

Geological age determinations on a biometrical basis (comparison of eight parameters)

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RIASSUNTO — Allo scopo di confrontare otto diversi metodi di determinazione di età su base biometrica, sono stati presi in esame due campioni del Miocene dell'Indonesia. Entrambi contengono numerosi esemplari di *Lepidocyclus* (con nucleococche tipo nephro- e trybliolepidina), *Miogyropsina* (tipo bispirale: con due spirali attorno alla nucleococca) e *Cycloclypeus sensu lato*. Il campione più vecchio proviene dall'isola di Larat (Molucche), mentre quello più giovane dall'isola di Madura (NE di Giava). Sono stati misurati due parametri in *Lepidocyclus*, tre in *Miogyropsina* e tre in *Cycloclypeus*.

ABSTRACT — With the aim to compare eight different methods of age determinations on a biometrical basis, two Miocene samples from Indonesia were examined. Both were rich in specimens of *Lepidocyclus* (with nucleocochs of the nephro and trybliolepidine type), *Miogyropsina* (bispiral type: two spirals around the protoconch) and *Cycloclypeus sensu lato*. The oldest sample is from the isle of Larat (Moluccas), the youngest from the isle of Madura (N.E. of Java). Of *Lepidocyclus*, *Miogyropsina* and *Cycloclypeus* two, three and three parameters were measured, respectively.

INTRODUCTION

In many cases geological age determinations by traditional methods encounter serious objections. Guide fossils are generally not reliable. They are only useful when one can be certain, that there is no disagreement amongst paleontologists about species determinations. As long as there are « lumpers » and « splitters », however, this is a pious wish.

Age determinations on the basis of associations of genera and/or species have still another drawback. One has to be sure that all genera and species react in the same way to a change of environment, which is hardly probable.

It is no wonder that because of these difficulties a more objective method of age determination comes into fashion. Especially micropaleontologists are in favour of the biometrical method. For in this case a particular evolutionary phase is designated by a numerical value instead of by the name of a species or subspecies.

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Very grateful acknowledgments are due to Mr. J. A. Postuma, at Rijswijk, for examining the planktonic foraminifera from the sample of Larat.

THE MATERIAL

Examined are the foraminifera genera *Lepidocyclina* (with nucleococonchs of the nephro- and trybliolepidine type), *Miogypsina* (bispiral type: two spirals around the protoconch) and *Cyclocypeus* sensu lato, occurring in two samples from Indonesia:

a) A sample from a locality at the isle of Madura (N.E. of Java): Kombangan, Bg 312 (Van der Vlerk & Postuma, 1967, table I). This sample contains the following foraminifera:

Lepidocyclina angulosa Provale
Lepidocyclina martini (Schlumberger)
Lepidocyclina rutenii Van der Vlerk
Miogypsina indonesiensis Drooger
Cyclocypeus indopacificus Tan

According to Adams (1970, table) the presence of *Lepidocyclina martini* indicates a Lower Tertiary f (Middle Miocene) age. It should be emphasized, however, that this age determination is based on the species determination of the present authors. It is quite possible that other paleontologists classify this species with *Lepidocyclina rutenii*, in which case an Upper Tertiary f (lower part of the Upper Miocene) age is more probable.

After an examination of the planktonic fauna of the Kombangan sample, Postuma

(Van der Vlerk & Postuma, 1967, table I) placed this sample in the *Globigerinatella insueta* zone.

b) The second sample is from the stratum typicum of the genus *Miogypsina*: the isle of Larat (Moluccas). It contains the following larger foraminifera (Van der Vlerk, 1924, 1966; Drooger, 1953; Tan, 1932):

Lepidocyclina parva Oppenoorth
Miogypsina borneënsis Drooger
Miogypsina dehaartii (Van der Vlerk)
Cyclocypeus eidae Tan

Consulting the table of C. G. Adams' (1970) « Reconstruction of the East Indian Letter Classification of the Tertiary » this sample belongs to the Upper Tertiary e (Lower Miocene). This age determination is in agreement with the age determination of Mr. J. A. Postuma, who kindly examined the planktonic fauna. He concluded, that the sample ought to be placed at the boundary of the *Globorotalia kugleri* and the *Catapsydrax dissimilis* zone.

MEASUREMENTS

Measurements, necessary for a biometrical method of research, were made of various properties, here called « parameters », observable in horizontal thin sections of the juvenile stages of megalospheric specimens of the genera *Lepidocyclina* (with nucleococonchs of the nephro- and trybliolepidine type), *Miogypsina* (bispiral type: two spirals around the protoconch) and *Cyclocypeus* sensu lato.

At least some dozens of thin sections for each parameter had to be determined, carefully selected so as to cut exactly the equatorial plane of the sectioned specimens.

Most of the measurements were made on a large scale (400×) camera lucida drawing of the actual specimens. Angles were measured with a goniometer. Linear measurements of curved lines were obtained with a curvimeter. The results of the measurements

are given both by their arithmetic means and in the form of histograms.

PARAMETER A OF LEPIDOCYCLINA

Parameter A indicates the degree to which the deutoconch encloses the protoconch (fig. 1). It is therefore also called the «grade of enclosure». In order to determine this parameter all that needs to be done is to measure the inner side of the common wall between proto- and deutoconch (in fig. 1, c.w.) as well as the total circumference of the protoconch, also measured at the inner side (in fig. 1, c.w. + b). The ratio between these two measurements is expressed in a percentage:

$$\text{parameter A} = \frac{\text{c.w.}}{\text{c.w.} + b} \times 100 = \dots\%$$

As said above *Lepidocyclina*'s are only measured when the specimens have a nucleoconch of the nephro- or tryblielepidine type. Specimens with for instance a trilocular nucleoconch and *Lepidocyclina radiata* sensu Cole (Cole, 1963) were excluded.

Former investigations (Van der Vlerk, 1959, 1963, 1966, 1968; Van der Vlerk &

Postuma, 1967; Van der Vlerk & Gloor, 1968; Coleman, 1963; Lange, 1968; Matsumaru, 1971; Pieroni 1965; Serpagli & Sirotti, 1967) have shown that the nucleoconch changes, as one moves from older to younger Tertiary strata, gradually and persistently from an isolepidine- via a nephrolepidine- to a tryblielepidine type (fig. 2).

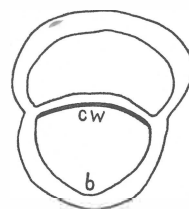


Fig. 1 - Horizontal section of the nucleoconch of a *Lepidocyclina* (nephrolepidine type. Para-

$$\text{meter A} = \frac{\text{c. w.}}{\text{c.w.} + b} \times 100 = \dots\%$$

In table 1 the first mentioned four localities are from a section at the isle of Madura, Indonesia. *Lepidocyclina*'s from Astrup were sampled at a locality which lies only somewhat above the type locality of the Chattian (Cassel). From some samples, moreover, the planktonic foraminifera are examined (Van der Vlerk & Postuma, 1967; Vaughan & Cole, 1941).

