently in the Campanian and Lower Maestrichtian of Israel. They show a rather great range of variation as far as dimensions and ornamentation are concerned, a fact observed also by Hiltermann and Koch (1950) in northern Europe.

Rare specimens resembling somewhat *B. decorata gigantea* Hiltermann and Koch were found in the Maestrichtian of Israel, but a closer study is required to establish their identity with any known species of *Bolivinoidea*.

Bolivinoidea draco miliaris Hiltermann and Koch Plate 28, figures 9-12, 14

1950. *B. draco miliaris* HILTERMANN and KOCH, p. 604, figs. 2-4 No. 26, 32-34, 39-41, 46-48, fig. 5 No. 39a-c.

Remarks.—The stratigraphical range of this subspecies is greater in Israel than in northern Europe. It occurs in Israel together with *B. peterssoni* Brotzen, *Neoflabellina coranica* (Marie), etc. There is no evidence that the specimens of *B. draco miliaris* in these Upper Maestrichtian strata are redeposited. Additional study might reveal certain characteristics of the late Maestrichtian specimens which may distinguish them from those of the Campanian and early Maestrichtian. It might be noteworthy in this connection that *Bolivina decurrens* (Ehrenberg) Marsson also has a shorter stratigraphical range in northern Europe than in either the Gulf-Caribbean area or in Israel. It seems that ecological factors have affected the stratigraphical ranges of certain species in northwestern Europe, since except the above-mentioned two species, *Bolivinoidea paleocenica* (Brotzen) also occurs in that region only in the Lower Maestrichtian. In Scandinavia, however, it occurs also in the Paleocene and in Israel in the Maestrichtian, as well as in the Dano-Paleocene (see also below). Most probably ecological factors are also responsible for the "Stensiöinen-freier Bereich" of Wicher (1953) in the lower part of the Upper Maestrichtian, characteristic of boreal Europe, according to Wicher (1953).

In Israel *B. draco miliaris* occurs most frequently in the Upper Campanian.

Bolivinoidea draco draco (Marsson)

Plate 29, figures 1-3

1878. *Bolivina draco* MARSSON, p. 157, pl. 3, 25a-d.
1950. *Bolivinoidea draco draco* (MARSSON) HILTERMANN and KOCH, p. 598, figs. 2-4 No. 52-54, 58-60, fig. 5 No. 53, 69, 70, fig. 1 No. 72a-c, 73a-b.

Remarks.—This subspecies is a guide-fossil for the Maestrichtian of Israel, where it occurs very frequently. In the higher Maestrichtian it occurs associated with the closely related *B. draco dorreeni* Finlay.

Bolivinoidea draco dorreeni Finlay

Plate 29, figures 4-7

1940. *Bolivinoidea dorreeni* FINLAY, p. 453, pl. 63, figs. 56-58.

Remarks.—This form is characterized mainly by the prominently "fenestrate" or reticulate ornamentation, which distinguishes it from *B. draco draco*. It is, however, closely related to this latter subspecies and is connected with it by transition-forms.

Our specimens correspond closely to *B. dorreeni* Finlay, except in the fact that the specimens figured by Finlay (1940) are somewhat more elongated than ours. The index of the specimens figured by Finlay,

ca. 1.5, remains, however, within the range of the *draco*-group (see below). On the other hand, Finlay mentions only the greatest length of *B. dorreeeni*, but not the greatest breadth, or the length/breadth index.

The most interesting fact about *B. dorreeeni* Finlay is its occurrence in the Piripauan stage of New Zealand, the age of which is given by Finlay as Santonian (!). Three alternative explanations might be offered for this surprising stratigraphical range of a member of the *draco*-group, to which *B. dorreeeni* certainly belongs. a) either the specimens of *B. dorreeeni* have not been found by Finlay *in situ*; b) or the *draco*-group is polyphyletic and evolves in New Zealand from another than the *decorata*-group, appearing there as early as Santonian; c) or the age-determination of the Piripauan stage as given by Finlay is incorrect. Although no literature which would allow any conclusion on the age of the Piripauan stage is available to this writer, the latter assumes an incorrect age-determination as the most likely explanation. Finlay states that *B. dorreeeni* is a Piripauan index fossil; on the other hand neither in the Eastern, nor in the Western hemisphere are rhomb-shaped *Bolivinoidea*s with a continuous rib ornamentation known to occur before the Maestrichtian. Furthermore, the evolution of the *draco*-group has been traced back clearly to the *decorata*-group (Hiltermann and Koch, 1950) which itself does not appear earlier than Campanian.

These considerations allow the identification of our specimens with *B. dorreeeni* Finlay, which we regard as a subspecies of the *draco*-group (*s. str.*, not in the sense of Hiltermann and Koch, 1950).

Most probably *B. draco dorreeeni* is involved in Wicher's (1953) record of a "reticulate new subspecies" belonging to the *draco*-group and appearing in the boreal Upper Maestrichtian. The specimen of *B. rhomboidea* (Cushman) figured by Wicher (1949) on pl. 7 probably represents *B. draco dorreeeni* Finlay.

Length of *B. draco dorreeeni*: up to 0.7 mm.

Frequent in the higher Maestrichtian (especially Upper Maestrichtian) of Israel.

***Bolivinoidea watersi* (Cushman)**

Plate 29, figure 8

1927. *Bolivina watersi* CUSHMAN, Cushman. Lab. Foram.

Research Contr. vol. 2, p. 88, pl. 12, fig. 6.

Remarks.—Specimens belonging to this species occur in the Lower Campanian of Israel. Certain individuals of this small and easily overlooked species somewhat resemble in outline and chamber-form *Bolivina decurrens* (Ehrenberg) Marsson (*non* Wicher, 1942).

B. watersi occurs sporadically at a number of localities in Israel.

***Bolivinoidea pustulata* Reiss, sp. nov.**

Plate 29, figures 9-10

Holotype.—Pl. 29, fig. 9a, b, $\times 110$, from the Lower

Campanian of Judeida (Type-locality). No. 813: Pal. Coll. of Geol. Institute of Jerusalem.

Diagnosis.—Test elongated, club-shaped in outline; section flatly elliptical, periphery sharply rounded to subacute; ornamentation consisting of prominently raised, circular knobs, arranged in two paramedian rows on the earlier chambers, followed by fairly indistinct knobs and elongated weakly raised lobes, arranged in two or—rarely—three paramedian rows in the later chambers; ornamentation restricted to the medial part of the test; sutures depressed, distinct and slightly curved; length: up to 0.5 mm.

Relationships and remarks.—This species resembles somewhat *B. texana* Cushman, which, however, is much less ornamented and has no knobs on the earlier chambers. Our species differs from *B. laevigata* Marie in its more elongated form, in its more rounded periphery and in its ornamentation consisting of prominent pustule-like knobs on the early chambers.

Occurrence.—*B. pustulata* occurs rather rarely in the Lower Campanian of Israel.

