An introduction to Paleozoic faunas and floras of Indonesia

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ABSTRACT

In the Indonesian region the most complete Paleozoic sedimentary section is in West Papua, where parts of the older Australian continental margin sequence are exposed. The oldest fossils are Ordovician-Silurian age corals and graptolites. The only Early Paleozoic fossils in West Indonesia are the enigmatic occurrence of a Devonian coral and stromatoporoid in limestone blocks in a melange section of uncertain age in NE Kalimantan. Late Paleozoic faunas and floras are more widespread across Indonesia, mainly on Sumatra, Timor and West Borneo, where the oldest fossils are of Late Carboniferous and Permian ages.

Paleozoic fossils from Indonesia are mainly marine organisms, but non-marine Permian plant fossils are known from Sumatra and West Papua. Some assemblages or species signify 'low-latitude Tethyan' settings; others have 'anti-tropical/subtropical Tethyan' or 'Gondwanan' affinities, which helps constrain plate reconstruction models.

INTRODUCTION

This paper is one of four papers published in this journal. Two of these were published recently in this journal (Van Gorsel et al. (2014) on Cenozoic microfossils and biostratigraphy and Van Gorsel (2014) on Cenozoic macrofossils. The remaining two, on Paleozoic and Mesozoic fossils, are discussed in this issue. Together they represent a brief 'Introduction to the paleontology and biostratigraphy of Indonesia', which could have been the title of a useful book that has never been written. This series of papers is not a systematic treatise of paleontology, but rather an introduction to the principal fossil groups and their significance, and references to key literature for more detailed information.

Studies of Paleozoic and Mesozoic faunas and floras are not just of historic interest, but are essential for unraveling the early history of Indonesia. Such fossils are often the only tool for age control, which is fundamental to all regional geological studies, or provide a 'reality check' for radiometric and other age dating tools. They also provide local paleoenvironment and regional paleoclimate information, thus constraining depositional settings and paleolatitudinal position. This together with paleobiogeographic patterns of faunal/floral similarities between tectonic blocks or endemism further help constrain plate tectonic reconstructions.

Many of the genus and species names used in historic literature on Indonesian fossils are outdated. In this paper we still use some of these original names, but recognize that these may not be in agreement with the latest taxonomic concepts and classifications. It is, however, important to realize that correct taxonomy and consistent identifications are very important. Misidentifications and inconsistent taxonomy will lead to incorrect conclusions on biostratigraphic ages and paleobiogeographic patterns. Unfortunately, paleontological research on macrofossils of Indonesia has come to a virtual standstill, as it has worldwide, and the number of experts that are qualified to properly analyze pre-Cenozoic macrofaunas and floras of Indonesia is limited.

History and Data on Pre-Cenozoic Paleontology of Indonesia

A significant body of literature has been published on Pre-Cenozoic fossils from outcrops in the Indonesian region over the last ~150 years, in which thousands of species have been identified and described. However, relatively little modern work has been done and this work has never been properly summarized in a textbook on the paleontology of Indonesia. Many of these papers, books and monographs are from the colonial era, published in the early 1900's, and written mainly by German and Dutch academic paleontologists. As a result, much of this work may be hard to find and is poorly known today. Yet, much of this early descriptive paleontology work is still relevant today, and the purpose of this paper is to review some of this historic knowledge, and place in a modern geologic context.

Notable series of paleontological monographs include:
- 'Beitrage zur Geologie von Niederlandisch Indien' edited initially by G. Boehm and later by J. Wanner (1913-1959);
-'Palaeontologie von Timor' series edited by J. Wanner (1914-1929). 30 monographs in 16 volumes;

- 'Wetenschappelijke Mededeelingen Dienst Mijnbouw Nederlands Indie', 1-28 (1929-1940). Mainly paleontological contributions from Geological Survey, Bandung, paleontologists Van der Vlerk, Gerth, Umbgrove, Oostingh, Tan Sin Hok and Von Koenigswald.
- 'Geology and Palaeontology of Southeast Asia', Tokyo University Press, 1-25 (1964-1984). A remarkable series edited by T. Kobayashi et al., documenting numerous paleontological studies by Japanese paleontologists in mainland Southeast Asia and Indonesia from the 1950's - 1980's.
- CCOP Technical Publications. Contain paleontological papers on Paleozoic - Mesozoic paleontology of mainland SE Asia and western Indonesia by French group of Henri Fontaine and associates Beauvais, Tien and Vachard in the 1980's - 1990's.
- More current paleontological papers, or geologic papers with significant pre-Cenozoic paleontological content, include those by Hasibuan, Kristan-Tollman, Martini, Grant-Mackie, Skwarko, Charlton and others (see Bibliography).

Comprehensive listings of all faunas and species known from Indonesia were published in 1931 in the Professor Martin Memorial volume (Escher et al. 1931). This volume also includes reviews of stratigraphy of the Paleozoic by Brouwer and the Mesozoic by Wanner. A more recent and more concise compilation of macrofossil species is by Skwarko and Yusuf (1982). Another useful and still remarkably accurate review of pre-Cenozoic faunas/floras distribution in Indonesia is in Umbgrove (1938).

Literature on Paleozoic - Mesozoic fossils has been captured in the 'Bibliography of the geology of Indonesia and surrounding areas' (online at www.vangorselslist.com or see the Biostratigraphy chapter from this, published as Berita Sedimentologi 29A). It lists >1400 titles of books and papers from Indonesia and SE Asia with data on Paleozoic - Mesozoic fossils. The discussions below and the annotated bibliography should facilitate access to this wealth of published research from the region. The tables in this series of papers focus on references on Indonesian fossils.

KEY REFERENCES- PRE-CENOZOIC PALEONTOLOGY GENERAL

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

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Harsono Pringgoprawiro, D. Kadar and S.K. Skwarko, 1998. Foraminifera in Indonesian stratigraphy, Vol.3: Palaeozoic and Mesozoic foraminifera. Geol. Res. Dev. Centre, Bandung, p. 1-150.

Hasibuan, F., 2008. Pre-Tertiary biostratigraphy of Indonesia. In: Proc. Int. Symp. Geoscience resources and environments of Asian Terranes (GREAT 2008), 4th IGCP 516 and 5th APSEG, Bangkok, p. 323-325.

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Kobayashi, T., R. Toriyama and W. Hashimoto (eds.), 1984. Geology and Palaeontology of Southeast Asia, University of Tokyo Press, 25, 488p.

Skwarko, S.K. and G. Yusuf, 1982. Bibliography of the invertebrate macrofossils of Indonesia (with cross references). Geol. Res. Dev. Centre, Bandung, Spec. Publ. 3, p. 1-66.

Umbgrove, J.H.F., 1935. De Pretertiaire historie van den Indischen Archipel. Leidsche Geol. Meded. 7, p. 119-155.

Umbgrove, J.H.F., 1938. Geological history of the East Indies. AAPG Bull. 22, p. 1-70.

Van Gorsel, J.T., 2014. An introduction to Cenozoic macrofossils of Indonesia. Berita Sedimentologi 30, p. 63-76.

Van Gorsel, J.T., P. Lunt and R. Morley, 2014. Introduction to Cenozoic biostratigraphy of Indonesia- SE Asia. Berita Sedimentologi 29, p. 6-40.

PALEOZOIC FOSSIL GROUPS

In the Indonesian region Early Paleozoic fossiliferous rocks are known only from West Papua, south of the Central Range and on the Birds Head (but not in Papua New Guinea). Of significant interest, but unfortunately poorly documented and poorly understood, are reported occurrences of Devonian fossils in the accretionary system of North Borneo. An early review of Paleozoic stratigraphy is by Brouwer (1931)

Early Paleozoic fossiliferous platform sediments and faunas of SE Asia are best-known from outside Indonesia, particularly on the Sibumasu terrane (NW Malay Peninsula and Langkawi islands-Peninsular and NW Thailand-E Myanmar-Yunnan; but not from the eastern Malay Peninsula or Sumatra [see references in separate Bibliography]). Pre-Carboniferous rocks may therefore be expected in the southern extension of the Sibumasu block in Sumatra, but there is no fossil evidence for this yet (Fontaine and Gafoer 1989).

Late Paleozoic (Carboniferous-Permian) deposits in Indonesia are more widespread than Early Paleozoic rocks. They have been reported only from Sumatra, West Papua (South of the Central Range and the Birds Head) and Timor and adjacent islands (Figure 1). Blocks of Late Carboniferous - Early Permian fusulinid limestones are also known from both the NW Kalimantan - Sarawak border region and from NE Kalimantan,

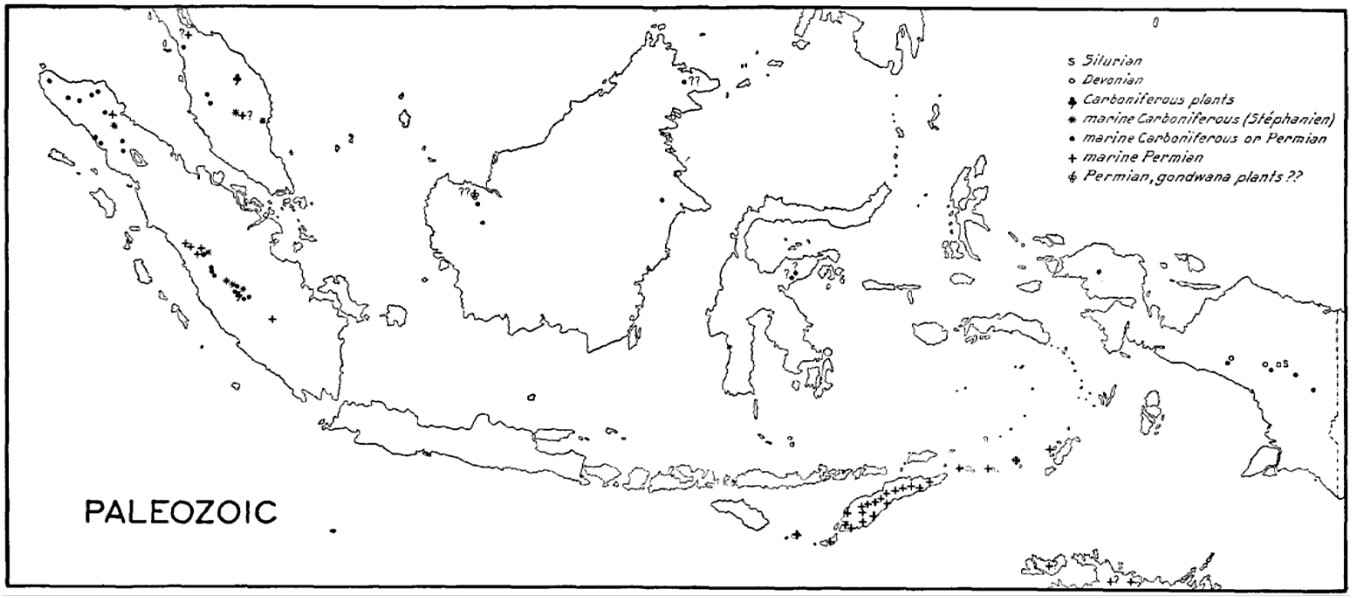


Figure 1. *Distribution of Paleozoic rocks/ fossils in Indonesia (Umbgrove 1938), showing the main Paleozoic outcrop areas on Sumatra, NW Borneo, Timor and New Guinea.*

however these occurrences are probably in accretionary melange of younger age.