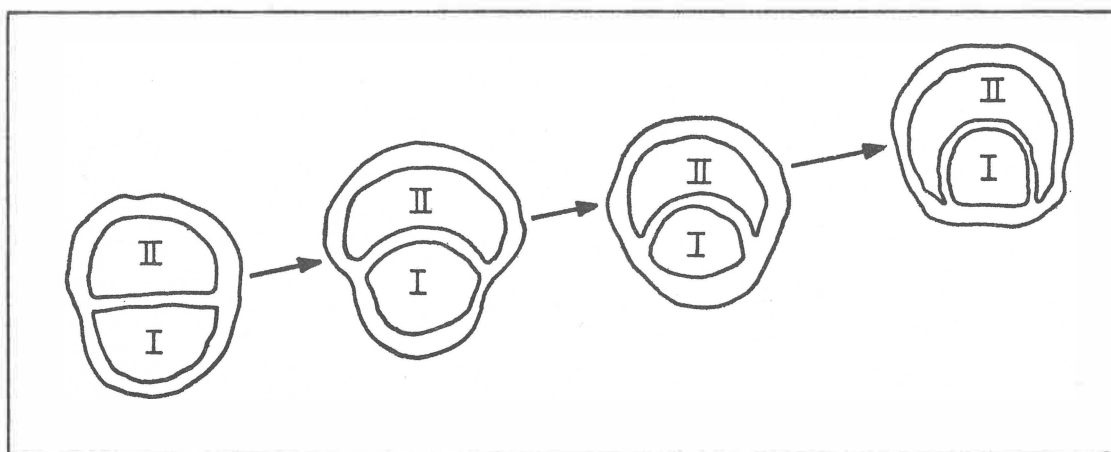


Fig. 2 - Evolutionary trend of parameter A of *Lepidocyclina*.

TABLE 1 - Biometrical age determinations with the aid of parameter A of *Lepidocyclina*. Correlations of the classifications after Bolli (1965), Adams (1970), Serpagli & Sirotti (1967) and Van der Vlerk & Postuma (1967).

Locality	Aver. A	Planktonic zones	Letter classif.	Standard classif.
K. Ambunten-Mandala, Be 1421-1431, Madura.	64.8%	<i>Globorotalia</i>	Upp. (?) Tert. f	Late (?) Mioc.
Kombangan, Bg 295-297, Madura.	58.5%	<i>barisanensis</i>	Lower	
Kombangan, Bg 312-G 113, Madura.	56.7%	<i>Globigerinatella</i>		Middle Miocene
Kombangan, Bg 333, Madura.	52.3%	<i>insueta</i>	Tertiary f	
		<i>Catapsydrax</i>		
		<i>stainforthi</i>		
Cellamonte, near Turin, N. Italy.	48.8%	<i>Catapsydrax</i>		Burdigalian
Gr. Nid-Sausset, W. of Marseille, France.	46.2%	<i>dissimilis</i>		Aquitanian
Arenarie M. Cervarola, N. Italy.	45.9%	<i>Globorotalia</i>		
Astrup, near Osnabrück, N.W. Germany.	42.6%	<i>kugleri</i>		Chattian

PARAMETER D.C. OF LEPIDOCYCLINA

Parameter d.c. (degree of curvature) indicates the degree of curvature of the wall between the proto- and deutoconch, measured at the inner side of the protoconch (fig. 3). This degree of curvature is defined by the percent ratio between height and breadth (fig. 3, h and br):

$$\text{d.c.} = \frac{h}{br} \times 100 = \dots\%$$

The evolutionary trend of this parameter is schematically shown in Fig. 4.

In table 2 the samples from Kombangan, Krاندji and Mlangi were taken from a section at Madura.

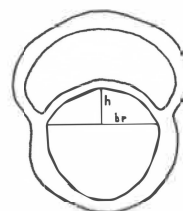


Fig. 3 - Horizontal section of the nucleoconch (nephrolepidine type) of a *Lepidocyclina*.

$$\text{Parameter d.c.} = \frac{h}{br} \times 100 = \dots\%$$

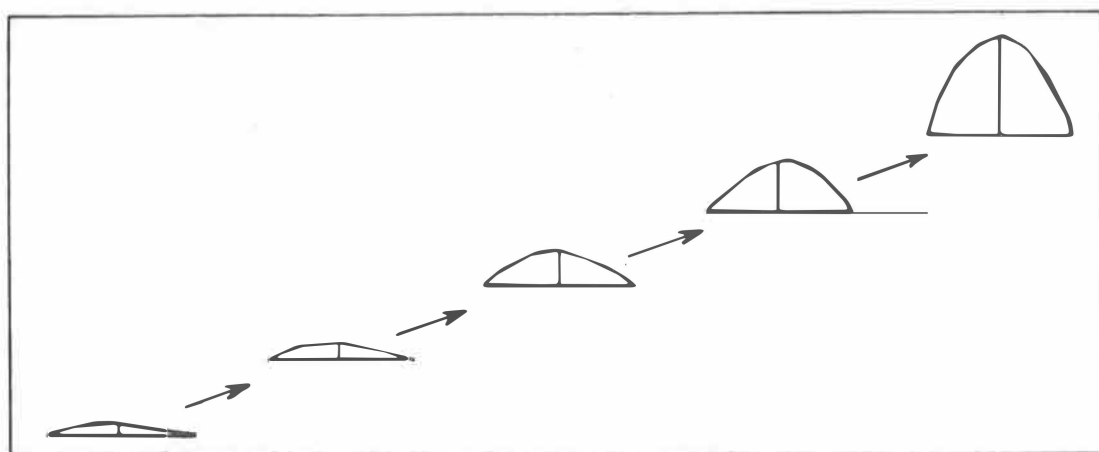


Fig. 4 - Evolutionary trend of parameter d.c. of *Lepidocyclina*.

TABLE 2 - Biometrical age determinations with the aid of parameter d.c. of *Lepidocyclina*. Correlations of the classifications after Bolli (1965), Adams (1970) and Van der Vlerk (1968).

Locality	Aver. d.c.	Planktonic zones	Letter classif.	Standard classif.
Kombangan, Bg 296, Madura.	63.0%	<i>Globorotalia barisanensis</i>	Lower Tertiary f	Middle Miocene
Kombangan, Bg 312, Madura.	55.3%	<i>Globigerinatella</i>		
Kombangan, Bg 333.	49.9%	<i>insueta</i>		
		<i>Catapsydrax stainforthi</i>		
Cellamonte, near Turin, N. Italy.	32.2%	<i>Catapsydrax dissimilis</i>		Burdigalian
Grand Nid-Sausset, W. of Marseille, France.	30.1%	<i>Globorotalia</i>		Aquitanian
Krandji, h 266, Madura.	26.4%	<i>kugleri</i>		Upp. Tertiary e
Astrup, near Osnabrück, N.W. Germany.	24.1%		Chattian	
Krandji, h 280, Madura.	11.5%	<i>Globigerina ciperoensis ciperoensis</i>	Lower Tertiary e	Middle and Early Oligocene
Mlangi, h 494, Madura.	10.0%	<i>Globorotalia opima opima</i>		
Cipero formation, Trinidad.	5.0%	<i>Globigerina ampliapertura</i>		

The planktonic foraminifera have been examined by Postuma (Van der Vlerk & Postuma, 1967) and Vaughan & Cole (1941).

PARAMETER V OF MIOGYPSINA

Parameter V, introduced by Drooger (1952) expresses the degree of symmetry of the two spirals around the protoconch (fig. 5). The small spiral starts from the smaller primary auxiliary chamber (fig. 5, PA II). The large spiral starts from the larger primary auxiliary chamber (fig. 5, PA I). The mean values vary from 0 to 100%. When the spirals have the same length, the angle $\beta = 2\alpha$ (fig. 5). Thus the parameter

$$V = 200 \frac{\alpha}{\beta} = 200 \frac{\alpha}{2\alpha} = 100\%.$$

When the spiral, starting from the smaller primary auxiliary chamber (PA II in fig. 5) is absent,

$$\text{parameter V has a value of } 200 \frac{\alpha}{\beta} = 0\%.$$

In figure 6 the evolutionary trend of parameter V is given. Because both samples examined (Kombangan, Bg 312 and Larat)

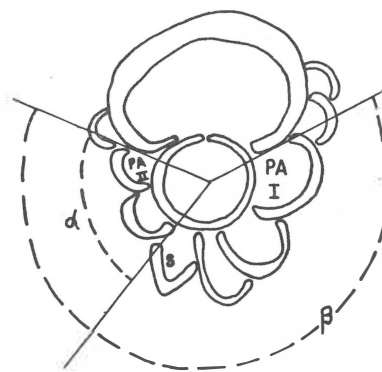


Fig. 5 - Horizontal section of the nucleoconch of a bispiral *Miogypsina*.

$$\text{Parameter V} = 200 \frac{\alpha}{\beta} = \dots, \%$$

have two spirals around the protoconch, figure 6 shows only the trend of the so-called bispiral *Miogypsina*'s.

