An introduction to Mesozoic faunas and floras of Indonesia

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ABSTRACT

This paper is a continuation of the paper on Paleozoic and reviews the main Mesozoic fossil groups of Indonesia and key literature, with focus on groups that are of biostratigraphic or paleobiogeographic significance.

INTRODUCTION

Mesozoic-age rocks are relatively widespread in Indonesia, from Sumatra, Java and Kalimantan in the West to Sulawesi, the Outer Banda Arc (Sumba, Timor, Tanimbar, Seram), the Sula Islands and New Guinea in the East. Typical fossil Mesozoic macrofossil groups that are useful for age dating and paleobiogeographic information include ammonites, belemnites and mollusks. Brachiopods and foraminifera are locally important as well.

For age dating of Mesozoic rocks microfossils tend to be more significant than macrofossils. The preferred microfossil groups are:
1. Radiolaria in deep marine deposits;
2. Conodonts in Triassic and older shallow marine carbonates;
3. Dinoflagellate cysts in Late Triassic- Early Cretaceous shallow marine clastic sediments;
4. Planktonic foraminifera and Calcareous nannofossils in Cretaceous and younger open marine deposits;
5. Spores-pollen in non-marine - marginal marine deposits.

Early reviews of Mesozoic geology and stratigraphy of Indonesia include Wanner (1925, 1931) and Umbgrove (1935, 1938). Mesozoic fossil localities on Sumatra were discussed by Tobler (1923) and Fontaine and Gafoer (1989). Another useful collection of Pretertiary paleontologic sudies in SE Asia is Fontaine (1990).

KEY REFERENCES- MESOZOIC GENERAL

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TRIASSIC

Triassic sediments are widespread across Indonesia, and represent a wide variety of facies, including volcanics, non-marine to deep marine clastics and shallow marine to pelagic carbonates and oceanic radiolarian cherts. They represent depositional settings around two branches of the Tethys Ocean, Paleo-Tethys and Mesotethys, separated by Cimmerian Blocks that stretch all the way from Turkey in the West to Sibumasu in the East. These Tethys ocean branches closed in Late Triassic and Early Cretaceous times respectively. Debates continue on the exact position of these Tethys sutures and possible Sibumasu -equivalent blocks in the Indonesian region east of the Malay Peninsula and Sumatra.

Early Triassic marine sediments are known only from Timor. Middle and Late Triassic rocks are more widespread in both West and East Indonesia (but not in West Papua- PNG). At many localities the Triassic is developed in a 'flysch-type' clastic facies, locally overlain by Norian-Rhaetian limestones (Savu/ Roti, Timor, Leti/Babar, East Sulawesi, Seram, Ambon, Misool, Buru, Buton).

Late Triassic marine faunas of Indonesia are generally of low-latitude Alpine - Tethyan affinity, although some provinciality of Eastern Indonesia and the Australia-New Guinea margin is suggested by endemic bivalves and brachiopods (*Misolia*).

The end of the Triassic is a major extinction event, one of the 'Top 5' in the Phanerozoic, causing extinction of the vast majority of shallow marine

species of, including all conodonts, and 90% of reef-building coral and sponge species. As a result, no reefal limestones are known from the Jurassic of Indonesia (see also Charlton and Van Gorsel 2014, this volume).

A vast amount of literature exists on Triassic faunas of Indonesia, most of which are listed in Table 1. Early reviews of Triassic faunas and facies in the Indonesian region include Zwierzycki (1925), Wanner (1931) and Umbgrove (1935). A recent, brief review of Triassic biostratigraphy and correlations of East Indonesia is by Hasibuan (2010).

KEY REFERENCES- TRIASSIC PALEONTOLOGY GENERAL

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Triassic Shallow Marine Bivalves

The composition of Triassic bivalve assemblages in the Indonesian region varies depending on facies and paleogeographic setting: (1) shallow marine '*Myophoria* faunas' and (2) deep marine, pelagic bivalve faunas characterized by *Daonella, Halobia* or *Monotis* (see next chapter).

Shallow marine Middle - Late Triassic bivalve-dominated limestones and sandstones with common *Myophoria, Cardita*, *Gervillia*, *Costatoria*, *Paleocardita*, *Indopecten verbeeki*, *Pinna blanfordi*, *Krumbeckiella* = *Timoria timorensis* Krumbeck), etc., have been reported from both West (Sumatra) and East Indonesia (Misool, Buru) (Figure 1).

Among the richest assemblages are the *Nucula* marls from Misool (Jaworski 1915). These are generally viewed as 'Tethyan' in nature, but may be assumed to be part of the southern, Gondwana margin of the (Meso-?)Tethys in Triassic time. The bivalve-rich 'Padang Fauna' of West Sumatra, collected by Verbeek NE of Lake Singkarak, was initially described by Boettger (1881) as an Early Eocene age assemblage. It contains *Myophoria, Paleocardita globiformis, Pinna blanfordi* and *Pecten (Indopecten) verbeeki* and was re-described and re-interpreted as Late Triassic in age, with strongest affinities to Circum-Mediterranean Carnian faunas, by Krumbeck (1914).

'*Myophoria* sandstone' is also known from various localities in the central belt of the Malay Peninsula and Singapore (authors in Table 1), in what is now called the Semantan Formation and which are viewed as marine deposits in a foreland basin tied to the closure of the Paleo-Tethys during final eastward subduction of Western Malaya lithosphere beneath Eastern Malaya (Ismail et al. 2007).

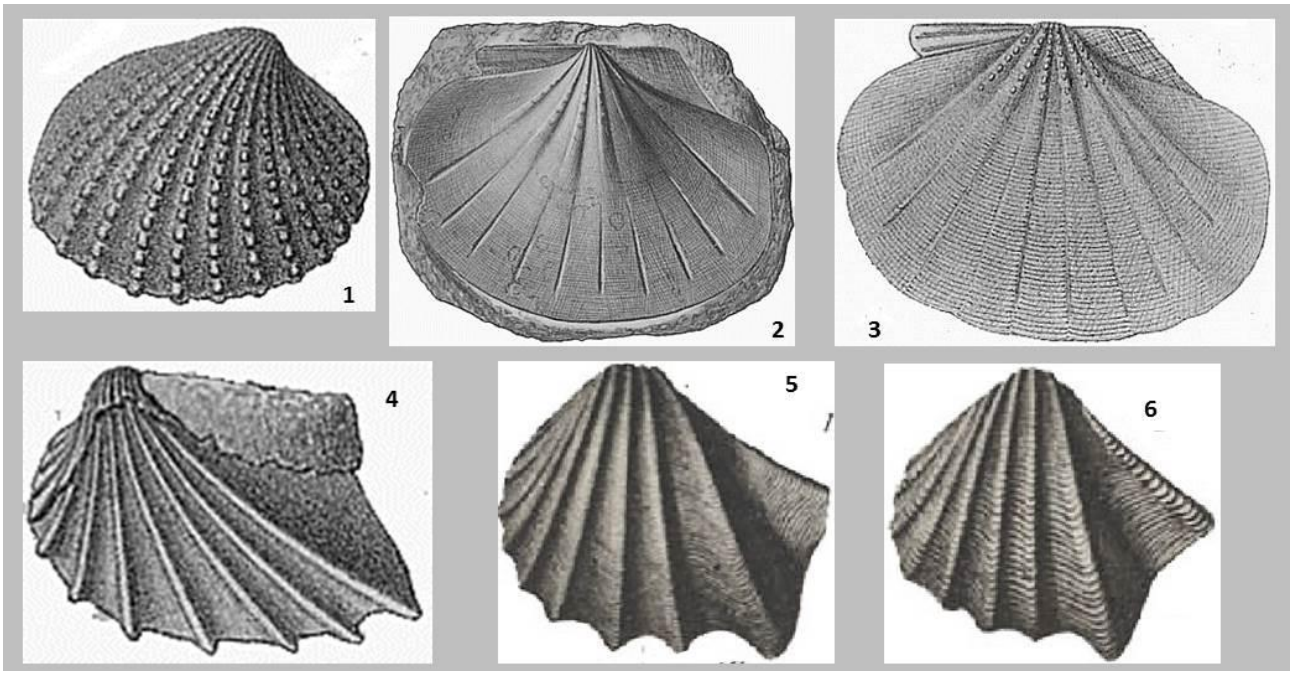


Figure 1. *Typical Late Triassic shallow marine bivalves from Sumatra and Misool. 1.* Paleocardita globiformis, *2-3.* Pecten (Indopecten) verbeeki *and 4.* Myophoria myophoria *from West Sumatra (from Boettger 1881, Krumbeck 1914). 5-6.* Myophoria vestita *from* 'Nucula *Marls' of Misool (Jaworski 1915).*

KEY REFERENCES- TRIASSIC BIVALVE MOLLUSCS

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Jaworski, E., 1915. Die Fauna der obertriadischen Nuculamergel von Misol. In: J. Wanner (ed.) Palaontologie von Timor II, 5, p. 73-174.

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Triassic (hemi)-pelagic Bivalves

Middle and Late Triassic deep marine shales and pelagic deposits in the Tethyan and Circum-Pacific regions often contain beds with common flat, thin-walled bivalves (also called 'flat clams' or 'paper shells'; Figure 2). The dominant genus of these pelagic bivalves, varies with age: *Claraia* in Early Triassic, *Daonella* in Middle Triassic (E. Carnian), *Halobia* in Late Triassic (Carnian- Norian) and *Monotis* in latest Triassic (M. Norian- Rhaetian; McRoberts 2010). Where found, they are often abundant and rock-forming. They are important biostratigraphic index fossils.

In Indonesia Triassic pelagic bivalves are mainly found in East Indonesia, in the deep marine deposits of Timor, Roti, Buton (Sikumbang et al. 1995), Seram (Wanner 1907), Buru, Misool, Babar, etc. In West Indonesia they are known from Sumatra. They are not known from Australia, but this could be due to a scarcity of open marine facies of that age.

Depending on age, the following genera are dominant (McRoberts 2010):

1. *Daonella* is the dominant genus of Tethyan pelagic bivalves in Middle Triassic to Early Carnian time. In Early Carnian it evolves into *Halobia*. Kobayashi (1963) recognized five Anisian - Early Carnian *Daonella* zones in SE Asia. Middle Triassic *Daonella indica* is locally abundant in the Norian of Timor (Krumbeck 1924, Kutassy 1930, 1931). It was also reported from Roti (Rothpletz 1892), Buru (Boehm 1910, 1919) and Misool (Wanner 1907, Hasibuan 1990, 2010). A species closely related to *D. indica* was reported from the Mount Hagen area in the Highlands of Papua New Guinea by Skwarko (1973). Volz (1899) described locally common *Daonella* and *Halobia* from the Lake Toba area, West Sumatra. Similar *Daonella* is also known from Thailand (*D. sumatrensis* Volz; Kobayashi and Tokuyama 1959, Pitakpaivan 1969) and Peninsular Malaysia (*Daonella indica* and *D. pahangensis*; Kummel 1960, Kobayashi 1964, Sato 1964).
2. *Halobia* in Late Triassic (Carnian - M Norian; *Halobia* died out in mid-Norian). Late Triassic *Halobia* is mainly represented by *Halobia comata*. It is the most common species in the Carnian of Timor (Wanner 1907, Krumbeck 1924) and is a Carnian index species in the eastern Tethys province (Kobayashi and Tokuyama 1959, Kobayashi and Masatani 1968). *Halobia* is also known from Roti (Rothpletz 1892), the Lake Toba area of Sumatra (Volz 1899) and the Semanggol Fm of Pensular Malaysia (Newton 1925).

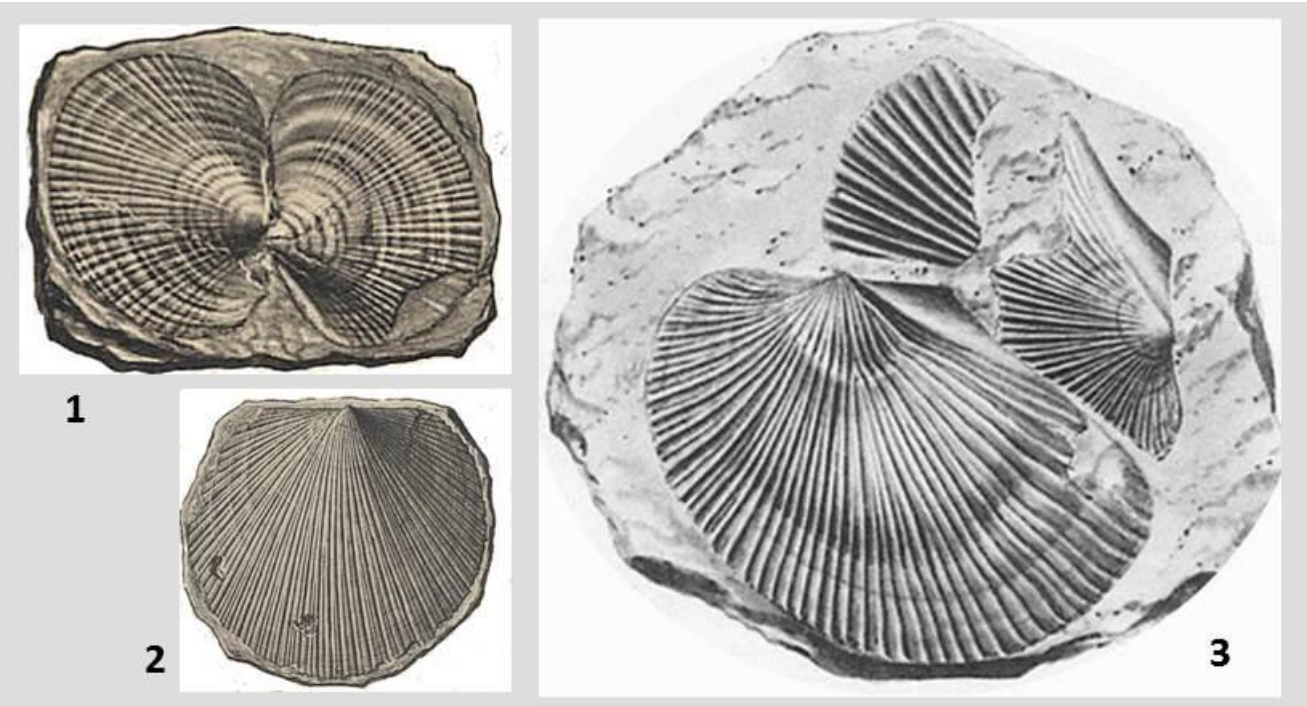


Figure 2. *Middle-Late Triassic hemi-pelagic bivalves 1. Small double-valve* Halobia comata*, 2.* Daonella indica *from Timor (Krumbeck 1924); 3.* Monotis salinaria *from Seram (Wanner 1907).*

3. *Monotis* (Late Norian). After a diversity and abundance peak in the Late Norian, a major extinction event of most species of *Monotis* was observed at the end of the Norian across the Tethys and other areas (Hallam 1981, McRoberts et al. 2008). This extinction event also affected other pelagic groups like ammonites, but not shallow marine carbonate fossils. In Indonesia *Monotis salinaria* is known from Seram (Wanner 1907), Buton (Sikumbang et al. 1995), Roti and Timor (Rothpletz, 1892, Wanner 1931, Kristan-Tollmann et al. 1987) and from NW Kalimantan (Vogel, 1904, Zeijlmans van Emmichoven, 1939) where it is in Upper Triassic flysch associated with the Serian Volcanic complex.

These pseudo-pelagic, thin-shelled bivalves probably have an 'anti-tropical' geographic distribution, like morphologically similar bivalve groups in the Late Jurassic (*Buchia, Aucella, Malayomaorica*) and Cretaceous (*Inoceramus*). Some provinciality between species has been suggested for Late Triassic *Monotis* (Westermann 1973, Thenius 1980, Silberling 1985), with Tethyan Norian assemblages characterized by *Monotis salinaria*.

KEY REFERENCES- TRIASSIC DEEP MARINE BIVALVE MOLLUSCS

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Triassic Ammonoids

Early, Middle and Late Triassic ammonoid assemblages are the most diverse of all ammonoid assemblages in Indonesia, and most of the species are from condensed pelagic cephalopod limestones of Timor. They were described in voluminous monographs by Welter (1922, 1915 and 1914 respectively) and Diener (1923). The Triassic 'Cephalopod Limestone' of Timor is a condensed, pelagic facies commonly called 'Hallstatt-type', and is the only place in Indonesia with a complete marine Triassic succession. Unfortunately the formation is mainly known from blocks in melange formation, but at Kapan, West Timor, Wanner (1913) observed the transition between Permian crinoid limestone into Early Triassic cephalopod limestone. Restored thickness suggests the entire Triassic in cephalopod limestone facies is very thin (<10m). Many of the fossils in this limestone are coated with a thin manganese layer, reflecting long periods of non-deposition, on a deep sea floor. Timor is the only place in Indonesia with known Early and Middle Triassic ammonoids.

