The life and scientific legacy of Indonesian paleontologist Dr. Tan Sin Hok (1902-1945)

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ABSTRACT

Tan Sin Hok was probably Indonesia's most influential paleontologist. He was born and raised in West Java and was the only Indonesian with an academic earth science education from The Netherlands before World War II. His Ph.D thesis in 1927 was a pioneering study on little-known Cretaceous radiolaria and Tertiary calcareous nannofossils from Roti and Timor. Subsequent work during his professional career as paleontologist of the Geological Survey in Bandung mainly focused on evolution of Cenozoic larger foraminifera. Tan's scientific legacy was accomplished before he was 40 years old, when the Japanese occupation terminated his research and the turmoil immediately thereafter took his life.

Although Tan Sin Hok made significant original contributions to taxonomy and evolution of several microfossil groups, he initially failed to recognize the potential biostratigraphic value of radiolaria and nannofossils; important high-resolution zonations of these groups were developed by other workers in the 1950's and later. Tan's novel approach to evolution and systematics of larger foraminifera of Indonesia appeared to resonate only with 'schools' in The Netherlands, probably largely because his publications were mainly written in Dutch and German and published in Dutch and 'Netherlands Indies' journals with limited distributions.

INTRODUCTION

Tan Sin Hok was an internationally well-known Indonesian micropaleontologist, although few geologists in Indonesia today are familiar with his work. This current series on Biostratigraphy of SE Asia in Berita Sedimentologi would not be complete without a tribute to this important scientist.

Tan Sin Hok's life story was the focus of a recent short paper in GEOMAGZ magazine (Munasri, 2014). Additional information on Tan Sin Hok's personal history is in the obituary by Mohler (1949) and in the transcripts of 600 personal letters sent to relatives in The Netherlands by Tan Sin Hok's Dutch wife Eida Tan-Schepers between 1929-1946, (online at *http://brieven-tan-schepers.nl).* These letters generally end with a few lines by Tan Sin Hok himself.

PERSONAL HISTORY

Education

Tan Sin Hok was born in 1902 in Cipadang near Cianjur, West Java, from a Chinese father and a Sundanese-Chinese mother, and was the youngest of three brothers. The Tan family operated a successful rice-milling business. He grew up in Sundanese culture and spoke Malay (now Bahasa Indonesia) and Sundanese languages as his mother tongue. In 1907, at age five, Tan Sin Hok entered Primary School (Europeesche Lagere School) in Cianjur. When he was eight years old in 1910, his father died. Following Chinese customs, he and his family were then adopted by the family of his uncle, who also ran a rice mill business near Cianjur. Subsequently, Tan Sin Hok attended Koning Willem III grammar school in Batavia, graduating in 1919.

The relative affluence of the Tan family enabled their uncle Tan Kiat Hong to spend 18,000 Dutch Guilders from his own resources to fund the studies of Tan Sin Hok and his older brother Tan Sin Houw in The Netherlands. Tan Sin Hok thus became the first (and only) Indonesian before World War II with an academic degree in earth sciences and mining (there were no academic institutions with geology/mining programs in Indonesia at that time). Tan started at the School of Mines of the 'Technische Hoogeschool' (Technical University) of Delft in late 1919, at age 17, and graduated as a Mining Engineer in 1925, followed by completion of a Ph.D degree under Professor H.A. Brouwer in October 1927. Tan's thesis was a study of Cretaceous-Tertiary pelagic marls and their microfossils from the Outer Banda Arc islands, mainly Roti.

Paleontologist in Bandung (1929-1942)

After graduation Tan spent a year in Bonn, Germany, to become familiar with paleontological collections of Indonesian fossils in the department of Professor J. Wanner.

In June 1929 Tan and his Dutch wife arrived back in Indonesia, where he started work as a paleontologist at the Paleontological Laboratory of the 'Dienst van den Mijnbouw' in Bandung (= Bureau of Mines or Geological Survey; now Badan Geologi = Geological Agency), where he would remain for the remainder of his career.

