An introduction to Cenozoic macrofossils of Indonesia

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ABSTRACT

A brief overview is presented of the principal groups of Cenozoic macrofossils from outcrops in Indonesia. Prior to the 1930's macrofossils, in particular mollusks, were the principal objects of paleontological and biostratigraphic studies in Indonesia. Since then focus has shifted to microfossils, but it is argued that macrofossils still have the potential to significantly contribute to the knowledge of biostratigraphy, paleoenvironments, paleoclimate, paleobiogeography and plate tectonic reconstructions of the region. Cenozoic marine macrofossil assemblages from Indonesia all represent tropical faunas of Indo-Pacific province affinity.

INTRODUCTION

Cenozoic sediments and volcanics cover about ¾ of the islands of Indonesia (Van Bemmelen, 1949). Marine and also some non-marine fossils are present in many of these outcrops, but the vast majority (>95%) of modern paleontological studies has been on microfossils (e.g. review by Van Gorsel, Lunt and Morley, 2014; Berita Sedimentologi 29). However, a significant collection of publications also exists on Cenozoic and older macrofossils. Unfortunately, most of this work dates from before World War II, was written in Dutch or German, is little known and can be hard to find. Because of their vintage the taxonomy in many of them is need of revision. Therefore, and since there is no 'Paleontology of Indonesia' textbook, reviews of the main macrofossil groups from Indonesia, with comments on their biostratigraphic and paleobiogeographic significance and with key references for further study, should be useful for the current and future generations of geologists.

This paper on Cenozoic macrofaunas and floras is the first of several papers on Indonesian fossil groups to be published in this journal. A full reference list is in the 'Bibliography of Biostratigraphy and Paleontology of Indonesia' (Berita Sedimentologi 29A, 2014), which also includes a selection of paleontological papers from surrounding SE Asian countries. Quaternary mammals and hominids are also not part of this paper, but many references on this significant group of fossils from Indonesia are also in the above Bibliography.

MACROFOSSIL GROUPS

Cenozoic macrofossils are mainly represented by mollusks and corals in marine deposits and by plants, petrified wood and fresh-water mollusks in terrestrial deposits. Fossil groups that were important in pre-Cenozoic time like cephalopods and brachiopods are greatly diminished after the end-Cretaceous extinction event.

Although theoretically many macrofossil taxa have biostratigraphic value, they have lost their significance as biostratigraphic tools today, primarily because it is much easier to collect a few hundred microfossils (even in small drill samples) than it is to collect adequate macrofossil assemblages. As a result there are very few active experts in the macrofossil field and their vertical ranges and calibrations to modern time scales tend to be poorly known.

Most of the early paleontological monographs and papers on Cenozoic macrofossils were by paleontologists of the 'Dienst Mijnwezen', now known as Geological Survey of Indonesia, in Bandung (Van der Vlerk, Gerth, Umbgrove, Oostingh, Von Koenigswald) and associated academics in Europe (Martin, Beets, etc.). Table 1 lists the key papers for each fossil group.

A key publication on Indonesian fossil genera and species is the Martin memorial volume, edited by Escher et al. (1931). It contains comprehensive listings of all Cenozoic fossil species described from Indonesia, including chapters on Cenozoic mollusks by Van der Vlerk, corals by Gerth, echinoids by Wanner and plant fossils by Posthumus. Some of this biostratigraphic-paleontological literature may be >100 years old, but since these old publications tend to contain mainly descriptions of fossils and fossil localities and often contain superb illustrations, they are still valuable today.

Key General References

Escher, B.G., I.M. van der Vlerk, J.H.F. Umbgrove & P.H. Kuenen (eds.), 1931. De palaeontologie en stratigraphie van Nederlandsch Oost-Indie, Leidsche Geologische Mededelingen. 5 ('Feestbundel Prof. Dr. K. Martin'), 1, p. 1-648.

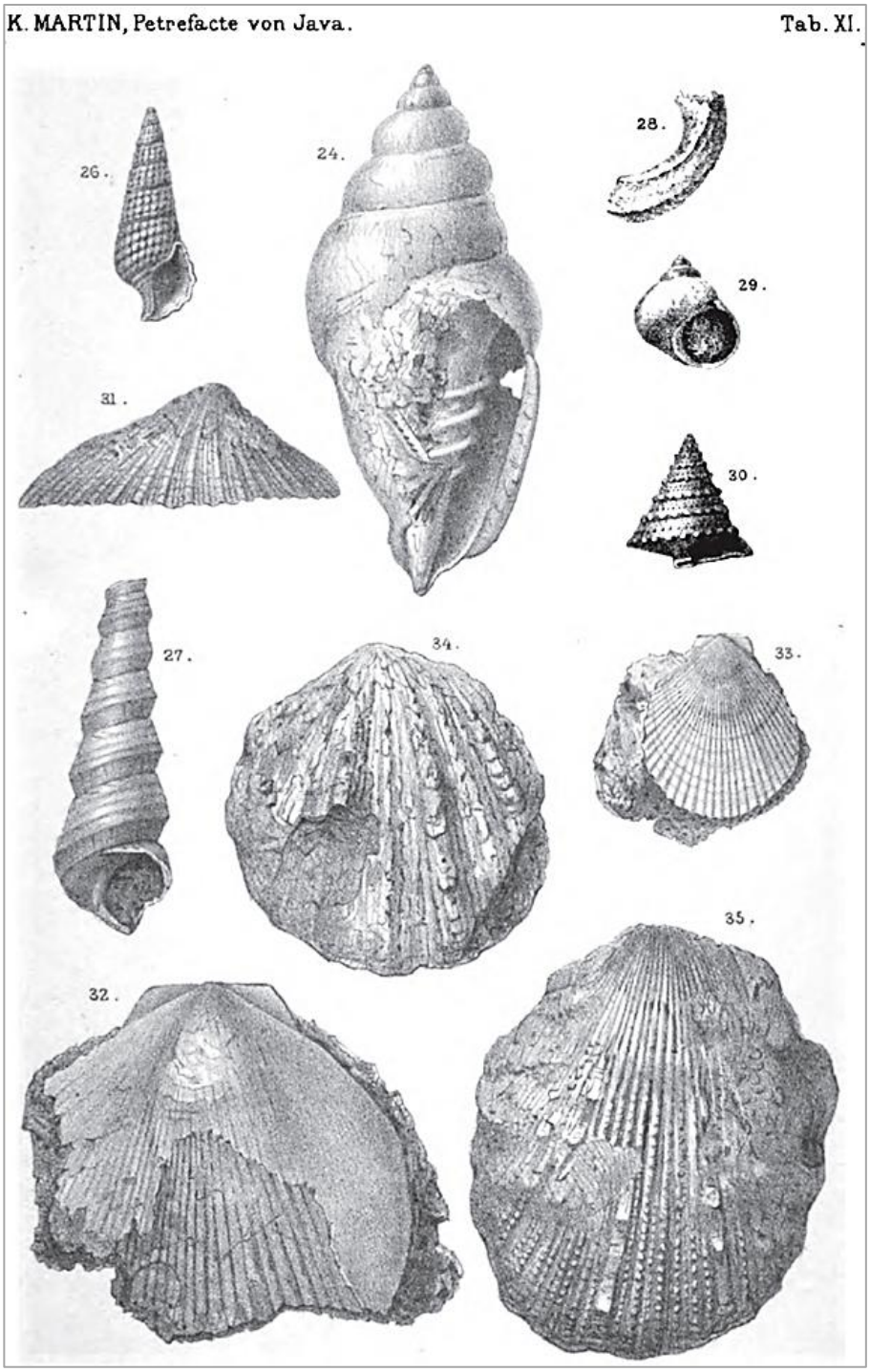


Figure 1. *Typical Mio-Pliocene marine mollusks from West Java, mainly from Priangan: 24 Voluta grooti, 26 Cerithium everwijni, 27. Turritella javana, 28. Siliquaria, 29. Turbo obliquus, 30. Trochus woodwardi, 31. Patella deformis, 32. Pecten placunoides, 33. Pecten senatorius, 34. Spondylus costatus, 35. Spondylus imperialis (Martin 1883)*

Krijnen, W.F., 1931. Annotations to the map of the more important fossil localities in the Netherlands East Indies. Leidsche Geol. Meded. 5 (K. Martin Memorial Volume), p. 509-551.

