20. THE TERTIARY

BY

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With 2 tables.

A jubilee book in honour of Professor MARTIN is the right place for an essay on the Tertiary of the Dutch East Indies, as it was he who laid the foundations of stratigraphy in that district.

The basis upon which he founded the subdivisions of the tertiary deposits has proved the firmer the more it has been tested.

He laid down two fundamental principles upon which further investigations have been built.

In the first place he showed that during the Tertiary an autochtonous fauna developed in the East Indies and in the second place he insisted that a subdivision of the Tertiary systems can only be obtained by comparing their fossil contents with the fauna that still exists in these regions and not with the European Tertiary fossils. It might appear to be a simple matter to compare fossils with living species, but when entered upon it is found to be difficult in the extreme. Thousands of molluscs have passed through the hands of this untiring investigator and only those who have themselves experienced the endless difficulties that attach to the determination of fossil material are able to form an idea of the energy it must have cost to bring this comparative study to a satisfactory conclusion.

As the fauna that flourished in the East Indies was entirely different, it is not possible to apply the names current for European series with typical faunae to the East Indian Tertiary epoch.

The investigations of Vredenburg and De Cotter, in British India have rendered it possible to make a rough comparison between Java and Europe via Burma and Northwestern India (vide: MARTIN, Leidsche Geol. Meded., Dl. IV, Afl. 1), but a detailed correlation is not possible.

The authors have therefore decided to use the subdivision by letters as proposed by VAN DER VLERK-UMBGROVE (Wet. Meded. N°. 6).

The basis for the subdivision in stages and horizons is formed by the foraminifera of the strata.

The discussion of the Tertiary will be begun with the eastern part of Borneo, as it is of special value in this part of the East Indies, which is also a region of great economic importance.

To avoid the mistake made by some investigators of the stratigraphy of Europe it is necessary to employ more comprehensive and vaguer terms besides these stage-names. There is the more reason for following this method as barren series comprising several stages are often to be dealt with.

In this article the terms Lower Tertiary and Upper Tertiary will therefore be used. If necessary a subdivision into an inferior, middle and superior part can be introduced.

The lower margin of the Upper Tertiary generally coincides with an important transgression plane. Paleontologically the beginning of the Upper Tertiary is marked by the first appearance of *Lepidocyclina*. Thus the Lower Tertiary can be correlated with the stages *a*—*c* and the Upper Tertiary with the stages *d*—*h*.

In the **LOWER TERTIARY OF BORNEO** three regions with different facies can be clearly recognized. The southern facies is marine and close to the shore. It extends over the peninsula Mangkalihat, the Koetei-basin, the surroundings of the Meratoes-mountains and the Barito-basin. The northern facies is geosynclinal and is found in Boeloengan and Beraoe. The third facies is brackish and coastal and is met with in Central Borneo.

The **southern facies** is built up of deposits that as a rule are not more than 1000 m. thick. In the development that is lithologically most differentiated we may distinguish from bottom to top: 1 basal conglomerate, 2 sandstone with layers of coal, 3 marl, 4 limestone. We are here dealing with a shelf-region with calm sedimentation. Originally the floor gradually sank. The sedimentation kept pace with the sinking movement. Afterwards the sinking movement exceeded the sedimentation (formation of marls). Finally the sea became shallower (formation of limestone).

At other localities the lithological boundaries are too vague to render these four subdivisions recognizable. But we can always distinguish a lower part, composed of coarse terrigenous detrital sediments and an upper part with more calcium carbonate, mainly composed of organic sediments.

The standard section, clearly showing this subdivision into four parts was published in 1875 by VERBEEK (Jaarb. Mijnw., 1875[1]). It is situated in Martapoera. Afterwards KROL (Verhand. Geol. Mijnb. Gen., geol. ser., Dl. 8, 1925) gave some additions to VERBEEK's results.

From top to bottom they distinguish:

4. limestones, according to VERBEEK 20—90 m., according to KROL 10 m., with *Camerina fichteli-intermedia* (= *N. sub-Brongniarti*), *C. biaritzensis, C. striata.* This is VERBEEK's γ-stage, in age equivalent to our stages *c* and *d.*
3. marl, according to VERBEEK 250 m., according to KROL 596.10 m. with *Camerina pengaronensis, Discocyclina javana, D. dispansa, D. omphalus, D. decipiens.* This is VERBEEK's β-stage and must be reckoned to our stage *b.*

2. sandstone without coal-layers, according to KROL 74.55 m. with *mollusca* and imprints of *plants.*
1. sandstone with coal-layers, according to KROL 175.45 m. (according to VERBEEK 2 and 1 are together 160 m.) with *mollusca* and imprints of *plants.*

In West-Pasir, at the eastern side of the Pre-Tertiary core of the Meratoes-mountains an almost identical section may be distinguished according to the provisional results of POTT and ZEYLMANS VAN EMMICHOVEN (Jaarb. Mijnw., Alg. ged., 1927 and 1928):

3. *Camerina*-limestone with a few interjacent beds of marl-sandstone, thickness 200—600 m.
2. Clay-sandstone with small beds of fossiliferous lime-sandstone and chalk-marl with *Discocyclina,* about 280 m. thick.
1. Basal conglomerate occurring locally, resting on conglomerate and quartzitic sandstone with *Orbitolinae.*

Nearer the coast the Koekoesan-mountains form a domelike island of Pre-Tertiary rocks in the Tertiary strata. According to POTT and ZEYLMANS VAN EMMICHOVEN we can again distinguish in the older part of this Tertiary an upper part of *Camerina*-limestone and in the lower part clay-sandstone.

From the island Poeloe Laoet GÖLLNER (Jaarb. Mijnw., Verh. 1e ged., 1921) mentions:

2. marl-stage, composed of grey marls and marl-sandstones; it is only locally exposed and probably incompletely; thickness about 85 m. Fossil contents according to RUTTEN (Jaarb. Mijnw., Verh. 2e ged., 1914): *Discocyclina omphala* and *Camerina cf. bagelensis.*
1. sandstone-stage, composed of grey clay-sandstones and stratified claystones with several pitch-coal layers.

There is as yet only very little known concerning the older Tertiary in the hinterland of the exceptionally broad strip of Upper Tertiary of Central-Koetei. Investigations by the „Opsporingsdienst van den Dienst van den Mijnbouw" are in progress at present. ZEYLMANS VAN EMMICHOVEN (Jaarb. Mijnw. 1929, Alg. ged.) gives the following section from the region above Long-Iram, this is far inland:

4. Limestone division,
3. Clay-marl division,
2. Clay-sandstone division,
1. Conglomerate-division.

From the region of the northern tributaries of the middle Mahakam, S. Belajau and S. Klindjau the same investigator mentions:

2. Marl-claystones and limestones with lime-sandstones, containing *Camerina, Discocyclina, Pellatispira.*
1. Conglomerates, composed of Pre-Tertiary components, quartz-sandstone in thick series of strata with marls and small limestone beds, containing *Camerina, Discocyclina, Pellatispira.*

Here, therefore, a fairly clear subdivision can be made into an older, conglomerate-sandstone part, of terrigenous detrital composition and a younger part, rich in limestone.

For the last time this type of Lower Tertiary is exposed in the Boengaloen dome of northern Koetei. Here the limestone series contains at its basis a black-grey limestone. Besides this soft quartzsandstones and hard shales occur. The limestone contains *Camerina cf. bagelensis, Discocyclina cf. dispansa var. minor, Discocyclina sp., Pellatispira.* The younger parts of the limestone series already belong to the Upper Tertiary (Beboeloeh-zone = *e* 5). Between these two there is without doubt an unconformity. Again in the Northern part of the peninsula Mangkalihat LEUPOLD found extensive Lower Tertiary deposits. Along the upper S. Taballar he observed:

3. the Taballar-marls with a small layer at the base with *Camerina bagelensis* and *Discocyclina dispansa.*
2. the sandstone-stage, composed of an alternation of beds of sandstone and marls, containing *Camerina thalica, C. nuttali, C. kelatensis* and *C. variolarius.*
1. a red sandstone and a basal conglomerate, consisting of pebbles of radiolarian chert, lying unconformably on the Danau-formation.

The paleontological investigation has shown that the sandstone stage represents the very oldest part of the Lower Tertiary, for *C. thalicus* and *C. nuttali* have been described by DAVIES from the Ranikot-beds of British India (Quart. Journ. Geol. Soc., vol. 83, pl. 2, 1927), that have been correlated with the Montian.

Of the Taballar-marls the lowest part probably belongs to the Tertiary-*b* and the highest part possibly to the Tertiary-*c*.

Apparently the Southern facies was divided by a ridge from the Northern facies. Thus HARTING found an exposure along the S. Kelei, slightly to the North of the Taballar-section, in which the Lower Tertiary is reduced to about 40 m. It was found to be a *radiolarian* chert-conglomerate with a lime cement. The cement contains *Camerina fichteli* and the rock lies unconformably on the *radiolarian* cherts of the Danau-formation. This represents a transgression of the highest part of the Lower Tertiary over the Pre-Tertiary formations. Thus the North part of the shelf was bounded by dry land during the Tertiary-*a* and -*b*. LEUPOLD also found the Tertiary-*c* (limestones with *Camerina*) transgressing over the Danau-formation about 55 km. E. of the spot discovered by HARTING. From this it follows that the ridge ran from East to West.

RUTTEN also mentions a conglomerate (Samml. Geol. Reichs-Mus. Leiden, Ser. 1, Bd. 10) from cape Mangkalihat. From the foraminifera it contains, *Discocyclina javana, D. dispansa var. minor* and *Camerina sp. sp.*, we can conclude that this rock is older than those just mentioned, but younger than the basal conglomerate from the Taballar region. We must therefore conclude that in the Mangkalihat region various stages of the Paleogene can transgress directly over the Danau-formation. The basal conglomerate of *radiolarian* chert that formed were always identical, but they were not everywhere of the same age.

In the region in which the **Northern facies** is found the Lower Tertiary is not a comparatively thin shelfdeposit, but a thick series of strata formed under geosynclinal circumstances. All the same the sediments here were no more deposited in a deep sea, than in the South. The powerful supply of terrigenous material, combined with a continual sinking of the bottom caused the deposits to grow to great thickness. But deep sea deposits are here unknown. In Boeloengan and Beraoe we observe a lower formation of sandstones and shales, sometimes called mica-sandstone-formation, that is several thousands of meters thick and an upper formation of limestones and marls. Thus we here find the same cycle of sedimentation as in the South, notwithstanding the very different circumstances, under which the sediments were formed. The occurrence here and there in the lower part of fossiliferous limestone-beds has rendered it possible to ascertain the age of this series. (Wet. Meded., Nr. 9; Tohoku Imp. Univ., Vol. V, No. 4, 1921).

In the upper series also, fossils have been met with, so that we can subdivide the Lower Tertiary of Boeloengan as shown in the table.

Paleontologically these deposits are characterized as follows:

Mangkaboea-marls:	*Camerina fichteli.*
Seilor-beds:	*Camerina fichteli-intermedia, Heterostegina reticulata, Fasciolites javanus.*
Bratan-beds:	*Camerina fichteli-intermedia, C. pengaronensis, Heterostegina reticulata.*
Marah-beds:	*Camerina* and *Discocyclina.*
Orang-beds:	*Camerina cf. pengaronensis, Assilina orientalis, A. granulosa var. minor, Discocyclina javana, D. fritschi.*

To the **brackish water facies** of the Lower Tertiary we must count the Melawi-group, consisting of unvarying or only slightly varying sandstones. MARTIN and KRAUSE (Samml. Geol. Reichs-Mus., Leiden, Ser. 1, Bd. V) described the mollusca they contain and were led to assume an Eocene age. According to MOLENGRAAFF marked plateau-landscapes occur on the sandstones in the Madi-mountains (Borneo exp., 1900).

The sandstone-formation in the source-district of the Barito was identified with this plateau-sandstone by KEMMERLING (Tijdschr. Kon. Ned. Aardr. Gen., 1915). The age of the latter could not yet be definitely fixed. Most investigators, however, assign an Upper Tertiary age to this formation.

To the **coastal-facies** of the Lower Tertiary we may reckon the coarse clastic rocks with *Fasciolites, Discocyclina* and *Camerina,* that MOLENGRAAFF discovered as pebbles in the region of the Sg. Emboeloeh. He supposed at that time that these deposits lay transgressively over the Old-slate formation but he nowhere discovered plateaus or remains of these. MOLENGRAAFF's supposition has, however, been confirmed, for in the upper reaches of the S. Kajan, half a days journey above the Bem Brem waterfalls HARTING discovered plateau-mountains composed of this rock (Mijningenieur, 1930).

The **UPPER TERTIARY OF BORNEO** shows several differences to the Lower Tertiary. The South region of the shelf-facies and the region of the brackish water and coastal facies of the Lower Tertiary are for the greater part converted into land. Along the margin of this ancient land there was a belt of sea that can be clearly devided into 4 basins: 1. the Barito-basin, 2. the basin of Pasir and Koetei, 3. the basin of Beraoe and Boeloengan, 4. the basin of the Tidoengsche landen and the Cowie-harbour district. In between these basins lie regions that must have acted as geanticlines during the Upper Tertiary; namely between 1 and 2 the Meratoesgebergte, between 2 and 3 Mangkalihat, between 3 and 4 the Latongbergland and as Northern limit to 4 the Simpornapeninsula.

Of these 4 basins the Barito-basin may be looked upon as an Eastern spur of the great geosyncline of Sumatra, the ingression of the central part beginning from the South. In the other 3 basins, however, we are dealing with ingressions from E. to W. originating from an original Strait of Makassar.

Naturally two extreme types of facies developed in this series of basins and geanticlines. On the summits of the geanticlines a not very thick reef-limestone was formed. The sinking basins, on the other hand, attracted the rivers. Here an extreme facies of detrital geosynclinal character was formed. Between these two extremes are transitions: the mixed facies.

In the Upper Tertiary of Borneo we can thus distinguish:

a. the Barito-basin, with geosynclinal facies.
b. the regions East and West of the Meratoes-Mountains with limestone facies.
c. the coastal region of Pasir with mixed facies.
d. Central-Koetei, with geosynclinal facies.
e. N. Koetei (on the Sangkoelirangbay) with mixed facies.
f. Peninsula Mangkalihat with limestone facies.
g. Beraoe with geosynclinal facies.
h. Salimbatoe-Antjam (Central Boeloengan) with mixed facies.
i. Tidoengsche landen with geosynclinal facies.

a. **Barito-basin.** Concerning the stratigraphic classification of the Upper Tertiary of this large basin little can be said with certainty at present, although it was this very territory from which DOUVILLÉ in 1905 tried for the first time to found a classification upon the distribution of the larger foraminifera. The sections examined by BUXTORF, upon which this paleontological research was founded, were never published, and there are very few precise data on the Barito-Tertiary to be found in the literature. In any case it appears that we have to do with a very thick Upper Tertiary series, consisting chiefly of sandy, clayish rocks, between which brown coal-seams many appear at any horizon of which coal the habitude varies between good brown coal and young lignites. This is enough to show that in this series a large part of the Upper Tertiary is represented, from the oldest horizons to the „Pliocene". Where in the northerly and easterly regions of the basin the deepest

horizons appear, a series is found below the sandy-clays with coal-layers that contains more marls and limestone with *d*- and lower-*e*-fauna which is in part closely allied to the „Limestone-stage'' of the youngest Lower Tertiary.