In the Early Triassic ammonoid faunas had to recover from the mass extinction at the end of the Permian, after which new, diverse ammonoid assemblages developed rather rapidly. In Indonesia Early Triassic ammonoid faunas are known only from the cephalopod facies of Timor, from where Welter (1922) described 71 species of genera *Meekoceras, Flemingites*, etc. Middle Triassic ammonoids from Timor were first documented by Welter (1915). As noted by Welter (1922) Early Triassic ammonoid assemblages from West Timor share many similarities with Himalayan-Mediterranean Triassic faunas.

Late Triassic ammonoid faunas of Timor are extremely rich and diverse and are characterized a.o. by haloritids *Halorites* and *Juvavites*, *Anatomites, Amarassites* and many others (Figure 3). Von Arthaber (1926) distinguished 110 species in the Carnian-Norian. Tatzreiter (1981) counted 90 species of trachyostracous ammonoids (not counting the more numerous leiostracous ammonoids) in a 1m thick block of condensed Middle Norian limestone at Baun. Wanner (1931) reported 462 species from a 2m thick block of Carnian Cephalopod Limestone at Bihati.

Numerous authors, including Wanner (1913), Welter (1914, 1915) and Diener (1923), noted the remarkable similarities between the ammonite assemblages of Timor and the Alpine-Mediterranean and Tethyan Himalayan regions, particularly the Hallstatt Limestone facies of the Austrian Alps. A major extinction event affected Triassic ammonoids at the end of the Norian, after a diversity peak in Carnian - Early Norian time (Hallam 1981).

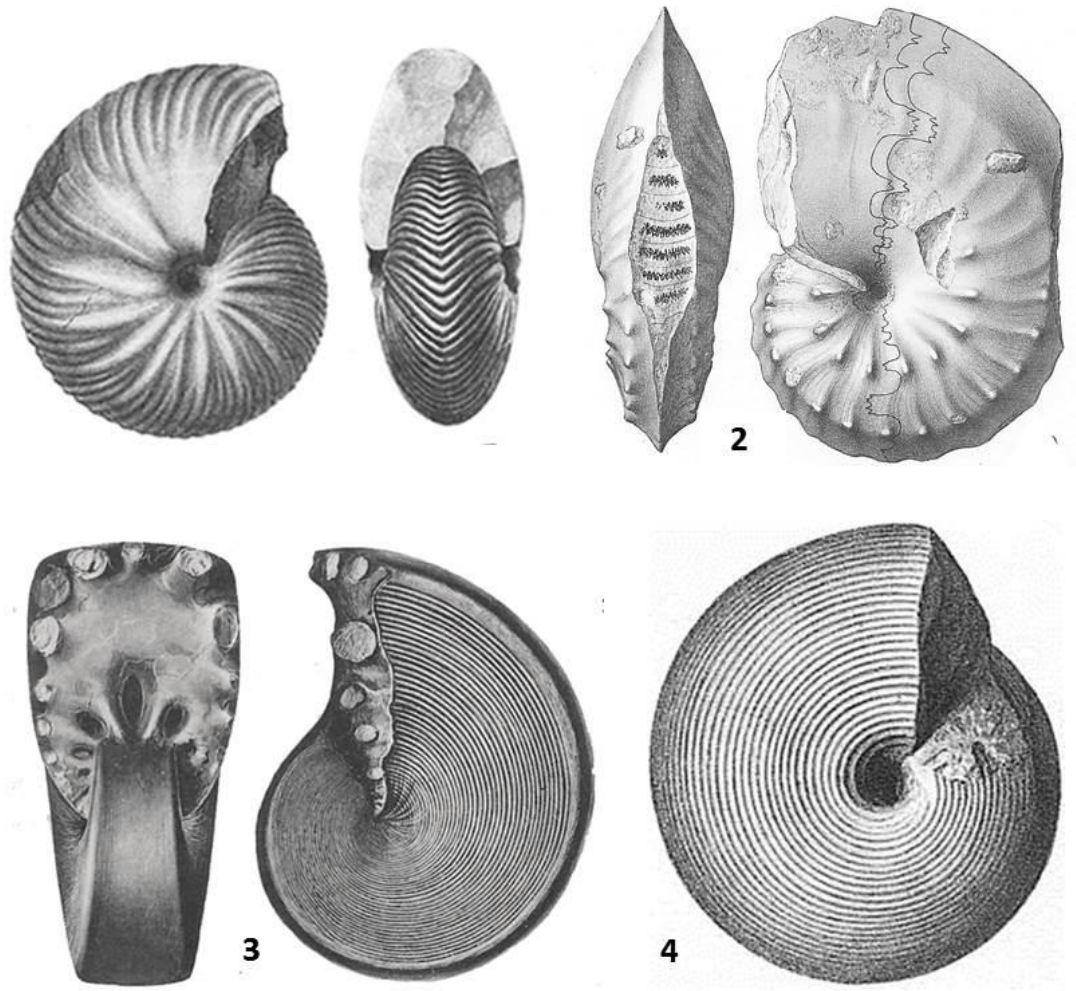


Figure 3. *Late Triassic ammonoids from Timor. 1.* Juvavites sarasinii *from Bihati (Diener 1923), 2.* Neotibetites *(Krumbeck 1913), 3.* Cladiscites crassestriatus *from Bihati 2 (diameter 8 cm; Von Arthaber 1927), 4.* Agathiceras.

KEY REFERENCES- TRIASSIC AMMONOIDS

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Welter, O.A., 1922. Die Ammoniten der unteren Trias von Timor. In: J. Wanner (ed.) Palaeontologie von Timor 11, 19, Schweizerbart, Stuttgart, p. 83-154.

Triassic Belemnoids

Characteristic strongly ribbed belemnoids of the genus *Aulacoceras* are locally abundant in the Upper Triassic of Timor (Figure 4). From the Carnian-Norian of the Baung and Niki-Niki areas 2500 specimens were collected by Wanner and Molengraaff and studied by Von Bulow (1915). The Jonker 1916 expedition collected another >3000 specimens. They are also known from Savu and Roti (Wanner 1907, 1911). They were originally described as *Asteroconites savuticus* Boehm, 1907 and *Aulacoceras timorense* Wanner, 1911, but are all varieties of the Alpine-Mediterranean species *Aulacoceras sulcatum* Von Hauer 1860, first described from the Hallstatt Limestone in Austria (Gheyselinck 1934).

The Timor belemnites are commonly covered in black manganese coating, attesting to the deep marine, condensed facies of the Tethyan oceanic 'Halstatt-facies' in which they are found.

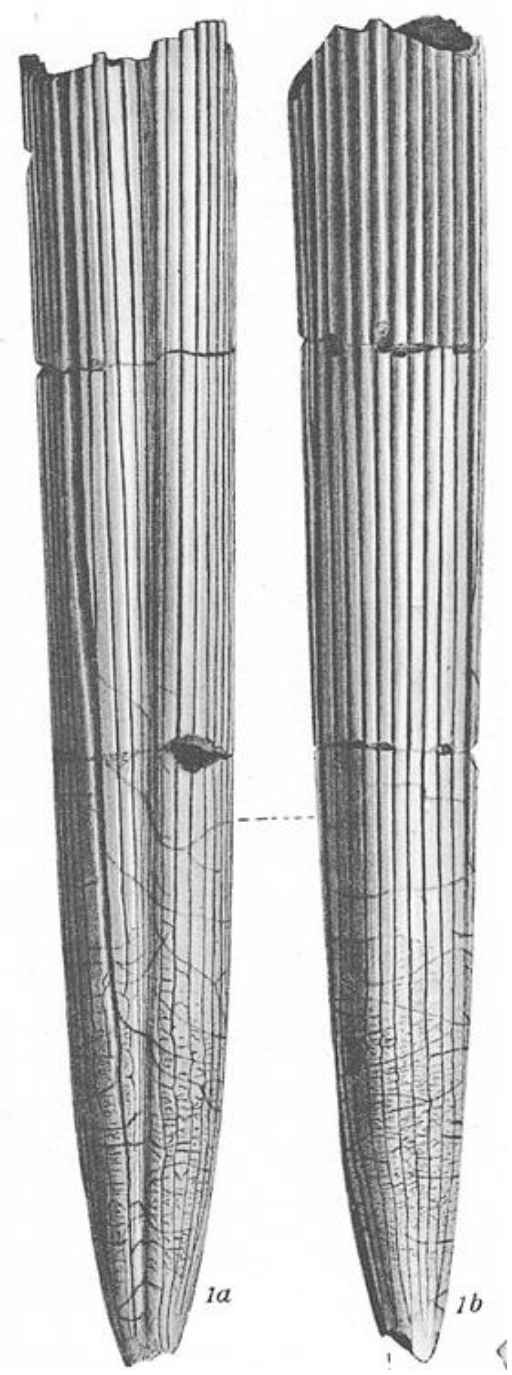


Figure 4. *Late Triassic (Carnian-Norian) belemnoid* Aulacoceras sulcatum *var.* timorensis *from Bihati, Timor (Von Bulow, 1915).*

KEY REFERENCES- TRIASSIC BELEMNITES

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Triassic Brachiopods

Late Triassic brachiopod assemblages in East Indonesia often contain the rhynchonellid brachiopod species *Misolia misolia* (Figure 5). The species is typical of Carnian-Norian (and younger?) shelfal marine deposits of the Gondwana margin of the southern/eastern Mesotethys (Dagys, 1993), and has been reported from Oman through the Spiti area of the Himalayas to East Indonesia and the NW Australian margin. In eastern Indonesia it is present in Misool, Timor, East Sulawesi, Buru, Seram, Ambon and Buton (references in Table 1).

Less widely distributed in the Late Triassic of eastern Indonesia is the brachiopod genus *Halorella*, which is commonly viewed as a genus more typical of the Mediterranean/northern margin of the (Meso-)Tethys (Ager and Sun 1989). However, species of *Halorella* described from Timor and Seram (Wanner 1907, Krumbeck 1921, 1924, Kruizinga 1931) have been re-assigned to *Timorhynchia* and *Halorelloidea* by Ager (1988).

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Triassic Corals

Following the major end-Permian extinction event, corals are relatively rare globally through much of the Triassic. The Late Triassic is a time in which coral reef limestones become common again along the Tethys margins, although calcareous sponges and algae remain important components of these reefal limestones.

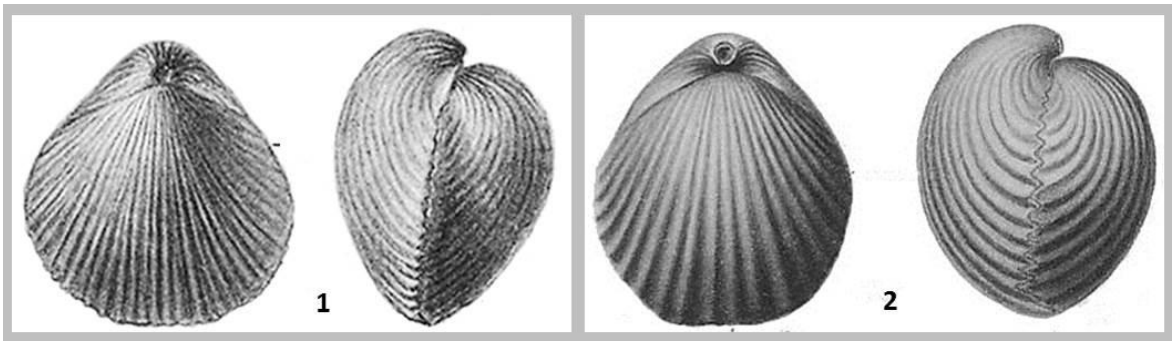


Figure 5. *Triassic rhynchonellid brachiopod* Misolia misolia *Von Seidlitz. 1. from Tifu, Buru (size ~3 cm); 2. from 'Athyrid Limestone' (= Bogal Fm) of Misool (size~3.5 cm) (Von Seidlitz, 1913).*

In Indonesia Late Triassic corals are known from 'Fau Limestone' of Timor (Vinassa de Regny 1915), the Manusela Limestone of Seram (Wanner 1907, Wilckens 1937) and from Bangka (De Neve and De Roever 1947). Characteristic genera include *Thecosmilia* spp., *Isastraea, Retiophyllia* and *Montlivaltia* (Figure 6). Many of the species from Timor are the same as those from the Austrian Alps (Vinassa de Regny 1915).

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Late Triassic Hydrozoan or Stromatoporoid Lovcenipora

Upper Triassic reefal limestones in SE Asia often contain a hydrozoan or stromotoporoid named *Lovcenipora vinassai* (Seram, Timor; Wanner 1952; Figure 6). This is a Tethyan taxon, common in the Late Triassic of the Mediterranean. It was erroneously equated with a somewhat similar-looking Late Jurassic Tethyan hydrozoan *Cladacoropsis mirabilis* (Renz 1926), but these are separate taxa (Yabe 1946). It had led workers like Van der Sluis (1949) to erroneously assign a Jurassic age to the Manusela Limestone of Seram, an opinion followed by Van Bemmelen (1949), but fiercely protested by Wanner et al. (1952), and still somewhat entrenched in Seram geological literature (Kemp 1992, etc.; see also Charlton and Van Gorsel, 2014; this volume).

In Indonesia Triassic *Lovcenipora* is known from Seram, Buru (Gerth 1910) and the Fatu Limestones of Timor (Vinassa de Regny 1915, Pia 1924). *Lovcenipora* has also been described from Jurassic - Cretaceous of Sumatra, but in most cases these are misidentifications and should be assigned to *Cladocoropsis miriabilis* (e.g. Yabe 1946).

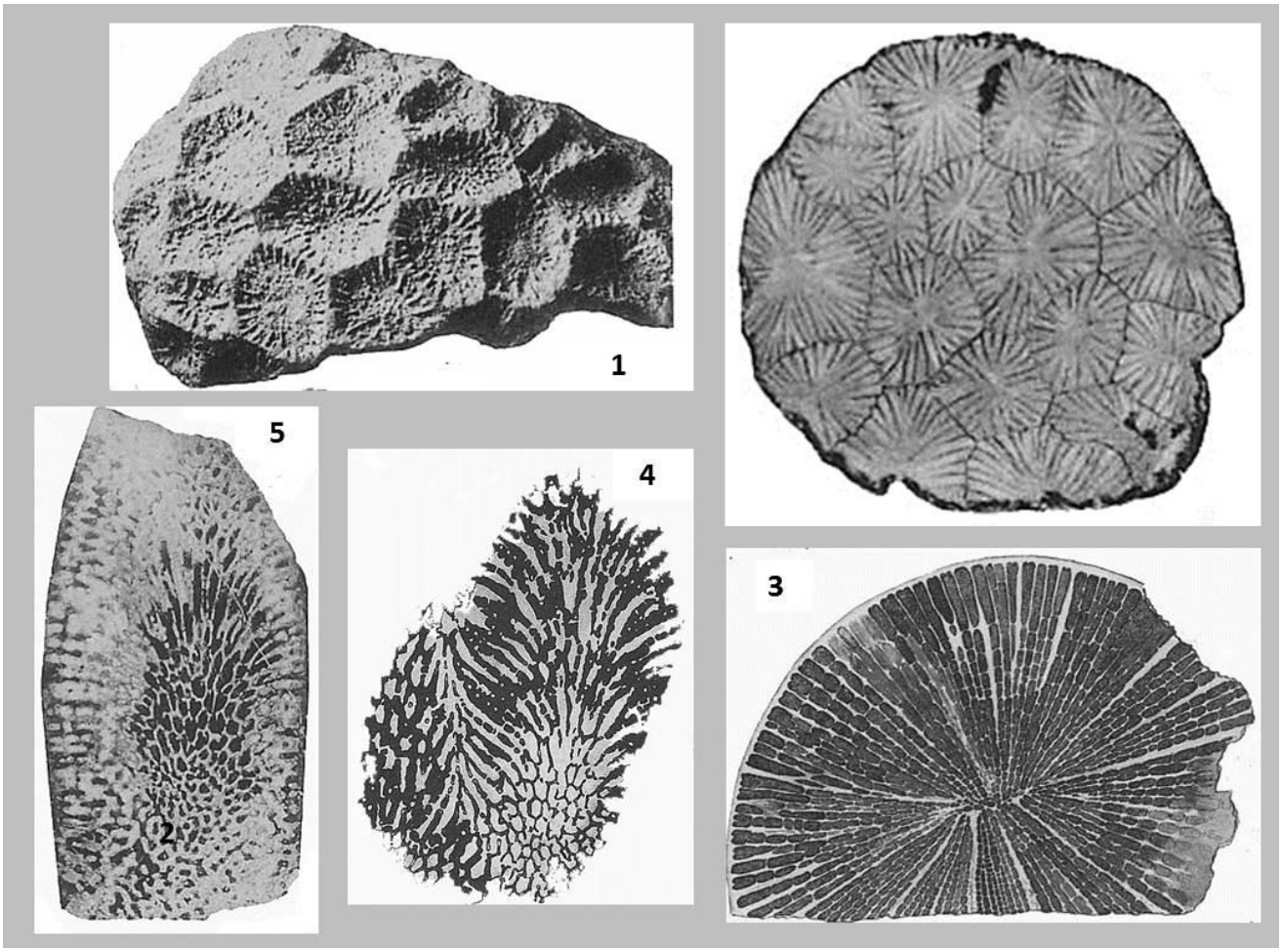


Figure 6. *Late Triassic corals and Lovcenipora from Timor and Seram. 1.* Isastraea verbeeki *and 2.* Isastraea guembeli *from Timor (Vinassa 1915); 3.* Montlivaltia molukkana *from Seram (Wanner, 1907), 4.* Lovcenipora vinassai *from East Seram (described as coral* Pachypora intabulata *by Wanner, 1907); 5.* Lovcenipora vinassai *from Timor (Vinassa 1915).*

KEY REFERENCES- *LOVCENIPORA*

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Yabe, H., 1946. On some fossils from the Saling Limestone of the Goemai Mts., Palembang, Sumatra- I. Proc. Japan Acad. 22, 6, p. 200-203.

