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Borelis from Israel[1])

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With 2 textfigures and 2 plates (I and II)

ABSTRACT

Borelis melo melo and *B. melo curdica* occur in shallow- and warm-water sediments of the Hashefela and Coastal Plain regions of Israel. These strata are of Tortonian (s. str.) age (*nepenthes*-Zone). Available evidence seems to indicate that the Neogene group of *Borelis melo* is restricted to strata of post-Helvetian, pre-Messinian (?Karpatian, «Badenian» and Tortonian) age; its first appearance seems to coincide closely with the «*Orbulina*-datum». *Borelis schlumbergeri* occurs in Recent sediments in the Gulf of Elat. The species mentioned are figured for the first time from Israel. A schematic diagram illustrates the stratigraphic sequence in western Israel and a sketch map shows the distribution of Miocene formations containing *Borelis*.

INTRODUCTION

The genus *Borelis* DE MONTFORT, 1808 (= *Neoalveolina* SILVESTRI, 1928; see REICHEL, *47*) occurs in Israel in Miocene, shallow- and warm-water strata, widely distributed in the Coastal Plain and Hashefela regions (fig. 1), as well as in Recent sediments in the Gulf of Elat (*4*, *27*, *28*, *29*, *48*, *49*, *50*, *60*). The species recorded from the Miocene are *Borelis melo melo* (FICHTEL and MOLL) and *B. melo curdica* (REICHEL); in Recent sediments *B. schlumbergeri* (REICHEL) occurs.

The purpose of the present paper is to clarify the stratigraphic position and significance of the Neogene *Borelis* in Israel and in the Mediterranean area and to figure the Miocene and Recent species from Israel.

MIOCENE BORELIS

(Pl. 1, figs. 1–8, pl. 2, figs. 1–2)

a. Local lithostratigraphy

Borelis melo melo and *B. melo curdica* occur in Israel in fossiliferous, bioclastic, sparitic limestones, yellowish to reddish-pink in colour, rich in Miliolidae, *Amphistegina*, molluscan and echinoid fragments, and calcareous algae. These lime-

[1]) Published with the permission of the Director, Geological Survey of Israel. Some of the geological observations contained here form part of G. GVIRTZMAN's Ph.D. thesis at The Hebrew University, Jerusalem.

[2]) Geological Survey of Israel, Jerusalem.