Illustrious predecessors at the Paleontological Laboratory in Bandung included I.M. van der Vlerk (1922-1928) and J.H.F. Umbgrove (1926-1929), who had established a significant tradition of larger foram studies, but who both had returned to academic positions in Leiden and Delft respectively when Tan Sin Hok arrived in Bandung. After Van der Vlerk's departure to The Netherlands in 1928, the Laboratory was briefly headed by H.P. Gerth in 1928-1929, who was then replaced by mollusk specialist C.H. Oostingh in October 1929, who had arrived around the same time as Tan Sin Hok.

For the 10+ years from 1929-1940, interrupted by a year-long leave in Europe in 1937-1938, Tan and Oostingh formed the Paleontological Laboratory staff, part of this time also with mammal specialist Ralph Von Koenigswald (1931-1934). Their primary responsibilities were paleontological support work for Mijnwezen's mapping programs on Java, Sumatra, Kalimantan and Sulawesi-Buton. In addition, they conducted productive research programs on taxonomy, evolution and biostratigraphic zonation of larger foraminifera and mollusks respectively.

Much of Tan's time in Bandung was a period of decline for the Bureau of Mines, with several rounds of budget and personnel reductions following the 1929 economic crisis. In a letter of January 1934 Tan mentioned budget cuts that resulted in the dismissal of Von Koenigswald and other engineers, and a 25% reduction in salary for all Mijnwezen personnel. This was also the time when the systematic mapping of Sumatra was terminated and other field programs were scaled back. Publications of results of surveys as 'Verhandelingen' of the Jaarboek van het Mijnwezen had already virtually ceased after 1930.

Tan Sin Hok published about 30 papers in his Bandung period, mainly on Tertiary larger foraminifera. Thalmann (1949) mentions that during a May 1941 visit Tan still had numerous manuscripts for future publications, but these have never been published.

After Oostingh's untimely death of pneumonia in April 1940 Tan Sin Hok was the only remaining professional paleontologist at the Survey. However, the German occupation of The Netherlands in May 1940 forced a re-focusing of activities at 'Mijnbouw' towards strategic minerals. Tan was re-assigned from paleontology to geological fieldwork, conducting surveys of gypsum, quartz sand and coal deposits, mainly on Java (see also titles of 1940-1941 unpublished reports at end of this paper).

Tan Sin Hok's work and reputation attracted visits to Bandung by other prominent micropaleontologists of that time, including Australian academics Irene Crespin (1939) and Martin Glaessner and oil company geologists/micropaleontologists working in Indonesia like Hans Kupper (BPM, Plaju) and Hans Thalmann and H.J. MacGillavry (NKPM/Stanvac, Palembang; 1939-1941).