Most of the Paleozoic sediments of Indonesia are in marine facies, so most studies deal with marine macro- and microfossils. In the Paleozoic dominant groups are brachiopods, ammonoids, corals, stromatolites, crinoids, blastoids, graptolites and trilobites. Microfossils tend to be more significant than macrofossils for Paleozoic biostratigraphy, with conodonts, radiolaria and foraminifera as the most important groups:

1. *Radiolaria*: in deep marine Paleozoic - Mesozoic deposits radiolaria offer high resolution biostratigraphy. Belts of radiolarian-rich cherts and shales can be used to trace the locations of former ocean basins and distal continental margins;
2. *Conodonts*: key group for dating of Paleozoic - Triassic shallow marine limestones;
3. *Benthic foraminifera*: important in dating Late Paleozoic shallow marine limestone (incl. fusulinids). An illustrated listing of Paleozoic-Mesozoic foraminifera species from Indonesia was compiled by Harsono, Kadar and Skwarko (1998, vol. 3; limited edition);

Paleozoic vertebrate faunas are very rare in the SE Asia region, and represented only by Late Silurian - Devonian marine fish fossils in mainland SE Asia and in West Papua (Turner 1995).

KEY REFERENCES- PALEOZOIC GENERAL

Brouwer, H.A., 1931. Paleozoic In: B.G. Escher et al. (eds.) De palaeontologie en stratigraphie van Nederlandsch Oost-Indie, Leidsche Geol. Meded. 5 (K. Martin memorial volume), p. 552-566.

ORDOVICIAN

The oldest fossils described from Indonesian territory are from the Ordovician-Silurian of West Papua. Cambrian and Late Precambrian sediments are probably present in this as well, but no diagnostic fossils have yet been recovered. Studies of Paleozoic fossils from West Papua are few, probably partly because faunas are not abundant and partly because outcrops of Early Paleozoic are in areas with difficult physical and political access. Most of the fossils described are from float samples from rivers draining the southern slopes of the Central Range.

Ordovician fossils reported from West Papua include:

1. Conodonts from 'basement limestone' in oil exploration wells Noordwest 1 and Cross Catalina 1 in the Central Range, including Ordovician *Serratognathus bilobatus* (Nicoll 2006). These limestones are part of the extensive Middle Cambrian - Early Ordovician Goulburn Group of carbonate-dominated shelf sediments, which underlie most of the Arafura Sea and West Papua South of the Central Ranges (Zhen et al. 2012);
2. Llanvirnian graptolites from shale from the Heluk River in the eastern foothills of the Central Range (Fortey and Cocks, 1986; not described or illustrated);
3. Possible occurrences of Ordovician-age orthoconic nautiloids of the *Orthoceras*-group, described as *Irianoceras antiquum* by Kobayashi and Burton (1971), but this was deemed to be a junior synonym of *Bactroceras latisiphonatum* Glenister 1952 by Crick and Quarles van Ufford (1995). These nautiloids are from black shale nodules in river float within and south of the Central Range of West Papua (Figure 2). The problem is that (1) the nodules look very similar to those from Kembelangan Formation black shales, which yield common Middle-Late Jurassic ammonites, and (2) the fossils appear to have been collected in areas with nearby outcrops of Jurassic rocks, but no Paleozoic. These observations suggest a likely Jurassic age for these nautiloids, but this type of straight



Figure 2. *Ordovician(?) straight nautiloid in silicified black shale nodule, presumably collected in Central Range, West Papua. Length of fossil= 7cm (purchased in Wamena market by author)*

nautiloids is not known from post-Triassic rocks anywhere in the world. It is hard to decide whether these 'Ordovician' nautiloids represent (1) material from as yet unidentified outcrops of Ordovician shales in the Central Range; (2) an as yet undescribed nautiloid species of Jurassic age, or (3) reworked Ordovician fauna into Middle-Late Jurassic sediments.

4. Another occurrence of molds of possible Ordovician *Orthoceras* is in phyllitic shale (presumably Kemum Formation), just N of the mouth of the Wesan River in the NW part of the Birds Head (Kruizinga 1957).

KEY REFERENCES- ORDOVICIAN

Crick, R.E. and A.I. Quarles van Ufford, 1995. Late Ordovician (Caradoc-Ashgill) ellesmerocerid *Bactroceras latisiphonatum* of Irian Jaya and Australia. Alcheringa 19, 3, p. 235-241.

Fortey, R.A. and L.R.M. Cocks, 1986. Marginal faunal belts and their structural implications, with examples from the Lower Palaeozoic. J. Geol. Soc. London 143, p. 151-160.

Kobayashi, T. and C.K. Burton, 1971. Discovery of ellesmereoceroid cephalopods in Irian, New Guinea. Proc. Japanese Academy 47, 7, p. 625-630.

Martin, K., 1911. Palaeozoische, Mesozoische und Kaenozoische Sedimente aus dem sud-westlichen Neu-Guinea. Sammlung. Geol. Reichsmus. Leiden, ser. 1, 9, 1, E.J. Brill, p. 84-107.

SILURIAN

Similar to the Ordovician, Silurian-age fossils are known only from West Papua:

1. Graptolites *Monograptus turriculatus* and *M. marri* from the highly-deformed deep water sediments of the Kemum Formation in the north-central Birds Head (Llandoverian; Visser and Hermes 1962);
2. Small trilobites and brachiopods from float samples in rivers draining the southern slopes of the Central Range (Martin, 1911), associated with Silurian conodonts (Ludlowian; Van den Boogaard 1990);
3. Conodonts from Modio Dolomite in Charles Louis Range, SW West Papua, with *Panderodus* cf. *simplex*, indicate a Silurian age (Nicoll and Bladon 1991);
3. Silurian cosmopolitan coral *Halysites wallichi* was also found in river float in a tributary of the Noordoost/Lorentz River (Musper, 1938; Figure 3);
4. Late Silurian (M Ludlow) thelodont and acanthodian fish scales from Lorenz River in eastern W Papua and Kemum Fm of north part of Birds Head (Turner et al. 1995).

KEY REFERENCES- SILURIAN

Musper, K.A.F.R., 1938. Over het voorkomen van *Halysites wallichi* Reed op Nieuw Guinea. De Ingenieur in Nederl.-Indie (IV Mijnbouw en Geologie), 5, 10, p. 156-158.

Nicoll, R.S. and G.M. Bladon, 1991. Silurian and Late Carboniferous conodonts from the Charles Louis Range and central Birds Head, Irian Jaya, Indonesia. BMR J. Austral. Geol. Geoph. 12, 4, p. 279-286.

Turner, S., J.M.J. Vergoossen and G.C. Young, 1995. Fish microfossils from Irian Jaya. Mem. Assoc. Australasian Palaeont. 18, p. 165-178.

Van den Boogaard, M., 1990. A Ludlow conodont fauna from Irian Jaya (Indonesia). Scripta Geol. 92, p. 1-27.

Visser, W.A. and J.J. Hermes, 1962. Geological results of the exploration for oil in Netherlands New Guinea. Verh. Kon. Nederl. Geol. Mijnbouwk. Genootschap, Geol. Series 20, p. 1-265.

DEVONIAN

Devonian-age fossils are relatively widespread on mainland SE Asia (Malay Peninsula, NE Thailand, S China, Cambodia, Vietnam), and also along the Australia-New Guinea margins. All these regions were probably in low latitudes in Devonian time, favoring widespread carbonate development. However, Devonian fossils are relatively rare in Indonesia, and are known only from West Papua and NE Kalimantan.

Devonian Corals

Middle or Late Devonian corals, including *Heliolites* and *Favosites*, and stromatoporoids, have been reported from the dark grey 'Modio Dolomite Formation', which outcrops south of the Central Range of West Papua (Gerth 1927, Keijzer 1941, Oliver et al. 1995).

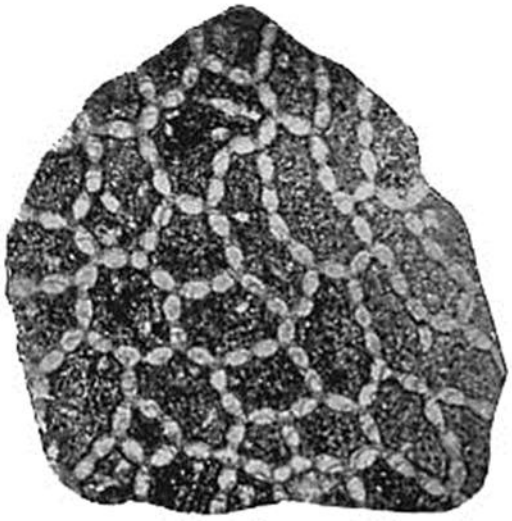


Figure 3. *Section across Early Paleozoic tabulate 'chain coral'* Halysites wallichi *from Peningih/Oesak tributaries of the Noordoost/(=Lorentz) River, West Papua (Musper 1938).*

These carbonates may be remnants of a widespread Middle Devonian reef system that continues for about 2000 km along the East Australia and New Guinea margin (Copper and Scotese 2003, Torsvik and Cocks 2013). Pebbles of M-U Devonian sandstones with the brachiopod genus *Spirifer* have been reported from the same region (Teichert, 1928).

In NE Kalimantan Devonian corals (*Heliolites*) and the stromatoporoid *Clathrodictyon* cf. *spatiosum* are present in limestone blocks in the 'Danau Formation' melange complex at the Telen River (Rutten 1940, 1947). *Heliolites* is a genus that is geographically widespread, also known from Indochina, NE Thailand, Laos, East Australia and Europe. Age of the melange complex has not been properly documented, but is likely Early Cretaceous (Tate 1992).

KEY REFERENCES- DEVONIAN

Copper, P. and C.R. Scotese, 2003. Megareefs in Middle Devonian supergreenhouse climates. Geol. Soc. America Spec. Paper 370, p. 209-230.

Gerth, H., 1927. Eine *Favosites* Kolonie aus dem Palaozoikum von Neu-Guinea. Leidsche Geol. Meded. 2, 3, p. 228-229.

Oliver, W.A., A.E.H. Peddler, R.E. Weiland and A. Quarles van Ufford, 1995. Middle Palaeozoic corals from the southern slope of the Central Ranges of Irian Jaya, Indonesia. Alcheringa 19, p. 1-15.

Rutten, M.G., 1940. On Devonian limestones with *Clathrodictyon* cf *spatiosum* and *Heliolites porosus* from Eastern Borneo. Proc. Kon. Nederl. Akad. Wet. 43, 8, p. 1061-1064.

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Teichert, C., 1928. Nachweis Palaeozoischer Schichten von Sudwest Neu-Guinea. Nova Guinea 6, 3, p. 71-92.