Middle - Late Triassic Calcisponges and Tubiphytes

In most of the Tethyan Upper Triassic reefal limestones, from the Circum-Mediteranean to Iran to Seram and Timor, calcareous sponges are the dominant reef builders (Vinassa de Regny 1915, Wilckens 1937). *Tubiphytes* are also locally common in Triassic reefal limestones of Indonesia. Its taxomic position is still debated: cyanobacterial, hydrozoan, sponge, red algae, etc. (Riding and Li Guo 1992). Both groups remain little studied in the Indonesian region.

KEY REFERENCES- TRIASSIC CALCISPONGES

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Heterastridium

Hetrastridium is an interesting Late Triassic hydrozoan fossil that is widespread in the Norian of the Tethyan realm. It is a globular fossil, with a diameter typically 1-5cm and is the only hydrozoan colony with a probably pelagic lifestyle. It is locally abundant in the Upper Norian of the Hallstatt limestone in the Carnian Alps, then ranges through the Tethyan belt towards East Indonesia, The Philippines and New Caledonia (Campbell 1974) to Panthalassan terranes in Japan, New Zealand and North America.

In Indonesia *Heterastridium conglobatum* is locally common on Timor (Gerth 1915, 1942; Figure 7). It is found mainly in the thin, condensed pelagic 'Cephalopod Limestone', which is mainly composed of ammonites, and which is commonly compared to the 'Hallstatt-facies' of the Northern Calcareous Alps. Other occurrences include East Seram (Gerth 1909, 1942) and Misool (Krumbeck 1913).

KEY REFERENCES- LATE TRIASSIC *HETERASTRIDIUM*

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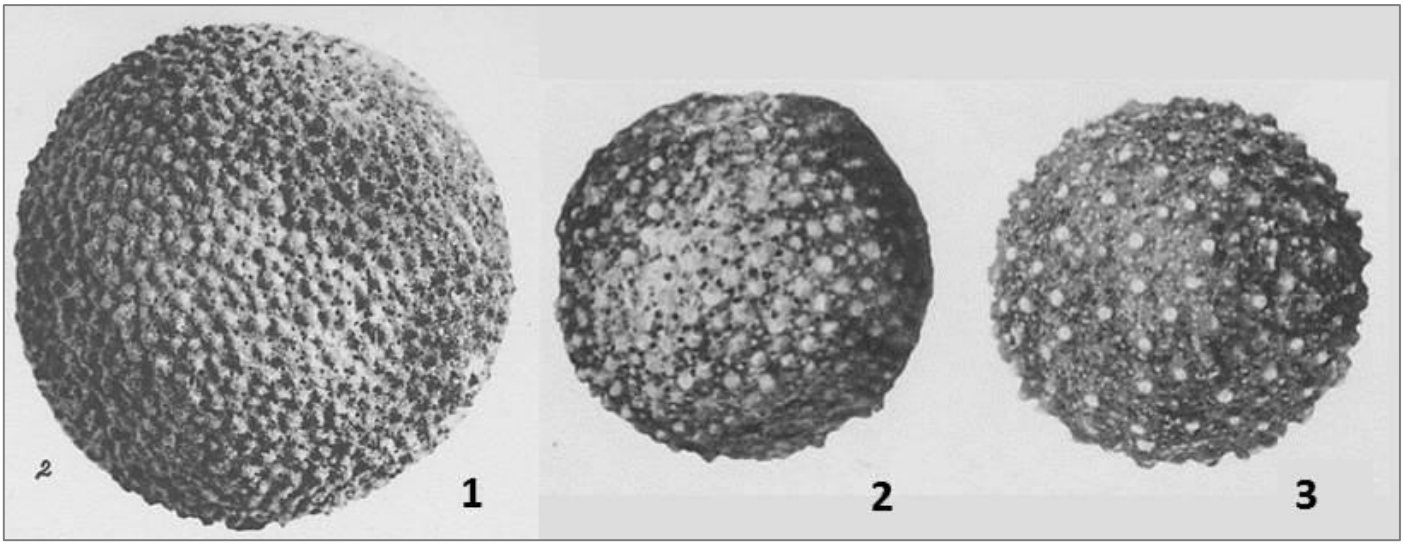


Figure 7.- *Late Triassic pelagic hydrozoan* Heterastridium conglobatum *from Timor. 1. From Bihati (size ~3.2cm); 2-3 From Oe Batok, Amarassi (size ~2 cm) (Gerth, 1915, 1942.).*

Late Triassic Dasyclad Algae

Calcareous algae are relatively common in the Tethyan Upper Triassic sponge-dominated reefs. A dasyclad algal species from the Norian S of Bula village in NE Seram was described by Pia (1924) as *Macroporella sondaica* n.sp. (Figure 8). This species has not subsequently been reported elsewhere.

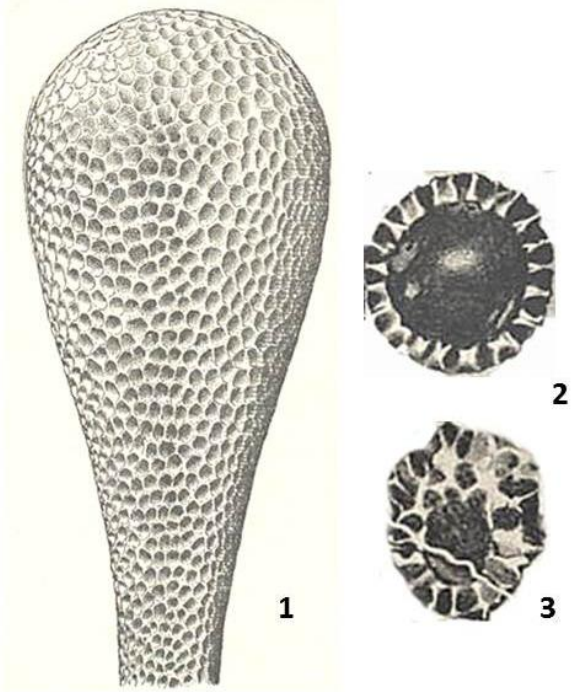


Figure 8*- Late Triassic dasyclad* Macroporella sondaica *from Manusela Limestone in Bula area, NE Seram (Pia 1924). 1. Reconstruction of exterior (actual size ~0.6cm); 2-3. Tangential sections.*

KEY REFERENCES- TRIASSIC CALCAREOUS ALGAE

Pia, J., 1924. Einige Dasycladaceen aus der Ober-Trias der Molukken. Jaarboek Mijnwezen Nederl. Oost Indie 52 (1923), Verhand., p. 137-149.

Late Triassic Floras

Triassic plant fossils are rare in Indonesia, mainly because Triassic rocks in non-marine facies are very rare here. No Early - Middle Triassic floras are known from the Indonesian region. Late Triassic floras were described from two areas, both of East Asian affinity:

(1) Krusin flora' in the SW Sarawak - NW Kalimantan border area, with a.o. *Clathropteris meniscoides* (Kon'no, 1968, 1972). This is a tropical flora, very similar to the Norian-Rhaetian 'Tonkin Flora' floras of North Vietnam and Khorat, Thailand, all part of the *Dictyophyllum-Clathropteris* floral province (Kimura 1984, Dobruskina 1994). *Clathropteris meniscoides* was found also found in dredge samples from the Reed Bank in the South China Sea (Kudrass et al. 1986).

(2) 'Bintan Flora' of SW Bintan, Riau islands. A fairly rich floral assemblage for which a Late Triassic age was suggested by Jongmans (1951), but it differs from the more typical Thailand and Malaysian floras of that age by the absence of characteristic sphenophytes and ferns. This could reflect a (local?) drier climate, but still of Late Triassic age (Wade-Murphy and Van Konijnenburg 2008) or a younger Jurassic- Early Cretaceous age (Kon'no 1972). Some of the floral elements described by Wade-Murphy (2008), like *Brachyphyllum* sp., are known only from Jurassic beds in Thailand and China. Although the exact age of this flora is still disputed, its Asian-European affinities are not.

As on mainland SE Asia, these plant fossils are in 'post-orogenic' clastic sediments that are unconformable over Permian and older 'Indosinian-deformed' sediments and Triassic granitoids. It shows that these two areas must be part of the Sundaland area of SE Asia that amalgamated in the Late Triassic.

KEY REFERENCES- LATE TRIASSIC FLORAS

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Late Triassic Palynofloras

Triassic microflora assemblages of the Gondwanan region (Australia) tend to be dominated by *Falcisporites*. Two different palynoflora provinces were recognized in the Late Triassic of Australia, which appear to be essentially latitudinal floral belts (Dolby and Balme 1976):

1. warm-temperate 'Onslow microflora' along parts of the NW Shelf, probably representing paleolatitudes of ~30-35°S (Martini et al. 2004);
2. higher latitude, cool-temperate 'Ipswich microflora', typically low diversity *Falcisporites*-dominated assemblages, on the Eastern margin from Queensland to the South (Dolby and Balme 1976, Buratti and Cirilli 2007, Cesari et al. 2013).

These assemblages have also been recognized in Indonesia, although details are poorly documented. Floras from Triassic pelagic deposits of West Timor contain an 'Onslow' palynoflora, very close to that of the Circum-Mediterranean area, while the Late Triassic of Seram shows a mixture of Onslow and Ipswich elements. By contrast, the latest Triassic of East Sulawesi show characteristics of the cooler Ipswich Microflora, indicating a higher latitude paleoposition (Martini et al. 2004).

KEY REFERENCES- LATE TRIASSIC PALYNOFLORAS

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TABLE 1 TRIASSIC		
FAUNA/FLORA	AREA	REFERENCES
Trias faunas, biostratigraphy	General	Wanner 1907, 1931, Hasibuan 2008
	Timor	Charlton et al. 2009
Late Tr(?) Bintan Flora	Riau Archipelago,	Jongmans 1951, Wade-Murphy et al. 2008
Late Trias Tonkin/ Krusin Flora	N Vietnam, Thailand	Kon'no and Asama 1973
	Reed Bank, S China Sea	Kudrass et al. 1986
	SW Sarawak	Kon'no 1968, 1972
Late Trias Palynofloras	Seram	Martini et al. 2004
Dinoflagellates	Seram	Helby et al. 1987, Martini et al. 2004
Late Trias corals	Buru	Gerth 1910
	Timor	Vinassa de Regny 1915, Roniewicz et al. 2005
	Seram	Wilckens 1937
***Heterastridium* (hydrozoan)**	Timor, Seram	Gerth 1909, 1915, 1927
	Misool	Krumbeck 1913
U Trias brachiopods (incl. Rhaetian *Misolia*)	Misool	Von Seidlitz 1913, Hasibuan 1990, 2012, MacFarlan et al. 2011
	Seram	Deninger 1918, Krumbeck 1922, Wanner 1923, 1952
	Buru	Von Seidlitz 1913, Krumbeck 1913
	Ambon	Jaworski 1927
	East Sulawesi	Von Loczy 1934, Von Kutassy 1934
	Buton	Hasibuan 2010
	Timor	Krumbeck 1922, 1924, Grunau 1957
	NW Australia margin	Campbell 1994
M-L Trias pelagic bivalves *(Daonella, Halobia, Monotis)*	Thailand	Kobayashi and Tokuyama 1959
	W Kalimantan, Sarawak	Vogel 1904, Tamura and Hon 1977, Silberling 1985
	Misool	Wanner 1907, Hasibuan 1991, 2010
	Seram	Krumbeck 1922
	Timor, Roti	Rothpletz 1892, Wanner 1907, Krumbeck 1924, Kutassy 1931, Ichikawa 1958, Gruber in Kristan-Tollmann 1987
	Sumatra	Volz 1899, Krumbeck 1914
	PNG	Skwarko 1967, 1973, Skwarko and Kummel 1974
M-L Trias shallow marine bivalves (*Myophoria* assemblages)	W Sumatra	Boettger 1981, Krumbeck 1914, Musper 1930
	Buru	Krumbeck 1913
	Misool	Jaworski 1915
	Papua New Guinea	Skwarko 1963, 1973
	Malay Peninsula, Singapore	Newton 1903, 1925, Cox 1936, Tokuyama 1961, Kobayashi and Tamura 1968, Tamura

		1970, 1973
Gastropods	Timor	Tichy 1979
Lovcenipora	Seram, Buru	Wanner 1907, 1952, Gerth 1910, Pia 1924
	Timor	Vinassa de Regny 1915, Krumbeck 1921, 1924?
	Sumatra	Vinassa de Regny 1915
U Trias foraminifera	Timor	Kristan-Tollmann 1988
	Sumatra	Vachard 1989
	PNG	Kristan-Tollmann 1986, 1990
U Trias belemnites	Timor	Wanner 1911, Von Bulow 1915, Gheyselinck 1934
U Trias ammonites	Timor	Wanner 1911, Welter 1914, 1915, Diener 1923, Kieslinger 1924, Von Arthaber 1926, Tatzreiter 1980,1981, 1983
	Buru, Seram	Krumbeck 1913, Wanner 1928
E-M Trias ammonites	Timor	Welter 1915, 1922, Kummel 1968, Nakazawa and Bando 1968, Brayard et al. 2009
Trias conodonts	Sumatra	Metcalfe et al. 1979, 1989
	Timor	Nogami 1968, Koike 1984, Berry et al. 1984, Nicoll and Foster 1998
M-U Trias radiolarians	Timor	Hinde 1908, Rose 1994, Sashida et al. 1996, 1999
U Trias dasyclad algae	Seram, Buru	Pia 1924

JURASSIC

In Indonesia Jurassic deposits have been described from W and N Sumatra, from NW Kalimantan and from many of the islands of East Indonesia and New Guinea. Sediments and faunas are quite different between West and East Indonesia.

Summaries of Jurassic stratigraphy and faunas of Indonesia were presented a.o. by Wanner (1931), Umbgrove (1935), Sato (1975) and Sukamto and Westermann (1992). Those of West Indonesia and parts of mainland SE Asia and The Philippines were reviewed by Fontaine et al. (1983).

The richest Jurassic marine faunas are Middle-Late Jurassic assemblages of ammonites, belemnites, bivalves and radiolaria from terranes in East Indonesia (Sula Islands, Timor-Roti, Buton, East Sulawesi, Misool) and in the New Guinea Central Range and Birds Head (Figures 9-14). These faunas are not tropical Tethyan assemblages, but are probably subtropical to warm temperate faunas (latitudes >30°S), that lived along the SE margin of the (Ceno-)Tethys Ocean. They contain endemic faunal elements that characterize a faunal realm, variously called 'Austral', 'South Tethyan', 'Indo-SW Pacific' or 'Himalayan' (Enay and Cariou 1997). In these areas the Jurassic tends to be overlain by relatively thin Cretaceous pelagic limestones.