From DOUVILLÉ's scanty data, the section for the Upper Tertiary in the West-limb of the Meratoes-Mountains in the Oeloe-Soengai territory examined by BUXTORF woud seem to be about as follows:

f 2 / *f* 1	H-beds of DOUVILLÉ	Sandstone-shale-formation with brown coal-seams
e 5 / *e* 4	G-beds of DOUVILLÉ	Sandstone-formation with browncoal-seams and limestone-beds
e 3 / *e* 2		Marls with limestone-beds
e 1	.....	Marls with silicified beds / Limestone
d	D-beds of DOUVILLÉ	Limestone
c	C-beds of DOUVILLÉ	Marls and lime-sandstones, marls = limestone-stage of VERBEEK in Martapoera.

KROL also gives a few details concerning the Upper Tertiary overlying the classic Eocene section of Martapoera. Here also there is a sandy clayish series, in which brown coal-layers are found at various levels. From the habitude of the rocks and coal we get the impression that this series only includes „Upper Neogene'' and „Pliocene''. The older portions, rich in limestone-layers are not found. Nevertheless neither the older writers nor KROL assume either a break in the succession or an unconformity between this series and the underlying Lower Tertiary. There is, however, an indication of an unconformity by the transgressive position of the brown coal-formation for according to KROL's map the brown coal-formation in a southerly direction constantly transgresses upon older horizons and towards the South cape of Borneo comes to lie directly upon the pre-Tertiary of the Meratoes-Mountains.

In the most northerly part of the basin the Upper Tertiary formation possibly merges with the continental formation of the Plateau sandstone of Central Borneo, which forms the extreme upper reaches of the Barito-basin.

b. **Meratoes-Mountains.** There are indications that towards the Meratoes-Mountains the limestone content of the basin sediments of the Barito-basin rapidly increases, especially in the *e*-part. This can be verified in a few places, where above the pre-Tertiary nucleus sediment bridges of Tertiary have remained between the Barito- and the Pasir-Koetei-basin, as well as in the folded-in Tertiary synclines, such as the great Intra-Meratoes-basin of West-Pasir. The above mentioned section by BUXTORF-DOUVILLÉ of the western mountain-side in Oeloe Soengei

tends towards this limestone facies. In the syncline of West-Pasir (S. Samoe-S. Kendilo) the group containing limestone of the older Upper Tertiary with interstratified marls and clay-sandstone, which joins on to the limestone stage of the Upper Lower-Tertiary, attains a thickness of 900—1700 m. The limestones form large limestone mountains in the region of the water-shed between Pasir and Oeloe Soengei. The limestone facies reaches upwards in the series at any rate to the upper boundary of stage *e* (Beboeloeh horizon), perhaps even higher. In the core of the syncline of West-Pasir there immediately follows another higher Upper Tertiary clay-sandstone-group of a good 2200 m. thickness and many lignite-seams with a water content of 21 to 26 %, of a fairly young habitude therefore (upper-*f* to -*g*). A large part of the older Upper Tertiary which in the Barito-basin and the Koetei-basin consists of the normal sandy clay-basin facies with coal-seams, has here become reef-limestone. In the youngest part of the Upper Tertiary the basin facies seems to penetrate into this geanticlinal region.

c. **Coastal region of Pasir.** Here also the base of the Lower Tertiary consists of a limestone-mass with intercallations of marl, as appears in the surroundings of the Pre-Tertiary mass of Koekoesan. The limestone-mass appears to rest unconformably on the Lower Tertiary (POTT, Jaarb. Mijnw., Alg. ged., 1927). ZEYLMANS also ascertained the existence of Tertiary-*d* in these quarters, so that the lower part of the Upper Tertiary seems to be complete. (Jaarb. Mijnw. 1928, Alg. ged.). It is not clearly to be seen, however, whether this Tertiary-*d* is continuous with Tertiary-*e* and therefore lies above the unconformity assumed by POTT. The Upper Tertiary further consists of a lignite-formation with numerous thick layers, (25—30 % of water), age Tertiary-*g-h*.

Between this formation and the limestone-formation below there is a rather large gap and an unconformity. For W. Pasir POTT assumes a thickness of at least 2200 m. for this lignite-formation (Jaarb. Mijnw., Alg. ged. 1927).

d. **Southern and Central Koetei.** This is the classic region, where RUTTEN carried out his pioneer stratigraphic research and to which the wealth of oil has drawn so many eminent geologists.

The whole Upper Tertiary is here principally sandy clay deposits of great thickness, more or less rich in coal seams, the whole of which is often called Koetei-formation. Here and there some limestone-beds containing fossils are interspersed, which render possible a classification on paleontological principles. But the percentage of limestone in the composition of the whole series is small and varies a good deal, as there are regions (Louise-concession near Sanga-Sanga) where there are hardly any limestone-beds at all. An accurate correlation of the various parts of the Koetei-formation in different portions of the basin is not easy, therefore, either on lithological or paleontological principles, and has led to a good deal of confusion in the nomenclature.

In the following stratigraphic table a correlation is given of the stratigraphic names given by the various investigators. To this is added

the classification which the present writers consider the most practical, especially from the paleontological point of view.

From above downwards we can distinguish:

Tertiary.			Thickness.		Lithological composition.
h-g	Kampong Baroe-beds		min. 1200 m.	Lignites with more than 20 % water	Preponderently clayish series of very young habitude, barely hardened sandstone, partially hardened to iron sandstone, a good many lignite-beds, estuarian facies. A few limestone-beds in the N. (Karangmoemoes, Madoepar), „Upper Miocene" *coral* fauna, no more *Lepidocyclinae!*
f 3	Balik-papan-	Gelingseh- or Upper-Balikpapan-beds	total 1200 m.	Half lustrous brown coal with 11—20 % water	In this horizon a good many small limestone-beds (Klandasan near Balikpapan, SCHÜRMANN) „Upper Miocene" *coral* fauna, guide foraminifera: *Trybliolepidina rutteni.* Further for the greater part a sandstone stage consisting of very soft grey sandstone that weathers white, dark shale and a good many thin coal seams. In this older part is the original fossil locality of foraminifera S. Mentawir, RUTTEN. Limestone on the Pelarang anticline (SCHÜRMANN). Lithologically ill-defined boundary.
f 2	beds	Mentawir-beds s. str. or Lower Balikpapan-beds			
f 1	Poeloebalang-beds		1000—1500 m.	Brown coal with less than 11 % water	In the uppermost part the original fossil localities of foraminifera Poeloe Balang and S. Blakin of RUTTEN. Principally greenish-grey still pretty soft sandstone, sometimes containing lime; conchoidal shale; a good many brown coal-seams. Lithological transition.

Tertiary	Thickness		Lithological composition
e 4/5 Beboeloeh-beds	1000 m.		Many limestone beds, some up to 200 m. in thickness, quickly dying out; laterally with Beboeloeh fauna; also marls containing fossils. In this part probably also original fossil locality of foraminifera S. Pamaloean, RUTTEN.
e 1-3 Pamaloean-beds s. str.	very thick, probably several thousand meters	Water-content of the coals very small, decreasing to 2 %	Monotonous series of hard, concretionary, conchoidal shales, rarely somewhat marley, poor in fossils, and finely bedded sandstones with leaf remains, and especially sandy-clayish rocks. Coal scarce, here and there a limestone-bed not yet much investigated. Boundary with Lower Tertiary still very doubtful.

For the paleontologic characterization of the different stages and horizons see our paleontological table.

e. **N. Koetei (Sangkoelirang-bay).** The sandy Central-Koetei-facies merges towards the North-East into a more marly facies, poor in coal, in which the organic components become of greater importance as compared to the detrital material. The younger part of the Upper Tertiary is developed in a marly facies, called the Sangkoelirang-marls. In this two lithological types may be distinguished. One of these is a soft, chalk like unstratified marl almost purely organical with countless minor foraminifera *(Globigerina)*. The other type is a coarse grained, soft marl, consisting of fairly coarse quartzsand, fine detritus of shells and many benthonic *smaller foraminifera* and *Lepidocyclinae,* with here and there beautifully preserved *corals* and *mollusca.*

The latter type is the Sampajau-marl, an organic coastal facies. These layers, that may partly include coral-limestone-beds, sometimes replace a larger or smaller part of the normal sandy clays of the Koetei-formation. The transition of the marl-facies begins in the higher horizons of the Upper Tertiary (Gelingseh- and Kembang-beds). In the most extreme cases it reaches down to the basis of the Mentawir-beds, but the Poeloebalang-beds retain the normal Koetei-facies. A particularity here is the intercallation of light, acid, volcanic tuffs in the upper parts of the Upper Tertiary. As follows from the exposures in the core of the Boengaloen-dome, the oldest strata of the Upper Tertiary (*e*-stage) are developed in limestone facies.

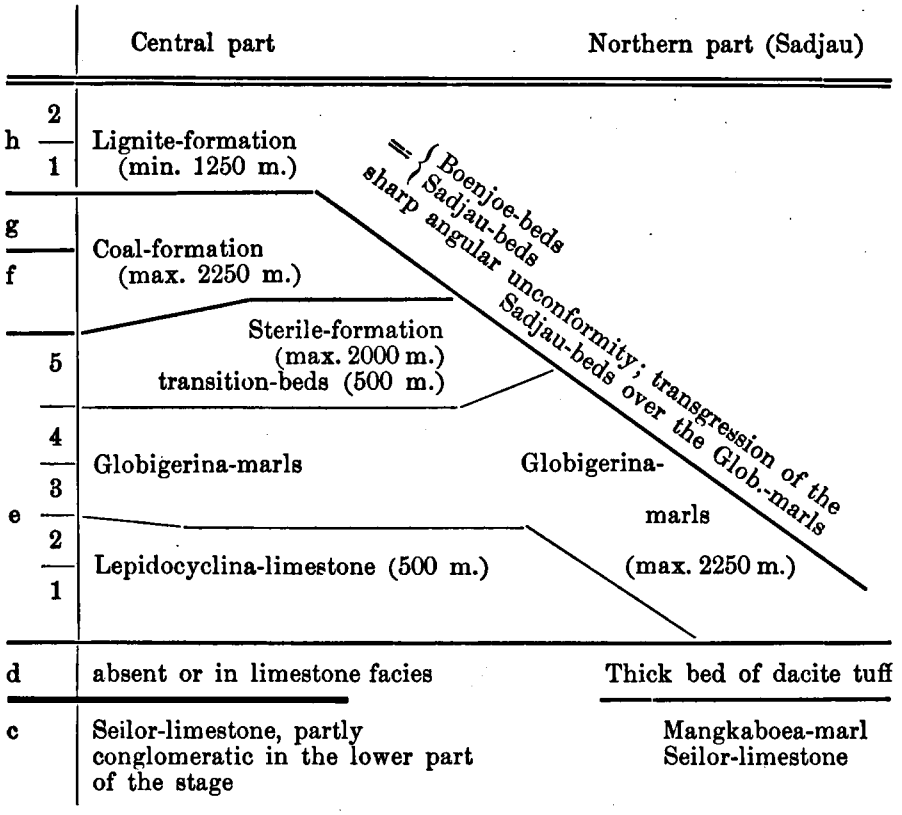
f. **Peninsula Mangkalihat.** To the N.E. of the Sangkoelirangbay the whole Neogene gradually changes to a pure limestone facies through the transition of a marl facies. On the South-West side of the watershed of the peninsula in the drainage area of the Menoebar Globigerina-marls are still interstratified with the limestone (Menoebarmergels = „Upper Miocene'' without Orbitoids). On the North side of the peninsula, however, the Upper Tertiary has almost entirely changed to the facies of reef-limestone, that forms high, irregular limestone-mountains. In this facies we can distinguish two parts, the older Taballar-limestones and the younger Domaring-limestones that are divided by a fairly thin zone in which the limestone-beds alternate with fossiliferous clays, sand and coal-seams. These Taballar-limestones comprise the stages *d* (represented at the basis by a series rich in dolomite) *e* and the lowest part of *f*, as follows from the foraminifera they contain. At the transition to the Menkrawit-beds a rich fauna of *mollusca* was found (under examination) together with: *Lepidocyclina angulosa, Lepidocyclina ferreroi, Alveolina bontangensis, Alveolina boscii* and *Miogypsina thecideaeformis.* The Menkrawit-beds themselves are characterized by the occurrence of *Lepidocyclina rutteni* and represent the very youngest part of Upper Tertiary, that still contains *Lepidocyclina.* In the Menkrawit-beds a rich fauna of *foraminifera* has been discovered (Wet. Meded., Nr. 9). Probably the Domaring-limestones do not lie absolutely conformably over the other limestone-formation. They no longer contain *Lepidocyclina* and correspond with the upper part of the Kg. Baroe-beds of Koetei.

The thickness of the whole limestone-series is difficult to estimate as the dip measurements in the badly stratified reef-limestones are not to be trusted. The thickness will hardly exceed 1000 m., of which 600 m. are counted for the Taballar-limestones.

The Upper Tertiary limestone-formation rests slightly unconformably on the Lower Tertiary Taballar-marls (stages *b*—*c*). The unconformity follows from the fact, that they rest directly on the Pre-Tertiary (Danau-formation) in the most Northern part of the peninsula in the quarter, where the existence of a ridge has already been mentioned in the discussion of the Lower Tertiary. The absence of the Lower Tertiary is partly primary, partly a consequence of a slight elevation and erosion on the old ridge. In connection with this the basal parts of the limestone-formation often contain conglomerate limestone with *Eulepidinae* and pebbles of *radiolarian* chert. RUTTEN also described similar limestone from the drainage basin of the Lasan in the hinterland of Mangkalihat (Verhand. Geol. Mijnb. Gen., geol, ser., Deel VII). It is of importance further to note the occurrence of acid tuffmaterial, characteristic for Tertiary-*d.*

g. **Beraoe.** In the very thick series of sediments in the basin of the Beraoe a characteristic subdivision on lithological data can be carried out. HARTING was the first to point this out (VERBEEK-gedenkboek).