Mollusks

Mollusks (bivalves and gastropods) are the most common macrofossils in the Cenozoic of Indonesia. Their diversity is overwhelmingly high with about 4000 known Recent species in Indonesia. They are found in depositional environments ranging from fresh water to deep marine. Biogeographically Cenozoic mollusks belong to the Indo-Pacific bioprovince, which is very different from the Mediterranean Province.

Most of the early paleontological studies were dedicated to this fossil group and most of these were by Professor Karl Martin of Leiden University, who was nicknamed the 'Linnaeus of Java' and who studied collections assembled by geologists/ mining engineers of the 'Dienst Mijnwezen of the East Indies'. Martin published numerous monographs and papers between 1879 and 1937, especially from Java, from where he identified a total of 1412 species of mollusks (Figures 1, 2). From the Pliocene of North Sumatra 347 species were identified (Martin, 1928), and 232 species from the Pliocene of Timor (Tesch 1915, 1920).

Taxonomic revisions of many of the species described by Martin were proposed by Beets (1950) and Shuto (1974, 1978). The Martin collection from Indonesia is stored at the Naturalis Museum in Leiden, The Netherlands, and contains the type specimens of 912 new species (Van den Hoek Ostende et al., 2002). The latest, comprehensive illustrated catalog of Martin's Cenozoic mollusk species from Java is by Leloux and Wesselingh (2009).

Special mention should also be made of series of papers on Mio-Pliocene mollusks from:
- West Java by Oostingh (1933-1941),
- Kendeng zone, East Java, by Van Regteren Altena (1938-1950),
- East Kalimantan and other areas by Beets (1941-1986).

A major compilation of species of Cenozoic Mollusca described from Indonesia was produced by Skwarko et al. (1994; Geological Survey, Bandung, limited edition).

The Mollusk 'percentage of extant species' Method of Biostratigraphy

Mollusks were the principal group used for age dating of Cenozoic sediments, until microfossils became the preferred biostratigraphic tools. Larger foraminifera, with their Ta-Tf 'Letter Stages', became prominent after the late 1920's, and later also planktonic foraminifera, calcareous nannofossils and palynology.

Martin developed a 'Lyell-type' method of relative age determination, based on the decreasing percentage of living species in increasingly older fossil

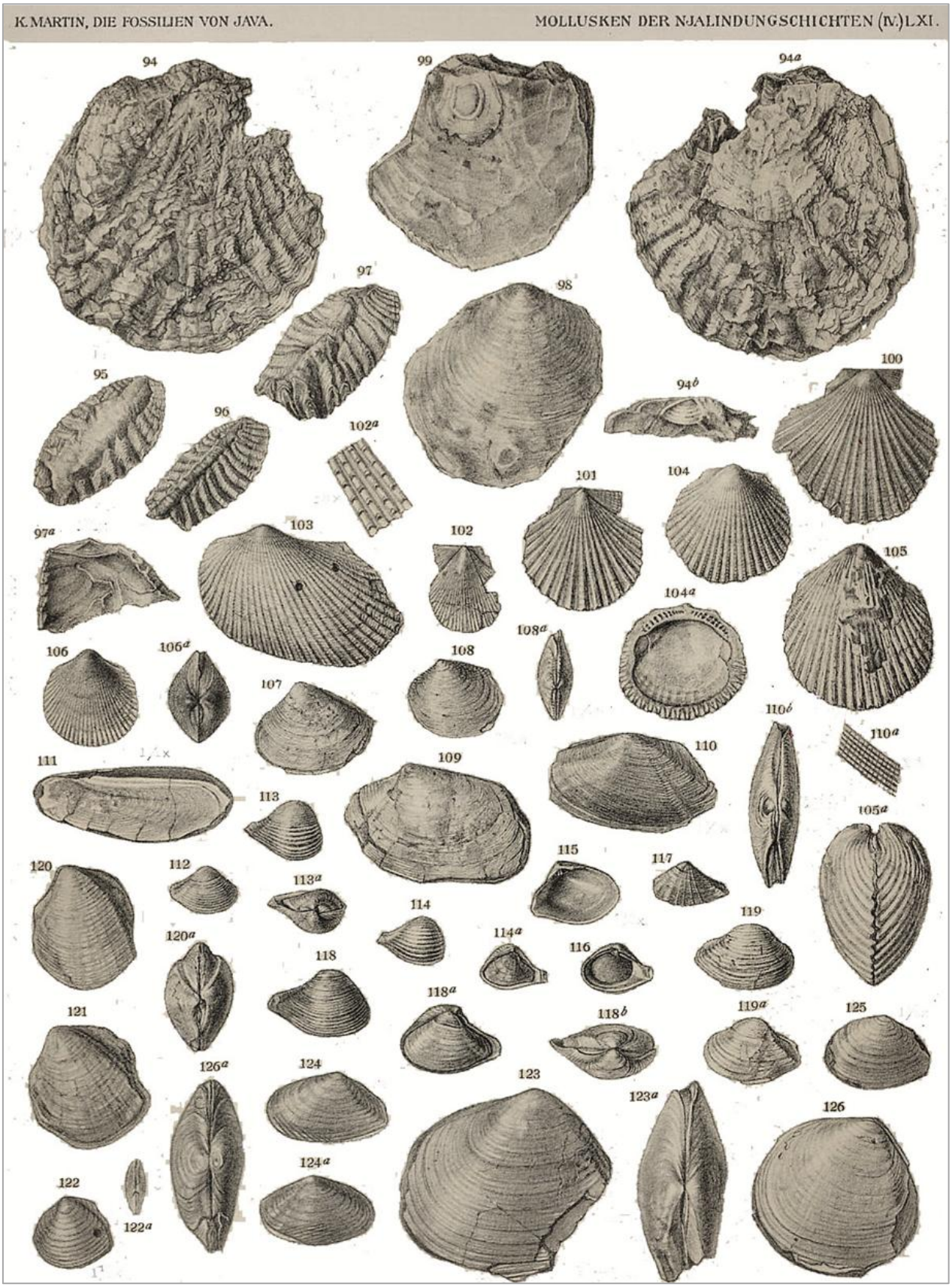


***Figure 2**. Marine bivalve mollusks from Middle-Late Miocene Nyalindung Beds, West Java (Martin 1921).*

populations. Percentages of living species by stage were (Van der Vlerk, 1931):
- Eocene: 0 %;
- Early Miocene: 8-20%;
- Late Miocene: 20-50%;
- Pliocene: 50-70%;
- Quaternary: >70%.

These numbers appeared to differ from the ratios for the same stages in Europe and this was a key reason why it was believed that the Far Eastern and European parts of the Tethys Ocean had become separated by the end of the Eocene. The merits of this pre-plate tectonic argument developed after this, but this observation alone was the driving force to develop larger foraminiferal Letter Stage

stratigraphy, simply because the stages of Europe did not seem applicable to SE Asia.

The Lyellian percentage method of extant mollusks appeared to work reasonably well, but there were anomalies, especially in cases of deep marine mollusk assemblages. For instance, faunas from asphalt-bearing Sampalakosa beds of Buton were initially interpreted as Oligocene by Martin (1933, 1935), because none of the 35 mollusk species was known from the Recent. However, associated foraminifera and diatoms suggest a Late Miocene-Pliocene age, and the mollusks were subsequently recognized as deeper marine fauna, whose modern equivalents are poorly known (Beets 1952).