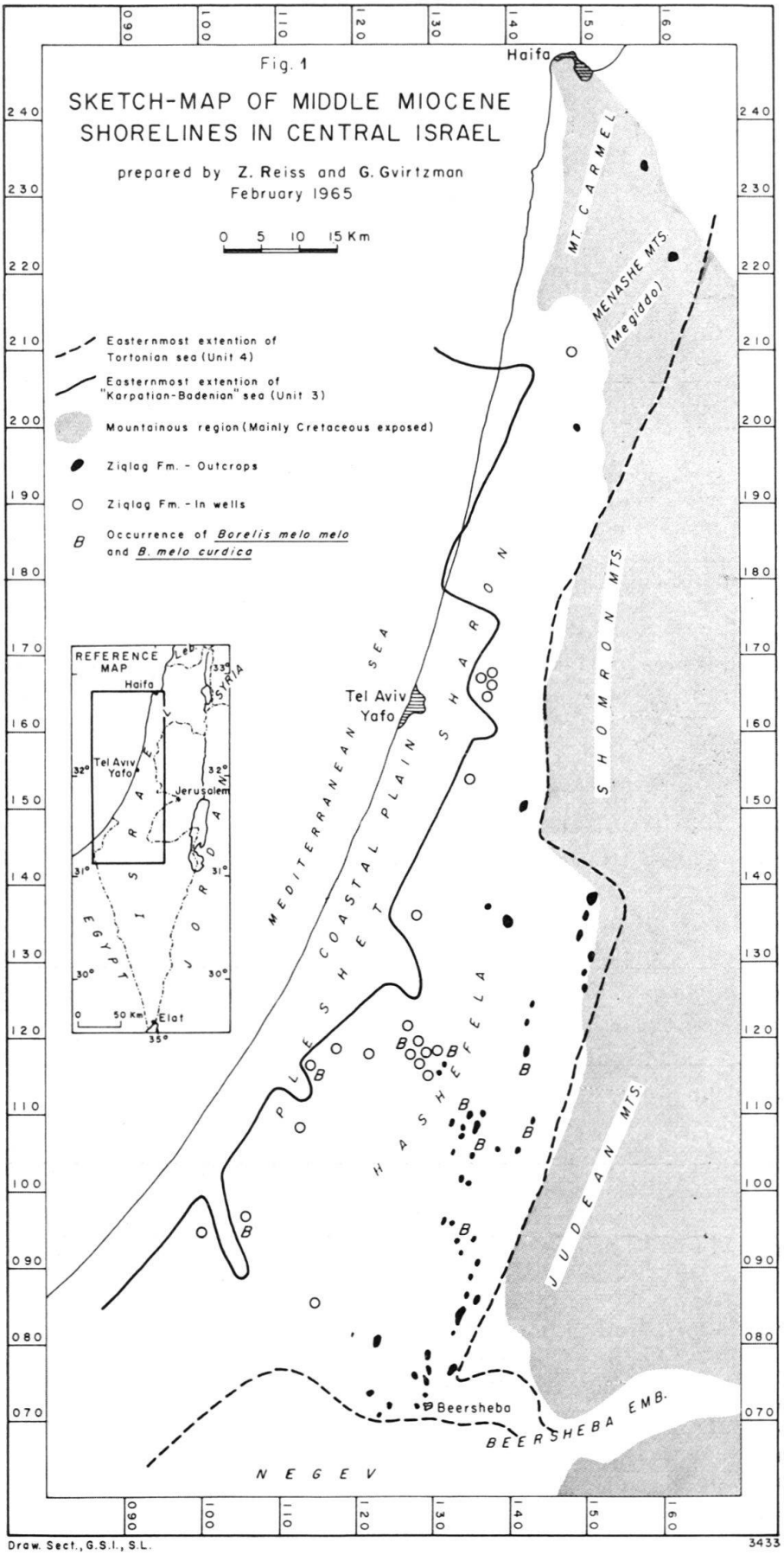
Fig. 1
SKETCH-MAP OF MIDDLE MIOCENE SHORELINES IN CENTRAL ISRAEL
prepared by Z. Reiss and G. Gvirtzman
February 1965
0 5 10 15 Km
Easternmost extention of Tortonian sea (Unit 4)
Easternmost extention of "Karpatian-Badenian" sea (Unit 3)
Mountainous region (Mainly Cretaceous exposed)
Ziqlag Fm. - Outcrops
Ziqlag Fm. - In wells
B Occurrence of Borelis melo melo and B. melo curdica
REFERENCE MAP
Haifa
Tel Aviv Yafo
Jerusalem
Elat
SYRIA
EGYPT
ISRAEL
JORDAN
Haifa
MT. CARMEL
MENASHE MTS.
(Megiddo)
SHOMRON MTS.
JUDEAN MTS.
MEDITERRANEAN SEA
COASTAL PLAIN
SHARON
PLESHET
HASHEFELA
Tel Aviv Yafo
Beersheba
BEERSHEBA EMB.
NEGEV
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stones are associated with coral and milleporid reefs, with shell-beds of pelecypods and gastropods (among them *Strombus coronatus* DEFR.), as well as with littoral conglomerates. The lithology and fossil assemblages of this shallow- and warm-water «reef complex» (*33*) have been described by various authors (*1, 2, 3, 7, 9, 27, 29, 31, 43, 44, 45, 49, 51, 60*). Lately, the present writers (*31*) have proposed the name «Ziqlag Formation» for this complex (figs. 1 and 2). The Ziqlag Formation occurs mainly on the surface, but also in the subsurface of the Coastal Plain (fig. 1) where it is intercalated in a sequence of predominantly marly-clayey-sandy strata referred to earlier as «Sakiebeds» (sensu lato) (*49*). These strata together with intercalated anhydrite, coarse clastics, and volcanics, as well as with shallow-water marginal and reefal developments, are now included in the Saqie Group[3]) which comprises a number of distinct formations (*31*). The Saqie Group forms the lower part of the «Upper Clastic Division» of Middle East authors and is clearly distinguished both from the underlying, predominantly chalky-marly, flinty-phosphatic Hashefela Group and from the overlying predominantly sandy, as yet unnamed group (*31*). The accompanying fig. 2 is a diagrammatic illustration of the Saqie Group sequence. The lowest formation is the Bet Guvrin Fm. which passes laterally into the (*Lepidocyclina, Miogypsinoides, Heterostegina* bearing) Lakhish Fm. The upper part of the Bet Guvrin Fm. is absent on the surface, due to regional regression, differential movements and faulting, followed by the formation of deep erosion channels. The overlying Ziqim Fm. is restricted to the westernmost Coastal Plain and to the erosion channels. It contains intercalations of anhydrite, coarse clastics and volcanics and carries in its lower part *Aturia* and Pteropoda. The Ziqim Fm. is overlain by the Yafo Fm., whose lower part passes laterally into the *Borelis*-bearing Ziqlag Fm. Lenses and tongues of the latter occur within the lower Yafo Fm. in the subsurface. The Yafo and Ziqlag Formations are clearly transgressive over a peneplained «matureland» (*28, 31, 49*).

b. Bio- and chrono-stratigraphy

Mainly on the basis of megafossils, the Ziqlag Fm. was attributed variously to the «Middle Miocene», «Vindobonian», «Helvetian», or «Tortonian» (*1, 2, 3, 4, 9, 27, 29, 43, 44, 45, 51;* see *8*). The fact that *Borelis melo* was recorded possibly from the Burdigalian and mainly from the Helvetian and Tortonian (*46*) was taken by various authors as supporting a general Middle Miocene age of the Ziqlag Fm. (*4, 27, 29, 48*).

Biostratigraphic studies on planktonic Foraminifera carried out at the Geol. Survey of Israel Paleontology Division by Z. REISS and P. MERLING during the last years, have facilitated the subdivision of the Saqie Group into several biostratigraphic units, ranging in age from Late Eocene to Early Pleistocene (*49*). These units can be correlated with zones and subzones recognised elsewhere in the belt of tropical Paleogene and Neogene seas (*49* and see fig. 2).

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[3]) The spelling in Roman characters of Hebrew and Arabic geographical and stratigraphical names employed here follows instructions issued by the Director, GSI, in accordance with Israel law.