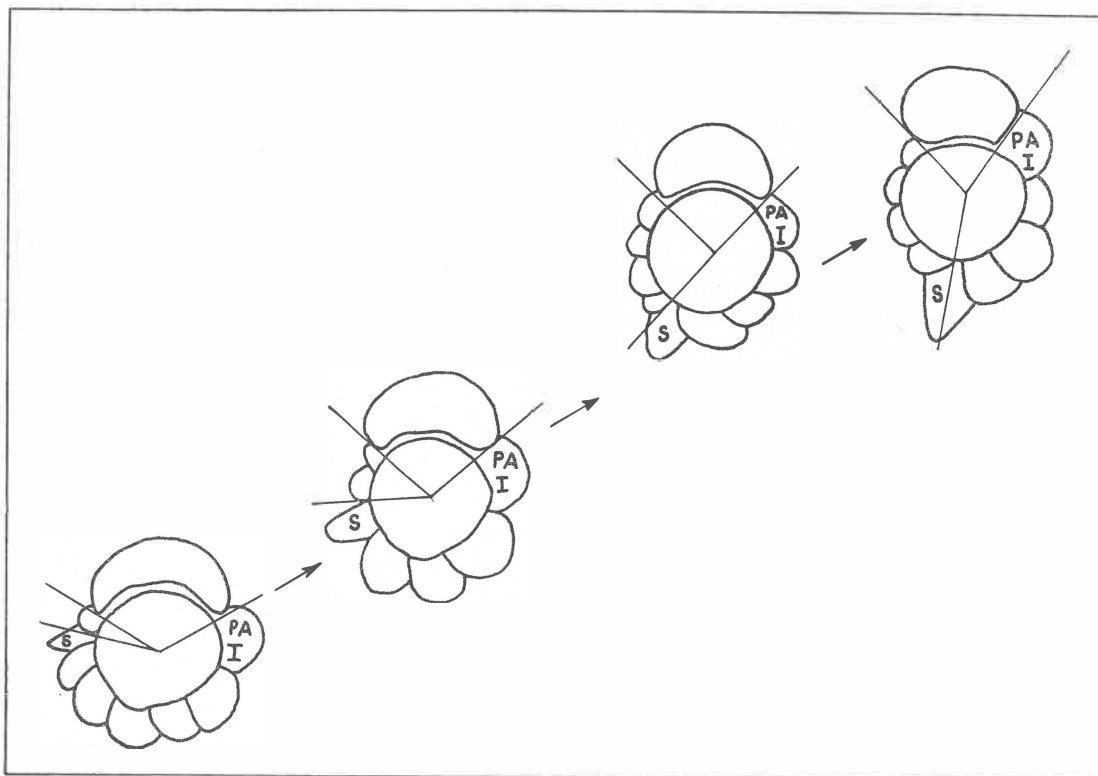


Fig. 6 - Evolutionary trend of parameter V of a bispiral *Miogypsina*.

TABLE 3 - Biometrical age determinations with the aid of parameter V of *Miogypsina*. Correlations of the classifications after Bolli (1965) and Adams (1970).

Locality	Aver. V	Planktonic zones	Letter classif.	Standard classif.
Kombangan, Bg 295-297, Madura	81.2%	<i>Globorotalia barisanensis</i>	Lower Tertiary f	Middle Miocene
		<i>Globigerinatella insueta</i>		
Tanah Poteh Olor, Ct 2679 A, Madura	41,0%	<i>Catapsydrax stainforthi</i>	Upper	
Prupuh, h 6-7, Madura	38.3%	<i>Catapsydrax</i>	Tertiary e	
Cellamonte, near Turin, N. Italy	31.0%	<i>dissimilis</i>		
Grand Nid-Sausset, W. of Marseille, France	11.0%	<i>Catapsydrax kugleri</i>		Burdigalian
				Aquitanian

In table 3 the samples from Kombangan, Tanah Poteh Olor and Prupuh are taken from a section at Madura (Van der Vlerk & Postuma, 1967). The values of parameter V from *Miogypsina* of Cellamonte and Grand Nid-Sausset were determined by the present authors.

PARAMETER V¹ OF MIOGYPSINA

Parameter V¹ gives the percentage ratio between the length of the small and the large spiral around the protoconch of a bispiral *Miogypsina* (fig. 7). The measurements

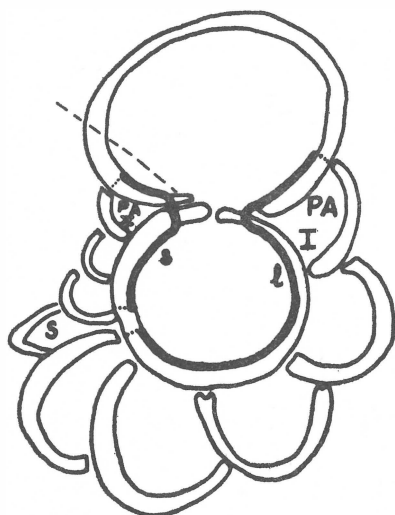


Fig. 7 - Horizontal section of the nucleoconch of a bispiral *Miogypsina*.

$$\text{Parameter V}^1 = \frac{s}{l} \times 100 = \dots, \%$$

are taken at the inner side of the nucleoconch. It occurs sometimes, that both primary auxiliary chambers are equal in size, in which case it is difficult to define which is the primary and which the secondary auxiliary chamber. Experience has shown that the chamber at the side where the wall of the deuteroconch clearly curves inward may be considered as the secondary auxiliary chamber (PA II). In the section the deuteroconch is connected with this PA II by a

small tubular passage. Where the wall of the deuteroconch is only slightly curved lies the primary auxiliary chamber (PA I). The deuteroconch and this PA I are connected by a broad stolo passage.

Parameter V¹ is introduced here for the first time. For comparisons the data at disposal are still too scarce.

PARAMETER γ OF MIOGYPSINA

Parameter γ is the angle between the apical frontal line and the line connecting the centres of protoconch (I) and deuteroconch (II) (fig. 8). This parameter was introduced by Drooger (1952). Considering bispiral *Miogypsina*'s only, Drooger gives γ a negative value when the line connecting the two centres (called by Amato & Drooger, 1969, the medio-embryonic line) is situated in the direction of the secondary auxiliary

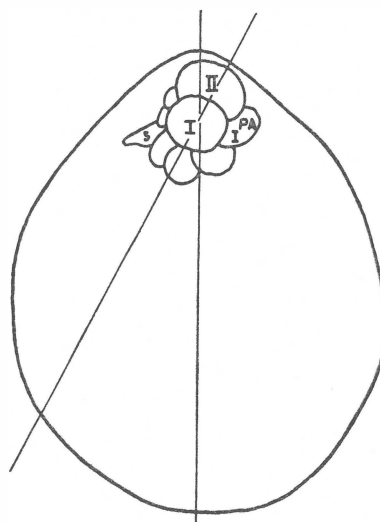


Fig. 8 - Horizontal section of the nucleoconch of a bispiral *Miogypsina*. Parameter γ = angle between the apical frontal line and the line connecting the centres of proto-and deuteroconch.

chamber (PA II). When the medio-embryonic line is situated in the direction of the primary auxiliary chamber (PA I) parameter γ is given a positive value (fig. 8 and fig. 9).

