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Remarks and Suggestions Regarding the Stratigraphy and Micropalaeontology of the Tertiary of Australia

by

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REMARKS AND SUGGESTIONS REGARDING THE STRATIGRAPHY AND MICROPALAEONTOLOGY OF THE TERTIARY OF AUSTRALIA.

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A paper titled "Three foraminiferal zones in the Tertiary of Australia" was published by M. F. Glaessner in the Geological Magazine, Vol. LXXXVIII, July-August, 1951, pp. 273-283.

Three zones, each characterized by a key foraminifer are postulated, i.e. a *Hantkenina alabamensis* zone of Upper Eocene age, a *Victoriella plecte* zone of assumed Chattian (Upper Oligocene) age, and an *Austrotrillina howchini* zone of Burdigalian (Lower Miocene) age. A fourth zone with *Sherbonina* of Aquitanian (?Upper Oligocene) age is tentatively suggested. These zones are correlated with the official "stages" of Victoria. However, attention is drawn to the fact that the "Stages" might be rock units (formations) rather than rock-time units.

Shortly after the publication of Glaessner's paper the "zone" fossils *Hantkenina*, *Victorella*, and *Sherbonina* were discovered at the Bureau in rock specimens collected by Dr. Raggatt and Miss Crespin in one zone at the Bird Rock section, Torquay, Victoria. *Victoriella plecte* moreover, was found associated with *Hantkenina* in Upper Eocene rocks between Johanna River and Brown's Creek.

It appears that the discovery of these foraminifera in a suite of rocks which until quite recent time was assigned a Lower Miocene age, has far-reaching consequences for the Tertiary of Victoria. Provided *Hantkenina* in the Bird Rock section is autochthonous, which apparently it is, the zone in which it occurs in association with *Victoriella* and *Sherbonina* is of Upper Eocene age. Consequently the *Victoriella* zone as postulated by Glaessner, is no longer valid. As *Victoriella plecte* appears to be a local form which, so far has not been found outside of Victoria, excepting at Mount Gambier, the assigning of a Chattian age to this form is fictitious.

Glaessner (1951) states that *Austrotrillina howchini* "has not actually been recorded from any single sequence of strata above the beds containing *Victoriella*", by inference, however, he places this zone above the "Janjukian".

Austrotrillina howchini is an important key fossil in the Indo-Pacific region, although its range varies in different areas. Glaessner (1943) in his table of "Correlation of marine Rocks in the Indo-Pacific Region" indicates its range as Te to F Tf_{1-2}. Van der Vlerk (1931) assigns it to Te with the possibility of an extension of its range into Tf_1. In his more recent table (1948) he shows it ranging through the whole of Te into Tf_1. Tan Sin Hok (1939) lists it under the lower part of the Neogene (n_1) or Te. Glaessner (1951) places his *Austrotrillina howchini* zone in the Burdigalian (approximately Tf_1).

In the North-west Basin Miss Crespin (unpublished information) found *Austrotrillina howchini* in association with *Flosculinella bontangensis*, *Katacycloclypeus*, *Cycloclypeus* indopacificus, small Lepidocyclina (Nephro- and Trybliolepidina) and Miogypsina. The co-occurrence of A.howchini and F.bontangensis is an interesting feature which allows quite a close classification of these rocks. According to van der Vlerk (1931) F.bontangensis ranges from Tf_1 to Tf_3 with a possible extension downward into Te_5. Mohler (1949) was able to define the range of F.bontangensis and other species of Flosculinella more specifically, at least in one area (South-west Borneo) i.e.

F.borneensis Alveolinella quoyi	Tf_{2-3}
F.bontangensis F.globulosa	Tf_1
F.reicheli	Te_5.

His table which shows also the ranges of a number of other large foraminifera in relation to those of the above Alveolinidae is attached as enclosure 3.

If we assume that F.bontangensis has the same restricted range in the North-west Basin as it has in South-west Bornea, then the A.howchini - F.bontangensis association as it is found in the Tulki and Trealla Limestone, must also be of Tf_1 age. But even with the extended ranges, that is to say

A.howchini	$Te - Tf_1$
F.bontangensis	$Tf_1 - Tf_3$,

it is clear that their zone of overlap falls into Tf_1.

The underlying Cycloclypeus indopacificus - Nephrolepidina - Trybliolepidina assemblage in the uppermost part of the Mandu Limestone, has also to be assigned a Tf_1 age, because C.indopacificus according to Tan (1930 and 1932), ranges from Tf_1 to Tf_3, and is not found in Te in the East Indies (see also van Bemmelen (1949), table on p. 87).

As A.howchini seems not to occur with the true eulepidine fauna of the main part of the Mandu Limestone, it is probable that in the Tertiary sequence of Australia, in particular that of the North-west Basin (Cape Range), this species has made its appearance at a later time (Tf_1) than in the East Indies where it is already found in association with Eulepidina in Te. The upper limits of its range in Australia, however, are not definitely known yet.