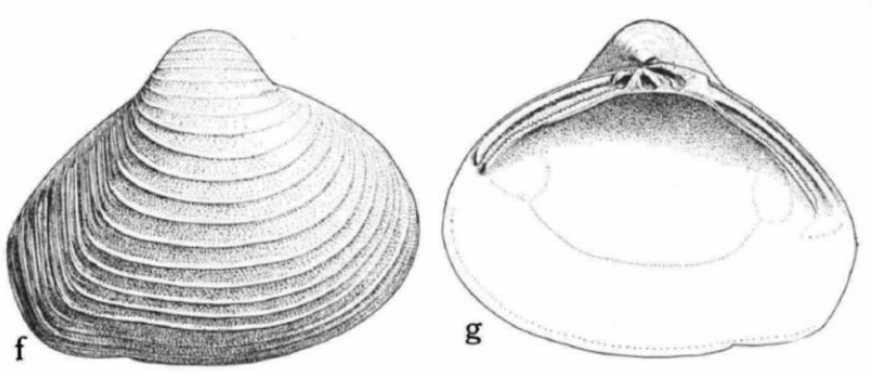


Figure 3. *Typical fresh-water mollusk from Pleistocene, Central Java (*Corbicula gerthi*)*

Oostingh (1938) and Shuto (1978) started building more conventional mollusk biozonations of the Miocene- Pleistocene of Java, based on vertical ranges of species. Many of their zones are based on species of the gastropod genus *Turritella*. Shuto (1978) and Baggio and Sartori (1996) also proposed updates of the Lyellian percentages proposed by Martin. As noted above, neither this mollusk zonation, nor the percentage method are used for dating Cenozoic sediments today, mainly because microfossils have proven to be more reliable and more convenient to collect in large numbers, but also because the paleontological expertise required for this probably no longer exists in Indonesia.

Fresh- and Brackish-water Mollusks

Fresh-water faunas are generally rare in the Cenozoic of Indonesia, reflecting the relative rare occurrences of non-marine depositional environments. They are generally present only on the larger islands of West Indonesia. The oldest Cenozoic fresh-water mollusk faunas are from the Eocene of Kalimantan and Central Sumatra. The Melawi Group of the Upper Kapuas river area in Central Kalimantan, presumably of Eocene age, contains mollusk species mainly characteristic of fresh (*Melania, Paludomus*) and brackish water (*Cyrena, Corbula*) (Martin 1898). Along the Meratus Mountains front in SE Kalimantan Middle Eocene clay beds associated with coals contain large fresh-brackish water species *Cyrena borneensis* and *Corbicula pengaronensis* (Boettger, 1875)

On Sumatra the early rift phase of Eocene-Oligocene rift basins contain lacustrine and deltaic-esturine facies, but fresh-water mollusks have been poorly documented. On Java the oldest non-marine mollusk faunas appear in the basal Pleistocene (Figure 3; Van Benthem Jutting, 1937), around the same time as the arrival of Asian mammal and hominid populations.

Key References Mollusks

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Gerth, H., 1921. Coelenterata. In: Die Fossilien von Java auf Grund einer Sammlung von Dr. R.D.M. Verbeek und von anderen bearbeitet durch Dr. K. Martin. Sammlung. Geol. Reichs-Museum Leiden (N.F.) 1, 2, 3, p. 387-445.

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Corals

Corals are common in most Oligocene to Recent limestones across Indonesia. The fossil coral collections at Naturalis Museum, Leiden, contain 271 species from 210 localities in SE Asia, mainly Indonesia (Leloux and Renema, 2007). However, relatively little work has been done on their biostratigraphic zonations, biofacies and paleobiogeography and most of the taxonomic work is relatively old.

Modern coral reefs in Indonesia have been described fairly extensively, particularly in a series of studies by Umbgrove between 1928 and 1947 (see Table 1). Umbgrove also identified and described about 150 species of Recent corals and coral reefs around Java, Sumatra and Sulawesi. Key review papers on modern Indonesian coral reefs include Umbgrove (1946, 1947).

Gerth (1921) recognized the Neogene-Recent corals of Indonesia as typical Indo-Pacific assemblages. The Indo-Australian Archipelago today has the highest coral diversity in the world (Renema et al. 2008).

Most coral species have fairly narrow temperature ranges in which they thrive, and are therefore sensitive to climate changes. Both periods global cooling and extreme warming can negatively affect coral diversity and abundance. Cenozoic corals and coral reefs in Indonesia therefore show distinct periods of diversification and decline (Wilson 2002 and others).. Corals are generally rare in Eocene (too warm?) and Early Oligocene (too cold?) carbonates of SE Asia, which are dominated by larger forams and coralline algae (Wilson and Rosen 1998). The Late Oligocene- Early Miocene was a period of increased coral diversification and relatively wide distribution of coral reefs (Wilson 2002, 2011, Johnson et al. 2011). This was then followed by several steps of declining diversity and carbonate abundance in Middle Miocene and later time.

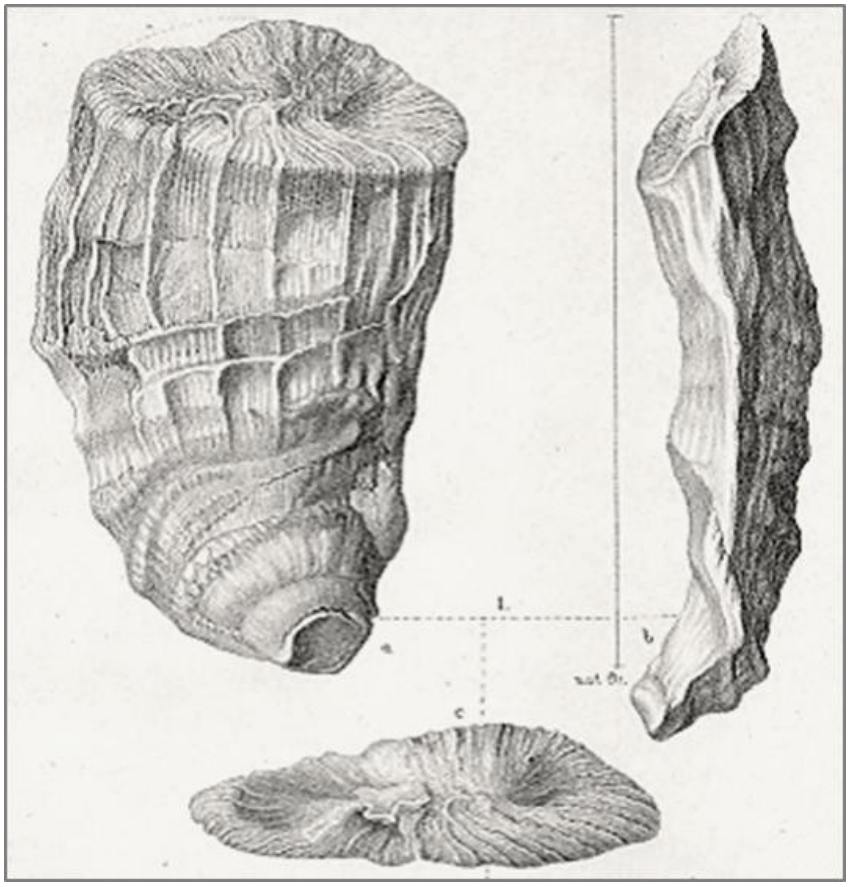


Figure 4. *Eocene solitary coral Epismilia? flabelloides from SE Kalimantan (Von Fritsch 1877)*

An elegant review paper on Indonesian Cenozoic corals is Osberger (1956), which includes listings of principal deposits and range charts of species. Notable case studies on Cenozoic fossil corals from Indonesia include (see also Table 1):
- Von Fritsch (1877): Eocene corals of SE Kalimantan (Figure 4)
- Felix (1913-1921): Miocene-Pleistocene corals from Java, Kalimantan, Timor (Figure 6),
- Gerth (1923): 120 coral species from the Late Tertiary of East Kalimantan
- Gerth (1921, 1933): corals from Eocene- Miocene of Java (Figure 5);
- Umbgrove (1924-1950): corals from Miocene-Pleistocene of Kalimantan, Java, Sumatra, Buton, etc.
- Osberger (1954, 1955): Late Tertiary corals from Java.

In an attempt to use corals for biostratigraphy relative age dating Umbgrove (1946) and Osberger (1956) used the Lyellian method of increase in percentage of living coral species through time, similar to what Martin used for mollusks: Eocene-Oligocene 0%; Early Miocene, 6-9%; Middle Miocene 15-30%, Late Miocene-Pliocene 30-60% and Pleistocene ~80% . As argued by Osberger (1956), whilst the overall trend is real, there is too much variability for this method to be reliable for age dating. Also, as with mollusks, these percentages did not hold up well when dealing with less well-known deeper marine assemblages. For instance, corals from the Lower Pleistocene Pucangan Formation of the Kendeng zone of East Java only had 50% known Recent species, which was explained by Umbgrove (1946) as due to the relatively deep water facies with common poorly known solitary species.