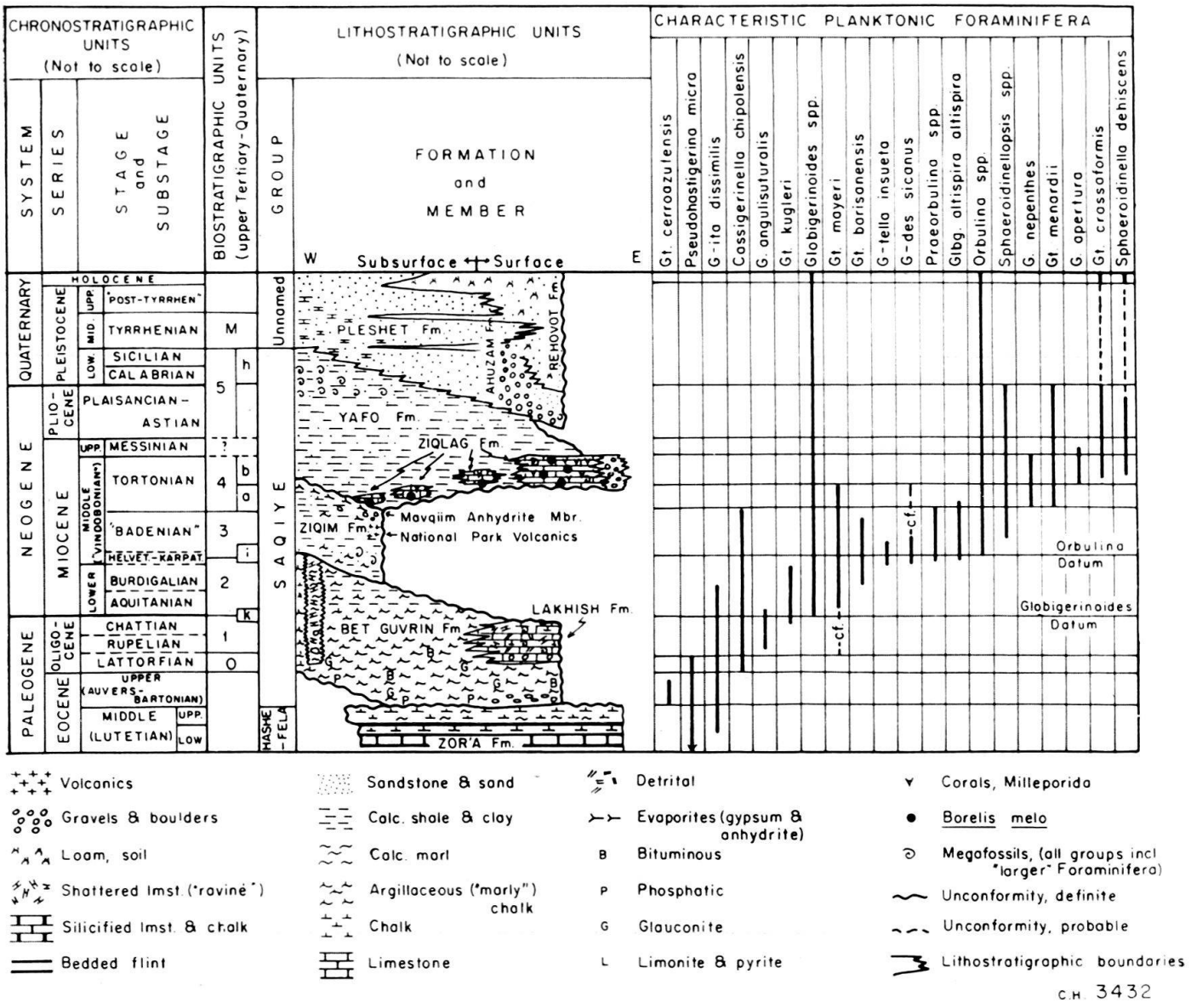

Fig. 2. Stratigraphic sequence in the Coastal Plain and Hashefela Region of Israel. Prepared by, Z. REISS and G. GVIRTZMAN, February 1965.

The lowermost biostratigraphic unit of the Saqie Group is characterised by *Globigerapsis Hantkenina*, *Chiloguembelina*, *Globigerinita dissimilis* (CUSHM. & BERMUDEZ), *Globorotalia* (*T.*) *cerroazulensis* COLE, *Globigerina ampliapertura* BOLLI, etc. It corresponds to the *semiinvoluta-*, *danvillensis-*, and *gortanii*-Zones of various authors and is definitely of Late Eocene age. The overlying biostratigraphic unit (marked «O» on fig. 2) is characterised mainly by the association *Pseudohastigerina* and *Cassigerinella* with *G. dissimilis*, *G. ampliapertura*, *G.* ex gr. *tripartita* KOCH, *Chiloguembelina*, etc. The next-higher Unit 1 is characterised mainly by the absence of *Pseudohastigerina*, by the occurrence of *Cassigerinella* and *Chiloguembelina*, *Globigerina angulisuturalis* BOLLI, *Globorotalia* (*T.*) ex gr. *opima* BOLLI, various *Globoquadrina* (but no *G. altispira altispira*), *Globorotalia* (*T.*) cf. *mayeri* (CUSHM. & ELLISOR), *Globigerinita dissimilis*, etc., and – in its highest part (lower subunit «k» in fig. 2) – by the appearance of *Globorotalia* (*T.*) *kugleri* BOLLI. Unit 2 is characterised mainly by the appearance of *Globigerinoides* (s. str.) and of typical *G.* (*T.*) *mayeri*, in association with *G. dissimilis* and *Chiloguembelina* in the lower part of the unit and – at the top of the unit (subunit «i» in fig. 2) – with *Globigerinatella insueta* CUSHM. & STAINFORTH,