According to Miss Crespin ("Micropalaeontology of the Cape Range Area", unpublished report) there is a marked contrast in the composition of the assemblages found in the Trealla Limestone of the Cape Range.

The lower assemblage is characterized by Austrotrillina howchini, Flosculinella bontangensis, Cycloclypeus indocpacificus, Nephrolepidina angulosa, Trybliolepidina gippslandica, T.martini, Gypsina howchini, and Marginopora vertebralis.

The higher assemblage "usually contains one of the zonal species A.howchini and F.bontangensis together with Marginopora vertebralis, Sorites marginalis, Valvulina davidiana, V.fusca and many small miliolidae".

It is apparent that, although the two zone foraminifera A.howchini and F.bontangensis with which we are primarily concerned, are present in both assemblages, the key foram C.indopacificus and the assemblages of Nephro- and Trybliolepidina have disappeared in the higher assemblage and are replaced by an association of forams of a younger aspect such as *Sorites*, *Valvulina* and miliolidae. This change must have been caused by changing environmental conditions and is not likely to indicate a younger age, for the following reasons: In the East Indies the subgenera *Nephrolepidina* and *Trybliolepidina* range from Te_1 to Te_5 respectively right through to the top of Tf_3. There, the incidence of their stratigraphic disappearance is identical with the Tf_3/g boundary. There are of course some species which do not range through the whole of Tf, as for instance *Nephrolepidina borneensis* ($Te-f_1$), *N.verbeeki* (Te_5-f_1), *N.sumatrensis* (Te_5-f_2), *Trybliolepidina rutteni* (Tf_3). The subgenera *Trybliolepidina* was found to be genetically younger than *Nephrolepidina* and reaches its peak in the younger stages of Tf. However, there is no evidence at hand yet, that any of the species of *Nephrolepidina* and *Trybliolepidina* which are present in the Trealla Limestone of the Cape Range, actually do have a range restricted to say Tf_1 or f_2, which would be proof of their stratigraphic disappearance within Tf_1 or f_2. Consequently for the determination of the age of the Trealla Limestone we have to rely on the zone foraminifera *A.howchini* and *F.bontangensis* alone. As there is no evidence for an extended range of these key forms, in the Cape Range area, their range of overlap (Tf_1) as it is established in the East Indies (South-west Borneo) is accepted.

For the Cape Range area the following stratigraphic-palaeontological subdivision can therefore be postulated:

Formation	Foraminifera	E.I.Stages	Approx.Age.
Yardie	*Marginopora vertebralis*	?	?Pliocene
Hiatus comprising stages Tf_{2-3} and younger (Mid. & Upper Miocene)			
Trealla Lst.	*Austrotrillina howchini* *Flosculinella bontangensis* abundant *Marginopora*, *Sorites* *Valvulina*, small miliolidae *A.howchini*, *F.bontangensis* *Cycloclypeus indopacificus*, *Nephro-* & *Trybliolepidina*	Tf_1	Lower Miocene
Tulki Lst.	*A.howchini*, *C.indopacificus*, *Katacycloclypeus annulatus*, *Nephro-* & *Trybliolepidina*, *Myogypsina excentrica*		
Mandu Lst.	*C.indopacificus*, *Nephro-* & *Trybliolepidina*		
	Eulepidina manduensis, *E.badjirraensis*, *Cycloclypeus eidae*, *C.posteidae*	Te	Oligo-Miocene

It is apparent that a wide hiatus, comprising Tf_{2-3} and possibly younger time equivalents, separates the Trealla Limestone from the overlying Yardie Formation. This gap was caused either by non-deposition of post-Tf_1 erosion. Consequently the calcareous middle part of the Yardie Formation can not be an intercalation of Trealla Limestone as this would be in conflict with basic geological principles. Text and plans of the Cape Range report should therefore be changed accordingly.

Coming back to Glaessner's (1951) paper it can be said that his Austrotrillina howchini zone and its chronological position is the only zone which can be accepted as correct. Therefore his paper can not be considered an improvement on the existing stage of stratigraphic knowledge of the Tertiary of Australia. On the contrary, the postulation of three foraminiferal zones of Upper Eocene, Chattian and possibly Aquitanian age respectively, the key foraminifera of which occur together in Upper Eocene rocks, in undoubtedly erroneous.

It does not clarify the confused state of the Tertiary stratigraphy which largely was caused by incorrect field correlations based on incomplete and disconnected stratigraphical sections, the application of stage names to lithological (rock) units, the premature postulation of foraminiferal zones and hasty correlation with European Tertiary stages, before the range of the key foraminifera within the Australian Tertiary sequence was properly established.

This state of ambiguity and confusion could have been avoided through the application of sound stratigraphical principles. In our opinion a sound stratigraphical investigation of a new area comprises the following logical steps:

a) The measuring, describing and graphical representation of the most complete section within the area as the standard section. Rock units are established and their contacts defined. Special attention is paid to changes in lithology, breaks in sedimentation, mode of deposition, whether uniform, cyclic or irregular. Close sampling is essential.

b) Search for the lateral extension of the established stratigraphic sequence, measuring, describing and graphic representation of additional sections, comparison and correlation with the standard section. Correlation is based on marker horizons and, if present, on the cyclic development of the stratigraphic sequence. The rock-units are given formation names according to the Australian Code of Stratigraphic Nomenclature. The facts are presented in a geological map of adequate scale, and if possible an isopach map, columnar sections and facies diagrams.