Key References Corals

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Felix, J., 1921. Fossile Anthozoen von Borneo. Palaontologie von Timor, Schweizerbart, Stuttgart, 9, 15, p. 1-61.Gerth, H. (1921)- Coelenterata. In: Die Fossilien von Java auf Grund einer Sammlung von Dr. R.D.M. Verbeek und von anderen bearbeitet durch Dr. K. Martin. Sammlung. Geol. Reichs-Museum Leiden (N.F.) 1, 2, 3, p. 387-445.

Gerth, H., 1923. Die Anthozoenfauna des Jungtertiars von Borneo. Sammlung. Geol, Reichsmuseums Leiden, ser. 1, 10, p. 37-136.

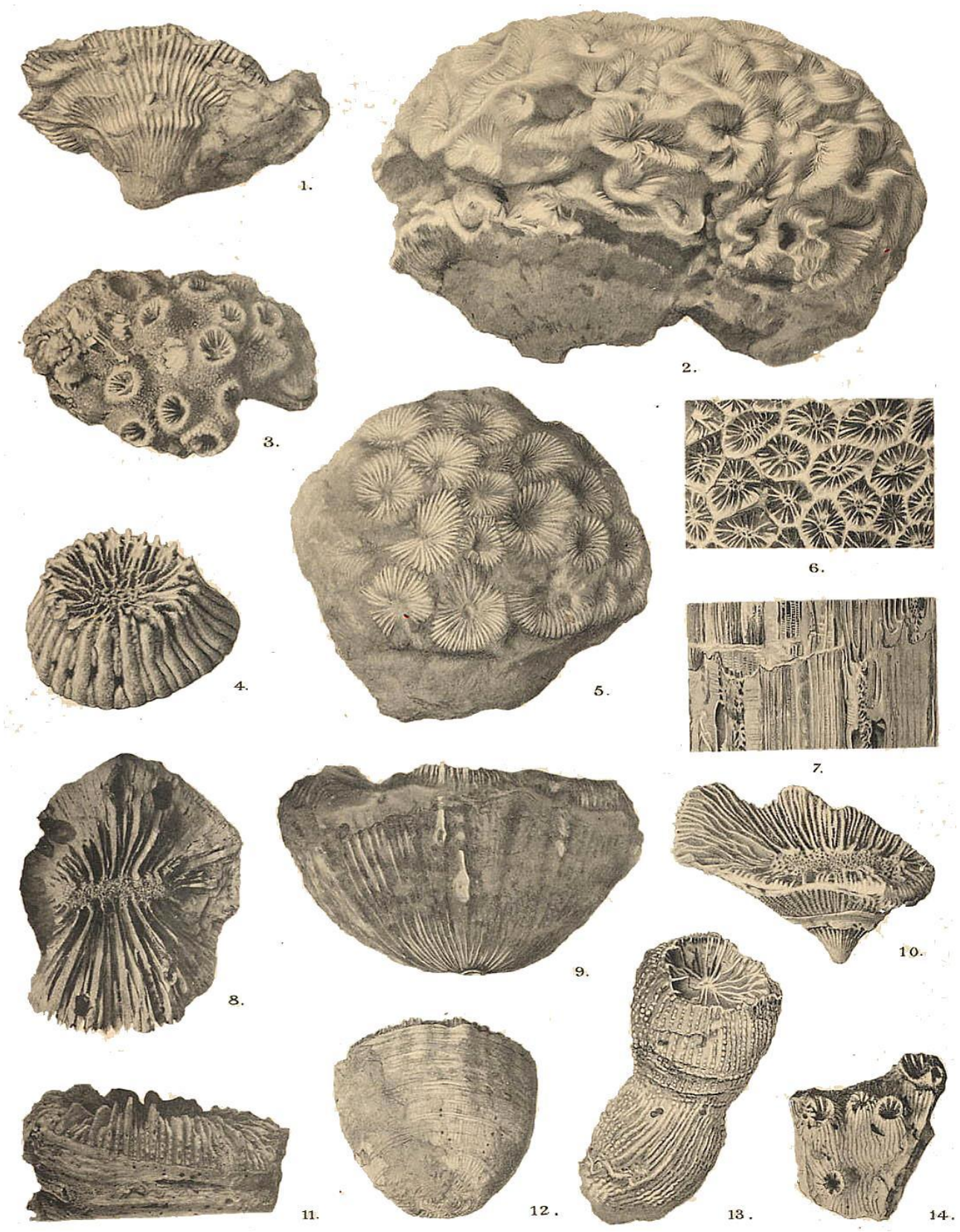


***Figure 5**. Example of Miocene- Pliocene corals from Java. 1. Lithophyllia explanata, 2. Hydrophyllia martini, 3. Astreopora sp., 4. Heterocyathus rousseaui, 5. Confusastraea obsoleta, 6-7. Prionastraea dubia, 8-10. Antillia spp., 11-12. Anthemiphyllia verbeeki, 13. Lithophyllia spinosa, 14. Echinopora crassatina (Gerth 1921).*

Gerth, H., 1931. Coelenterata. In: Onze palaeontologische kennis van Nederlandsch Oost Indie. Leidsche Geol. Meded. 5 (K. Martin volume), p. 120-151.

Gerth, H., 1933. Neue Beitrage zur Kenntnis der Korallenfauna des Tertiars von Java. I. Die Korallen des Eocaen und des alteren Neogen. Dienst Mijnbouw Nederl.-Indie, Wetensch. Meded. 25, p. 1-45.

Leloux, J. & W. Renema, 2007. Types and originals of fossil Porifera and Cnidaria of Indonesia in Naturalis. Nat. Natuurhist. Museum Techn. Bull., Leiden, 10, p. 1-305.