Globigerinoides sicanus DE STEFANI, *Praeorbulina* spp. (= *Porticulasphaera*, pars, auct.), *Globoquadrina altispira altispira* (CUSHM. & JARVIS). *Globorotalia* (*T.*) *barisanensis* LEROY appears in the upper part of Unit 2. Unit 3 is characterised mainly by the appearance of true *Orbulina*, by the persistence of *Cassigerinella*, *G.* (*T.*) *mayeri* and *G.* (*T.*) *barisanensis*, as well as of *Praeorbulina* and *G. altispira altispira*. *Globorotalia* (*G.*) *praemenardii* CUSHM. & STAINFORTH and *Sphaeroidinellopsis* spp. appear within this unit. The next-higher Unit 4 is characterised by the occurrence (and range) of *Globigerina nepenthes* TODD, associated with *Globorotalia* (*G.*) *menardii menardii* (D'ORB.) and *G.* (*G.*) *menardii miocenica* PALMER, as well as with *Globigerinoides* and *Orbulina*. *Cassigerinella* and *Praeorbulina* are absent, *G.* (*T.*) *mayeri* disappears in the lower part of the unit (subunit 4a), while *Globigerina apertura* CUSHM., *Globorotalia* (*G.*) *crassaformis* GALLOWAY & WISSLER, and *Sphaeroidinella dehiscens* (PARKER & JONES) appear in its upper part (subunit 4b). Unit 5 is still poorly defined and is characterised mainly by the disappearance of *G. nepenthes*, *G. menardii*, *Sphaeroidinellopsis*, etc. Its upper part (subunit «h») contains *Hyalinea balthica* (SCHR.).

The boundary between Units 1 and 2 corresponds to the «*Globigerinoides*-datum» (*6*). It is situated within subunit «k» which corresponds to the *kugleri*-Zone of various authors. The boundary between Units 2 and 3 corresponds to the «*Orbulina*-datum» (*6*) (= *Orbulina*-surface; *37*). It is situated within subunit «i» which corresponds to the *insueta-Zone* (part of the *sicanus*-(= *bisphericus*-)Zone of various authors). Unit 3 corresponds largely to the *fohsi*(s.l.)-Zone, while Unit 4 corresponds to the *nepenthes*-Zone of various authors.

The chronostratigraphic significance of the *Globigerinoides* and particularly of the *Orbulina* datum is a subject of considerable dispute between authors. Some of them claimed that *Globigerinoides* appears at first in the Oligocene, others regarded its appearance as occurring in the Miocene. The *Orbulina*-datum was placed variously in the Oligocene, between the Aquitanian and Burdigalian, at the base of the Tortonian, or in the Late Aquitanian (*6*, *13*, *14*, *16*, *17*, *19*, *20*, *21*, *22*, *23*, *24*, *25*, *26*, *35*, *37*, *40*, *41*, *42*, *57*). At first the present writers (*49*) have followed EAMES et al. (*24*) in attributing a Middle Aquitanian age to the *Globigerinoides*-datum and a Late Aquitanian age to the *Orbulina*-datum. In this interpretation some earlier determinations of larger Foraminifera from the Lakhish Fm. (see above), believed to indicate a «Middle» and «Upper Oligocene» (including Aquitanian!) (*2*, *8*), were also taken into account. Unit 0 was attributed to the Oligocene; Units 1, 2 and the basal part of Unit 3 to the Aquitanian, the main part of the latter unit to the Burdigalian; and Unit 4 was placed in the Helvetian and Tortonian. Unit 5 was attributed (partly on definite megafossil evidence) to the Pliocene and Early Pleistocene. It was, however, pointed out by the present writers (*49*) that the various stage names are used (outside their type-areas) «with considerable reservation» (op. cit., p. 7) and «subject to revision in accordance with the findings of investigations now in progress in various parts of the world» (op. cit., p. 4). It was also emphasised that as far as age determinations in Israel on the basis of megafossils and benthonic Foraminifera are concerned «in several cases serious doubts still exist» (op. cit., p. 6).

Of particular importance to the solving of the problems involved – which have a direct bearing upon the stratigraphical significance of Neogene *Borelis* – are the findings published lately concerning the planktonic foraminiferal assemblages of stage-stratotypes and their comparison with such assemblages associated elsewhere

with «larger» Foraminifera and megafossils (*13*, *14*, *15*, *18*, *26*, *35*). According to these findings the type-Aquitanian and type-Burdigalian fall within an interval comprised between the *Globigerinoides*- and the *Orbulina*-datum (Unit 2). Characteristic megafossils of the type-Helvetian (*52*) occur in the Mediterranean area and in the Paratethys associated with planktonic Foraminifera, as well as with «larger» Foraminifera, indicating that the Helvetian (s. str.) corresponds mainly to the *sicanus-insueta* Zone, below the *Orbulina*-datum (*11*, *12*, *13*, *18*, *40*, *41*, *58*). The so-called «Upper Helvetian» of the Vienna Basin and the Paratethys («Laaer Serie», «Karpatische Formation») overlies Helvetian (s. str.) strata and contains *G. sicanus* and *Praeorbulina*. True *Orbulina* appear near the boundary of the «Upper Helvetian» for which the new stage-name «Karpatian» was proposed (*12*). The type-Tortonian corresponds largely to the *nepenthes*-Zone (*15*).