Figure 9 gives the evolutionary trend of the parameter, at least for bispiral *Miogypsina's*.

In table 4 the samples from Kombangan, Tanah Poteh Olor and Prupuh were taken from a section at Madura.

PARAMETER PC OF CYCLOCLYPEUS

Parameter PC indicates the number of p(re)cyclic or nepionic chambers of *Cycloclypeus* (sensu Mac Gillavry, 1965, i.e. including the proto-and deuterocoench).

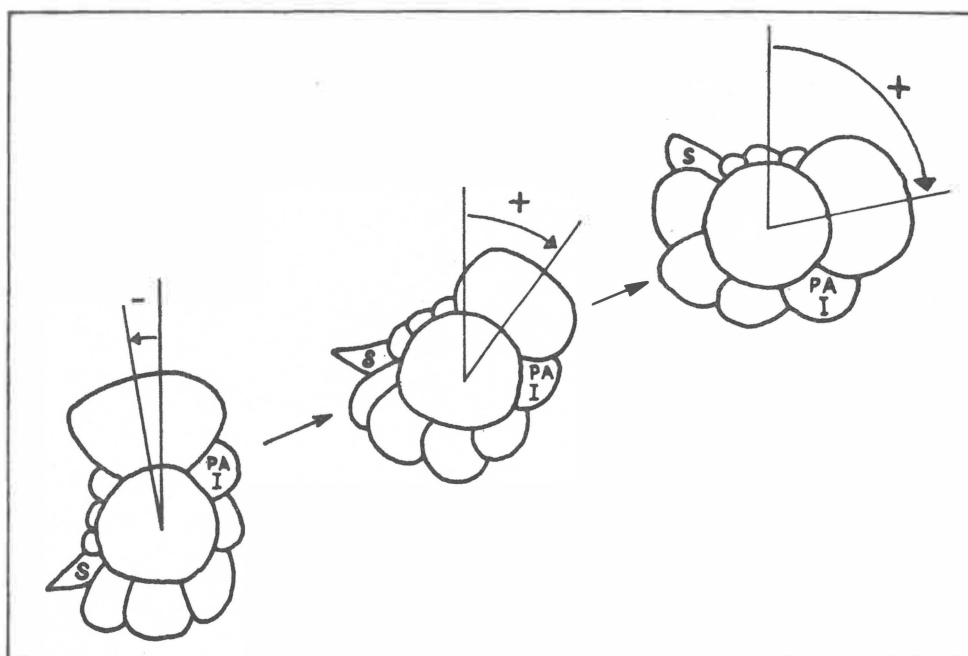


Fig. 9 - Evolutionary trend of parameter γ of a bispiral *Miogypsina*.

TABLE 4 - Biometrical age determinations with the aid of parameter γ of *Miogypsina*. Correlations of the classifications after Bolli (1965) and Adams (1970).

Locality	Aver. γ	Planktonic zones	Letter classif.	Standard classif.
Kombangan, 295-297, Madura	+7.9°	<i>Globorotalia</i> <i>barisanensis</i>	Lower	Middle
		<i>Globigerinatella</i> <i>insueta</i>	Tertiary f	Miocene
Tanah Poteh Olor, Ct 2679 A, Madura	+24.8°	<i>Catapsydrax</i> <i>stainforthi</i>	Upper	
Prupuh, h 6-7, Madura	+29.7°	<i>Catapsydrax</i> <i>dissimilis</i>	Tertiary e	
Cellamonte, near Turin, N. Italy	+25.0°			Burdigalian
Gr. Nid-Sausset, W. of Marseille, France	-89.0°	<i>Globorotalia</i> <i>kugleri</i>		Aquitanian

The number of nepionic chambers reduces progressively from the Lower Oligocene to Recent (fig. 10). This decrease has been studied in detail by Tan Sin Hok (1932). In each population Tan has found particular dominating nepionic mutants. During evolution mutants with larger numbers of nepionic chambers become successively extinct, while mutants with smaller numbers of nepionic chambers appear. This evolutionary decrease in the number of nepionic chambers has, according to Tan, taken place «autonomically and saltatorily». Later authors (Cosijn, 1938; Drooger, 1955) have questioned the existence of Tan's nepionic mutants, c.q. elementary species, and therefore his conception of saltatory decrease.

In comparing the histograms of Larat and Kombangan, Bg 312 (table 8) with the frequency distributions of Tan's populations, some difficulties arise

1) The maxima in the frequency distributions are generally not as distinct as in Tan's curves and variation statistics (Tan, 1932, tables III & IV), as has been shown by Cosijn (1938) and Drooger (1955). Likewise the histogram of Larat does not show polymodality as opposed to the frequency curves of Tan's *Cycloclypeus eidae* populations: S. Sumbal, S. Sekuro.

2) The population of Kombangan, Bg 312 contains rather numerous specimens with a relatively large number of nepionic chambers (11-23). These individuals probably represent a very primitive form of *Cycloclypeus carpenteri* and resemble somewhat *Cycloclypeus victoriensis*. The latter species was considered by Tan to represent a primitive *Cycloclypeus indopacificus*. The forms from Kombangan, Bg 312 were classified with *Cycloclypeus carpenteri* on the

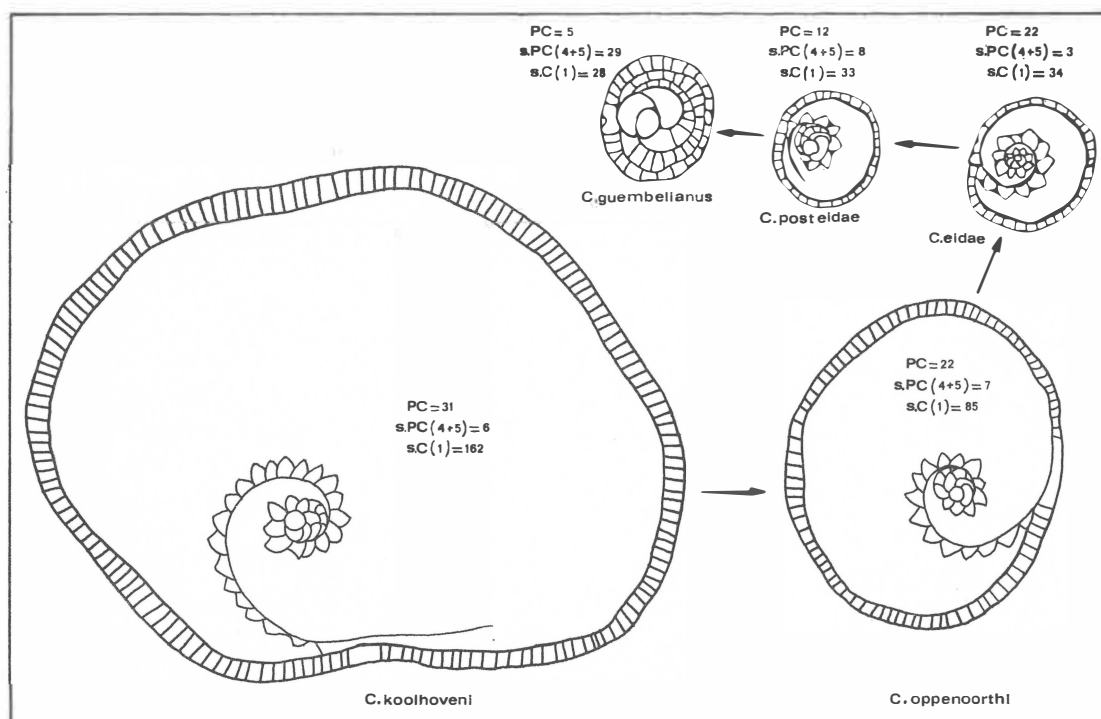


Fig. 10 - The three evolutionary trends of *Cycloclypeus*.