TABLE 1 ORDOVICIAN- DEVONIAN

FAUNA/FLORA	AREA	REFERENCES
Devonian corals	West Papua	Gerth 1927, Keijzer 1941, Oliver et al. 1995
	NE Kalimantan	Rutten 1940, 1947, Sugiaman and Andria 1999
Devonian brachiopods	West Papua	Stehn 1927, Feuilleteau de Bruyn 1921
Late Silurian-Devonian fish	W Papua	Turner et al. 1995
	SE Asia	Wang et al. 2010
Silurian corals	W Papua- S of C Range	Gerth 1927, Teichert 1928, Musper 1938
Silurian conodonts	W Papua- S of C Range	Van den Boogaard 1990, Nicoll and Bladon 1991
Ordovician-Silurian graptolites	W Papua, Birds Head	Visser and Hermes 1962 (Silurian)
	W Papua, Heluk River	Fortey and Cocks 1986 (M Ordovician)
Ordovician? orthoconic nautiloids	W Papua Star Mountains	Kobayashi. and Burton 1971
	W Papua Central Range	Crick and Quarles van Ufford 1995
	Birds Head	Kruizinga 1957
E Ordovician conodonts	W Papua, S Central Range	Nicoll 2002

CARBONIFEROUS

Carboniferous deposits are relatively rare in Indonesia, and are limited to North Sumatra, West-Central Sumatra, West Papua and possibly also NW Kalimantan. In the late 1800's most of the Permian limestones from Sumatra and Timor were erroneously assigned to the Carboniferous (equivalent of 'Kohlenkalk' of NW Europe).

Sumatra
Early Carboniferous sediments are the oldest sediments identified in Sumatra and may be from two different tectonic blocks (Fontaine and Gafoer, 1989, Barber et al. 2005):
- temperate late Visean Alas Fm limestones in North Sumatra. These are probably part of the Sibumasu Terrane, which at this time was still part of Australian margin. With conodonts (Metcalfe 1983)
- shallower marine and warmer-climate Kuantan Fm limestone with corals (*Syringopora, Siphonodendron*), calcareous algae (*Koninckopora*) and cosmopolitan foraminiferal assemblages from West Sumatra (Agam River, NE of Padang; Fontaine and Gafoer, 1989, Kato et al. 1999). This is part of the West Sumatra Block, with affinities more similar to the low-latitude Indochina Block.

The un-fossiliferous, glacial pebbly mudstones of the Bohorok Formation of West and North Sumatra are probably of Late Carboniferous - earliest Permian age, but fossils are lacking.

NW Kalimantan - West Sarawak
In NW Borneo, in the border area between West Sarawak and NW Kalimantan, the oldest fossil-bearing rocks are tightly folded, steeply dipping sediments with chert and grey limestones of the Terbat Formation. These contain diverse latest Carboniferous and earliest Permian fusulinid assemblages with *Pseudoschwagerina*, *Paraschwagerina*, etc. (Krekeler 1932, 1933, Cummings 1962, Sanderson 1966, Vachard 1990, etc.). Correlative deposits are present in NW Kalimantan (Zeijlmans van Emmichoven, 1939). The fusulinid assemblages suggest affinity with low latitude Cathaysian regions, not with Sibumasu terrains.

West Papua
Conodonts from the Aimau Fm in the SW Tamrau Mountains of the Birds Head contain conodonts typical of Late Carboniferous (*Hindeodus minutus, Neognathus*; Nicoll and Bladon 1991).

KEY REFERENCES- CARBONIFEROUS

Fontaine, H. and S. Gafoer, 1989. The Carboniferous. In: H. Fontaine and S. Gafoer (eds.) The Pre-Tertiary fossils of Sumatra and their environments, CCOP Techn. Publ. TP 19, Bangkok, p. 19-29.

Metcalfe, I., 1983. Conodont faunas, age and correlation of the Alas Formation (Carboniferous), Sumatra. Geol. Mag. 120, 6, p. 737-746.

Nicoll, R.S. and G.M. Bladon, 1991. Silurian and Late Carboniferous conodonts from the Charles Louis Range and central Birds Head, Irian Jaya, Indonesia. BMR J. Austral. Geol. Geoph. 12, 4, p. 279-286.

Sanderson, G.A., 1966. Presence of Carboniferous in West Sarawak. AAPG Bull. 50, 3, p. 578-580.

Vachard, D., 1990. A new biozonation of the limestones from Terbat area, Sarawak, Malaysia. In: H. Fontaine (ed.) Ten years of CCOP research on the Pre-Tertiary of East Asia, CCOP Techn. Bull. 20, p. 183-208.

PERMIAN

Rich Permian faunas and floras are known from many localities in SE Asia-Indonesia-West Papua. For reviews of the shallow marine and non-marine Permian faunas and floras of SE Asia see Fontaine (1986, 2002). A comprehensive review of Permian marine faunas of Timor is by Charlton et al. (2002). For biostratigraphic correlations of marine sequences brachiopods and mollusks have been the main tool in the Gondwana realm, while fusulinid foraminifera are the principal group used for correlation along the Tethyan margin.

TABLE 2 CARBONIFEROUS

FAUNA/FLORA	AREA	REFERENCES
Corals	W Sumatra	Fontaine 1983, 1989
	West Papua	Kato et al. 1999
	Thailand	Fontaine et al. 1991
Foraminifera	W Sumatra	Metcalfe 1983, 1989, Vachard 1989
	NW Borneo	Cummings 1962, Sanderson 1966, Vachard 1990
Conodonts	Sumatra	Metcalfe 1983, 1986
	West Papua	Nicoll and Bladon 1991

In Indonesia Permian faunas and floras are common on Timor, West-Central Sumatra and West Papua (not including Papua New Guinea) and, to a lesser degree, from Borneo. The Permian faunas from Timor are famous for yielding the richest marine Permian faunas in the world (Figure 4), with over 600 species described by 1926 (Wanner 1926). Most of the Permian fossiliferous sediments on Timor are not in any stratigraphic order, but occurs as isolated blocks in melange, olistostrome or broken formations. It is generally accepted that material from the famous fossil localities of Somohole and Bitauni areas are older (E Permian, ~Sakmarian- Artinskian) than those from the Basleo and Amarassi areas (late Middle Permian, ~Capitanian).

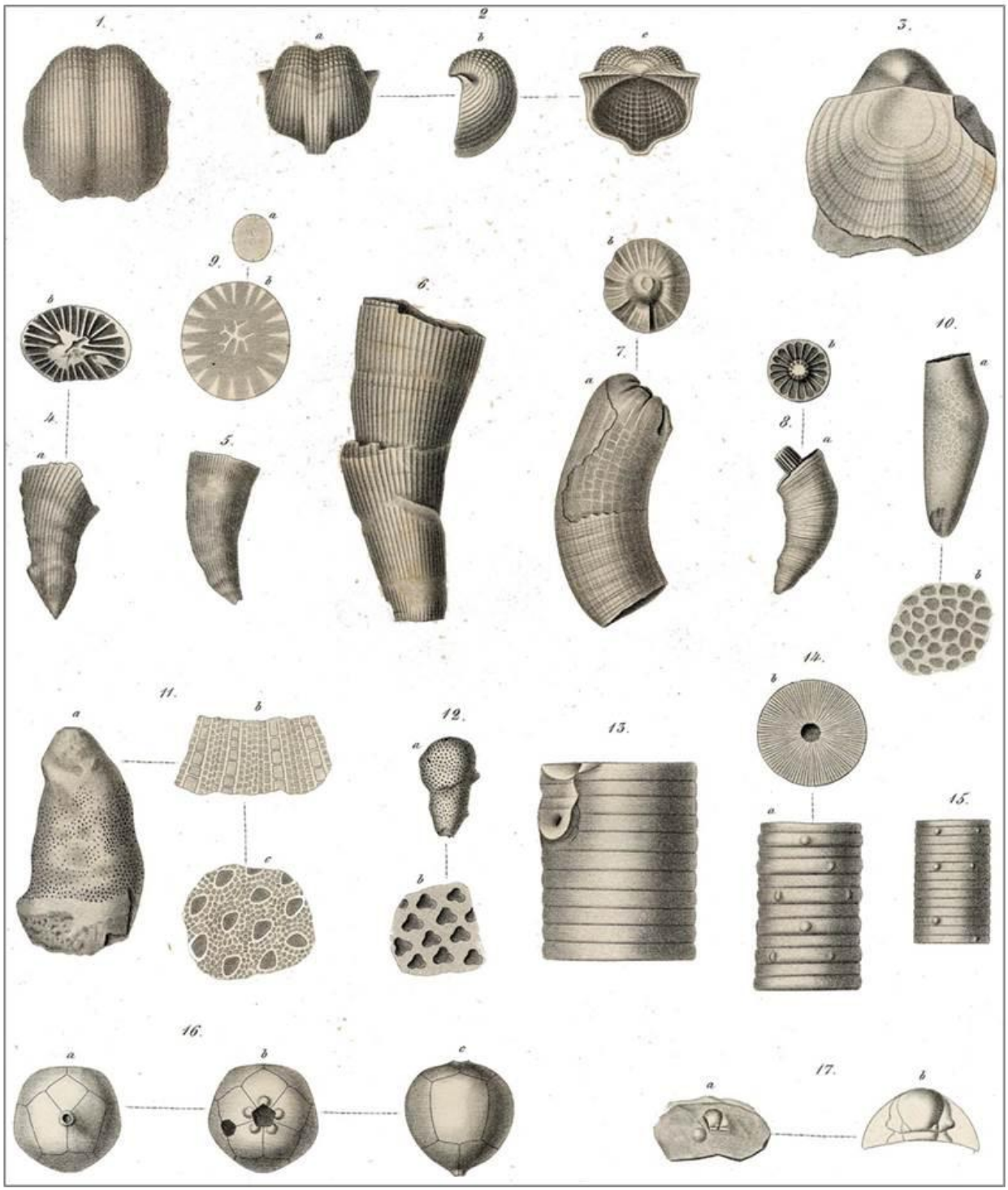


Figure 4. *A typical selection of Permian fossils from Timor (Beyrich, 1865). 1-3 Brachiopods* Productus semireticulatus *(1-2) and* P. punctatus*; 4-12. Corals* Zaphrentis*?,* Cyatophyllum, Clisiophyllum *(7-9),* Calamopora, Heliolites *(11),* Alveolites *(12). 13-16. Crinoids, 16.* Hypocrinus schneideri, *17. Trilobite* Phillipsia parvula.

Interpretation of Permian fossils and stratigraphy in SE Asia is made difficult by the lack of a globally accepted time scale. Different authors used different sets of stage names, the names of which originated from the traditional centers of Permian studies in the USA, Russia, China or Western Europe. The subdivision most used today is that sanctioned by the International Commission on Stratigraphy.

KEY REFERENCES- PERMIAN

Charlton, T.R., A.J. Barber, R.A. Harris, S.T. Barkham et al., 2002. The Permian of Timor: stratigraphy, palaeontology and palaeogeography. J. Asian Earth Sci. 20, p. 719-774.

Fontaine, H., 1986. The Permian of Southeast Asia. CCOP Techn. Bull. 18, p. 1-111.