Between Helvetian and Tortonian there is, therefore, a considerable time-interval corresponding to what has been called «Upper Helvetian» (= Laaer Serie, Karpatian) and «Lower Tortonian» (= lower part of the «Tortonian in the Vienna Basin» = Badener Serie). This fact has been emphasised in the past by various authors (*21*, *40*, *41*, *58*; see also *5*, *13*, *30*, *36*) but, unfortunately, disregarded. Since the Karpatian is older than the Badener Serie (so-called «Lower Tortonian in the Vienna Basin») it cannot be used as an intermediate stage between Helvetian and Tortonian, as originally proposed (*12*). There remains still an unnamed interval, corresponding largely to our biostratigraphic Unit 3, between the *Orbulina*-datum and the *nepenthes*-Zone. This interval seems to correspond mainly with the Italian «Elveziano» which is certainly younger than the Helvetian (for this reason many age determinations of «Helvetian» by comparison with Italy refer in fact to post-Helvetian strata). For the sake of clarity the present writers use for the time being the provisional name «Badenian» for all strata younger than Helvetian-Karpatian and older than those of the type-Tortonian. The «Badenian» corresponds to the lower part of the Badener Serie (the upper part is of Tortonian, s. str., age) and largely to our Unit 3 (see fig. 2).

Determinations by various authors of «Tortonian» by interregional correlation with the Vienna Basin may refer either to the «Badenian» or to the Tortonian (s. str.), or to both.

It follows that any discussion concerning the placing of the Helvetian-Tortonian boundary is simply meaningless. It follows also that DROOGER's (*21*) proposals concerning the placing of this boundary near the disappearance of the last Miogypsinidae and the appearance of *Orbulina* refers in fact to the boundary between Karpatian and «Badenian». The problem whether the last Miogypsinidae disappear at the end of the Helvetian or within the Karpatian requires further study; indeed, *Miogypsina* has been recorded together with *Orbulina* in an assumed natural association (*24*). However, there is little doubt that the last Miogypsinidae disappear near the *Orbulina*-datum.

From these considerations the more exact stratigraphic position of the *Borelis melo*-bearing Ziqlag Formation in Israel can be determined: it corresponds to the *nepenthes*-Zone (*49*) and is, therefore, of Tortonian (s. str.) age, as, indeed, assumed by BLAKE (*9*).

c. Stratigraphic significance of the *Borelis melo*-group

The known species of *Borelis* fall into two groups according to their length/diameter index, viz. a group of ovoid to elongated-fusiform species, known from the Oligocene to the Recent and comprising *Borelis pygmaea* HANZAWA, *B. parvulus* HANZAWA, *B. haueri* (D'ORB.), *B. philippinensis* HANZAWA, and *B. schlumbergeri* (REICHEL); and a group of spherical forms, known from the Late Eocene to Recent and comprising *B. vonderschmitti* SCHWEIGHAUSER, *B. melo melo* (FICHTEL and MOLL), *B. melo curdica* (REICHEL), and *B. bradyi* (SILVESTRI). The last-named Recent species is believed to be in part identical with the Neogene *B. melo melo* (*47*) and in part with *B. haueri* which is regarded by REICHEL (*46*) as a variety of *B. melo melo*. *B. primitivus* is near to *B. haueri* (*25*). Despite the assumed identity of *B. melo melo* with *B. bradyi*, there are no definite Pliocene occurrences known of either of these species. The phylogeny of *Borelis* is still unknown in detail.

The *Borelis* occurring in the Israel Neogene belong to the spherical group, and only the latter will be briefly discussed. *B. vonderschmitti* is known from the Late Eocene. No Oligocene spherical species have been recorded hitherto. *B. melo melo* and *B. melo curdica* were recorded from the Miocene. Again, no spherical forms are known from the Late Miocene or from the Pliocene (– Pleistocene).

The range of *B. melo melo* and *B. melo curdica* warrants closer scrutiny. In Europe, *B. melo melo* was recorded from shallow-water strata rich in *Amphistegina*, calcareous algae, and Milleporida to which a «Middle Miocene», «Vindobonian», or «Tortonian» age was attributed («Leithakalk», «Nulliporenkalke», «Lithothamnienkalke» of Austria, Hungary, Transylvania). There, it occurs in places with *B. haueri* (*39*). These shallow-water sediments are marginal developments of clayey-shaly strata containing planktonic Foraminifera («Tegel», «Badener Serie») (*30*) which indicate clearly a post-*Orbulina* datum position, i.e. generally a «Badenian» and Tortonian age. (Compare the similarity in facies of the «Leithakalke» with the Ziqlag Fm. and that of the «Tegel» with the Yafo Fm.) In Spain and in Majorca, strata with *B. melo melo* and *Orbulina* overlie strata with *Miogypsina mediterranea* and are, therefore, post-Helvetian (? post-Karpatian) in age (and not as assumed by COLOM, *17*). In Sicily *B. melo melo* occurs with planktonic Foraminifera of the *fohsi* (s. l.)-Zone (*24*) indicating a «Badenian» age (cf. EAMES et al., *24*, DROOGER, opp. cit.). In North Africa, strata correlative with those mentioned from Sicily contain also *B. melo melo* (*24*, *46*). In the Middle East (Iraq, Iran), the first *B. melo melo* occur with *Miogypsina* and *Orbulina* (*10*, *24*). In East Africa, the first *B. melo melo* occur with *Orbulina* (*24*, cf. *32*). The first *Borelis melo melo* are recorded from the Pacific Ocean and Far East regions with *Orbulina* and the last *Miogypsina* (*16*, *24*, *25*, *26*). In Egypt, *B. melo melo* is recorded from strata rich in corallinacaean algae and *Amphistegina* («Lithothamnium Limestone», «Nullipore Rock»), overlying *Miogypsina cushmani*-bearing strata. The exact age of the *B. melo*-bearing strata («Zone of *B. melo*») is still uncertain in Egypt, but is apparently definitely post-Helvetian (*53*, *54*, *55*). Earlier, an «Upper Vindobonian» age was attributed to them (*56*). *B. melo* is recorded from the Miocene Pakhna Fm. of Cyprus, but the exact position of the occurrences is unknown (*34*).