***Bolivinoidea compressa* Reiss, sp. nov.**

Plate 30, figures 1-3

Holotype.—Pl. 30, fig. 1a, b, $\times 110$, from the Upper Campanian of Er Ruweis (Type-locality). No. 839 (a): Pal. Coll. Geol. Institute, Jerusalem.

Diagnosis.—Test extremely flat; periphery very acute and keeled; sutures strongly curved, limbate, clear and somewhat depressed; ornamentation consisting of nearly circular, weakly raised knobs, arranged in two (very rarely only one) paramedian rows; length: up to 0.5 mm.

Relationships and remarks.—Our species is apparently closely related to a hitherto undescribed species occurring in the Campanian of Germany. *B. compressa* also resembles the species figured by Hiltermann (1952, fig. 5) as *B. decorata laevigata* Marie, which, in the writer's opinion, does not correspond to *B. decorata laevigata* Marie. Marie's subspecies has no circular knobs, as shown in Hiltermann's specimen, but has very faintly raised, elongated lobes, arranged in two to three paramedian rows (Marie, 1941). Furthermore, the holotype of *B. decorata laevigata* figured by Marie does not show any ornamentation on the lower part of the test. Our species seems also near to *Bolivina decurrens* Wicher (*non* Ehrenberg, *nec* Marsson) figured by Wicher, 1942 on pl. 26, fig. 24. Wicher's specimen, however, shows more prominently raised knobs.

Occurrence.—*B. compressa* occurs rarely and sporadically in the Campanian of Israel.

***Bolivinoidea praecursor* Reiss, sp. nov.**

Plate 30, figures 4-7

Holotype.—Pl. 30, fig. 4a, b, $\times 110$, from the Upper Campanian of Er Ruweis (Type-locality). No. 839 (b): Pal. Coll. Geol. Institute, Jerusalem.

Diagnosis.—Test flatly elliptical in section; periphery acute, sometimes slightly keeled in the early chambers; sutures distinct, very oblique and slightly curved; ornamentation consisting in the early stages of rather faintly raised, somewhat irregular knobs, in the later stages of distinct, somewhat nodular and short, elongated lobes; the latter are arranged in two (rarely three) paramedian rows; length: up to 0.45 mm.

Relationships and remarks.—*B. praecursor* is apparently closely related to *B. peterssoni* Brotzen and is regarded by the writer as the ancestor of the latter species (hence the *derivatio nominis*). It is distinguished from *B. peterssoni* by its more elongated form, less acute and only rarely slightly keeled periphery and also by the elongated form of the lobes. Our species is apparently related to *B. decorata laevigata* Marie (length/breadth index, from data given by Marie, 1941: 1.6-2.0), which, however, has very faintly raised, scarcely perceptible lobes. Marie's figure of the holotype suggests furthermore that the ornamentation of *B. decorata laevigata* is restricted to the upper half of the test. Since it appears doubtful that *B. decorata laevigata* is indeed a subspecies of *B. decorata* (Jones) or even that it is directly connected with the latter, the writer proposes to elevate *B. decorata laevigata* to specific rank.

The writer was unable to examine topotypes of *B. laevigata*, but has seen specimens of *Bolivinoidea* from western Europe, labelled *B. decorata laevigata*, which represent at least two different species, differing moreover in some details from the original figure of *B. laevigata*. One of the forms from Germany is apparently closely related to our *B. praecursor*. Most probably a similar form is involved in Hiltermann's (1952) record of *B. peterssoni* from the Upper Campanian and Lower Maestrichtian of northwestern Germany. Wicher (1953) on the other hand believes his *Bolivinoidea* sp. ("traubig")—considered by Wicher to be the ancestor of *B. peterssoni*—to be involved. This writer has examined specimens of *B. sp.* ("traubig") most kindly supplied by C. A. Wicher and found them to belong to the species recorded and figured by Hiltermann and Koch (1950) and Hiltermann (1952) as *Bolivinoidea decorata delicatula* Cushman. For reasons to be discussed later, it is most unlikely that this latter species, which is different from *B. decorata delicatula* Cushman, is the ancestor of *B. peterssoni*. Wicher's (1953) figure of his *B. sp.* ("traubig") is not sufficiently clear.

Such extremely broad forms as figured on pl. 30, fig. 8 might represent transition forms between *B. praecursor* and *B. paleocenica* (Brotzen).

Occurrence.—*B. praecursor* occurs fairly frequently in the Upper Campanian and Lower Maestrichtian of Israel.

Bolivinoidea sp.

Plate 29, figure 11

Remarks.—The identity of this species is not yet established. Extremely rare specimens have been found in the Upper Campanian of Israel (with *Globotruncana calcarata* Cushman). It is characterized by its rather broad general form with an acute periphery and 3 paramedian rows of distinctly raised oblong lobes. It seems to be related to *B. laevigata* Marie, which, however, is apparently not ornamented in the early stages. More material is needed to establish the identity and relationships of our form. A specimen is figured for further reference.

Bolivinoidea peterssoni Brotzen

Plate 30, figures 12-14

1945. *B. peterssoni* BROTZEN, p. 49, pl. 1, fig. 10.

Remarks.—Specimens belonging to this species occur in the Upper Maestrichtian of Israel.

Bolivinoidea paleocenica (Brotzen)

Plate 30, figures 9-11

1948. *Bolivina paleocenica* BROTZEN, p. 66, pl. 9, fig. 5.

1952. *Bolivinoidea paleocenica* (BROTZEN) HILTERMANN, pp. 61, 63, figs. 4, 5.

Remarks.—This species has been recorded from the Paleocene of Scandinavia (Brotzen, 1948) and from the Lower Maestrichtian of northwestern Germany (Hiltermann, 1952, Wicher, 1953). In Israel it occurs throughout the Maestrichtian (except in the basal layers), and also in the "Dano-Paleocene."

The writer has so far not observed any essential differences between the specimens from the Maestrichtian and those from the "Dano-Paleocene." After discussion with F. Brotzen he agrees that the Maestrichtian form should be separated from the post-Maestrichtian one. However, until more material has been examined, both forms are included for the time being in *B. paleocenica*.

We do not believe that the post-Maestrichtian specimens are redeposited, as is supposed by Wicher (1953) to be the case in the Paleocene of Sweden. In the first place *B. paleocenica* ranges in Israel higher in the Maestrichtian than in northern Europe (see also the remarks concerning *B. draco miliaris*, *Bolivina decurrens* and *Stensiöina* above). Secondly, it would be surprising that just one of the rarest forms of the Maestrichtian of Israel should be found redeposited in the "Dano-Paleocene," while much more common and abundant species occur redeposited only rarely and then mostly in the basal layers of the "Dano-Paleocene."

Bolivinoidea delicatula Cushman

Plate 31, figures 1-4

1926. *Bolivina decorata* CUSHMAN (*non* JONES), p. 586, pl. 15, fig. 11.