For the stratigraphical subdivision the reader is refered to the stratigraphical table but for the relative thickness of the strata and the differences in facies the following diagram is given.



As explanation of this diagram the following may be stated:

The Globigerina-marls consist predominantly of a hard, distinctly greenish grey marl with numerous smaller foraminifera (both benthonic and *Globigerinae*). The development of the Globigerina-marls from the Taballar-limestones takes place from South to North and begins in the higher parts and gradually passes to the lower parts.

Locally transition-beds may be distinguished, in which the marls interchange with shales. They represent the upper part of stage-*e*. The sterile formation (termed sterile by HARTING on account of the absence of coal-seams) is a practically pure shale-formation.

The fossil content of a few small intercallated limestone-beds proves the age to be the margin between *e* and *f*. In the South there is more upper-*e* and in the North more lower-*f*.

The coal-formation was termed „glanskool-formatie" (glance coal) by HARTING. As, however, some of the coal contained is half-glance coal, the authors have not adopted the name here. In general it is a shale-sandstone-formation with very numerous coal-seams.

The coal content is on the average 6—9 % of the whole section. In the West limb of the Rantau-Pandjang-anticline, on which the coal mine Parapattan is situated, the total of the coal-seams is 70 % (v. D. VELDE, VERBEEK-gedenkboek).

The water content of the coal increases from 9 % at the bottom to 20 % at the top and accordingly the habitude changes from real glance coal to that of half-glance coal. The formation is very poor in limestone and hardly contains fossils. RUTTEN mentions: *Lepidocyclina ferreroi, L. angulosa* and *Miogypsina polymorpha var. spiralis.* From this the only possible conclusion is that we are dealing with the middle or upper part of Tertiary-*f*. The upper margin we assumed (coals with 20 % water) must about coincide with the margin *g-h*.

In the central part of the Beraoe-basin the glance coal-formation is conformably covered by the lignite-formation, that has a similar lithological composition. The lignites it contains have a water percentage of 20—37 %. In the North-East part of the basin there is a marked unconformity between the highest strata of Lower Tertiary and the older part of the Upper Tertiary. The stratigraphical hiatus increases to the North. Finally the youngest layers come to lie on the Globigerina-marls. In this part of the basin, the so-called Sadjau-region, a subdivision of the Tertiary-*h* is possible (compare HARTING, VERBEEK-gedenkboek) in Boenjoe- and Sadjau-beds. The Boenjoe-beds consist of a series very rich in lignite, further dark grey, butiminous or white puttey-like, plastic clay and above all grey clay, containing leaf remains, and beautifully stratified by fine sand-layers.

They contain numerous very thick lignite-beds; at the basis a bed with a maximum thickness of 22 m. The total thickness is at least 1000 m.

A weak unconformity divides this series from the underlying Sadjau-beds. The latter are composed of two parts. The upper of these, the green clay and tuffaceous sand-series, is composed principally of soft green tuffaceous sands partly consolidated to sandstone, the lower of light blue-green, plastic, homogenous clay, probably also tuffaceous with a few thin lignite-beds. Total thickness 360 m. The lower division contains a few thick lignite-seams in its upper part.

The lower part is practically free of coal and consists predominantly of gravel. In a fresh condition it has a typical blue-green colour. Total thickness 600 m. On the margin of the green clay- and tuffaceous sandstone-series and the gravel- and sand-series a number of oilhorizons are found.

h. **Salimbatoe-Antjam (Central Boeloengan).** At Tandjong Seilor on the S. Kajan the whole older part of the Upper Tertiary is invisible in consequence of a transgression of the youngest part to the edge of the region occupied by Upper Tertiary. From the S. Kajan to the S. Sekatak the older part is exposed in the so-called Salimbatoe-Antjam-region. To the East of the protruding cape of Lower Tertiary of the Latoeng-mountains it is again entirely covered by younger strata, that transgress into the Lower Tertiary.

During the whole of the Upper Tertiary the deposits were formed under the influence of the geanticlinal ridge of the Latoeng mountains, that consists of very intensively folded Lower Tertiary. In consequence of this a facies of the Lower Tertiary has developed here, that is rich in reef-limestones. There is much resemblance both to the Mangkalihat-facies and the Beraoe-basin-facies.

The stratigraphical table shows the subdivision of the Upper Tertiary of Central-Boeloengan. To this the following may be added: the Boenjoe-strata occur on P. Boenjoe and P. Tarakan and are developed similarly to the Sadjau-region.

The Sadjau-Tarakan-series have been found both on the main land and on P. Tarakan, where they are rich in oil and attain a thickness of at least 1200 m. They are divided from the underlying deposits by a sharp unconformity: they partly transgress onto the Lower Tertiary.

The Antjam-series is built up of a blue grey firm clay, rich in mollusca and corals; a few limestone-beds and small beds of transition-coal between half-glance coal and lignite; thickness 150 m.

Below the Antjam-series with a slight unconformity the Koendjang-series follows. This is composed principally of reef-limestone and fossiliferous chalk-marls and clays. Thickness 200 m.

Yet another unconformity is found between the Koendjang-series and the limestone-coal-formation. There is a strong lithological resemblance between these two formations, but the latter contains less limestone and shows shales and thick glance coal-seams with a water percentage of 14 %.

The Globigerina-marls are generally somewhat sandy and not so homogenous as those of Beraoe. In the highest part soft marls occur that contain countless *larger foraminifera* and interchange with limestone-beds (of the same age as the Upper-Naintoepo-series). The middle part consists predominantly of marls. In the lower part marls interchange with limestone-beds. In part the lowest division is replaced by an undivided mass of Lepidocyclina-limestone.

The stage-*d* is represented by lime-sandstone, shale, limestone-beds and beds of acid effusive rocks with their tuffs.

A marked unconformity divides the Upper from the Lower Tertiary.

i. **Tidoengsche landen.** This region with the adjacent Cowie Harbour-region of Southern British-Borneo again forms a geosynclinal border basin, filled by an Upper Tertiary series of great thickness. It is separated from the basin of Boeloengan and Beraoe by the geanticlinal sill of the Latoeng-mountain country. The transition in the geanticlinal limestone-series on the southern slope of the latter cannot be followed, however, because of the transgressive overlapping of „Pliocene''. In the „Pliocene'' both basins were united into one facies region.

From above downwards the following section of the Upper Tertiary could be traced:

The stage-*h* is only present on the island of Mandoel in greater thickness. Here we can distinguish from above downwards:

c. Upper lignite-group (lignites with 33 % water) (SCHÜRMANN), possibly already Boenjoe-beds.

b. Sand- and gravel-series, 600—700 m. with oil.

a. Lower lignite-group (lignites with 27 % water with oil, 130—190 m.). *a* and *b* are equivalents of the Tarakan-beds.

In the further regions of the Tidoengsche Landen (Noenoekan,

Sebatik, Simengaris-region) stage-*h* is only represented by a thin covering.

Below Tertiary-*h* on Mandoel follow the so-called Mandoel-marls, a series of soft sandy marls and clays, marl-limestone and impure limestone-beds, with much *mollusc*-detritus, *corals* and *smaller foraminifera*, but without *Lepidocyclinae*. They correspond exactly to the Antjam-beds of Central Boeloengan. Below they merge into a sandy clayish, very monotonous formation similar to the Koetei-formation. This covers the whole of stage-*f* and the upper part of stage-*e*. It is here given the name of Simengaris- or Sebatik-formation. As it is very poor in fossils, never having yielded any characteristic *foraminifera*, no classification can be made on a paleontological basis. As in the Koetei-formation a classification on lithological principles is also very precarious.

The percentage of sandstone, shale and coal in the composition of this formation, which is the only basis for a classification, changes laterally very rapidly, so that the classifications of the various separated regions of this formation in the Tidoengsche Landen are difficult to correlate with eachother.

In the neighbourhood of Mandoel only the youngest parts of it are known from the borings in the subjacent beds of the Mandoel-marls and from the hill country of Linoeang Kajan, where a great many brown coal-seams are found (water content about 15 %) and the facies completely corresponds to the brown coal-formation of Beraoe.

In the Simengaris-river-basin, which is entirely filled by this formation, two parts can be distinguished: a young part, the Taboel-beds, chiefly consisting of very soft clay-sandstones full of coallike vegetable detritus and soft shales with concretions with here and there *Operculinae*, thickness min. 2500 m. This part probably corresponds to the largest part of stage-*f* (Balikpapan-layers, part of the Poeloe-Balang-beds in Koetei, lignite-formation in Beraoe).

The oldest portion is indicated by the name of Meliat-sandstone and consists chiefly of pure, white, medium hard quartz-sandstone, between which are a few shale-beds with *Operculinae* and ill preserved *molluscan* remains and a good many brown coal-seams (water only 4 %). This series of 2200—3000 m. thickness corresponds to horizons-*e* 4—5 and possibly to the lowest part of -*f* (Beboeloeh-beds and Lower Poeloe Balang-beds in Koetei, Sterile-formation and part of the Globigerina-marls in Beraoe).

In the South, in the neighbourhood of the island Mandoel and the hilly country on the S. Linoeang Kajan only the younger part of the Simengaris-formation is found, containing many lignite-seams corresponding to the Taboel-layers, the facies being exactly like that of the lignite-formation of Beraoe.

The islands Noenoekan and Sebatik consist entirely of this formation, where yet another lithologic subdivision was found.

The whole is almost entirely free from coal, nor are any characteristic fossils found. On Noenoekan about 4800 m. and on Sebatik 4500 m. are exposed without the older subjacent beds appearing.

Below the pure sandstone-series in the Seboekoe-river-basin there follows a lithologic transition-formation, which in its youngest parts

consists of a close alternation of well stratified clay-sandstones and shales (Upper Naintoepo-beds); going downwards it includes more and more marls and small *Lepidocyclina*- and limestone-beds (Lower Naintoepo-beds).

The whole series has yielded very rich *larger foraminifera* faunae, which were collected by one of the present writers and were described paleontologically in 1924 by the other. The upper part contains *Eulepidinae*, but in contrast to the zones *e* 4—5 no *Miogypsinae* (zone e 3), the lower part is characterized by the large number of *Eulepidina dilatata* and its microsphere variety *Lepidocyclina dilatata var. tidoenganensis*, the giant of the East India *Lepidocyclinae*, the discs of which attain a diameter of 8 cm., forming complete lumachellae (zone *e* 2).

The occurrence of corresponding fossil horizons in the Barito-basin may be deduced from DOUVILLÉ's work and they could also be observed in other places in North Borneo, but in all the rest of the Indian Tertiary they are unknown. The thickness of the Naintoepo-series is 500—700 m. By the disappearance of the interstratified sandy clays the Naintoepo-beds merge downwards into pure marls, the Mesaloi-marls. It is a fairly hard, greenish-grey, entirely homogeneous marl, with *Globigerinae*, free of sand and of exactly the same lithological type as the Globigerina-marls of the basin of the Beraoe. But while the latter may include the whole stage-*e* the facies here is confined to the very oldest part of this stage. This horizon is characterized by the presence of *Eulepidinae* and the absence of *Nephrolepidinae* with the exception of a very typical species, *Nephrolepidina isolepidinoïdes* with an embryonal-apparatus, which in its development stands between the isolepidine and the nephrolepidine types.

The occurrence of this form in a horizon, which lies between stage-*d* (in which *Isolepidinae* occur) and the Naintoepo-horizons (in which the normal *Nephrolepidinae* already appear) is very remarkable. It is, moreover, very characteristic that in the deepest horizon of stage-*e* no real *Spiroclypeus* is found, although strongly involuted *Heterosteginae (Heterostegina borneënsis)* do occur. Corresponding faunae are unknown in the other parts of the Upper Tertiary of the Indies, except perhaps in the Barito-basin (DOUVILLÉ's E-F beds). The Mesaloi-marl-series is about 1000 m. thick.

The oldest series of beds is again a lithological transition formation, the Tempilan-beds, of alternating, thin bedded sandstones and shales and marls of the Mesaloi-marl type, which by the increase upwards of the latter gradually merges into the pure marls. The thickness is about 1000 m. The *Eulepidinae* here occur together with *Camerina fichteli-intermedia* (stage-*d*). *Eulepidina papuanensis* found here, seems to be guide-fossil for this stage. Instead of the further developed *Heterostegina borneënsis* here only the normal *Heterostegina ruida* is amply represented.

In a downward direction there is a lithological transition into sandstone, probably of *e*-age. It could not, however, be ascertained if there was a complete conformity. Within the Upper Tertiary series no sharp unconformity could be observed. It is, however, not improbable that the middle Upper Tertiary sandstone-series is in a transgressive position with regard to the lowest Upper Tertiary. From this part the Plateau-sand-

stone of Central Borneo could have developed in an inland direction. Disregarding the evident, though faint folding, the high Meliat-sandstone-mountains show a remarkable morphological resemblance to the Plateau-sandstone-mountains of Central Borneo. The water percentage in the interstratified coal differs also little from the Boekit-Alat-coal of the Melawi-region.

The Upper Tertiary series of the Tidoengsche Landen continues into the neighbouring Cowie Harbour-region of Southern British North Borneo. The formations distinguished by REINHARD (Geogr. Journal 1924) from above downwards: Susui-sandstone, Tambalunan-shales, Higher transition-beds and Kapilit-sandstone correspond as a whole to our Simengaris-formation. The age of the Tambalunan-shales is determined by the presence of *Alveolina bontangensis*. The presence of *Lepidocyclina isolepidinoïdes* shows that here the deeper horizons (Naintoepo-beds and Mesaloi-marls) are present also. To these REINHARD's Lower-transition beds and Kalabakang-shales probably belong.

The Tertiary of **SUMATRA** can be divided into 4 parts:

a. the E. Sumatra geosynclinal region that can be subdivided into a North, a Central and a South part.
b. the intra-Barisan-basins, that are the basins in the great Pre-Tertiary mountain range.
c. the W. Sumatra region.
d. the islands along the West coast.

The North part of the E. Sumatra geosynclinal region is situated on a fold-axis, that must have run out to sea freely, in consequence of which this part was far more exposed to marine ingressions from the North than the central and South part. Thus variable facies were produced in this otherwise small region, with consequent lithological and faunistic differences. The stratigraphical table shows that these are also expressed in the names of the stages and horizons.

The most detailed division was given by the geologists who surveyed the Atjeh I region (Jaarb. Mijnw., Verhand. 1e ged. 1917).

From the fossils found in the various stages a stratigraphical division could be made.