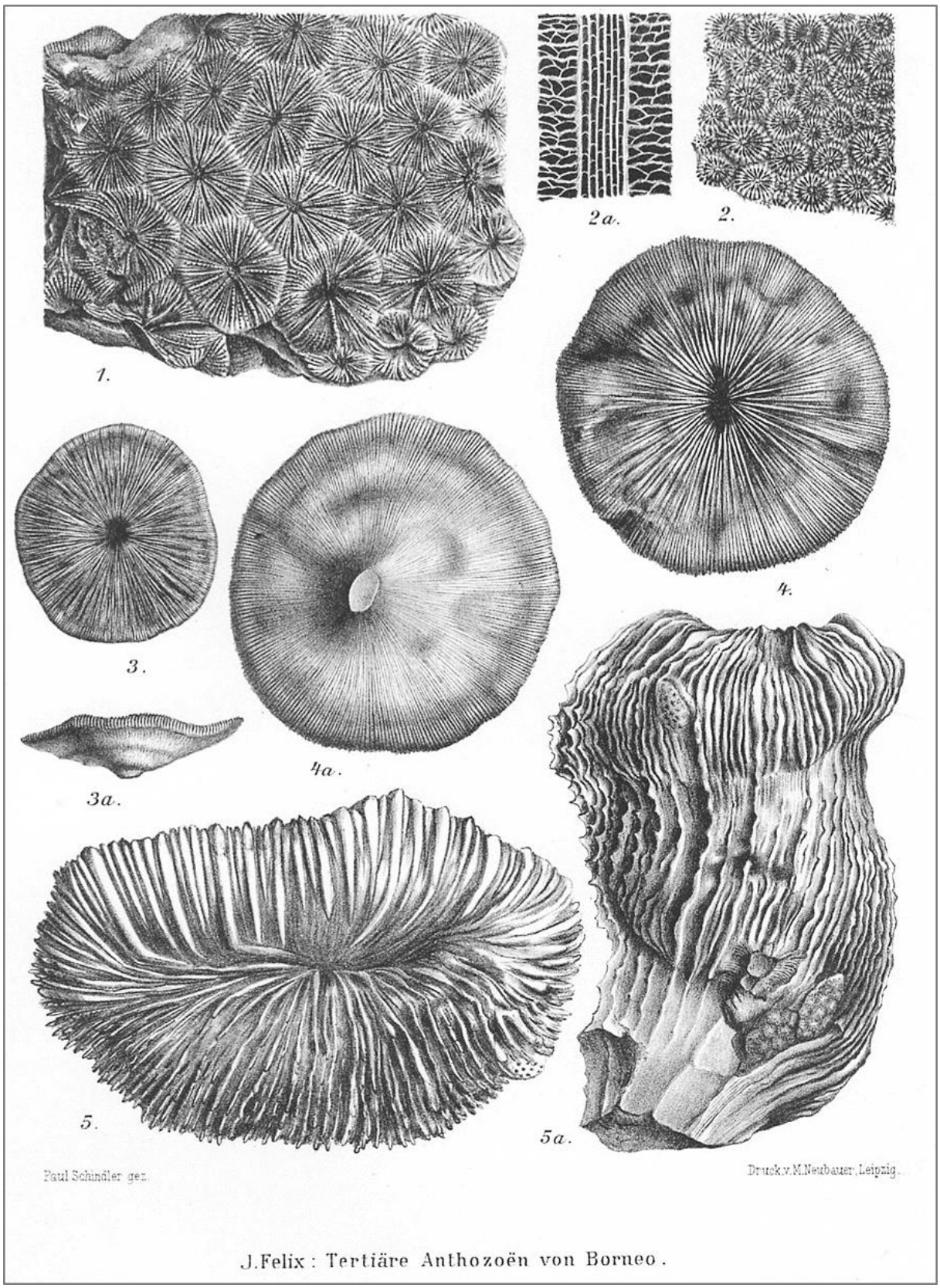


Figure 6. *Late(?) Miocene corals from Darvel Bay area, Sabah, NE Borneo. 1. Acanthastraea polygonalis, 2. Orbicella transiens, 3. Cycloseris martini, 4. Cycloseris wanneri, 5. Lithophyllia grandissima (Felix 1921)*

Osberger, R., 1954. Jungtertiare Korallen von Java, Teil I. Neues Jahrbuch Geol. Palaont. Abh. 100, 1, p. 119-158.

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Wilson, M.E.J. & B.R. Rosen , 1998. Implications of paucity of corals in the Paleogene of SE Asia: plate tectonics or center of origin? In: R. Hall & J.D. Holloway (eds.) Biogeography and geological evolution of SE Asia, Backhuys Publ., Leiden, p. 165-195.

***Table 1**. Key references on Cenozoic macrofossils of Indonesia*

TABLE 1 CENOZOIC MACROFOSSILS		
FAUNA/FLORA	**AREA**	**REFERENCES**
General	Indonesia	Escher et al. (1931)
Mollusks (bivalves and gastropods)	Indonesia	Van der Vlerk (1931), Beets (1950), Shuto (1977, 1978), Skwarko et al. (1994), Baggio & Sartori (1996), Beu (2005), Robba (2013)
	Java	Jenkins (1864), Martin (1879-1932), Boettger (1883), Haanstra & Spiker (1932), Oostingh (1933-1941), Wanner & Hahn (1935), Pannekoek (1936), Schilder (1937, 1941), Van Regteren Altena (1938-1950), Shuto (1974, 1978, 1980), Premonowati (1990), Zacchello (1984), Premonowat (1990), Robba (1996), Scolari (1999, 2001), Bazzacco (2001), Piccoli & Premonowati (2001), Rolando (2001), Van den Hoek Ostende et al. (2002), Hasibuan (2004), Leloux and Wesselingh (2009)
	Kalimantan, Borneo	Boettger (1875), Martin (1914), Beets (1941-1986), Cox (1948)
	Sumatra	Woodward (1879), Boettger (1880, 1883), Icke & Martin (1907), Martin (1928), Oostingh (1941), Haanstra & Spiker (1932), Wissema (1947)
	Sulawesi	Schepman (1907), Beets (1950)
	Buton	Martin (1933, 1935, 1937), Beets (1952), Janssen (1999)
	Seram, Timor	Fischer (1927), Tesch (1916, 1920), Robba et al. (1989)
	West Papua	Beets (1986)
Tertiary Corals	Indonesia	Osberger (1956), Leloux & Renema (2007), Wilson & Rosen (1998), Wilson (2002)
	Java	Reuss (1867), Martin (1879, 1880), Felix (1913), Gerth (1921, 1933), Yabe & Eguchi (1941), Umbgrove (1945, 1946a,b, 1950), Osberger (1954, 1955), Premonowati (1990, 1996)
	Kalimantan	Von Fritsch (1877), Felix (1921),Gerth (1923), Umbgrove (1929)
	Sumatra	Gerth (1925), Umbgrove (1926)
	Sulawesi	Von Kutassy (1934)
	Buton	Umbgrove (1943)
	Timor, Seram	Felix (1915, 1920), Umbgrove (1924)
	Flores, Sumba	Umbgrove (1939), Umbgrove (1946)
	New Guinea	Felix (1912), Gregory & Trench (1916), Yabe & Sugiyama (1942a,b)
Calcareous Algae	Indonesia	Lignac-Grutterink (1943), Johnson & Ferris (1949), Ishijima et al. (1978)
	N Borneo	Johnson (1966)
Echinoids	Multi-region	Lambert & Jeannet (1935), Jeannet & Martin (1937)
	Kalimantan, Java	Von Fritsch (1877), Gerth (1922)
	Timor, Aru Islands	Gerth (1927), Currie (1924)
Plants, Wood	Indonesia, SE Asia	Krausel (1925), Posthumus (1931), Kramer (1974), Bande & Prakash (1986), Van Konijnenburg et al. (2004)
	Java	Goppert (1854), Crie (1888), Krausel (1923, 1926), Den Berger (1927), Musper (1938, 1939), Mandang et al. (1996, 2004), Srivastava & Kagemori (2001)

TABLE 1 CENOZOIC MACROFOSSILS		
FAUNA/FLORA	**AREA**	**REFERENCES**
	Kalimantan	Geyler (1875)
	Sumatra	Heer (1874, 1879), Krausel (1922, 1929), Den Berger (1923), Musper (1938, 1939), Schweitzer (1958)
Fish (pre-Pleistocene)	S Sulawesi	Brouwer & De Beaufort (1923), De Beaufort (1934)
	C Sumatra-Eocene	Rutimeyer (1874), Gunther (1876), Von der Marck (1876), Sanders (1934), Musper (1936)
	C Java	De Beaufort (1928), Vorstman (1929; otoliths)
Vertebrates (pre-Pleistocene)	C Sumatra-	Eocene bird skeleton: Lambrecht (1931), Van Tets et al. (1989)
	C Sumatra	Oligocene bird tracks: Zaim et al. (2011), Zonnneveld et al. (2011, 2012)
	Java – U Miocene	Sea cow: Von Koenigswald (1952)
	E Kalimantan	Eocene Anthracocerid and Suidae teeth: Stromer (1931)
	Timor- Eocene	Anthracocere skull: Von Koenigswald (1967), Ducrocq (1996)
	PNG Miocene	Turtle: Glaessner (1942), Sea cow: Fitzgerald at al. (2013)

Echinodermata

Fossil echinoids are relatively uncommon in the Cenozoic of Indonesia, although they are present in small numbers in most marine environments. Their taxonomy and stratigraphic distributions is also relatively poorly studied. The main papers on this group are from Gerth (1922, 1927) (Figure 7) and Jeannet and Martin (1937).

Key References Echinoids

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Jeannet, A. & R. Martin, 1937. Ueber Neozoische Echinoidea aus dem Niederlandisch-Indischen Archipel. Leidsche Geol. Meded. 8, 2, p. 215-308.

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Plant fossils, Petrified wood

Plant fossils are locally common in Eocene and Mio-Pliocene non-marine deposits of Western Indonesia (Sumatra, Java and Kalimantan; Figures 8, 9). Fossilized wood and plant leaves may be found in two settings: (1) in claystones associated with coal beds, fossilized under poorly oxygenated swamp conditions, or (2) in tuff deposits, where entire forests were killed and preserved after major volcanic eruptions, and where silicified tree trunks may still be found in growth position. The latter are particularly common in various silica-rich Late Miocene-Pliocene volcanoclastic deposits of West Java and South Sumatra. There is an urgent need to renew the study of fossil woods, since mining of Mio-Pliocene fossil wood for ornamental purposes is currently a major extractive industry in West Java, etc., This is a major opportunity to study the taxonomy and taphonomy of these ancient forests, but there is no evidence that this work is being done. These fossils need to be better understood before their localities are destroyed.

Early descriptions of plant fossils include:
- Mio-Pliocene floras from West Java collected by Junghuhn (Goppert, 1854) (Figure 9);
- Eocene plant fossils collected by Verbeek from the Ombilin Basin, C Sumatra (Heer 1874, 1879);
- Eocene plant fossils collected by Verbeek from SE Kalimantan (Geyler, 1877; Figure 8).

