STATISTICAL STUDIES ON THE PHYLOGENY OF SOME FORAMINIFERA.

CYCLOCLYPEUS AND LEPIDOCYCLINA FROM SPAIN, GLOBOROTALIA FROM THE EAST-INDIES.

BY

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With plate 1—5.

CONTENTS.

INTRODUCTION.

During my stay in Spain a rock was found in the surroundings of Ronda, wherein Cycloclypeus was met with by the side of other foraminifera. The scarcity of our knowledge about the occurrence of this genus in Europe and in the Mediterranean Basin, induced me to collect in different parts of Spain, more material wherein *Cycloclypeus* might occur, especially Oligocene and Miocene rocks. The inducement became even stronger, when a publication by TAN SIN HOK about the genus *Cycloclypeus* Carpenter, demonstrated the value this genus has for stratigraphy.

The results obtained during the examination of the samples, induced me to deviate from my original intention, of giving a survey of the development of the foraminifera-containing Oligocene in some parts of Spain and to try and follow the way indicated by the provisional results. To do so it proved to be desirable to involve other material in this examination.

The „Bataafsche Petroleum Maatschappij" was found willing, to put a number of samples of „small" foraminifera at my disposal, while Dr. I. M. VAN DER VLERK gave me important sub-recent material from the „Rijksmuseum voor Geologie" at Leyden for examination.

Dr. R. D. CROMMELIN allowed me to use his preparations of *Lepidocyclina isolepidinoides* from a sample from S. Lemoe (eastern Borneo), also from the „Rijksmuseum voor Geologie" at Leyden.

The Spanish samples examined, as well as their preparations and thin sections, are kept at the „Instituut voor Mijnbouwkunde" at Delft. The rest of the drilling-samples of the „Bataafsche Petroleum Maatschappij" is at the „Rijksmuseum voor Geologie en Mineralogie" at Leyden.

Most of the *Cycloclypeus*-containing samples were selected for this genus with so much care that, to me, there does not seem to be much possibility that a sufficient number of them should be left for further examination. Of sample no. 44 Ronda only, a sufficient quantity of unselected material is still in stock.

The same may be said of *Globorotalia menardii-tumida,* from the drilling-samples of the „Bataafsche Petroleum Maatschappij". Here too, most of the samples examined will not contain more than a few specimens of this species; there are, however, a number of unexamined samples left.

The determination of the fauna's in chapter I par. 2, was done with the aid of the following papers:

J. BOURCART et ELIZABETH DAVID. Etude Stratigraphique et Paléontologique des Grès à Foraminifères d'Ouezzan au Maroc. Mém. Soc. Sciences Naturelles du Maroc. No. 37, 1933.

J. BOUSSAC. Etudes paléontologiques sur le Nummulitique alpin. Mém. Carte Géol. France. 1911.

H. BRADY. Rep. Voyage Challenger. Zoology, vol. 9, 1884.

G. CHECCHIA-RISPOLI. La serie nummulitica dei dintorni di Termini Imerese. Giorn. Sc. nat. ed econom. Palermo. 27, 1909.

ELIZABETH DAVID. Les grands foraminifères Miocènes de la zone désertique Syrienne. Haut-Comm. de la république française en Syrie et au Liban. Notes et Mém. t. 1. Contributions à l'étude géologique de la Syrie septentrional, 1933.

H. DOUVILLÉ. Révision des Lepidocyclines. Mém. Soc. Géol. Fr. t. 2, facs. 2, 1925.

R. DOUVILLÉ. Observations sur les faunes à Foraminifères du sommet du Nummulitique italien. Bull. Soc. Géol. Fr. 4e S., t. 8, 1908.

F. GÓMEZ LLUECA. Los Numulítidos de España, Comision de invest. pal. y prehist. Mem. No. 36, (serie pal. no. 8), 1929.

S. HANZAWA. Some fossil Operculina and Miogypsina from Japan and their stratigraphical significance. Sc. Rep. Tôhoku, Imp. Univ. sec. ser. vol. 18, no. 1.

P. LEMOINE and R. DOUVILLÉ. Sur le genre Lépidocyclina. Mém. Soc. Géol. Fr. Pal. t. 12, Mém. 32, 1904.

P. ROZLOZNIK. Studien über Nummulinen. Geol. Hungar. Ser. Geol. facs. 2, 1929.

C. SCHLUMBERGER. Note sur le genre Miogypsina. Bull. Soc. Géol. Fr. 3e S., vol. 28, 1900.

A. SILVESTRI. Considerazioni paleont. e morf. sui generi Operculina, Heterostegina, Cycloclypeus. Boll. Soc. Geol. Italia. 26, 1907.

TAN SIN HOK. On the genus Cycloclypeus Carpenter. Wet. Med. Dienst Mijnb. Ned.-Indië, no. 19, 1932.

The measurements and the magnitudes derived from them which were important for the examination, were put down in a register, which is kept at the „Instituut voor Mijnbouwkunde" at Delft.

Now that I am at the end of my examination, I should like, in the report of its results, to express my thanks to those who contributed to it.

I want to express my deep sense of obligation in particular to:

Prof. Dr. J. H. F. UMBGROVE for his suggestions during the description of the results of my examination, published at the same time as a doctor's thesis. Many of his ideas have been incorporated in these pages that were written under his supervision.

Dr. I. M. VAN DER VLERK, for his many good advices, and his readiness at all times to put at my disposal his great knowledge of literature on foraminifera.

Prof. Dr. B. G. Escher, for the hospitality he accorded to me in the „Rijksmuseum voor Geologie en Mineralogie te Leiden", the assistance he granted me in my examination, both in word and in deed and his consent to publish the result of my work in the „Leidsche Geologische Mededeelingen, deel X, afl. 1".

The „Bataafsche Petroleum Maatschappij", for the foraminifera-samples that were put at my disposal, and the finantial support that was granted to me.

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Miss A. B. Bauduin, for the pains she took in translating my manuscript into English.

Mr. W. F. Tegelaar, for the exactness with which he executed the drawings.

I cannot conclude these prefatory remarks, without mentioning the part my wife had in collecting and selecting the samples. Without her enthusiastic help, many a beautifully preserved foraminifera-shell would have been lost.

CHAPTER I.

EXAMINATION OF CYCLOCLYPEUS-CONTAINING ROCKS FROM SPAIN.

1. Former discoveries of Cycloclypeus in Europe.

Before discussing the Spanish localities and the examination of the *Cycloclypei* found there, it is desirable to give a short summary of the older discoveries of *Cycloclypeus* in Europe and the Mediterranean basin, because this genus must here be considered as belonging to the less generally occurring foraminifera.

In 1905 SILVESTRI described *Heterostegina cycloclypeus* from a *Lepidocyclina*-containing limestone-breccia from Anghiari (Italy) (39) [1]. The next year SCHUBERT reported a similar discovery in *Lepidocyclina*-limestones from Sestola (Italy) (36), under the name of *Heteroclypeus*.

As is apparent from a later publication by SILVESTRI (41) about this species, which he now gives the name of *Heterostegina depressa* var. *cycloclypeus,* we have here, undoubtedly, a real *Cycloclypeus.* He also reports the occurrence of recent forms from the Adriatic. (41) Table II. Fig. 13 and 14.

The geological age of the exposure of Anghiari was first determined by SILVESTRI to be Aquitanian (40), later as Tongrian (41). TAN SIN HOK, who discusses this problem (45) p. 11, thinks that the occurrence of *Miogypsina complanata* and several species of *Lepidocyclina* and the lack of *Camerina,* points to Miocene. I entirely agree with this opinion and, moreover, the conclusion regarding the age, that we can draw for the equatorial sections published (41) tab. II, fig. 8 and 9, agree with this opinion too, as we shall see later on (see p. 20).

Some reports of discoveries of *Cycloclypeus* occur in literature which, according to YABE (55) p. 55, need further confirmation. This applies to Prever's communications about the Eocene occurrence of Aniene, East of Rome (32), of which neither a description nor a picture exists, and Trauth's (48) about the Eocene of Radtstadt in Pongau Salzburg, to which only an excentric vertical section was added (tab. 4, fig. 8 and 9), which might just as well have come from a *Heterostegina.*

A form, described by SILVESTRI as *Cycloclypeus communis,* occurring in a *Lepidocyclina*-limestone of Paxos, (Ionic isles) (42) is, according to YABE, probably no *Cycloclypeus* because it shows lateral chambers. In my opinion the vertical section tab. 4, fig. 6, is that of a *Eulepidina.*

[1]) Figures between brackets refer to the list of literature.

Miss E. DAVID (12) describes on p. 126 a *Cycloclypeus* species accompanied by *Lepidocyclina elephantina* from the Djebel Bichri, on the right-hand bank of the Euphrates, between Rakka and Deiz ez Zor. Although pl. X fig. 1 gives only a vertical section, it is evident from the description, that we have undoubtedly to deal with *Cycloclypeus*. She considers the layers with large *Lepidocyclina*'s as belonging to the Burdigalian; they may, however, be of an older age, (Aquitanian or Upper-Oligocene), as will appear later. (See p. 17).

Finally, Mme. DE CIZANCOURT (10) reports from the Polish Carpathians near Bukowiec: *Cycloclypeus guembelianus*, accompanied by *Camerina fabiani, C. subfabiani, C. rutimeyri, C. chavannesi, C. striatus, C. budensis, C. bericensis, C. incrassatus, C. semicostatus, Discocyclina scalaris, D. nummulitica, D. pratti, Asterodiscus pentagonalis, A. stellaris, Actinocyclina pinguis* and *Spiroclypeus granulosus* — a fauna, the age of which points according to the author, to Priabonian. The shell depicted here (10) tab. XXXIV fig. 17, the rim of which is transparant, probably because it has been moistened with glycerine or some such liquid, clearly shows the cyclic structure of the last chambers. According to the description, the central part of the shell is thickened, the edge very thin, and the diameter only 1 mm. The surface of the shell is probably smooth, at any rate no pillars are mentioned.

As *Cycloclypeus* has never yet with certainty been met with in the Eocene and the Spanish samples examined are also of a more recent date, the exposure of Bukoviec is certainly worth a further examination.

2. Geological description of the Cycloclypeus localities in Spain.

The easily crumbling foraminifera-breccia's wherein *Cycloclypeus* was found in a number sufficient to enable us to make a detailed examination, were all found in the marginal region of the Betical Cordilleras. Those of Ronda and Jaen in the northern-, those of Villajoyosa north east of Alicante, in the southern marginal region.

a. The Oligocene of Ronda.

Three K.M. East of Ronda, (see also the sheet Ronda no. 1051 of the top. map, scale 1:50.000) spotted Triassic marls with gypsum and red sandstones appear to view along the Rio Grande and the Arroyo de Linarejos; in the South and East they are covered by limestones and dolomites which, in the region of the sketch map made by the author, only occur in the farthest S.W. (fig. 1). Mostly the Triassic marls are directly covered by folded tertiary sediments showing a general trend from N.E.—S.W., parallel with the chains of the Betical Cordilleras.

Although the greater part of the „Flysch" from the basin of Ronda belongs to the Eocene, as BLUMENTHAL (1). indicates, a ridge of strongly folded limestones, which proved to contain an Oligocene fauna of foraminifera, was met with at point 770, north-east of the Cortijo de Cochinitas. To the north this Oligocene appears to end very soon, but in a S.W.-direction these limestone banks could be followed across

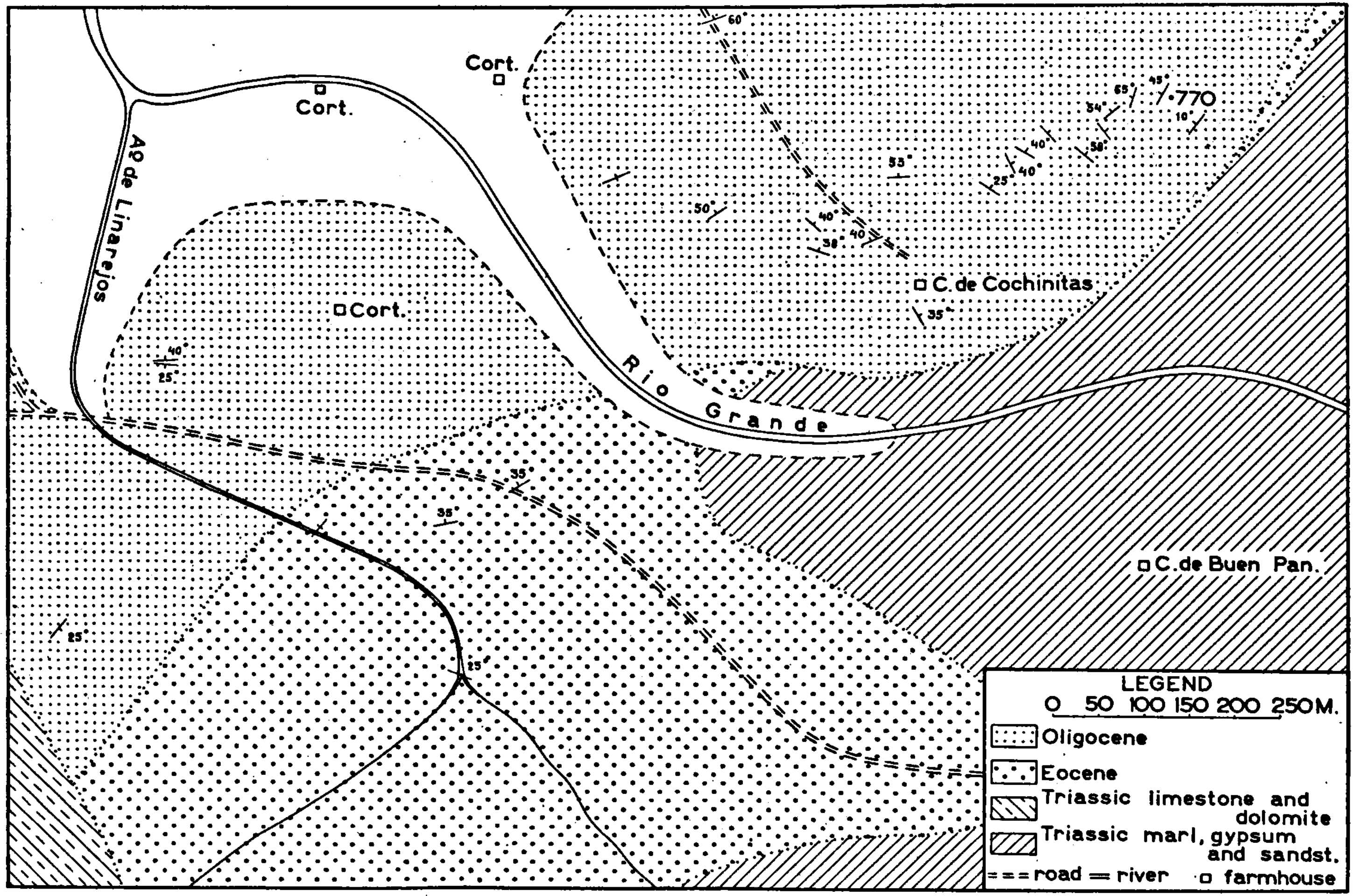

Fig. 1.

Geological map of the region 3 KM. East of Ronda.

the Rio Grande and the Arroyo de Linarejos, to where they end transgressing across much older limestones and dolomites. The foraminiferal limestones are covered by coarse sandstones, rich in glimmer, wherein no fossils were found. The thickness of the foraminiferal Oligocene amounts to about 50 M.

About 100 M. south-west of point 770 a much weathered and, consequently easily crumbling foraminiferal limestone-breccia, dipping 58° to the NE, was found on the hill-crest (sample 44). Herein the following species were determined:

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) levis H. DOUV.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Discocyclina sp.
Camerina fichteli (MICH.).
Cycloclypeus cf. *guembelianus* BRADY.
Heterostegina depressa D'ORB.
Operculina complanata DEFR.
Discorbina sp.
Gypsina sp.
Amphistegina sp.
Textularia several sp.
Globigerina sp.
A shark's tooth.

Of *Camerina fichteli* only a few specimens were found. The two shell fragments of *Discocyclina* clearly appeared as alien elements in this fauna. They point probably to movements of the earth's crust, which caused the Oligocene to transgress locally across elevated Eocene sediments, from which it may be concluded, they originated.