The Lower Tertiary begins with the mica-quartz-breccia, in which limestone and rocks containing coal occur. In this series possibly the oldest known Tertiary *foraminifera* of Sumatra were found by HIRSCHI (T. K. N. A. G. 1910), namely *Assilina, Camerina, Discocyclina cf. pratti*. The mica-quartz-breccia is covered transgressively by the mica-sandstone-horizon. VAN ES (Jaarb. Mijnw. 1917, Verh. 2e ged.) found at the base a limestone with *Camerina* and *Discocyclina*, so that the lowest part of this series should be placed in Tertiary-*b*. Possibly the highest part is Tertiary-*c*.

This is the close of the Lower Tertiary. The whole must be marine as marine fossils are everywhere included.

According to the Atjeh-geologists the following stage, the black-shale, is connected with the mica-sandstone by transitions.

At the base of the black-shale *Camerinae* together with *Lepidocyclinae* were discovered. The age of this stage must therefore be Tertiary-*d*. In contrast with the other parts of Atjeh the black-shale of Atjeh I could be subdivided into black-shale s. str. and Peunoelin-sandstone. Above this, follows a very thick series of clayish strata: the marginal-clay. Again it is only in Atjeh I that this can be subdivided.

At the base a rich fauna of *larger foraminifera* was discovered, that has been described by OPPENOORTH (Verhand. Geol. Mijnb. Gen., Geol. ser., Deel 2). The combined occurrence of *Eulepidinae* with *Miogypsinae* renders a correlation possible with the Beboeloeh-zone of E. Borneo (Tertiary-*e* 5).

The Atjeh-geologists do not assume unconformities above the mica-sandstone. It should be pointed out, however, that in the southern part of the region (Langkat) according to VAN LOHUIZEN's map (Jaarb. Mijnw. 1921, Verh. 1e ged.) the mica-sandstone is of greatly varying thickness at the eastern edge of the pre-Tertiary mountains. Further the black shale can reach to the edge of these mountains and finally both stages can wedge out between the marginal clay and the Pre-Tertiary. It must be admitted that this was partly explained by unlikely polygonal faults at the edge of the Pre-Tertiary, but it seems from the map that the Lower Tertiary is only present in relics below transgressing deposits of the Tertiary-*d*. Finally even these relics disappear in consequence of the overlapping of the Upper Tertiary.

From the Tertiary-*e* upwards variations in the depth of the sea occurred as a consequence of the differing rates of sedimentation and geosynclinal subsidence. This explains why now one and then the other genus of *foraminifera* took the upperhand, and also the distinctions Robulina-clay, Rotalia-zone, Operculina-zone. But it is obvious that from the frequency of a certain foraminiferal genus only local subdivisions can be deduced. No stratigraphical importance can be attached to it. These numerous *smaller foraminifera* will nevertheless prove to be of great importance for the stratigraphy. But this will only become evident after the determination of the various species and varieties. As this has not yet been done a rich field of work awaits the micropaleontologist.

Larger foraminifera that could point to Tertiary-*f* have not yet been found. But we may assume that the larger part of the marginal-clay belongs to this stage.

The numerous mollusca from the Rotalia-zone and younger beds have been examined a few years ago by MARTIN. As result we now know that these beds, the tuffaceous sandstone-zone included, a series of 6000 m. thick, belong to the „Pliocene". This great thickness, however, indicates that possibly we are dealing with Tertiary-*g* and -*h* as well. The very uppermost zone containing brown coal, shows that the regressions took place very late in this region.

The central and South part of the E. Sumatra geosynclinal region differs entirely from the North part. Thus the existance of Lower Tertiary has as yet not been proved anywhere by fossils. There are reasons, put forth below, for assuming that it is entirely absent.

Along the entire eastern edge of the Barisan-mountains and also in

the neighbourhood of the Pre-Tertiary domes, as the Tigapoeloe-mountains, quartz-sandstones with coal-seams occur, that lay unconformably on the Pre-Tertiary with basal conglomerates. From convention all these deposits have up till now been counted as Lower Tertiary, influenced by the analogy with the quartz-sandstones with coal of the Ombilin-basin. It will be proved, however, when dealing with this intra-Barisan-basin, that the correctness of the dating of the quartz-sandstones is open to doubt.

This analogy — if we allow it — is not opposed to an Upper Tertiary age of these quartz-sandstones. Furthermore there are arguments directly in favour of this view. They are the following:

1. It is always pointed out that the quartz-sandstones are conformably covered by the reef-limestones or beachformations at the base of the Goemai-Telisa-series. For the whole of southern Sumatra an age Tertiary-*e* 5 is assumed for these and in Indragiri possibly even Tertiary-*f* 1.

2. The water content of the lignites interstratified with the quartz-sandstones is not so small that a Lower Tertiary age should be assumed. Thus the coal from the environments of the Tigapoeloe-mountains have a water percentage of about 10 %, around the Doeablas-mountains about 9 %, in the Sepoetih-basin (Lampongsche Districten) 5—11 %. TOBLER already looked upon these deposits in Djambi as the equivalents of the Goemai-Telisa-series. Coals with similar water contents correspond in eastern Borneo to the upper margin of the Poeloe-Balang-series (Tertiary-*f* 1).

3. In the upper parts of similar quartz-sandstones and conglomerates in the Lampongsche Districten beds, interstratified conformably, with *Spiroclypeus tidoenganensis* and *Miogypsina dehaarti* (Tertiary-*e* 4) occur.

We believe these arguments sufficient for the exclusion of Lower Tertiary in this region. It is more probable that we must place the quartz-sandstones in the Upper Tertiary, with Tertiary-*e* 4 as upper margin. It has been sufficiently shown by the paleontological investigations of the last years that the fossiliferous limestones and shore deposits at the lower margin of the Goemai-Telisa-series are not older than Tertiary-*e* 5 (Batoeradja-limestone). The former determinations of age by H. DOUVILLÉ, that pointed to the presence of several horizons of the Upper Tertiary, are found to need correction on account of the modern insight obtained from the distribution of the larger foraminifera.

Between the base of Tertiary-*e* 5 and the lower margin of the Upper Tertiary the deposits on Borneo attain thicknesses of 3000 m. The quartz-sandstone-series of Central and Southern Sumatra may correspond with part of this series.

Up till the Tertiary-*e* 4 the freshwater and brackish deposits prevail, but with the Tertiary-*e* 5 marine conditions begin.

The sediments of Tertiary-*e* 5 sometimes overlap the pre-Tertiary (Goemai-mountains) from which it follows that a positive shift of the strandline took place (Beboeloeh-transgression).

Following this transgression the basin soon increased in depth during the lower part of Tertiary-*f*.

But the sedimentation outstripped the geosynclinal subsidence and during the Tertiary-*f* the littoral facies predominated. During the Ter-

tiary-*g* the numerous deposits of lignite were formed, proving that at this period dry land must have begun to form.

During Tertiary-*h* the sea made way for dry land, which follows from the terrestrial and fluviatile deposits.

Starting with the Tertiary-*e* 4 an enormous sedimentation took place in the oblong basin of central and South Sumatra. The history of the basin was so uniform, that deposits were formed that allow of the same subdivision, over exceptionally great distances. Here TOBLER introduced the subdivision into Goemai-Telisa-series, Lower-, Middle- and Upper-Palembang-series. However, it remains questionable, whether this subdivision, that is based upon lithological characteristics, especially for the younger part, runs parallel with the stratigraphic subdivision. In his „Voordrachten over de geologie van Nederlandsch Oost Indië" RUTTEN already suspected that the sedimentation of the central part sooner outstripped the geosynclinal subsidence than in the South part, that is as much as to say that the sea bottom was converted into dry land sooner than in the South.

In analogy herewith the age of the Lower Palembang-series (or rather the Lower Palembang-facies) decreases towards the north. Thus TESCH described a molluscan fauna collected by BROUWER in the Kampar region as „Uppermost Miocene". We are here in the transition to the facies region of northern Sumatra. The connection, however, is obscured over a distance of about 300 km. by a covering of recent volcanic deposits.

To confirm this supposition an investigation of the microfauna of the various strata may prove to be of great value. Here too, however, but little has been done in this direction. Several foraminiferal faunae have been investigated, but almost exclusively *larger foraminifera*. Through these investigations we are able to fix several stratigraphical horizons. Thus from the combined occurrence of *Eulepidina* and *Miogypsina dehaarti* the lower part of the Batoeradja-group could be placed in Tertiary-*e* 4 and the Gilas-series and the Lower Palembang-series must begin with the Tertiary-*f* 3 on account of the presence of *Lepidocyclina (Tryblio-lepidina) rutteni*.

On the other hand the occurrence of several *foraminiferal* faunae has been cited, that as yet await a thorough investigation. Thus it would be of importance to investigate the *Lepidocyclina*-limestones that VON STEIGER mentions from the basis of his „Marl-formation" (Jaarb. Mijnw., Verhand. 1e ged., 1920). In the same manner a more detailed investigation of the limestone of Merambang in the Southwest part of the Goemai-mountains, would help us to determine more accurately the lower margin of the Goemai-series.

The intra-Barisan-basins. In the mountain chains of the Pre-Tertiary spine of the island, a large number of isolated, generally small Tertiary basins are found. Of these the Ombilin-basin soon attracted notice on account of its wealth of coal. VERBEEK made the first investigations here, his work being completed by TOBLER and in the latter years by MUSPER (Jaarb. Mijnw. 1929, Verh.).

In analogy with the Lower Tertiary of S. E. Borneo VERBEEK attempted to distinguish the following series from bottom to top:

1. a breccia-series, 2. a marl- and shist-series, 3. a quartz-sandstone-series and 4. a limestone-series. VERBEEK considered the whole to be of Lower Tertiary age. It soon transpired, however, that the youngest part belongs to the Upper Tertiary. Later other changes in VERBEEK's stratigraphy were found to be necessary. Since MUSPER's investigations we now distinguish:

1. a breccia- and marl-shale-series resting unconformably on the Pre-Tertiary rocks. At the basis coarse clastic detritus of the Pre-Tertiary often occurs. Upwards follows an alternation of fine grained marls-shales and coarse grained beds. The slow sedimentation of the marl-shales, from which one of the richest fish-faunae of the world is known, must frequently have been interrupted by the supply of very coarse terrigenous material.

2. a quartz-sandstone-series, chiefly composed of white quartz-sandstone, shale, coalshale and coal. The most recent investigations by MUSPER have shown that they rest unconformably on the breccia-marl-shale-series, so that it generally lies directly on the Pre-Tertiary. At the base of this series a basal conglomerate occurs in which MUSPER found marine *foraminifera*, while the Pre-Tertiary substratum had been bored into by *mollusca*. This series further contains the well known coal measures of the Ombilin-basin, that are being worked. The thickness of the series may exceed 1000 m.

3. a marl-series, that rests conformably on the foregoing group according to MUSPER. It consists of tuffaceous marls and shales with locally at the base a marly-sandy conglomerate. About 300 m. above the base lies the limestone of Batoe-Mendjoeloer, the famous *foraminifera* locality, that belongs to the Tertiary-*e* 5 (Beboeloeh horizon of Borneo) according to the investigations of UMBGROVE. In another region at Tg. Bonai Aoer an equivalent limestone, with a similar fossil content is already found 30—40 m. above the quartz-sandstone-formation. Above the limestone of Mendjoeloer the marl continues. In this the *molluscan* faunae of Tg. Ampaloe and of Bt. Lawas occur, the latter also containing *Lepidocyclina sumatrensis var. inornata* and *Miogypsina thecideaeformis*. The upper part of the marl section belongs to Tertiary-*f*. therefore. MARTIN believes the *mollusca* of Tg. Ampaloe to be „Upper Miocene".

We are therefore sure that the marl-series is Tertiary-*e* 5 to Tertiary-*f*, but we are as yet uncertain as to the age of the quartz-sandstone-series. Truly MUSPER points out that they are conformable, but the following is curious: 1. the occurrence of conglomerates at the basis, 2. the convergence of the basis of the marl-series with the Pre-Tertiary substratum, 3. the strongly varying divergence in thickness of the quartz-sandstone-series and 4. the fact, that the lower part of the marl-series is of the age of the Beboeloeh-horizon, a horizon that is found to be transgressive throughout the whole archipelago.

If a transgression and a break actually exist, the quartz-sandstone-series may belong to the Lower Tertiary, as was assumed by VERBEEK

on account of the analogy with the sandstone-series containing coal of Pengaron.

But if the contact is conformable, it seems impossible to place this series in the Lower Tertiary as it follows directly below the fossiliferous horizons high up in the Upper Tertiary. The water content of the coal does not need to withhold us from this conclusion as we know of coal that is certainly Lower „Neogene" with a water content of no more than 20 % (Pamaloean-series, Meliat-sandstone). An other argument in favour of this point of view is the existence of a very thick stage of breccia-marls below, to which a Lower Tertiary age is generally assigned.

To the south of the Ombilin-basin in depressions of the Barisan a number of similar intramontane basins are to be found, that were examined by TOBLER (Jb. Mw. 1919, Verh. 3e ged.).

In the north Korintji-basin a conglomerate-sandstone-group is met with and above it a coal-bearing shale- and sandstone-group, that TOBLER looked upon as an equivalent of the Goemai-Telisa-series.

An almost identical section is found in the Asai-Rawas-basin. In this coal is already met with in the basal portions with a very low water percentage (1,2 %). This part may be correlated with the breccia-marl-shale-series of the Ombilin-basin. The shale-series also contains coal and is reckoned to the Goemai-Telisa-series to which it shows a marked lithological resemblance.

The Kesiro-basin also contains a similar series. In the upper part a coal is found with 8,6 % water, that is held to be „Lower Miocene". As in the Ombilin-basin conformity between the lower („Eocene") and upper („Lower Miocene") series is assumed. The age determinations must also be accepted with some reserve. It should be pointed out, however, that TOBLER correlated the coal-bearing beds with the Goemai-Telisa-series.

The west Sumatra region consists in its northern part at the transition to the intra-Barisan-basins of the Tertiary region of the Upper Impoe. Here we find predominating andesite tuffs over a thickness of 2000 m. with a few marine sedimentary inclusions, amongst others on the Bt. Linggis, where *Lepidocyclina verbeeki* and *Miogypsina* are encountered. This points to an age Tertiary-*f* 1. TOBLER also believes this to be a tuffaceous facies of the Goemai-Telisa-series. It is noteworthy that this series rests directly upon the Pre-Tertiary.

HARTING's reports on the neighbourhood of Tambang Sawah (Jb. Mw. 1929, Verh.) are in accordance with this. Here too a marl-shale-series with coal-seams with 11,5 % water, lies directly on the Pre-Tertiary, the age being Tertiary-*f*, which follows from UMBGROVE's determination of *Miogypsinae*. The covering beds are also tuffaceous and contain a lignite horizon. HARTING brings these together in a „breccia-series".