Significant papers on petrified wood from Java and Sumatra include:
- papers by Musper (1938, 1939) on age and localities of fossil wood on Sumatra and West Java;
- monographs on Cenozoic woods from SE Asia by Kramer (1974a, b).

For additional references see Table 1 and the Bibliography.

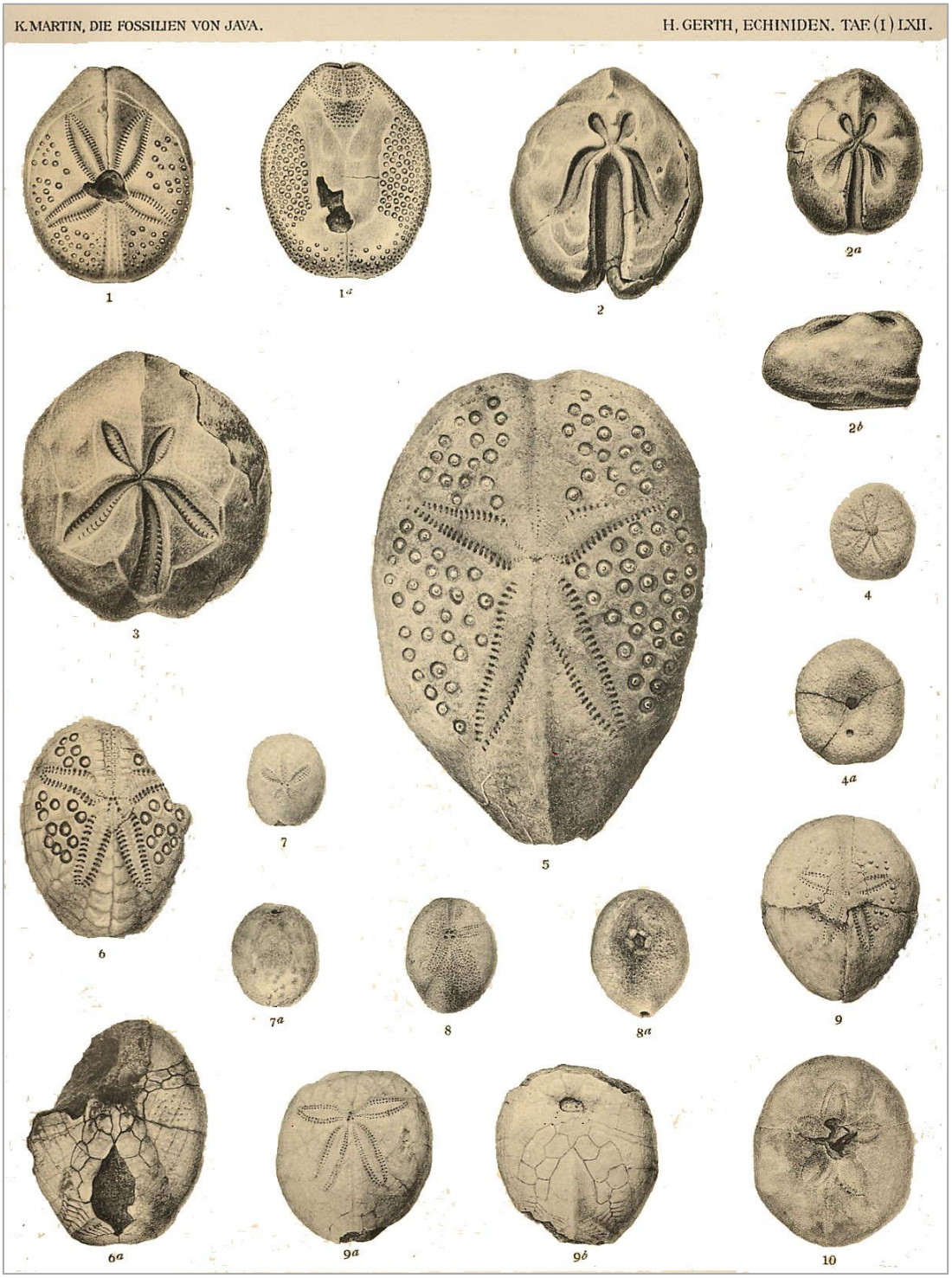


***Figure 7**. ?Miocene echinoids from Java (Gerth, 1922)*

Modern floras show distinct provinciality across Indonesia, although the 'Wallace Line' does not appear to be a very distinct boundary in plant distributions (e.g. Van Welzen et al. 2011). Cenozoic plant fossils also undoubtedly show similar, or even more pronounced, provincialism between West (Asian-affinity) and East Indonesia (New Guinea-affinity), but this is poorly documented, partly because plant-bearing deposits in Eastern Indonesia are extremely rare.

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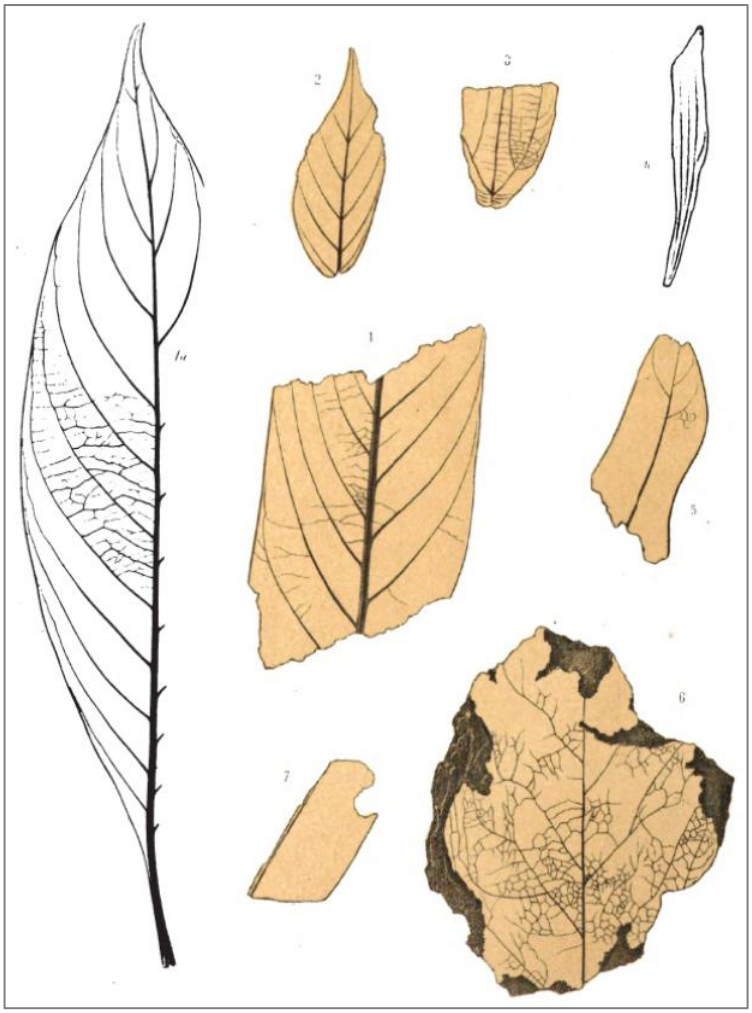


***Figure 8**. Plant fossils from coal-bearing Eocene of Pengaron, Barito Basin, SE Kalimantan. 1. Phyllites (Grumilea) mephitidioides, 2. Grumilea affinis,3. Entoneuron melastomaceum, 4. Carpites(Dipterocarpus) pengaronensis, 5. Phyllites (Sterculia?), 6. Phyllites (Loranthus) deliquescens, 7. Leguminosites? (Geyler, 1877)*

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Pre-Pleistocene Vertebrate fossils

Vertebrate fossils are very rare prior to the well-documented invasion of 'Asian' land mammals (including hominids) across large areas of western Indonesia in latest Pliocene- Early Pleistocene time. That migration was facilitated by the emergence above sea level of zones of tectonic uplift, growth of volcanoes and periodic exposure of the Sunda shelf during glacial lowstands. A discussion of the diverse Quaternary mammal assemblages is beyond the scope of this paper, but numerous references can be found in the chapter of this name in the Bibliography of the Geology of Indonesia.