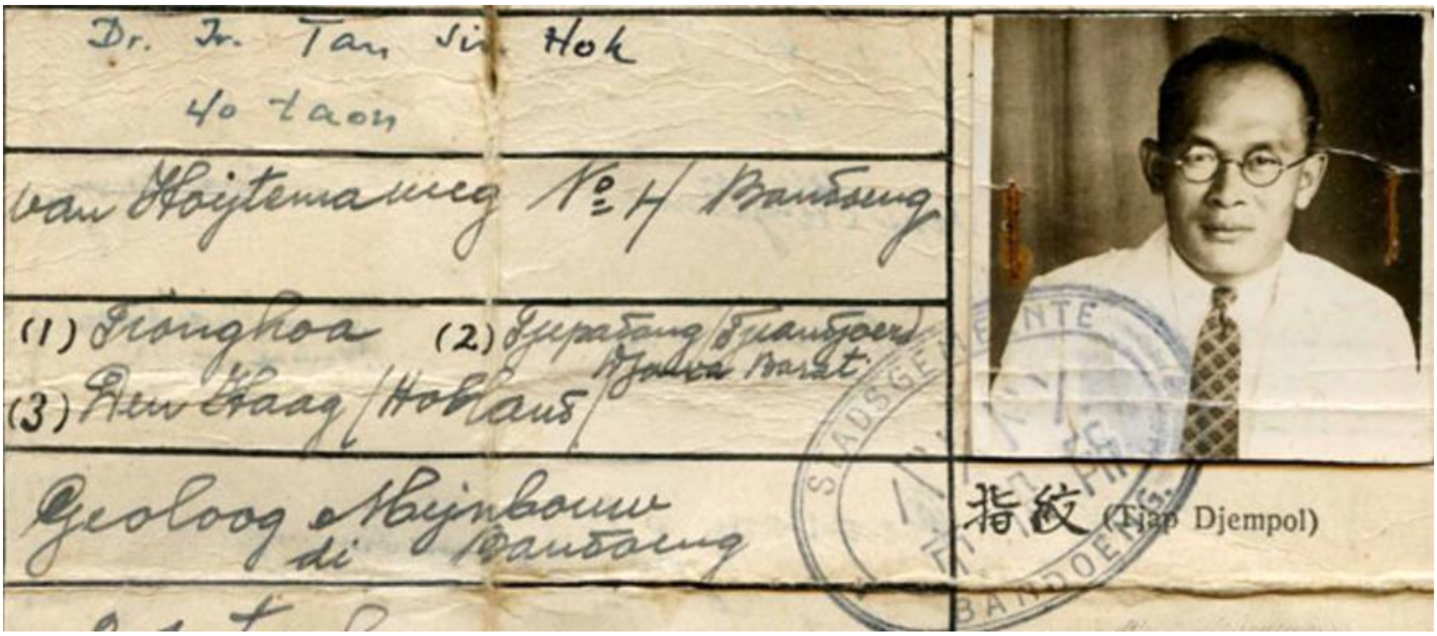


***Figure 1**. Part of Tan Sin Hok's City of Bandung identity card during Japanese Administration in 1942 (from www.brieven-tan-schepers.nl)*

Japanese Occupation and post-war murder (1942-1945)

After the Japanese invasion in March 1942 Tan Sin Hok initially continued to work at the Geological Survey, but now under Japanese administration (Figure 1). His first task under Japanese administration was a survey of Eocene-Oligocene coal deposits of SW Java (Cibadak near Sukabumi and Cimandiri near Bayah). He may have deliberately misrepresented the results of this survey work. In a letter of 13 November 1945 Mrs. Eida Tan-Schepers wrote (HvG translation): *"Hok continued his geological work after the surrender in March '42. He found it far from pleasant to work for these guys, most of whom understood very little of the business, but he felt obliged to continue to work, while making sure that they did not get their hands on all of the geological information" (*www.brieven-tan-schepers.nl/index.php/1945/item/594-1945-11-13). Lunt (2013 p. 196) confirms Tan Sin Hok's apparent sabotage. Unlike most maps produced by 'Mijnwezen', Tan's maps of the SW Java coal regions in his 1942-1943 reports were very difficult to reconcile with topography and known geology of the region, so it was suspected Tan could have deliberately misrepresented these strategic coal occurrences.

On September 1, 1943 Tan and his family were arrested and interned in Japanese prison camps, like his European former colleagues, presumably because of being a member of the Freemasons. He spent two years in internment, first at Sukamaskin prison in Bandung and later in a camp in Cimahi, West Java. Due to his strong health Tan survived this internship relatively unscathed. He was released at the end of August 1945 and was reconciled with his wife and three children two weeks later.

Despite his sympathy for the Indonesian Independence movement, Tan became a victim of Indonesian extremist nationalists on 1 December 1945, only three months after his release from interment and only 43 years old. He was shot and killed in his house in Bandung, while his family escaped from the back of the burning house through a corn field to safety at the Borromeus hospital. Tan's body is buried at the cemetery for Dutch victims of the war at 'Ereveld Pandu' in Bandung. His wife and three children repatriated to The Netherlands in April 1946.