(PC - values of *C. posteldae*, *C. eidae*, *C. oppenoortbi* and *C. koolboveni* read: 13, 23, 23 and 31, respectively).

ground of the number of secondary chamberlets of the first neanic chamber (O'Herne, in press; see also parameter sC (1)) and on the ground of the age, which is obviously too young for *Cycloclypeus eidae*.

The frequency distribution of Kombangan, Bg 312 agrees most with Tan's frequency curves of Ngampel, K. Lawak and K. Goeng which are Vindobonian in age. Larat agrees most with Tan's S. Sumbal and S. Sekuro, without showing the pronounced polymodality of the latter.

Since the frequency distributions cannot be simply compared, for reasons mentioned above, only the predominating nepionic mutants of Tan's populations are given in table 5.

CYCLOCLYPEUS PARAMETER s.PC (4+5)

Parameter s.PC (4+5) concerns the number of s(econdary) chamberlets of the 4th

and 5th primary p(re) — c(yclic) or nepionic chambers, together. This increase is slow at first, but accelerates in the younger forms, i.e. *Cycloclypeus carpenteri/guembelianus*. Van der Vlerk (1966) concludes that « from stratigraphically old to young, there is a gradual increase of secondary chamberlets of the 4th + 5th primary chambers, combined ». The histograms (table 8) indeed show a distinct increase in the younger sample Kombangan, Bg. 312 as compared to Larat. Larat, however, gives an average of 4.9 which in Van der Vlerk's table (Van der Vlerk, 1966, fig. 1) would point to a Rupelian age whereas Larat is known to be of Aquitanian age.

It should be considered, that Van der Vlerk's mean values are based on *Cycloclypeus* of the *carpenteri* - group, whereas Larat has a *Cycloclypeus eidae* population. This may be the cause of the discrepancy as, within the same horizon, individuals with larger numbers of nepionic chambers have less chamberlets in « 4 + 5 » than individuals with smaller numbers of nepionic chambers.

TABLE 5 - Some of Tan's (1932) parameters PC of *Cycloclypeus*, for comparison with those of Larat and Kombangan, Bg 312.

Approximate stratigraphical position of Tan's populations	Predominating Nepionic Mutants	Standard Classification
T 1608 (Tegal) Ngapak Tjidjenkol	5 5 (5), 6	Pliocene
Ambende Tjikadoe K. Lawak K. Goeng Ngampel	6, (7), 8 (6,7), 8 (6,7), 8 (6,7), 8	Late and Middle Miocene
Singkoewang Pamaloean Kebon Mantingan	8 8, 14 17	Burdigalian
Bodjonglopan S. Sekoero	(17), 19 (17), 19, (21)	Aquitanian
S. Soembal Tjiapoes 14	19, (21) (21), 23	
Tjiapoes 6,12 Tjiapoes 4 Tjimanggoe	26, (29) (26), 29 (26), 29, (32)	Middle and Lower Oligocene

Furthermore, *Cycloclypeus eidae* has, on an average, a smaller value of s.PC (4+5) than either the older or younger species. The parameter s.PC (4+5) is probably connected with the size of the protoconch, which in the case of *Cycloclypeus eidae* is also smaller.

In table 6 the approximate values of s.PC (4+5) are indicated. This value is less reliable because from *Cycloclypeus koolhoveni* and *Cycloclypeus oppenoorthi* only a few specimens could be examined. The same applies to the earlier forms of *Cycloclypeus carpenteri* (Rupelian, Chattian).

imens investigated was small in the case of *Cycloclypeus koolhoveni*, *Cycloclypeus oppenoorthi* and the earlier forms of *Cycloclypeus carpenteri*. The parameter s.C (1) is practically independent of the number of nepionic chambers in the younger forms such as *Cycloclypeus carpenteri* and *Cycloclypeus (post) eidae*. In the older species, such as *Cycloclypeus koolhoveni* and *Cycloclypeus oppenoorthi*, s.C (1) decreases as the mutant has fewer nepionic chambers.

Parameter s.C (1) is less variable than parameter s.PC (4+5).

PARAMETER s.C. (1) CYCLOCLYPEUS

Parameter s.C (1) refers to the number of s(econdary) chamberlets of the first c(yclic) or neanic chamber in *Cycloclypeus*. This parameter decreases during evolution, rapidly at first but more gradually after the Middle Miocene when its value becomes practically constant. This evolutionary decrease is obvious from a comparison of early and late forms (fig. 10).

In table 7 the approximate values of s.C (1) are given for various ages. As with parameter s.PC (4+5) the number of spec-

RESULTS

Age determinations on a biometrical basis have their merits and demerits. Advantages are:

a) The undeniable fact of a higher grade of objectivity, because the degree of evolution is expressed by a number instead of a name (see: « Introduction »). A good example are Middle Oligocene *Lepidocyclina*'s with a parameter A of nearly 35%. In America these are called *Lepidocyclina yurnagunensis*, in Europe: *Lepidocyclina praetournoueri* and in the Far East and Australia: *Lepidocyclina isolepidinoides*.

TABLE 6 - Values of parameter sPC (4-5) for 4 populations of *Cycloclypeus*.

	carpenteri	eidae	oppenoorthi	koolhoveni
Quaternary (Recent)	24			
Pliocene				
Late and Middle Miocene	14.4 10.6	7.1		
Burdigalian	8.9			
Aquitanian		4.9		
Chattian	6.3			
Middle and Lower Oligocene			6.5	6.1

TABLE 7 - Approximate values of parameter sC(1) of *Cycloclypeus*.

Species	Approximate values	Standard classification
<i>C. carpenteri/guembelianus</i>	20 to 30	Late and Middle Miocene
	30 to 40	Burdigalian Aquitanian
<i>C. oppenoorthi</i>	80 to 135	Chattian Middle and
	160-210	Early Oligocene

b) The use of numbers may make it easier to come to worldwide correlations, sometimes even when dealing with benthonic genera. Figure 11 gives such an example. It shows a diagram of the presumed reproductive cycle in the benthonic living *Lepidocyclina*. Worldwide correlation of Middle Oligocene strata in America, Europe, the Far East and Australia can be satisfactory explained by the planktonic character of the very small zygotes: the initial stages of the microthalamic generation (Van der Vlerk & Gloor, 1968).

Age determinations on a biometrical basis have, as can be expected, also their drawbacks. Some of them are:

1) The possibility of lack of a distinct evolutionary trend.

2) The necessity to have available a substantial number of loose specimens of the genus to be examined. A foraminifera-bearing limestone therefore is of no use.

3) The eventual necessity of making a lot of thin sections. This is probably the reason why instance Amato and Drooger (Amato & Drooger, 1969) make the me-

dian planes of larger foraminifera visible by « half sectioning ». A drawback of the latter method is the impossibility to study the specimens by a magnification of 400 $\times$ or 500 $\times$ as the present authors use to do. Considering, however, that an experienced person produces some dozens of thin sections within a few hours, one ought not to be too pessimistic about this drawback.

4) The fact that some grade of subjectivity by measurements of a curved line with the help of a curvimeter, for instance, seldom gives the same results twice. Experience, however, shows that these discrepancies disappear or at least nearly disappear when one takes the averages of some dozens of measurements.