Within a comparatively small and lithological uniform area it can be assumed that the planes of formation boundaries are coindident with time planes, i.e. that ~~ligh~~ lithological boundaries are rock-time unit boundaries. Such ~~as~~ an assumption, however, is no longer permissible in an area of large extent, where onlap and offlap conditions caused by a transgressive and regressive sea are possible or suspected.

A time measure therefore has to be introduced which is independent from lithological variations caused by changing depositional conditions. It is usually found in the co-existing faunae - in the case of the Australian Tertiary sediments the foraminifera - although it is realized that certain forms are more susceptible to changes in environment than others. The incidence of their appearance and disappearance can ~~a~~ naturally suggest an event which could be taken as having occurred simultaneously throughout the area, whereas in fact it is in close connection with a lithological change, which might not be contemporaneous throughout the area.

Apart from the typical facies indicators, there ~~are~~, however, a large number of forms which are not susceptible to such changes. Their range is defined by biological factors - mutation and evolution. They are the time markers, not so much in the range of one single species or sub-species, but in their typical assemblages. Their ranges usually overlap within the time units, but there are also forms the ranges of which are restricted. They represent true zone fossils.

In the accompanying theoretical facies diagram (encl. 1) the rock units, the time units and the ranges of foraminifera are shown. On the western side of the area five rock units (formations a-e) are defined, whereas on its eastern margin only three rock units (formations a-c) are present. Formation b indicates near-shore conditions. Its position within the stratigraphical column is not constant. It progresses from a lower position in the west to a higher position in the column in the east, indicating a progressive shifting of these near-shore conditions to the east, which means a transgressive sea or onlap.

The range of the foraminifera x and y is clearly a function of environment. These forms are facies indicators and have no stratigraphic significance. However, a number of species and sub-species of foraminifera, the ranges of which are indicated on the right hand side of the diagram, are assumed to be uninfluenced by facies changes. It is to be seen that each time unit or stage is characterized by an assemblage of certain forms, a number of which are true zone fossils, whereas others have a range which is wider than one time unit. Therefore it is possible to define time units A, B and C by their respective foram assemblages within the area represented by the facies diagram and quite independent from other areas, either adjacent or more distant.

This line of approach was followed by van der Vlerk (1931) and others in the East Indies. It resulted in the letter classification system there. In the beginning it was based on incomplete stratigraphical data and therefore stood under severe criticism by Shell geologists who were in a position to work out the stratigraphy of the Tertiary sequence with all the refinement of modern field methods, and also by Government geologists who covered much wider ground than the East Bornea survey, where van der Vlerk's type sections were located. The late Tan Sin Hok (1939) pointed out some weaknesses of the letter classification and extended the range of several genera, as for instance Spiroclypeus and Assilina.

In its rectified form van der Vlerk's scheme was extensively and satisfactorily applied not only in the former Dutch East Indies but also in Sarawak and British North Bornea, by various oil companies operating in those areas, and in the Philippines.

It was also used by Glaessner in Papua-New Guinea for A.P.C. and I.E.C., who replaced it later by local stage names.

Various authors correlated the letter classification with European stratigraphic nomenclature as follows:

Tertiary	h	... Pliocene
	g	... Pliocene or Miocene
	f	... Miocene
	e	... Lower Miocene or Upper Oligocene (Aquitanian)
	d	... Oligocene
	c	... Lower Oligocene
	b	... Eocene
	a	

Uncertainty exists as to the correct correlation of Tg which some authors consider as uppermost Miocene, whereas others (Tan, 1939) include it in the Pliocene. The position of Te depends on the question whether the Aquitanian be included in the Miocene or the Upper Oligocene, whereby the Chattian is sometimes taken as a time equivalent of the Lower Aquitanian.

Judging by the discrepancies in the existing literature it is clear that the time has not come yet for an unquestionable world-wide correlation of the Tertiary sediments based on large foraminifera. Such discrepancies are revealed by a comparison of almost any two palaeontological publications and are so obvious and numerous that reference to any of them can be dispensed with.

Whereas van der Vlerk's letter classification is based on the distribution of large foraminifera, extensive work has been done on small foraminifera for local correlation by micropalaeontologists of various oil companies and the former Netherlands East Indies Mining Service (Dienst van Mijnbouw). For several reasons their work was mainly confined to the younger Tertiary sequence, which had been subdivided by Oostingh (1938) with the help of molluscs into five local stages (in descending order: Bantamian, Sondian, Cheribonian, Preangerian and Rembangian). The two lower stages show Miocene, the three upper stages Pliocene affinities. In the last decade or so several authors have tried to correlate the East Indian Tertiary with the European classification, but it has to be realized that such correlations on small foraminifera are bound to be incorrect.