Unlike the Permian, Triassic and Cretaceous-Cenozoic periods, no Early-Middle Jurassic reefal limestones are known from the Indonesian region. The often quoted 'Early- Middle Jurassic' reefal Manusela Limestone of Seram is of Late Triassic age; see Charlton and Van Gorsel 2014; this volume). Late Jurassic shallow marine near-reefal carbonates are present in areas of West Indonesia:

- West Sumatra: at several localities, but generally viewed as mud mounds (Beauvais 1985), and associated with arc volcanics of the 'Woyla Terranes' (Barber et al. 2005);
- West Sarawak- NW Kalimantan border area: locally thick latest Jurassic Bau Limestone.

Jurassic rocks are either absent or in non-marine - very shallow marine clastic facies on the Sundaland part of West Indonesia and continuing into the Malay Peninsula and Thailand. This is mainly due to uplift after the Late Triassic 'Indosinian' collision between the Sibumasu and Indochina terranes.

Much of the NW Australia-New Guinea Mesozoic Jurassic passive margin experienced rifting and an overall deepening-upward facies trend through the Jurassic, with continental breakup and creation of new oceanic crust in the Late Jurassic. Relatively widespread Middle Jurassic - earliest Cretaceous sandstones (Plover, Toro, Woniwogi Formations) form significant hydrocarbon reservoirs here.

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Sukamto, R. and G.E.G. Westermann, 1992. Indonesia and Papua New Guinea. In: G.E.G. Westermann (ed.) The Jurassic of the Circum-Pacific, Cambridge University Press, p. 181-193.

Early Jurassic Ammonites

Early Jurassic ('Liassic') ammonites are relatively rare in the Indonesian region, but rich assemblages known from Outer Banda Arc island Roti, Timor and Yamdena (mud volcanoes), and from Buton and East Sulawesi (Jaworski 1933). The richest assemblages with 41 species are from Liassic deep water marls of Roti Island, described by Krumbeck (1922; Figure 10-1-3). They are dominated by *Dactylioceras* spp. and *Arietites* spp., also *Arnioceras, Lytoceras, Phylloceras,* etc. Most species here are similar to European-Mediterranean/Tethyan species.

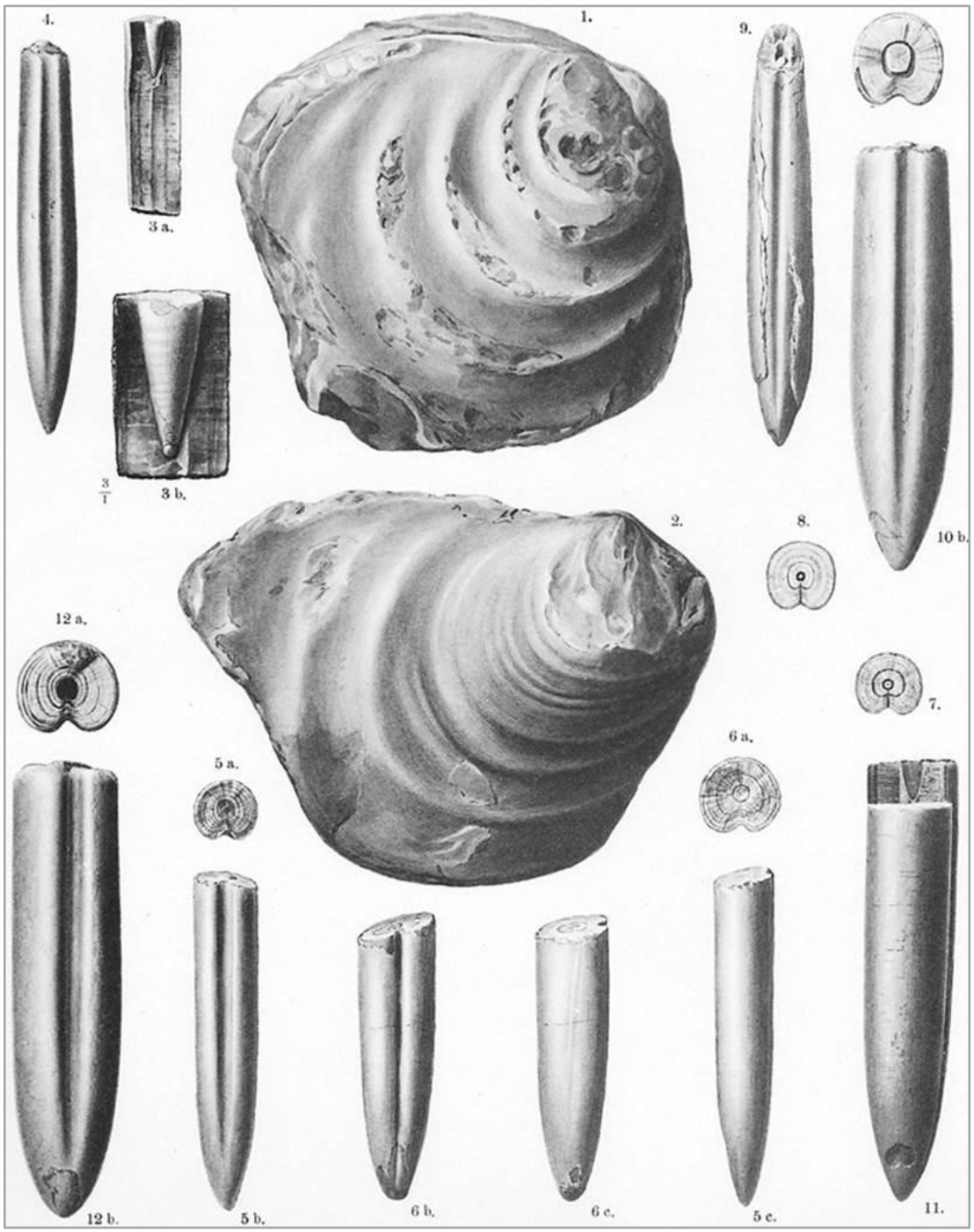


Figure 9. *Late Jurassic (Oxfordian) fauna from Wai Galo, Sula islands (Boehm 1905). 1-2. Pelagic bivalves* Inoceramus sularum *and* I. taliabuticum*; 3-12. Belemnites of the* Belemnopsis galoi *group (5-11) and* Belemnopsis moluccana *(12).*

These Early Jurassic 'Tethyan' ammonite assemblages from grey nodular marls are very similar from Roti to Timor, Babar and Yamdena (Tanimbar), suggesting a continuous deep water facies belt, with an uninterrupted oceanic connection with the western Tethys in Early Jurassic time. And they are probably all part of a continuous Triassic-Paleogene deep marine stratigraphic succession. An interesting implication of this could be that if this belt was located along the distal NW Australian continental margin, as is generally assumed, it likely already faced the Tethys Ocean, and it would seem unlikely that any major land area (part of 'Argoland') would have rifted off this part of the margin in Late Jurassic time.

Ammonites from West Kalimantan of supposedly Early Jurassic age appear to have no species in common with the Roti material (Krause 1911, Krumbeck 1922, Hirano et al. 1981).

KEY REFERENCES- EARLY JURASSIC AMMONITES

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Middle-Late Jurassic Ammonites

Ammonite assemblages characteristic of the 'Indo-Pacific Realm' are known from West Papua (Lengguru, Central Range), Papua New Guinea, Sula islands and outer Banda Arc islands like Timor, Roti and Babar (references in Table 2 and Bibliography) (Figure 11). They are characterized by *Macrocephalites spp.* and *Satoceras* in the Late Bathonian-Callovian, the *Mayaites* group and *Sulaites* in the Oxfordian- E Kimmeridgean, *Uhligites* and *Blanfordiceras* in the Tithonian.

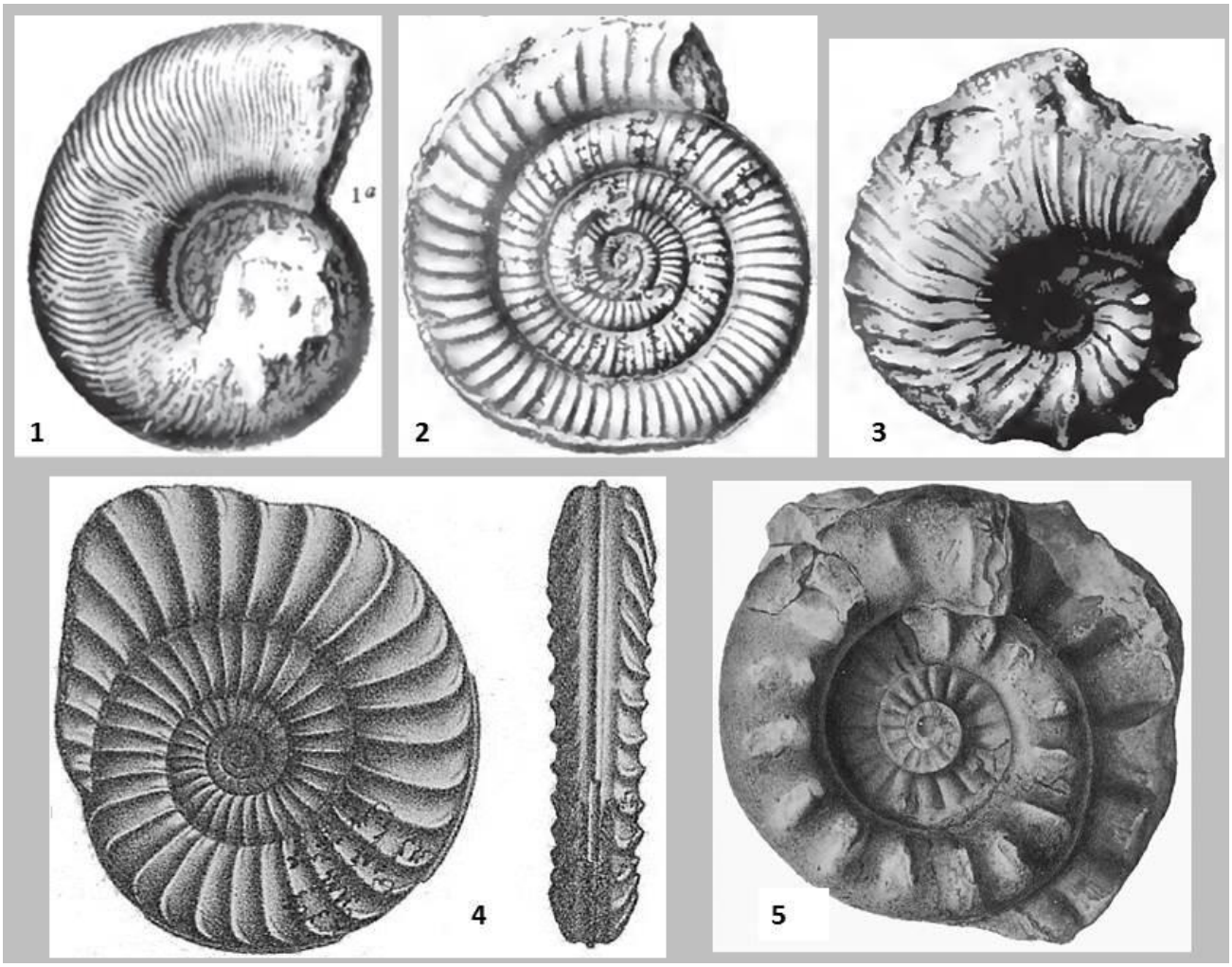


Figure 10. *Early Jurassic ammonites. 1.* Lytoceras rotticum, *2.* Arietites (Euechioceras) wichmanni *and 3.* Aegoceras subtaylori *3 from Roti (Krumbeck 1922); 4.* Arietites geometricus *from Batu Baraketak mud volcano, Roti (Rothpletz 1892); 5.* Aegoceras borneense *from West Kalimantan (Krause 1911).*

As mentioned above, they show strong affinities with faunas from the Tethyan Himalayas to New Zealand, all areas that all restore to the southern margin of the Neotethys Ocean (Thierry 1976, Von Hillebrandt et al. 1992, Enay and Cariou 1997, Page 2008). The East Indonesia- New Guinea assemblages are different from Jurassic ammonite assemblages from West Kalimantan and Thailand (Kozai et al. 2011), which have northern Tethyan affinities (but it should be noted that open marine Jurassic sediments with ammonites are rare on Sundaland).

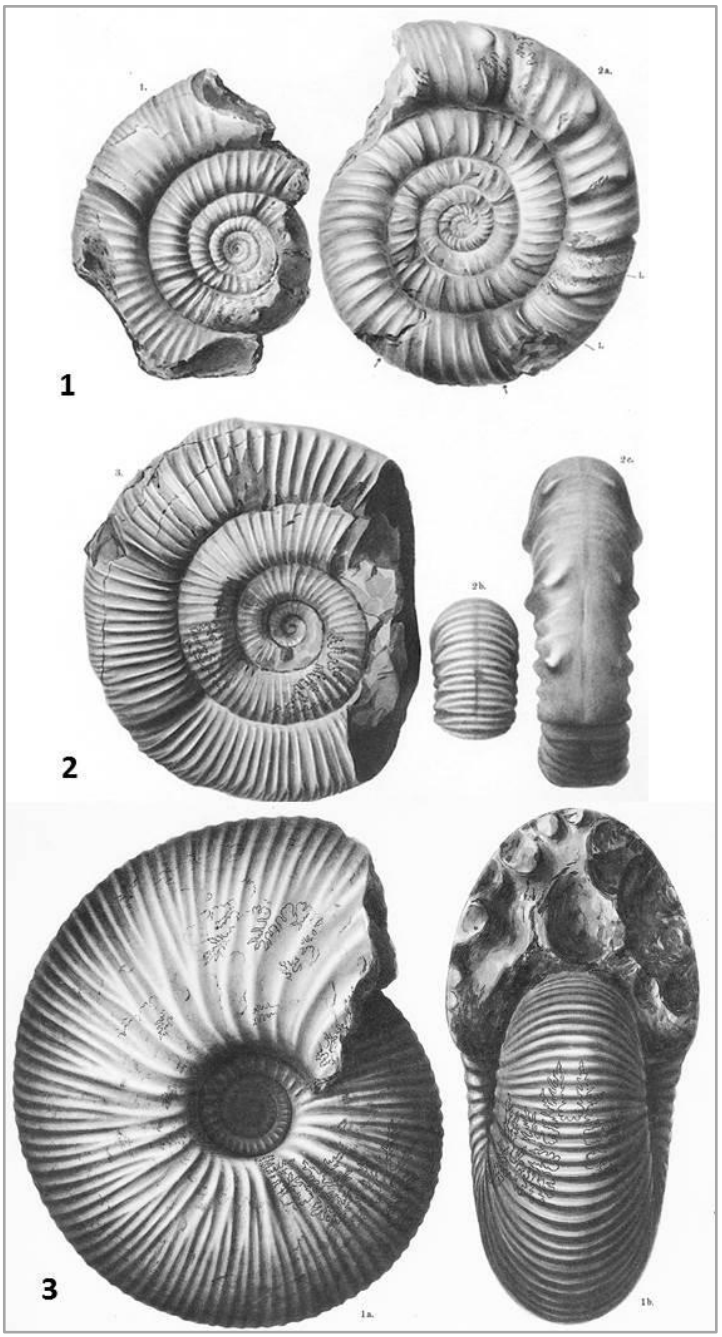


Figure 11. *Late Jurassic (Oxfordian) ammonites from Wai Galo, Taliabu, Sula islands (Boehm 1907). 1.* Perisphinctes ternatus *and* P. indonesianus*; 2.* Perisphinctes aff. wartae*; 3.* Macrocephalites rotangi.

KEY REFERENCES- MIDDLE- LATE JURASSIC AMMONITES

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Middle-Late Jurassic Belemnites

Late Middle Jurassic to earliest Cretaceous belemnites are common only in parts of Eastern Indonesia and Papua New Guinea, in particular Misool and the Sula islands but also in Buton, Central-East Sulawesi, Buru, Seram, Timor, Roti, Babar, Yamdena and West Papua (Table 2, Figure 9)

The very first Mesozoic fossils ever reported from Indonesia were belemnites found on Taliabu, Sula islands, by naturalist Rumphius (1705), who described them as 'bullets' and 'fingers'. Boehm (1907) described five new Late Jurassic species of *Belemnopsis* from the same area. Early monographs on Jurassic-Cretaceous belemnites of East Indonesia were by Kruizinga (1921) and Stolley (1929), followed by studies of Stevens (1964), Challinor and Skwarko (1982) and Challinor (1989-1991).