In table 8 the results of the investigations of the eight parameters, mentioned in the title, are summarized.

a) *Parameter A of Lepidocyclina*. As can be seen in table 8 *Lepidocyclina* from Larat has a parameter A with an average value of 45.2%. The maximum in the histogram is lying between 40% and 50%. For *Lepidocyclina* of Kembangan, Bg 312 these

values are respectively 56.3% and between 50% and 60%. An examination of the planktonic fauna has lead to the conclusion, that the sample from Larat has to be placed at the boundary between the *Globorotalia kugleri* and the *Catapsydrax dissimilis* zones. The sample from Kombangan, Bg 312 has to be placed in the *Globigerinatella insueta*

zone. A consultation of table 1 shows only a small difference between the sample from Larat and a sample from the Aquitanian of Arenarie M. Cervarola in N. Italy. To summarize it can therefore be said that parameter A of *Lepidocyclina* gives the impression to be of a high degree of reliability as to geological age determinations.

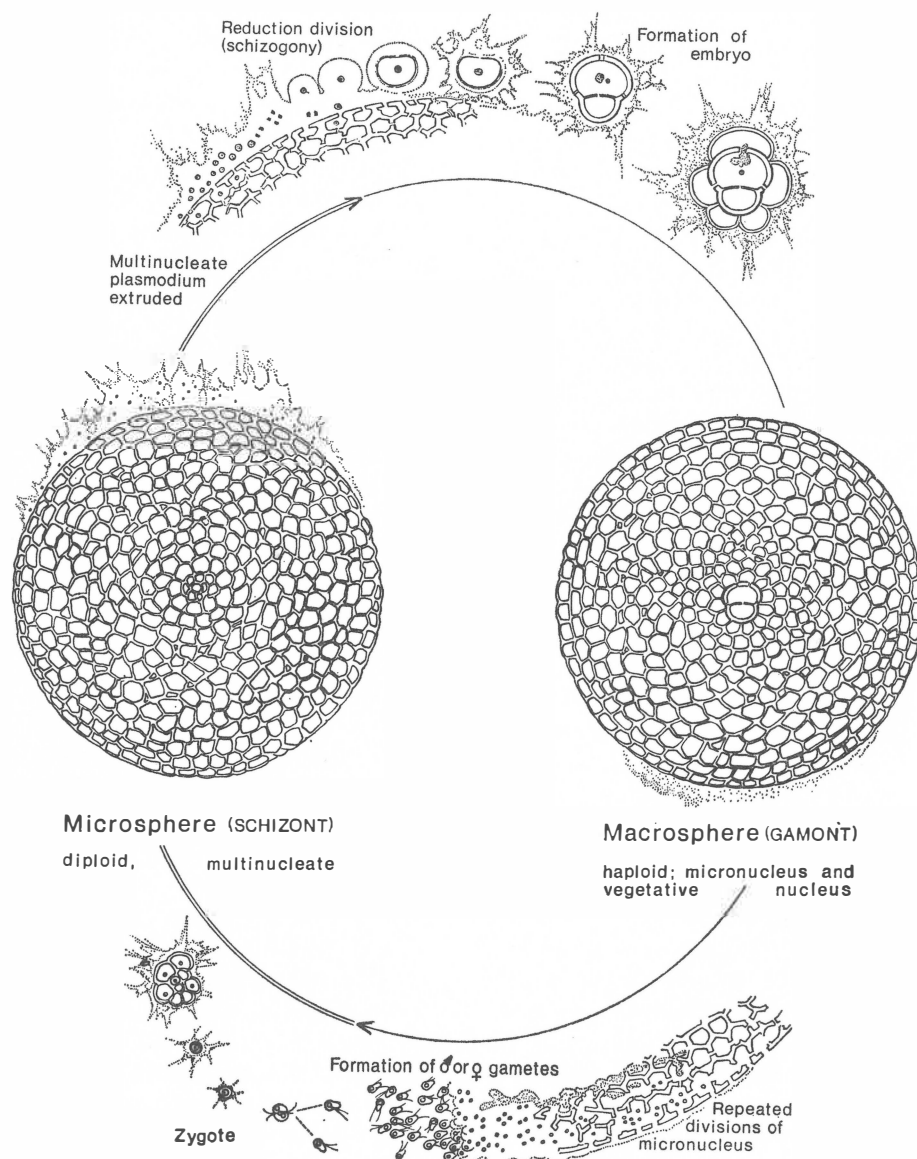


Fig. 11 - Diagram of presumed reproduction cycle in *Lepidocyclina*, as known from living Foraminifera (after H. Gloor).

b) *Parameter d.c. of Lepidocyclina*. Consulting the tables 8 and 2 the same can be said about parameter d.c. of *Lepidocyclina*. Allowance has been made, however, for the fact, that for comparison only a few samples were available. Therefore one ought to be careful in pronouncing a judgment.

c) *Parameter V of Miogypsina*. A less optimistic view ought to be taken considering the results of the measurements of parameter V of *Miogypsina* (tables 8 and 3). Larat and Kombangan, Bg 312 show only a small difference of the averages of the parameters. The maxima of the histograms coincide (table 8). Furthermore an examination of table 3 gives negative results. The samples Kombangan, Bg 295-297 have a parameter V with a value, intermediate between the parameters V of *Miogypsina* from Larat and Kombangan, Bg 312. Ascertaining, moreover, that the planktonic faunas of the samples Kombangan Bg 295-297 belong to the *Globorotalia barisanensis* zone (table 3) enhances the contradiction.

d) *Parameter V¹ of Miogypsina*. This parameter introduced for the first time seems to lead to a more hopeful result than the former (table 8). The difference between the average values (Larat: 77.7%; Kombangan, Bg 312: 84.0%) is somewhat larger and the maximum of the histogram of Kombangan, Bg 312 shows the desired shift to the right (table 8).

e) *Parameter γ of Miogypsina*. It could be expected that *Miogypsina* from the youngest sample, Kombangan, Bg 312, might have a higher value of parameter γ as compared to Larat. However *Miogypsina* of Larat has a parameter γ with an average of $+29^\circ$ and *Miogypsina* of Kombangan, a parameter γ with an average of only $+10.7^\circ$ (table 8). An examination of table 4 makes the question still more controversial. The value of the parameter γ of *Miogypsina* from Kombangan, Bg 312 is still somewhat higher than the analogous value of the younger samples Kombangan, Bg 295-297.

Moreover this table 4 shows marked irregularities in the values of the parameters γ of *Miogypsina* from the section at Madura: from old to young: Prupuh: $+29.7^\circ$; Tanah Poteh Olor, Ct 2679 A: $+24.8^\circ$ and Kombangan, Bg 295-297: $+7.9^\circ$. Therefore one may conclude, that parameter γ of *Miogypsina*, at least in this case, is useless.

f) *Parameter PC of Cyclocypeus*. Although PC probably remains the best parameter of *Cyclocypeus* for age determinations, a comparison with Tan's results is often difficult. Because many of Tan's samples were not sufficiently large, the smaller maxima in his frequency curves and variation statistics have very little, if any, meaning. A distribution identical or very similar to Tan's will therefore seldom be found. In the case of PC it is probably best to consider the clearly dominating mutants or the mean number of nepionic chambers only.