Caudri (1934) describing a Young Tertiary fauna of small foraminifera from the island of Soemba (Lesser Sunda Islands) says: "The East Indies have been an independent region during the whole Tertiary" (this is questioned by Tan Sin Hok (1939) for the Eocene) "inhabited by an indigenous marine fauna and the stages in the East Indian Archipelago can never be directly correlated in detail with accurate synchronous limits with classic Western Europe." Therefore "the relative value of correlation and limits must never be forgotten".

The same warning was sounded by LeRoy (1941) i.e. "The terms Pliocene, Miocene, Oligocene and Eocene, as applied to the Tertiary sequence of Europe, have been used frequently by authors in designating the age of sediments and faunas of the Indo-Pacific Region; European stage names as Burdigalian and Aquitanian have also been employed. The assignment of such terms on the basis of small foraminifera to the East Indian faunal and sedimentological units should be made with reservation, as the data are believed far too inadequate to denote time correlations between the two regions. More knowledge of the stratigraphy, distribution of the faunas, and facies relationships must be available before this is done."

Environmental conditions as controlling factors for the distribution of foraminifera are rightly considered by some authors as of prime importance for benthonic assemblages. In their opinion such assemblages might reflect similar facies conditions in different areas rather than contemporaneity. It appears that better results might be expected of a correlation which is based on the occurrence of planktonic (pelagic) forms, which are less subjected to environmental conditions and possess a greater mobility, allowing a more rapid distribution, than the benthonic forms. A step in this direction was done by LeRoy (1948) whose findings for instance suggest that Orbulina universa probably is an almost world-wide key fossil for the Middle Tertiary. Also the significance of Globotruncana for the Upper Cretaceous is generally recognised.

However, as far as we see the problem at the moment, neither the large nor the small foraminifera can be used yet as time markers for world-wide correlations, although they are invaluable for correlations within a single sedimentary province.

The question now arises what line of approach should be followed for the stratigraphic classification of the Australian Tertiary sediments. While introducing his letter classification van der Vlerk was in the fortunate position to break new ground. Although there was a fair amount of preliminary work done on large foraminifera by authorities such as Douville, Rutten and Provale, it was based on carefully sampled standard sections, whereas the regional mapping as carried out by Mining Service was based on the mapping of rock units (formations) and therefore no confusion was introduced by the adoption of "stage" names. In Victoria and South Australia we are encumbered by an inherited system which was proved to be hardly workable and urgently needs revision.

There are three possibilities open: (a) to apply van der Vlerk's letter classification, (b) to introduce a new i.e. Australian letter classification, (c) to apply rock unit (formation) names which later, i.e. when the stratigraphy and the spread of zone foraminifera is definitely known, can be replaced by time unit (stage) names.

(a) Van der Vlerk's letter classification:

This classification has been successfully applied outside of the East Indies (Papua-New Guinea, Philippines). As far as Miss Crespin's work on the large foraminifera of the North-west Basin (Cape Range) has shown, strong affinities with the East Indies exist there. The epicontinental seas transgressing unto the margins of the Western Australia stable area, must have been in direct connection with the East Indian idiogeosynclines. Such connection is still apparent in South Australia and parts of Victoria. However, with increasing distance from the type area (East Indies) more and more local forms make their appearance and correlations, based on a few common forms, might become more difficult. There might also be a gradual shifting of the ranges caused by the time lapse necessary for long distance migration and a certain degree of uncertainty as to the synchroneity of species ranges is not altogether to be excluded. However, notwithstanding these drawbacks, in our opinion reference to the East Indian letter classification can advantageously be made, instead of referring to the more distant European Tertiary terminology.

(b) An Australian letter classification:

The advantage of such a classification would be a complete break with the past. It would allow the gradual building up of a sound stratigraphy. Conflict with the inherited confused "stage" system would be avoided, because it would be based on the ranges of foraminifera species which are indepentent from facies changes.

However, there is a large amount of information on the Tertiary stratigraphy collected over many years, which when critically sifted, might still form a sound basis on which to gradually build up a new stratigraphy.

(c) Rock Unit (formation) names and subsequent adoption of local stage names.

This procedure is followed by the Bureau in the present field mapping campaigns. It is very suitable method for the mapping of the Tertiary sequence in the North-west Basin.

If the pitfalls of hasty correlation and premature introduction of stage names are avoided, it should be possible with the help of the numerous foraminiferal faunae with strong East Indian affinities, to build up an integrate stratigraphy there.

In Victoria and South Australia, however, we are facing an entirely different situation, because of the confused state of the stratigraphy there. In order to make this method a working proposition, the pseudo-stage concept should be discarded altogether. In its stead rock unit (formation) names should be adopted and the foraminiferal assemblages of each of these formations should be defined. All surface and subsurface (well logs) sections should be compiled and plotted as columnar sections together with the graphs showing the vertical zonation of foraminifera. If proper care is taken to eliminate facies indicators from time markers, the ranges of species and subspecies can be established not only in each column, but also from one column to the other. Thereafter a correlation of the different formations should be possible and time unit (stage) names can be introduced, implying a redefinition of all the conventional, mostly fictitious "stages".