THE SCIENTIFIC LEGACY

Tan Sin Hok is known primarily for his work on radiolaria, calcareous nannofossils and larger foraminifera. However, during his work at the Geological Survey in Bandung he also provided paleontological support to ongoing mapping work and published brief papers on identifications of Cretaceous planktonic foraminifera, Permian brachiopods and fusulinid foraminifera, etc., across Indonesia.

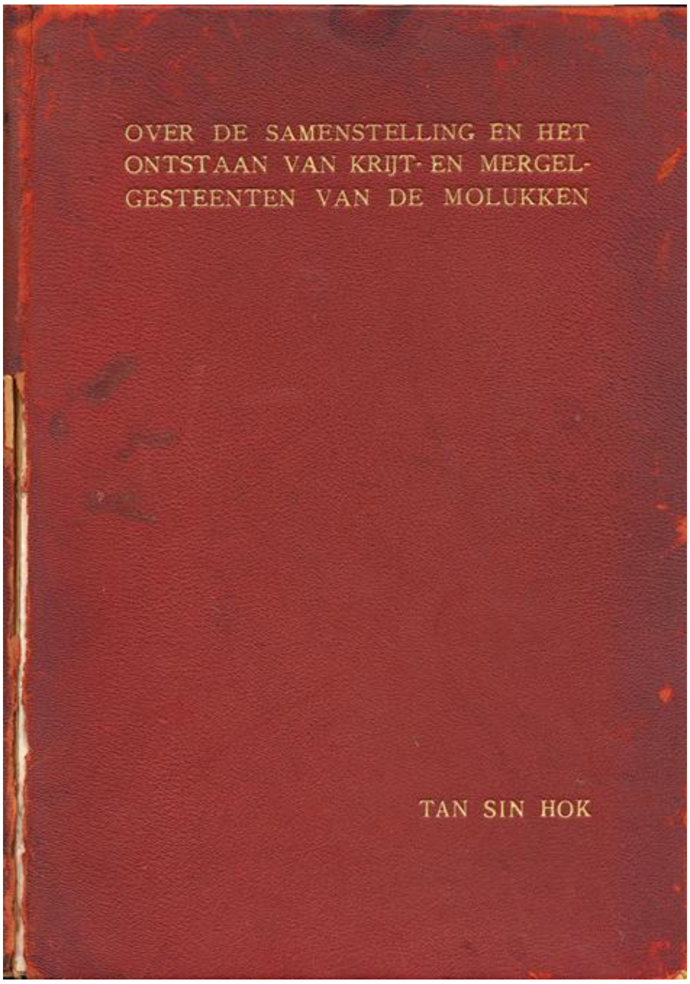
The card catalog at the library of the Geological Agency in Bandung (Figure 2) contains more than 60 entries of unpublished reports and publications on paleontology, field surveys and economic geology, written by Tan Sin Hok until 1942 for the Bureau of Mines (Dienst van den Mijnbouw). Unfortunately, some of the Tan Sin Hok reports, especially the unpublished ones, are not available any more from the library. Also the original thin sections of the Tan Sin Hok collection are no longer officially stored at the Geological Museum in Bandung after the major renovation in 2000.