- 1927(a). *Bolivinooides decorata delicatula*. CUSHMAN, p. 90, pl. 12, fig. 8.
 1927(b). *Bolivinooides decorata delicatula*. CUSHMAN, p. 158, pl. 28, fig. 7.
 1928. *Bolivinooides decorata delicatula*. CUSHMAN, p. 99, Pl. 14, 9.
 1929. *Bolivina decorata* WHITE (non JONES), p. 43, pl. 5, fig. 1.
 1932. *Bolivinooides decorata delicatula*. CUSHMAN and JARVIS, pl. 13, fig. 2.
 1946. *Bolivinooides decorata delicatula*. CUSHMAN and RENZ, p. 36, pl. 6, fig. 4.
pars 1946. *Bolivinooides decorata delicatula*. CUSHMAN, p. 313, pl. 48, figs. 10, 13 (non figs. 11, 12, 14).
non 1926. *Bolivina latticea* CARSEY, p. 27, pl. 4, fig. 9.
non 1931. *Bolivinooides decorata delicatula*. CUSHMAN, p. 308, pl. 35, fig. 13.
non 1931. *Bolivina decorata*. PLUMMER, p. 181, pl. 10, fig. 10 (refigured holotype of *B. latticea* CARSEY 1926).
non 1932. *Bolivinooides decorata delicatula*. CUSHMAN, p. 388, pl. 51, fig. 6.
non 1941. *Bolivinooides decorata delicatula*. MARIE, p. 188, pl. 29, fig. 280.
non 1950. *Bolivinooides decorata delicatula*. HILTERMANN and KOCH, p. 612, fig. 5, No. 65-67.
non 1952. *Bolivinooides decorata delicatula*. HILTERMANN, pp. 61, 63, figs. 4, 5.

Remarks.—This writer intentionally does not apply the trinominal name *B. decorata delicatula*, since there is yet no evidence that this species is derived from *B. decorata* (Jones) or even from the *decorata*-group, and thus representing a subspecies of *B. decorata*.

Specimens of this species from Israel have been compared by F. Brotzen with topotype-material from the Velasco-shale formation of Mexico and found to correspond entirely to the American species (written communication, October 22, 1952).

The writer separates from *B. delicatula* the specimens figured by Cushman (1931, 1932, refigured 1946 pl. 48, figs. 11 and 12) from the Taylor and Navarro formations of the Gulf Coast region. These specimens differ from *B. delicatula*, figured from the Velasco shale and from the Lizard Springs marl, in the rapid increase of the breadth of the test, smaller length/breadth index (1.7-1.8 as against 2.2-2.5), in the ornamentation composed of elongated and short, almost rectangular, closely spaced ribs, arranged in a very regular pattern all over the chambers, and in their different stratigraphical range (Campanian-Maestrichtian against late Danian to Paleocene). It might be significant that Cushman himself (1931, 1932) notes with regard to the Taylor and Navarro specimens the comparatively short test with an "ornamentation of the surface... more like that of the variety than of the typical species" (*B. decorata* (Jones), writer's note) and "on the whole (tending) toward the variety

(*B. decorata delicatula* Cushman, aut. note) rather than the typical form of the species."

The writer proposes, therefore, for this species the name *Bolivinooides regularis*, sp. nov. (holotype: pl. 35, fig. 13, Cushman, 1931, from the Saratoga Chalk, Saratoga, Arkansas, Howard County (station 79 of Cushman 1946), refigured in Cushman 1946, pl. 48, fig. 12. Deposited (see Cushman 1946) in the Cushman Collection, U. S. Nat. Museum, Washington, D. C.

As far as the specimen figured by Cushman (1946) as *B. decorata delicatula* from the Taylor marl of Texas (*l.cit.*, pl. 48, fig. 14) is concerned, the writer agrees with Hiltermann and Koch (1950) that it belongs to the group of poorly ornamented *Bolivinooides* (such as *B. watersi*, *B. laevigata*, *B. pustulata*, *compressa*, *praecursor*, etc.).

Although the specimens figured as *B. decorata delicatula* by Hiltermann and Koch (1950) and Hiltermann (1952) have a greater length/breadth index than *B. regularis*, sp. nov. as figured by Cushman (1931, 1932) they show a markedly similar ornamentation and general form. On the other hand the writer has seen material from Germany which leads him to the conclusion that generally the specimens of *B. decorata delicatula* Hiltermann and Koch (*non* Cushman) have a smaller length/breadth index than the specimens figured by Hiltermann and Koch (1950), (i.e., mostly between 1.7-2.0, agreeing closely with the specimens of *B. regularis*, sp. nov. as figured by Cushman). The specimens from Germany, furthermore, have tests which increase rapidly in breadth and the ornamentation is distinctly that of *B. regularis*. The stratigraphical range of *B. decorata delicatula* Hiltermann and Koch (*non* Cushman) also agrees closely with that of *B. regularis* in the Gulf Coast region (Campanian-Lower Maestrichtian), but not with that of *B. delicatula* Cushman (Danian-Paleocene). For these reasons the writer includes *B. decorata delicatula* Hiltermann and Koch (*non* Cushman) in *B. regularis*. To this latter species also belongs—as pointed out above—*B. sp.* ("traubig") of Wicher (1953). The specimen figured by Marie (1941) as *B. decorata delicatula*, might belong to *B. regularis*; it is certainly not a *B. delicatula*. *B. latticea* Carsey might be an independent species. The publications of Dain (1934), Subbotina (1936) and Keller (1939) were not available to the writer.

No specimens of *B. regularis* have been observed so far in Israel.

In its typical form *B. delicatula* occurs in Israel only in the "Dano-Paleocene."

***Bolivinooides curta* Reiss, sp. nov.**

Plate 30, figures 15-16

Holotype.—Pl. 30, fig. 16 a, b, $\times 110$, from the Dano-Paleocene (*Globigerina-Truncorotalia* zone) of

Tzor'a (Type-locality). No. 1845: Pal. Coll. Geol. Institute, Jerusalem.

Diagnosis.—Test small, rather flat and elongated, often subelliptical; section flatly elliptical; periphery acute; ornamentation consisting of rather strong short ribs, formed by the raised lobes, covering very regularly the chambers of the whole test; suture-lines marked by the ornamentation pattern; length: up to 0.35 mm.

Relationships and Remarks.—*B. curta* is apparently closely related to *B. delicatula* Cushman, but is distinguished from the latter by its much smaller and shorter test and smaller length/breadth index. It is much smaller than *B. regularis*, sp. nov. and has a more acute periphery.

Occurrence.—This small and short species occurs fairly frequently in the "Dano-Paleocene" of Israel.