Borelis melo curdica was described from Turkey, from limestones rich in algae, Bryozoa and Foraminifera, in an assemblage identical with those of the Vindo-

bonian «Leithakalk» in the Vienna Basin (and North Africa) (*46*). It occurs together with *B. melo melo* in Sicily (see above), in N. Africa, Egypt, and in the Middle East (*10, 24, 53, 54, 55, 59*) with the last *Miogypsina* and with *Orbulina*, hence in post-*Orbulina* datum strata. *B. melo curdica* is associated in Iran also with *B. haueri* (*10*).

It seems, therefore, that *Borelis melo* appears close to the first appearance of true *Orbulina*. The stratigraphic significance of *Borelis melo* has been recognised by EAMES et al. (*24*), who stated that *B. melo* is a form «unknown anywhere below the Burdigalian» (op. cit., p. 28); correcting the «Burdigalian» in the sense of EAMES et al., their statement should read that *B. melo* is unknown anywhere below Karpatian-«Badenian» strata, a conclusion with which available evidence agrees.

As already pointed out by REICHEL (*46*), *Borelis* of the *melo*-group are unknown from post-Middle Miocene Neogene strata. (REICHEL's (*47*) later statement that *B. melo curdica* occurs in the Upper Miocene of Turkey requires qualification.)

It seems, therefore, that *Borelis melo melo* and *B. melo curdica* are restricted to the Middle Miocene, Late Karpatian?, «Badenian» and Tortonian, the *Borelis melo*-Zone (*53, 54, 55*) corresponding to the uppermost *insueta*-, *fohsi*(s.l.)-, and *nepenthes*-Zones of the planktonic sequence. The *B. melo*-group has, therefore, considerable significance for the zonation of Neogene sediments in shallow-water facies. In Israel, suitable environments for the thriving of *Borelis melo* are unknown from pre-Tortonian strata; for this reason only the upper part of the *B. melo*-Zone has been recognised up to now in this country.

RECENT BORELIS

(Pl. 2, figs. 3–8)

Borelis schlumbergeri (REICHEL) (= *Neoalveolina pygmaea* HANZAWA *schlumbergeri* REICHEL) was recorded from Recent sediments of the Gulf of Elat (*50*). It occurs at a depth interval of 1.5–20 m, being frequent at more than 3 m depth.

The accompanying fauna is characterised by Miliolidae, *Peneroplis*, *Marginopora*, *Amphistegina*, and – between 5 and 20 m – by *Operculina*. Between 1.5 and 3 m depth, corals are frequent, while alcyonarian spicules, bryozoans and molluscs occur frequently in all *Borelis*-bearing assemblages.

The shape of *B. schlumbergeri* is highly variable, ranging from nearly ovoid to elongated-fusiform (pl. 2). Although *B. schlumbergeri* is similar to *B. pygmaea* these species seem to be unrelated, as there is a considerable time gap between them.

B. schlumbergeri is widely distributed in the Indian Ocean and in the Red Sea.

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Plate I

Figs. 1–7. *Borelis melo melo* (FICHTEL & MOLL).

1 and 5. No. 7037-S. Khirbet es Sura. 2 and 3. No. 3055-S. Lakhish. 4 and 6. No. 7036-S. Lakhish. 7. No. 13533-IT 639, Heletz 23 well (specimen showing a few shifted, alternating chamberlets in last coils).

Fig. 8. *Borelis melo curdica* (REICHEL). No. 13533-IT 640, Heletz well.

Figs. 1–6 are random sections in limestone; figs. 7 and 8 are oriented thin-sections of isolated specimens. Figs. 2, 3, 7 and 8 – nearly axial sections; fig. 4 – nearly equatorial section; fig. 6 – equatorial section; figs. 1 and 5 – oblique sections.

All specimens from the Ziqlag Formation, Middle Miocene, Tortonian (Unit 4), Israel.

All figures magnified 73×.