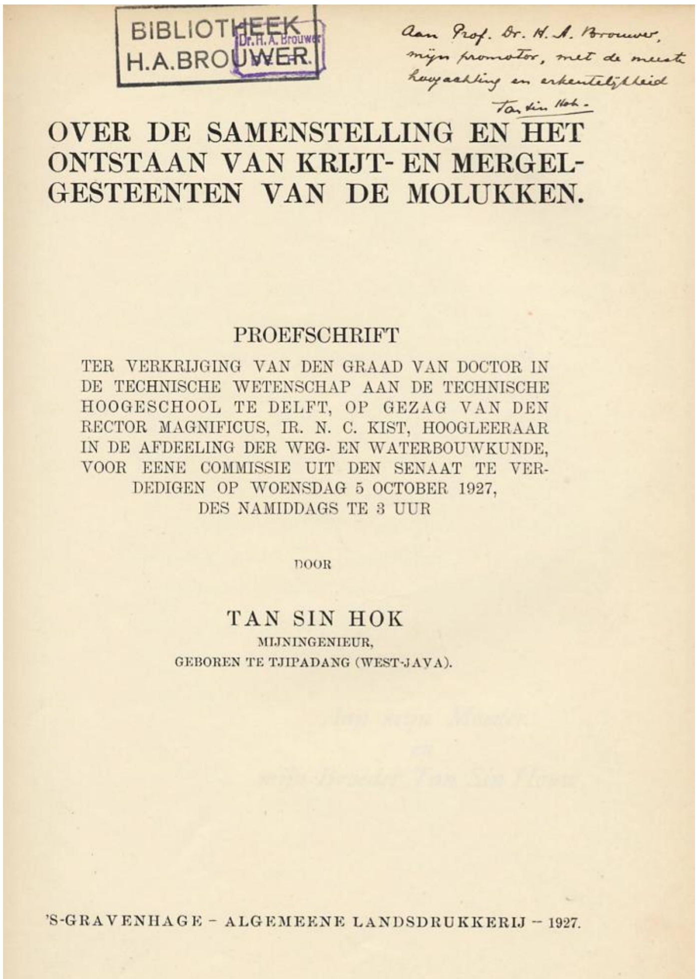
During his career Tan Sin Hok described many new genera and species of radiolaria, calcareous nannofossils and larger foraminifera, some of which are still used today as important index fossils. In turn, several genera and species foraminifera, nannofossils and radiolaria were named in his honor by later workers (Table 1).

Figure 2*. Tan Sin Hok entries in the card catalog of the library of the Geological Agency, Bandung, containing titles of about 60 reports and publications, written between 1927 and-1943 (see also Reference lists).*

Composition of chalk- and marl rocks of the Moluccas (1927)

Tan's first major work was his 1927 thesis 'On the composition and origin of chalk and marl deposits of the Moluccas' (Figure 3), in which numerous new species were described in these then poorly-known microfossil groups. This rapidly made Tan the leading authority on radiolaria and calcareous nannofossils, judging from his contribution on these groups in the major review 'The paleontology and stratigraphy of the Netherlands Indies' (K. Martin Memorial Volume) (Tan Sin Hok, 1931).




BIBLIOTHEEK H.A.BROUWER

OVER DE SAMENSTELLING EN HET ONTSTAAN VAN KRIJT- EN MERGEL-GESTEENTEN VAN DE MOLUKKEN.

PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN DOCTOR IN DE TECHNISCHE WETENSCHAP AAN DE TECHNISCHE HOOGESCHOOL TE DELFT, OP GEZAG VAN DEN RECTOR MAGNIFICUS, IR. N. C. KIST, HOOGLEERAAR IN DE AFDEELING DER WEG- EN WATERBOUWKUNDE, VOOR EENE COMMISSIE UIT DEN SENAAT TE VERDEDIGEN OP WOENSDAG 5 OCTOBER 1927, DES NAMIDDAGS TE 3 UUR

DOOR

TAN SIN HOK

MIJNINGENIEUR,

GEBOREN TE TJIPADANG (WEST-JAVA).

'S-GRAVENHAGE – ALGEMEENE LANDSDRUKKERIJ – 1927.