That such transgressive phenomena occur more often, is proved by the fossil contents of other samples examined; thus I found in my sample of DE VERNIEUL and COLLOMB's (51) well-known locality, described by R. DOUVILLÉ (14), near the so-called „Puente Viejo" across the Guadalquivir (see the top. sheet Baeza no. 927, scale 1:50.000), some bipyramidal quartz crystals („Jacintos de Compostela"), which often occur in Triasic marls. At the same time some much-weathered *Orbitolina*- and finally also some *Discocyclina*- and *Camerina*-shells were found. R. DOUVILLÉ fixed the age of this exposure as Lower-Miocene (Aquitanian) (15) pp. 102 ff., although he did not find any *Miogypsina*. The *Orbitoids* were described by P. LEMOINE and R. DOUVILLÉ (25). In my sample no. 408 which, undoubtedly, hails from the same locality, *Miogypsina complanata* was found comparatively often; this confirms its Aquitanian age. So it appears that the lowest Miocene was here transgressively deposited on sediments which, according to the erosion-products found, belong to the formations: Triassic, Cretaceous, Eocene and possibly also Oligocene. On p. 127 R. DOUVILLÉ (15) describes the tectonic in relation with this locality, while H. DOUVILLÉ (13) p. 61—62 gives a historical survey of the well-known facts.

In sample no. 468 from the region of Villajoyosa, which will be exhaustively described later on, and the Oligocene age of which could be ascertained, some *Discocyclina* shells were found too, pointing to transgressive phenomena.

Returning to the description of the Oligocene of Ronda, it may be observed that the thickness of the foraminifera-containing part is not large enough to enable us to state any change in the composition of the fauna in a vertical direction, the thin sections from the other limestone banks offered no reason to do so. In these preparations were found by the side of the forms already mentioned: *Biloculina* sp., *Rotalia* sp., *Planorbulina* sp., *Lithothamnium* sp. and *Bryozoa.*

The Orbitoidal-limestones from the exposure with the double dip-sign, between the Rio Grande and the Arroyo de Linarejos, also proved to contain *Cycloclypeus* cf. *guembelianus.* They yielded, however, only one specimen of which a good equatorial slide could be made.

b. The Oligocene of Villajoyosa.

In the hilly coastal region north of Alicante, tertiary foraminiferal rocks appear to view in several places which generally seem to belong to the Eocene. North of Villajoyosa, however, GOMEZ LLUECA (19) described some exposures of which the fossil contents points to an Oligocene age.

In this slightly folded Oligocene (see fig. 2), I was able to survey a cross-section along the road from Villajoyosa to Orcheta, down to the Eocene marls, which proved already to contain *Assilines* in the quarry of the brick-works (exposure 5).

The northern limb of the synclinal fold, the axis of which runs, roughly, through the Ermita de S. Antonio, shows rather regular, weak dips in a southerly direction. North of Moli de Llinares the regularity is interrupted by a small secondary fold with a northward dip of 30°.

Some exposures of which the fossil contents proved to be of importance for further examination, are described here:

Exposure 4, situated opposite the station of Villajoyosa.

The section-measurements allow of no decision, with regard to the age of the marls and foraminiferal breccia that appear to view here, with respect to the other exposures.

GÓMEZ LLUECA who gives an enumeration of the *Camerinae* (19) p. 216 and *Orbitoidae* (19) p. 354 he found there, mentions: *Camerina vascus, C. boucheri, C. bouillei, C. cisnerosi, C. tournoueri, Lepidocyclina elephantina, L. raulini, L. formosoides, L. dilatata, L. eodilatata, L. roberti,* and *L. royoi. Lepidocyclina marginata, L. praemarginata, L. tournoueri, L. simplex, L. morgani.*

As it seems improbable to me that GÓMEZ LLUECA describes here the fossil contents of another exposure than the one meant by me, I have here quoted his results.

In sample no. 454 of exposure 4, I determined the following foraminifera:

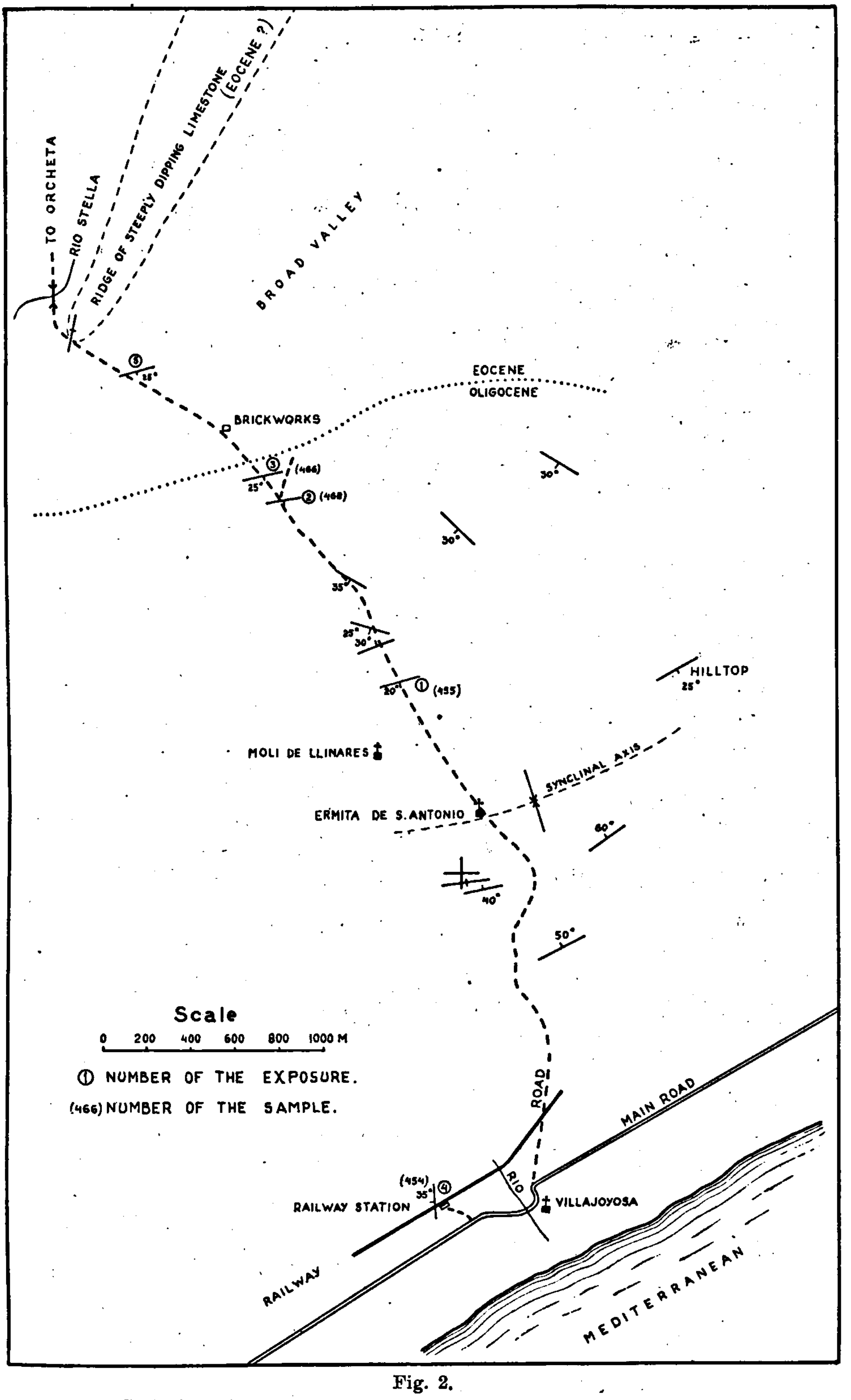

Fig. 2.
Geological sketch of the region between Villajoyosa and Orcheta.

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) elephantina (Mun. Chalmas). (GÓMEZ LLUECA probably considers the large microspheric specimens as belonging to this species. They show, however, a great resemblance to *L. dilatata.* See also (25) p. 13.
Lepidocyclina (Eulepidina) roberti H. DOUV.
Lepidocyclina (Eulepidina) raulini LEM. and R. DOUV.
Lepidocyclina (Eulepidina) formosoides H. DOUV.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) morgani LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) praemarginata R. DOUV.
Lepidocyclina (Nephrolepidina) partita H. DOUV.
Camerina fichteli (MICH.).
Camerina globulus (LEYM.).
Camerina cisnerosi (GÓMEZ LLUECA).
Operculina complanata DEFR.
Operculina paronai CHEC.-RISP.
Heterostegina depressa D'ORB.
Heterostegina cf. *praecursor* TAN.
Cycloclypeus cf. *guembelianus* BRADY.
Cycloclypeus cf. *carpenteri* BRADY.
Amphistegina sp.
Cristellaria sp.

The material, rich in species, also furnished some specimens which may perhaps be considered as an intergrowth of two shells of *Lepidocyclina tournoueri,* orientated vertically on each other. YABE and HANZAWA (56) described analogous forms of *Lepidocyclina sumatrensis,* as *Lepidocyclina sumatrensis* BRADY forma *mirabilis.* As we do not know whether the form found contains only one embryonic apparatus, as is the case with „*mirabilis*", it cannot yet be decided whether we have here to deal with a phenomenon caused by intergrowing, or with a special species. In exposure 1, which will be discussed after this, this form was also found in a rock-slide.

Thin sections of some harder limestone-banks from exposure 4, furnished us yet with: *Textularia* sp., *Gypsina* sp., *Globigerina* sp., *Carpenteria* sp., *Lithothamnium* sp. and *Rotalidae.*

Exposure 1, north of Moli de Llinares.

The foraminiferal breccia's which are here intersected by the road, are situated in the northern limb of the syncline of the Ermita de S. Antonio, wherein a small secondary fold occurs about 200 metres more to the north, after which the layers very soon resume their regular position, dipping in a southerly direction. Thus there is sufficient certainty to suppose, on the strength of the section measurements, that exposures 2 and 3, situated close to the boundary of the Eocene, are stratigraphically older than exposure 1.

In sample no. 455 of the detritus of the sediments that appear to view here, I found the following foraminifera:

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) formosoides H. DOUV.
Lepidocyclina (Eulepidina) roberti H. DOUV.
Lepidocyclina (Eulepidina) raulini LEM. and R. DOUV.
Lepidocyclina (Eulepidina) royoi GÓMEZ LLUECA.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) praemarginata R. DOUV.
Camerina fichteli (MICH.).
Camerina cisnerosi (GÓMEZ LLUECA).
Operculina complanata DEFR.
Operculina paronai CHEC.-RISP.
Operculina bartschi CUSHMAN.
Heterostegina depressa D'ORB.
Cycloclypeus cf. *guembelianus* BRADY.
Amphistegina sp.
Cristellaria sp.

From some thin sections I determined further: *Planorbulina* sp., *Lithothamnium* sp., *Carpenteria* sp. and numerous thick-walled *Rotalidae* (?). Just as in exposure 4, some sections of a possible intergrowth of two *Lepidocyclina*-shells were found, but this time in a rock-slide.

GÓMEZ LLUECA (19) gives on pp. 216 and 354 an enumeration of the *Camerina* and *Lepidocyclina* species, he found also in a sample from Moli de Llinares. As the two exposures cannot be identified with certainty, I shall not quote his statement of the fossil contents, although it agrees almost entirely with the list given above.

In the samples of both the exposures that follow, no *Cycloclypeus* was found. As these samples are, however, of importance for the ensuing examination, as will appear later, a description of their foraminiferal contents follows below.

Exposure 2, about 200 M. from the boundary Eocene-Oligocene, where a path bends off the road to Orcheta in a northerly direction.

From the measurements of the section it is evident, as has already been mentioned, that this exposure must be stratigraphically older than exposure 1, Moli de Llinares.

In the easily crumbling foraminiferal-breccia of exposure 2, (sample no. 468) I determined:

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) formosoides H. DOUV.
Lepidocyclina (Eulepidina) raulini? LEM. and R. DOUV.
Lepidocyclina (Eulepidina) levis? H. DOUV.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) partita H. DOUV.
Discocyclina sp.

Camerina fichteli (MICH.).
Camerina incrassatus (DE LA HARPE).
Operculina complanata DEFR.
Heterostegina depressa D'ORB.
Amphistegina sp.
Cristellaria sp.

Some *Discocyclina*-shells were found, pointing probably to a transgression across Eocene sediments, as was already mentioned on p. 10.

Exposure 3, was found about 100 M. north of the former.

According to the dip of the layers the foraminiferal breccia of exposure 3 must be older than that of exposure 2. A little farther to the north we reach the Eocene marls, that form the broad valley wherein the brick-works and quarry are situated, where these marls already proved to contain *Assilinae* principally (exposure 5).

Sample no. 466 of exposure 3 contained:

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) formosoides H. DOUV.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) partita H. DOUV.
Camerina fichteli (MICH.).
Camerina intermedius (D'ARCH.).
Camerina fabiani? (PREVER).
Camerina globulus (LEYM.).
Camerina incrassatus (DE LA HARPE).
Camerina cisnerosi (GÓMEZ LLUECA).
Spiroclypeus sp.?
Operculina complanata DEFR.
Heterostegina depressa D'ORB..
Cristellaria sp.
Two small *Echinoid* shells.

Camerina occurs in this sample about as frequently as *Lepidocyclina*, a striking difference from all other samples, wherein *Camerina* always occurs less frequently.

c. *The Miocene of Jaen.*

The geology of the region of Jaen is exhaustively treated in R. DOUVILLÉ's thesis (15). A more recent publication by R. BRINKMANN and H. GALLWITZ (6) whose geological survey comprises this region too, does not give any new points of view about the Miocene, that is of especial interest to us, and so it will be sufficient, if we refer to the detailed description R. DOUVILLÉ gives of it.

According to him the Aquitanian consists of marls with *Globigerina*, *Radiolaria* and *Diatoms*, the so-called „boue à *Globigerines* et *Radiolaires*" or „Moronite" (15), pp. 97 and 98, a facies that he considers to point to an origin in a deeper sea. In these sediments neretic *Lithothamnium*-limestones occur now and then, containing a foraminiferal fauna, the age of which, was fixed as Upper Aquitanian by DOUVILLÉ.

DOUVILLÉ (15) pp. 103 and 104, mentions: *Lepidocyclina schlumbergeri*; according to H. DOUVILLÉ (13) p. 72, this is a variety of *Lepidocyclina dilatata*; then: *Lepidocyclina marginata, L. morgani,* and *L. tournoueri.*

He emphatically mentions, that the genus *Miogypsina* was not found.

So the determination of the age is essentially dependent on the negative fact that *Camerinae* are absent, while the upward boundary is sufficiently fixed, as the marly complex is, in many places, regularly covered by a molassus, wherein occur the species: *Pecten beudanti* and *P. praescabriusculus,* which are characteristic of the Burdigalian.

I took samples from some of these exposures, indicated by DOUVILLÉ. The exposure immediately on the southern edge of the town of Jaen, on the right-hand bank of the Arroyo de la Alcantarilla about 100 M. below the bridge, proved to be of especial importance for the ensuing examination. For the exact situation of this exposure the top. sheet of Jaen, no. 947, scale 1:50.000, may be consulted. The exposure is there situated at the initial letter of the word „Alfareria".

DOUVILLÉ (15) p. 156, again found here the same *Lepidocyclina* fauna mentioned above, viz.: *L. schlumbergeri* LEM. and R. DOUV., (according to H. DOUVILLÉ (13) p. 72, a variety of *L. dilatata* (MICH.), *L. morgani,* LEM. and R. DOUV., *L. tournoueri,* LEM. and R. DOUV., and *L. marginata* (MICH.).

From sample no. 228 Jaen of this exposure, I determined

Lepidocyclina (Eulepidina) dilatata (MICH.).
Lepidocyclina (Eulepidina) formosoides H. DOUV.
Lepidocyclina (Eulepidina) levis H. DOUV.
Lepidocyclina (Eulepidina) royoi GÓMEZ LLUECA.
Lepidocyclina (Nephrolepidina) tournoueri LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) morgani LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) praemarginata R. DOUV.
Lepidocyclina (Nephrolepidina) partita H. DOUV.
Operculina complanata DEFR.
Operculina paronai CHEC.-RISP.
Heterostegina depressa D'ORB.
Cycloclypeus cf. *guembelianus* BRADY.
Miogypsina complanata SCHLUMB.
Amphistegina sp.
Cristellaria sp.
Vulvulina sp.