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Wanner, J., 1926. Die marine Permfauna von Timor. Geol. Rundschau 17a, Sonderband (Steinmann Festschrift), p. 20-48.

Early Permian Cold-climate Bivalves and Brachiopods

Early Permian glacial marine deposits across northern Gondwana (Australia, India, etc.) often contain thick-shelled bivalves of the genera *Atomodesma* (Figure 5) and *Eurydesma* and the cool-climate brachiopod *Globiella foordi* (now also called *Cimmeriella foordi*). Comparable bivalve assemblages may be present in the Early Permian of the Sibumasu - Cimmerian terranes now in Sumatra, NW Malaysia, W Thailand and SW China (Sun 1993).

In Indonesia assemblages with these genera were found in the Early Permian Maubisse Formation of Timor (Beyrich 1865, Wanner 1922, 1940, Hasibuan 1994), but they are associated with relatively diverse marine faunas and glacio-marine deposits are not known from Timor. These faunas may suggest a proximity to glacial Gondwana of this part of Timor in earliest Permian time, but are not necessarily part of the glaciated terranes.

The presence in Timor Leste of a diverse fusulinid assemblage interpreted as of latest Carboniferous - earliest Permian age and presumably representing a relatively warm climate (Davydov et al. 2013) is puzzling in the context of widespread glaciations on Gondwana at this time.

KEY REFERENCES- EARLY PERMIAN BIVALVE MOLLUSCS

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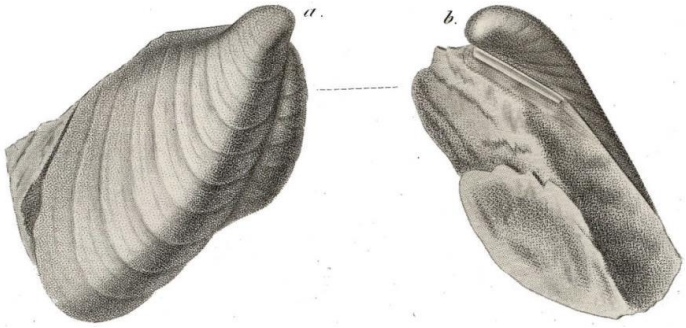


Figure 5. *Permian bivalve Atomodesma exarata from the Kupang area, West Timor (Beyrich 1865).*

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Permian Corals

Permian corals, generally in carbonate lithologies and associated with fusulinid larger foraminifera, are relatively widespread in SE Asia. Assemblage compositions differ with age, water depth and with paleogeographic position. Early Permian limestones from the Indochina terrane (East Thailand, etc.) contain typical 'Cathaysian', tropical, high-diversity coral and fusulinid assemblages, dominated by compound corals, while in the Early Permian of the Sibumasu Terrane corals are absent or dominated by small, solitary rugose corals, reflecting cooler and/or deeper waters (e.g. Peninsular Thailand; Fontaine et al. 1994, Yunnan, SW China; Wang and Sugiyama 2002). The low diversity assemblages dominated by solitary rugose coral species, have been called '*Lytvolasma* faunas' or '*Cyathaxonia* faunas'. They are generally viewed as 'anti-tropical', cooler climate coral assemblages (Kossovaya 2009). By late Middle and Late Permian time the Sibumasu terranes had moved towards tropical latitudes and started to have similar high-diversity coral and fusulinid faunas as the Indochina terranes.

In Indonesia Permian coral faunas are known mainly from:

1. Timor (Figure 6). Permian corals are locally very abundant in the Maubisse Formation/ Basleo beds. They are mainly '*Cythaxonia*-faunas' with solitary corals like *Lytvolasma, Timorphyllum, Lophophyllidium, Verbeekiella* (incl. *Verbeekiella australis* Beyrich; Figure 7), *Zaphrentis, Amplexus and Wannerophyllum*. Colonial rugose corals like *Michelinia*, *Favosites*, *Lonsdaleia timorica* (Figure 7) and *L. molengraaffi* are present as well, but are relatively rare (Gerth 1921, Koker 1924, Wang 1947, Von Schouppe and Stacul 1955). The Timor Permian coral assemblages are very similar to those reported

from the Baoshan Block, SW China (Zhao and Zhou 1987).

2. Sumatra. Corals have been reported from several localities in West Sumatra. Some of the Middle Permian limestones from West Sumatra contain high diversity corals that look similar to 'Cathaysian' assemblages of Central Thailand (Guguk Bulat; Fontaine 1983, 1989).
3. West Papua. Permian corals are widely distributed in the Aifam Fm (Visser and Hermes 1962, p. 54), including solitary *Amplexus* on the Birds Head (Broili 1924). However, typical low-latitude compound corals appear to be absent here (Fontaine et al. 1994, p. 39).

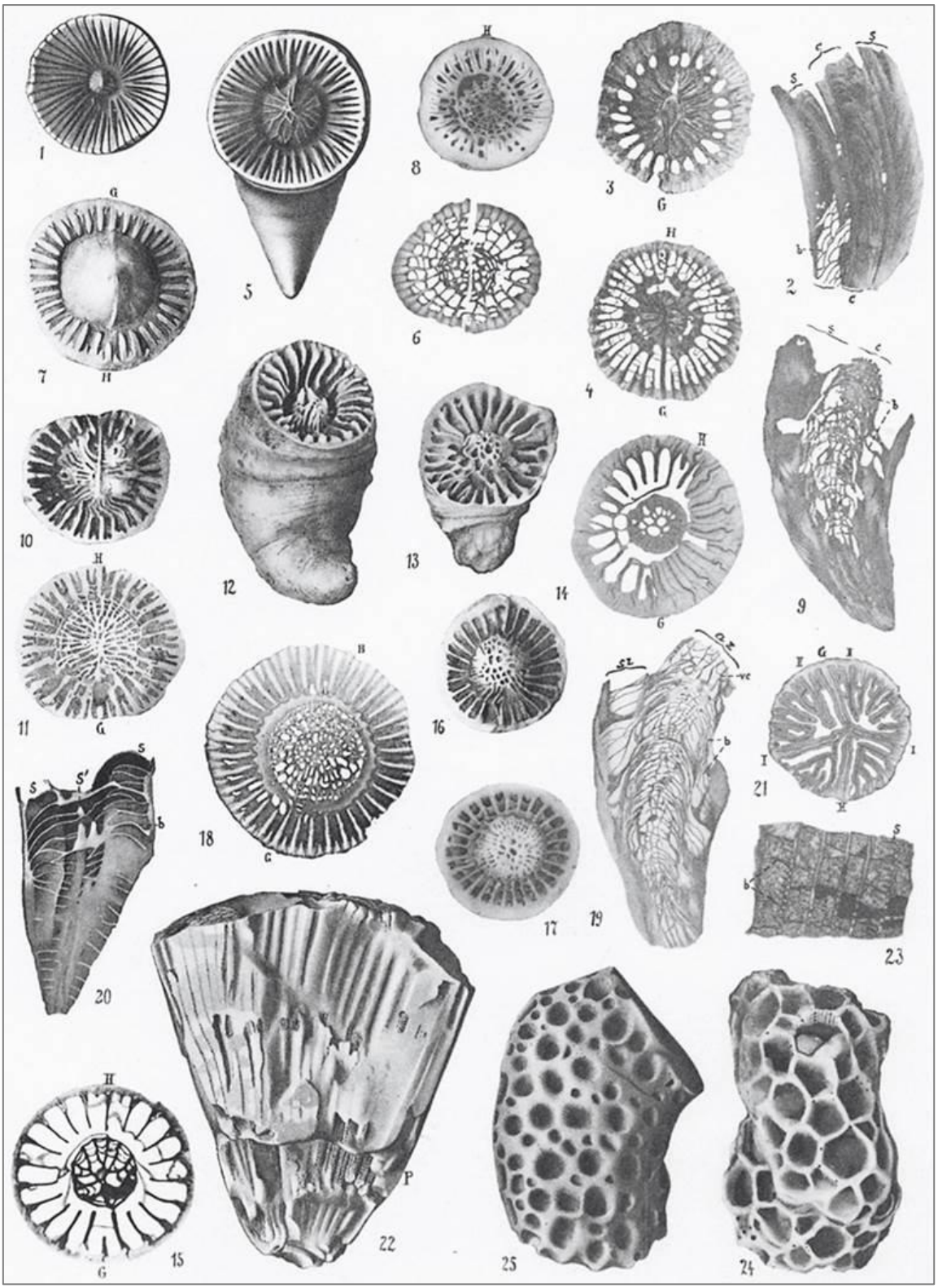


Figure 6. *Permian solitary and compound corals from Timor (Gerth 1921): 1-4.* Carcinophyllum wichmanni, *5-9.* Carcinophyllum cristatum, *10-11.* Dibunophyllum rothpletzi, *12-15.* Dibunophyllum (Verbeekiella) australe, *16-19.* Dibunophyllum (Verbeekiella) *spp., 20-21.* Pterophyllum, *22-23.* Favosites *sp. and 24-25.* Michelinia indica.

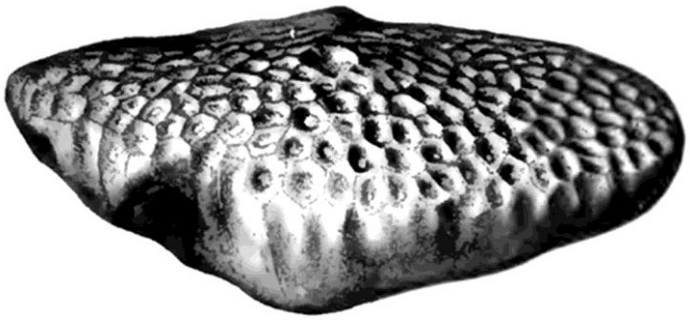


Figure 7. *Permian compound coral Lonsdaleia timorica from Timor (Gerth 1921).*

Gerth (1926) already noted that the Permian coral fauna of Timor indicated a relatively warm paleoclimate, while Permian deposits on adjacent Australia contained glacial deposits, suggesting that Timor and Australia must have been farther apart in Permian time. However, if the Permian corals on Timor are younger than the earliest Permian glacial deposits on Gondwana, which they probably are, the contrast may not be as significant.

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Permian Ammonoids

Permian ammonoids are generally rare in Indonesia/SE Asia, but the ammonoid assemblages of Timor are among the richest in the world (Smith, 1927, Wanner 1932). Wanner (1926) counted 37 species of ammonoids and 21 nautiloids. Most numerous genera are *Agathiceras* and *Paralegoceras* (= *Metalegoceras*; Figure 8). Another Permian ammonoid locality in Indonesia includes *Agathiceras* from the folded series of Belitung (Kruizinga, 1950).

Blendinger et al. (1992) noted the remarkable similarity between the Middle Permian ammonoids from the cephalopod limestone of Timor with those from the West Mediterranean (Sosio Lst, Siclily) and Oman, suggesting unrestricted faunal exchange in a Middle Permian seaway along the distal N margin of Gondwana. Ehiro (1997, 1998) classified the Middle Permian ammonoid faunas from 'allochthous Timor' in his' Equatorial Tethyan province', based on the presence of taxa like *Timorites* and *Waagenoceras*, which are not known from Australia.