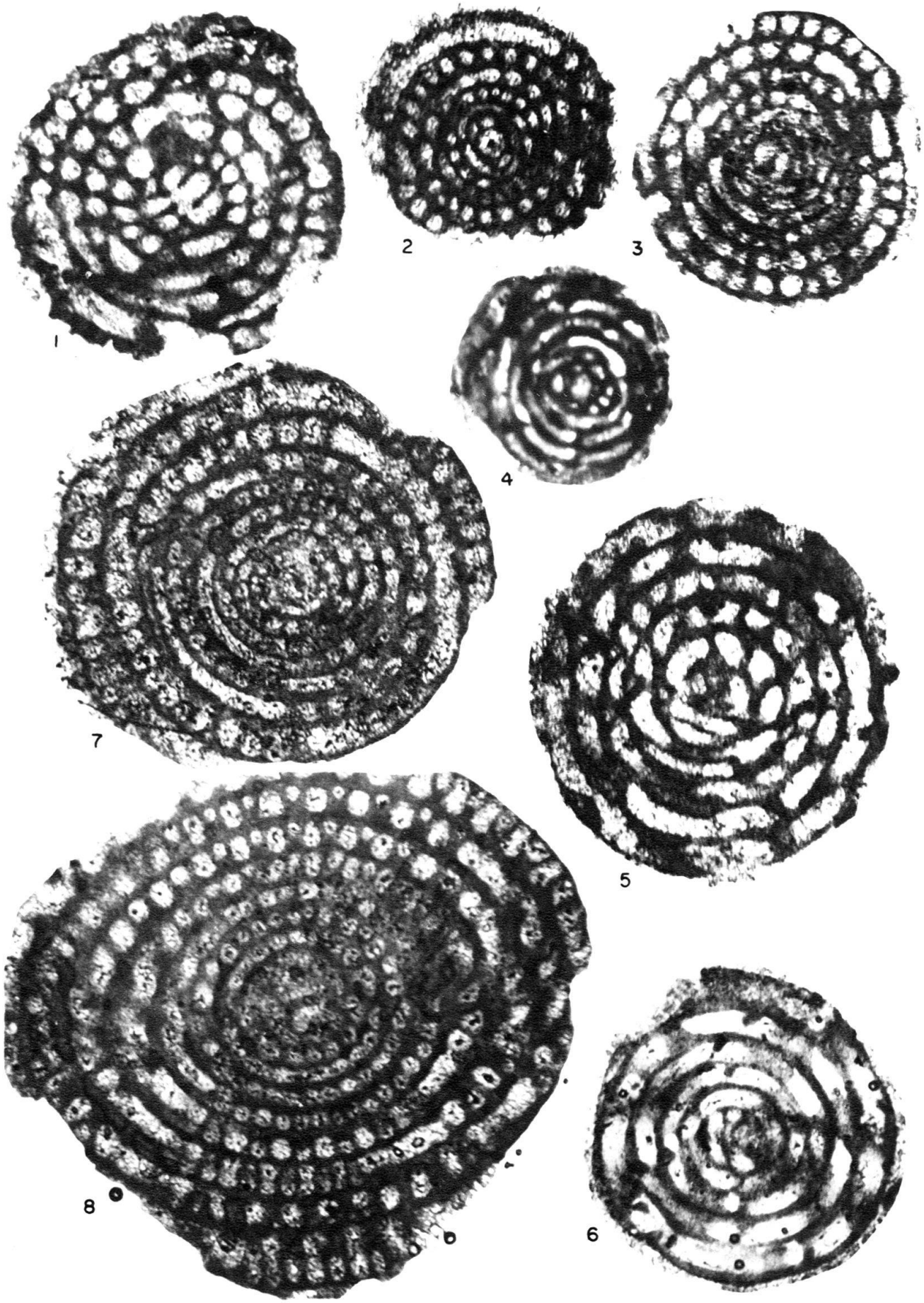
1
2
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Plate II

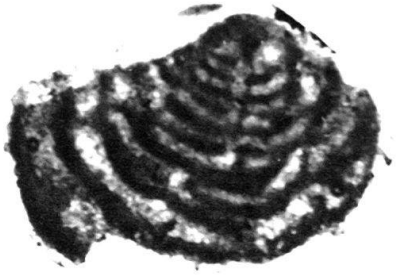
Fig. 1. *Borelis melo curdica* (REICHEL). No. 7037-S. Kh. es Sura. Part of oblique section.

Fig. 2. *Borelis melo melo* (FICHTEL & MOLL). No. 7036-S. Lakhish. Partly tangential section parallel to the axis.

Figs. 3–8. *Borelis schlumbergeri* (REICHEL). Fig. 3 – No. 15195-IT 634; fig. 4 – No. 15192-IT 636; fig. 5 – No. 15195-IT 633; fig. 6 – No. 15194-IT 632; fig. 7 – 15192-IT 635; fig. 8 – No. 15194-IT 631.

Figs. 1 and 2 are random section in limestone from the Ziqlag Formation, Middle Miocene, Tortonian (Unit 4), Israel. Figs. 3–8 are oriented thin-sections of isolated specimens, all from Recent sediments, Gulf of Elat, Israel. Figs. 3–5 and 7–8 are nearly axial sections; fig. 6 is a slightly oblique, nearly equatorial section.

All figures magnified 73×.



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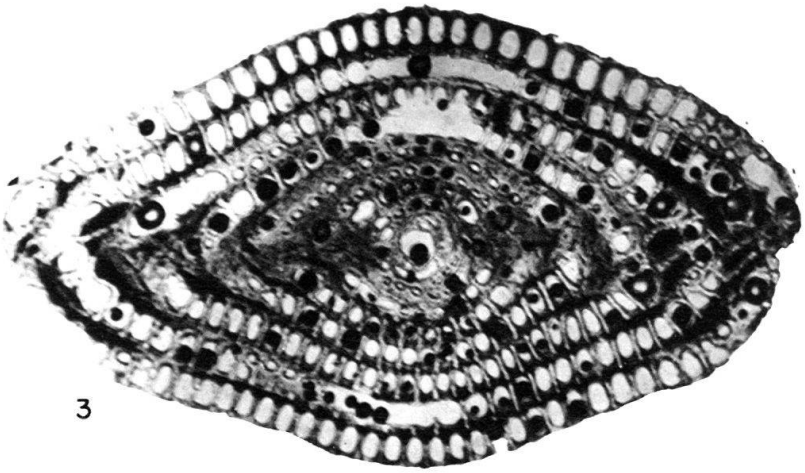