GENERAL REMARKS

The material from Israel, as well as published records, descriptions and figures of the various species of *Bolivinoidea* lead the present writer to distinguish three major groups of Upper Cretaceous and Lower Tertiary *Bolivinoidea*, which have been segregated in the text, the range-chart and the tables showing the length/breadth index-values. Each group differs from the other in several constant characters, especially in the ornamentation. Within each group related sub-groups can be distinguished. Each group evolves through a stratigraphically well-marked succession of species and subspecies with certain evolutionary tendencies as far as both, form and ornamentation, are concerned.

1). The first major group comprises forms with strong ornamentation, distributed over the whole length of the chambers, obscuring the sutures and composed of oblique rows of strongly raised, oblong tubercles, knots, beads or continuous *costae* (ribs). In some forms the *costae* are connected by thickenings of the chambers, running parallel with and covering the sutures, resulting in a fenestrate or reticulate pattern. The outline of the forms belonging to the first major group evolves from carrot-like through wedge-shaped to broadly rhomboid. The section evolves from rounded-rectangular (with convex or concave sides) through broadly oval or elliptical to flatly rhomboid. The apertural face of the test is, mostly prominently, a thickened "rim". Forms with a broad to rounded periphery are followed by those with a sub-acute to acute periphery, which in turn are followed by keeled forms.

The evolutionary pattern of this major group has been analyzed by Hiltermann and Koch (1950).

To this group belong: *B. strigillata austinana* Cushman, *B. strigillata strigillata* (Chapman) [the writer accepts for the time being Hiltermann's (1952) suggestion to regard *B. austinana* and *B. strigillata* as sub-

species of *B. strigillata*, *B. strigillata austinana* appearing, however, apparently earlier than *B. strigillata strigillata*]; *B. clavata* (Cushman), *B. explicata* (Cushman and Hedberg), *B. angulata*, sp. nov. *B. decorata decorata* (Jones), *B. decorata gigantea* Hiltermann and Koch, *B. draco miliaris* Hiltermann and Koch, *B. draco draco* (Marsson), *B. draco dorreeni* Finlay.

Three sub-groups might be distinguished within this major group: one including the elongated carrot- or bolt-shaped forms with a broad periphery: *B. strigillata austinana*, *B. strigillata strigillata*, *B. clavata*, *B. explicata*, *B. angulata*; the second comprising wedge- or club-shaped flat forms, whose ornamentation does not show a continuous *costae*-pattern or a marked tendency toward it: *B. decorata decorata*, *B. decorata gigantea*; and the third sub-group comprising broadly rhomboid forms, the ornamentation of which is composed of rows of beads and knots, partly connected, with a marked tendency to form continuous *costae*, or by continuous *costae*, which in some forms are connected by transversal thickenings of the chambers: *B. draco miliaris*, *B. draco draco*, *B. draco dorreeni*.

The three sub-groups follow each other stratigraphically, but are generally co-existent for some time.

In the accompanying table of length/breadth indices the succession of indices of the forms belonging to the first major group also marks their stratigraphic sequence, in support of Hiltermann's and Koch's (1950) conclusions.

The first major group disappears completely at the end of the Maestrichtian.

2). The second major group, as interpreted by the writer, comprises forms characterized mainly by a rather poor ornamentation, which is, moreover, localized and restricted to the medial part of the test. The ornamentation is composed of circular to oval knobs, weakly raised, sometimes somewhat tubercular, more or less elongated lobes or, more rarely, of short, dash-like and rather weak ribs. Sutures not obscured by the ornamentation, mostly depressed, often limbate. The general outline of the test evolves from "drop"-shaped through wedge-shaped to oval or broadly elliptical and even broadly rhomboid. Section broadly to flatly elliptical in older forms, extremely flat, lense-shaped in later forms. Apertural end of the test devoid of a thickened rim. Periphery sharply rounded to sub-acute in older forms, acute to keeled in later ones.

To this major group belong: *B. texana* Cushman, *B. pustulata*, sp. nov., *B. compressa*, sp. nov., *B. praecursor*, sp. nov., our *Bolivinoidea* sp., *B. laevigata* Marie, *B. watersi* (Cushman), *B. peterssoni* Brotzen and *B. paleocenica* (Brotzen).

The succession of length/breadth indices of the species belonging to this second major group occurring in Israel also marks their stratigraphic sequence, with one noteworthy exception, *B. paleocenica*. This latter species would be expected, according to the table of

STRATI- GRAPHY SPECIES	SANTONIAN	CAMPANIAN			MAESTRICHTIAN		DANO - PALEOCENE	
					LOWER	UPPER	GLOBIGERINA ZONE	GLOBIGERINA- TRUNCORO- TALIA ZONE
B. CURTA							?	
B. DELICATULA								
B. PALEOCENICA								
B. PETERSSONI								
B. SP.				?				
B. PRAECURSOR				?				
B. COMPRESSA				?				
B. PUSTULATA				?				
B. WATERSI								
B. DRACO DORREENI								
B. DRACO DRACO								
B. DRACO MILIARIS								
B. DECORATA DECORATA								
B. ANGULATA								

TEXT FIGURE 1

Range-chart of Upper Cretaceous and Lower Tertiary *Bolivinoidea* from Israel.

L/B INDEX SPECIES	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0
B. CURTA																
B. DELICATULA																
B. PALEOCENICA																
B. PETERSSONI																
B. SP.																
B. PRAECURSOR																
B. COMPRESSA																
B. PUSTULATA																
B. WATERSI																
B. DRACO DORREENI																
B. DRACO DRACO																
B. DRACO MILIARIS																
B. DECORATA DECORATA																
B. ANGULATA																

TEXT FIGURE 2

Table showing ranges of length/breadth indices of *Bolivinooides* from Israel. (Thick lines indicate optimum occurrence).

indices, to appear in the late Maestrichtian or even later, but it occurs already in Lower Maestrichtian. However, as already noted under *B. praecursor* such very broad forms as figured on pl. 30, fig. 8, possibly belonging to this latter species and occurring in Israel in the highest Campanian and early Maestrichtian, MIGHT represent transition forms to *B. paleocenica*. We would have, therefore, to extend the length/breadth index-range of *B. praecursor* to about 1.1 thus linking *B. paleocenica* with *B. praecursor*. In this case *B. praecursor* would be the "co-existing," more elongated form, while the broadly rhomboid *B. paleocenica* would represent the end form of this group. A similar example is seen in the case of *B. decorata gigantea* (optimum index 1.5-1.6, maximum 2.0) which appears even later than the first broadly rhomboid forms of the *draco*-subgroup, co-existing, however, with this latter sub-group, which actually represents the last development of the first major group. It might be significant that *B. paleocenica* is the last survivor of the second major group, which disappears almost completely at the end of the Maestrichtian, leaving only *B. paleocenica* to continue into Paleocene times. It appears, therefore, that the evolutionary tendency of the general form of the test in the second major group is the same as that in the first one. The second major group appears later than the first one.