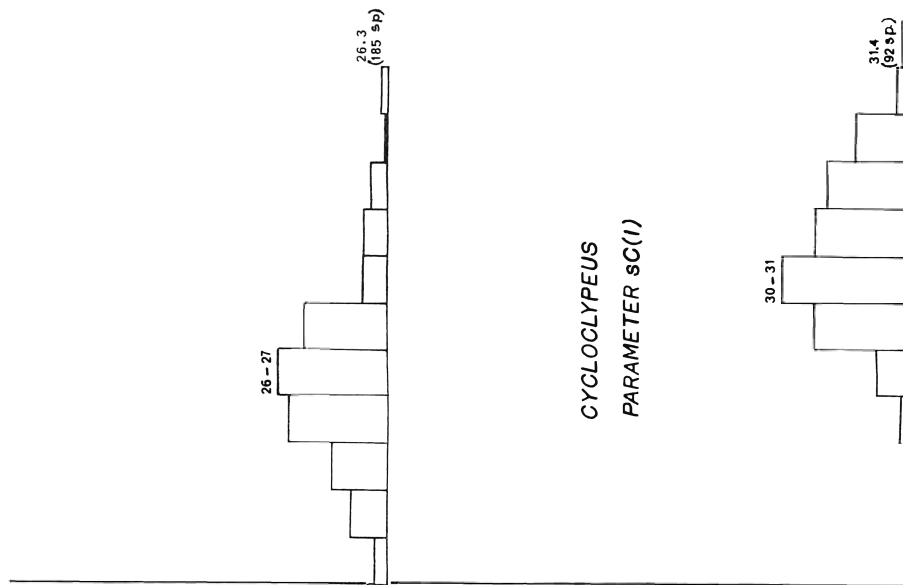
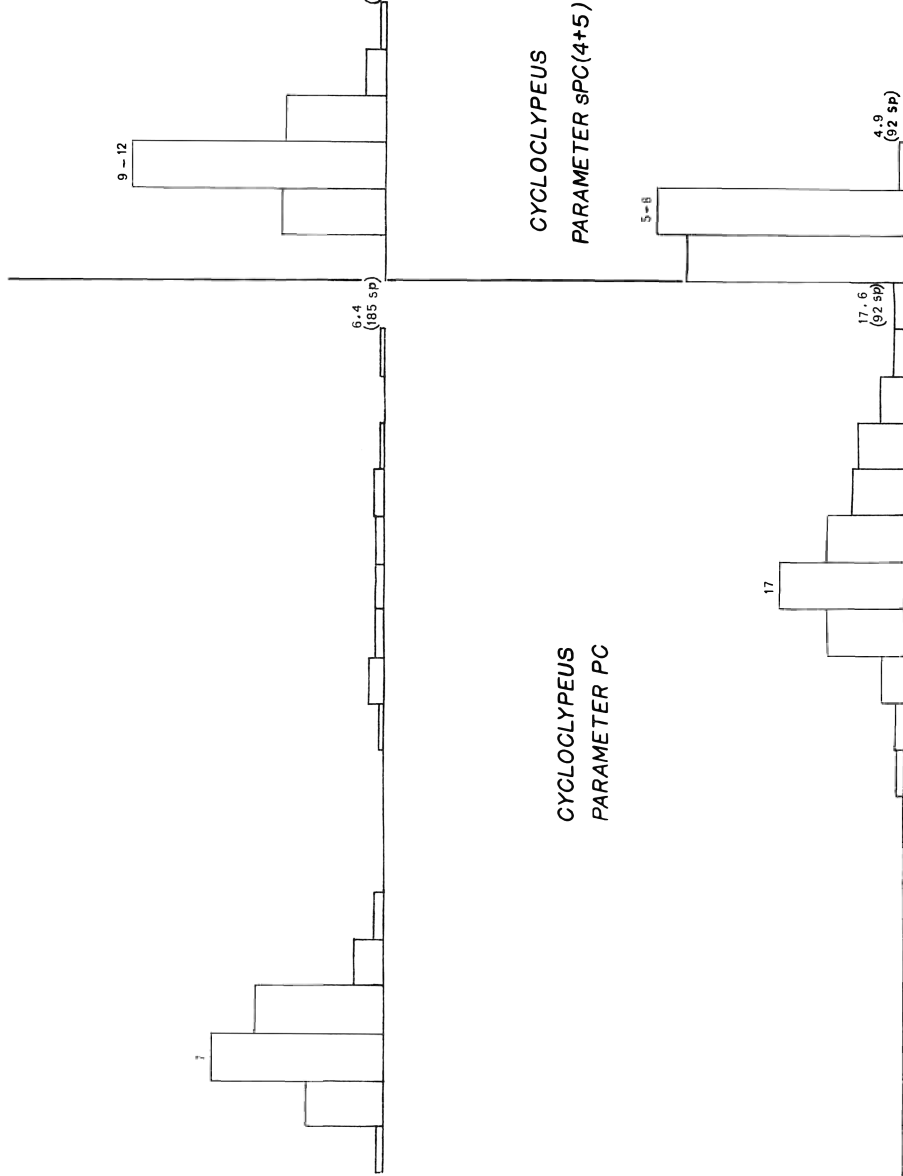
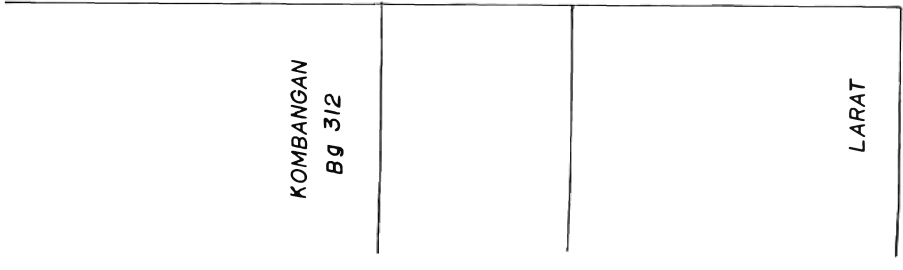
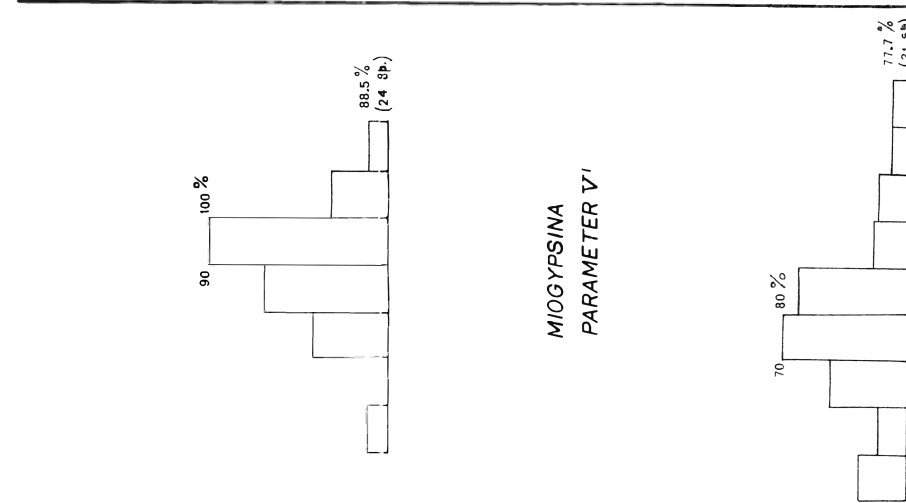
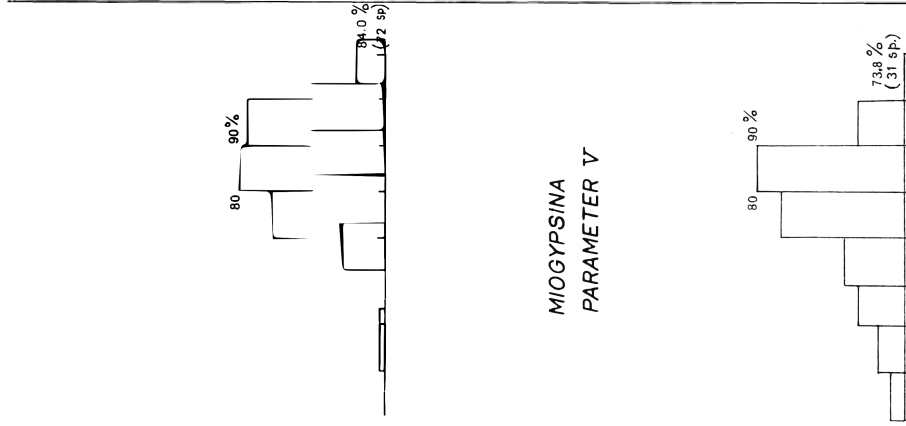
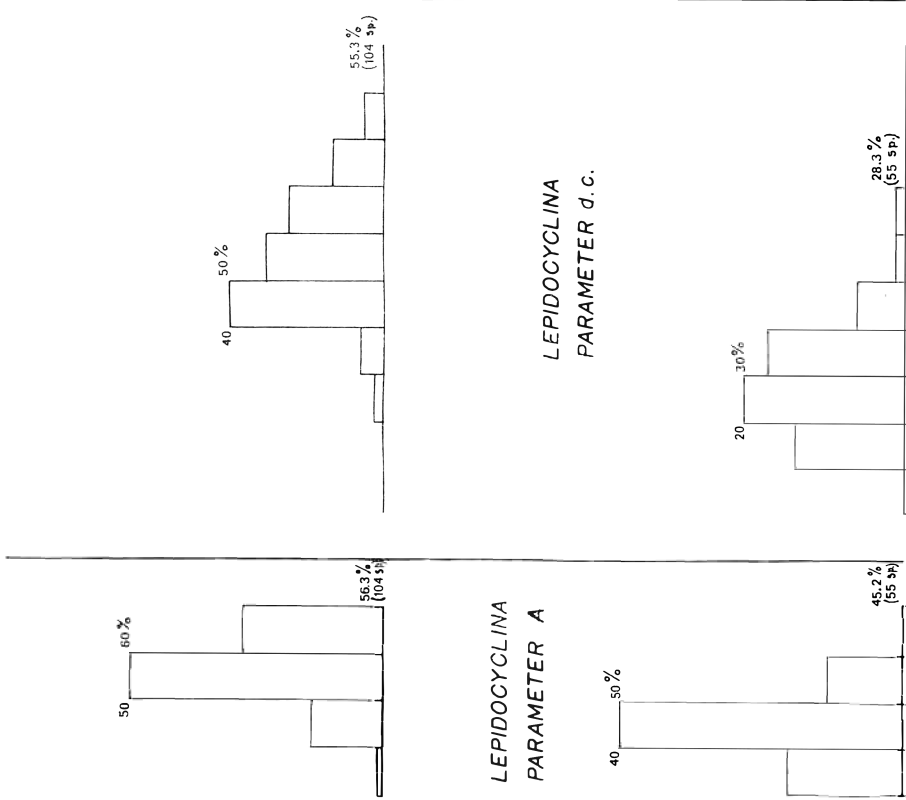
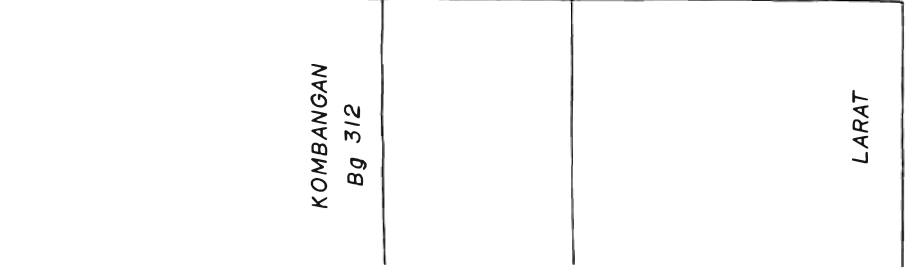
In the case of sample Kombangan, Bg 312 the age may, in this way, be fixed as Middle or Late (?) Miocene. A more precise age determination is hardly feasible especially since mutant 7 (= Tan's 5) does not predominate in any of Tan's populations and is therefore not considered one of his « elementary species ».