The oldest known land mammal species in Indonesia are Eocene anthracocere remains from Kalimantan (Stromer 1931) and Timor (Von Koenigswald 1967, Ducrocq 1996). Other pre-Pleistocene vertebrate fossils of Indonesia are mainly lacustrine and marine fish.

Eocene lacustrine fish and shore bird fossils from Sumatra

The presence of a rich fish fauna in Eocene lacustrine calcareous shales of the Ombilin Basin, Padang Highlands, Central Sumatra, has been known for a long time. Fish fossil collections by Verbeek were first studied by Rutimeyer (1874), Gunther (1876) and Von der Marck (1876, 1878). In 1927 Musper collected an additional 1200 specimens, which were studied by Sanders (1934), who distinguished 15 species, some of which are very similar or identical to species still found in Indonesia today (*Notopterus*; Figure 10).

A skeleton of a water bird of the pelican family *(Protoplotus beauforti)* was found in the same lacustrine deposits at Sipang, West Sumatra (Lambrecht, 1931). Also worth mentioning in this context are Oligocene shore bird footprints in the fluvial-estuarine Sawahlunto Formation of the Ombilin Basin (Zaim et al. 2011, Zonneveld et al. 2011, 2012)

Eocene Anthracoceres of Timor, Kalimantan

The only pre-Pleistocene terrestrial mammal fossils in Indonesia are rare remains of Eocene anthracoceres in Kalimantan and Timor. Anthracoceres are *Hippopotamus*-like mammals that are known from many M-U Eocene localities of Europe and mainland SE Asia (mainly Myanmar, South China), but not from Australia-New Guinea. The first record of Early Tertiary mammal remains from Indonesia are two teeth from probable Eocene-age beds of the non-marine-brackish Melawi Group at Gunung Sebumban Ulu, Sedona River, in the Sanggau area of West Kalimantan (Stromer 1931). One of these was identified as a small anthracocerid *Artiodactylus*, part (Figure 11-top).

A second Eocene anthracocere fossil is from the northern part of West Timor. It is a fragment of a skull with five teeth, which was described as *Anthracothema verhoeveni* by Von Koenigswald (1967) (Figure 11). According to Ducrocq (1996) it belongs in the genus *Anthracotherium*. The fossil was found by a local teacher in red-brown sediments with some shells on the bank of the small Mota Bour river, 2-3 km west of Laharus in the Atambua District. It was given to a local priest, who passed it on to missionary and paleoanthropologist T. Verhoeven in 1966, who later visited the alleged location. Non-marine Eocene deposits have not been well documented from Timor, but Eocene nummulitic limestones that grade upward into

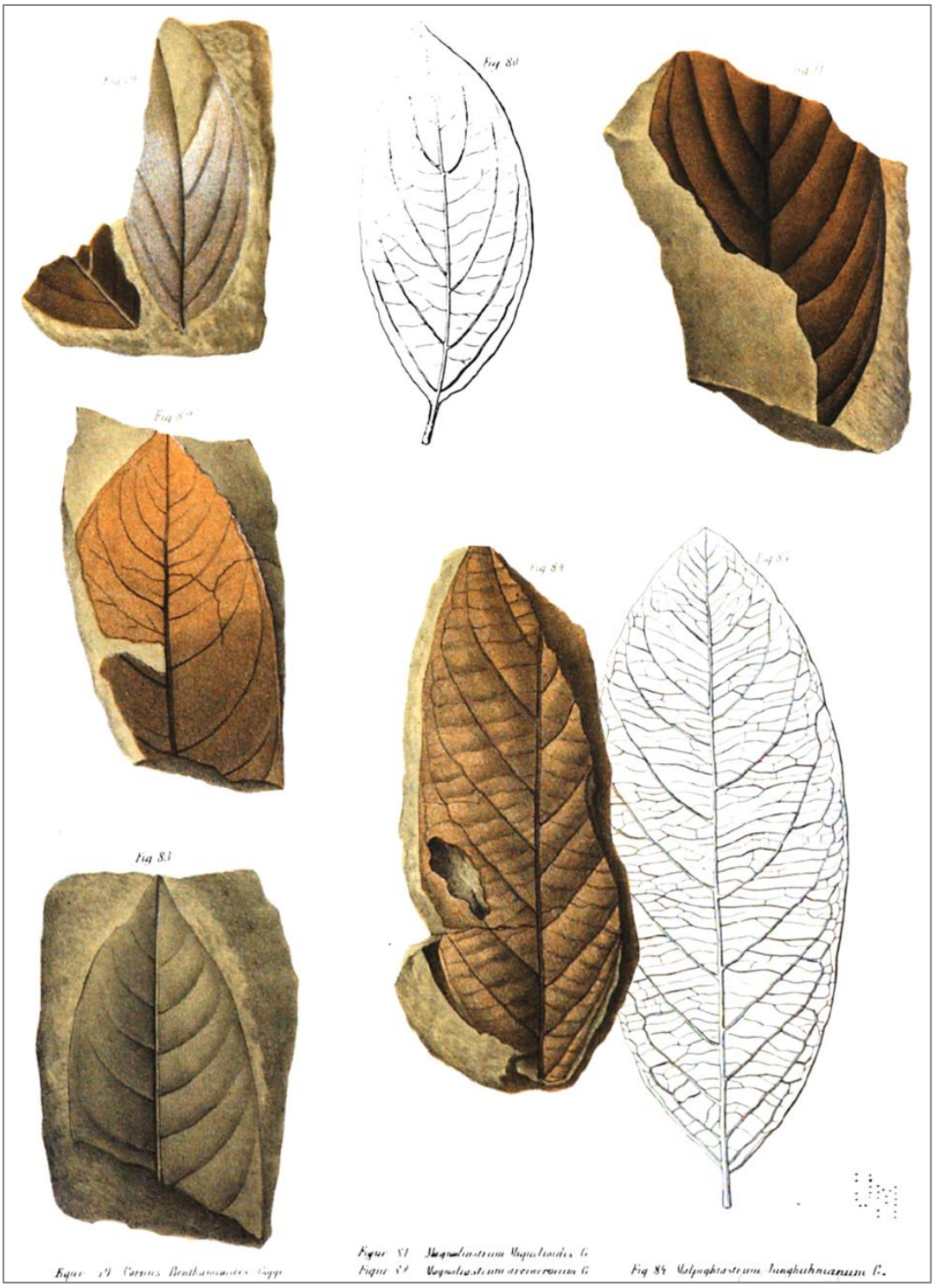


***Figure 9**. Mio-Pliocene plant fossils from Java, collected by Junghuhn. 79. Cornus benthamioides, 80. Benthamia fragifera, 81-83. Magnoliastrum spp, 84. Malphigiastrum junghuhnianum, 85. Heteroptris chrysophylla (Goppert, 1854).*

sandstone of possible continental origin were observed nearby (P. Sondaar in Ducrocq 1996). The presence of Nummulites limestone indicates that the anthracocere fossil is from the 'Banda Terrane', a Cretaceous-Miocene tectonostratigraphic assemblage on Timor with a stratigraphic succession that is very similar to that of West Sulawesi, and which has long been viewed as a terrane derived from the Sundaland margin.

As pointed out by Von Koenigswald (1967) and Ducrocq (1996), anthracocerids are fossils of Laurasiatic affinity, which are relatively widespread in Myanmar and South China. They cannot have been part of the autochthonous NW Australian margin deposits in Eocene time. Assuming that (1) this fossil was indeed found in NE West Timor (it is hard to imagine how and why a rare fossil from outside Indonesia would have been brought to a remote village in Timor) and (2) that anthracoceres were not capable of crossing major ocean basins (the distance between the NW Australian margin and SE Asia was 1000's of kilometers in Eocene time), it suggests that this part of Timor was part of the Asian (Sundaland) margin in Eocene time.