Like the ammonites, belemnites are good biostratigraphic marker fossils. The belemnite zones of East Indonesia were calibrated to the NW Australian dinoflagellate zonations by Challinor (1989, 1991). Three main assemblages may be recognized (Challinor 1991, 1992):

1. *Dicoelites- Conodicoelites* in (Late Bajocian?) Callovian - Early Oxfordian;
2. *Hibolithes* in late Callovian- Oxfordian;
3. *Belemnopsis gerardi*, *B. moluccana* and *B. stolleyi* groups in basal Oxfordian- latest Tithonian.

The dominance of the above genera, with the absence of the Tethyan genus *Duvalia*, suggest the East Indonesia-New Guinea Late Jurassic belemnites are not low-latitude Tethyan faunas, but a higher latitude 'Austral'/'peri-Gondwanan' assemblage. This fits with what was concluded for the associated ammonites and the common association with the bivalve genus *Inoceramus*, which, like most pelagic bivalves, probably displays an anti-tropical geographic distribution.

KEY REFERENCES- MIDDLE-LATE JURASSIC BELEMNITES

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Early Jurassic Bivalves

Early Jurassic shallow marine bivalves are relatively rare in the Indonesian region. One assemblage was described from West Kalimantan, which includes *Gervillia borneensis* and *Corbula* (Martin 1889, 1898).

An Early Jurassic (Pliensbachian?) heavy bivalve assemblage with *Lithiotis*, *Pachymegalodus* and *Gervilleioperna* was described from one of the Fatu Limestones at Lelefoei Pass, Timor, by Krumbeck (1923; Figure12). This assemblage is unique for SE Asia. However, it is known from other regions of the Tethys, and, in the absence of corals and other reef builders after the end-Triassic extinction event, they are known as the only reefoid mound builders in the Early Jurassic.

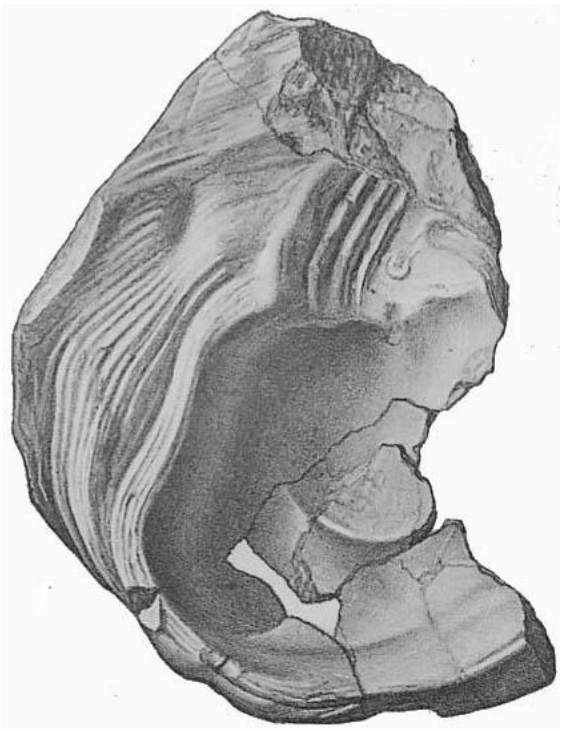


Figure 12. *Thick-shelled Early Jurassic bivalve* Lithiotis timorensis *from Lelefoei Pass, Timor (Krumbeck 1923).*

In mainland SE Asia (Thailand, Vietnam) the late Early-M Jurassic deposits, which are the first marine sediments unconformably over post-Indosinian orogeny unconformity (Sibumasu-Eurasia collision), often contain bivalve assemblages with endemic North Tethyan margin species, including the characteristic pectinid *Parvamussium donaiense*. This has not been found in Indonesia yet, but could one day be found in Sumatra and West Kalimantan.

KEY REFERENCES- EARLY JURASSIC BIVALVES

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Middle-Late Jurassic Bivalves

Several papers describe Middle Jurassic shallow marine bivalve faunas from NW Borneo, including Newton (1897) and Vogel (1896-1904). Common genera include *Astarte*, *Protocardia* and *Corbula* and also oyster-like bivalve *Alectryonia amor* (Figure 13). Their exact ages remain somewhat uncertain, but their European-East Asian affinities are not disputed.

Late Jurassic bivalves have been described from the Kedadom-Pedawan formations of SW Sarawak (Wilford and Kho 1965, Tamura and Hon 1977) and from West Kalimantan (Vogel (1896, 1900, Newton 1903), all probably from the Bentayang Fm. The latter fauna contains *Trigonia molengraaffi*, which under the genus name *Myophorella (Haidaia)* is very common in the Upper Jurassic of Japan (Hayami 1984; Figure 13, 3-4).

According to Hayami (1984) Upper Jurassic bivalve assemblages from Indonesia are from different zoogeographic realms:
- East Asia/Eurasian Province: Borneo island are part of the, with close affinities to faunas from Mindoro, Philippines and NE Japan;
- SW Pacific/Maorian Province: East Indonesia (Timor-Roti, Seram, Misool, Sula, New Guinea).

Late Jurassic (Kimmeridgean-Tithonian) open marine facies of East Indonesia contain the characteristic *Buchia*-type hemipelagic bivalves *Malayomaorica malayomaorica* Krumbeck and *Inoceramus* of the *Retroceramus haasti* group (Krumbeck 1923, Wandel 1936; Figure 14). *M. malayomaorica* is known from Misool (Lelinta Shale), Buru, Seram (Kola Shale), Buton (Rumu Fm; Sikumbang et al. 1995), East Sulawesi (Hasibuan and Kosworo 2008), Timor, Roti and the distal parts of the NW Australia-New Guinea margin in Papua New Guinea (Maril Shale; Glaessner 1945, Skwarko 1967) and the Dampier Peninsula of N Australia (Langey Beds; Brunnschweiler 1960). It is also known from New Zealand and Antarctica.

These bivalve assemblages and associated ammonite and *Belemnopsis* belemnite assemblages are commonly viewed as higher latitude, 'bipolar' or 'anti-tropical' faunas of the Austral' or Maorian' biogeographic provinces (e.g. Crame, 1986, Damborenea 2002). They differ from age-equivalent assemblages of West Indonesia and mainland SE Asia and paleogeographically can be tied to the northern Gondwana margin of Australian-New Guinea in Late Jurassic time.

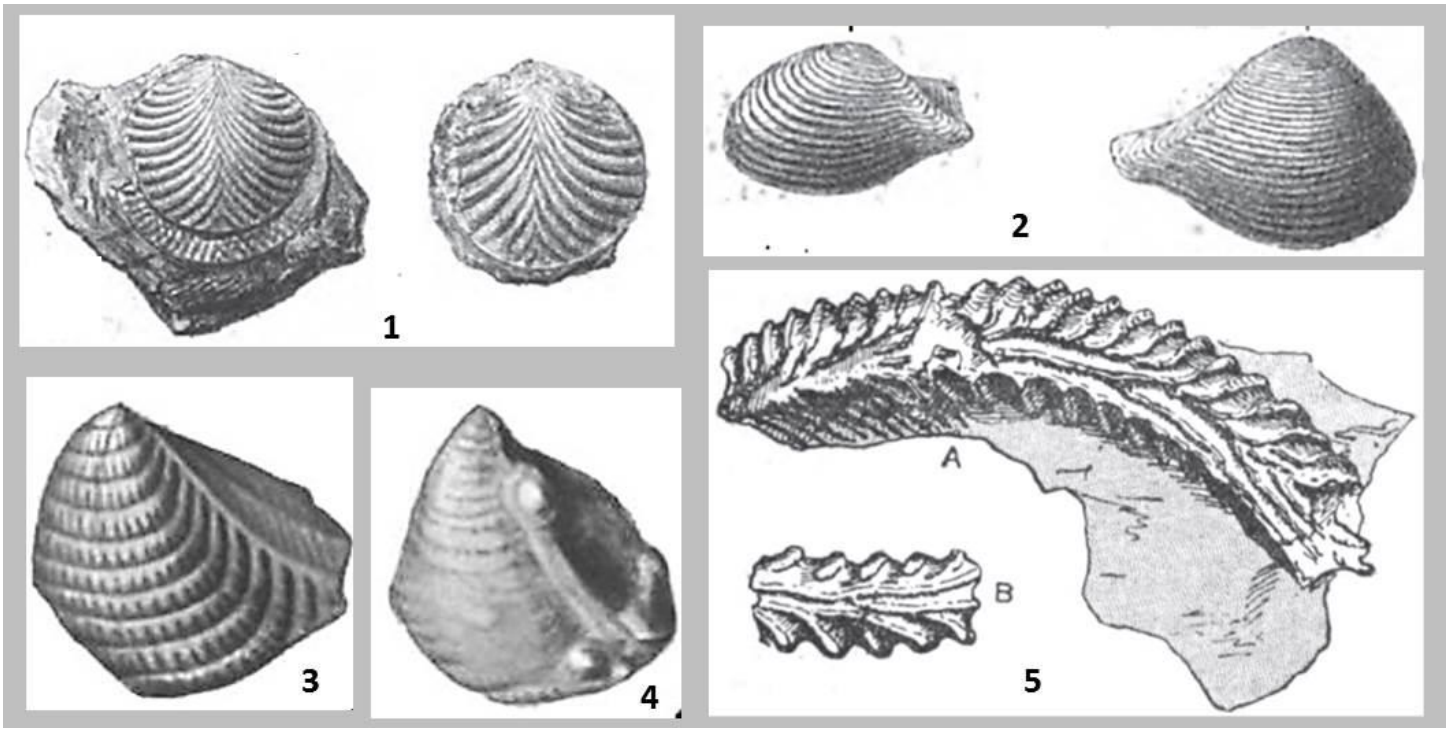


Figure 13. *Middle and Late Jurassic shallow marine bivalves from West Kalimantan and SW Sarawak. 1.* Astarte eastonii. *2.* Corbula eastonii *from Sungei Pasi, West Kalimantan (Vogel 1900). 3-4.* Trigonia molengraaffi *from Buduk area, West Kalimantan (Newton 1903). 5.* Alectryonia amor *from SW Sarawak (Newton, 1897).*

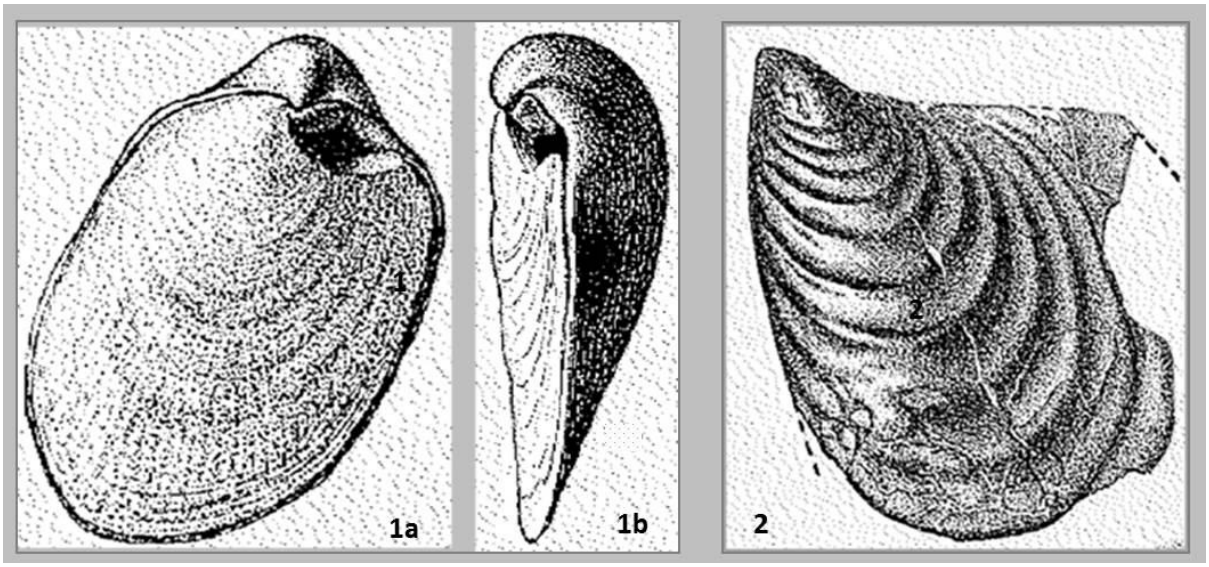


Figure 14. *Late Jurassic (~Kimmeridgean) bivalves from Misool (Wandel 1936). 1a-b* Malayomaorica malayomaorica*; 2.* Inoceramus (Retroceramus) subhaasti. *These are generally viewed as temperate Gondwana-margin species.*

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Jurassic- Early Cretaceous Dinoflagellate Biostratigraphy

Oil industry age dating of Jurassic and Cretaceous sedimentary successions in East Indonesia and New Guinea basins relies primarily on dinoflagellate palynology. Its zonations were first established are well-documented from the NW Australian margin (Helby, Morgan and Partridge 1987, 2004, Partridge 2006, Riding et al. 2012). Dinoflagellate zonations have also been used along the adjacent Papuan continental margin (Davey 1988). This type of biostratigraphy is routinely applied in West Papua, PNG and East Indonesia oil and gas exploration wells, but no recent updates have been published.

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Late Jurassic Foraminifera

In the Indonesian region Late Jurassic shallow marine limestones with the arenaceous foraminiferal genus *Pseudocyclammina* are known from two areas. They are generally associated with the branched calcisponge or stromatoporoid *Cladocoropsis mirabilis* (which in some of the older literature has been mistaken for Triassic *Lovcenipora)*:

(1) Bau Limestone at the NW Kalimantan-West Sarawak border area. Mainly characterized by *Nautiloculina oolithica, Pseudocyclammina lituus* (Figure 15) and *Torinosuella peneropliformis* (Bayliss 1966);

(2) South, West and North Sumatra. These shallow marine limestones are interpreted as reefs on and around volcanic islands in an active arc and are tied to the 'Woyla Terranes' (Barber et al., 2005). *Pseudocyclammina* from the Saling Limestone of the Gumai Mountains of South Sumatra was initially identified as *Choffatella* (Silvestri 1925), but this was corrected by Silvestri (1932). Subsequent faunal descriptions are in Yabe (1946), Hanzawa (1947), Beauvais (1983, 1985, 1989) and Bassoulet (1989).

Late Jurassic *Pseudocyclammina-Cladocoropsis* limestones are common in the Late Jurassic, from the Mediterranean, the Alps, Turkey and the Middle East to Japan (e.g. Leupold and Maync, 1935). The *Pseudocyclammina* limestones are biogeographically closely tied to the Alpine-Mediterranean-Middle East Tethyan region, and are not known from Eastern Indonesia, New Guinea or Australia. They appear to signify low latitude deposits, marking the margins of the Eurasian continent in Oxfordian-Kimmeridgean time.

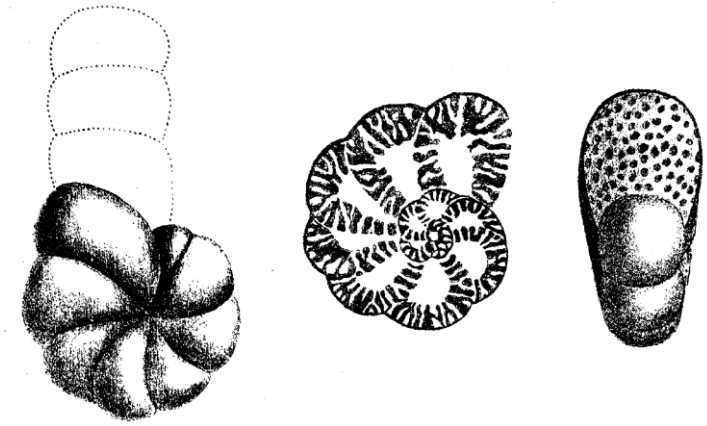


Figure 15. *Tethyan Late Jurassic arenaceous foram* Pseudocyclammina lituus *(Yabe and Hanzawa, 1926).*

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Latest Jurassic - Early Cretaceous Calcispheres

On many of the islands of East Indonesia the latest Jurassic-Cretaceous interval is developed as deep marine pelagic limestones. Late Jurassic-Early Cretaceous pelagic limestones may contain abundant small circular calcareous planktonic organisms known as calcispheres and/or calpionellids (e.g. Flugel, 2010). These are probably calcareous dinoflagellate algal cysts and are known from Timor, Roti, Buton, East Sulawesi, Seram and Misool. They are commonly associated with belemnites and are generally overlain by Upper Cretaceous pelagic limestones with *Globotruncana*.