I found only a few specimens of *Miogypsina,* in opposition to some analogous exposures of this foraminiferal breccia, which, according to their appearance and fossil contents, must be of about the same age, and where this genus proved to occur much more often. This was e.g. the case with sample no. 408, of which some characteristics were mentioned on p. 9. As, however, *Cycloclypeus* did not occur here, this sample was of no importance for the ensuing examination.

In none of the samples examined here *Camerina* was found, except in sample no. 408, where as we saw, they occurred as an alien element in the fauna.

d. Other Cycloclypeus localities in Spain.

Although the locality that must yet be mentioned, was of no importance for the ensuing examination, because the material proved to be not large enough to yield a sufficient number of specimens of *Cycloclypeus*, I want to mention it here, because it should be worth a further examination.

A few hundred metres south of the village of Busot, situated at about the same distance from Alicante and Villajoyosa, runs a ridge of foraminiferal limestones with a strike-direction of 50° N. and a N.W.-dip of 60°. Where the new road connecting the village with the Baños de Busot, intersects this ridge, sample no. 272/6 was taken, which, on examination yielded some smooth shells of *Cycloclypeus* cf. *guembelianus*, of which two equatorial slides were made.

A provisional determination of this fauna yielded the following species:

Lepidocyclina (Eulepidina) dilatata (MICH.) (forms-A. and -B.)
Lepidocyclina (Eulepidina) raulini or *formosoides?*
Lepidocyclina (Nephrolepidina) tournoueri? LEM. and R. DOUV.
Lepidocyclina (Nephrolepidina) marginata (MICH.).
Lepidocyclina (Nephrolepidina) praemarginata R. DOUV.
Cycloclypeus cf. *guembelianus* BRADY.
Heterostegina sp.
Operculina sp.
Camerina sp. (radiate form, without pillars and not reticulate.)

3. Stratigraphical comparison and determination of the relative age of the localities.

As in the preceding paragraph the relative age of only a few exposures in the region of Villajoyosa could be determined by fieldwork, I want here to try and reach this aim in another way for the six samples discussed under *a, b* and *c*. The four ways that may lead to this are:

a. comparison of the fauna's; whereby in the region of Villajoyosa the results of the fieldwork may be used.
b. determination of the relative age of the *Cycloclypei* according to TAN's method.
c. the evolutional trend of the operculinoidal part of the *Cycloclypeus*-shell.
d. the evolutional trend of the size of the proloculum of *Cycloclypeus*.

a. Comparison of the fauna's, in relation with the results of the fieldwork in the region of Villajoyosa.

The foraminiferal contents of all samples consists for a great part of *Orbitoids*. The *Lepidocyclina's* are generally represented by a great number of species, and always the same species. If we compare Orcheta no. 466, situated about 50 M. from the boundary Eocene—Oligocene, with Jaen no. 228, the only one of the six samples that will be discussed here wherein *Miogypsina* was found, then we find, that in the Lower-Oligocene most *Lepidocyclina* species are already present, those with a *Nephrolepidina*-, as well as those with an *Eulepidina*-embryonic-apparatus. Only some, always sparsely occurring species such as *L. levis, L. morgani* and *L. praemarginata,* were not found here. It is remarkable that in this sample (no. 466) the *Camerina's* play such an important part, quantitatively as well as with regard to the number of species. The frequentative proportion *Camerina-Orbitoid* is here about one, whereas in the other samples the *Camerina's* always have a subservient occurrence. This gives already the impression that Orcheta no. 466 is, stratigraphically, probably the oldest of the samples examined. From the measurements of the geological sketch-map fig. 2, it appears convincingly, that sample no. 466 represents the oldest of the Oligocene exposures found in this region.

As *Miogypsina* was found in sample no. 228 from Jaen, by which R. DOUVILLÉ's opinion (15) who, without being aware of the occurrence of *Miogypsina,* as we saw on p. 15, fixed its age as Aquitanian, is considerably strengthened; we are safe in assuming that this sample is the most recent of the examined series, all the more so, because *Camerina* which has always been found in the other samples, was not met with here.

If we can determine the extreme component parts of our series of samples with sufficient certainty, on account of the foraminiferal contents, the stratigraphical determination of the relative place of the four remaining samples is much more difficult. The only remarkable thing that appears in comparing the fauna's, is the occurrence of the large forms of *Lepidocyclina* cf. *L. (Eulepidina) elephantina* (Munier Chalmas) in the sample Villajoyosa no. 454. H. DOUVILLÉ (13) p. 69, observes about this species, that it is always found in the company of the last small *Camerina's* so, according to DOUVILLÉ, in the Upper-Oligocene, or, at the base of the Aquitanian. BOURCART and ELIZABETH DAVID (2) pp. 9 and 55, and GIGNOUX and FALLOT (18) p. 439, think that *L. elephantina* still occurs in the Burdigalian, which is denied by SENN (38) pp. 102 and 103. As several *Camerina* species occur in our sample no. 454, DOUVILLÉ's determination of the age seems to be the more probable one, so that we reach the result, that no. 454 is older than Jaen no. 228 and probably younger than the other samples.

The fauna's of the three remaining samples do not show sufficient differences to serve as a base for a determination of the relative age; moreover, it has been proved that Ronda no. 44 is relatively poor in species.

If, however, we use at the same time the data yielded by the field-work in the region of Villajoyosa—Orcheta (see pp. 10 to 14 and fig. 2) then it appears that, from old to young, the position of Orcheta no. 466, Orcheta no. 468, and Moli de Llinares no. 455 is fixed. As we saw that Villajoyosa no. 454 and Jaen no. 228 are younger, it is only the position of Ronda no. 44 that remains uncertain.

b. Determination of the relative age of the Cycloclypei according to TAN SIN HOK*'s method. Nomenclature.*

Before giving a summary of this method, I want to make some observations first.

In the discussion of the course of the further examination it will often be necessary, to indicate a collection of fossils originating from a certain sample. To avoid the use of the word „population" which, perhaps, ought to be restricted to living organisms, the word „plethe" derived from the Greek translation, might be used in imitation of SCHMID (35) p. 54. As SCHMID indicates, this conception has been introduced by BRINKMANN (5) p. 53, meaning a fossil population. As the conception „plethe" implicates at the same time that we have to deal with a certain well defined species, which, as will appear in the last chapter, could not, strictly speaking be proved, I prefer to use in the following pages the word „group" instead of plethe.

A further observation regards the, in my opinion, not very fortunately chosen terminology, TAN uses for the different parts into which the *Cycloclypeus* shell can be divided (45) pp. 16 ff. It is based on the division of the individual development of organisms given by GRABAU in his „Principles of Stratigraphy" (20) p. 971. Now TAN calls the part of the equatorial chamber-plane situated immediately around the protoconch, and formed by the uncontinuous septa, the „nepionic", or babyhood stage. Around this, the cyclic chambers formed by the concentrical ring-formed septa constitute the „neanic" or youth stage. If necessary sub-stages are distinguished with the aid of the prefixes „ana", „meta" and „para".

In this way TAN considers the not subdivided chamber(s), following immediately after the protoconch and forming a part of the nepionic apparatus, as constituting the ana-nepionic apparatus.

Such a division leads to the idea that the „babyhood" of a *Cycloclypeus* individual with a small nepionic apparatus, consisting of a small number of uncontinuous chambers, must have been of a shorter duration than that of an individual with a larger nepionic apparatus. As, furthermore, a small nepionic apparatus is generally attended with a large neanic apparatus, it follows that a short „babyhood" must be the cause of a long „youth" stage, while two specimens with a neanic apparatus differing in size, must also have had youth stages of different duration.

Not considering the improbable consequences of such a nomenclature, it also seems unnecessary to me. If in future, we shall speak of the heterosteginoidal stage, with which we shall indicate the spiralbuilt part of the shell, which entirely agrees with that of a *Heterostegina,* and wherein, just as there, we can yet distinguish an operculinoidal stage for the undivided chamber(s), while considering the ring-shaped chambers situated around the heterosteginoidal apparatus as the cyclic stage, such a denomination seems clear to me, without any further additions.

If after these observations, we proceed to the description of TAN's method, we see that it is based on a pecularity in the development of the genus *Cycloclypeus,* noticed already by VAN DER VLERK, viz. that the recent forms are characterised by a smaller number of heterosteginoidal chambers than the fossil forms (52) pp. 385 and 393.

From a statistical examination of the *Cycloclypeus* material taken from four samples of a known relative age, TAN found that the frequency of the number of heterosteginoidal septa of *Cycloclypeus oppenoorthi,* can be graphically represented by a broken line. The tops showing in this line, which agree with the variates with a maximal frequency, he regards as „phenotypes". It now appeared that the same tops occurred in groups that differed only slightly in age. When this difference became greater, such a shifting occurred, that new „phenotypes" characterized by a smaller number of heterosteginoidal septa appeared in the younger group, whereas at the same time some phenotypes representing the greatest number of heterosteginoidal septa in the older group, had disappeared.

The evolutional picture of the heterosteginoidal apparatus of *Cycloclypeus* thus obtained, was used by TAN, to determine the relative age of a *Cycloclypeus*-group of unknown stratigraphical position.

This is explained by his Table IV, wherein the relative age of the four Tjiapoes samples, coming from a continuous section, may be considered as known, while, on the strength of the evolutional trend derived from it, as given above, the relative age of the other localities was determined.

TAN repeatedly points out, that the determinations of age worked out in this way, have always proved to agree with the conclusions that could be derived from geological fieldwork and the palaeontologic contents of the exposures (45), pp. 7, 98, 128 and 132.

So far the review of TAN's method; we will now see in how far our own research agrees with it.

In four of the six samples discussed, *Cycloclypeus* appeared to occur in a sufficient number, to enable us to investigate the relative age of the localities. If for doing so, we use the picture of the development of the heterosteginoidal apparatus studied by TAN (see Pl. II, fig. 1) it appears that, when we arrange the different curves in such a way, that the result corresponds with the characteristics of this picture given above — leaving the right-hand curve of Villajoyosa out of consideration — the chronological order of the samples Moli de Llinares no. 455, Villajoyosa no. 454 and Jaen no. 228 agrees with the relative age of these exposures, as found above (see p. 17 and 18, and Pl. I, last column but one).

At the same time, the position of Ronda no. 44, which could not be determined before, is now fixed. So we see that the results obtained by the application of TAN's method, agree with those obtained in another way.

Here we may also make an observation about the age of some localities of *Cycloclypeus* mentioned before, of which the number of specimens found is, however, not large enough for an exact determination.

This applies in the first place to the sample Busot no. 272/6 mentioned on p. 16, which yielded two equatorial sections of *Cycloclypeus* with, respectively 32 and 27 heterosteginoidal septa. If, on the strength of these two data, we should be inclined to give a relative age determination, then it appears from Pl. II fig. 1 that they fit best in the frequency-curve of the sample Moli de Llinares, no. 455, so that we would have to conclude to a similar age, which is not at variance with our knowledge of the foraminiferal contents of this sample.

On p. 6 we mentioned the *Cycloclypeus*-locality of SILVESTRI near Anghiari, (Italy). According to his pictures of two equatorial sections (41) Tab. II, fig. 8 and 9, the number of heterosteginoidal septa amounts to respectively 17 or 18 and 14 or 15. TAN (45) p. 56, counts in the same pictures respectively 16 or 17, and 13 or 14 of these septa. If we take 17 and 14 as representing the most probable values, then it appears from Pl. II, that the Anghiari occurrence may very well be of about the same age as the sample Jaen no. 228. This is in accordance with the foraminiferal contents of the respective exposures, which both contain *Miogypsina.*

Here already I ought to call attention to the fact, which we shall prove later on, that it is necessary for the method of determining the relative age applied here, to compare similar species, a condition which has to all probability been fulfilled.

Before finishing this paragraph I want to remind the reader that, up to now, we have only occupied ourselves with the development of the heterosteginoidal apparatus of the megaspheric generation. It may, however, be expected that the microspheric generation will show a parallel development. From Pl. 1, column 3, it appears that this is indeed the case, although of course, not too great an importance must be attached to the reliability of the results, because of the small number of specimens.

c. *The development of the operculinoidal apparatus of Cycloclypeus.*

The megaspheric protoconch of *Cycloclypeus* is generally succeeded by one or more chambers, not divided by secondary septa, forming together the operculinoidal apparatus. From the table fig. 3 it appears that this apparatus shows an evolutional picture similar to that of the heterosteginoidal one. Here too such a shifting occurs, that from old to young, the percentage of the number of individuals with two undivided chambers decreases regularly, while that with one such chamber continually increases. At the same time specimens with more than two operculinoidal chambers gradually disappear.

Groups:		*Cycloclypeus* cf. *guembelianus*						*Cycloclypeus* cf. *carpenteri*			
		number of sections, expressed as percentage of the total amount,									
		for:	1	2	3	4	5	0	1	2 operc. chamb.	
Jaen	no. 228	(27 sect.)	96	4?							
Villajoyosa	no. 454	(43 sect.)	82	16	2			2	94	4?	(47 sect.)
Ronda	no. 44	(94 sect.)	79	20	1						
Moli de Llinares	no. 455	(161 sect.)	68	28	2	1	1?				

Fig. 3.

Development of the macrospheric operculinoidal apparatus of *Cycloclypeus*.

The place occupied by the different samples in the picture of development, agrees again with the relative age already ascertained in another way, (see Pl. I).

The operculinoidal apparatus of the microspheric generation will probably show a development parallel to the megaspheric one. The number of specimens available, was however too small, to admit of a certain proof, (see Pl. I, column 5).

d. The development of the size of the proloculum, in relation with the relative age of the Cycloclypeus groups.

1st. On the evolutional-picture of the average size of the proloculum of the various groups.

In his table VII Tan (45) mentions the relation between the number of heterosteginoidal septa and the average size of the proloculum of the various groups examined by him. From this we see, that the average diameter of the proloculum generally increases, when the number of heterosteginoidal septa decreases, or, in other words, the younger the group, the larger the average diameter of the proloculum. We must, however, immediately add the restriction, that the rule formulated in this way is only applicable to the separate „sectio's", wherein the sub-genus *Cycloclypeus* s. str. is divided by him. Thus it appears e.g. from his table, that the oldest *Cycloclypei* from the „sectio" *C. koolhoveni* have a much larger average proloculum diameter than the older representatives of the „sectio" *C. eidae,* which, according to Tan are younger, because the variation in the number of heterosteginoidal septa points here to a further advanced development of the heterosteginoidal apparatus, than is the case with the „sectio" *C. koolhoveni.* We shall return to this question later on.

If, for the present, we restrict ourselves to one „sectio", it is apparent that in general the size of the proloculum does increase when the number of heterosteginoidal septa decreases, but exceptions occur. It is possible that they have been caused by too small a number of measurements, through which the calculated average may considerably diverge from the real average.

If, however, the relation found between the average size of the proloculum and the number of heterosteginoidal septa should, on closer inspection, indeed prove to be a regular process, then it follows from the picture of development found for the heterosteginoidal apparatus, that also the average size of the proloculum of the various groups, must show regular alteration related with their relative age.

In order to obtain the most exact possible data about this, the horizontal proloculum-section of all the available specimens was projected with a linear magnification of 268 times, the surface was mensurated and herefrom the diameter of the proloculum was calculated, presupposing a globular shape for the latter. The average values of these magnitudes may be found for each group separately in columns 6 and 7 of Pl. I.

Indeed it now appears that the relative ages of the groups, already fixed in three different ways, (see Pl. I, columns 2, 3 and 13 as well as table fig. 3) also fit the regular picture that can be composed for the development of the average size of the proloculum of the various groups, as follows from columns 6 and 7 of Pl. I.

Herewith we have obtained a confirmation of the supposed development of the average size of the proloculum, a development which will be discussed for two other foraminifera in the course of the ensuing examination.

2nd. On the frequency-curves for the surface of the horizontal proloculum sections.

Pl. II, fig. 2, shows the frequency-curves for the surface of the horizontal proloculum sections of the different groups in chronological order, constructed with the aid of the results of the mensuration of the horizontal proloculum-sections.

If, for the moment, we leave the right-hand curve for Villajoyosa out of consideration, we see that the regular increase in the average size of the surface of the proloculum of the groups, seems to be brought about, by the gradual disappearance of the top in the class of 4.5/6 cM^2, whereas in the class of 7.5/9 cM^2 (lin. magn. 268 times), a new top shows itself in the Ronda group, which appears to take the most important place in the younger groups. At the same time we see, that analogous tops in different groups occupy the same places.