The writer does not agree with Hiltermann and Koch (1950) who believe the group of poorly ornamented *Bolivinoidea* (such as *B. watersi*, *B. laevigata*, *B. peterssoni*) to have evolved from *B. regularis* (= *B. decorata delicatula* Hiltermann and Koch, non Cushman): such forms as *B. texana*, *B. watersi*, *B. pustulata* are at least as old, or even older, than *B. regularis*. It might be possible, however, that this second major group has evolved from such forms as *B. strigillata austinana*, which has been described by Cushman (1946) as having walls which are "smooth, except for a series of deep rounded pits marking the suture-lines." Both major groups might, therefore, have evolved from a common ancestor (*B. strigillata austinana* ?), one line of development leading to forms rich in ornamentation, the other to forms which are poorly ornamented. The apparently parallel development in general form of both major groups is an additional suggestion for such an assumption.

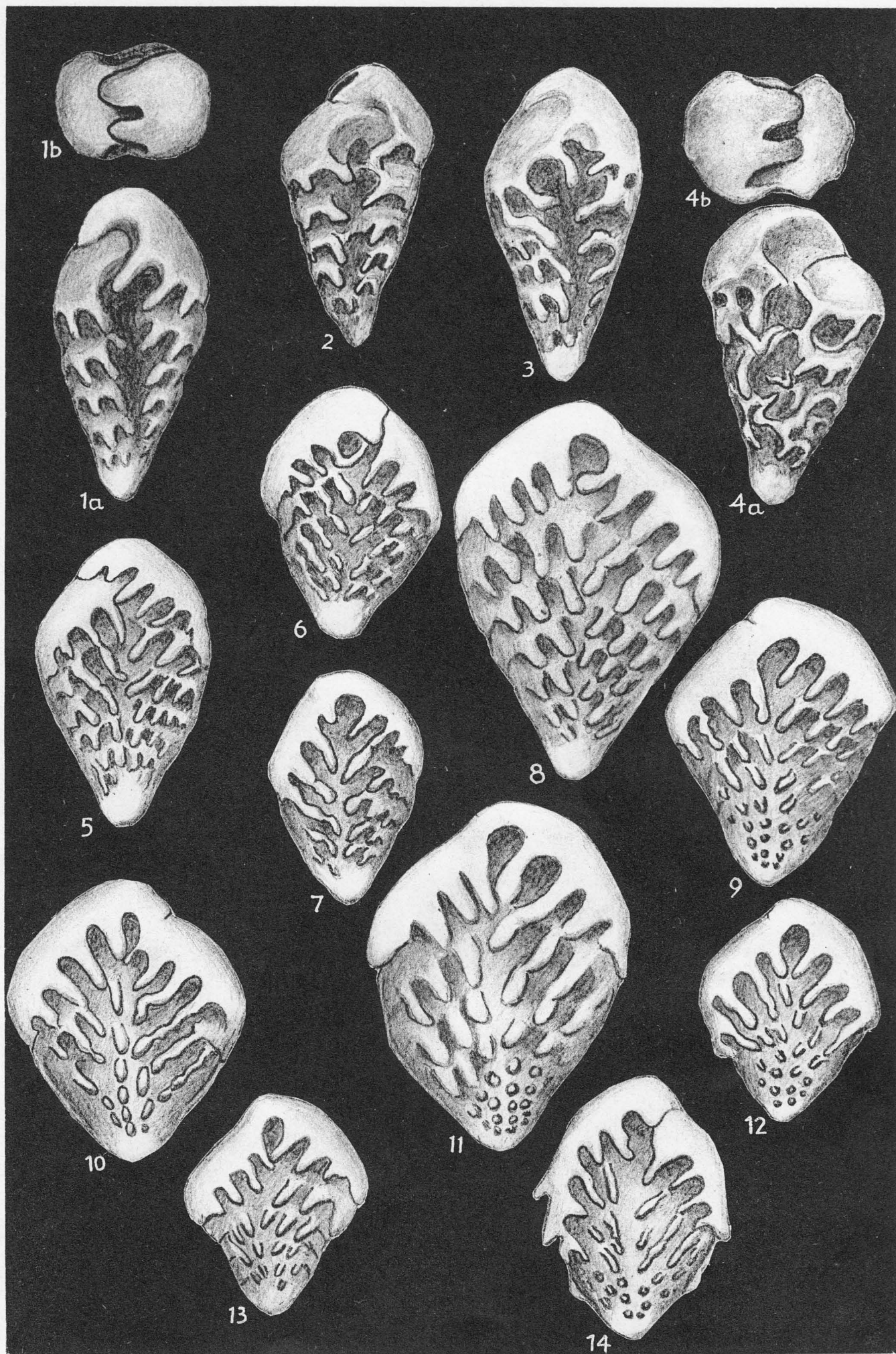
The second major group disappears with *B. paleocenica* in the Paleocene. Brotzen (1948) believes *B. paleocenica* to belong to a group of *Bolivinoidea* including *B. velascoensis* (Cushman) and to be near to such Tertiary forms as *Bolivina reticulata* Hantken, *Bolivina byramensis* Cushman, *B. scalprata retiformis* Cushman, *B. subreticulata* Parr and *B. fastigia* Cushman. However, none of these species, except the last named one, can be regarded as belonging to the genus *Bolivinoidea* as originally defined by Cushman and as lately redefined by Hofker (1952). *B. velascoensis* (Cushman) and *B. trinitatensis* Cushman and Jarvis show certain characteristics (raised and somewhat sinuous sutures, ornamentation, lack of retral processes) which place them in the genus (or subgenus) *Aragonia* Finlay rather than in the genus *Bolivinoidea* Cushman. Furthermore the wall-structure of *B. velascoensis* and *B. trinitatensis* will have to be studied in detail to establish the genus to which these species belong. In agreement with Hofker (*l.cit.*) we exclude these species from the genus *Bolivinoidea*. The writer, furthermore, believes that *B. paleocenica* is not related to any one of the above mentioned forms, except to *B. fastigia* to which it is generically related.

3). The third major group which, in the writer's opinion should be distinguished, comprises forms which are usually club-like or broadly subelliptical in outline, with a rounded, subacute or acute periphery, never distinctly keeled. Section flatly elliptical. Apertural end devoid of a thickened rim. Ornamentation covering the whole test in a regular pattern and clearly marking the suture-lines at the junction of the ornamentation (lobes) of consecutive chamber-pairs. The ornamentation is composed of rather weakly raised short ribs, formed by the basal lobes, sometimes associated with weak knots. Often the ornamentation is marked by the depressions, grooves, or pits, between the basal lobes and by the depressed sutures, rather than by the ribs or knots themselves.