Figure 8. *One of the most common Permian ammonoids from West Timor (Bitauni):* Metalegoceras sundaicum *(formerly* Paralegoceras*; Haniel 1915).*

KEY REFERENCES- PERMIAN AMMONOIDS

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Permian Trilobites

Trilobites are relatively rare in Indonesia, but have been reported only from Permian sediments of Sumatra (Roemer 1880), Timor (Tesch 1923, Gheyselinck, 1937) and float in the Noord River in West Papua (Martin 1911). They are mainly of the genus *Pseudophillipsia: P. timorensis* Roemer from Basleo, West Timor and *P. sumatrensis* from the Padang Highlands of West Sumatra (Figure 9). Leman and Sone (2002) described similar *Pseudophillipsia* from the early Capitanian (Middle Permian) from Pahang, Central Belt of Malay Peninsula (= west margin of East Malaya/Indochina terrane).

KEY REFERENCES- PERMIAN TRILOBITES

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Permian Fusulinid Foraminifera

Fusulinid larger foraminifera are tropical-subtropical shallow marine carbonate taxa (estimated paleolatitude range between 0 and 40° N and S), with a reputation of being excellent guide fossils in Carboniferous - Permian time. Fusulinids are widespread in Permian shallow marine limestones across SE Asia and areas further west, generally on terranes that border the Paleotethys suture. Hundreds of papers have been written on this group in SE Asia. For more details see references in Table 3 and the Permian chapter of the annotated bibliography.

Interpretation of fusulinid foram faunas can be very difficult. The taxonomy is overwhelming, with over 100 genus names and 1000's of species names. In the Permian of Thailand and Malaysia Toriyama (1984) recorded 265 species belonging to 70 genera; in the Permian of Afghanistan Leven (1997) counted 282 species and 58 genera; in the Middle Carboniferous - E Permian of Japan Ota et al. (1997) counted 56 species in 23 genera. These large numbers partly reflect actual high diversity, but probably also reflect overly ambitious splitting of taxa and also the creation of separate sets of names being used by different 'schools'. Fusulinid experts tend to be either from Japanese, Russian or American 'schools', each working with their own sets of species names, many of which are undoubtedly synonyms of named species from other regions. Difficulties in fusulinid identifications are also illustrated by comments of fusulinid experts themselves, who frequently disagree with each other on species identifications and genus attributions. So, while fusulinids are a powerful tool in Permian limestone biostratigraphy, the apparent taxonomic disarray makes it hard to determine exact ages and establish paleobiogeographic relationships between regions.

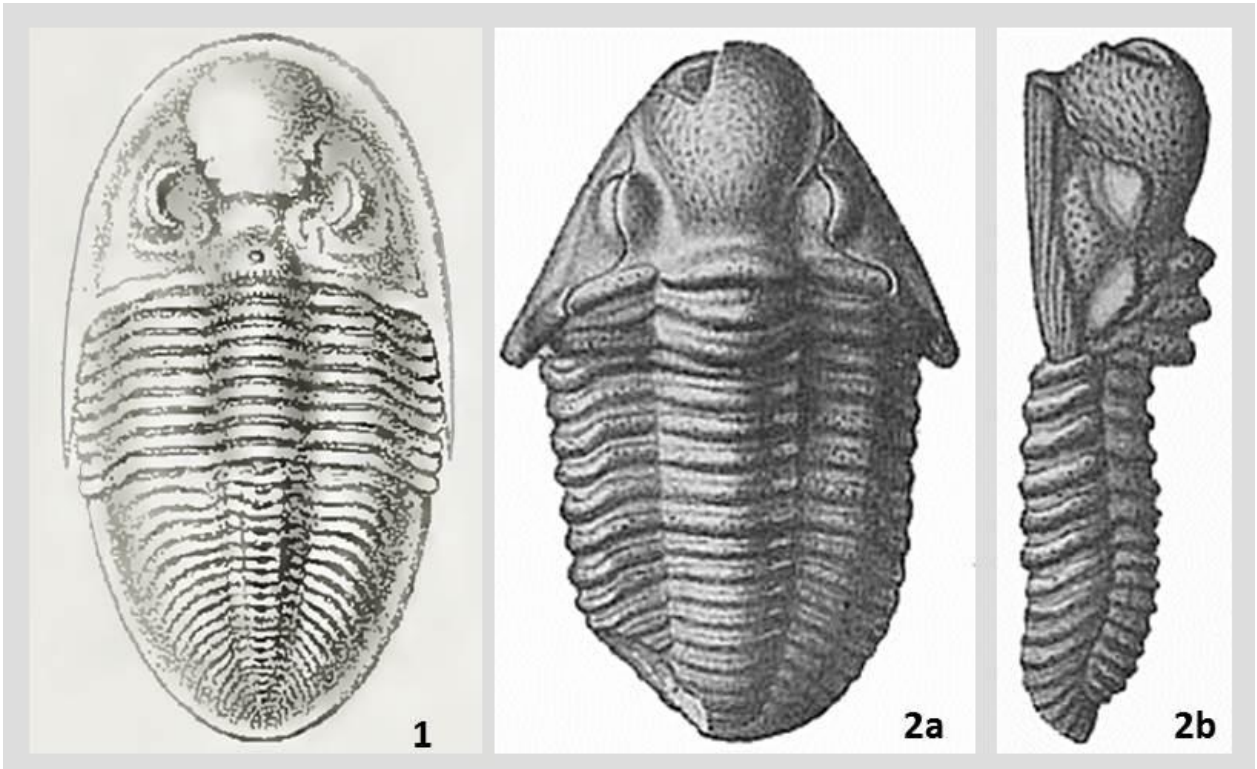


Figure 9. *Permian trilobites. 1.* Phillipsia sumatrensis *from Permian of Padang Highlands, W Sumatra (Roemer 1880) (also assigned to* Pseudophillipsia *or* Griffithides*); 2 and 3.* Neoproetus indicus *from Bitauni, West Timor (Tesch 1923).*

Fusulinids reached a maximum in diversity and sizes in the Middle Permian, as did other reefal fauna (corals, large molluscs, etc.). A significant extinction event of large fusulinids took place at the end of the Middle Permian (end or late Capitanian; e.g. Hada et al. 2014). The Late Permian is characterized by fusulinid assemblages that are reduced in size and diversity. Fusulinids went completely extinct at the mass extinction event at the end of the Permian.

In Indonesia Permian fusulinid foraminifera have been reported from 6-7 main areas, mainly on Sumatra, NW Borneo, Timor and the Birds Head of West Papua:

1. *NW Kalimantan-Sarawak border area.* The oldest fusulinids in Indonesia are from the Late Carboniferous - earliest Permian 'Terbat Limestone' of the NW Kalimantan- Sarawak border area. They were first reported by Krekeler (1932, 1933), and by several generations of subsequent authors (Table 3). Fusulinid assemblages are quite diverse and similar to 'Tethyan' faunas from E Thailand and S China (Cummings 1962, Vachard 1990, Fontaine 1990, Sakamoto and Ishibashi, 2002), from a time when glacial deposits were widespread on Gondwanaland and Gondwanaland-derived terranes like Sibumasu. Pebbles of this fusulinid limestone were also found in conglomerates of Triassic, Jurassic and Cretaceous age in W Sarawak and also in the basal Eocene of the NW Kutai Basin. Tan Sin Hok (in Krekeler 1933) examined the fusulinid beds from Sadong valley and believed them to be same species (and same volcanoclastic facies) as the Early Permian assemblages of Jambi. Fontaine (1990) believed these to be of Late Carboniferous - earliest Permian age. The age and nature of the Terbat Limestone assemblages clearly demonstrates affinities to the Indochina Block, not Gondwana or Sibumasu (as do associated Triassic-Jurassic faunas and floras). The Terbat localities used to regarded as part of SW Borneo terrane, but recently they were placed in a separate small block of Indochina affinity named Semitau Block by Metcalfe (2013);
2. *Padang Highlands, West Sumatra* (Figure 10). Middle Permian fusulinids have long been known from the Padang Highlands of West Sumatra, mainly from the famous Guguk Bulat locality. Several of the large Middle Permian fusulinid index species of the Tethyan province were first described from Sumatra, like *Verbeekina verbeeki* (Geinitz, 1876), *Sumatrina annae* (Volz, 1904) and *Schwagerina padangensis* (Lange, 1925). Tien (1988) also recorded *Colania douvillei*. Many of the fusulinid species described from this part of West Sumatra are also common on the 'Cathaysian' Indochina Block of NE Thailand, but some have also been reported from the Sibumasu terrane, which by the end of the Middle Permian had moved into lower latitudes (e.g. Ueno et al. 2003).
3. *Jambi, SW Sumatra.* Early Permian fusulinids from the '*Productus* Limestone' horizon in the Mengkareng Formation at Telok Gedang along the Merangin River, Jambi, on the 'West Sumatra Block' are of great interest because they underlie the beds with the famous 'Cathaysian' Jambi Flora, which is a significant element in tectonic reconstructions of Sumatra. Fusulinids were analyzed by various specialists (Ozawa 1929, Thompson 1936, Vachard 1990, Ueno et al. 2007). Most abundant is a species named *Pseudofusulina rutschi (*Thompson), originally assigned to *Schwagerina,* but subsequently classified in *Triticites and Rugofusulina. Rugofusulina rutschi* is very similar to a more widely known species *R. alpina* Schellwien and may be synonymous (Tien 1989). Also present is *Pseudoschwagerina meranginensis* (assigned to *Sphaeroschwagerina* by Davydov et al. 2013). It is a low-diversity assemblage that is generally believed to be of Early Permian age, with age interpretations varying from Upper Asselian (Tien 1989, Vachard 1990) to 'most likely Sakmarian' (Ueno 2007). However, since none of the species described from this locality can be tied directly to assemblages elsewhere, any conclusions on precise age and paleobiogeographic affinity would therefore appear to lack a real firm basis. From the nearby Batu Impi locality West of Bangko, fusulinids from thin limestones in the volcanoclastic Palepat Fm, which overlies the beds with Jambi flora, were studied by Tien (1989) and Ueno et al. (2007; moderately rich Artinskian-Kungurian). Two additional small occurrences on Sumatra worth flagging are in West Sumatra (Batang Siputar; Hahn and Weber 1981) and South Sumatra (Bukit Pendopo; Palembang; De Neve 1949).
4. *Timor and adjacent islands Leti and Roti.* Fusulinids are also known from various localities on Timor, and are also present on adjacent Roti and Leti islands (Schubert 1915a, Thompson 1949, Davydov et al. 2013). Many of the Timor assemblages are of low-diversity, but high abundance, and are dominated by a species initially described as *Fusulina wanneri* by Schubert (1915), the type species of the 'anti-tropical' genus *Monodiexodina* (Figure 11). The small fauna of verbeekinids described from Leti Island by Schubert (1915b) with *Doliolina lepida* var. *lettensis* differs from assemblages known from Timor (Thompson 1949). Another apparently different latest Carboniferous - earliest Permian assemblage from Timor Leste was described recently by Davydov et al. (2013).
5. *Birds Head of West Papua.* Rare fusulinids have been reported from West Papua, the only undisputed occurrences on Permian Gondwanaland, but are poorly documented. One occurrence in the Birds Head was figured by Visser and Hermes (1962, p. 54). Another possible fusulinid occurrence was reported, but not figured, from Permian limestone in a consultant biostratigraphy report of oil

exploration well TBF 1X (3947m; NE of Misool in Bintuni Bay, south of Birds Head).