The Jaen-curve has, probably on account of the small number of measurements on which it is founded, a somewhat irregular shape, so that we must not attach too great an importance to it (see pp. 41 and 42, for the way wherein the frequency-curves have been constructed).

e. On the relative age of the Cycloclypei from the exposure Villajoyosa and the divergent shape of the frequency-curves.

Of this exposure about 50 shells of *Cycloclypeus* were examined originally. From this examination it appeared that the frequency-curve for the number of heterosteginoidal septa strongly diverged from the normal form. To see this, the curve from the right-hand upper corner of Pl. III, may be compared with the curves of Pl. II, fig. 1. The curve of Pl. III immediately begins with the highest top at 13 heterosteginoidal septa, after that gradually decreasing in height, which never happens with the other curves.

The most obvious explanation was, that we must consider the possibility that the *Cycloclypeus* material of this sample might be of a heterogeneous composition.

To investigate this further, 44 new specimens were selected and first accurately examined for external characteristics. Anticipating the description of the *Cycloclypeus* species that will follow, I may here already point out that the shells from all the samples examined up to now, proved to be smooth, while the septa of the chamberlets on the rim were sometimes clearly visible through the shell.

It now appeared, that shells with clearly visible pillar-heads occurred here by the side of smooth ones (see fig. 4*a* and 5*a* p. 28). Of the 44 specimens examined, 24 were smooth, 18 with pillars and two had indistinct habitus.

After this the internal characteristics were examined. It then appeared that the number of heterosteginoidal septa of the pillared individuals ranged from 11 to 16, and the size of the surface of the horizontal sections of the proloculum from 8 to 22 cM^2 (lin. mag. 268 times), whereas for the smooth shells these figures ranged from 12 to 24 and 5 to 14. Although the corresponding curves covered each other over a comparatively large distance, or, in other words, showed an important transgression, it appeared that a distinct difference existed between the two forms, also as regards the internal characteristics. As of the originally examined sample the number of heterosteginoidal septa as well as the surface of the proloculum sections was known of each specimen, it was still possible to trace which specimens must have been pillared, and which must have had smooth shells.

The results of the examination thus conducted, have been included in Pl. III. In the left-hand part the curve for the surface of the horizontal section of the proloculum is seen for the entire sample, and below that the analogous curves for the form with smooth and pillared shells apart. By adding these two, the upper curve is obtained. In the right-hand part the curves for the number of heterosteginoidal septa are found in the same way, from which appears, that they have a normal shape as regards the separate form groups.

So the result is that there appears to exist a considerable difference between individuals of the two groups of *Cycloclypei*, as regards the external- as well as the internal characteristics. This difference is again found, when we include the operculinoidal apparatus in the examination. From the table fig. 3 it appears viz. that this apparatus has, in the pillared *Cycloclypei,* reached a more advanced stage of development, agreeing more or less with that of the sample from Jaen, than the smooth *Cycloclypei.*

Now that we have determined the frequency-curves for the number of heterosteginoidal septa and the surface of the horizontal section of the proloculum for both groups from the sample Villajoyosa no. 454, we must yet trace, in how far the data obtained fit the chronological scheme that we have constructed for the rest of the samples. From Pl. II, fig. 1 it appears that the situation of the frequency-curve of the number of heterosteginoidal septa for the smooth-shells, which agree with the *Cycloclypei* found in the rest of the samples, lies between that of Jaen and that of Ronda, a result which agrees with what has been derived from the composition of the accompanying fauna's (see p. 17).

But the average value of the surface of the horizontal section of the proloculum also confirms, as appears from Pl. I, column 6, the relative age-determination, which we found again just now for this sample.

We reach the same result when we trace the development of the operculinoidal apparatus represented in the table fig. 3. Here too the sample Villajoyosa no. 454 again ranges itself without difficulty between those from Ronda and Jaen.

Of less importance, but yet agreeing with the relative age to which we concluded above along different lines, is the number of heterosteginoidal septa of the microspheric generation. From Pl. I column 3, we see the gradual decrease of this number as the samples are of a younger date. The small number of microspherical specimens available, however, are cause that we cannot attach great value to this result. The same may be said of the number of operculinoidal septa of the microspheric form indicated in Pl. I, column 5.

Data about the pillared *Cycloclypei* may also be found in Pl. I, while the frequency-curves for the number of heterosteginoidal septa and the surface of the horizontal section of the proloculum are represented in Pl. II and III.

In the beginning of this paragraph it was mentioned that the cause of the abnormal shape of the frequency-curve for the number of heterosteginoidal septa, must, in all probability, be sought in the circumstance that the *Cycloclypeus* material in this sample should be of a heterogeneous composition. The examination with regard to this, as we saw, completely confirmed this idea, but this does not give us the certainty that both groups are of the same age. We must take into account the possibility that, during the formation of these sediments, alien foraminifera-material may have been deposited as the erosion products of older sediments, together with the autochthonical deposits.

We can point out at once that, apart from both form-groups of *Cycloclypeus* which, according to their internal characteristics, may very well be of different ages, nothing in the composition of the very rich Villajoyosa fauna (see p. 12) indicates that we have here to deal with a fauna wherein alien elements occur.

In relation with the possibility that the pillared *Cycloclypei* might be of a more recent date than those of Jaen, which will agâin be pointed out later on, an extensive but unfruitful search for *Miogypsina* was undertaken.

So I reach the conclusion that there is not a single reason which renders the possibility mentioned acceptable, apart from the circumstance, that such particular factors are fortunately exceptions in the process of sedimentation. So everything points to the fact that there is no question here of washing in of alien material, so that we may safely assume that both form-groups have the same age, i.e. that they lived at the same time.

4. Conclusions.

When we summarize the results of the examination conducted up to now, we can best do so on the basis of Pl. I wherein the results of the examination of *Cycloclypeus* and the composition of the accompanying fauna's are arranged in the form of a table. It then appears that the process of evolution of the internal features expressed in figures, forms on the one hand, a confirmation of the relative age of the exposures already fixed in another way with more or less certainty while, on the other hand, the now known relative age of the samples enables us to draw a clear, albeit restricted, picture of the development of the different features examined.

As regards the former, it may be said, that the results of the examination of the internal features, give a strong support to the determination of the relative age of the *Cycloclypeus*-groups as it was already fixed in another way, viz. derived from the composition of the accompanying fauna's and as the results of the geological fieldwork. So we come to the conclusion that we can now dispose of six samples of which, although the mutual distance of the exposures may amount to 500 KM., the relative age could be determined with a large measure of probability.

As regards the latter, it appears that the changes that were found in the features examined in relation with the relative ages of the groups, point to an „orthogenesis", so to a development in a certain direction. We state viz. that the number of chambers regularly decreases for the heterosteginoidal- as well as for the operculinoidal apparatus and that this decrease is attended with a regular increase in size of the proloculum.

It is not my intention to go here further into the extremely difficult and intricate problems connected with the so-called „species problem". So without formulating the conception „species" in general, I want to try and make it acceptable that the two form-groups of *Cycloclypeus* from the sample Villajoyosa, belong to two sharply divided orthogenetic series of development, which I will call species. On these two orthogenetic series, the species description in the ensuing paragraph is based.

As we dispose of more groups of a known relative age of *Cycloclypei* with a smooth shell, it was, as we saw, possible to compose an evolutional picture of three different features. Of the pillared *Cycloclypei* we have only one group, and if for a moment we do not consider the difference in the external shell habitus, we can now trace the places of the three internal features of this group, where they should belong in the analogous known pictures of evolution. It then appears that each of the examined three features of the pillared *Cycloclypei* are in a stage of development that is even further advanced than that of the *Cycloclypei* from the sample of Jaen (see Pl. II and fig. 3). From this it follows that there is a considerable hiatus between the stages in the development of the internal features of the pillared and the smooth *Cycloclypei* of the sample from Villajoyosa. So we reach the conclusion that, apart from the difference in external features (pillared and smooth) there is, at the same time a considerable difference between the internal features of the shells of the two groups, which certainly justifies us in distinguishing two separate series of evolution, belonging to the genus *Cycloclypeus.*

The picture of evolution we have found for several internal features of the smooth shells is, of course limited, and must be regarded as part of the picture that would show the entire phylogenesis. However, the extreme terms of the evolutional-series known to us, — so the groups of Moli de Llinares and Jaen — differ relatively so little as regards the external as well as the internal features, that there is certainly no reason to draw boundaries in this evolutional series. Below follows the description of both the evolutional series as two separate species.

5. Description of the Cycloclypei.

In the preceding paragraph we discussed the reasons why, in connection with the evolutional picture of the features of the various groups of *Cycloclypei,* we shall distinguish two species of *Cycloclypei.* Below follows a description of these two species:

Cycloclypeus cf. guembelianus Brady.

Fig. 4*a*. Shell from sample no. 455. 9 ×.
Fig. 4*b*. Equatorial section, showing 30 heterosteginoidal septa. 25 ×. Sample no. 455.
Fig. 4*c*. Equatorial section, showing 22 heterosteginoidal septa. 22.5 ×. Sample no. 454.

	1881,	*Cycloclypeus*	*guembelianus*	BRADY. Quart. Journ. Micr. Sci. 21, N.S. p. 66.
	1884,	„	„	BRADY. Challenger Rep. p. 751, Pl. CXI, fig. 8*a, b*.
	1891,	„	„	MARTIN. Samml. Geol. Reichsmus. Leiden. N. F. Bd. 1, (Anhang), p. 3.
(pars.)	1900,	„	*carpenteri*	CHAPMAN. Journ. Linn. Soc. (Zoology), Vol. 28, p. 22, pl. II, fig. 6, pl. III, fig. 3.

1922, *Cycloclypeus guembelianus*	VAN DER VLERK. Studien Numm. en Alveol. p. 391.
1932, „ cf. „	TAN SIN HOK. Wet. Med. Dienst Mijnb. Ned.-Ind. no. 19, p. 90, pl. XXIV, fig. 8—11.

External characteristics: shell smooth, mostly with a more or less excentrical umbo. Septa of the equatorial chamberlets on the rim sometimes clearly visible. Diameter of the shell up to 4½ mM, with a thickness of ½ mM; thickness of the rim 0,2 mM. Microspherical shells only slightly larger, than those of the megaspherical generation.

Internal characteristics: The variation-limits of the picture of evolution for three internal shell-features, follow from the table below:

	Oldest group. (Lower? Oligocene)	Youngest group. (Aquitanian)
Average surf. hor. prol. sect.	6.92 cM^2	9.63 cM^2 [1])
Greatest number heterost. septa ...	40	18
Smallest „ „ „ ...	20	10
Greatest „ opercul. „ ...	4 (5?)	2
Smallest „ „ „ ...	1	1

Cycloclypei of this species, older than Lower? Oligocene or younger than Aquitanian may give values for these characteristics that fall outside the extreme values derived from the table.

Shape of the equatorial chamberlets about square, or slightly stretched radially.

The description of the shell given here, agrees with that of the authors mentioned above, insofar as regards the external features and the shape of the equatorial chamberlets. As the material described by them hailed from regions situated far from the mediterranean basin, it seemed advisable to me, to add the restriction „cf" to the name of the species.

Localities in Europe: Moli de Llinares (Spain), Ronda (Spain), Villajoyosa (Spain), Jaen (Spain), Anghiari (Italy), Bukowiec ? (Austria).

Cycloclypeus cf. carpenteri Brady.

Fig. 5*a*. Shell from sample no. 454. 9 ×.
Fig. 5*b*. The same shell, showing the opposite side. 9 ×.
Fig. 5*c*. Equatorial section, showing 16 heterosteginoidal septa. 25 ×. Sample no. 454.

[1]) The surface of the horizontal section of the proloculum was ascertained with a linear magnification of 268 times.

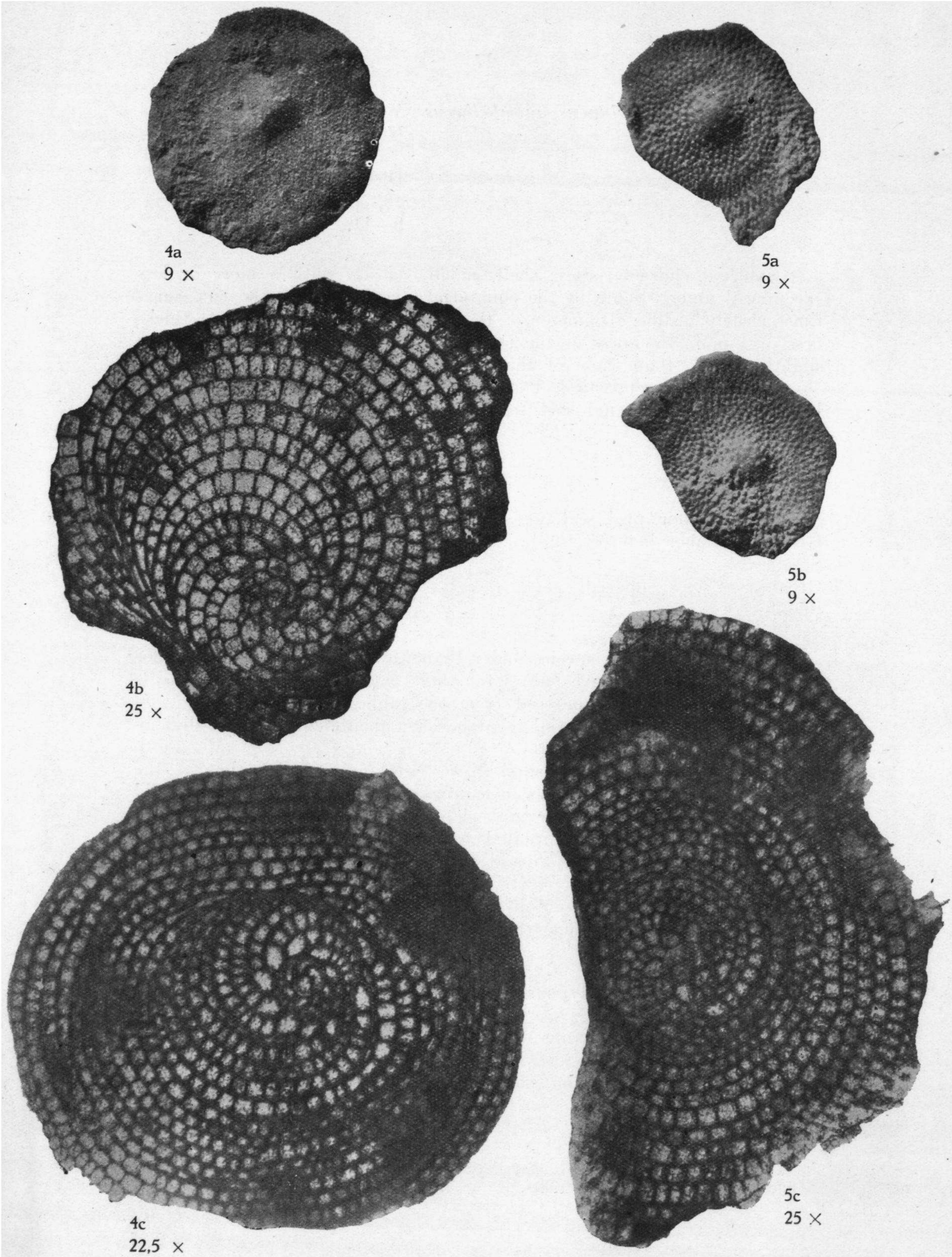

Fig. 4 *a, b* and *c*. *Cycloclypeus* cf. *guembelianus* BRADY.
Fig. 5 *a, b* and *c*. *Cycloclypeus* cf. *carpenteri* BRADY.

	1862,	*Cycloclypeus* sp.	Carpenter,	Intr. to the study of the foram. p. 292, pl. XIX, fig. 2—7.
	1881,	„	*carpenteri*	BRADY. Quart. Journ. micr. sci. 21, N. S. p. 67.
	1891,	„	„	MARTIN. Samml. Geol. Reichsmus. Leiden, N. F. Bd. 1 (Anhang), p. 3.
(pars.)	1900,	„	„	CHAPMAN. Journ. Linn. Soc. (Zoology), Vol. 28, p. 22, pl. II, fig. 1.
	1905,	„	„	var. *papillosa*. SILVESTRI. Boll. Soc. geol. Ital. 26, 1907, p. 52, pl. II, fig. 13 and 14.
	1922,	„	„	VAN DER VLERK. Stud. Numm. en Alveol. p. 63.
	1932,	„ cf.	„	TAN SIN HOK. Wet. Med. Dienst Mijnb. Ned.-Ind. no. 19, p. 75, pl. V, fig. 4 ?, pl. XXIV, fig. 1—7.