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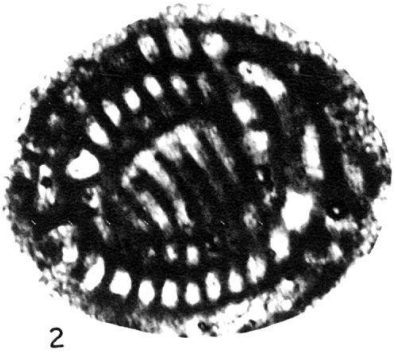

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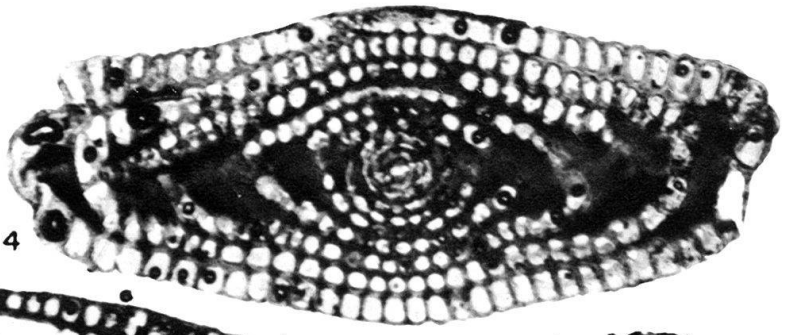

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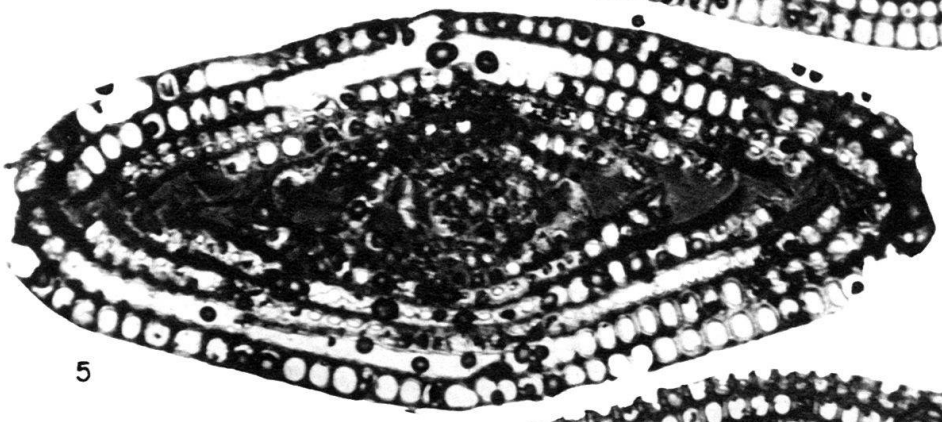

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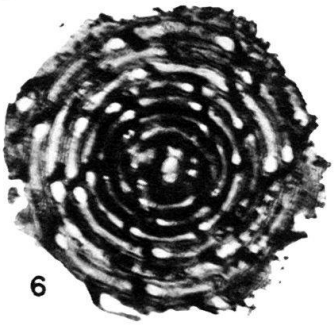

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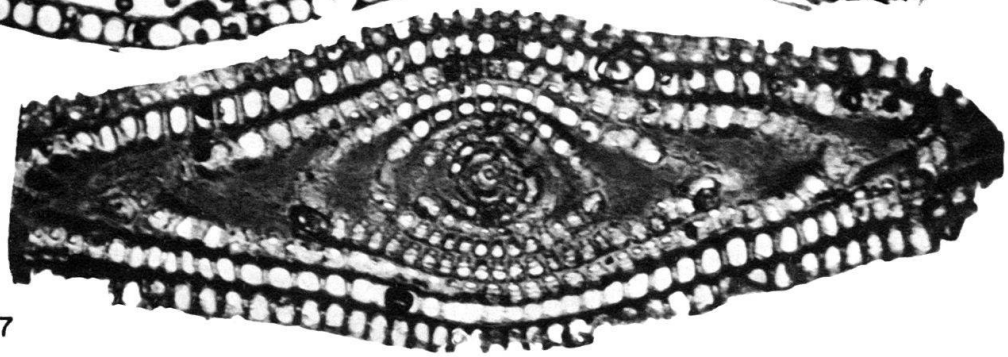

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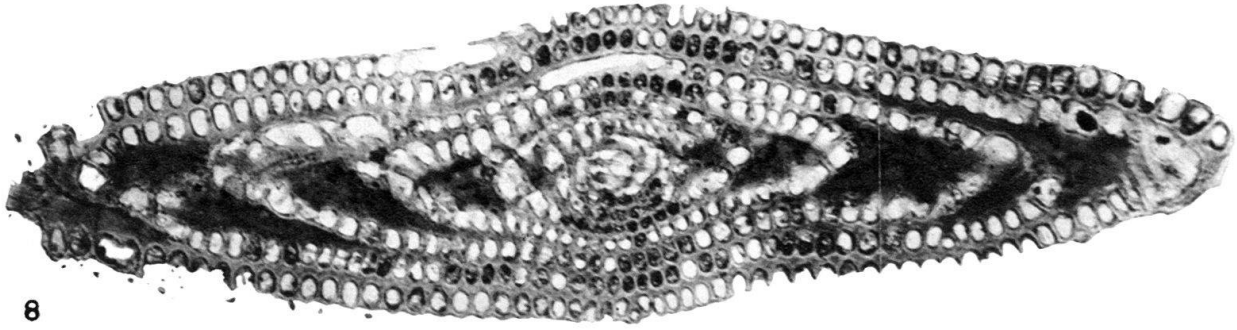

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