6. *Bangka - Belitung.* Lesser-known fusulinid localities are in the intensely folded Permian beds of North Bangka (De Roever 1951) and Belitung (Strimple and Yancey 1974).

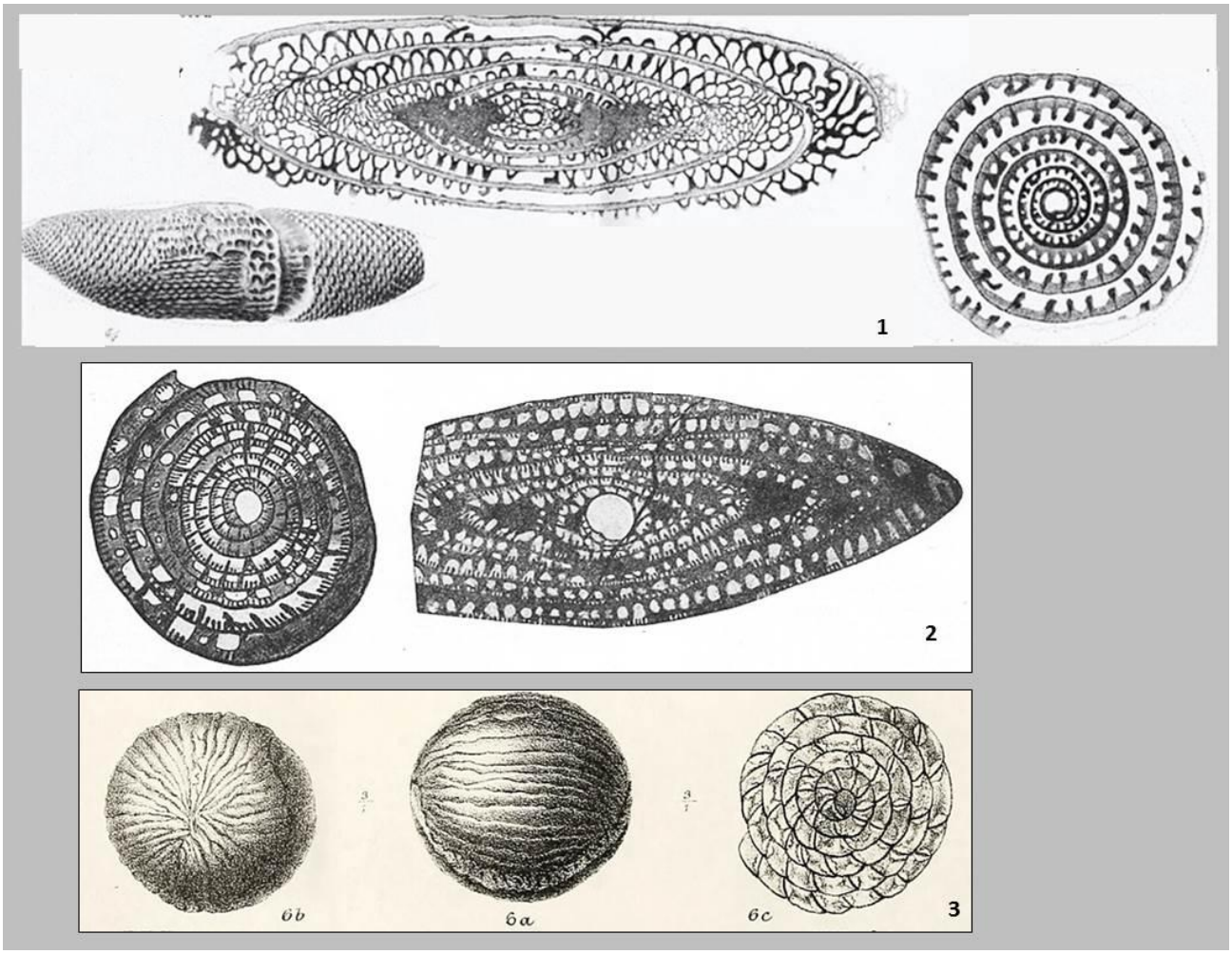


Figure 10. *Middle Permian fusulinid foraminifera from West Sumatra. 1.* Fusulina granum-avenae *Roemer from West Sumatra (exterior view and longitudinal and axial sections) (Verbeek 1896). 2.* Sumatrina annae *from Bukit Bessi, NE of Lake Singkarak (axial and longitudinal sections) (Volz, 1904). 3.* Verbeekina verbeeki *(Geinitz), from Guguk Bulat, Padang Highlands, (originally described as* Fusulina princeps *by Brady, 1875).*

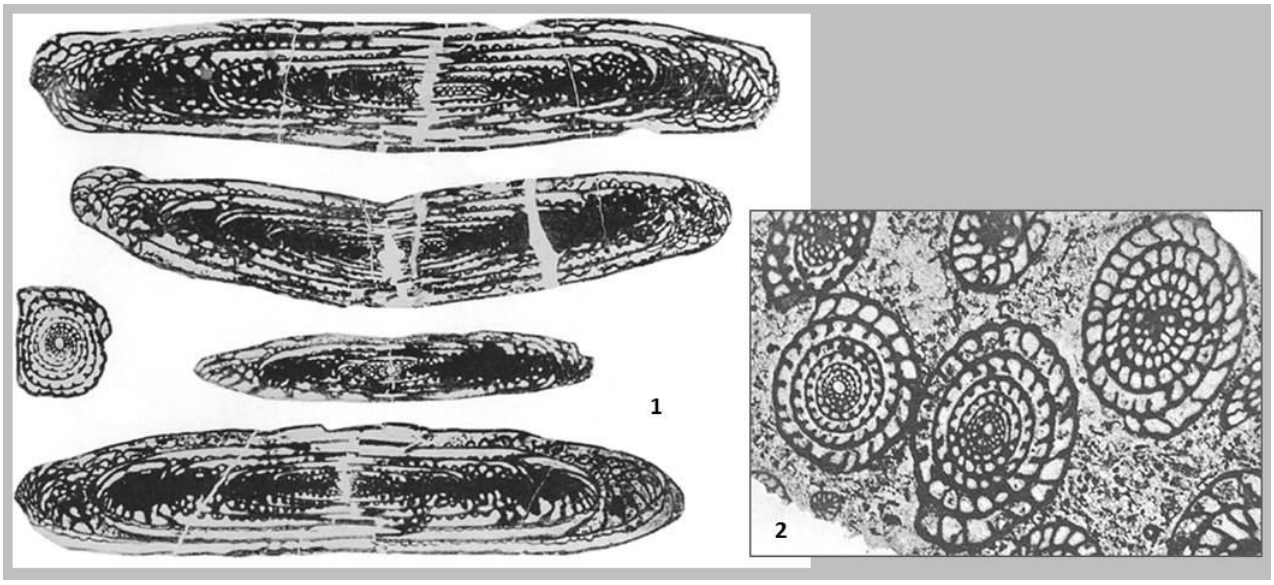


Figure 11. *Permian fusulinid* Monodiexodina wanneri *(Schubert) from SW Timor. 1. From limestone blocks in melange in Bunu River, East of Niki-Niki,(Thompson 1949); 2. From road between Bele and Toi (Schubert, 1915).*

Three paleogeographic domains may be distinguished in SE Asia, partly based on fusulinids, which are useful for constraining plate reconstructions:

1. 'Tethyan'/Cathaysian', with high diversity fusulinid assemblages (NW Borneo and some of the Timor and West Sumatra fusulinid assemblages?);
2. Subtropical/Warm temperate domains, with low diversity fusulinid assemblages with 'anti-tropical' genera like *Monodiexodina* and *Polydiexodina,* in Early Permian, and higher diversity 'Tethyan-affinity' fusulinid assemblages by late Middle Permian (typical of' Cimmerian Transit plates' like Sibumasu (Ueno 2006; in Indonesia *Monodiexodina* has been reported from Timor and West Sumatra)
3. Gondwanan terranes (India, Australia): contain no fusulinids.

Interesting assemblages of Late Middle Permian smaller benthic foraminifera with the pillared miliolid *Shanita amosi*, commonly associated with *Hemigordius renzi* and *Hemigordiopsis,* have been found in many limestones localities on mainland SE Asia. These are commonly viewed as 'anti-tropical' species and appear to be restricted to the 'Cimmerian'/Sibumasu terranes' (Fontaine et al. 1994, Jin and Yang 2004). *Shanita* has not been reported from Indonesia, but this may be due to absence of limestones of the right age and facies and/or lack of studies in places like Sumatra. *Hemigordius* is present in the Murgabian (early M Permian) limestones of Bukit Pendopo, South Sumatra (Tien, 1989). The nearest occurrence of *Shanita* in the Indonesian region is from 'basement carbonates' (Tampur Formation) in the Singa Besar 1 well, in the Malaysian sector of the Malacca Straits (Fontaine et al. 1992), which is on the Sibumasu Block.

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Permian Brachiopods

In Indonesia Permian brachiopods are known from Sumatra, Timor and West Papua (Table 3). The principal monographs on Indonesian brachiopods are by Broili (1915, 1916), Hamlet (1928) and Wanner and Sieverts (1935), all from Timor. Permian brachiopods were described from Sumatra by Meyer (1922) and West Papua by Archbold (1981).

Productus and *Spirifer* groups dominate the Timor and West Papua assemblages (Figure 12). The brachiopod faunas from Timor are relatively rich (49 species). However, unlike many other fossil groups from Timor like crinoids and blastoids, no new species were identified in the first monograph on this group by Broili (1916), attesting to the relatively cosmopolitan nature of these brachiopod taxa. Studies on paleobiogeographic patterns within Permian brachiopod assemblages therefore appear to have been somewhat non-diagnostic, due to the widespread geographic distribution of many of the taxa. Crippa et al. (2014) also noted that Indonesian Permian brachiopod faunas show very low endemicity, consisting mainly of Boreal and Palaeoequatorial genera.