Calcispheres were first recorded from Roti by Brouwer (1922) and Tan Sin Hok (1927), who named them *Orbulinaria*. Bothe (1927) described them from Buton, naming them *Lagena orbulinaria*, implying they are foraminifera. The first systematic paleontologic study of this group in Indonesia was by Wanner (1940), proposing the new species *Stomiosphaera moluccana* and *Cadosina fusca* (Figure 16) and documenting additional occurrences from Ofu in SW Timor, the Facet Limestone of Misool, the Manusela Limestone of Seram and from East Sulawesi. Subsequent key studies in Indonesia-SE Asia are by Vogler (1941) and Bolli (1974). The latter assigned all species described by Wanner and Vogler to the genus *Pithonella*.

Two species of Tithonian *Calpionella* from the northern Australia Dampier Peninsula were described by Brunnschweiler (1960). Limestones with *Stomiosphaera moluccana* and *Cadosina fusca* are also common in the Alpine-Mediterranean region (incl. Carpathians, Apennines), where these species are generally viewed as of latest Jurassic (Tithonian) age.

Wanner (1940) estimated the paleobathymetric range of this facies as possibly between 2000-4000m. The calcisphere facies does definitely reflect a pelagic deep marine environment, but it is above the Carbonate Compensation Depth and therefore probably shallower than deepest basinal facies from the region, which are reddish shales with radiolarian cherts and manganese nodules.

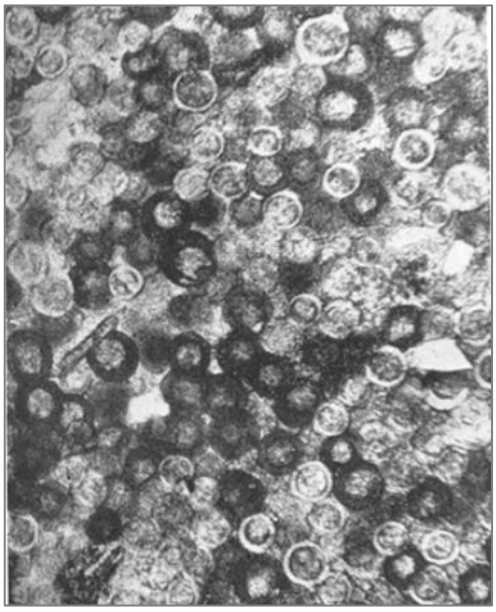


Figure 16. *Thin section of Late Jurassic pelagic calcisphere limestone from Ofu, SW Timor, with* Cadosina fusca *(dark rings) and* Stomiosphaera moluccana *(Wanner, 1940).*

KEY REFERENCES- LATE JURASSIC- CRETACEOUS CALCISPHERES

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Jurassic-Early Cretaceous Dinoflagellate Cysts Zonation

Dinoflagellate cysts have been the most useful fossil group for high-resolution biostratigraphic zonation of Jurassic- Early Cretaceous sediments along the NW Australia- New Guinea continental margin. Most of the hydrocarbon exploration wells drilled in this region were analyzed by the pioneers of this dinoflagellate zonation Helby, Morgan and Partridge (1987, 2004) and most of the reports from Australian waters are available from Geoscience Australia, Canberra.

This dinoflagellate zonation has been used for exploration wells that penetrated Mesozoic in East Indonesia-West Papua (e.g. Fraser et al. 1996), but unfortunately most of this data remains confidential.

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Late Jurassic- Early Cretaceous Fossil Wood

Mesozoic silicified wood is relatively common in the Late Jurassic - Early Cretaceous of mainland SE Asia. The Khorat Group of NE Thailand contains large silicified trunks of *Araucaryoxylon* sp. (= *Agathoxylon*) (Asama 1982, Philippe et al. 2004). Similar wood fossils are known from Cambodia, Laos and the Malay Peninsula (Philippe et al., 2014).

These are mainly from conifer trees and most or all are in 'post-orogenic', non-marine and shallow marine deposits that overlap and unconformably overlie the deformed zone of Late Triassic Sibumasu-Indochina collision. Woods from these areas are similar, but species show some endemism, probably due to biogeographical isolation. These woods have no clear annual growth rings, suggesting low latitude warm-wet climate, without significant seasonal variations.

A few occurrences in West Indonesia show similarities to the mainland SE Asia coniferous woods:

1. Sugi Island, Riau Archipelago: '*Protocupressinoxylon*', described by Roggeveen (1932);
2. West Kalimantan: silicified wood in a collection of fossils in the British Museum from the Buduk area was studied recently by Philippe et al. (2014). Middle Jurassic mollusks from the same collection were described by Newton (1903; see above). The wood specimens were identified as representatives of the new genus *Shimakuroxylon* (formerly known a.o. as *Araucarioxylon japonicum* Shimakura), a genus is believed to be endemic to terranes that lined southernmost East Asia in the Jurassic, primarily the Indochina plate. The West Borneo wood therefore likely resided on a landmass that was connected to Indochina in Late Jurassic time.

KEY REFERENCES- LATE JURASSIC- EARLY CRETACEOUS FOSSIL WOOD/ PLANTS

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TABLE 2	JURASSIC	
FAUNA/FLORA	**AREA**	**REFERENCES**
Jurassic Stratigraphy	Sumatra	Fontaine et al. 1983
	Indonesia	Wanner 1931, Sato 1975, Sukamto and Westermann 1992
U Jurassic calcispheres (*Pithonella*)	Seram, Buton, Misool, Timor	Brouwer 1919, Tan Sin Hok 1927, Wanner 1940, Vogler 1940, Bolli 1974
	Buton	Bothe 1927
	Roti	Tan Sin Hok 1927
Late Jurassic limestones with *Cladocoropsis, Pseudocyclammina*	NW Kalimantan/ Sarawak (Bau Lst)	Wilford and Kho 1965, Wolfenden 1965, Beauvais and Fontaine 1990
	Sumatra	Silvestri 1925, 1932, Yabe 1946, Hanzawa 1947, Bennett et al. 1981, Beauvais 1983, 1989, Bassoulet 1989
	NE Palawan	Fontaine et al. 1983, Bassoulet 1983
U Jurassic corals	Sarawak	Beauvais and Fontaine 1990
	Sumatra	Beauvais 1983, 1989
Late Jurassic shallow marine foraminifera	W Sarawak (Bau Lst)	Bayliss 1966
	Sumatra	Silvestri 1925, 1932, Yabe 1946, Bassoulet 1989,
Middle- Late Jurassic Belemnites	Misool	Stolley 1929, 1935, Challinor 1989, 1991
	Sula Islands	Boehm 1907, 1912, Kruizinga 1921, Stolley 1929, Challinor and Skwarko 1982, Challinor 1989, 1991
	Timor, Roti, Babar	Rothpletz 1892, Stolley 1929, Stevens 1964
	Yamdena	Stolley 1929
	W Papua/ PNG	Challinor 1990
	Central Sulawesi	Stolley 1943
	Indo-Pacific	Stevens 1965
E-M Jurassic bivalves	NW Kalimantan, Sarawak	Martin 1899, Vogel 1896, 1900, Newton 1897, 1903, Tamura and Hon 1977, Hayami 1984
	Timor	Krumbeck 1923
	Misool	Soergel 1913, Wandel 1934, Hasibuan 2004
	PNG	Skwarko 1973, Grant-Mackie et al. 2006
U Jurassic bivalves (*Malayomaorica, Inoceramus haasti*) ('anti-tropical')	Sula, Buru, Seram,	Krumbeck 1923, Wandel 1936
	Timor, Roti	Krumbeck 1922, 1923
	Misool	Krumbeck 1934
	E Sulawesi	Hasibuan and Kosworo 2008
	Papua New Guinea	Glaessner 1945, Edwards and Glaessner 1953
	Australia NW Shelf	Brunnschweiler 1960
M-U Jurassic ammonites	Sula Islands	Kruizinga 1926, Westermann and Callomon 1988
	W Papua- PNG	Boehm 1913, Gerth 1927, 1965, Schluter 1928,

		Westermann and Getty 1970, Westermann and Callomon 1988, Westermann 1995
	Timor, Roti	Boehm 1908
	Babar	Callomon and Rose 2000
	W Kalimantan	Schairer and Zeiss 1992
E Jurassic ammonites	Yamdena, E Sulawesi	Wanner and Jaworski 1931, Jaworski 1933
	Roti, Timor	Krumbeck 1922
	W Kalimantan	Krause 1911, Hirano et al. 1981
M-U Jurassic Radiolaria	Sumatra	McCarthy et al. 2001
	SE Kalimantan	Wakita et al. 1998
	W Sarawak	Jasin et al. 1996, Jasin and Said 1999
	East Sulawesi	Hojnos 1934
	Sula Islands	Pessagno and Meyerhoff Hull 2002
	Timor, Roti	Sashida et al. 1999, Haig and Bandini 2013
U Jurassic nannofossils	Sula islands	Panuju 2011
	Timor	Kristan-Tollmann 1988a,b
	PNG	Haig 1979
Jurassic- E Cretaceous Dinoflagellate zonations	NW Australia margin	Cookson and Eisenack 1958, 1960, 1974, Helby Morgan and Partridge 1987, 2004, Partridge 2006, Mantle 2009, Mantle and Riding 2010, Riding, Helby et al. 2012
	Papua New Guinea	Davey 1988, 1999, Welsh 1990
	Misool	Helby and Hasibuan 1988, Sarjeant et al. 1992
	Sula Islands	Lelono and Nugrahaningsih 2012
Spores-Pollen	NW Australia margin	Burger 1996
Jurassic Coccoliths	Timor	Kristan-Tollmann 1988
E Jurassic brachiopods	Seram	Wanner and Knipscheer 1951
***Lithiotis* Limestone**	Timor Fatu Limestone	Krumbeck 1923, Geyer 1977, Hayami 1984

CRETACEOUS

Rocks of Cretaceous age are widespread across Indonesia, in facies varying from non-marine to oceanic. Lower Cretaceous faunas from the Sundaland margin (SW Sumatra, Kalimantan) are low-latitude Tethyan faunas, and are very different from those of the NW Australia-New Guinea margin and East Indonesia's Sula Spur, which represent higher latitude, Indo-Pacific faunas. The Sundaland and Australian- New Guinea margins were widely separated in Cretaceous time by the MesoTethys (mostly closed by mid-Cretaceous time) and Neotethys Oceans. Oceanic and microcontinental terranes of this oceanic realm are now scattered across Eastern Indonesia, with deep marine, pelagic Cretaceous deposits generally rich in radiolaria.

An extensive review of Cretaceous stratigraphy and paleontology of SE Asia is Hashimoto et al. (1975).

KEY REFERENCES- CRETACEOUS

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(Latest Jurassic-) Early Cretaceous Radiolaria

As noted above, radiolarian-rich sediments signify deep marine environments, especially when they are non-calcareous, contain bedded chert and are generally associated with red shales and manganese nodules. These usually represent ocean floor environments. Where they are interbedded with clastic sediments they may represent deep marine distal continental slope deposits.

Radiolarian-rich sediments appear to be particularly common in Latest Jurassic - Early Cretaceous time in both West and East Indonesia.

They represent three or four different paleogeographic settings (see also Table 3):

1a. Distal NW Australian passive margin: well-dated Early Cretaceous assemblages from Roti (Tan Sin Hok 1927), Timor (Grunau 1965, Munasri 1998) and Ungar (Tanimbar; Jasin and Haile 1996);

1b. Indian Ocean: A continuation of the above but today still on non-subducted ocean floor, are occurrences of Early Cretaceous radiolaria from the Argo Abyssal Plain (Baumgartner 1993) and the northern Indian Ocean- Timor Sea (Renz 1974, Riedel and Sanfilippo 1974);

2. Cretaceous distal margin and accretionary complexes of Sundaland.
   a. North-Central Kalimantan and West Sarawak: 'Danau Formation', dated as latest Jurassic-Early Cretaceous by Hinde (1900), Valanginian-Barremian by Pessagno (in Tan 1978) and Late Tithonian-Albian by Jasin (1996).
   b. Sabah, North Borneo: Chert-Spilite Formation: pelagic cover of ophiolite sheet with E Cretaceous (Valanginian-Barremian) radiolaria (Jasin 1991, Aitchison 1994) (with numerous 'Tan Sin Hok species');
   c. SE Kalimantan Meratus melange: M Jurassic - E Cretaceous radiolaria (Wakita et al., 1998);
   d. SW Sulawesi: Bantimala, Barru areas, Early Cretaceous radiolaria reported by Wakita et al. (1994, 2000) and Munasri (2013);
   e. Central Java (Lok Ulo; Okamoto et al. 1994, Wakita et al. 1994);

3. 'Gondwanan Terranes in East Indonesia: Cretaceous radiolarians reported from East Sulawesi (Hojnos 1934) and Buton (Soeka 1991).

Key monographs on Cretaceous radiolaria from Indonesia include:

1. Hinde (1900) from North-Central Kalimantan. Hinde described 100 species from Central Kalimantan, 67 from radiolarian cherts in the Danau Formation and 39 from associated diabase tuffs and marls, with only 6 species in common. Hinde interpreted these faunas as most likely Late Jurassic, but modern authors interpret the Danau Formation radiolaria as mainly Early Cretaceous species within a younger accretionary complex (e.g. Sanfilippo and Riedel, 1985, Jasin 1996). Species like *Stichocapsa rotunda* Hinde *(= Syringocapsa* or *Obesacapsula)* range from Berriasian-lower Hauterivian (Pessagno et al., 1984). *Stichocapsa cribata* Hinde is limited to the Valanginian in W Pacific ODP sites (Matsuoka, 1992).

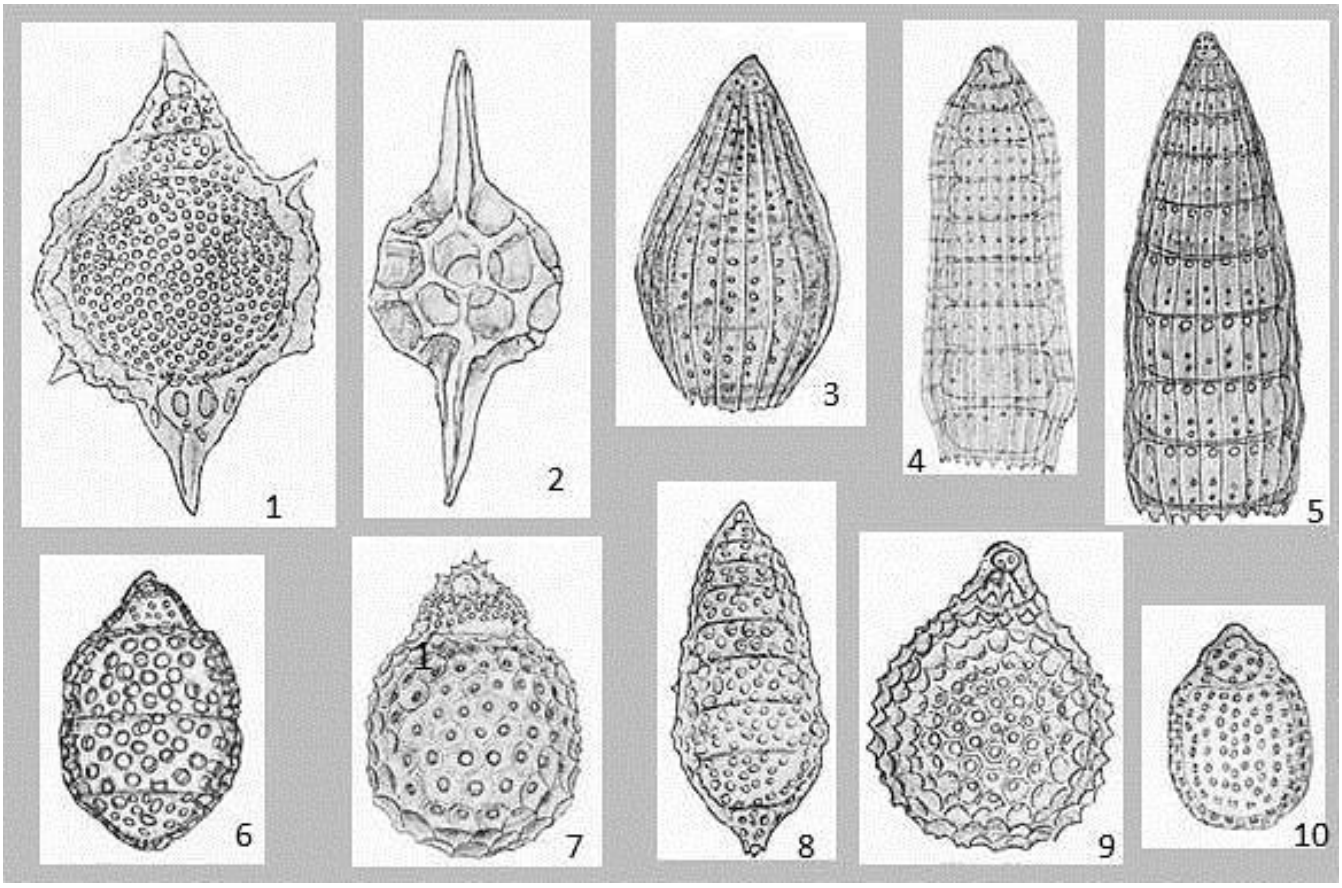


Figure 17. *Selection of Early- mid-Cretaceous radiolaria species from Roti island, described by Tan Sin Hok (1927). Cosmopolitan/ Tethyan species: 1.* Cyrtocapsa grutterinki*, 2.* Stylospharea (= Pantanellium) squinaboli*, 3.* Eucyrtidium (=Archaeodictyomitra) brouweri*, 4.* Lithomitra (=Archaeodictyomitra) excellens*, 5.* Stichomitra *(=* Archaeodictyomitra *or* Dictyomitra*)* pseudoscalaris*. High latitude species: 6.*Stichocapsa wichmanni*, 7.* Theocapsa curata*, 8.* Eusyringium niobeae*, 9.* Tricolocapsa spinosa*, 10.* Tricolocapsa parvipora.