External characteristics: the surface of the shell is generally covered with clearly visible rather thick pillarheads. They are sometimes more or less pear-shaped in section, the narrowed ends pointing to the centre, which is connected with their originating in the points of intersection of the septa of the equatorial chamberlets, whereby the narrowed ends fall together with the centrally directed septa. Umbo generally clearly developed. Septa of the equatorial chamberlets sometimes visible on the rim. Diameter of the shell up to 4½ mM., thickness about ½ mM. Microspherical specimens were not found.

Internal characteristics: the internal features of the shell were only ascertained for one group of an Upper-Oligocene age, as follows from the table below:

	Group of Upper-Oligocene age.
Average surf. hor. prol. sect.	14.03 cM. [1])
Greatest number heterost. septa	17
Smallest „ „ „	11
Greatest „ opercul. „	2
Smallest „ „ „	0

The shape of the equatorial chamberlets is about square or slightly stretched radially.

The description of the shell given here, agrees with that of the authors mentioned insofar, as the external characteristics and the shape

[1]) The surface of the horizontal proloculum section was ascertained with a linear magnification of 268 times.

of the equatorial chambers are concerned. The material described by them hails from the Netherlands East-Indies and the Pacific. SILVESTRI, however, describes a recent form from the Adriatic, as the variety „*papillosa*" the picture of which (41) pl. II, fig. 14, agrees with the species described by myself. As yet, it seems advisable to me to add the restriction „cf." to the name of the species, until material from more localities will be studied in details.

Localities in Europe: Villajoyosa (Spain), Adriatic (recent).

Observation. TAN gives for the number of heterosteginoidal septa of *C.* cf. *guembelianus* and *C.* cf. *carpenteri* a dispersion of respectively 2—6 and 2—5, (45) pp. 90 and 75. In my opinion this dispersion cannot form a criterion for the determination of the species, as is sufficiently indicated by the result of my examination. The divergent values for the dispersion following from the tables above, cannot give any rise to doubt as regards this species-determination.

6. Critical discussion of the way in which Tan Sin Hok uses the evolutional picture of the heterosteginoidal apparatus as a geological chronometer.

The evolutional picture of the heterosteginoidal apparatus of *Cycloclypeus* as it was examined and described by TAN (45), we find briefly discussed in our paragraph 3 *b*, pp. 19 and 20. The reason why I want to draw the attention to one of his conclusions and at the same time to the way in which he uses the evolutional picture as a chronometer, lies in the circumstance that ,during my examination some points came to the fore, that could not without more ado, be brought in accordance with his ideas.

When we trace the picture of evolution of the heterosteginoidal apparatus as it follows from TAN's table IV and my Pl. II fig. 1, we see that, this development occurs roughly, for both in the same way and in the same direction. By the side of this concurrence we see, however, an important difference.

The tops shown by the frequency-curves of table IV, might, according to TAN, be regarded as phenotypes, if it were not for the fact that, they always occupy the same places in the different groups and so remain constant during a considerable time-interval, so that they must be regarded as hereditary, i.e. as mutants. For, so he says: „In „genetics it is shown that hereditary shifts take place discontinuously „and that the saltations may be great or minute. These hereditary „shifts are called mutations and the specimens possessing them are the „so-called mutants. The various nepionic phenotypes we therefore have „to call mutants." (45) p. 97.

If we now return to our frequency-curves of variation of Pl. II, fig. 1, it appears that here the various tops do not, as a rule, occupy the same places. This only seems to occur as an exception, and obviously, to be only the case with the top of 29 heterosteginoidal septa in the curves of Moli de Llinares and Ronda. Of course the possibility must be taken into account that, in small groups with a large dispersion the place of the less important tops cannot always be accurately fixed, which is e.g. the case with the tops of 24, 26 and 28 heterosteginoidal septa in the curve of Villajoyosa. In one instance it could be ascertained with great certainty that there could be no question of hereditary phenotypes. This regards the tops of 25, respectively 26 heterosteginoidal septa from the groups Ronda and Moli de Llinares, which consist successively of 17 and 14 variates. A mistaken determination of place of these tops seems very improbable to me.

From the situation of the tops in the frequency-curves of the groups examined by myself, one gets the impression that, perhaps with the exception of 29 heterosteginoidal septa, the respective phenotypes are not hereditary, which, at the same time does away with the possibility that they might be regarded as mutants.

We come now to the following point, viz. to the way in which the evolutional picture of the heterosteginoidal apparatus may be used as a geological chronometer (see also pp. 19 and 20). As was already discussed more than once, the character of the trend of this evolution may be derived from the four frequency curves of my Pl. II, fig. 1. The fifth curve, which, as we saw relates to another species, offers us the possibility to compare the evolutional pictures of two species with each other, even though, as regards *C. carpenteri,* we can only dispose of the variation picture of one group. If we do make this comparison, it appears that the two pictures of evolution have shifted with regard to each other, for the frequency-curve of *C. carpenteri,* would be situated above that of Jaen in the picture of evolution of *C. guembelianus* (see also pp. 25 and 26). From this we may draw the general conclusion that the pictures of evolution of a certain feature will probably run parallel for different species of the same genus, but that these pictures may have shifted with regard to each other.

In order to be able to use the evolutional picture of the heterosteginoidal apparatus as a geological chronometer, we must clearly realize, that we cannot start from one given diagrammatic picture consisting of a number of curves of a known relative age, wherein we need only fit the curves of groups of unknown stratigraphical position, to ascertain their relative age, but that each species has gone through its own development, the picture of which can *only* serve to ascertain the age of groups of the *same* species.

If we see now in what way Tan uses the picture of the evolution of the heterosteginoidal apparatus as a chronologic time-scale, we notice that he starts from four orientated groups of *C. oppenoorthi,* from the section of Tjiapoes (Java). The four frequency-curves concerned of his table IV, form the basis of the determination of the relative age of other groups. Thus it follows from these chronologically arranged curves that the *C. eidae* group of sg. Soembal (Borneo), is younger than that of Tjiapoes 14, (Java).

In connection with this, it is yet of importance to quote what he remarks on p. 98 about: „the chronological sequence of the Cyclo- „clypean populations."

„We found that both the phenotypical composition of the various

„populations of Tjimangoe and Tjiapoes is a function of geological time. „This result is devoid of any hypothesis, being based on populations the „stratigraphical position of which is known from the field.

„Using this result as a working hypothesis we arranged the popul-„ations of which the stratigraphical position is not known in detail „according to it. Up till now the sequence obtained is not at variance „with the parallellization drawn from other organisms or from the field. „This absence of contradiction warrants the usefulness of the principle."

After this quotation and what preceded it, it will be clear that the way in which TAN uses the picture of evolution of the heterosteginoidal apparatus as a geological chronometer, is at variance with the views obtained by my own research.

I do not want to say that it would be wrong, to take the Sg. Soembal group to be younger than that of Tjiapoes 14, on the contrary, the foraminiferal contents of the exposures sufficiently proved this. In my opinion, however, the two groups must not be directly compared, their position is in principle, side by side, and only on examination of a sample in which *C. eidae* occurs, as well as *C. oppenoorthi,* it can be proved in how far the respective pictures of evolution have shifted with regard to each other.

That TAN had a premonition of the complications that might occur on comparison of Cycloclypean groups of the same age, is apparant from what he remarks about K. Lawak, p. 101:

„It is remarkable, that the frequency distribution of the nepionic „variance of *C. inornatus* of K. Lawak differs from that of *C. indo-„pacificus,* var. *terhaari,* of the same locality. With the former species „the nepionic stage with four septa has not yet developed while it is „already the case with the latter species. This means that the nepionic „evolution of the former species is slower than that of the latter."

Evidently the difference was here not great enough to draw his attention sufficiently and to make him realize its great importance.

Finally some observations follow here on the practical usefulness of the method of using the heterosteginoidal apparatus of *Cycloclypeus* as a geological chronometer.

It is an advantage that we have here do deal with integer variates, because the number of heterosteginoidal septa is, of course a whole number. The graphic representation of the distribution of the variates is simpler and more reliable than is the case when we have to deal with class-variates. The reliability of the results is for the rest of course dependent on the number of variates examined. I will not go farther into this, because the frequency-curves with which we have to deal here, show a divergence from the usual binomial type, which makes the formulas in which we otherwise express the reliability in figures, lose their practical usefulness. For the rest it remains in general true, that the reliability increases with the number of variates and that, to reach the same reliability, more variates are needed with a large dispersion than with a small one.

Then, the practical usefulness of the method is unfavourably influenced by the difficulties experienced in determining the number of heterosteginoidal septa. It appears viz. that the heterosteginoidal apparatus generally shows irregularities through which the determination of the number of these septa is in many cases rendered illusionary, and often even quite impossible. Miss CAUDRI (7) p. 184, and TAN (45) p. 21, point this out exhaustively.

In this connection we might suggest the possibility that the persistency of the tops in TAN's frequency-curves, on which he bases extensive considerations, may perhaps have been influenced by this behaviour so easily leading to a subjective judgement.

Finally I may remind the reader that, as goes of course without saying, the possibility for the application of the method is bounded by the numerousness with which the genus *Cycloclypeus* occurs in the sediments.

CHAPTER II.

ON THE DEVELOPMENT OF THE PROTOCONCH OF LEPIDOCYCLINA TOURNOUERI LEM. AND R. DOUV.

In the preceding chapter we obtained an insight in the course of the evolution of some features of *Cycloclypeus* while, at the same time we were able to determine the relative age of six samples with a great degree of probability.

It is obvious now, that we must try to put this insight to the test, with the aid of the results of the examination of other foraminifera. The six samples with their known relative age, offered the possibility to do so, because they all proved to contain *Lepidocyclina tournoueri*. This induced me to consider this species in the first place for a further examination.

1. On the morphogenesis of the protoconch.

During the examination of the groups of *Lepidocyclina tournoueri* from the six well-known samples, it appeared that the normal nephrolepidinal protoconch showed transformations indicating, that here we did not have to deal with variates that happened to show accidentally more or less important deviations from the average phenotype, but that these deviations seemed to point to changes in the picture of evolution, because a certain regularity could be traced in their manner of occurrence.

Thus sample no. 466 from Orcheta and, to a lesser extend, also no. 468, yielded quite a number of shells of *L. tournoueri* with a protoconch that was strongly reminiscent of that of *Lepidocyclina* s. str. („Isolepidina"). The second chamber of the protoconch was here as large as, or only slightly larger than the first, the dividing septum was flat, or slightly convex and the protoconch comparatively thin walled, just as is the case with the normal nephrolepidinal type. H. Douvillé (13) p. 60 and 61, fig. 62, 63, described this type that, according to him, externally agrees with that of *L. tournoueri,* as *L. praetournoueri.*

In the same way the most recent sample, Jaen no. 228, contained some variates which diverged considerably from the usual nephrolepidinal protoconch. In this case the deviations were, however, of the tryblio-lepidinal type.

Between these two extreme forms all sorts of transitions were found in the remaining samples, which together, formed one consecutive picture of evolution. The isolepidinal protoconch connected with the nephrolepidinal one by transitional types which were described as isolepidinoidal forms by VAN DER VLERK (54) p. 23, eventually proved to merge gradually into the trybliolepidinal protoconch which, however, was not found before the Lower-Miocene samples.

The picture of evolution obtained in this way, comprising a geological period of time from Lower-Oligocene to Lower-Miocene, is of course very limited, which is also apparent from the relative rarity with which the iso- and trybliolepidinal variates occur in the oldest and the youngest sample.

Let us now consider what other investigators have to say in relation with this: VAN DER VLERK (53), p. 19, examined a large numbre of *Lepidocyclina rutteni* from Tji Boerial and Tji Tangkil, near Bandoeng (Java). Of the 253 specimens examined, 244 showed the normal trybliolepidinal protoconch (53), pl. III, fig. 4*a*. Of the 9 remaining specimens 6 were represented, of which 3 had a divergent protoconch, which might point to a future stage of evolution (53), pl. III, fig. 4 *e–g*. Of the other three, 2 had a nephrolepidinal form (53), pl. III, fig. 4*b* and *c*, whereas the third shows a protoconch that already reminds us of that of *Isolepidina* (53), pl. III, fig. 4*d*. Compared with the groups of *L. tournoueri* described above, the dispersion appears to be exceptionally large here, which may partly be ascribed to the large number of specimens examined. MARTIN (28) p. 47—49, determined the age of this locality to be Upper-Miocene (upper part of Tertiary-*f*).

Another examination that gives an impression of the development of the nephrolepidinal protoconch is UMBGROVE's research of *Lepidocyclina transiens* (50) p. 109. He gives there a picture of some 20 protoconches of this species, wherein clearly trybliolepidinal types occur by the side of typical nephrolepidinal forms, while also numerous transitional forms are present. The stratigraphic age of the locality could not be ascertained in this case. Later it became apparent that *L. transiens* is an index fossil for Tertiary-*e* (Lower-Miocene).

Miss CAUDRI (8) gives on p. 118 pictures of nephrolepidinal and trybliolepidinal protoconches occurring together in samples of *L. martini*, *L.* aff. *rutteni*, *L. douvillei*, and *L. borneënsis*.

On perusal of a collection of preparations of *L. isolepidinoides* from a sample from S. Lemoe, western Baritoe basin (East-Borneo), in the „Rijksmuseum voor Geologie" at Leyden, and prepared by CROMMELIN, it became evident to me, that the transition from *Isolepidina* to *Nephrolepidina* occurs in the Dutch East-Indies as well. Most of the protoconches were here of the type *Nephrolepidina-isolepidinoides*; by the side of these, however, some specimens with an isolepidinal protoconch were met with. The age of this locality is, according to a verbal communication of Dr. VAN DER VLERK, lower Tertiary-*f*.

Miss CAUDRI (8) p. 104, mentions in her description of the nephrolepidinal protoconch of *L. parva*, from Soemba, the find of one specimen with a protoconch that shows a strong resemblance with the isolepidinal type. The age of this sample was ascertained to be Tertiary-*f*.

Finally CUSHMAN (11) describes the occurrence of *Isolepidina* and transitions to nephrolepidinal protoconches with *L. canellei* var. *yurnaqunensis*, pl. XXXIII, fig. 3—8. The picture of „pliolepidinal" protoconches, pl. XXXII, fig. 6, and pl. XXXIII fig. 9, appear to be of the usual type, but they are surrounded by some very large „peri-embryonic" chambers, through which they somewhat resemble *Pliolepidina*.

The survey given above, confirms the picture we have formed of the development of the protoconch of *Lepidocyclina*, when examining the groups of *L. tournoueri* from the Spanish samples.

2. On the size of the proloculum.

For the examination of the changes of size of the proloculum of the groups of *L. tournoueri*, I made use of the sections situated in the plane of the equatorial chambers. In general it may be expected that the largest section of the proloculum will be situated within this plane, so that, by ascertaining the surface of these sections, data are obtained, that may enable us to form a conception of the changes of the size of the proloculum during a certain geological time-period.

According to the picture fig. 6, the magnitudes *a* and *b* of the horizontal sections of the protoconch were measured with a micrometer-ocular under the microscope, and the average value determined for each group. If we regard *a* and *b* as the axes of an ellipse, then $\frac{1}{4}\pi ab$ gives us approximately the required surface. From some check-measurements, whereby the surface was at the same time mensurated, it appeared that the results obtained in this way were only slightly different from the actual surfaces.

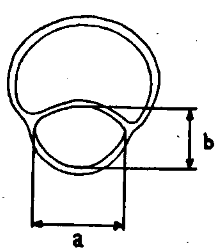

Fig. 6.

During the examination of the size of the proloculum of *Cycloclypeus* I had, as I already mentioned, the opportunity of projecting the magnified proloculum section, after which the surfaces were mensurated. For a very minute examination this method is to be preferred, but for practical reasons it was impossible to use this method for the measurement of the proloculum of *L. tournoueri*.

In the table on p. 37 the results of the measurements are given for the various groups and the average surface of the horizontal section of the proloculum has been calculated for each group. The results have, at the same time been included in Pl. I, column 12.

If these data are chronologically arranged (see Pl. I), it appears that the average size of the proloculum of the groups gradually changes in such a way, that the oldest group shows the greatest and the youngest group the smallest average.