In southern Benkoelen MOERMAN (Jb. Mw. 1915, Verh. 1e ged.) assumes „Eocene" at the base of the Tertiary. He calls this stage the sand- and shale-series. As MOERMAN discovered *Globigerinae* in this stage, this might possibly represent marine Lower Tertiary.

In the Upper Tertiary MOERMAN found *Lepidocyclina*-limestones, that

evidently occur at the basis. They are propably of the same age as the Batoeradja-limestone as they contain *Spiroclypeus*. Further we find: breccia's, sandstones, marl-sandstones, shales and marls with coal-seams, evidently a tuffaceous series with marine inclusions. The *molluscan* fauna of Kamoemoe, described by BOETTGER, as of „Upper Miocene'' age occurs in the same series. TOBLER was inclined to place these fossil localities at the base of the Lower Palembang-series.

A third, still younger series, that MOERMAN counts as „Upper Miocene'', consists of sandstones, grey-marls and shales. The *molluscan* faunae of Konkai, Kampar and Kroë, described by BOETTGER, that occur in this series are reckoned to the „Middle Miocene'' by MOERMAN. TOBLER placed them in the Lower Palembang-series, just as the Kamoemoe-beds. Finally it should be pointed out that the coal-seams occur throughout the entire Upper Tertiary with 1,4—20,4 % water.

Of the islands along the west coast our knowledge of the paleontology is fairly extensive, but of the stratigraphy only little is known.

The only islands, of which we have informations are Nias and Engano. Since VERBEEK, however, no fieldwork has been executed.

According to VERBEEK the entire island Nias consists of a fairly intensively folded series of soft, grey to blue marls, greyish clays alternating with fine grained marley or clayish sandstones, a few scarce small brown coal-seams. They are unconformably covered by limestone, that was sometimes looked upon as an unconformable slab of „Pliocene'', sometimes as elevated reef-limestone. The latter is partly right, as elevated coral-limestone also occurs above the „Neogene'' formation on Engano. Partly the limestone belongs in the series as *Lepidocyclina*-limestone (Gg. Sitoli).

From the investigations of MARTIN and DOUVILLÉ (Samml. Geol. Reichsmus. Leiden, Ser. I, Bd. 8) it followed, that on Nias the stages Tertiary-*a* to -*g* must be represented. The occurrence of marine Lower Tertiary here is of especial importance.

It is curious, that as far as the representative fossil samples show, a break occurs from Tertiary-*a* to -*e* 5, as all the Upper Tertiary samples point to an age Tertiary-*e* 5 (Hilegara). Should a Beboeloeh-transgression be assumed here too?

From the *mollusca* MARTIN proved the existence of „Middle- and Upper „Miocene'' (Hiliberoedjoe and Dahana).

On Engano slightly folded Upper Tertiary with brown coal has been found, covered by horizontal limestones.

The **LOWER TERTIARY OF JAVA** is only known from two regions. One is situated in South Bantam and West Priangan, the other in Central Java.

In West Java the oldest series is exposed in West Priangan on the Tjiletoe-bay. Here we meet with a series of breccia's, sandstones, marls and limestones (with *Camerina* and *Discocyclina*) covered by a series of barren quartziferous sandstones and clay-shales, with coal-seams. The shallow sea must have been converted into land. It is not impossible,

however, that fairly soon afterwards a subsidence of the land or a rise of sea level took place, for in Bantam, in the coal-fields of Bajah and Tjimandiri, sandstones, black-shales and limestones are again found, that must be of marine origin and that lie upon the continental deposits according to ZIEGLER. The presence of the foraminifera: *Camerina djokdjokartae* and *Discocyclina fritschi* prove that these strata, the Tjitaroetoepbeds (Jb. Mw. 1928, Alg. ged.), are of the same age as the well known Nanggoelan-series. For the limestone-stage of Tjiletoe an age Tertiary-*a* must be assumed, which is in accordance with the data of GERTH (Proc. 4th. Pac. Sc. Congr., 1929).

The Tertiary-*c* is also represented in West Java. This follows from the occurrence of quartz-sandstone with lenses of limestone, that contain *Camerina fichteli-intermedia* (amongst others at Tagogapoe).

Thanks to the investigations of the „Opsporingsdienst" the stratigraphy of the Lower Tertiary of the „Zuidergebergte" in Djogjakarta and Soerakarta is well known. There we can distinguish from young to old:

3. the Gamping-series, consisting of shales with countless foraminifera, amongst others *Discocyclina omphalus*. From this, and the absence of *Assilina* we must assume an age Tertiary-*b*, probably the same age as the Priabonian of Europe.
2. the Dawa-beds, marls and slabs of limestones in which amongst others *Camerina gizehensis* is found, that also occurs in British India, N. Africa and Europe. This species is characteristic in British India for the upper part of the Middle Kirthar, in Europe for the Auversian.
1. the Woengkal-series, divided from the Dawa-series by an unconformity. They contain the following most characteristic fossils: *Assilina spira* and *Discocyclina sowerbyi*. These render a correlation possible with the Middle Kirthar and the Lutetian of Europe.

GERTH (Academieverslagen 1930) believes the *foraminifera*-fauna of Gg. Gamping to the west of Djogjakarta to be still older, namely Tertiary-*a* 1.

The classical region West of the Kali Progo in the West of Djogjakarta also contains Lower Tertiary strata, the famous Nanggoelan-series. Here also *Discocyclina omphalus* is found amongst others, making a correlation with the Gamping-series probable. These strata are famous for the rich fauna of *mollusca*, that MARTIN has described. He was thus able to show, that during the Priabonian there existed a fauna in East India that shows some striking resemblances with that living in the basin of Paris at the same time, without, however, one single species being in common. At this moment the region of the East Indian Archipelago was already separated from the Tethys and the development of the characteristic autochthonous fauna began.

A third region of Lower Tertiary in Central Java lies further to the West in the Lohoeloe-mountains. The Lower Tertiary strata recline on Pre-Tertiary rocks except in the North. HARLOFF (exc. guides 4th. Pac. Sc. Congr.) describes a basal conglomerate with Pre-Tertiary com-

ponents, in which lenses of limestone occur, that contain some *Assilinae*. This proves an age of Tertiary-*a* and an unconformable contact.

The occurrence in the neighbourhood of conglomerates, that contain pebbles of the limestones just mentioned points to an unconformability above this rock also. These higher rocks do not appear yet to belong to the Upper Tertiary.

All Lower Tertiary deposits of Java are littoral formations. They are only known along the southern edge of the island and GERTH supposes, that the north coast of the Lower Tertiary sea was to be found within the region of the present island (Geol. Rundschau, Bd. 22, H. 3—4).

The **UPPER TERTIARY OF JAVA** has first been subdivided by MARTIN, on the evidence of large collections of *mollusca*, that had been collected by JUNGHUHN, VERBEEK, FENNEMA and himself on Java. He was able to compare the mollusca from a certain bed with the recent fauna. The percentage of forms he found that are still alive was a measure of the relative age of the investigated bed.

In the Upper Tertiary of Java 3 distinct facies running the entire length of the island can be distinguished, a geosynclinal facies in the middle, flanked on both sides by transitions to a shelf- or a geonticlinal facies.

The **geosynclinal facies** spreads over the whole of the North part of the island with the exception of the strip North Semarang-Madoera. As in E. Borneo and Sumatra deposits, thousands of meters thick, are met with.

In southern Rembang, where the axis of the geosyncline must have lain, it is often difficult to make a subdivision, on account of the monotony of the sediments. Further towards the north, however, in Middle Rembang, where the sea was shallower, the intercallation of more littoral sediments renders a very detailed subdivision possible, that we will become acquainted with when dealing with the zone of the northern facies.

The deposits of Boemiajoe in Tegal also belong to the geosynclinal facies. This locality has become famous lately from the discovery of countless species of vertebrates.

The lowest part of the series is occupied by a clay-marl- and limstone-series, in which some *Lepidocyclina (Trybliolepidina) rutteni* has been found. Obviously this series should be correlated with the Wonotjolo-beds of Midden-Rembang. Above follow a tuffaceous sandstone, a breccia-series of 1000 m. and a conglomerate series of 200—250 m. Possibly these are of the same age as the Ledok-series, Globigerina-marls, and the clay-marls of Rembang, respectively, but there is no certainty. The conglomerate-series are followed by the Turritella-zone, 127 m. thick, containing a rich *mollusca*-fauna, that shows great resemblance to the fauna described by MARTIN from the Tji Djoerei in Cheribon. MARTIN believes these beds to be „Pliocene", but older than the Sondé-beds. Finally we find a vertabrate-zone of 600 m. In the lower parts lignite-seams occur with 50 % water and remains of mammals. VAN DER MAAREL determined amongst others *Mastodon perimensis, Stegodon airawana* and a *Hippopotamus.*

The geologists of the survey of Java count this zone to the „Pliocene" (Jb. Mw., Alg. ged. 1929).

To the geosynclinal facies we must further count the fossiliferous beds of Tjandi, Pangka, Tji Djadjar, Tji Djoerei and Waled, that have become famous since MARTIN determined and described the *mollusca* they contain, and further the enormous series in the section of the Tji Kao valley in Krawang that W. C. KLEIN described in great detail (VERBEEK-gedenkboek).

MARTIN also described several *mollusca* from a boring at Batavia (Samml. Geol. Reichs-Mus. Leiden, Ser. 1, Bd. 3) and concluded that the boring had sunk through the Quaternary and „Pliocene" into the „Upper-Miocene". These localities also belong to the geosynclinal facies, so that it becomes evident, that the North Javanese geosyncline may be looked upon as a continuation of the East Sumatra geosyncline.

To the **northern facies** belongs the already mentioned strip North Semarang-Madoera, in which the facies forms a transition between geosynclinal and shelf-facies.

Over the entire breadth the Upper Tertiary can be divided into three parts, with distinct lithological characters namely a lower part, with *Lepidocyclina* and rich in lime, a middle part rich in *Globigerina* and an upper part principally of clay-marls, in which locally large *mollusca* faunae have been met with (Sondé-series). In S. Rembang, where the axis of the geosyncline was situated it is frequently difficult to distinguish the boundaries of these three parts. In Midden-Rembang, where the sea was shallower the intercallation of littoral sediments open the possibility of a further subdivision. The lowest part we find is an „Orbitoidal-limestone" about 500 m. thick, that is probably younger than the „basis-marls" in Madoera. The covering Amphistegina-marls and Ngrajong-series may be correlated with 'T HOEN's N 1. They attain a thickness of 400 m. and are more sandy and locally contain small coal-seams. The *Lepidocyclinae* they contain point to an age Tertiary-*f* 1-2. It is impossible to say in how far the strata, called „Rembang-series" in the literature, can be correlated with the whole or with part of the whole series just mentioned, as all writers are not agreed on the boundaries of these „Rembang-series".

The Ngrajong-beds are covered by the Wonotjolo-beds, the lowest member of the Globigerina-series. The occurrence of *Lepidocyclina rutteni* proves that the lower margin of the Wonotjolo-beds coincides with the boundary between Tertiary-*f* 2 and *f* 3. The Ledok- and Globigerina-marl-beds form the middle and upper parts of the *Globigerina* containing series, of 400—900 m. thickness.

The upper series covers the Globigerina-marls unconformably. Mainly, they are clay-marls, here and there with rich faunae of *mollusca*, and with transitions to limestone, so called „karrenkalk". To these series the Toeri-beds and the Sondé-beds belong. The latter especially are well known, from the rich *mollusca*-fauna that MARTIN described. He found 53 % still living species, on which evidence he counts these strata to the „Pliocene".

The **southern facies**, as the northern, forms a transition between the geosynclinal facies and the shelf-facies. This is marked especially by the intercallations of limestones.

In the southern facies, that runs the entire length of southern Java, we can distinguish 3 regions. The first region situated in Bantam and southern Priangan, is characterized by its strong affinity to the Upper Tertiary of Sumatra, the second region, situated in middle Java, has a more „Javanese" character. In between we find a third region, within which the famous fossil localities of Njalindoeng and Tjilanang are found.

In the region of Bantam and southern Priangan the sea bottom probably rose after the deposition of the Tjitjaroetoep-series (during Tertiary-*c*). There is namely a stratigraphical hiatus between the Lower Tertiary sediments and the lower part of the Upper Tertiary, the Tjidjengkol-beds.

The lowest parts of these beds, about 150 m., consist of clay-marls, limestone and marl-sandstones, merging downwards into coarse, hard, green, andesitic conglomerates and gravel stones, locally with tuffs.

Besides *Camerina fichteli-intermedia* it contains the first *Lepidocyclinae* and therefore belongs to Tertiary-*d*. The upper part, also about 150 m. thick, is composed of coral- and algae-limestones with a few small layers in between of shales, clay-marls and lime-sandstone; it contains *Eulepidinae* and *Pliolepidinae* and must be counted to the Tertiary-*e*. After a stratigraphical break, the Tjimapag-series follows upwards, that is chiefly composed of shales, sandstones, marls with *Lepidocyclina, Spiroclypeus* and *Miogypsina cf. dehaarti*. This Tjimapag-series, that is about 1000 m. thick, thus belongs in the topmost part of the Tertiary-*e*. It is unconformably covered by the „Pliocene" (Jb. Mw., Alg. ged., 1928 and 1929).

Probably southern Bantam was land during the deposition of the Tjimapag-series and the „Pliocene"-deposits. Further to the north, however, a limestone has been found, that contains *Lepidocyclina, Miogypsina* and *Alveolina globulosa*, that also belongs to Tertiary-*f*, thus forming the link between the marine deposits of southern Bantam and those of Middle Bantam, as they have become known through the investigations of ZIEGLER (Jb. Mw. 1918, Verh. 1e ged.).

Following VAN ES, ZIEGLER used the names employed by TOBLER for Sumatra: the Lower, Middle and Upper Palembang-series „although — as ZIEGLER himself says — the petrographic resemblance is but small between the series of strata of the two regions and it is doubtful whether the correlation is allowable from a paleontological point of view".

ZIEGLER distinguishes, from younger to older:

4. Uninterrupted tuff-deposits, the so called „Upper Palembang-series".
3. Grey to black tuffaceous clay-sandstones of andesitic origin; also actual tuffs with much brown coal: the so called „Middle Palembang-series". Thickness 600—1000 m. Water content of the coal 19 %.
2. Limestone-beds with *Lepidocyclina, Cycloclypeus* and corals, up to 200 m. in thickness.
1. Compact, well stratified shales with concretions, the so called „Lower Palembang-series", thickness min. 600 m.

From the fossil content of the limestones, mentioned sub 2, it is clear that here too the lithological and the paleontological limits do not coincide when using the names introduced by TOBLER.