All references to disconnected occurrences of one single species should be avoided and should only be made in case the stratigraphic range of such a species is properly established. This would eliminate possible confusion as to the actual range of single species. In this respect Glaessner's (1951) paper is an outstanding example of sweeping statements and correlations based on insufficient and largely erroneous stratigraphic-palaeontological data (see loc.cit. chapter IV "The place of the foraminiferal zones in the standard Tertiary sequence").

Such a systematic compilation of existing and new stratigraphic and palaeontological information is to be done independently for each basin, and only after correlation within each of these basins is established beyond reasonable doubt, should inter-basinal correlation be attempted.

The necessity of the palaeontologist being intimately familiar with the local stratigraphic sections can not be over-emphasized. Only in this way is it possible to eliminate facies forms and key forms. The influence which, for instance, a cyclic development of the sedimentary sequence can have on the vertical range of foraminifera assemblages, can be understood and demonstrated only by a close comparison of the faunae with the litho-facies. In micropalaeontology the time has come when a mere inventory of foraminiferal assemblages is no longer the sole aim, but when ecological considerations are coming more and more in the foreground. There exists an extensive literature on the ecology of present day foraminifera, the principles of which can be applied and is being applied to fossil foraminiferal populations. The benefit which the geologist can derive from such data is invaluable for the reconstruction of environmental conditions which have obtained during the deposition of a sedimentary sequence.

Only as a last stage of the investigations, and only in case definite affinities of the Australian Tertiary faunae (and not only single species) with extra-Australian regions are established, should a wider correlation be attempted. This means of course that for a long time to come the Australian Tertiary stratigraphy, in particular that of Victoria and South Australia, would not figure prominently in international stratigraphic and micropalaeontological literature. However, the contribution to the knowledge of world-wide relationship of Tertiary foraminiferal faunae would undoubtedly be more valuable and lasting, if the results of these investigations would only be made known to international science, after all the pains-taking work of intra-basinal and inter-basinal correlation is completed.

(W. F. Schneeberger)

6th February, 1952.

Enclosures:

1) Theoretical facies diagram showing rock- and time units and ranges of zone foraminifera.

2) I.M. van der Vlerk (1948), Stratigraphy of the Caenozoic of the East Indies based on foraminifera.

3) Mohler, The Stratigraphic distribution of Alveolinidae and some other large foraminifera in the Oligocene and Miocene of Bornea.

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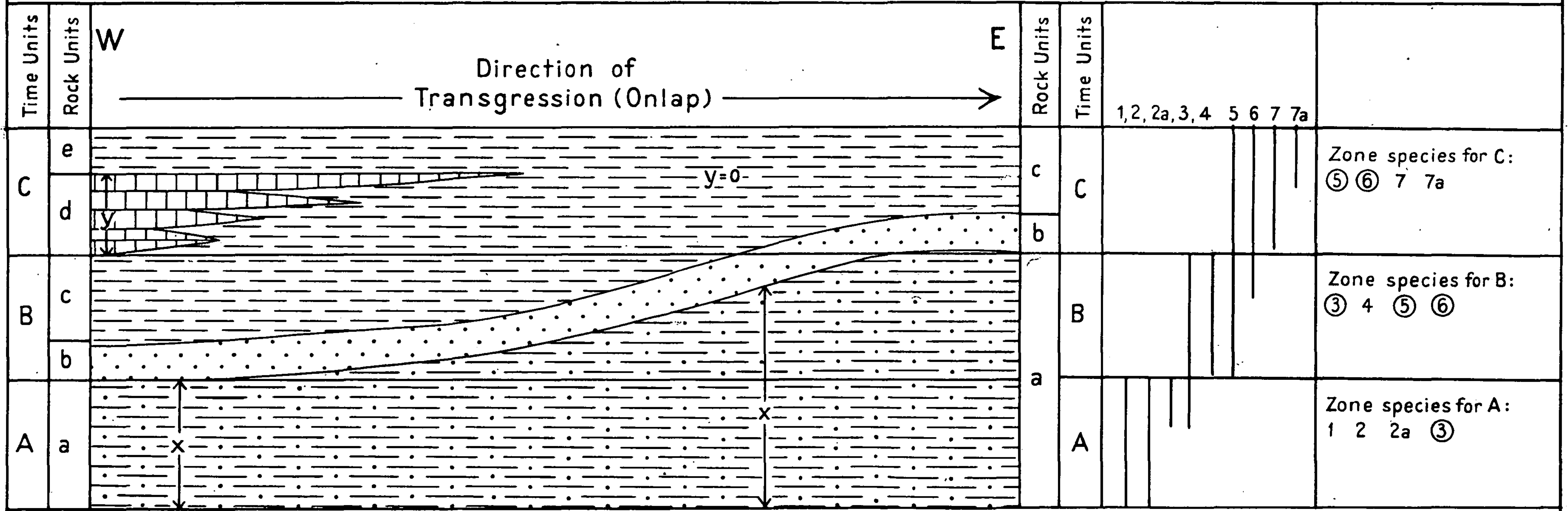
Theoretical Facies Diagram showing Rock-and Time Units and Ranges of Zone Foraminifera



x, y - Ranges of Foraminifera x & y, forms which are susceptible to change in environment