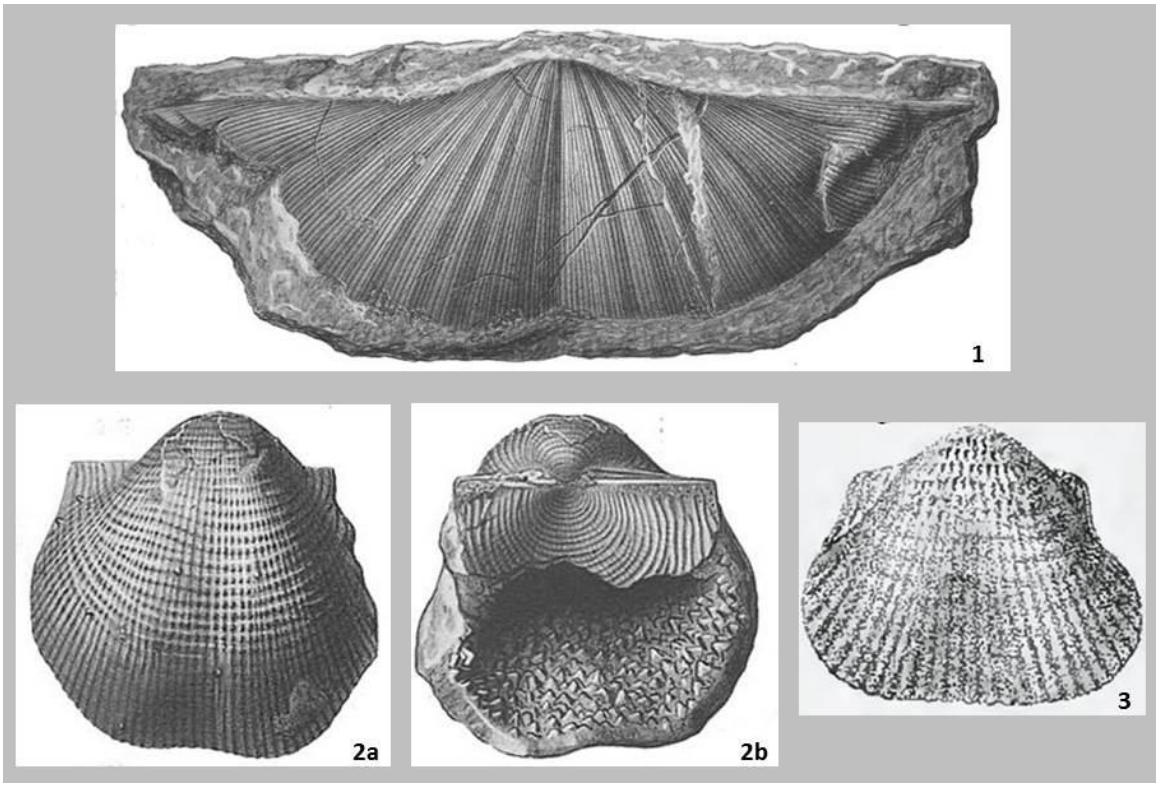


Figure 12. *Permian brachiopods. 1. Spirifer from Timor (Broili, 1916)'; 2. Stereochia (Productus) semireticulatus from Timor (Broili, 1916) and 3. from Sibelabu, SE of Padang, West Sumatra (Woodward 1879).*

The genus *Stereochia* (Figure 12-2,-3 is of interest because it is commonly regarded as an anti-tropical genus (Shi et al. 1995, Crippa et al. 2014). In mainland SE Asia *Stereochia-Meekella* brachiopod fauna characterizes the Sibumasu terrane in Peninsular Thailand and the NW Malay Peninsula (Fang 1994). In Indonesia *Stereochia* was reported as '*Productus semireticulatus*' from Timor (Beyrich 1865, Broili 1916) and from the Padang Highlands, West Sumatra (Woodward 1879). It is also the dominant brachiopod genus associated with the Early Permian Jambi flora of SW Sumatra (*S. semireticulatus* or *S. irianensis*; Hasibuan et al. 2000, Crippa et al. 2014).

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Permian Crinoids and Blastoids

Timor Island has long been famous for its unique Permian deposits with abundant, diverse and well-preserved crinoid and blastoid faunas. Wanner (1923) identified 239 crinoid species in 75 genera. Two-thirds of these species are not known outside Timor (Wanner 1924, Webster 1998). Half of all crinoid species are poteriocrinids, with dominant genera *Timorocrinus, Ceriocrinus, Parabursacrinus,* etc.

Most of the Timor crinoids and blastoids are from red-brown marls and tuffs with interbedded limestones, a formation named Maubisse Formation in Timor Leste or Sonnebait Series in older literature on West Timor (Figure 13). They were believed to be relatively warm, shallow marine deposits, but they may actually be mostly hemi-pelagic organisms that ended up in clastic-free deep water carbonates that are often associated with basic volcanics (seamounts?). The richest occurrences are in the Basleo area near Niki-Niki, and are probably from exotic blocks in Neogene melange deposits. Associated cephalopods suggest these are probably mainly of Middle Permian age (Haniel 1915). Crinoid assemblages from the Amarassi region of SW Timor are less diverse and probably of Late Permian age (Wanner 1923).

Blastoid assemblages of Timor have the highest abundances and diversity in the world. Of the 13 Permian blastoid genera known from Timor only three or four also occur outside Timor. The main monographs on blastoids are Wanner (1924, 1940, Figures 14, 15).

The only other place in SE Asia where some of the Timor species of crinoids and blastoids were found is in the late Early-Middle Permian Ratburi Limestone of Peninsular Thailand (Racey et al. 1994; Sibumasu Terrane; Figure 16). Species of 'Basleo fauna' include the crinoids *Timorocrinus pumulus* Wanner 1924, *Parabursacrinus* and *Timorocidaris sphaeracantha* Wanner 1920, and the blastoid *Deltoblastus permicus* (Wanner 1910). Outside SE Asia rare *Deltoblastus* have been reported from Oman and Sicily, both also on Cimmerian terranes. Although they are present in much smaller numbers in Peninsular Thailand than at the Timor localities, their presence does suggest they were in the same faunal province around Artinskian time.

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Figure 13. *Early Permian pink crinoid-blastoid limestone from SW Timor, with well-preserved* Deltoblastus permicus *from 'Sonnebait Formation' melange, Basleo area (photo Debbie Gilbert).*

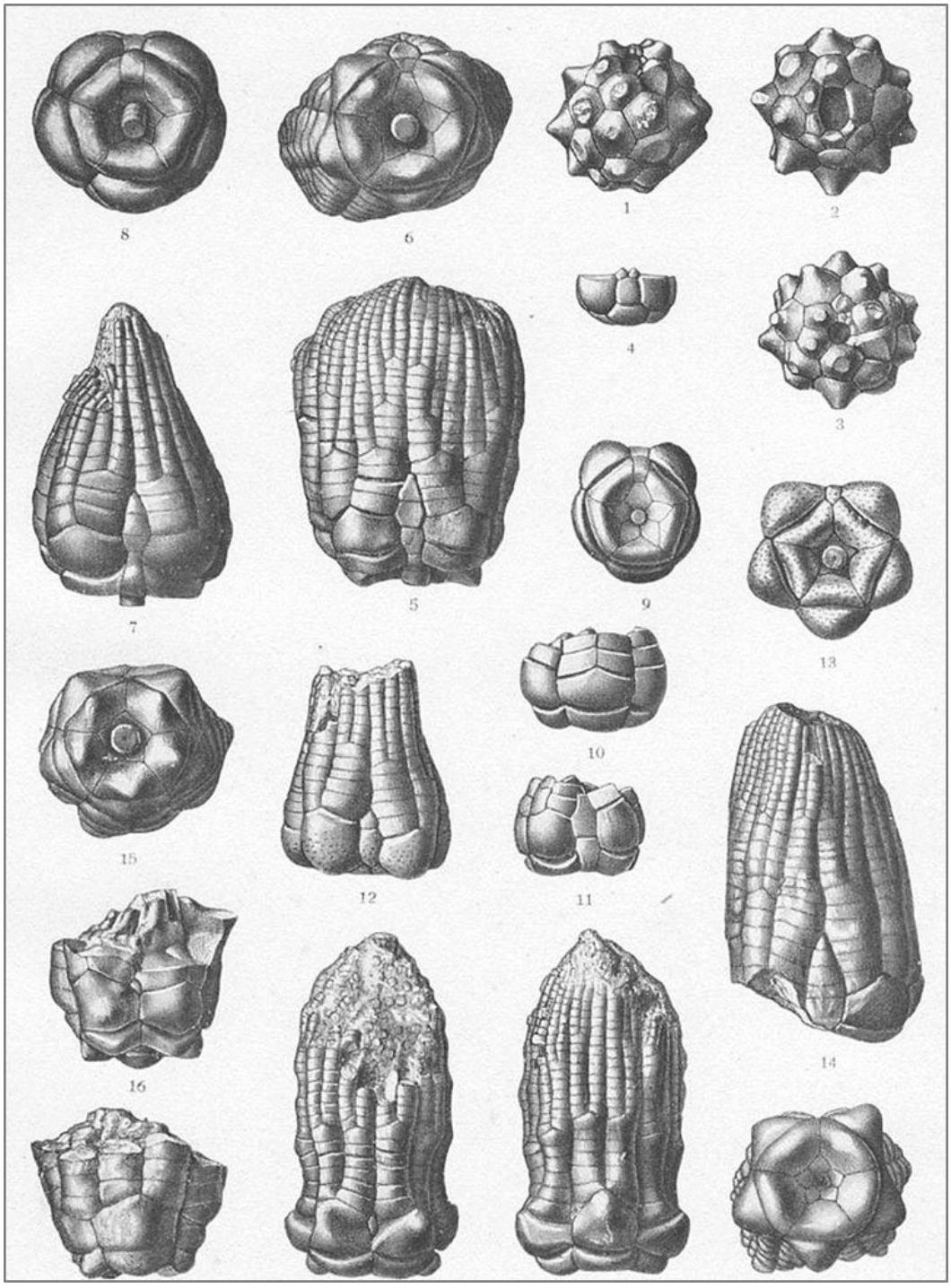


Figure 14. *New genera and species of crinoids from Basleo area, Timor (Wanner 1923, Plate 12). 1-3.* Jonkerocrinus spinosus, *4.* Cadocrinus variabilis, *5-14.* Parabursacrinus *spp., 15-20* Notiocrinus *spp.*

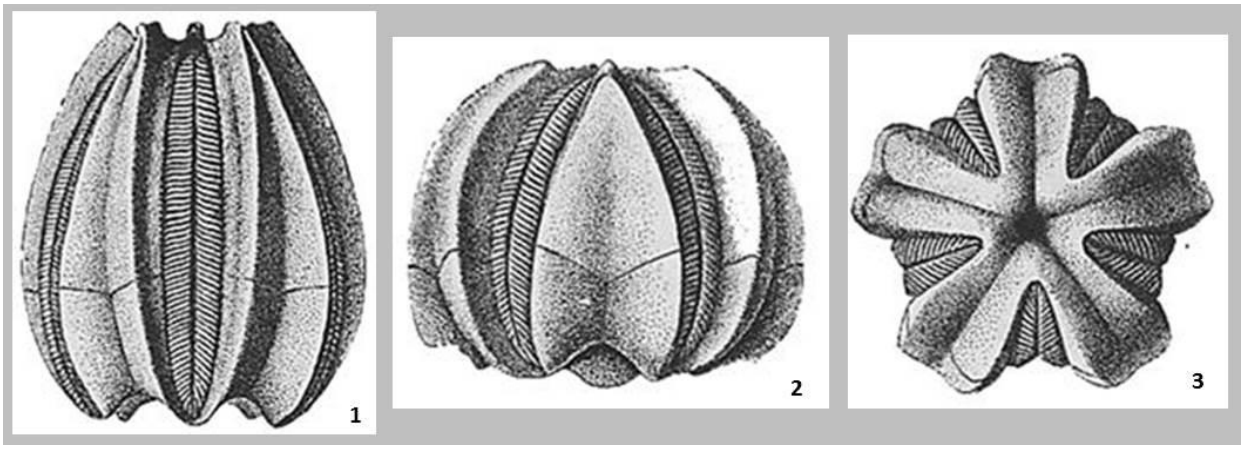


Figure 15. *Blastoid* Schizoblastus (= Deltoblastus) delta *from Koeafeoe, West Timor (Wanner 1924).*