Figure 3. *Doctoral Thesis of Tan Sin Hok at 'Technische Hogeschool Delft' in 1927, entitled ' On the composition and genesis of chalks and marl rocks of the Moluccas'. With hand-written dedication to his promotor Prof. Dr. H.A. Brouwer. It is a pioneering study of radiolarians and calcareous nannoplankton from Cretaceous and Tertiary deep water sediments of Timor, Roti, Yamdena, Halmahera and Ambon.*

RADIOLARIA STUDIES

Before 1927, relatively little work had been done on fossil radiolaria of Indonesia. The only two substantial publications were by British paleontologist G.J. Hinde: in 1900 (Late Jurassic-Early Cretaceous radiolaria from samples collected by Molengraaff in Central Kalimantan), and in 1908 (Triassic-Cretaceous radiolaria from samples collected by Verbeek in Roti, Savu, Sulawesi, etc.). Tan Sin Hok's 1927 thesis work on radiolaria from Roti island was thus a significant contribution.

Taxonomic description of assemblage from Roti

Tan Sin Hok (1927) systematically described 4 new genera and 141 species of radiolaria from four marly limestone samples from an area West of Bebalain, SW Roti. The assemblages are diverse, and well-preserved, and 138 of the species identified were believed to be new (see Table 1). The samples were collected by Brouwer in 1912 and Verbeek in 1899. Most species were found in sample 150, but samples 149, 154 and 384 appear to contain a lower diversity selection of the same species. Unfortunately, in his species descriptions Tan did not specify from which of the samples the holotype came from.

All described species were illustrated by hand-drawn figures (selected examples in Figure 4). The only species identified by Tan as a previously-described species was *Eucyrtidium cinctum* (Hinde) (= *Dictyomitra cincta)*, originally described by Hinde (1908) from a chert sample collected by Verbeek on nearby Savu Island.

Age interpretation of Roti Radiolaria

Unfortunately, Tan Sin Hok's work did not do much to stimulate the use of radiolaria as biostratigraphic indicators. This was partly caused by his misinterpretation of the age of the Roti assemblages. For no apparent plausible reason, other than possible lithologic similarities with nearby Neogene marls, Tan assumed the radiolarian marls to also be of Late Neogene age. In reality most species are now known to be mostly of Early Cretaceous age, but some are regarded as Middle and Late Jurassic elements.