The only *Lepidocyclina (L. rutteni)* that occurs in the Palembang-series on Sumatra, was found in the lowest part of the Lower Palembang-series. Here *Lepidocyclinae* were found between Lower and Middle Palembang-series. Therefore the margin between Lower and Middle Palembang-series in Bantam must certainly lie lower in the stratigraphical timescale than on Sumatra.

For the region in Middle Java the deposits of the West Progo-mountains and in the Djiwo-hills may be taken as typical examples.

In the West Progo mountains occurs andesite, that is covered either by an andesitic agglomerate or by shell-clays, marls, sandstones, reef-limestones, claystones and clay-marls, with a rich fauna of molluscs and foraminifera, generally known as the W. Progo-beds. MARTIN examined the *mollusca* he and others collected there. He found 8 % still living forms, so that he decided on a „Lower-Miocene" age and considers this fauna as the most ancient of the „Neogene" of Java. The foraminifera contained in this series: *Lepidocyclina (Nephrolepidina) sp., Miogypsina thecideaeformis* and *Alveolina globulosa* would, however, point to a somewhat younger age (Tertiary-*f* 1 or -*f* 2).

In the Djiwo-hills the Upper Tertiary reaches a thickness of 4500 m. Here, however, we see a clear division in an Upper series (Kepek- and Wonosari-series), not thicker than ± 500 m. (Jb. Mw. 1928, Alg. ged.) divided from the much thicker lower part by an unconformity.

7. The Kepek-series consists of clay marls with *Globigerina* and intercallated beds of sandstone and laminated limestone with *Lepidocyclina.*
6. The Wonosari-series contains weakly folded, laminated limestones and reef-limestones, at the base merging into marly, tuffaceous rocks. On account of the presence of *Lepidocyclina rutteni* these beds must be reckoned to Tertiary-*f* 3, so that the overlying Kepek-series, that also contain *Lepidocyclinae* and therefore cannot be younger than Tertiary-*f*, must also belong to Tertiary-*f* 3.
5. The Sambipitoe-series are divided from the Wonosari-series by an unconformity. They consist of brownish green, tuffaceous sandstones and light yellow shales, amongst others with *Lepidocyclina verbeeki.* They probably belong to Tertiary-*f* 1, so that possibly during the Tertiary-*f* 2 the region was dry.
4. The Nglanggran-series that are about 1000 m. thick, are divided from the covering Sambipitoe-series by beds of volcanic agglomerates. They consist of hard andesite agglomerate.
3. The Semilar-series are about 1350 m. thick. They are sharply divided from the overlying beds. They consist of dacitic tuffaceous sandstones, tuffaceous limestones and very coarse pumice breccia-beds.
2. The Boelat-series consist of conglomerate-beds of andesitic material, alternating with brownish green sandstones and in the upper beds party-coloured tuff breccias. Towards the east the rocks are finer grained and grey shales predominate.

1. The Kebo-series contain in their upper parts beds of pumice tuff-breccia, further down green, somewhat marly, hard shales and tuffaceous sandstones, alternating with yellow brown and grey shales with *Globigerinae* and *algae* and in the lowest part beds with pebbles of basalt, shist, quartz-sandstone and Lower Tertiary limestone.

The entire series lies unconformably on the Lower Tertiary. We cannot say, however, when this transgression took place as the subdivision of these oldest beds of the Upper Tertiary has been made entirely on lithological evidence.

The third region, that shows a southern facies, lies in between the two former. To these belong the Tagogapoe-beds, the Njalindoeng-beds and the Tjilanang-beds.

The deposits in the neighbourhood of Tagogapoe we know from the description by HARTING (exc. guides 4th. Pac. Sc. Congr.). The quartz-sandstones contain limestones with *Camerina fichteli-intermedia* and therefore belong to Tertiary-*c*. They are unconformably covered by a Lepidocyclina-limestone with *Lepidocyclina flexuosa, L. sumatrensis var. inornata, Spiroclypeus leupoldi* and *Miogypsina* (Tertiary-*e* 5). As in South Sumatra, the upper part of Tertiary-*e* transgresses over the Lower Tertiary. Above this limestone sandstone-beds and conglomerate-beds follow, the latter of which according to the foraminifera belong to the Tertiary-*f* 1 or 2.

In the classical fossil localities of Tjilanang and Njalindoeng MARTIN found 18 % still living forms in the former and 32—33 % (Leidsche Geol. Meded., Deel 3) in the latter. The Tjilanang-beds he therefore counts as „Upper Miocene" the Njalindoeng-beds as „Lower Miocene". Now in the Tjilanang-beds *Lepidocyclina (Trybliolepidina) rutteni* was found a few years ago (Wet. Meded., Nr. 1) so that these must be Tertiary-*f* 3. In the Njalindoeng-beds *Trybliolepidinae* were also found, but not the typical *L. rutteni*. The results of the investigation of the foraminifera do not necessarily contradict those of MARTIN, as was at first thought, when the subgenus *Trybliolepidina* was not known to occur outside Tertiary-*f* 3. It has been shown that this subgenus began even earlier. The investigations begun by the Java survey in these parts (Jb. Mw., Alg. ged., 1928) may bring the first solution of these problems.

Then the time will have arrived, that the important results, that MARTIN arrived at at the cost of so much labour, will obtain their full value, for MARTIN lacked the opportunity of coöperating with field geologists.

The **LOWER TERTIARY OF SOUTHERN CELEBES** shows a marked resemblance to that of S.E. Borneo. From bottom to top we first meet with a basal conglomerate, that rests unconformably on the Pre-Tertiary. Locally this is replaced by red sandstones and shales, as we already known them from the basis of the Lower Tertiary of Mangkalihat. Then follows a coal-sandstone-formation, that again strongly resembles that of south eastern Borneo in composition. Here too we find an alter-

nation of sandstones, shales, marls, limestones and brown coal. The water content of the coal varies strongly (1—20 %).

A difference with the Lower Tertiary of south eastern Borneo is the occurrence in south Celebes of andesitic tuffs, that are there unknown. ZIEGLER and 'T HOEN (Jb. Mw. 1915, Verh. 2e ged.) mention 200 m. as the thickness of the coal-sandstone-series, but as RUTTEN already pointed out (Voordrachten over de Geologie van Ned. Indië) a far greater thickness may be deduced from their sections.

The lowest part of the limestone-series, that lies conformably on the coal-sandstone-formation according to ZIEGLER-'T HOEN, must also be reckoned to the Lower Tertiary. The enclosed *foraminifera* show us that it must belong to the margin between Lower and Upper Tertiary. The Lower Tertiary is characterised by the occurrence of *Discocyclina* and *Camerina*.

The **UPPER TERTIARY OF SOUTHERN CELEBES** contains the upper part of the just mentioned limestone-series in its lowest part. In these strata BROUWER discovered a number of fossils, that were described by DE BEAUFORT, VAN STRAELEN and RUTTEN (Jb. Mw. 1923, Verh.). RUTTEN, who examined the foraminifera, found *Lepidocyclina brouweri*, *Spiroclypeus* and probably *Miogypsina*. These point to an age of Tertiary-*e*, more especially the upper part of this stage. The folding of the limestone-formation is very weak.

On the limestone-formation rests the Celebes-molasse that is about 3000 m. thick. In the lower part it consists of tuffaceous sandstones, lime-sandstones, tuff-marls, limestones and globigerina-marls, in the upper part of light coloured tuffs with thin lignite-seams and leaf remains. We may therefore assume a slow regression in southern Celebes during the deposition of the molasse. In the lowest part ZIEGLER and 'T HOEN found small *Lepidocyclinae* and *Miogypsinae*, so that this part must be reckoned to Tertiary-*f*.

Coral-limestone that may probably be looked upon as elevated Quarternary reef-limestone, rests unconformably on the Celebes-molasse.

In **SOUTH EASTERN CELEBES AND BOETON** only Upper Tertiary deposits are known, no Lower Tertiary rocks having been found. The oldest strata occur on Boeton, where BOTHÉ (Mijningenieur 1927, no. 6) found greyish clays, gravel clays, blue lime-sandstones and silicified limestones, that rest unconformably on Pre-Tertiary rocks. The gravel clays contain *Camerina*, *Lepidocyclina (Lepidocyclina) boetonensis* and *Orthocyclina*. Here too therefore we see a distinct transgression of the Tertiary-*d* stage. Over large expanses on Boeton we find Upper Tertiary strata, consisting of sandstones, clay-marls and shale bearing lime. Upwards this series is covered unconformably by globigerina-marls and chalky limestones. At the base of this series conglomerates and Lepidocyclina-limestone of varying thickness are found, of which BOTHÉ believes the age to be „Lower Miocene". We must therefore assume a second Upper Tertiary transgression, of which the age cannot be given exactly,

as Bothé does not mention the fossil contents. The „Lower Miocene" series can also fail entirely, so that the globigerina-marls come to rest directly on the Pre-Tertiary. This would be a third Upper Tertiary transgression.

As we will see later on, there is a strong resemblance between the Tertiary of Boeton and that of the islands of the outer Banda arc.

In the south eastern arm of Celebes we can also distinguish an Upper Tertiary transgression. There we find basal conglomerate, sandstones, shales and limestones, resting unconformably on the Pre-Tertiary.

Possibly an examination of the fossil content of the limestones will allow us to correlate this transgression with the second or third of Boeton. This Upper Tertiary series of the south eastern arm is often correlated with the Celebes-molasse of the southern arm.

The „Alveolina"-limestones, that cover a large part of the **EASTERN ARM OF CELEBES** as a central mountain chain belong to the Lower Tertiary.

The enclosed foraminifera: *Fasciolites wichmanni, Camerina cf. bagelensis* and *Discocyclina* point to an age Tertiary-*b*. These limestones are strongly folded.

It is improbable that the Toeli-limestones must also be counted to the Tertiary. It is true, that Hotz was of this opinion as he observed these limestones in close contact with limestones that are doubtless of tertiary age. Later investigations have shown, however, that this is the consequence of a complicated tectonic structure. That the Toeli-limestones are Pre-Tertiary need no longer be doubted.

The **UPPER TERTIARY OF EASTERN CELEBES** begins at the bottom with a strongly folded Lepidocyclina-limestone. This is exposed amongst others, on the coast at Kolokolo and on both sides of the central, Lower Tertiary limestone strip. Wanner (Neues Jahrb., B. 29, 1910) mentions the occurrence of *Eulepidina* and *Miogypsina* together in this limestone. Here again as on Sumatra and W. Java, we note the transgression of limestone of the Beboeloeh-horizon (Tertiary-*e* 5).

The Celebes-molasse follows unconformably on the Lepidocyclina-limestone. On the South coast it consists of blue grey marls, limestones, sandstones and sands. These are here slightly but distinctly folded and contain oil. Neither *Lepidocyclinae* nor *Miogypsinae* were found in them.

On the north coast at Todjo, Hirschi (T. K. N. A. G. 30, 1913) found strongly folded globigerina-marls, sandstones and conglomerates, that he also reckons to the Celebes-molasse. These conglomerates consist of enormous boulders and contain many basic igneous rocks. Probably overthrust sheets of Pre-Tertiary have been formed here. The thickness of the Celebes-molasse reaches 1200—1500 m.

In **NORTHERN CELEBES** only Upper Tertiary is known with certainty. Up to the present day Lower Tertiary has not yet been found. Concerning the stratigraphy of the northern arm the opinions are divided.

This must be attributed to the occurrence of a number of breccias and conglomerates, principally formed of volcanic material. In consequence of the predominating of volcanic material conglomerates of different ages can show a great resemblance.

The age of the Upper Tertiary limestones, that occur especially in the Minahassa at many localities can best be determined. It is these limestones that have become famous on account of their containing gold at Totok. These limestones contain *Spiroclypeus, Lepidocyclina sumatrensis* and *Miogypsina,* and can therefore be correlated with the Beboeloeh-horizon (Tertiary-*e* 5). The limestones are accompanied by sandstones and conglomerates with the same fauna besides globigerina-marls. They are enclosed between volcanic conglomerate of andesitic composition. On account of the intercallations of limestone KOPERBERG (Jb. Mw. 1928, Verh. 1e ged.) distinguishes a „pre-Burdigalian" and a „post-Burdigalian" part of the conglomerates. The first he correlates with MOLENGRAAFF's Woboedoe-breccia, described by MOLENGRAAFF from Soemalata in the centre of the northern arm (Zeitschr. prakt. Geol. 1902). In this region he distinguishes: 1. Woboedoe-breccia as upper formation, dipping slowly towards the coast; 2. further inland and probably unconformably covered by the Woboedoe-breccia, the Obapi-conglomerate; 3. the Doeloe Kapa-formation, a deposit, that is probably of Cretaceous age and has been metamorphosed by granite. The Woboedoe-breccia is a hard breccia or conglomerate consisting of fragments of diabase and augite porphyrite, of varying dimension, sometimes containing lime; the coarse clastic, volcanic material was probably deposited in sea. The Obapi-conglomerate is a real polygenous conglomerate, consisting of pebbles of granite, contact metamorphic rocks of the Doeloe Kapa-formation and limestone in a sandy cement, sometimes with lime and containing *foraminifera.* Without doubt this formation is a transgressive marine formation. Upwards it merges into shales with *Globigerinae.* The age could be fixed with certainty as Tertiary on account of the position further to the west at Paleleh.

AERNOUT, namely, considers the Obapi-conglomerate as of the same age as the cape Lintido-conglomerate of Paleleh, on account of the strong lithological resemblance. This rock consists of bits of shale, marl, quartz, limestone, chlorite and andesite. In this conglomerate UMBGROVE found *Lepidocyclinae* and *Miogypsinae.* If these fossils are embedded in the cement the age of the cape Lintido-conglomerate, and probably that of the Obapi-conglomerate also, must be Tertiary-*f.* Here the conglomerate merges upwards into a shale-formation of several hundred meters thickness, that is called the Timboelan-shale. This contains *Globigerinae* (UMBGROVE in AERNOUT, Mijningenieur 1927, No. 9) that do not allow a determination of the age, but are more likely to be Tertiary than Cretaceous in age. Above, the Woboedoe-breccia is again met with, containing pieces of the Timboelan-shale.

Probably the cape Lintido-Obapi-conglomerate and Timboelan-shale represent in this region of the northern arm the Totok-limestones and accompanying conglomerates and marls or are possibly even younger than these. As the original Woboedoe-breccia of Soemalata covers these fossiliferous deposits, and according to KOPERBERG the „pre-Burdigalian" an-

desite conglomerate is found below the fossiliferous beds, these „pre-Burdigalian" conglomerates may not be identified with the Woboedoe-breccia as KOPERBERG has done. It is difficult to ascertain whether these (older) andesite conglomerates occurring below the Totok-limestone are Tertiary. At Paleleh pebbles were found in the basal conglomerate of Gape Lintido of propylitisized andesite, that prove for this region also the presence of an oldest andesitic eruption phase, but of which the mother rock has not yet been found. This might be correlated with the (older) andesite conglomerates of KOPERBERG in the Minahassa.