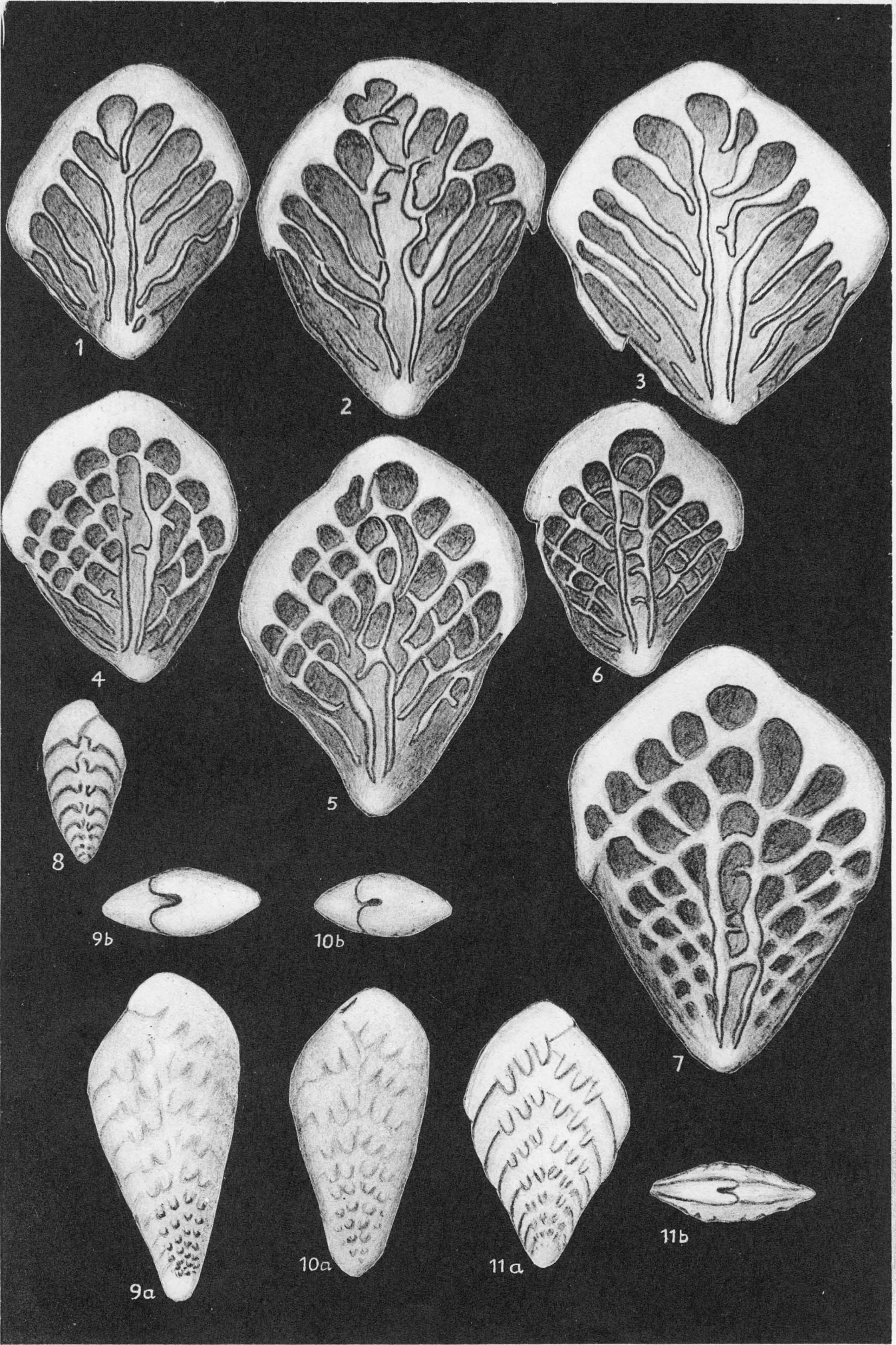
The relationship between the forms of this third major group, as well as the relationship between this group and the other two major groups, is not yet understood. Even the evolutionary tendency is still difficult to comprehend. To this group belong *B. regularis*, sp. nov., *B. delicatula* Cushman and *B. curta*, sp. nov. The succession of length/breadth indices of

EXPLANATION OF PLATE 28

FIGS.		PAGE
1-4.	<i>Bolivinoidea angulata</i> Reiss, sp. nov. × 110. No. 2139. Campanian. Tulkarem. Holotype: fig. 1a, b.	155
5-8, 13.	<i>Bolivinoidea decorata decorata</i> (Jones). × 110.	155
	5-6. No. D-2635. Lower Maestrichtian. Negev.	
	7-8. No. D-2753. Upper Campanian. Negev.	
	13. No. D-2580. Lower Maestrichtian. Negev.	
9-12, 14.	<i>Bolivinoidea draco miliaris</i> Hiltermann and Koch. × 110.	155
	9. No. D-2748. Upper Campanian. Negev.	
	10-11. No. 619. Upper Campanian. Innabe.	
	12, 14. No. D-3663. Upper Maestrichtian. Negev.	



Reiss: *Bolivinooides* in Upper Cretaceous and Lower Tertiary of Israel



Reiss: *Bolivinooides* in Upper Cretaceous and Lower Tertiary of Israel

B. delicatula and *B. curta* correspond again with their stratigraphic sequence. However, *B. regularis* which appears much earlier, has a length/breadth index sometimes as small as 1.7, reaching, on the other hand, such high values as 2.4. No form is known as yet which would prove a direct relationship between *B. regularis* and *B. delicatula*, and the time-lapse between these forms is considerable in both hemispheres. Hiltermann and Koch (1950) believe that *B. regularis* (= *B. decorata delicatula* Hiltermann and Koch, non Cushman) is derived from the *decorata*-group. Cushman (1946) on the other hand, interprets *B. texana* to be the ancestor of *B. regularis* (= *B. decorata delicatula* Cushman 1931, 1932, non 1927). Perhaps *B. regularis* represents a side-branch of the *decorata*-group or has evolved from *B. strigillata austinana*. It is even possible that *B. regularis* is not directly related to *B. delicatula* and the latter, an early Tertiary form, is more closely related to the Tertiary and Recent *Bolivinoidea*s (which form other groups) and resembles *B. regularis* only in type of ornamentation. Close study and additional evidence are needed to ascertain the relationships of this interesting group of *Bolivinoidea*s, which is especially difficult as long as no linking form between *B. regularis* and *B. delicatula* is known.

More detailed knowledge of the various species and subspecies of *Bolivinoidea*s will most probably result in the tracing of complete evolutionary series. In any case the present known species and subspecies of *Bolivinoidea*s can now be used in Israel for exact stratigraphical correlation and age-determination. The same is true of *Neoflabellina*. It has been ascertained by the writer that the different species and subspecies of *Neoflabellina* from the Upper Cretaceous and Lower Tertiary of Israel show evolutionary tendencies and phyletic changes which successfully can be used in stratigraphical work, as has been done by various authors in other regions of the world. Such short-living forms as *N. interpunctata-reticulata* (Wicher), *N. reticulata* (Reuss), *N. coranica* (Marie) or *N. semi-reticulata* (Cushman and Jarvis), to mention only one group, have been found to be especially valuable for stratigraphical work in Israel.