1 etc. Species with range restricted to one Time Unit

3 etc. Species with range wider than one Time Unit with the author's compliments

STRATIGRAPHY OF THE CAENOZOIC OF THE EAST INDIES BASED ON FORAMINIFERA

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ABSTRACT

Owing to the autochthonous nature of the Caenozoic fauna of the East Indies, it is premature to use European names in their subdivisions. The " letter-classification " introduced by Van der Vlerk and Umbgrove (1927) has proved of practical value but is somewhat obsolete. A more detailed subdivision as proposed by Leupold and Van der Vlerk (1931) was based on the distribution of different species of foraminifera. As, however, nearly every investigator has his own opinion about species-characteristics this subdivision has more or less failed. It would be better, perhaps, to found more exact stratigraphy on morphogenetic research (Tan Sin Hok, Cosijn, Bannink). In the stratigraphical table here proposed eight divisions of the Caenozoic era are distinguished, each of them defined by different combination of 26 genera and subgenera. Only 2 characteristic species, both of them transition forms between two genera, are used. The most important assemblages to be mentioned in this abstract are:—

(*a*) *Flosculina—Discocylina—Assilina—Nummulites—Pellatispira.*

(*b*) *Discocyclina—Assilina—Nummulites—Pellatispira—Biplanispira.*

(*c*) reticulate *Nummulites* without the above-mentioned genera.

(*d*) reticulate *Nummulites* with *Lepidocyclina* (*Eulepidina* and *Lepidocyclina* s. str.)

(*e*) Lower part: *Austrotrillina—Miogypsina* (*Miogypsinoides* and *Miogypsina* s. str.)—*Lepidocyclina* (*Eulepidina*)—*Lepidocyclina* (*Nephrolepidina*) *isolepidinoides—Heterostĕgina borneënsis—Spiroclypeus.*

(*e*) Upper part: the same assemblage without *Heterostĕgina borneënsis* but with *Flosculinella* and *Lepidocyclina* (*Multilepidina* and *Trybliolepidina*).

(*f*) Lower part: the same assemblage as upper " f " but without *Eulepidina* and *Spiroclypeus* and with *Miogypsina* (*Conomiogypsinoides*)—*Cycloclypeus* (*Katacycloclypeus*) and other species of *Nephrolepidina.*

(*f*) Upper part: *Flosculinella—Alveolinella—Miogypsina* s. str.—*Nephrolepidina—Trybliolepidina* (abundant) and several subspecies of *Cycloclypeus.*

(*g*) Upper Caenozoic and Recent: *Alveolinella—Cycloclypeus* s. str.

OWING to the autochthonous nature of the Caenozoic fauna in the East Indies, it has not been possible to use the recognized European stratigraphical nomenclature. An extensive examination of Caenozoic molluscs had lead K. Martin (1914) to this conclusion. For elucidating the stratigraphy of this area the fauna, still living, was the only material available to work on. Martin used the same percentage method for the Caenozoic of the East Indies as did Lyell and Deshayes, in the first part of the nineteenth century, in subdividing the Caenozoic of Western Europe. He soon realized, however, that the percentages to be used here were very different from those used in Europe. Since the beginning of the Eocene there had been considerable fluctuations in climate in Europe, which was not the case in the East Indies. Consequently the changes in the East Indian fauna will have been smaller than in the European. This means that the percentages characteristic of the various epochs of the East Indies ought to be higher than those of the same geological age in Europe. How much higher they should be, still remains an unsolved problem. Thus it will at once be seen that a correlation of this autochthonous area with the Caenozoic of Europe and, by the same token, of America is not yet possible. There is therefore, every reason to use a special nomenclature for the stratigraphy of the Caenozoic of the East Indies.

In 1927 I (Van der Vlerk 1927) proposed the use of a simple letter-classification, which, however, was not founded on the molluscs but on the foraminifera. Seven divisions (Caenozoic " a-g ") were established, each of them defined by a different combination of genera of foraminifera. This subdivision was only based on a small collection of samples collected in stratigraphical order. In subsequent investigations, however, it was found that this stratigraphical table provided a valuable basis of correlation throughout the East Indies region.

Some years later Leupold and Van der Vlerk (1931) published a more detailed subdivision based on the vertical distribution not only of genera, but also of subgenera and species. The epoch "a" was divided into two, the epochs "e" and "f" into five and three parts respectively. This subdivision was as yet not wholly satisfactory. In the first place it was founded largely on stratigraphical investigations which were executed exclusively in East Borneo; secondly, however carefully the work was carried out, the personal factor was bound to play too big a part in the determination of species. The vertical distribution shown in the table below keeps to a mean between those of 1927 and 1931. Only the epochs "e" and "f" are subdivided, not into five and three parts respectively, but each of them into a lower part and an upper part.