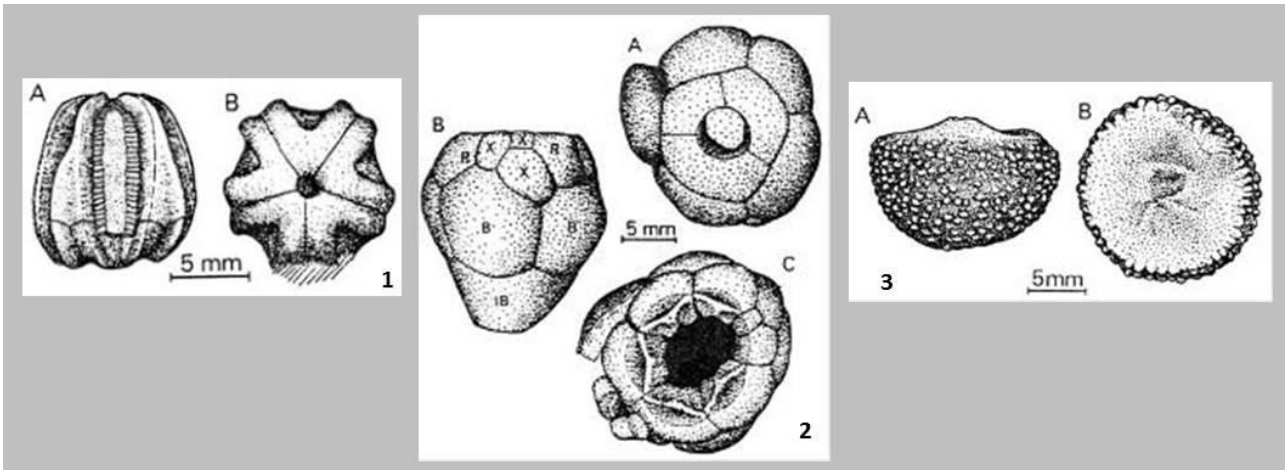


Figure 16. *'Timor fossils' from Ratburi Lst, Peninsular Thailand (from Racey et al.1994). 1. Late Early-Middle-Permian blastoid* Deltoblastus permicus*; 2. Crinoid* Trimerocrinus pumulus*; 3.* Timorocidaris sphaeracantha.

Permian Floras

Permian plant fossils, associated with thin coal beds, are known from West Sumatra and West Papua. Early Permian warm-Cathaysian floras are known from Sumatra and NW Kalimantan, while cooler-Gondwanan *Glossopteris* floras are present in West Papua (but mixed with some Cathaysian elements).

Permian floras have long been used in reconstructions of tectonic plates, with the presence of the tree-like seed fern *Glossopteris* typical of Gondwana (Australia- India) and *Gigantopteris* floras characteristic of low-latitude, 'Cathaysian' terranes (South China, Indochina). The Cathaysian nature of the Jambi flora played an important role in the plate reconstruction history of Sumatra (Barber et al. 2005).

Jambi Flora, W Sumatra

The famous Early Permian 'Jambi flora' from the Merangin River area in SW Sumatra was originally discovered by Tobler, and first described by Jongmans and Gothan (1925) (Figure 17). The flora was initially viewed as of Euramerican affinity, without Gondwanan or Cathaysian *Gigantopteris* flora elements. However, after the Jambi paleobotanical expedition of 1925-1927, Jongmans and Gothan (1935) also recognized some North Cathaysian species.

The Jambi flora was recently re-sampled and studied by a group from the Naturalis Museum, Leiden, and the Geological Survey of Indonesia (Van Waveren et al., 2007, Booi et al., 2009). They also recognize affinities to Cathaysian flora, but argue that is not a fully Cathaysian flora, but its greatest similarity is with floras from North China, either the Artinskian Shansi Series (Asama et al. 1975) or the Kungurian Lower Shihhotse beds (Van Waveren et al. 2007). The Jambi Flora is probably best characterized as a late Early Permian temperate subgroup of the true low-latitude Cathaysian floral province.

The age of the Jambi flora is Early Permian, but exactly what stage of the Early Permian has not been definitively established. Low diversity fusulinid foraminifera from underlying limestone beds appear to be of a rather endemic nature, which different fusulinid experts have interpreted as Late Asselian or Sakmarian (see above).

Permian plant assemblages are also known from West Papua, both the Birds Head and areas south of the Central Range. They were first described by Jongmans (1940, 1941), who documented only Cathaysian and Euramerican species (*Taeniopteris, Pecopteris, Sphenophyllum*). Hopping and Wagner (in Visser and Hermes 1962) also recognized Gondwanan *Glossopteris* and *Vertebraria*. The West Papua floras are generally viewed as mixed floras, dominated by Gondwanan elements, but with common Cathaysian elements (Asama et al. 1975, Li and Wu 1994, Rigby 1998, 2001).

A poorly known Permian plant assemblage was also reported from SE Belitung island by Van Overeem (1960). It was provisionally identified by Jongmans as a Permian Cathaysian (*Gigantopteris*) flora, but has never been described. No plant fossils are known from Timor, mainly because all Permian sediments are in marine facies.

The existence of mixed Gondwanan-Cathaysian floras in West Papua (and in parts of mainland SE Asia like Thailand and Laos is significant for Permian plate reconstructions. Because *Glossopteris* and many Cathaysian plants like *Gigantopteris* have relatively large seeds, which are unlikely be dispersed across wide oceans, these mixed Permian floras suggest some configuration of land connections (or only very narrow seaways) between the 'Cathaysian' and Gondwana provinces in Permian time, not a wide Paleotethys Ocean.



Figure 17. *Permian flora from Merangin River area, Jambi Province, West Sumatra. 1.* Lepidodendron mesostigma *from Mengkarang River (Jongmans and Gothan 1935), 2.* Pecopteris arborescens *from Sungei Garing (Jongmans and Gothan 1925).*

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TABLE 3 PERMIAN		
FAUNA/FLORA	**AREA**	**REFERENCES**
Permian General	Timor	Wanner 1926, Charlton et al. 2002
	Sumatra	Fliegel 1901, Fontaine and Gafoer 1989
Mixed *Glossopteris*-Cathaysian flora	West Papua,	Jongmans 1940, 1941, Hopping and Wagner in Visser and Hermes 1962, Rigby 1997, 1998, 2001, Playford and Rigby(2008, Srivastava and Agnihotri 2010
'Cathaysian' flora	West Sumatra	Posthumus 1927, Jongmans and Gothan 1935, Asama 1976, Li and Wu 1994, Van Waveren et al. 2005, 2007, Booi et al. 2008, 2009
	Belitung	Jongmans in Van Overeem 1960
	NW Kalimantan	Jongmans in Zeijlmans 1939
Palynoflora	West Papua	Playford and Rigby 2008
	Australia	Kemp et al. 1977
Permian- E Triassic Radiolaria	Malay Peninsula	Sashida et al. 1993, 1995, Spiller and Metcalfe 1994, 1995, Jasin 1997
	Thailand	Kamato et al. 2008, 2013
Crinoids	Timor	Wanner 1916,1923, 1929- 1951, De Maresz Oyens 1940
	Belitung	Strimple and Yancey 1976
Blastoids	Timor	Wanner 1924, 1940, Breimer and Macurda 1965, 1972, Webster 1998, Sprinkle and Waters 2013
Ammonoids	Timor, Leti	Wanner 1915, 1932, Haniel 1915a,b, Smith 1927, De Roever 1940, Gerth 1950, Furnish and Glenister 1971, Glenister et al. 1973
	Bangka/Belitung	Kruizinga 1950,
	West Papua	Glenister et al. 1983
Mollusks	Timor	C. Wanner 1922, 1940, 1942, J. Wanner 1940, Hasibuan 1994
	Sumatra	Fliegel 1901
	West Papua	Dickins and Skwarko 1981
Brachiopods	Sumatra	Fliegel 1901, Meyer 1922, Tan Sin Hok 1933, Hasibuan et al. 2000, Crippa et al. 2014
	Timor, Leti, Roti	Rothpletz 1892, Broili 1915, 1916, 1922, Krumbeck 1924, Hamlet 1928, Wanner and Sieverts 1935, Shimizu 1966, Archbold and Barkham 1989, Archbold and Bird 1989, Kato et al. 1999, Winkler Prins 2008
	West Papua	Visser and Hermes 1962, Archbold 1981, 1991, Archbold et al. 1982
Permian Fusulinid	West Sumatra	Geinitz 1876, Volz 1904, Von Staff 1909, Lange 1925, Ozawa 1929, Tan Sin Hok 1933, Thompson 1936a,b,

foraminifera		Hahn and Weber 1981, Fontaine 1983, Vachard 1989, Ueno 2003, 2006
	South Sumatra	De Neve 1949, 1961
	Bangka, Belitung	De Roever 1951, Van Overeem 1960
	NW Kalimantan/ W Sarawak	Krekeler 1932, 1933, Tan Sin Hok (in Krekeler 1933), Cummings 1962, Sanderson 1966, Fontaine 1990, Vachard 1990, Sakamoto and Ishibashi 2002
	NE Kalimantan (Upper Kutai)	Tan Sin Hok 1930, Sugiaman and Andria 1999
	Timor, Roti, Leti	Schubert 1915a,b, Thompson 1949, Nogami 1963, Charlton et al. 2002, Davydov et al. 2013
	West Papua	Visser and Hermes 1962
Tubiphytes	Sumatra	Tien 1986
	Timor	Riding and Barkham 1999 (= *Shamovella*)
Corals	Timor	Gerth 1921, Koker 1924, Wang 1947, Von Schouppe and Stacul 1955, 1959, Minato and Kato 1965, Niermann 1975, Sorauf 1984, 2004
	West Sumatra	Volz 1904, Minato and Kato 1965, Nguyen Duc Tien 1989a,b
	Thailand	Fontaine et al. 1994
Smaller foraminifera	Sumatra	Nguyen Duc Tien 1989a,b
	Sibumasu	Zhao and Zhou 1987, Wang et al. 2013
Conodonts	Timor	Van den Boogaard 1987
	SE Asia	Mei and Henderson 2001, 2002
Ostracodes	Timor	Grundel and Kozur 1975, Bless 1987

CONCLUSIONS

The Indonesian region is host to some important localities of Paleozoic fossil faunas and floras. This paper reviews some of the current knowledge and provides references to the many paleontological studies conducted here in the last 150 years.

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Key references are given at the end of each chapter. Additional titles not fully referenced here can be found in the Bibliography below (with English translations of non-English titles and many with brief annotations of content).

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