If this result is compared with what we found for the development of the proloculum of *Cycloclypeus* (see Pl. I), we state the very remarkable fact that, where for *Cycloclypeus* the average size of the

	Jaen nr. 228		Ronda nr. 44		Moli de Llinares nr. 455		Orcheta nr. 468		Orcheta nr. 466		Villa-joyosa nr. 454	
	in μ.		in μ.		in μ.		in μ.		in μ.		in μ.	
nrs.	a	b	a	b	a	b	a	b	a	b	a	b
1	278	203	300	188	195	128	165	128	248	218	322	247
2	360	263	233	180	278	210	315	210	375	300	263	173
3	300	218	315	225	326	225	285	248	293	218	247	187
4	285	165	233?	180?	293	188	278	165	353	330	390	233
5	278	150	338	195	263	165	308	233	315	225	218	165
6	255	165	263	188	188	128	300	263	248	203	277	195
7	300	255	300	220	240	165	300	195	225	158?	203	150?
8	293	210	293	214	214	150	390?	263	?	225	270	187
9	308	210	203	139	300	195?	345	270	278	203	225	180
10	338	210	263	200	375	263	353	285	195	158	240	210
11	300	150	263	192	270	218	275	180	323	270	292	210
12	203	150	278	158	308	173	225	165?	263	240	345?	218?
13	300	203	300	218	428	278	263	188	278?	323	300	202
14	278	173	315	193	525	300	285	195	345	308	285	195
15	300	173	323	210	353	300	255	188	225	158	330	263
16	210	135	263	180	210	165	323	240	300	210	308	225
17	225	180	218?	188?	293	188	270	248	270	203	315?	202?
18	293	188	285	203	248	210	308	240	240	158	352	240
19	360	248	383	255	248	158	375	308	248	180	270	210
20	240	150	338	235	338	210	270	173	285	233	278	180
21	263	210	285	188	225	165	225	173	263	218	240	165
22	225	165	278	188	338	225	225	175	308	285	307	203
23	353	210	338	240			150	105	240?	188	263	195
24	263	165	255	200			278	188	360	270	255	195
25	300	173	240	165			293	240	315	225	322?	210?
26	278	173	315	180			285	225	323	413	225	150
27			323	173			305	233	240	150	270	165
28			218	173			270	203	240	165	210	165
29							338	255	270	180	330	225
30							390	285	278	210?	285	187?
31							270	210	285	188	270	173?
32									233	210	233	202
33									338	278	255	188
34									360	255	262	180
35									248	188	300	202
36									255	188	240	173
37											308?	180
38											322	210
sum.:	7386	4895	7959	5468	6456	4407	8917	6677	9863	8132	10627	7440
average:	284μ	188μ	284μ	195μ	293μ	200μ	288μ	215μ	282μ	226μ	279μ	196μ
$\frac{1}{4}\pi ab$:	0.0419 mm^2		0.0435 mm^2		0.0460 mm^2		0.0486 mm^2		0.0500 mm^2		0.0430 mm^2	

proloculum increases as the groups are younger, the course of this development is reversed in the case of *L. tournoueri.*

3. Conclusions.

From the investigation of the morphogenesis of the protoconch of *L. tournoueri* it appeared that we have to deal with an evolutional series: *Isolepidina-Nephrolepidina-Trybliolepidina,* of which the three main types mentioned proved to be connected with each other by transitional stages. This result is, as we saw, supported by what was found as regards the shape of the protoconch of other *Lepidocyclina* species.

TAN (46 and 47) also reached the same conclusion, when studying the „peri-embryonic" equatorial chambers of various *Orbitoids.* His hypothetical phyletic series is, however, more extensive, and comprises also *Orbitocyclina* and *Polylepidina.*

In this connection it is of importance to point out that the various *Lepidocyclina* species, which show the evolutional picture given above, will not, as a rule find themselves in the same stage of development when being of the same age. It is e.g. known that in the Dutch East-Indies *Lepidocyclina (Nephrolepidina) borneënsis* and *L. (Trybliolepidina) rutteni* may occur in the same sample.

From this it appears again, what we have been able to prove with regard to *Cycloclypeus,* that the pictures of evolution of species going through an analogous process of evolution, will generally have shifted with regard to each other.

As for the second part of our investigation of the development of the protoconch of *L. tournoueri,* where we found a gradual change in the average size of the proloculum (see Pl. I), I do not now want to go any further into the hypothesis we might construe in connection with the development of the proloculum of *Cycloclypeus,* because more data will be obtained in the following chapter.

Here I only want to point out, that this gradual change in the size of the proloculum of *L. tournoueri* is another confirmation of the determination of the relative age of our six samples (see Pl. I).

CHAPTER III.

EXAMINATION OF SOME GROUPS OF GLOBOROTALIA MENARDII-TUMIDA.

The results of the examination of the groups of *Cycloclypeus* and *Lepidocyclina* made it desirable, especially in connection with the ideas which they suggested about the development of the proloculum, to extend the examination to other foraminifera, in order to obtain more certainty about these questions.

The available material consisted of a sub-recent sample, dredged near the Kei-islands (Dutch East-Indies), by the Danish expedition of 1922 under the leadership of Dr. TH. MORTENSEN, and a number of drilling-samples of a known depth, from the well Bodjonegoro I (Java) of the „Bataafsche Petroleum Maatschappij", containing „small" foraminifera. Some of these drilling-samples were put together because, apart, they were too poor in foraminifera.

The depths of the samples were as follows:

201—209 M., together with 211—215 M. depth.
401—404 M. depth.
604 M. „
1007 M. „
1627 M. „

I shall indicate these samples in the following pages as: 208 M., 403 M., 604 M., 1007 M. and 1627 M. For the exact depth the list given above may be referred to.

In the sub-recent- as well as in the five drilling-samples, *Globorotalia* occurred often enough to enable us to attempt a statistical examination. In accordance with SCHMID (35), p. 53, I joined the series of forms *Globorotalia (Pulvinulina) menardii-tumida* under the name of *„menardii"*.

The advantage of this material existed especially herein, that it offered the possibility to examine a foraminiferal species from yet another family, which might render the contingent results of greater general importance in connection with the results already obtained.

The usefulness of the material is, of course, highly influenced by the degree of accuracy of the relative age-determination. We must viz. take into account the possibility that irregularities may occur in the drilling-section, caused by a repetition of series of strata. In this case the depth-figures would no longer at the same time indicate their relative age.

We may regard this possibility as excluded in four samples out of five, on the strength of information given to me by the chief-geologist of the Central Geological Department of „The Bataafsche Petroleum Maatschappij" at The Hague, according to which the strata drilled through to a depth of 1400 metres are flying flat and the samples above that depth no doubt represent a normal stratigraphical section. The connection between the sample below 1600 metres and the higher ones is not so clear.

From this it follows that we may assume the relative age of the four higher samples as known, whereas the fifth and deepest sample is of an not quite certain age.

1. External characteristics of the shell.

Before entering upon a discussion of the external features of the shell, I want to make some remarks in connection with the classification, for which I shall follow the review given by SCHMID (35), pp. 50—53.

The great variability of the shape of the shell has been the reason, that two closely connected forms were distinguished, viz. *Pulvinulina menardii*, D'ORB., and *Pulvinulina tumida*, BRADY. In his Challenger-work (4), pp. 690—692, BRADY gives a description of these two species, but at the same time he mentions that *P. tumida* must probably be regarded as a variety of *P. menardii.*

After SCHUBERT (37) and FISCHER (17) had degraded the species *„tumida"* to a variety, CUSHMAN (11) pp. 91 and 95, reinstated in 1931 the former opinion and described the two forms as *Globorotalia menardii*, D'ORB. and *Globorotalia tumida*, BRADY.

By his „biometric" examination SCHMID, however, reaches the conclusion that they must again be reunited under the name of *Globorotalia menardii* (D'ORB.). He now distinguishes, however, a megaspheric and a microspheric form, which ought to agree more or less with what, in literature is understood by *G. (Pulvinulina) tumida* (BRADY) and *G. (Pulvinulina) menardii* (D'ORB.), (35) p. 103.

In the groups I examined both forms also occurred, with all their transitions, so that I quite agree with SCHMID were ,on p. 51 he writes: „Beim Versuche, dieselben zwecks Bestimmung unter dem Binokular-„mikroskop zu sortieren und den beiden Species zuzuteilen, fiel mir „bald die Unmöglichkeit einer sichern Trennung der beiden Formen auf. „Es schienen in der Hauptmenge alle Uebergänge von der einen zur „andern Form zu existieren, obschon hinwiederum zwei in ihren „extremen Ausbildungen deutlich zu unterscheidende Typen vorhanden „zu sein schienen."

An analysis of the frequency-curve of the length of the shell and an examination of the correlative connection between the measurements of the shell, enabled him to point out, that his group consisted of two phenotypes and that it would not be exact to regard the *„tumida"* and *„menardii"* variates as the extreme terms of a homogeneous series of variation. They ought to be regarded as two separate phenotypes with a strong transgressive variability.

Although the irregular character of his frequency-curve (35), table II, fig. 2, does not support the reliability of the conclusions drawn from it, I think, on the strength of what can be derived from the correlation tables and my own examination, that SCHMID's opinion about this matter is right to a certain extent. The value of his research as far as the external elements of the shell are concerned, is especially determined by the large number (600) of specimens measured.

The frequency-curves for the lengths of the shells of the *Globorotalia* groups from the drilling-samples of the „Bataafsche Petroleum Maatschappij" and the sub-recent sample, showed irregular shapes too. The curves for the two youngest groups (sub-recent and sample 208 M.) showed a striking similarity with SCHMID's complicated curve, while those of the older samples showed a somewhat simpler form, probably on account of the smaller average length of the shell, coupled with a smaller dispersion. That the number of specimens measured was sufficient to give a reliable frequency-curve, may be deduced from the obvious agreement in form between the samples first mentioned and SCHMID's, but for the rest, the character of the curves proved to be so complicated that the value of contingent conclusions derived from them, must be regarded as very relative indeed.

This complicated character may be partly explained, for, except for the possibility that the groups are heterogeneous, and may exist of two or even more phenotypes, it may be expected that also differences in age of the shells measured, connected with their discontinuous growth, may cause disturbances in the shape of the frequency-curves. This latter possible cause is used by SCHMID to explain the occurrence of the so-called „tertiary" tops in his frequency-curve (35) pp. 97, 98.

The cause of these disturbances can be avoided if we use the quotients of the length and breadth (or thickness), instead of the measurements of the shell, as the basis for the construction of the frequency-curves. This makes them independent of the size of the shell and the irregularities that may occur in them, while changes in shape, insofar as a change in the proportion of the shell measurements results from them, can come to view.

Before I go further into this matter, I want to make some observations in connection with the more general rules applied in the construction of all frequency-curves discussed here.

As has been observed before, we must for the construction of these curves distribute our measurements over certain classes. Only for the frequency-curves for the number of heterosteginoidal septa of *Cycloclypeus* this was not the case, because we had there to deal with integer variates. The magnitude of the class-interval is, up to a certain point, arbitrary; we must however take into account, that remarkable peculiarities may disappear on account of too large a magnitude, whereas, in classes that are too small secondary tops may appear, caused by the limitation of the material measured, or by an insufficient accuracy in measuring.

About the accuracy with which the various measurements were executed something more will be told later on, see p. 45.

Besides the class-intervals, the position of their limits is also of importance for the graphic representation of our series of variation, which can easily be demonstrated with the aid of the following graphic example.

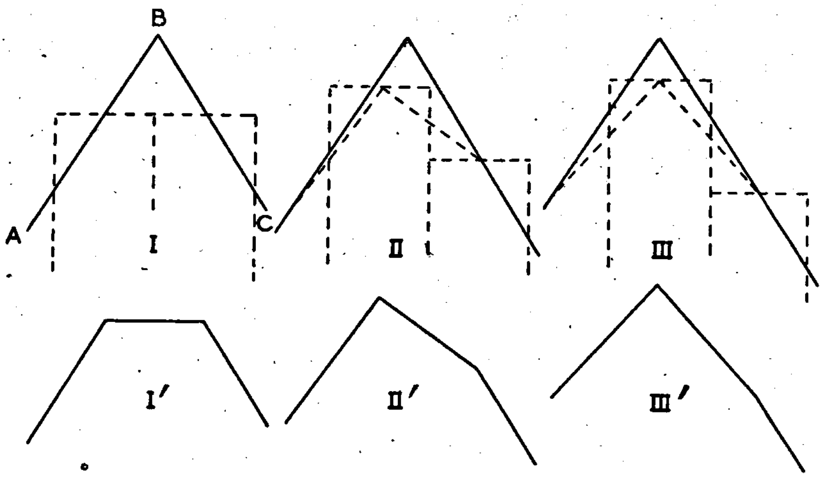

Fig 7.

Starting from a frequency-distribution of variates represented by the broken line ABC in the above drawing (fig. 7) we can, by dividing the variates into classes and shifting the limits of those classes, trace the influence of these actions, by comparing the original curve with the one originating in this way. Thus a class-division as indicated by the dotted lines in case I, gives a curve I′. By shifting the limits of the classes to the right along one fourth of the class-interval (case II), we obtain curve II′, while a further shifting along the same distance (case III), gives curve III′. On still further shifting we get the reflection of case II, and finally case I again.

So we see that in all cases class-division lowers the height of tops occurring in the frequency-curves, this lowering is greatest in case I and smallest in case III and it of course increases also with the class-interval. At the same time it appears, that the position of the tops may change as well (case II). So the influence of class-division is most unfavourable, when the common limit of two classes intersects the top of a frequency-curve and most favourable when such a top coincides with the medium of a class.

Conversely it follows from this behaviour that, if we are justified in expecting the frequency-curve of a number of measurements to show several tops, and if we want to ascertain the height of these tops, more values will be found for this, by shifting the limits of the classes, the highest of them being the most exact.

All our frequency-curves of class variates have been constructed in this way. The limits have always been shifted along one fourth of the class-interval so that, again and again of four determinations the best approximation of the position and height of the tops could be derived.

Returning to the frequency-curves for the shell indices of Pl. V, fig. 1, it may be observed now that they show a much more regular and simpler picture than the analogous curves for the length of the shells. In the centre we see two tops, situated close to each other, which appear as one, but much flattened top in two of the curves. So the groups probably consist of a mixture of two phenotypes, which appear to possess a great transgressive variability. The phenotype with the greater index-figure woud then have to agree with the „*tumida*" type which, according to SCHMID (35), p. 55, is characterised by smaller, thicker and relatively longer shells, while the smaller index-figure would mark the larger, thinner and rounder shells of the „*menardii*" type.

The heterogeneous character of the groups also appears, as was already pointed out by SCHMID, from the correlation tables for the shell-measurements, Pl. V, fig. 2. From these tables we see first of all, that the correlation between the length and breadth of the shell is always very high, as appears from the pronounced grouping of all the variates along one axis. The tangent of the angle at which this axis intersects the vertical, equals the quotient of the average measurements of the shells.

So we get:

for the sub-recent group: $\frac{866}{704} = 1.230 = \text{tg. } 50°55'$

„ „ 208 M. „ : $\frac{542}{449} = 1.207 = \text{tg. } 50°20'$

„ „ 403 M. „ : $\frac{435}{353} = 1.232 = \text{tg. } 50°55'$

„ „ 604 M. „ : $\frac{533}{433} = 1.231 = \text{tg. } 50°55'$

„ „ 1007 M. „ : $\frac{370}{310} = 1.194 = \text{tg. } 50°\ 5'$

„ „ 1627 M. „ : $\frac{358}{306} = 1.167 = \text{tg. } 49°25'$

The average length and breadth of the shells of the group examined by SCHMID amounted to 795.3- and 644.6 μ, which gives 51°0', as the tangent of the required angle.

So we see that the direction of the axis of the correlation picture changes extremely little. From the oldest group it increases gradually, showing irregular changes in the younger groups. An entirely analogous course may be observed as regards the average values of the length to breadth indices, see Pl. V, fig. 1. From this behaviour it may be concluded, that the ratio between the average length and -breadth of the shell may probably be regarded as a characteristic feature for the species.

As for the heterogeneous composition of the groups, it appears also in several cases from the distribution of the variates in the correlation field, Pl. V, fig. 2. Thus three centra, characterised by a maximum of variates may be distinguished in the sub-recent group. The limits between these regions were indicated approximately. Here too it appears that the transgressive variability is very great. In the same way two or three centra may be, more or less clearly, distinguished in the correlation fields of the other groups.