Although the more detailed studies on *Bolivinoidea*s and *Neoflabellina* of Israel are still in their first stages,

they support earlier stratigraphical conclusions arrived at by the writer on the basis of interregional correlation by means of small Foraminifera.

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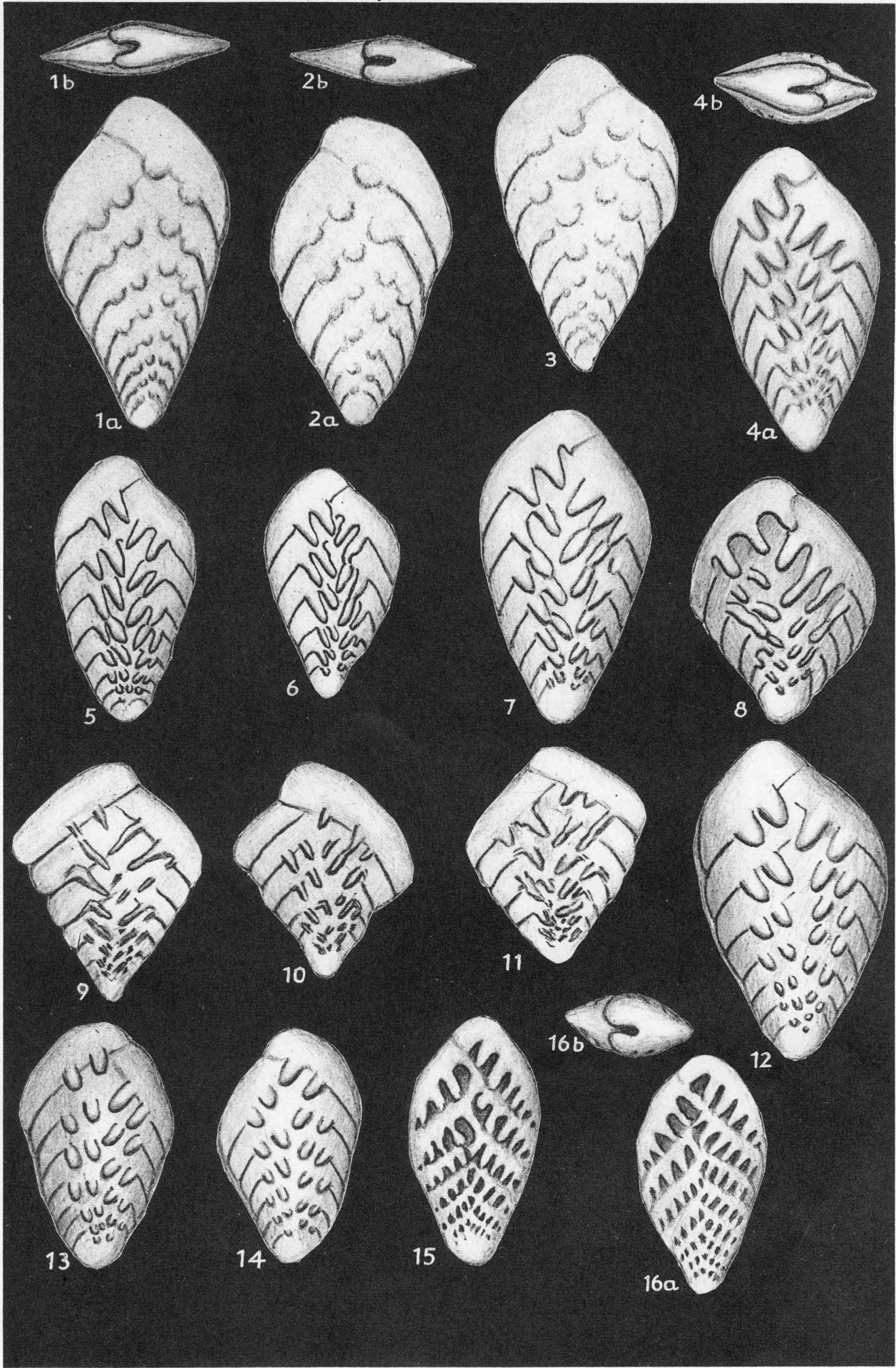
EXPLANATION OF PLATE 29

FIGS.	PAGE
1-3. <i>Bolivinoidea draco draco</i> (Marsson). × 110.	155
1. No. D-3656. Upper Maestrichtian. Negev.	
2. No. D-3648. Upper Maestrichtian. Negev.	
3. No. D-3663. Upper Maestrichtian. Negev.	
4-7. <i>Bolivinoidea draco dorreeni</i> Finlay. × 110.	155
4, 6. No. D-3667. Upper Maestrichtian. Negev.	
5, 7. No. D-3663. Upper Maestrichtian. Negev.	
8. <i>Bolivinoidea watersi</i> (Cushman). × 110. No. 4012. Lower Campanian. Beth Haemek	156
9-10. <i>Bolivinoidea pustulata</i> Reiss, sp. nov. × 110. No. 813. Lower Campanian. Judeida. Holotype: fig. 9a, b.	156
11. <i>Bolivinoidea</i> sp. × 110. No. 4177. Upper Campanian. Megiddo.	157