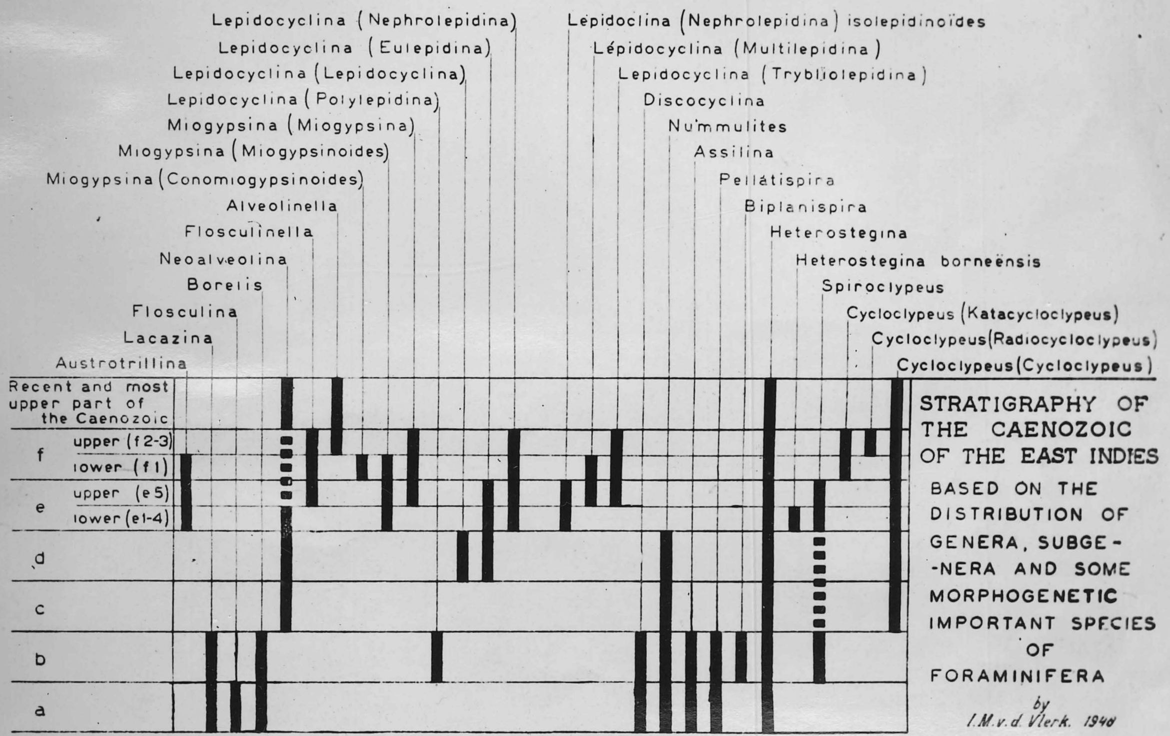

FIG. 1.—*Stratigraphy of the Caenozoic of the East Indies based on the distribution of Genera, Subgenera and some morphogenetic important species of Foraminifera.*

Lepidocyclina, *Assilina*, *Spiroclypeus* and *Cycloclypeus* are shown to have a wider stratigraphical distribution than was indicated in the older tables. Again the genus *Biplanispira*, since discovered, appears to be a good index-fossil for Caenozoic—"b". The main additions to the 1927 table, however, are shown in the distribution of the subgenera of *Miogypsina*, *Lepidocyclina* and *Cycloclypeus.* The subgeneric characteristics are sufficiently clear to avoid the tedium of specific identification which is not necessary for this stratigraphical work. *Lepidocyclina* (*Nephrolepidina*) *isolepidinoides* and *Heterostegina borneënsis* (Van der Vlerk 1929) are the only species added to the table. The first of these can be considered as a transition-form between the subgenera *Lepidocyclina* s. str. and *Nephrolepidina.* Its stratigraphical position is quite in harmony with this view. The second was originally considered to be a transition-form between *Heterostegina* and *Spiroclypeus.* In 1933 however *Spiroclypeus* was also found in Caenozoic—b (~~Tan 1937~~). Careful morphogenetic research on the genera *Heterostegina* and *Spiroclypeus* will have to be made before the true value of the above mentioned species of *Heterostegina* can be judged. The stratigraphical importance of the two species may, however, be an indication of the direction in which research must proceed in order to compose a more exact subdivision.

When describing a new species of *Cycloclypeus* from E. Borneo (Van der Vlerk 1923), I pointed out that a clear evolution in the structure of the nepionic stage could be observed. This suggestion was worked out by Tan Sin Hok (1932) in an excellent monograph on this genus, a study in which the stratigraphical signification of the morphogenetic method of research was clearly demonstrated. Investigations by the same author (Tan 1936, 1937) on *Miogypsina* a, b, by Cosijn (1938, 1942) on *Lepidocyclina*, *Cycloclypeus* and *Globorotalia*, and by Bannink (1948) on *Operculina* have each in turn completely confirmed this opinion.