In this regard SCHMID's tables are especially instructive on account of the great number of measurements. Thus in my opinion his correlation tables for the length and breadth, and for the length and thickness of the shells, p. 58 and 61, show three or probably even four maxima.

So we see that according to our correlation tables, two phenotypes seem to occur in the older groups and two or three in the younger ones.

Lastly, the table given below, represents the changes in the average measurements of the shell in connection with the relative age of the groups.

Groups.	average length of shell.	average breadth of shell.
Sub-recent:	866 μ	704 μ
208 M. :	542 μ	449 μ
403 M. :	435 μ	353 μ
604 M. :	533 μ	433 μ
1007 M. :	370 μ	310 μ
1627 M. :	358 μ	306 μ

After a regular increase in size from the oldest group upwards, the 403 M. group suddenly shows a much smaller average, after which the size of the shell appears to increase again in the younger groups.

2. Internal characteristics of the shell.

In this paragraph a survey will be given of the way in which the examination of the interior of the shell was carried on, after which the various problems to which the attention was drawn will be discussed one by one.

a. On the preparation of the sections and the way of measuring the diameter of the proloculum.

The *Globorotalia* shells, generally hollow and filled with air, could not as such immediately be used for making the preparations. The air-bubbles persistently retained by the shell-chambers can be very disturbing in measuring the internal elements of the shell. To expel the air from the shells as well as possible, they were boiled under a pressure of some millimeters of mercury, with powdered kollolith, under a temperature that was slowly increased to about 180° C. In this way we generally succeeded in expelling the air, although bubbles still often occurred which, however, as long as they remained outside the protoconch did not affect its measurement unfavourably.

The shells filled with kollolith were then lain with their dorsal sides down on object-glasses, after which sufficient balsam was added to cover them entirely. Thirty specimens arranged in five rows of six could in this way be easily accomodated on one object-glass. Under the binocular microscope it was now verified whether the ventral sides of the shells were about parallel with the surface of the object-glass and, if necessary, the position of the shell was altered with a warm preparation needle.

With this the preparations were ready for the continued examination but, before this was begun, the specimens were entered into a register wherein, later, the results of the measurements and further particulars were mentioned too. The arrangement of the shells on numbered object-glasses always made it possible to find back each register-number.

Before grinding, the lengths and the breadths of the shells were measured with an ocular micrometer, under a magnification of 60 times. As one division of the ocular micrometer equalled 15.5 μ and semi-divisions could yet be estimated exactly, the measuring accuracy amounted to about 8 μ.

After ascertaining the external measurements, the shells were carefully ground, whereby their internal structure could be judged from successive horizontal sections. On further grinding the protoconch gradually appeared with its surrounding chambers, after which the determination of the diameter of the proloculum could be started.

To do so, an ocular planimeter was used, provided with a measuring scale with marks, movable by the turning of the micrometer-screw. Under a magnification of 200 times, a rotation of the micrometer-screw over one division of the micrometer-barrel, agreed with a shifting of 0,23 μ of the scale-marks.

As the proloculum appeared to be practically globular, with only a slight flattening on the place bounding the second protoconchal chamber, only the largest diameter was a ruling factor for a reliable judgment of the size of the proloculum: To ascertain this diameter as well as possible, it was measured in several parallel sections and the largest value found, was considered to be the most exact. Thus as soon as the protoconch with its surrounding chambers was clearly visible, the diameter of the proloculum was measured according to fig. 8.

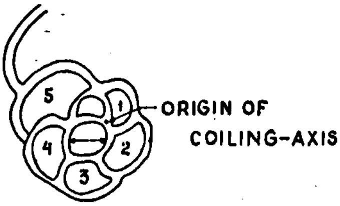

Fig. 8.

After some more grinding a new determination followed, a process of working that was repeated several times. The result was a series of determinations, generally from 3 to 5, with the greatest value somewhere in the middle.

The shape of the proloculum-sections was generally circular, or only slightly flattened locally. This made the measurements taken in this way sufficiently reliable. Therefore I did not consider it necessary, to try and reach a greater accuracy by projection and mensuration of the surfaces of the sections, the more so, because this would have been much more cumbersome.

b. Internal structure of the shell.

The shell of *Globorotalia menardii* consists of a number of ever-increasing chambers arranged according to a helicoid spiral round an axis, that we shall call the pivot or axis of coiling. This pivot has a greater or lesser thickness in the various groups and is furnished with several longitudinal channels. It originates in the left- or right-hand joining of the septum of the second protoconchal chamber to the proloculum (fig. 8), while the end of the axis of coiling is sometimes clearly visible in the centre of the ventral opening (fig. 9).

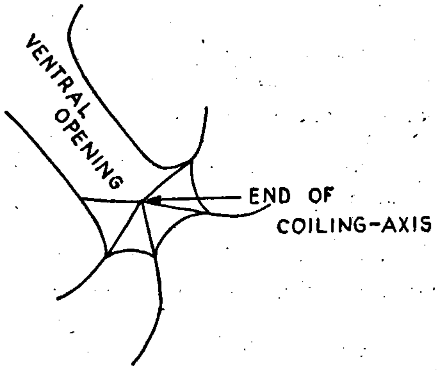

Fig. 9.

If the pivot is thick, the proloculum is situated in the top of the axis of coiling, sometimes even the entire protoconch and the first chamber. Thus the section of fig. 10 showed, after a little more grinding, these three chambers situated in the diameter of the thick axis.

The thickness of the axis of coiling appeared to show the following picture of evolution for the various groups:

Sub-recent group	:	thin axis.
208 M. „	:	thin axis.
403 M. „	:	thick axis.
604 M. „	:	thin axis (some few specimens with a thickness of the axis equal to the diameter of the prol.)
1007 M. „	:	thick axis.
1627 M. „	:	thick axis.

In some sections the stolons that form the connection between the chambers were well visible at the place where the chamber-septa join the pivot (fig. 10).

The first coil of the spiral is situated nearly in a level plane, so that a horizontal section of the protoconch shows up the adjoining chambers too (fig. 8). The number of chambers the dorsal wall of which is immediately connected with the wall of the protoconch, generally amounts to 5 (fig. 8). It was exceptional when their number amounted to 6, and in a few cases only, 4 chambers were found surrounding the protoconch. If there were 6 chambers the

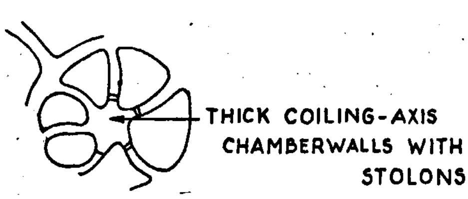

Fig. 10.

proloculum was generally small, whereas with 4 chambers it was large. This does not alter the fact that the shell with the largest diameter of the proloculum (28 μ) showed the normal number of 5 chambers surrounding the protoconch.

The trochoidal structure of the shell made it impossible to count the total number of chambers without special precautions. For some 10 cases, in which special attention was paid to this, it appeared that this number alternated between 13—19. SCHMID (35), pp. 85, 86, who ascertained the number of chambers of more specimens, found 15—23. The rather great difference can probably be accounted for by the greater average size of the shells of the group examined by him.

In the larger shell-chambers of the sub-recent group young specimens of *Globorotalia* and other foraminifera were often found. This was very exceptional in the older groups. It is remarkable that with these young specimens of *Globorotalia* some shells with a very small proloculum were found by the side of those with a normal or large proloculum.

A number of shells showed phenomena of dissolving. If, after the normally developed ventral chambers had been ground away, the protoconch ought to become visible, these chambers proved to have more or less disappeared, so that sometimes only a faint impression was visible on the shell-wall that had remained intact, and sometimes not even that. It is difficult to judge whether we have here to deal with dissolving (resorbtion) by the protoplasm, such as was found e.g. by MYERS (29) p. 399, (30) p. 360, and others, or whether diagenetic influences played a part here.

c. Direction of shell-coiling.

The direction of the coiling of the shell is determined by the situation of the point of origin of the axis of coiling, or, what amounts to the same thing, by the position of the first chamber after the two protoconchal ones, as appears from the horizontal section of the protoconch of fig. 8. For the rest this direction may of course immediately be determined as an external feature of the shell.

From this figure it may be seen, that this first chamber and the beginning of the pivot, are situated on the right side of the protoconch, by which a right-handed spiral originates. As in this section the dorsal side of the shell lies under, an orientation exactly opposed to that by which the direction of coiling is generally determined, the shell is in this case left-handed. The results of the determination of the coiling direction follow from the table below:

Sub-recent group:	pronounced	left-handed.	(1 %	right-handed)
208 M. „ :	„	right- „ .	(8 %	left „)
403 M. „ :	„	left- „ .	(1½ %	right- „)
604 M. „ :	„	left- „ .	(3 %	right- „)
1007 M. „ :	„	left- „ .	(10 %	right- „)
1627 M. „ :	„	left- „ .	(11 %	right- „)

From the table it appears that the coiling is not determined by chance, as in that case shells coiled right- and left-handed, would have to occur in equal proportions. The explanation of the phenomenon is here regarded as an unsolved problem.

d. Lack of the microspheric generation of Globorotalia menardii in the samples examined.

In connection with the investigation of the development of the proloculum of *Globorotalia,* the question whether a microspheric generation was to be found in this material by the side of a megaspheric one, was of importance. For, if this should be the case, we would have to take into account the possibility, that these microspheric specimens with initial chambers perhaps much smaller than the average size of those of the megaspheric generation, would exercise a disturbing influence on the size of that average. In that case we should have to eliminate the microspheric specimens before ascertaining the average size of the proloculum.

The results of the measurements and the examination of the internal structure of the shell furnish us, however, with sufficient data to be able to answer this question. On p. 46 we saw that as a rule five chambers surround the protoconch, it was an exception when 4 or 6 chambers were found. The shells with 6 chambers had a relatively small proloculum whereas those with 4-generally had a large one. Exceptions to this rule occurred however. So we see here the normal variation phenomenon that, by the side of the general number of 5 chambers, some specimens were found that diverged from it either in a positive or in a negative sense. As in none of the groups examined a specimen was found with more than 6 chambers surrounding the protoconch, there can in my opinion, be no question of a development that might be compared with a microspheric initial spiral.

If we now consider the proportion in size of the proloculum, we shall, if a microspheric generation is present, be justified in expecting a variation-series for this, as well as for the megaspheric generation, These series will probably show two separate non-transgressive curves, because with foraminifera the size of the average proloculum of both generations is generally entirely different. See e.g. the curve of *Nummulites variolarius* according to LISTER (26) p. 307. As far as I know, transgressive variability in this regard has never been met with with certainty, apart from SCHMID's, in my opinion, mistaken conception. Also the species *Truncatulina margaritifera* which is related to *Globorotalia menardii,* gives, according to SCHMID (35) p. 116, entirely separated frequency-curves for the size of the proloculum of the two generations. The diameter of the proloculum of the megaspheric generation alternated between 72- and 120 μ, that of the microspheric generation between 12- and 30 μ.

From the frequency-curves for the surface of the proloculum of Pl. IV it appears, that in none of them a separate curve appears that might represent the frequency-curve of the microspheric proloculum. But even if one would assume that transgressive variability cannot be considered to be excluded, still the left-hand extreme ends of the curves do not anywhere show a top that could represent the microspheric generation. The only specimen that might be considered as such is found in the curve of 208 M., indicated with 100 surface units. The proloculum-diameter amounted to 8,9 μ, but this specimen was probably not a microspheric one either, because the external measures of the shell were even below the averages found for the entire group.

Now this takes us to the last point that must be considered important for judging the presence or otherwise of a microspheric generation. For, as far as is known this generation is, with foraminifera, characterized by larger shell-measurements. If this is also the case here, this would if a microspheric generation is present, appear from the connection between the size of the proloculum and the shell measurements. In the correlation table (fig. 11) this connection has been given with regard to the sub-recent group. In such a table the lack of correlation is characterized by a regular grouping of the variates within the diamond, formed by connecting the central classes of the variation scales. Most of the variates then occur in the central part.

So we see that correlation is entirely lacking here. In the first

LENGTH OF SHELL

PROLOCULUM – DIAMETER	467–503	503–539	539–575	575–611	611–647	647–683	683–719	719–755	755–791	791–827	827–863	863–899	899–935	935–971	971–1007	1007–1043	1043–1079	1079–1115	1115–1151	1151–1187	1187–1223	1223–1259	1259–1295	1295–1331
11–12												1	1											
12–13										1														
13–14							1	1		1					2	1			1					
14–15				2			2	2	3	2	2	1	2		1		2							
15–16				1			1	1		5	3	2				1								
16–17						1	3	3	1	2	3					1								1
17–18				1							3	4	2	1	1	2	1		1		1			
18–19						2	3	1	1	2	4	7	1	2	2	1	1	1						
19–20					1		1		2	3	1	1	1		1	3	1	1		1		1		
20–21						1	2		5			1	5	1	3	3	1			1				
21–22				1			4	1	1	2	2	3	1	1	1	2	1							
22–23									2	2	1	1		2		1	1							
23–24								1	1	1	1				2			1						
24–25														1										
25–26											1													
26–27													1											
27–28																								

CLASS-INTERVAL 36 μ

Fig. 11.

Correlation table for the length of the shell and the diameter of the proloculum of the sub-recent group of *Globorotalia*.

quadrant, where we find the variates with the largest length of shell and the smallest diameter of the proloculum, the number of variates remains far below the average number per quadrant, whereas we might expect the contrary in the presence of a microspheric generation.

Finally it is of importance to point out here that in the globorotalian shell-chambers of the sub-recent group, and very seldom in the fossil groups as well, adolescent shells of *Globorotalia* occurred, among which there were a few with a small proloculum. Thus sub-recent shells were found with a proloculum-diameter of 8.4-, 9.0- and 9.1 μ while in the 208 M. group a young specimen was measured with a proloculum-diameter of 6.3 μ.

e. Frequency-curves for the size of the proloculum.

The measurements of the proloculum-diameter of the shells of *Globorotalia* yielded variation-series with two or more tops. In order to be able to compare the graphs of these series with those, found by direct measurement for the surfaces of the horizontal proloculum sections of *Cycloclypeus,* the relative size of the surface was first determined by squaring the diameter of each specimen. The frequency-curves for these surfaces are given in chronological order in Pl. IV.

The picture of evolution resulting from these curves shows several peculiarities: the average surface, amounting to 241 surface units in the group of 1627 M., gradually increases to 381 in the 604 M. group, and then gradually decreases to 352 in the sub-recent group. So we see here again a regular change in the picture of evolution wherein, however, a maximum is now passed, after which the development advances in the opposite direction.

Further it appears that the smallest proloculum-surface found is about the same for all groups, which makes the left-hand ends of the curves more or less fall within the vertical of 80 surface units. The curve of 403 M. does, however, not agree with this.

The right-hand ends of the curves act in a different way. Here the variates with the largest prolocula are found. They show a picture of evolution parallel to that of the average proloculum-surface. From the oldest group the maximum surface of the proloculum increases up to the 604 M. group and gradually decreases afterwards. That this is not caused by accidental circumstances is proved by a comparison of the 604 M. curve and that of the sub-recent group, for, although the number of variates of this youngest group is considerably larger, yet the maximum proloculum surface is smaller by a hundred surface units.

If we consider the courses of the right- and the left-hand ends of the curves in connection with each other, we see that the distance between the two, — which constitutes a measure for the dispersion —, increases from the oldest sample to a maximum in the 604 M. group and then gradually decreases.

Finally some remarks on the shape of the curves. Under all circumstances of class-division, whereby not only the place of the limits, but also the class-interval was varied, the 1627 M. curve kept its double-topped shape, wherein only the dispersion seems to be rather small.

Somewhat less constant in shape under various class-divisions, but yet sufficiently reliable as regards its double-topped shape, is the curve of 1007 M. The same can be said of the sub-recent curve that has been constructed with the greatest number of variates and shows 3 or probably 4 tops. Little can be said about the other curves, the relation between them not being very clear here.

So my impression is that the two oldest curves each show two tops, falling in twos within the same vertical line, whereas the younger curves have three or more tops which, to all probability, cannot be arranged into vertical lines.

3. Conclusions.

In the preceding paragraphs of this chapter we saw (see p. 43) that, according to the external features of the shell represented by the shell indices, the groups probably consist of a mixture of two phenotypes, the „*menardii*"- and the „*tumida*"-type. Further we found that this heterogeneous character of the groups also appears from the correlation tables for the lengths and breadths of the shells (p. 44 and Pl. V, fig. 2). According to these tables, the older groups would appear to consist of two phenotypes and the younger ones of two or three.