2. Tan Sin Hok (1927) described 141 radiolarian species from Roti island (Figure 17). He interpreted these as of Late Tertiary age, but these are now recognized as Early Cretaceous species. Riedel (1953) and Riedel and Sanfilippo (1974) suggested a likely Aptian-Turonian age, but on more recent range charts the species described by Tan Sin Hok are shown as Hauterivian-Barremian ages (e.g. Sanfilippo and Riedel, 1985 and others; see also Munasri and Van Gorsel, this volume). Comparable assemblages with high numbers of 'Tan Sin Hok Roti species' are from the Valanginian-Barremian of Sabah ('Chert-Spilite Complex'; Jasin 1991, 1992) and the Barru melange in SE Sulawesi (Munasri 2013).
3. Clowes (1997) and Munasri (1998), both in unpublished theses, described radiolarians from the Valanginian-Barremian/Aptian Nakfunu Formation of the Kolbano foldbelt of SW Timor. Both noted that the Timor and Roti Early Cretaceous assemblages are dominated by cold-water species, but mixed with some Tethyan taxa. Those from the Argo Abyssal Plain off NW Australia are almost exclusively non-Tethyan, cold-water species (Baumgartner, 1993).

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Cretaceous Ammonites

Cretaceous ammonite faunas are relatively rare in the Indonesian region, and assemblages appear to be of much lower diversity than those from preceding periods. In West Indonesia earliest Cretaceous ammonites are known from two areas, with very similar species, and of Tethyan-Mediterranean affinity:

1. West Sumatra: Ammonites at Dusun Pobungo W of Sarolangun in Jambi province are in steeply dipping shales of Tobler's 'Schiefer-Barisan' series and are dominated by *Neocomites neocomiensis* and *Thurmannites* (= *Kilianella)* (Baumberger, 1922, 1925; Figure 18-1). This ammonite assemblage represents a deep water facies, which was deformed by intense post-Valanginian deformation, possibly in an accretionary wedge setting.

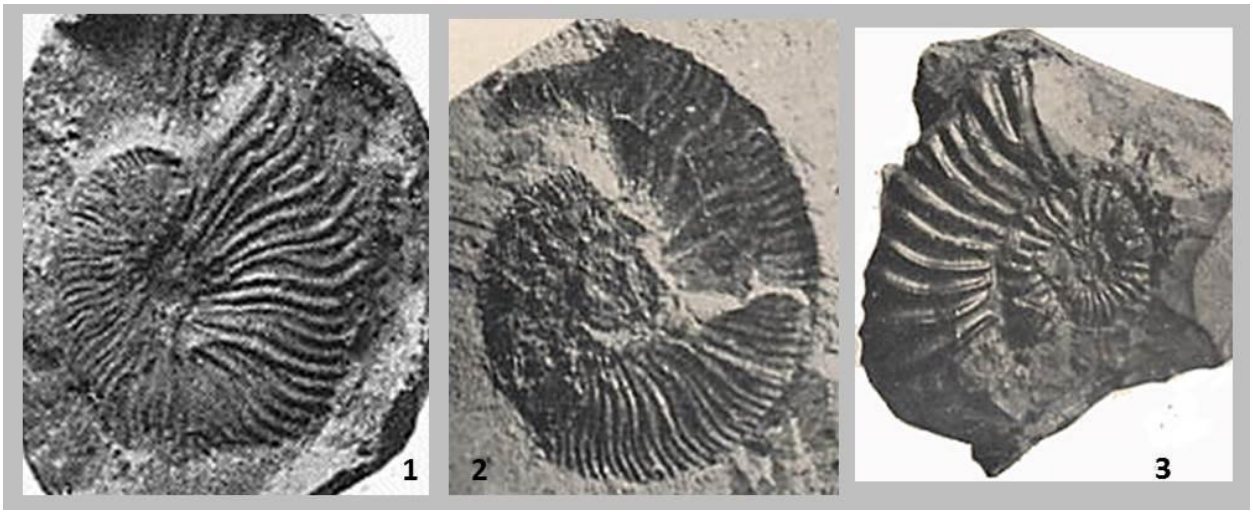


Figure 18. *Early Cretaceous ammonites. 1.* Neocomites neocomiensis *from Valanginian of Pobungo, Jambi, SW Sumatra (Baumberger 1925), 2.* Neocomites neocomiensis *and 3.* Thurmannia (Kilianella) *from Sebaraung area, NW Kalimantan (Von Koenigswald 1939).*

2. NW Borneo: 'Neocomian' ammonite assemblages with *Neocomites neocomiensis* and *Thurmannites* in both the Seberuang Formation of NW Kalimantan (Von Koenigswald 1939; Figure 18-2, 3) and in the Pedawan Formation of SW Sarawak (Ishibashi 1982).

Cretaceous ammonite assemblages are relatively rare in Eastern Indonesia and New Guinea, where bivalve and belemnite-dominated assemblages appear to be more common. Some Late Cretaceous ammonites were described from Papua New Guinea by Matsumoto and Skwarko (1991, 1993).

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Cretaceous Marine Mollusks

Cretaceous mollusks are mainly known from Kalimantan, Sumatra and New Guinea. Like the Late Jurassic bivalves, Cretaceous assemblages from West Indonesia appear to have low-latitiude Tethyan affinities, while East Indonesia - New Guinea faunas reflect higher latitude, Gondwana margin affinities.

Occurrences of Cretaceous mollusks from Western Indonesia include:

1. Early Cretaceous gastropods (*Nerinea*) and bivalves (*Cardita, Amussium*) from the Valanginian of Jambi, Sumatra, described by Baumberger (1925), who noted its Tethyan affinities.
2. Diverse Upper Cretaceous shallow marine mollusk assemblages from the Manunggul Formation of the Meratus Mountains near Martapura, SE Kalimantan. It contains characteristic *Nerinea* gastropods, oysters and *Trigonia*, an assemblage with affinities to faunas from the Tethyan region and Japan (Martin, 1889; Figure 19).

In East Indonesia Cretaceous mollusks are mainly represented by open marine, hemipelagic *Inoceramus* assemblages, including those from Misool (Boehm 1924, Heinz 1928, Hasibuan 2012), Sumba (Roggeveen 1929), Sula Islands, South Sulawesi and West Papua (Skwarko et al. 1983). Late Cretaceous shallow marine mollusks were described from Papua New Guinea by Skwarko (1967, 1983, etc.).

KEY REFERENCES- CRETACEOUS MOLLUSCS

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Skwarko, S.K., J. Sornay and T. Matsumoto, 1983. Upper Cretaceous molluscs from western Irian Jaya. Publ.Geol. Res. Dev. Centre, Bandung, Paleont. Ser. 4, p. 61-73.

Cretaceous Fresh-water Mollusks

Fresh-water mollusks of mid and Late Cretaceous age (*Trigonioides, Plicatounio*, etc.) are relatively widespread in Cretaceous non-marine basins of mainland Asia, like in the Khorat Group in Thailand. Few records of such faunas are known from Indonesia, probably mainly because most deposits of this age are in marine facies or are absent. The only Cretaceous fresh-water faunas are from the Upper Cretaceous of Kalimantan:

1. Brackish and fresh-water mollusks from the Silat group in the Kapuas region of N Central Kalimantan, with the gastropods *Faunus, Paludinopsis* and *Melania* and the bivalve genus *Corbula* (Icke and Martin 1906);
2. A Late Cretaceous (post-Turonian?) assemblage of small crustaceans (*Conchostraca*) and molluscs (*Estheria*) from the Meratus Mountain front near Martapura in SE Kalimantan (Kobayashi 1973, 1979).

The presence of these non-marine Asian-affinity faunas is significant, as suggests that this part of SE Kalimantan was probably attached to mainland SE Asia in Late Cretaceous time.

KEY REFERENCES- CRETACEOUS NON-MARINE MOLLUSCS

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Latest Jurassic - Cretaceous Rudists

Thick-walled, asymmetrical bivalves known as rudists are common in Late Jurassic - Cretaceous platform carbonates of the West Tethyan region and also in seamount limestones in the Equatorial Pacific Ocean and on some of the Circum-Pacific terranes (e.g. Winterer, 1991). They are not known from the Australia/Gondwana region.

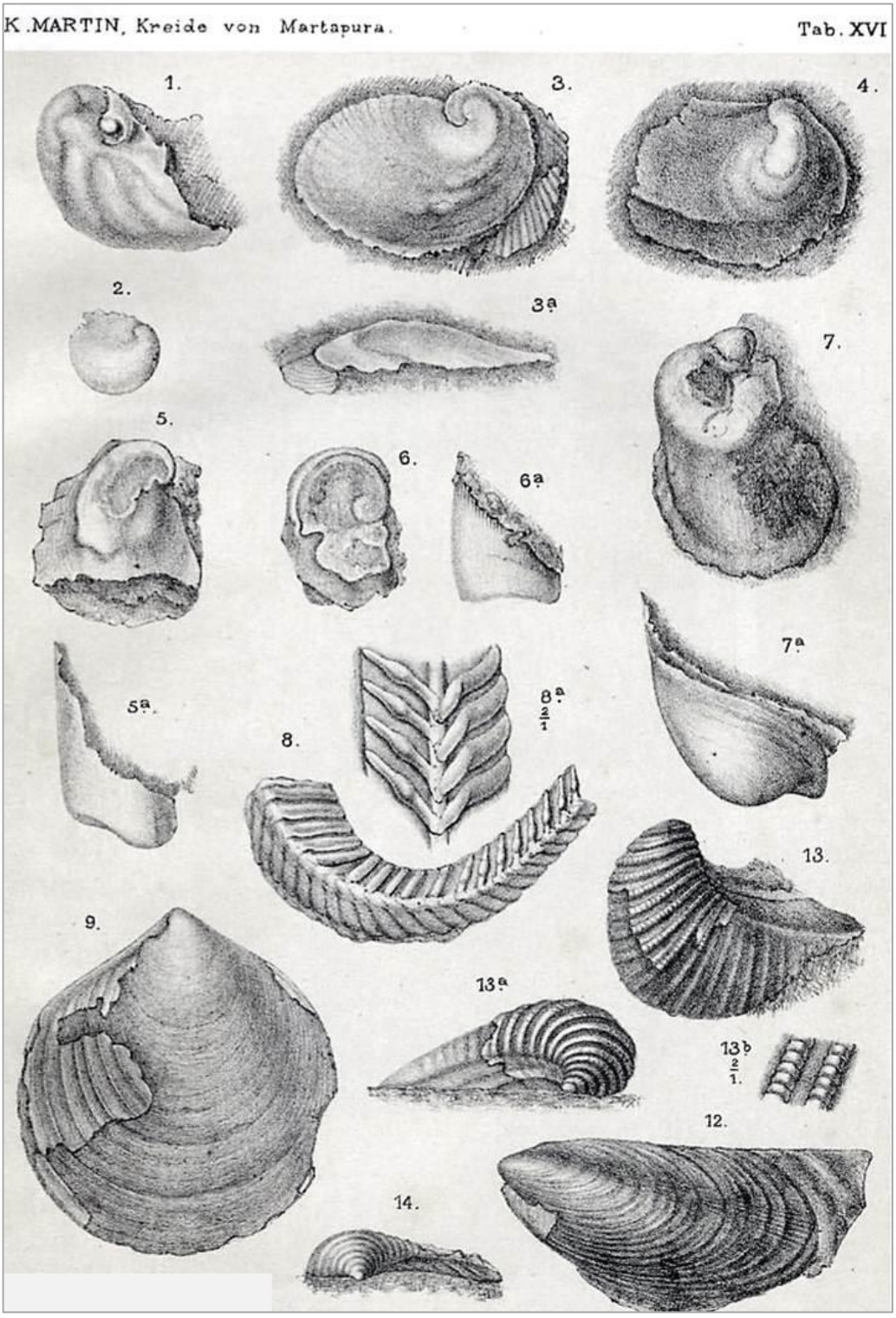


Figure 19. *Tethys-affinity Upper Cretaceous mollusks from the Martapura area, SE Kalimantan (Martin 1889). 1-4.* Ostrea (Exogyra) ostracina, *5-7.* Ostrea (Exogyra) borneensis, *8.* Ostrea (Alectryonia) martapurensis, *9.* Pecten, *12. Modiola hoozei, 13-14.* Trigonia limbata.

In the Greater Indonesian region rudists of different ages have been reported from three areas:

1. Bau Limestone of SW Sarawak: with latest Jurassic primitive diceratid rudistid *Epidiceras speciosum* (Lau 1973). This is a Tithonian-Berriasian tropical Tethyan form, known from southern Europe and from limestones in accreted terranes of SW Japan (Sano and Skelton 2010, Skelton et al. 2013).
2. Meratus Mountains front near Martapura, SE Kalimantan: Mid-Cretaceous rudists *Sphaerulites* and *Radiolites* in carbonates with *Orbitolina* larger foraminifera Figure 20-1). Ages assigned to the rudists vary from Senonian (Martin 1888), Cenomanian (Umbgrove, 1938) to Early Turonian (Hashimoto and Koike, 1973, 1974). They are in the Manunggul Formation, a 'post-collision' overlap assemblage, and are associated with the gastropod *Nerinea* (Figure 20-2) and bivalves *Ostrea* spp, *Trigonia*, etc. All these are mid-Cretaceous low-latitude 'Tethyan' taxa, reminiscent of the Gosau facies of the Austrian Alps (Martin 1889, Wanner 1925).
3. Islands SE of Misool: Several species of Late Cretaceous *Durania, incl. D. wanneri* and *D. deningeri* (Boehm 1924). These are relatively rare, and ages and affinities remain somewhat uncertain.

In SE Asia outside Indonesia rudists were found Aptian reefal limestones in a volcanoclastic succession on Cebu island, Philippines (Wolcke and Scholtz 1988, Masse et al. 1996).