All these deposits at Paleleh are broken through by the Dopalak-porphyrite. This rock carried the gold and may be compared to the gold bearing andesite of Totok. This correlation is rendered even more probable as GISOLF mentions, that a large part of the Dopalak-porphyrite should be named andesite (in: AERNOUT, Mijningenieur 1927, No. 9).

From the region of Bolaang Mongondow, situated between Paleleh-Soemalata and Totok, limestones are known from many localities with *Lepidocyclina*, conglomerate-limestones, sandstones and shales and marls bearing *Globigerinae*, that link the Totok-limestones to the *f*-deposits of the middle of the northern arm.

On the islands of the **INNER BANDA ARC** limestone-series are found that are easily recognized as the continuation of the Upper Tertiary limestone of the Zuidergebergte on Java. The age is probably no greater or not much greater than Tertiary-*f*. A second point of resemblance with the Zuidergebergte we can point to is the occurrence on Lombok of strongly folded breccias and tuffs, derived from andesites, but also from acid eruptions and situated directly below the limestone. In this we see an analogy with the tuffaceous series between the Eocene of the Djiwo-gebergte and the Wonosari-beds and Kepek-beds.

In Soembawa and Flores this limestone extends over the whole island, while on Bali and Lombok it is limited to the south. The limestones have been extensively studied, but the fauna is always monotonous. We always find: *Lepidocyclina (Nephrolepidina) angulosa, L. acuta, L. inflata, L. sumatrensis* (numerous). *Alveolina bontangensis, A. globulosa.* In a few samples from Soembawa *Eulepidinae* were discovered together with *L. sumatrensis* and from Flores *Spiroclypeus.* As far as we know Tertiary-*e 5* (Beboeloeh horizon) is again the oldest horizon represented. The bulk of the samples must be reckoned to the middle and upper parts of Tertiary-*f*.

Both on Soembawa and Flores besides the limestones, tuffaceous rocks of andesitic or of more acid composition are widely distributed. Through the occurrence of recent volcanoes it is, as on Java, often difficult to distinguish these rocks from the Quarternary ones. That, as on Lombok, part of them is of Tertiary age, cannot be doubted, as several limestones contain much tuffaceous material.

On none of these four islands Lower Tertiary has been discovered, and on the other islands of the inner Banda arc neither Lower nor Upper Tertiary occurs.

The islands of the **OUTER BANDA ARC** present Tertiary sections that resemble eachother markedly.

These islands are situated in the continuation of the islands west of Sumatra, so that the occurrence of marine Lower Tertiary sediments is in accordance herewith.

The occurrence of *Assilina* on Soemba shows that, as on Nias, the lower part of the Tertiary is already represented in marine facies. The presence on the other islands of this stage Tertiary-*a* has not yet been shown with certainty. It is not impossible, however, that the *Lacazina*-limestones of the Kei-islands should be placed here.

The stage Tertiary-*b* has on the other hand been encountered on many of the islands and is sufficiently characterized by the occurrence of *Discocyclina* and *Camerina*. Lithologically the rocks are characterized as follows: much limestone, especially marly laminated limestones, enclosed between lime-marls, mica-sandstones, shales and conglomerates. The series has the appearance of Flysch and is everywhere strongly folded. The Lower Tertiary has been included in the intricate Alpine structure of the Pre-Tertiary substratum of Timor, Letti and Ceram.

The islands, of which Lower Tertiary is known, are: Soemba, Rendjoewa, Rotti, Timor, Kei-islands, Ceram and Boeroe.

The Tertiary-*c* is only known with certainty in rocks collected by KEMMERLING on Soemba. The stage Tertiary-*d*, on the other hand, is found besides on Soemba also on the Kei-islands (ZWIERZYCKI, Jb. Mw. 1927, Verh. 1e ged.) which follows from the association of *Orthocyclina* with *Lepidocyclina*, as is the case for Boeton also. It should be emphasized that this stage is linked in a stratigraphic and tectonic sense to the Lower Tertiary-series.

After the deposition of Tertiary-*c* occurs a hiatus in the sedimentation. The next first strata are Middle to Upper Tertiary limestones, that rest unconformably on the folded Lower Tertiary and Pre-Tertiary. These Upper Tertiary limestones are much less intensively folded, sometimes lying horizontally (Kei-islands) and sometimes occuring in the form of terraces around the older nuclei of the islands, namely on Groot Kei and possibly on Ambon. They contain small *Lepidocyclinae* and must therefore be reckoned to the upper part of Tertiary-*e* and to Tertiary-*f*. That the lowest horizon belongs to the upper part of Tertiary-*e*, is proved by a limestone of Larat (Kei-islands) in which amongst other things large *Lepidocyclinae* and *Miogypsina dehaarti* (Ecl. geol. Helv., Bd. 18, No. 3) have been discovered. Again it is the „Beboeloeh-horizon" that transgresses over the older strata.

The islands, on which these middle Upper Tertiary limestones are found, are: Soemba, Rendjoewa, Timor, Kei-islands, Koer, Kasiwoe, Ceram and Boeroe. Nothing is known concerning accompanying rocks, except perhaps the andesite conglomerate and breccias that WITKAMP (T. K. N. A. G. 1912) mentions from Soemba. Otherwise the whole of the middle Upper Tertiary seems to be limited to the limestones, that have neither a large thickness, nor a large distribution. This is in strong contrast with the Upper Tertiary deposits of the large Soenda islands.

For the second time we can now assume a break in the sedimentation.

The next youngest deposit belongs to the uppermost part of the Tertiary (Tertiary-*h*). It consists of very soft, generally light coloured marls, often rich in foraminifera, and not or only slightly folded. These beds are known from Soemba, Rendjoewa, Savoe, Rotti, Timor, Tenimber-islands, Taam (Kei-islands) and Ceram). On Timor and on Ceram also they are situated in a strip parallel to the axis of the island, that probably formed a graben during the sedimentation. On Ceram, where they are known as the Foefa-series, they also occur on the north coast in a system dipping towards the sea. Upwards they here become coarser grained, even conglomeratic.

We may look upon the Globigerinae-limestones as of the same age but of different facies. On Timor for example they are found directly beside the marls. These limestones are sometimes sandy (Timor, Boeroe) sometimes laminated (Tenimber-islands) or they are developed as coral-limestone (Soemba, Savoe, Timor). On Soemba they contain chert beds and silicified corals. It is not impossible, however, that part of these limestones is of Quarternary age.

We may not close the discussion of the outer Banda arc without pointing out their great resemblance to Boeton, that is expressed in the two breaks in the Upper Tertiary sedimentation and the habitude of the whole. From a stratigraphical point of view Boeton could be directly joined to these islands.

BANGGAI-SOELA-OBI-MISOOL-PENINSULA OF ONIN-KOEMAWA MOUNTAINS AND AROE ISLANDS form a zone of geanticlinal facies, that lies at the southern side of the Upper Tertiary basin of southern New Guinea. In the west this facies is connected with the eastern arm of Celebes, while along the southern border analogies are found with the outer Banda arc.

The Lower Tertiary is only known from Misool and the Pyramiden and Valsche Pisangs to the east. It occurs there in the form of limestones with *Fasciolites*, that, it is true, do not contain *Camerinae* and *Discocyclinae*, but show a great resemblance to the Fasciolites-limestones of New Guinea, that do contain the latter two genera.

Over the entire length of this zone *Lepidocyclina*-limestones occur. On the peninsula Onin and the Koemawa mountains they appear as a limestone table. The oldest samples contain, moreover, *Spiroclypei* and must be placed in the upper part of Tertiary-*e*. *Lepidocyclinae* are further known from the basis of the limestone-mass, of which the entire archipelago of the Aroe-islands is built up, from the island Wajaban east of Misool and from Obi in limestones of which it is supposed, that they rest as terraces against the Pre-Tertiary, in the same manner as the Pleistocene coral terraces elsewhere. RUTTEN, however, already points out that it is also possible, that we here see the exposure of a folded formation. Finally it should be noted that on Soela loose blocks with *Lepidocyclinae* occur.

In the Banggai archipelago, to the west of the zone just discussed, Upper Tertiary limestones with *Lepidocyclinae* are also known, often

together with *Spiroclypeus*, and accompanied by marls, lime-sandstones and mica-sandstones, sometimes with thin coal-seams. This series transgresses directly over the crystalline shists, thus differing from the conditions on the neighbouring eastern arm of Celebes.

We are thus sure, that the limestones mentioned above may reach to the upper part of Tertiary-*e*, but it has not yet been ascertained which horizons of Tertiary-*e* and -*f* are represented.

It was already mentioned, that the Aroe-islands consist of a horizontal limestone table, the age of which according to the embedded lamellibranchiae and echinoidae is youngest Upper Tertiary. Here we are on the Sahoel flat, that belongs to the Australian continent.

Concerning New Guinea there are indications that part of the limestone series occurring here belongs to the youngest part of the Upper Tertiary, namely the Globigerina-limestones with cherts and marls with small foraminifera. The elevated, coral-limestones, dipping towards the south on Misool are taken to be „Plio-Pleistocene".

In southern Obi at various localities sandstones, marls and coral-limestones occur, that are probably of „Pliocene" age. They are slightly folded and lie directly on the Pre-Tertiary. The marls, the molluscan fauna of which was examined by FISCHER, show great resemblance to the Foefa-beds of Ceram, both lithologically and faunistically. On both sides of the Ceram graben a „pliocene" transgression seems to occur.

Another formation probably belonging to the upper part of the Upper Tertiary, consisting of conglomerates with traces of coal, is met with on the Soela-islands.

The greater part of the Banggai archipelago is occupied by limestone, that is not reckoned to the pleistocene reef-limestones, but to the „Pliocene" on account of the absence of marked terraces (Peling-limestones of KOOLHOVEN, Jb. Mw. 1929, Verh.). Probably these limestones are an equivalent of the Celebes-molasse. The other transgressive formations in this facies zone can also be compared to the „molasse".

THE NORTHERN MOLUCCA'S, VOGELKOP AND SNEEUWGEBERGTE. Between the geanticlinal zone just discussed, and the Pre-Tertiary mountains, that form the spine of New Guinea a broad geosynclinal zone is situated with thick Tertiary basin sediments.

In the Vogelkop, the Lower Tertiary consists of conglomerates, breccias, quartz and clay-sandstones and especially limestone with *Camerina, Discocyclina* and *Fasciolites*. From the occurrence at the base of conglomerates we can conclude that here we had a Lower Tertiary transgression. The Lower Tertiary occurs in the synclines of the Pre-Tertiary mountains and as uninterrupted strip along its southern border. Concerning the thickness and the degree of folding unhappily only little is known.

In the Sneeuw mountains the Lower Tertiary is developed as long ridges of limestone, in which countless *Camerinae, Discocyclinae* and *Fasciolites* occur. From the Wilhelmina top alone, sandstones are mentioned alternating with *Fasciolites*-limestones.

On the Radja Ampat-islands also marine Lower Tertiary must have been deposited, which follows from the breccia with fragments of an Eocene limestone, that BROUWER discovered.

Further Lower Tertiary is only known from the north eastern arm of Halmaheira. There it is found as strongly folded limestone, containing *Camerina, Discocyclina* and *Fasciolites.*

Assilina is known neither from the smaller islands nor from New Guinea, so that it is not certain whether the oldest part of the Tertiary occurs here.

The Upper Tertiary basin region of the Vogelkop is the first locality east of Celebes and Java where the sediments again reach great thicknesses. The Upper Tertiary is composed of an alternation of sandstones and shales. Generally many limestone-beds are present and laterally large portions seem to change entirely into limestone. At various horizons coal is found. The water content varies from 8—21 %. Coals are also found with only 3 %, but these possibly belong to the Lower Tertiary.

It cannot be ascertained with which horizon the Upper Tertiary begins and whether the sedimentation was uninterrupted. It is certain that a large amount belongs to the Tertiary-*f*. This follows from the frequent occurrence of *Alveolina bontangensis.* The presence of *Spiroclypeus* proves, that the upper part of Tertiary-*e* is also represented.

It should be pointed out, however, that at the foot of the Arfak mountains limestone-conglomerates and breccias occur with *Lepidocyclinae.* This points to an Upper Tertiary transgression.

Conglomerates and breccias have also been found in the Sneeuwgebergte, so that here too the Upper Tertiary seems to be transgressive. Further there were found here sandstone, shales, marls with brown coal-seams, but especially many limestones with *Lepidocyclina.*

On the Radja Ampat-islands Upper Tertiary occurs that is partly tuffaceous, conglomeratic and brecciatic, partly marls and limestones with coal. It is thick and has been intensively folded. The age could be ascertained by the occurrence of *Lepidocyclina* and *Miogypsina.*

Finally the occurrence should be mentioned on Halmaheira of strongly folded Upper Tertiary with *Lepidocyclina*-limestones, while much volcanic material is also present. Young lignite proves, that this series reaches up into the Upper Tertiary.

Thus in the discussed region we meet with a thick, strongly folded Upper Tertiary series, but a more precise stratigraphy cannot as yet be given, notwithstanding the rich foraminifera fauna it contains on which much paleontological information has already been published.

The Tertiary of **NEW GUINEA** may be looked upon as a typical example of the formation of a geosynclinal facies (ZWIERZYCKI, Jb. Mw. 1927, Verh. 1e ged.).

The Lower Tertiary seems to have a small distribution and is restricted to two localities in the lower reaches of the Toarim (WICHMANN, Nova Guinea, IV) and in the Nanggoi river (v. HOLST PELLEKAAN-RUTTEN, Versl. K. A. v. Wet., 29, No. 8). It consists of limestones with *Camerina,*

Discocyclina and *Fasciolites*. It is doubtful whether we should add a purple marl-shale, that occurs in the core of the Upper Tertiary anticlines, but in which no fossils have been found. The same can be said of a red limestone-formation in the upper reaches of the Tor and Foein, that correspond with the marl shale in position and colour.

The Upper Tertiary is widely distributed here and is well known through the investigations of ZWIERZYCKI (Jb. Mw. 1921, Verh. 1e ged.). ZWIERZYCKI divides it into 5 parts.

The oldest part, the conglomerate-beds, consists of conglomerates, breccias, sandstones, composed of elements, derived from underlying crystalline schists and Pre-Tertiary sediments. The presence of pieces of andesite and basalt proves that there were active volcanoes at the time.