Seeing that, as regards the internal features of the shell, we also dispose of the frequency-curves for the proloculum-size (Pl. IV) and the heterogeneous character of the groups was apparent here too, whereby the oldest sample appeared to consist of two phenotypes and the younger ones probably of three or four, we shall now trace in how far any connection is to be found between the in- and external features mentioned, which may be derived from the correlation tables for the shell index and the size of the proloculum (tables fig. 12).

From these tables it appears that the correlation between these magnitudes is completely lacking, or in other words, that the correlative variability is very great. On closer inspection it appears however, that more or less clearly discernable centra occur in the correlation fields. These centra are characterized by a concentration of variates. Thus the 1007 M. group has an important centre that is determined by the coördinates 200 μ^2 and 17,5, while a similar centre with the same coördinates occurs in the 1627 M. group. A second centre, showing however a much less pronounced concentration of variates, occurs in the 1007 M. group and is there determined by the coördinates 360 μ^2 and 23,5. The 1627 M. group seems to lack this centre, it is here situated at 320 μ^2 and 23,5. So we see that the most important centre of concentration of variates is, in both groups, determined by an abscis of 17,5 index units, agreeing with the position of one of the tops from the frequency-curves for the length and breadth indices of Pl. V, fig. 1, while the ordinal of 200 μ^2 determines at the same time the position of the most important top from the frequency-curves for the proloculum surface of the two oldest groups.

Herewith the connection between the in- and external features has been clearly established. As we saw further that the top at 17,5 index units represents the *menardii*-type, we can also define as such the top at 200 surface units from the frequency-curve for the surface of the proloculum. From the correlation table for the 1007 M. group it also follows, that the less important *tumida*-type is represented in the frequency-curve concerned, by the tops at 23,5 index- and 360 surface units. The connection is, however, not so convincing here, because it could not be demonstrated in the correlation table of the 1627 M. group (fig. 12).

1007 M GROUP

Surface of prol. in μ^2 \ Shell-index	4–7	7–10	10–13	13–16	16–19	19–22	22–25	25–28	28–31	31–34	34–37
100–140		1		1	1			1			1
140–180		1	2		2			1	1		
180–220		1	1	3	8	6	6	3	2		
220–260		1	2	2	6	5	3	2		1	
260–300	1		2	2	5	5	4	3	1	1	
300–340			2	2	1	1	1	1			2
340–380			2		1	2	4	2	1		
380–420		1	1				1				
420–460					1	1					
460–500					1		1				
500–540							2				
540–580											
580–620						1					

1627 M GROUP

Surface of prol. in μ^2 \ Shell-index	1–4	4–7	7–10	10–13	13–16	16–19	19–22	22–25	25–28	28–31	31–34	34–37
100–140	1					2						
140–180		1	1	3	3	4	3	2				
180–220	1	1	3	4	7	10	6	3	3	1		1
220–260		1	2	3	5	6	4	5	1			
260–300			1	2	5	2	2	1	1			
300–340				2	1	2	1	4		1	1	
340–380			2	4	2	2	1					
380–420												
420–460						1		1	1			

Fig. 12.

Correlation tables for the shell-index and the surface of the proloculum of the *Globorotalia*-groups of 1007- and 1627 M. In the index scale only the decimal figures are indicated.

For the rest it may be observed that the analogous correlative picture of the other groups was indistinct, probably owing to the presence of more types with large transgressive variability, so that here it proved to be impossible to recognize special types.

In discussing the external features of the shell, the connection between the average measurements of the shell and the relative age of the groups was indicated on p. 44 in the form of a table. By comparing these figures with the picture of evolution of the axis of coiling given on p. 46, a remarkable connection is established between these two features, as appears from the table below.

Groups.	Average length of shell.	Habitus of the axis.
sub-recent:	866 μ	thin.
208 M. :	542 μ	thin.
403 M. :	435 μ	thick.
604 M. :	533 μ	thin (some few sp. with axis slightly thicker).
1007 M. :	370 μ	thick.
1627 M. :	358 μ	thick.

We see that the increase of the size of the shell from the oldest group up to that of 604 M., is accompanied by a reduction of the thickness of the axis of coiling. After a considerable decrease in size of the shell accompanied by a greater thickness of the axis in the 403 M. group, the same development follows for the younger groups, viz. increase of the size of the shell and reduction of the thickness of the pivot. From this we may conclude that, in general, the groups with large shells will be characterized by a thin axis of coiling and groups with small shells by a thick one. With this it has, however, not been proved that this connection also exists for the shells of one particular group.

On p. 47 the direction of coiling of the shell was discussed, and as we have obtained some insight in the evolution of some other features of the shell, external as well as internal, we ought to ask ourselves if, perhaps, some connection exists between these and the direction of coiling. I have tried to trace this connection as regards the size of the proloculum as well as the shell-indices, but in both cases with a negative result, so that this has not taken us any nearer to an explanation of the problem of the direction of the coiling, either.

I want yet to make some observations in consequence of what was said on pp. 48 and 49 about the lack of the microspheric generation in the samples of *Globorotalia* examined by me, because it is there that I am at variance with SCHMID's opinion (35). By analysing the frequency-curves for the length of the shell in connection with the measurements of the diameter of the proloculum, SCHMID was induced to distinguish a microspheric as well as a megaspheric generation of *G. menardii* in his material originating from the Fufa layers of Ceram.

I will not go further into the peculiar shape of his frequency-curve for the length of the shell which, regarded in itself, cannot of course, give any certainty about the occurrence or otherwise of a microspheric generation. We are specially interested in the results of his „anatomical" examination of the shells. Of the 37 shells examined, the character of 8 could not be ascertained. Of the remaining 29, 19 were determined as megaspheric and 10 as microspheric, so a proportion of 2 : 1. As distinctive features he used: the size of the proloculum, the total number of chambers building up the shell, the shape of the so-called unrolled spiral and the connection between the measurements of the shell and the size of the proloculum.

The diameter of the proloculum of the 10 microspheric specimens ranged from 7,5- to 20 μ, that of the 19 megaspheric specimens from 18,8- to 30 μ. So the two series of variation partly cover each other.

The total number of chambers ranged from 19 to 23 for the 10 microspheric- and from 15 to 19 for the 19 megaspheric specimens. That this number is generally larger for specimens with a small proloculum than for those with a large one, is entirely in accordance with our own opinion.

The six shells for which the unrolled spiral was determined (fig. 3 p. 88) form two groups. Between these two there is an open space, of which we can, however, scarcely believe that, on examination of more specimens, it would not be occupied by other curves.

The connection between the measurements of the shell and the diameter of the proloculum would have to appear from his table 9 on p. 86 from two megaspheric and one microspheric specimen, that form the ends of the graph and so possess respectively the smallest and the largest shell-measurements. The latter has, moreover, the for a microspheric specimen relatively very large diameter of 20 μ.

These results of SCHMID's examination are, in my opinion, rather unconvincing as a proof of the occurrence of a microspheric generation in his material, the number of shells „anatomically" examined is too small for this.

CHAPTER IV.

CONSIDERATIONS IN CONNECTION WITH THE RESULTS OBTAINED.

The examination as it was described in the preceding chapters has had the result, that for three foraminifera an albeit limited picture was obtained of the development of some features. The size of the proloculum was traced for each of these foraminifera, and it is now worth the trouble, to review here once more the results of this examination in their mutual connection.

1. On the evolution of the average size of the proloculum.

As regards the groups of *Cycloclypeus* cf. *guembelianus* we found that the average size of the proloculum increased, with decrease of their geological age. So, the younger the group examined, the larger the proloculum appeared to be.

The samples of *Lepidocyclina tournoueri* examined, showed a reversed evolutional picture: a decrease in geological age is here accompanied by a decrease of the average size of the proloculum.

Finally the series of samples of *Globorotalia menardii* showed a development wherein the two converse pictures of evolution — as we found them for *Cycloclypeus* and *Lepidocyclina* — were united. Starting from the oldest sample, the average size of the proloculum first increased, and then after having passed a maximum, it decreased.

So we can draw up the following hypothesis, which was confirmed in every way by the results of the examination:

The foraminiferal proloculum goes through a development that is characterized by a gradual increase of the average volume, on which follows, after a maximum has been reached, a period wherein the reversed evolutional picture is passed through, during which the average volume is gradually reduced.

In such a development, whereby in imitation of SWINNERTON (44), p. 391, we can speak of a progressive- (anagenesis) and a retrogressive period (catagenesis), a climax is passed that is characterized by a maximal size of the average volume of the proloculum.

According to this view the proloculum of *Cycloclypeus* is still in the progressive period of its development, for we know that the recent forms have the largest prolocula, whereas *Lepidocyclina tournoueri* shows a decrease of the average size of the proloculum during the

Oligocene and Lower-Miocene, which points to its being in the retrogressive stage of its development, a period that ends in the Miocene with the extinction of the genus *Lepidocyclina*.

2. On the meaning of the frequency-curves.

If we measure the same feature of a great number of individuals of a species belonging to one group, we generally find that the measurements of one particular size-class occur very generally, and that diverging measurements occur more seldom as the divergences are greater. This is QUETELET's or GALTON's law. By setting out the results of the measurements and the number of times that a particular result was found, as coördinates in a system of axes, the frequency-curve for that feature is obtained.

The graphic representation originating in that way shows, in the simplest case, a symmetrical curve with one top, of which the abscis determines the average of the measurements and the ordinal the frequency of the measurements of the central class. This curve must, according to QUETELET, agree with GAUSS' fault-curve and be regarded as the ideal frequency-curve, with which most variation series occurring in biological practice, can be compared.

Now it is remarkable that all our frequency-curves for the size of the foraminiferal proloculum and, at the same time, those for the heterosteginoidal apparatus of *Cycloclypeus,* show a shape entirely different from GAUSS' fault-curve. Instead of one, they always show two or more tops, as appears from Pl. II and IV. This is also the case with LISTER's frequency-curve for the diameter of the proloculum of *Nummulites variolarius* (27) p. 307 and *Discorbina globularis* (26) p. 124, and HOFKER's curve for *Eponides repandus* (23) p. 89.

Investigations of the meaning of such many-topped curves, of which SIRKS in his „Handboek der Algemeene Erfelijkheidsleer" gives some examples (pp. 55 ff), brought to light the fact that there is a principal difference between the specimens belonging to various tops. This disparity originates in a difference in hereditary disposition (genotype).

Let us again consider the mutual connection between some results of the examination:

In the *Globorotalia* samples a microspheric generation is lacking. It seems probable, that this generation yet fulfills its part in the life-cycle of this foraminifer, but for some unknown reason it was not present in my material.

The curves for the megaspheric generation of the two oldest groups, which are still in the progressive period of development, show as regards the size of the proloculum, two tops, whereas the younger groups already situated in the retrogressive period, show three or four tops (Pl. IV).

Furthermore we found, as regards the measurements of the shell, two types for the older groups and two or three for the younger ones (Pl. V, fig. 2). These two types correspond with the *menardii-* and *tumida*-types and could be identified with the two tops in the curves for the size of the proloculum with the aid of the correlation-tables (fig. 12).

So we come to the conclusion, that the two older groups of *Globorotalia* consist of two types as regards the megaspheric generation. This composition of the „progressive" globorotalian-groups reminds us very strongly of the phenomenon HOFKER describes as „trimorphism" (22 and 23).

How are we to understand these tops? Are they in favour of two closely connected but genotypically different species, ore have we here to deal with the A_1- and A_2-forms of one species, in the sense meant by HOFKER?

Such a question already confronted BRADY, and was also answered, now in this and now in that sense, by the investigators coming after him, who regarded the *tumida*- and *menardii*-types either as varieties of the same species, or as belonging to different species. See p. 40 and lit. (35), pp. 52 and 53.

In my opinion only an examination of the life-cycle in living material, in the way in which MYERS did this with regard to *Patellina corrugata* (30) and *Spirillina vivipara* (31), may bring a definite solution here.

Moreover we may not attach too great a value to the reliability of the curves, in connection with the relatively small number of specimens measured, which applies as well to the curves discussed below.

However, I ought to point out here, that the frequency-curves for the size of the proloculum of the three youngest groups of *Globorotalia* (Pl. IV), which are already situated within the retrogressive period of their development, show more than two tops. Does the retrogressive process of development takes another course than the progressive one? We do not know with certainty, but it seems important to me, to point out the possibility.

The more so, as this trend of thought seems to be supported by the fact that the curves for the heterosteginoidal apparatus of *Cycloclypeus* (Pl. II, fig. 1), a feature which too is in a retrogressive stage of evolution, also show more than two tops.

And then, there is still another circumstance which should be stated here, viz. the possibility that in the retrogressive stages of evolution, the tops in the frequency-curves do not, as is probably the case in the progressive period of development, represent „constant types" (see pp. 22, 51 and 58, Pl. II and IV).

In mentioning these facts no explanation of the many-topped curves is given. However, it seems useful to me to point out these mutual connections. In future researches special attention should be given to this puzzling phenomenon.

The picture of evolution for the size of the proloculum furnished by the *Cycloclypeus* material consisted of three types, alternating in such a way, that no more than two of these types occurred in a *Cycloclypeus* sample of a certain age (Pl. II, fig. 2). By the side of these two types we found a third, which proved to occur very rarely and was characterised by a much smaller proloculum and an initial-spiral with a large number (8—14) of operculinoidal chambers.

So we reach the conclusion that, as regards the size of the proloculum, we can distinguish for each sample of a certain age a megaspheric and a microspheric generation, of which the former consists of two types.

As the rim of the greater part of the shells proved to be broken, it was not possible to determine the shell-measurements accurately, so that it could not be ascertained whether three types could also be distinguished for these measurements. The only fact stated in this connection was the slightly larger size of the microspheric shells.

Furthermore, it is of importance to remind the reader that the prolocula of all the *Cycloclypei* examined, proved to be in the progressive stage of their development.

Again, as in the two older „progressive groups" of *Globorotalia*, we meet with two types for the megaspheric generation in each of the *Cycloclypeus* groups. Again this reminds us HOFKER's trimorphism. And again we are confronted with the question whether we are studying either A_1- and A_2-forms in the sense of HOFKER, or two genotypically different although closely allied species. If the tops in the frequency-curves should characterise various „species" or series of evolution, we may yet observe, that in this case there ought necessarily to be a clear resemblance between the evolutional pictures of the different features, meaning that the various species that could be distinguished in one picture of evolution, would of course also have to appear in the other ones. In that case we might expect two tops, or two groups of tops, in each frequency-curve of the heterosteginoidal septa. It now appears that this is not at all the case with *Cycloclypeus*. The „species" that we might distinguish in the pictures of the evolution of the proloculum, cannot be found back in the analogous pictures of the number of heterosteginoidal septa.

These considerations support the idea that the two types which we could discern among the megaspheric prolocula of each *Cycloclypeus* group, must not be considered as different species. However, this does not mean that it necessarily supports the biological explanation given by HOFKER for his A_1- and A_2-forms. Indeed, we notice the tops, — in the progressive pictures of evolution for the size of the proloculum —, occurring with some constancy in vertical rows (Pl. II, fig. 2 and Pl. IV). It means that this feature is constant in a certain interval of time. In Pl. II, fig. 2 the top of 8¼ in the Ronda group, also appears in the groups of Villajoyosa and Jaen. However, in the curve of Villajoyosa a new top appears and an older one (that of 5¼) has disappeared.

In my opinion the remarkable connection that seems to exist between the sizes of the prolocula of the two rows of tops, is also in favour of our opinion about the constancy of the type. For, if we calculate the solid contents of the proloculum from the measured surface of the equatorial sections, by multiplication with the root of this surface, we find that this amounts to 12.0 and 23.7 volume units. So the younger row of tops has about double the proloculum volume as that of the older series.

Now it seems hardly possible to me, to correlate the constancy as well as the shifting of tops in our curves just mentioned, with A_1- and A_2-forms in the life-cycle of foraminifera as suggested by HOFKER in his theory of trimorphism. I must avow that I cannot give a good biological explanation for the interesting phenomena discussed here. Meanwhile the valuable investigations of MYERS' on the life-cycle in foraminifera show the complexity of the problem. Analogous biological researches by the side of detailed paleontological and stratigraphical i.e. phylogenetic studies in many other foraminiferal genera, may once provide us with sufficient data, to obtain a clear insight in this intricate problem.

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