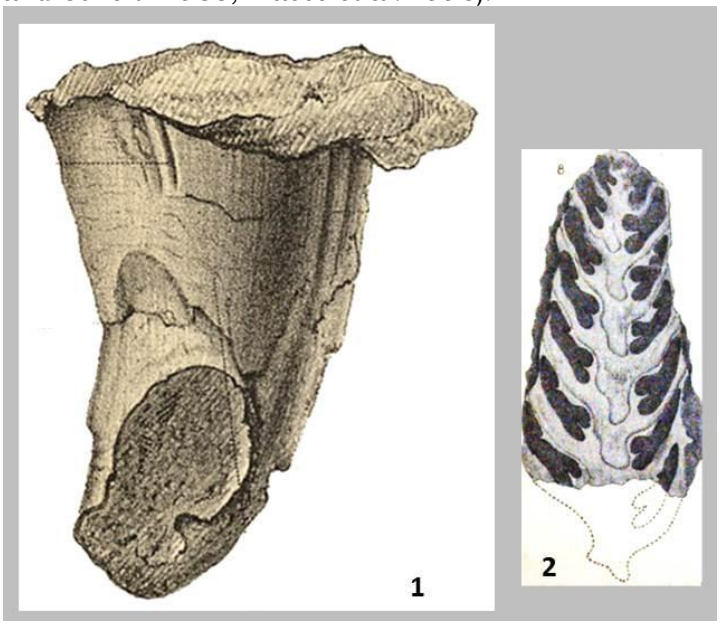


Figure 20. *Typical Upper Cretaceous mollusks from Martapura area, SE Kalimantan. 1. Mold of rudist* Radiolites *from Pangaringan River (Martin, 1888). 2. Section through internally complex gastropod* Nerinea schwaneri *(Martin. 1889).*

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Mid-Cretaceous Larger Foram Orbitolina

Early-Middle Cretaceous larger foraminifera of the *Orbitolina* group (Figure 21) are common in mid-Cretaceous shallow marine limestones all across the Tethys, where they are often associated with rudist bivalves. In SE Asia they are relatively frequent around the Early Cretaceous margin of Sundaland of West Indonesia and also from multiple locations in The Philippines (Cebu) and Japan.

Orbitolinids are most common and most widespread across Borneo, and their occurrences are described in some detail by Hashimoto et al. (1975):

1. West Sarawak and NW Kalimantan Aptian *Orbitolina*-rich horizons in the Pedawan and Seberoeang Formations (Hofker 1963, Hashimoto and Matsumaru 1977);
2. North-Central Kalimantan: five or more limestone horizons in the Selangkai Fm of the Upper Kapuas river region with Upper Aptian-Lower Albian *Orbitolina lenticularis* (Von Fritsch 1878, Martin 1889, Yabe and Hanzawa 1931, Hofker 1963, Hashimoto et al 1975).
3. Poorly documented occurrences in Boyan Melange, Upper Mahakam District, NE Mangkalihat Peninsula (Djamal et al. 1995);
4. Segama Highlands of Sabah Probable seamount limestones in accretionary complex (Leong 1972, Hutchison 2005);
5. SE Kalimantan: Occurrences of *Orbitolina* Limestones along the Meratus Mountains front East of Martapura. Hashimoto and Koike (1973) identified these as *Orbitolina* aff *scutum*, with Late Aptian ammonites. Schroeder (in Sikumbang, 1986) identified *Palorbitolina lenticularis* and *Orbitolina (Mesorbitolina) parva*, indicating an early Late Aptian age.

Other areas in Indonesia with *Orbitolina* include:

1. South Sumatra: two areas, (a) Ratai Bay, Lampung (Zwierzyki 1932; Menanga Fm) and (b) Lingsing Fm in the Gumai Mountains (Musper 1934, 1937). In both areas the limestones are associated with arc volcanics and are probably part of the accretionary 'Woyla Terranes'.
2. Central Java Lok Ulo accretionary 'basement' complex (Verbeek 1891, Niethammer 1909, Harloff 1933)
3. West Sulawesi: *Orbitolin*a and coral reported (but not described or figured) by Brouwer (1934) from the west side of the Latimojong Mountains, East of Pasui. This is probably shallow marine fauna displaced into Balangbaru/Latimojong Fm turbidites, probably at the mid-Cretaceous margin of Sundaland.

Orbitolina limestones appear to be restricted to a belt near the Early Cretaceous margin of Sundaland and continue north along the Eurasian continental margin to The Philippines and Japan. Many are associated with Cretaceous arc volcanics or accretionary melange complexes. *Orbitolina* is not known from the East Indonesia and Australia-New Guinea regions.

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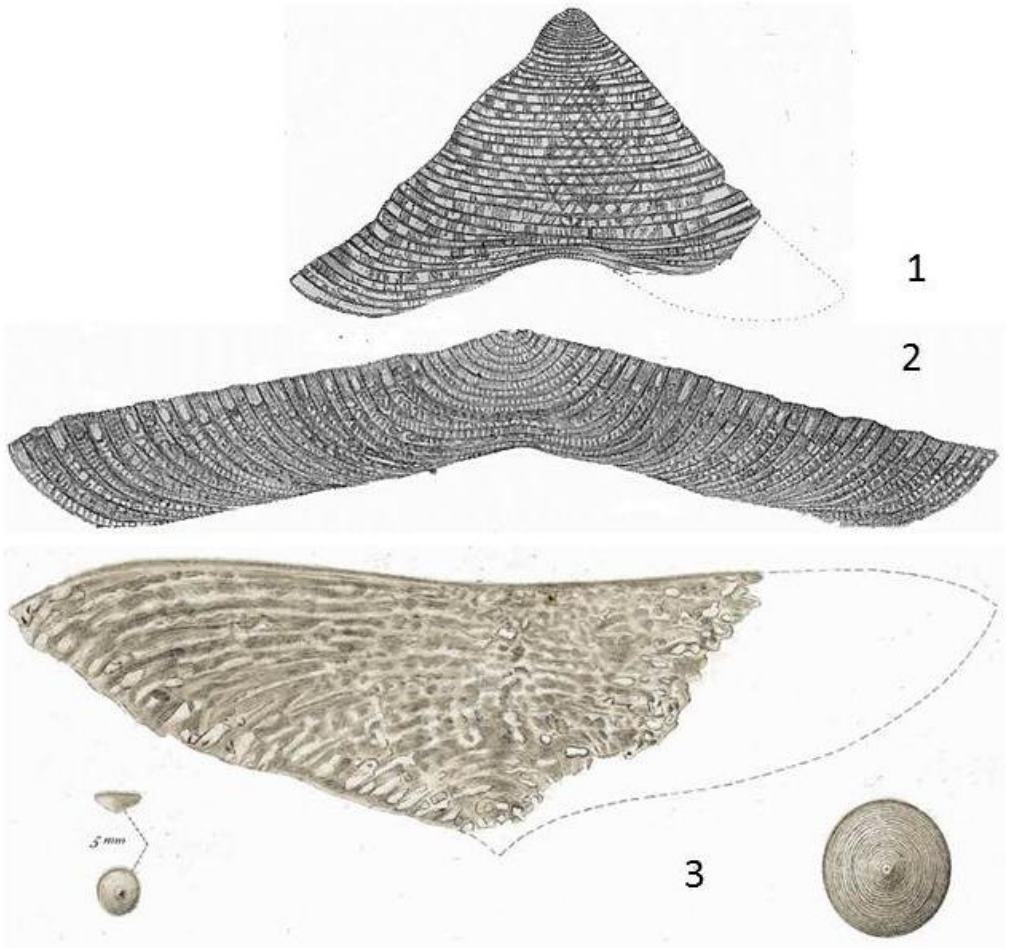


Figure 21. *Vertical sections and external views of Mid-Cretaceous larger foram* Orbitolina *(actual size ~5 mm). 1,2: from SE Kalimantan (originally named* Patellina scutum *and* P. trochus *and assumed to be of Eocene age by Von Fritsch 1879, but renamed Orbitolina lenticularis by Hashimota and Matsumaru 1974); 3.* Orbitolina lenticularis *from Central Java (Verbeek and Fennema 1898).*

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Late Cretaceous Orbitoidal Larger Foraminifera

Rare occurrences of Campanian-Maastrichtian orbitoidal larger foraminifera *(Pseudorbitoides, Lepidorbitoides)* have been reported from New Guinea and from Borneo. Reports from New Guinea include:

- *Lepidorbitoides* from the Birds Head (Visser and Hermes, 1962) and the Idenburg terrane at both sides of the West Papua- Papua New Guinea border area (Wilson et al. 1993, Hutchison 1975);
- *Pseudorbitoides* and *Orbitoides* from the Port Moresby area, PNG (Glaessner, 1960).

Rare occurrences on Borneo include poorly-documented occurrences of *Lepidorbitoides* in Sarawak (Milroy, 1953) and *Omphalocyclus* from Kalimantan (Van Gorsel, 1978).

Late Cretaceous orbitoids are also known from various localities in the eastern Philippines (Fernandez et al. 1994, Hashimoto et al. 1978). These foraminifera signify tropical shallow marine settings and are not known from the NW Australian margin. The New Guinea occurrences are only North of the Central Ranges, and paleobiogeographically they should be linked to assemblages known from Central Pacific seamounts (Van Gorsel 1978).

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Cretaceous Palynology

Cretaceous palynology is relatively well documented from the Cretaceous of the Khorat Basin in Thailand (*Corallina*-dominated; Racey and Goodall 2009) and from the Australia NW Shelf. In Indonesia relatively little palynology work was done or remains unpublished. One exception is work on the Plateau Sandstone of the NW Kalimantan/West Sarawak border region by Muller (1968), although much of what was called Cretaceous by this author may actually be of Paleogene age (Tate 1991).

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TABLE 3 CRETACEOUS

FAUNA/FLORA	AREA	REFERENCES
Faunas- General	SE Asia	Hashimoto et al. 1975
	Sumatra	Beauvais et al. 1989
Upper Cretaceous *Pseudorbitoides, Omphalocyclus*	Birds Head	Visser and Hermes 1962
	Papua New Guinea	Crespin and Belford 1957, Glaessner 1962
	Borneo	Van Gorsel 1978
Upper Cretaceous planktonic foraminifera (*Globotruncana*)	Timor, Leti	Schubert 1915, De Roever 1940, Sartono 1975
	Sula islands	Kholiq et al. 2011
	Misool	Vogler 1941
	Sabah	Adams and Kirk 1962
	Central Java	Asikin et al. 1992
	W Kalimantan	Tan Sin Hok 1936
	SE Sulawesi, Buton	Van der Vlerk 1925, Koolhoven 1932, Keijzer 1945
	PNG	Owen 1973, Haig 1981
	Halmahera	Brouwer 1923
Calcareous Nannoplankton	West Papua	Panuju et al. 2010
Molluscs	Sumatra	Baumberger 1923, 1925, Musper 1934
	Kalimantan	Martin 1889, Vogel 1904
	South Sulawesi	Hasibuan and Limbong 2009
	West Papua , PNG	Heinz 1928, Skwarko 1967, Skwarko et al. 1983
Early Cretaceous *Orbitolina*	Kalimantan	Von Fritsch 1879, Geinitz 1883, Martin 1888, 1889, Hofker 1966, Hashimoto and Matsumaru 1974, Djamal et al. 1995, Bassi et al. 2009
	West Sulawesi	Brouwer 1934
	W Sarawak	Hashimoto and Matsumaru 1977
	Sabah	Leong 1972
	Central Java	Verbeek 1891, Verbeek and Fennema 1896, Harloff 1929
	S Sumatra	Zwierzycki 1931, Musper 1934, Yabe 1946, Beauvais et al. 1989
Radiolaria	Sarawak, Sabah	Tan 1978, Jasin 1985-2000, Aitchison 1994, Asis and Jasin 2012, 2013, Jasin and Tongkul 2013
	C Kalimantan	Hinde 1900, Grunau 1965
	SE Kalimantan	Wakita et al. 1998
	SW Sulawesi	Wakita et al 1994, 2000, Munasri 1995, 2013
	South Central Java	Okamoto et al. 1994, Wakita et al. 1994
	Buton	Soeka 1991, Ling and Smith 1995
	Roti	Tan Sin Hok 1927, Riedel 1953

	Timor	Tan Sin Hok 1927, Clowes 1997, Munasri 1998
	Ungar (Tanimbar)	Jasin and Haile 1996
	N Indian Ocean	Renz 1974, Riedel and Sanfilippo 1974, Baumgartner 1993
Lower Cretaceous calpionellids	Buton, Timor	Wanner 1940
	NW Australia	Brunnschweiler 1960
Ammonites	Sumatra	Baumberger 1925
	SW Sarawak	Ishibasi 1982
	W Kalimantan	Krause 1904, Von Koenigswald 1939
	PNG	Matsumoto and Skwarko 1991, 1993
Lower Cretaceous belemnites	West Papua	Challinor 1989
	NW Australia-SE Asia	Mutterlose 1992
Fish (shark teeth)	Timor	Weiler 1932, De Beaufort 1932
Rudists	NW Borneo	Lau 1973, Fontaine and Ho 1989, Skelton et al. 2011
	SE Kalimantan	Martin 1888
	Misool	Boehm 1924

Mesozoic Vertebrate Fossils

Mesozoic vertebrate faunas are very rare in Indonesia, and mainly limited to marine fish and reptile fossils. No dinosaurs are known from Indonesia, although a dinosaur egg fossil was recently obtained from an undisclosed locality on Timor and donated to the Geological Museum in Bandung by Mr. Tom Kapitany from Melbourne, Australia.

Fish fossils include Jurassic fish scales from Misool (Hasibuan and Janvier, 1985) and as yet undescribed recent discoveries of well-preserved Triassic or Jurassic fish (including primitive coelacanths) from both West Timor and Timor Leste.

Mesozoic marine reptiles include Jurassic-age(?) ichthyosaurs from Seram and Upper Cretaceous mosasaurids from Timor (Von Huene 1931, Koevoet et al. 2014). The dolphin-like *Ichthyosaurus* may be found from Early Triassic through the Early Cretaceous, and they have a global geographic distribution. In Indonesia rare remnants of ichthyosaurids have been described from the Seram (Martin 1888; Figure 22, Von Huene 1931) and Timor (*Mixosaurus*; Von Huene 1931, Zammit 2010), with some of these reportedly showing affinities to Early Jurassic ichthyosaurids. A fragment of an *Ichthyosaurus* jawbone fragment was also reported, but not illustrated, from the mud volcano deposits of Tanimbar, where it is associated with Early Jurassic ammonites (Charlton 1991).

Mesozoic non-marine vertebrate fossils are relatively common only in mainland SE Asia, mainly in the Khorat Group of Thailand, from where Late Triassic, Late Jurassic and Early Cretaceous (mainly latest Jurassic- Early Cretaceous) amphibians, turtles, crocodiles, fish, dinosaurs and birds have been described. These are in the latest Triassic-Cretaceous terrestrial overlap deposits formed on the Indochina and Sibumasu terranes after their Late Triassic 'Indosinian' suturing. The vertebrate species suggest Laurasian faunal affinities, particularly with China (e.g. Buffetaut and Suteethorn 1993, 1998).

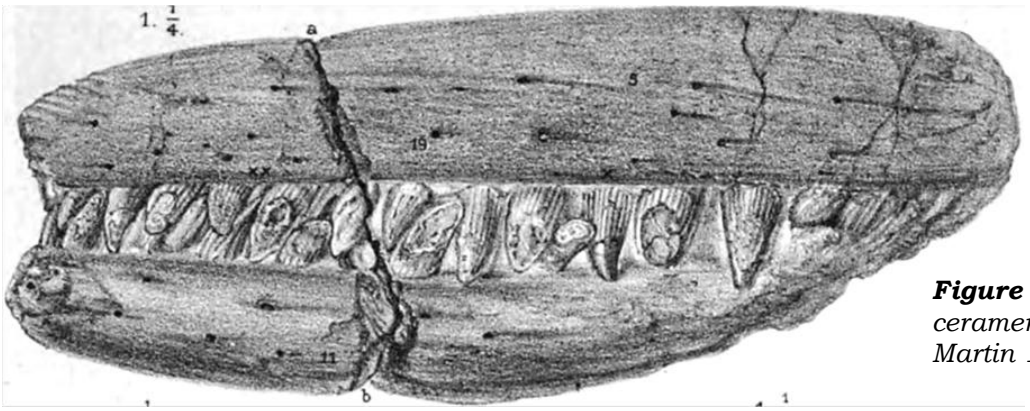


Figure 22. *Jaw of Ichthyosauras ceramensis from Seram (Jurassic?; Martin 1888).*

Mesozoic non-marine vertebrate fossils are not known from Indonesia, but they may one day be found in areas where Mesozoic coniferous wood has been found, like the Tin Islands and West Kalimantan (see below). The areal distribution of non-marine deposits with their Eurasian fossil faunas and floras, generally reflect areas that had become parts of the Eurasian continent (Sundaland), and thus provide constraints on plate tectonic reconstruction scenarios.

KEY REFERENCES- MESOZOIC VERTEBRATES

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CONCLUSIONS

This compilation of data on pre-Cenozoic faunas and floras is a reminder of the rich heritage of paleontological studies carried out over the last 150 years in Indonesia and a review of their significance for age dating and paleogeography and plate tectonic reconstructions.

REFERENCES

Key references are given at the end of each chapter. For additional titles not quoted in this paper see one of the Bibliography listings below:

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