It is further of great importance to our mind, that ZWIERZYCKI mentions *Spiroclypeus, Lepidocyclina* and *Miogypsina* from lenses and beds of limestone, intercallated in the conglomerate-beds, for this proves that in this region also a transgression occurred during the Beboeloeh-horizon of south eastern Borneo (Tertiary-*e* 5).

The Globigerina-beds, covering the Conglomerate-beds, consist of blue grey Globigerina-marls — sometimes these foraminifera are so profuse, that the rock becomes chalk-sandy marls and marl-sandstones, built up largely of tuffaceous material.

The sandstone-beds, that cover the Globigerina-beds, are largely composed of sandstone. The grain of these decreases towards the west while the intercallated beds of clay and marl become more important.

The Fossil-beds consist of shales and sandstones, rich in marine mollusca. Locally a few thin conglomerate-beds are intercallated, and prints of leaves and thin coal-seams have also been found.

The uppermost horizon, the lignite-beds, clearly demonstrates a regression in this region during the Upper Tertiary. These beds consist of clay and sandstones with brackish water and fresh water *mollusca*. Frequently thin lignite-seams are intercallated.

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Limits of members in conformable series, that coincide with limits of . . . . Stages / Zones

Approximate position of the limits of beds, which for the present are only lithologically defined . . . . . .

Idem, position varying even within the same district owing to lateral faciestransition. . . . .

Marine transgression, erosional unconformities, pronounced overlapping. . . . .

Idem, combined with marked angular unconformity . .

Supposed or approximate extension of the stratigrafical hiatus in the base of a transgressive member . . .

	S. E. Borneo		CENTRAL-KOETEI (Rutten)	CENTRAL-KOETEI (Jezler)	CENTRAL-KOETEI (Schürmann, Zeylmans, Van der Vlerk, Umbgrove a. o.)	CENTRAL-KOETEI Subdivision as proposed by the authors	N. KOETEI (Sangkoelirang-bay)	Mangkalihat-peninsula	N. and Central-Beraoe	Salimbatoe-Antjam, Central Boeloengan	Tidoengsche landen
h 2							Domaring-kalken		Boenjoe-lagen	Boenjoe-lagen	Boenjoe-lagen
h 1	Martapoera-lagen		„Plio-Mioceen"	Kembang-lagen	Kembang-lagen	Kg. Baroe-lagen	Boven-Sangkoelirang-mergels = Menoebar-mergels	Domaring-kalken	Sadjau-lagen	Sadjau-Tarakan-lagen	Tarakan-lagen
g	Assem-lagen				Kg. Baroe-etage; Gelingseh-lagen					Antjam-lagen	Mandoel-mergels
f 3			Boven-Mentawir-lagen	Ma. Djawa-lagen		Gelingseh s.str. = Boven-Balikpapan-lagen	Gelingseh-lagen	Menkrawit-lagen	Kool-formatie		Taboel-lagen
f 2	H-lagen van Douvillé	Boven-Kandangan-lagen.	Onder-Mentawir-lagen	Sanga-Sanga-lagen	Balikpapan-etage	Mentawir s. str. = Onder-Balikpapan-lagen	Onder-Sangkoelirang-mergels			Koendjang-lagen	
f 1			Poeloe Balang-lagen		Poeloebalang-lagen	Poeloebalang-lagen	Poeloebalang-lagen				
e 5		Onder-Kandangan-lagen		Prangat-lagen	Beboeloeh-horizon	Beboeloeh-lagen			Steriele formatie		Meliat-zandsteen
e 4	G-lagen van Douvillé		Pamaloean-lagen		Pamaloean s. str.-lagen	Sakadoea-lagen	Kalksteen v. d. Boengaloen-koepel	Taballar-kalken		Sitam-lagen (Kalksteen- en koolformatie)	
e 3									Globigerina-mergels		Boven-Naintoepo-lagen
e 2						Pamaloean s. str.-lagen				Globigerina-mergels; Lepidocyclina-kalksteen	Onder-Naintoepo-lagen
e 1	F-/E- lagen van Douvillé								Lepidocyclina-kalk		Mesaloi-mergels
d	D-lagen van Douvillé							Dolomiet-horizon		Tempilan-lagen	Tempilan-lagen
c	C-lagen van Douvillé	γ-lagen van Verbeek, Kalksteen-etage						Boven-Taballar-mergels	Seilor-lagen	Mangkaboea-mergels Seilor-lagen Bratan-lagen	Seilor-lagen
b	B-/A- lagen van Douvillé	β-lagen van Verbeek, Mergel-etage			Mergel-Kleisteen-afdeeling; Zandsteen- en conglomeraat-afdeeling		Kalksteen v. Gg. Kandango (Boengaloen)	Onder-Taballar mergels		Marah-lagen	Toelit-lagen
a 2	Zandsteen-etage zonder kool; Zandsteen-etage met kool	α-lagen van Verbeek						Zandsteen-etage		Orang-lagen	Tikoeng-lagen
a 1											Soedjau-lagen ?

	Atjeh III	Atjeh I	Atjeh II	Langkat	Kwantan-, Kampar- and Rokan-regions	Indragiri	Djambi	Central-Palembang, Goemai-mountains	S. Palembang and Lampongsche Districten	Padangsche Bovenlanden	Nias
h 2						Boven-Palembang-lagen	Boven-Palembang-lagen	Boven-Palembang-lagen	Boven-Palembang-lagen		
h 1		Tufzandsteen-zone Bruinkool-zone Operculina-zone Hoofdfossiel-zone Tufconglomeraat-zone Rotalia-zone	Djoeloe Rajeu-horizon Seuroela-horizon	Djoeloe Rajeu-horizon Seuroela-horizon	Kleizand- en tuf-formatie = Boven- en Midden-Palembang-lagen			Midden-Palembang-lagen			Dabana-mergels
g			Keutapang-horizon	Keutapang-horizon	Klei-formatie = Onder-Palembang-lagen	Midden-Palembang-lagen	Midden-Palembang-lagen	Onder-Palembang-lagen	Midden-Palembang-lagen		
f 3	Zandsteen-Conglomeraat-zone	Robulina-klei Tusschen zandsteen				Onder-Palembang-lagen	Onder-Palembang-lagen	Goemai-lagen			
f 2		Grensklei s. str.			Mergel-formatie = Telisa-lagen	Telisa-lagen	Telisa-lagen		Gilas-etage	Tuf-afdeeling	Hiliberoedjoe-mergels
f 1	Grensklei		Grensklei s. l.	Grensklei s. l.				Banken v. Lepidocyclina-kalk		Mergel-afdeeling met Kalksteen (Batoe Mendjoeloer)	(Hiligara)
e 5					Kwartszandsteen met kolen				Batoeradja-Kalksteen		Sitoli-kalk (Idanoj, Idaneumi)
e 4						Kwartszandsteen en conglomeraat met kolen	Kwartszandsteen en conglomeraat met kolen				
e 3								Kwartsconglomeraat- en zandsteen-formatie	Rantautidjang tut-serie (zoetwater) of Kwartszandsteen-serie met kolen (Sepoetih-bekken)		
e 2	Zwarte Kleisteen	Peunoelin-zandsteen									
e 1			Zwarte Kleisteen	Zwarte Kleisteen							
d		Zwarte Kleisteen s. str.									
c	Micazandsteen-etage	Micazandsteen-etage	Micazandsteen etage	Micazandsteen-etage		?	?	?		Kwartszandsteen-afdeeling met kolen (Ombilin-kolen)	
b				Koolmergel-etage							
a 2	Micakwarts-breccie-etage	Micakwarts-breccie-etage	Kwartszandsteen-breccie-etage	Onder-zandsteen-etage	Breccie-etage					Breccie- en mergelschalie-afdeeling	Breccies en conglomeraten (Hili Badaloe en Eho)
a 1											

	Bantam and S. Priangan	N. Priangan	Cheribon and Pekalongan	W. Djokjakarta	Djiwo-gebergte	N. Rembang	S. Celebes	E. Celebes	N. Celebes	The outer Banda-arc	N. New Guinea		
h 2	„Boven-Palembang"-tuffen		Vertebraten-zone Turritella-zone = Tji Djoerei-lagen		Tufzandsteen v. Wonosari	Sondé- of Kleimergel-lagen; Karren-kalk				Foefa-lagen	Bruinkool-zone		
h 1			Conglomeraat-afdeeling		Klei met Kalkconcretie's van Wonosari	Globigerina-mergel-lagen		Celebes-molasse	Dopalak-porphyriet			„Plioceen"	Boven-Jong-Tertiair (= „Jong Neogeen")
g	„Midden-Palembang"-lagen = Bondjongmanik-lagen		Breccie-afdeeling; Tufzandsteen-afdeeling			Ledok-lagen	Celebes-molasse		Woeboedoe-breccie		Fossielhorizon	„Jong-Mioceen zonder Orbitoiden"	
f 3	Kalksteen	Tjilanang-lagen Njalindoeng-lagen	Kleimergel-Kalksteen-afdeeling		Kepek-lagen Wonosari-lagen	Wonotjolo-lagen; Ngrajong-lagen					Zandsteen-zone	„Jong-Mioceen met Orbitoiden"	
f 2	„Onder-Palembang"-Kleisteenen	Conglomeraat-lagen van Tagogapoe				Amphistegina-mergels; Orbitoiden-kalk			Timboelan-Kleisteen	Lepidocyclina-kalken	Globigerina-zone		Midden-Jong-Tertiair (= „Midden-Neogeen")
f 1	Kalksteen	Zandsteen-lagen van Tagogapoe		W. Progo-lagen	Sambipitoe-lagen	Basis-mergels (Madoera)							
e 5	Tjimapag-lagen	Lepidocyclina-kalk v. Tagogapoe		W. Progo-andesiet	Nglanggran-lagen		Bovenged. Kalksteen-formatie	Kolokolo-Kalk „Loewoek-mioceen"	Totok-kalk; Obapi- of Kp. Lintido-conglomeraat	Miogypsina dehaarti-kalk	Conglomeraat-zone		
e 4					Semilir-lagen								
e 3					Boekat-lagen								Onder-Jong-Tertiair (= „Oud-Neogeen")
e 2					Kebo-lagen								
e 1	Boven-Tjidjengkol-lagen												
d	Onder-Tjidjengkol-lagen									Orthocyclina-kalk van Kei			
c		Kwartszanden v. Tagogapoe								Kalksteen van Soemba			Boven-Oud-Tertiair
b	Tjitjaroetoep-lagen = koolhoudende kwartszandsteen-formatie v. Bajak- en Tjimandiri-kolenveld			Nanggoelan-lagen	Gamping-lagen		Onderged. Kalksteen-formatie	Fasciolites kalk		„Flysch"achtige afzettingen	Discocyclina-kalk		Midden-Oud-Tertiair
a 2	Zandsteen-etage v. Tjiletoe Kalk-etage v. Tjiletoe				Dawa-lagen Woengkal-lagen		Koolzandsteen-formatie			Assilina-kalk van Soemba			
a 1				Kalk v. Gamping in W. Djokja ?			Basaal Conglomeraat; Roode zandsteen-formatie						Onder-Oud-Tertiair

THE DISTRIBUTION OF THE MOST IMPORTANT GENERA, SUBGENERA AND SPECIES OF LARGER FORAMINIFERA IN THE TERTIARY OF THE DUTCH EAST INDIES.

Comparison between subdivisions of the Indian Tertiary as proposed by different authors.

Subdivision of the Tertiary of Java (after Martin).	Upper Eocene						Lower Miocene	Upper Miocene	Pliocene
Subdivision of the Tertiary of Java (after Gerth) (Proc. 4th Pacific Sc. Congr. 1929)	Eocene: Lower Ypresiam	Eocene: Middle Lutetian	Eocene: Upper Auversian-Bartonian	Oligocene: Lower	Oligocene: Upper	Lower Miocene Upper Miocene: Aquitanian	Burdigalian	Vindobonian	
Subdivision of the Upper Tertiary of Sumatra (after Tobler) based on the foraminifera-determinations of H. Douvillé.						Lower Neogenic: Lower-Upper Aquitanian	Burdigalian Low. Miocene	Middle Neogenic Helvetian Middle Mioc.	Upper Neogenic: Upper Miocene / Pliocene
Subdivision of the Tertiary of S. E. Borneo (after H. Douvillé).		Lutetian	Bartonian	Sannoisian	Stampian	Aquitanian	Burdigalian		
Subdivision of the East Indian Tertiary (after Rutten, Voordrachten Geol. Ned. Indië, p. 86).		Lower Eogenic		Upper Eogenic		Lower Neogenic	Middle Neogenic		Upper Neogenic
Subdivision of the Upper Tertiary of E. Borneo (after Rutten, Voordrachten Geol. Ned. Indië, p. 223).					Mio-oligocene		Lower Miocene	Upper Miocene	Plio-Miocene / Pliocene
Tentative general subdivision of the Tertiary of the Dutch East Indies based on the main stratigraphical features (transgressions, unconformities) as proposed by the authors.	Lower Tertiary: Lower	Lower Tertiary: Middle	Lower Tertiary: Upper	Upper Tertiary: Lower		Upper Tertiary: Middle		Upper Tertiary: Upper	

STAGES / ZONES (based upon vertical distribution of larger foraminifera.)	a 1	a 2	b	c	d	e 1	e 2	e 3	e 4	e 5	f 1	f 2	g 3	g	h 1	h 2
Percentages of still living species of Mollusca.			0								18 8	20	30	35 45	50	60
CAMERINA																
C. nuttalli, thalica																
C. javana var. β Verb.																
C. djokdjokartae, vredenburgi																
C. pengaronensis (= manggolani)																
C. bagelensis																
C. fichteli-intermedia																
ASSILINA																
PELLATISPIRA																
HETEROSTEGINA																
H. borneënsis (= spiroclypoid Het. of Rutten)																
SPIROCLYPEUS																
S. pleurocentralis																
S. tidoengaensis																
S. leupoldi, margaritatus																
CYCLOCLYPEUS																
DISCOCYCLINA																
LEPIDOCYCLINA																
Isolepidina																
Eulepidina																
E. papuaënsis																
E. dilatata																
Pliolepidina																
Nephrolepidina																
N. isolepidinoides																
N. borneënsis																
N. angulosa																
N. inflata, ferreroi																
N. verbeeki																
N. sumatrensis and. var., douvillei																
Tryblolepidina																
T. rutteni																
Lepidocyclina microsph., spec. > 15 mm.																
L. flexuosa																
L. scuta																
MIOGYPSINA																
Miog. without lateral chambers																
M. dehaarti																
Miog. with lateral chambers																
M. thecideaeformis																
M. polymorpha																
FASCIOLITES																
F. wichmanni																
Clausulus pygmaeus (= Alv. spec. 8 Verb.).																
ALVEOLINA																
A. bontangensis																
A. boscii																
TELLINA howchini																