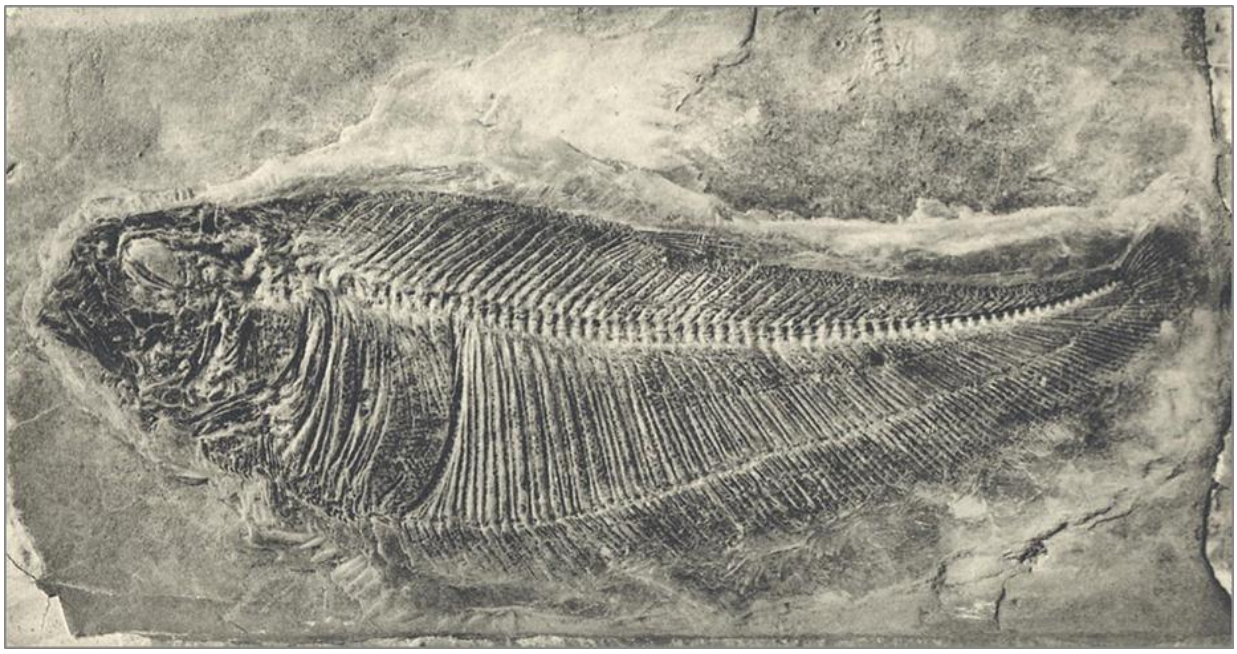


Figure 10. *Eocene lacustrine fish Notopterus notopterus from Central Sumatra (Sanders 1934)*

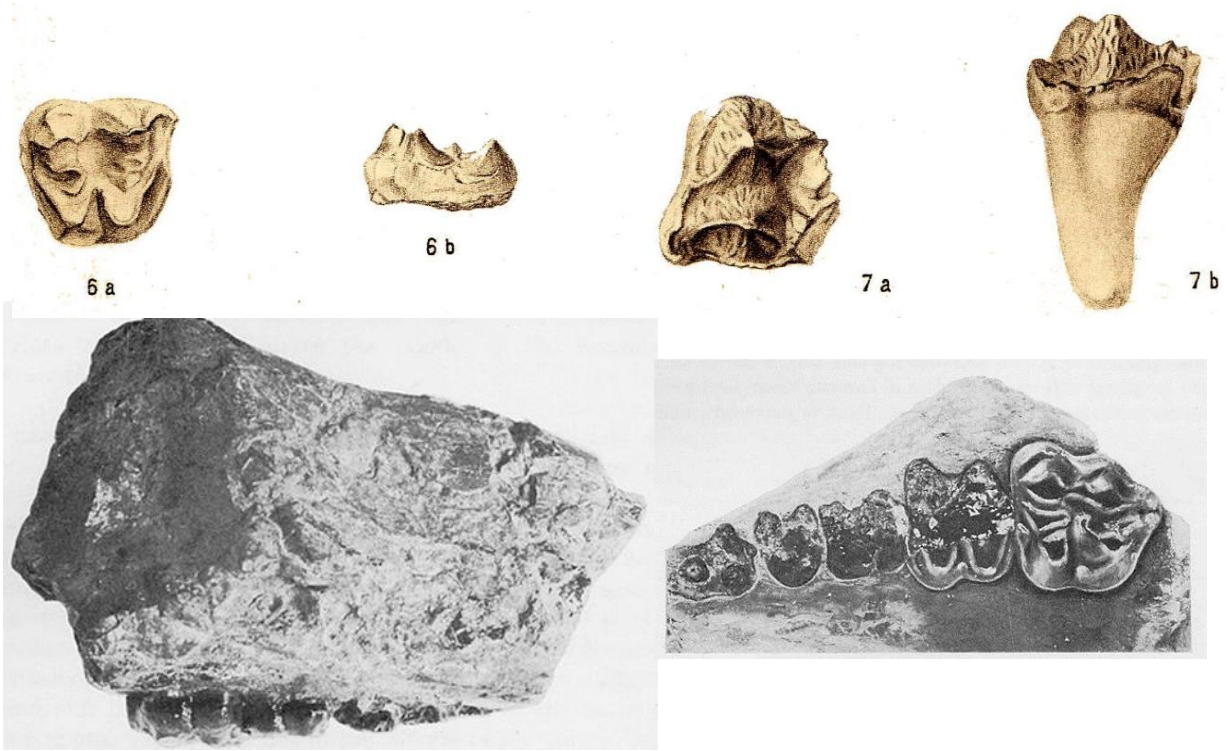


Figure 11. *Eocene 'Eurasian' mammalian fossils from West Kalimantan and Timor. Top: Molars of cf. Choeromorus (pig family; fig. 6a, b) and anthracoceriid (Fig. 7a,b) from Sanggau District, W Kalimantan (Stromer 1931). Bottom: Skull fragment and teeth of* Anthracothema verhoeveni (=Anthracotherium) *from Timor (Von Koenigswald 1967)*

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PALEOBIOGEOGRAPHY

Indonesia is well-known for its different present-day biogeographic provinces of land animals and plants. Asian-affinity floras and faunas dominate in the West (Sundaland) and Australian-New Guinea-affinity taxa dominate in East Indonesia, reflecting the fairly recent closing of wide ocean barriers between the formerly widely separated Asian and Australian continents. However, drawing the

boundary between the two domains has been done in different ways, depending on what groups are emphasized: the Wallace Line(s), Lydekker Line, Weber Line, Huxley Line, etc.. Most biogeographers today place Sulawesi and parts of the Moluccas in a transitional domain named Wallacea (e.g. Michoux 1994, 2010, Van Welzen et al. 2011).

In modern marine faunas these East-West differences are much less pronounced. Assemblages from Indonesia all represent tropical faunas of Indo-Pacific province affinity, with only minor differences between East and West. The Indo-Australian Archipelago is the area of maximum diversity ('hotspot') for corals and mollusks.

Although they undoubtedly exist, distinct biogeographic patterns have not yet been properly identified and documented in Cenozoic macrofossils. Microfossils have already shown some interesting paleobiogeographic patterns. For instance, the distributions of Eocene larger foraminifera *Pellatispira* and *Lacazinella* (supported by evaporite lithologies) suggest that the Paleocene-Eocene carbonates of the New Guinea margin are not fully tropical, but represent subtropical to warm temperate settings (Lunt 2003). Palynological studies show the arrival of Gondwanan floral elements in Indonesia in the Late Eocene and later, that can be tied to the collisions of India in the West and Australian- New Guinea derived terranes in the East (Morley, 2000). This is a field of research in which macrofossils have the potential to make significant contributions that will be applicable to tectonic and paleoceanographic reconstructions of the region.

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CONCLUSIONS

Most of the current studies on Cenozoic fossils of Indonesia are focused on microfossils, for obvious practical reasons. However, significant work has been done on Cenozoic and older macrofossils, which is still of considerable interest. Cenozoic macrofossil assemblages may hold paleobiogeographic patterns that are significant for unraveling plate tectonic and paleoceanographic histories, but few of these have been uncovered. Hopefully this and companion papers will stimulate future projects in taxonomic revision, biozonations and paleoenvironmental and paleobiogeographic patterns of macrofossils. And perhaps form the beginnings of a badly-needed 'Paleontology and Biostratigraphy of Indonesia' textbook.

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(For a comprehensive list of papers see the 'Bibliography of Biostratigraphy and Paleontology of Indonesia- SE Asia', published as Berita Sedimentologi 29A, or the complete bibliography at www.vangorselslist.com)