The population of Larat may with some certainty be determined as Aquitanian-Burdigalian in age.

g) *Parameter s.PC (4+5) of Cyclocypeus*. A disadvantage of this parameter is that it shows no perfectly continuous increase during evolution. For instance *Cyclocypeus eidae* and *Cyclocypeus carpenteri* populations of the same age give different values of s.PC (4+5).

The parameter could be useful for the younger species such as *Cyclocypeus carpenteri/guembelianus*, which show a rapid increase. It is not known, as yet, whether *Cyclocypeus carpenteri* and *Cyclocypeus guembelianus* give different values.

Another drawback is that the parameter is relatively variable within the same horizon, e.g. the value of s.PC (4+5) is gener-



EXPLANATION COMMENTS ON TABLE 8

The numbers at the foot of the histograms are the values of the parameter concerned.

To the right of each histogram is indicated the mean value of the parameter with, in parentheses, the number of measured specimens.

Lepidocyclus, parameter A is the degree to which the deuteroconch encloses the protoconch (fig. 1-2).

Lepidocyclus, parameter d.c. indicates the degree of curvature of the wall between the proto-and deuteroconch (fig. 3-4).

Miohypsin, parameter V expresses the degree of symmetry of the two spirals around the protoconch (fig. 5-6).

Miohypsin, parameter V' gives the percentage ratio between the length of the small and the large spiral around the protoconch (fig. 7).

Miohypsin, parameter γ is the angle between the apical frontal line and the line connecting the centres of proto- and deuteroconch (fig. 8-9).

Cycloclypeus, parameter PC indicates the number of precyclic (= nepionic) chambers (fig. 10).

Cycloclypeus, parameter PC(4 + 5) concerns the number of secondary chamberlets of the 4th and 5th primary chambers, together (fig. 10).

Cycloclypeus, parameter sC(1) refers to the number of secondary chamberlets of the first cyclic (= neanic) chamber (fig. 10).

ally raised in individuals which show « growth-anomalies ». The parameter is probably useless for species older than Middle Miocene.

The samples Larat and Kombangan, Bg 312 may, on the ground of parameter s.PC (4+5) be dated as Lower Miocene (or Chattian in the case of *Cycloclypeus eidae*) and Middle Miocene respectively.

h) *Parameter s.C (1) of Cycloclypeus.* Age determinations with the help of this parameter are, as yet, restricted to a rather rough classification on the basis of the various lineages of *Cycloclypeus*. As s.C (1) is dependent on the species (c.q. « sectio » sensu Tan) difficulties may arise in case of mixed populations (« overlapping » species).

As contrasted with s.PC (4+5) the parameter s.C(1) may be more suited for the older species with a rapidly decreasing value. From the Middle Miocene to Recent this parameter is probably of little use. Parameter s.C(1) may, however, be useful in combination with the parameter s.PC (4+5).

As parameter s.C (1) may be considered an important species characteristic the parameter is of value in rapid classification of populations, especially as it is about equal for megal- and microspheric individuals of a certain species.

On the basis of parameter s.C(1) the samples Larat and Kombangan, Bg 312 can be dated as Lower and Middle (or younger) Miocene respectively.

Finally one remark. The parameters V and γ of Miocene bispiral *Miogypsina*, although not promising in the present investigation, may be more useful in case of older formations. On the other hand parameters A and d.c. of *Lepidocyclina* may be less useful.

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