From the addition to our knowledge of the vertical distribution of genera and subgenera Tan (1936) claimed the non-autochthony of the Indo-Pacific region during the Eocene. This conclusion however, based on the presence of the subgenus *Polylepidina* in only one locality in East Borneo, seems to be premature. It is true, that *Spiroclypeus* is now also known from the Eocene of Borneo, but on the other hand the occurrence of this genus in the Eocene of Venezuela seems to be doubtful (Caudri 1944). The fact that genera and subgenera such as *Biplanispira*, *Austrotrillina*, *Flosculinella*, *Miogypsinoides*, *Trybliolepidina*, *Katacycloclypeus*, *Radiocycloclypeus* and a number of species of the other genera are restricted to the Far East is too important to doubt of the autochthony of this district.

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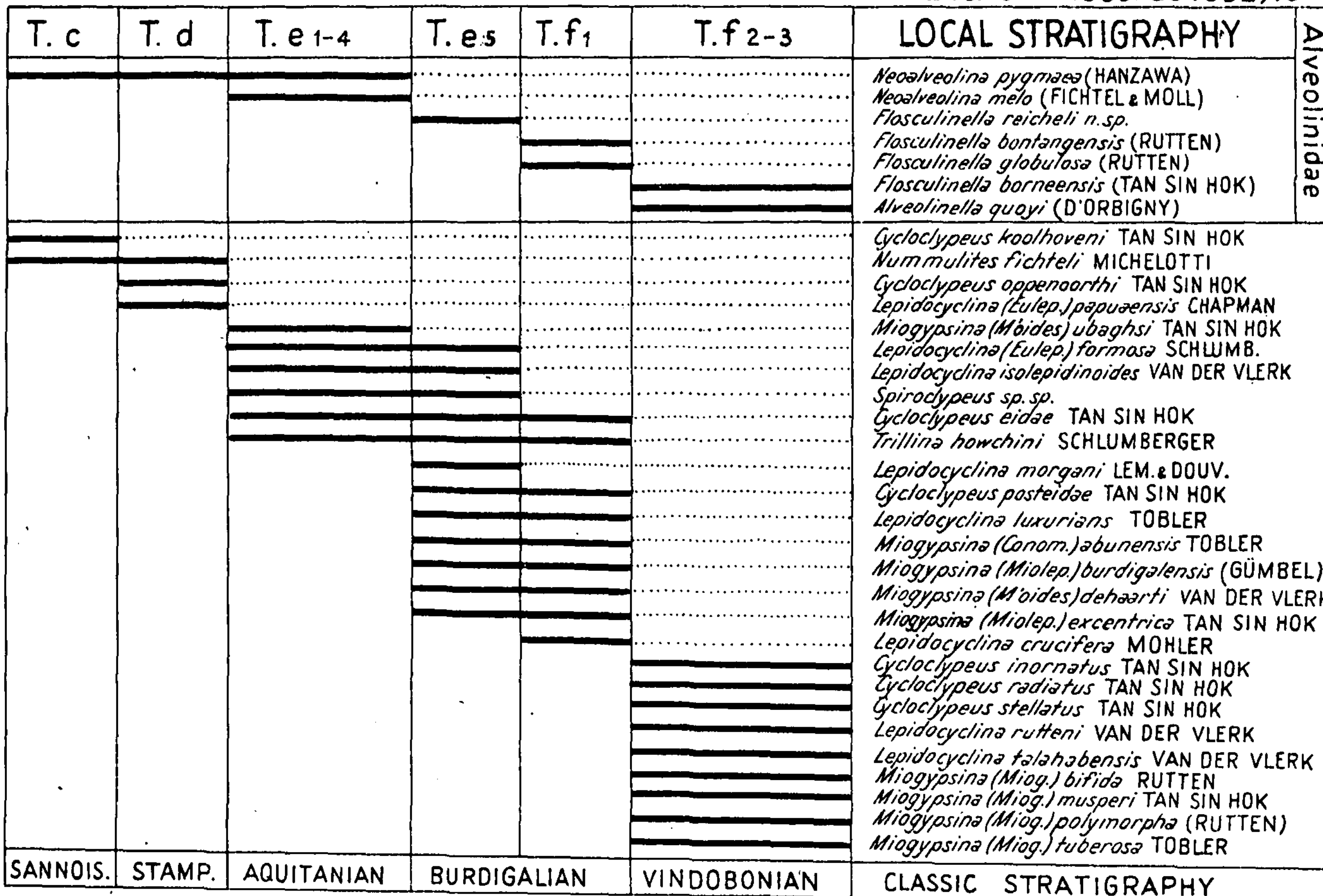

THE STRATIGRAPHIC DISTRIBUTION OF ALVEOLINIDAE AND SOME OTHER LARGE FORAMINIFERA IN THE OLIGOCENE AND MIOCENE OF BORNEO