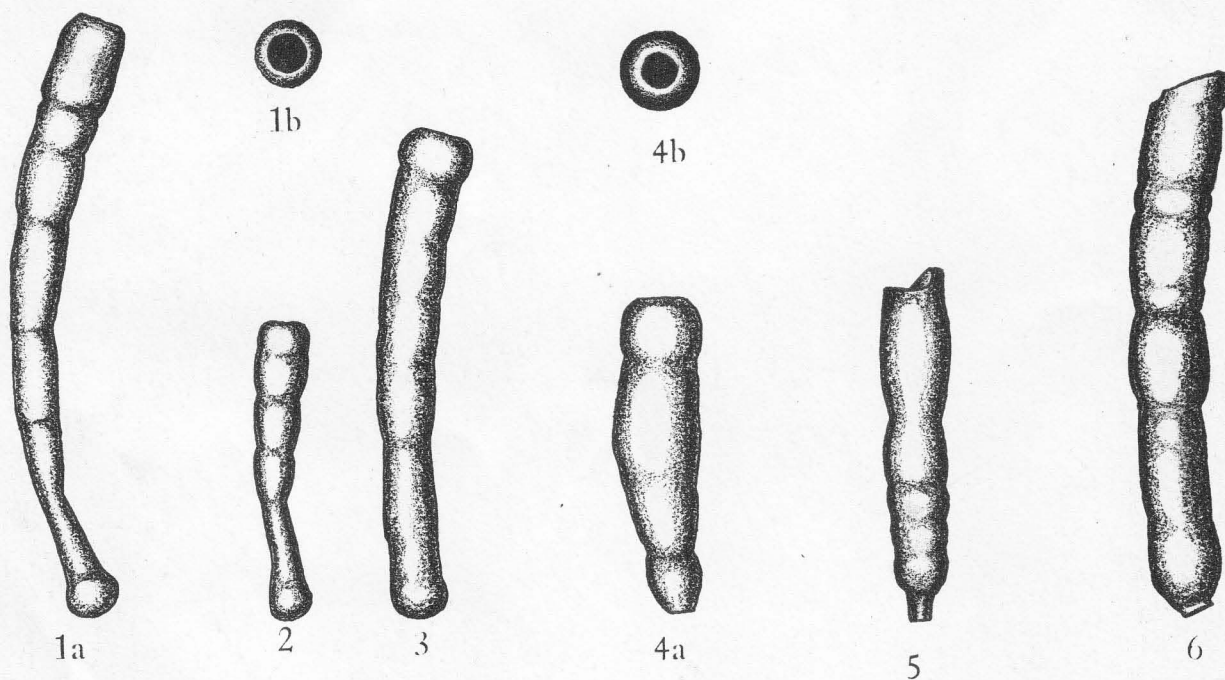
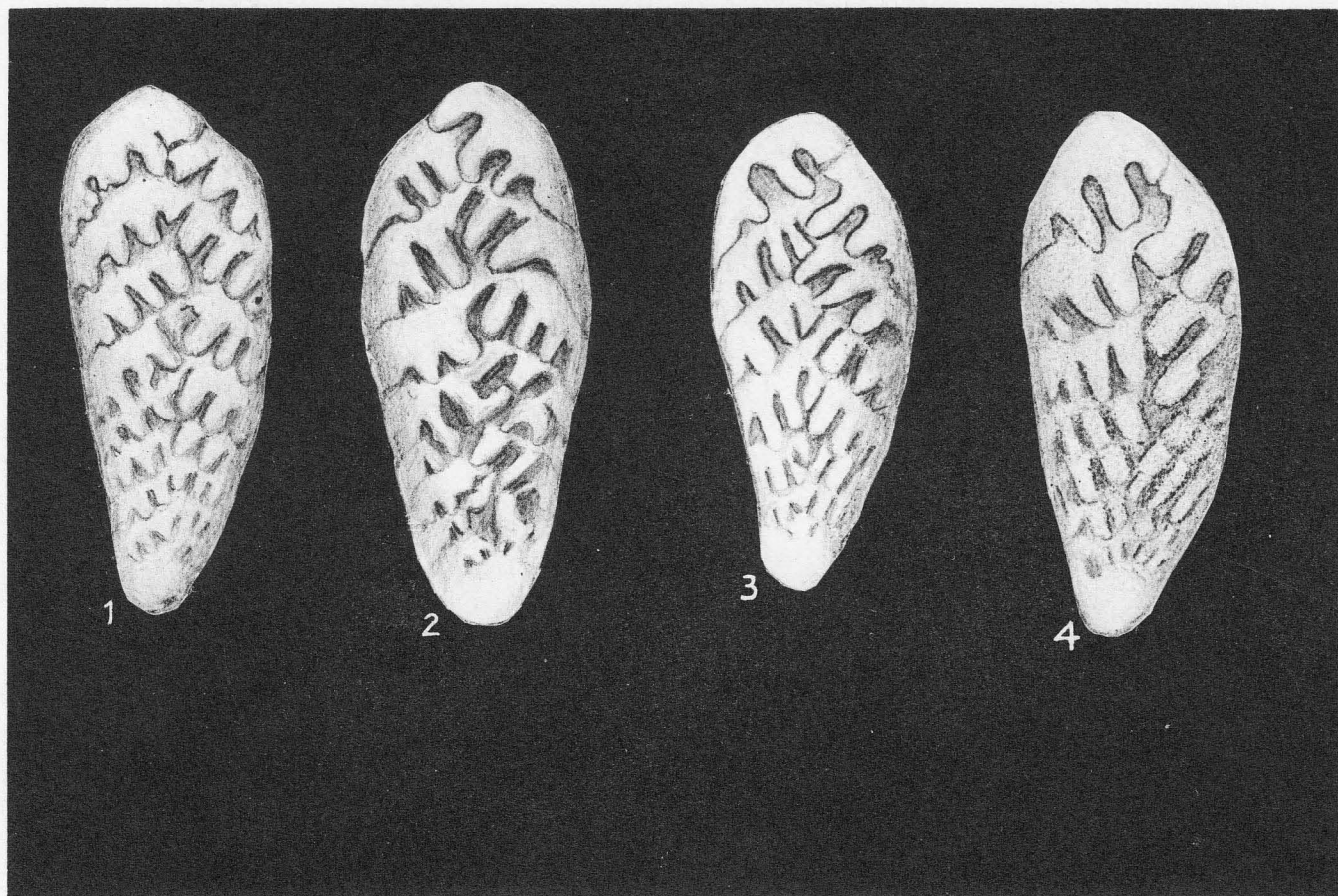
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EXPLANATION OF PLATE 30

FIGS.		PAGE
1-3.	<i>Bolivinoidea compressa</i> Reiss, sp. nov. × 110. No. 839(a). Upper Campanian. Er Ruweis.	
	Holotype: fig. 1a, b.	156
4-7.	<i>Bolivinoidea praecursor</i> Reiss, sp. nov. × 110.	156
	4-6. No. 839(b). Upper Campanian. Er Ruweis.	
	7. No. D-2302. Lower Maestrichtian. Negev.	
	Holotype: fig. 4a, b.	
8.	<i>Bolivinoidea</i> sp. [? <i>praecursor</i> Reiss, sp. nov., ? transition to <i>B. paleocenica</i> (Brotzen)]. × 110.	
	No. D-2688. Lower Maestrichtian. Negev.	157
9-11.	<i>Bolivinoidea paleocenica</i> Brotzen. × 110.	157
	9-10. No. D-3660. Upper Maestrichtian. Negev.	
	11. No. 2629. Lower Maestrichtian. Negev.	
12-14.	<i>Bolivinoidea peterssoni</i> Brotzen. × 110.	157
	12. No. D-3660. Upper Maestrichtian. Negev.	
	13-14. No. D-3362. Upper Maestrichtian. Negev.	
15-16.	<i>Bolivinoidea curta</i> Reiss, sp. nov. × 110. No. 1845. "Dano-Paleocene" (<i>Globigerina-Truncorotalia</i> zone). Tzor'a.	158
	Holotype: fig. 16a, b.	



Reiss: *Bolivinooides* in Upper Cretaceous and Lower Tertiary of Israel



Reiss: *Bolivinooides* in Upper Cretaceous and Lower Tertiary of Israel
 Conkin: *Hyperammmina Kentuckyensis* n. sp. from Mississippian of Kentucky, U.S.A.