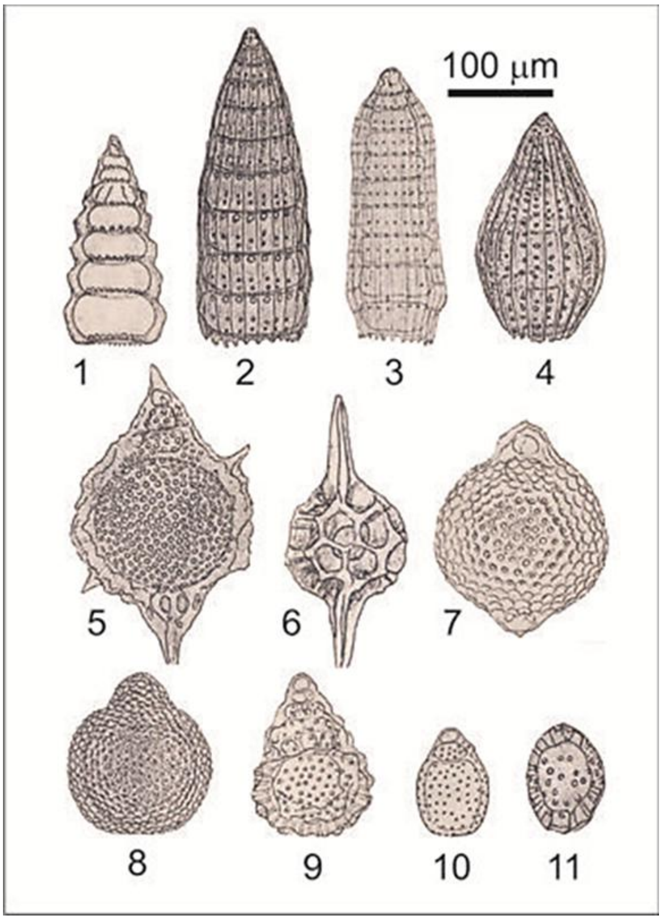


Figure 4. *Examples of radiolaria from Bebalain, Roti island, hand-drawn by Tan Sin Hok. These are distinct species, which are found in several places in Indonesia, Japan and Europe. 1. Pseudodictyomitra lilyae (Tan), 2. Dictyomitra pseudoscalaris (Tan), 3. Archaeodictyomitra excellens (Tan), 4. Arcaheodictyomitra brouweri (Tan), 5. Cyrtocapsa grutterinki Tan, 6. Pantanellium squinaboli (Tan), 7. Hemicryptocapsa capita Tan, 8. Tricolcapsa rusti Tan, 9. Sethocapsa rutteni (Tan), 10. Tricolocapsa parpivora Tan, 11. Archicapsa*

Riedel (1953) was the first to recognize the Late Jurassic- Early Cretaceous age of the radiolaria described by Tan from Roti Island (although Late Tertiary radiolaria are present in other samples from Roti). Bukry (in Riedel and Sanfilippo, 1974) analyzed calcareous nannofossils of Roti Sample 150 and concluded these were typical mid-Cretaceous species. A survey of range charts by modern radiolaria workers shows that (1) several of Tan's species, like *Dictyomitra pseudoscalaris* (Tan), *Eucyrtidium* (now *Archeodictyomitra*) *brouweri* and *Sphaerostylus lanceola* are still being used, (2) all of them are assigned an Early Cretaceous age, and (3) none of them are younger than early Aptian (Sanfilippo and Riedel 1985, Baumgartner 1992, Jasin and Haile 1996, O'Dogerty 2009, etc.).

Many of the Tan Sin Hok radiolarian species from Bebalain, Roti are also present in the Early Cretaceous of East Sulawesi (Hojnos 1934), the Barru area of South Sulawesi (Munasri 2013), the Kolbano area of West Timor (Munasri, in prep.) and Pulau Laut, South Kalimantan (Wakita et al., 1998). Some species were also found in Japan, China, Europe and the Middle-Late Jurassic of Panthalassan terranes of western North America (Hull 1997). *Tricolocapsa ruesti* Tan (also known as *T. rusti* or *Williriedellum ruesti*) was subsequently identified in the Middle Jurassic Wailuli Formation of Roti (Sashida et al. 1999). This species appears to be most common in the Middle Jurassic, but may range into Early Cretaceous (Paleobiology Database).

Examples of Tan species found outside of Roti and their interpreted ages include:
Pseudodictyomitra lilyae (Tan) (Early Cretaceous)
Dictyomitra pseudoscalaris (Tan) (Early Cretaceous)
Archeodictyomitra excellens (Tan) (Early Cretaceous)
Pantanellium squinaboli (Tan) (Late Jurassic- Early Cretaceous)
Hemicryptocapsa capita Tan (Early Cretaceous)
Cyrtocapsa grutterinki Tan (Middle Jurassic- Early Cretaceous)
Archeodictyomitra brouweri (Tan) (Early Cretaceous)
Sethocapsa rutteni (Tan) (Late Jurassic)
Tricolocapsa ruesti Tan (Middle Jurassic -Early Cretaceous)
Tricolocapsa parvipora Tan (Middle Jurassic)
Archicapsa pachiderma (Tan) (Early Jurassic).

The reason for Tan Sin Hok's major error in age interpretation is not clear. He was undoubtedly aware of the presence of Mesozoic radiolarian-rich limestones on Roti Island, as his thesis advisor Brouwer (1922) had already identified radiolarian marls from Roti with Triassic bivalves and with Jurassic ammonites and belemnites. On p. 65 and p. 73-74, Brouwer even argued that some of the white radiolarian-rich marls near Bebalain (including samples 150, 154 which Verbeek (1908) assumed to be of Neogene age), were more likely of Mesozoic (Jurassic) age, because of the presence of small manganese nodules (not known from Late Tertiary marls but common in Jurassic), and absence of planktonic foraminifera (common in true Neogene marls).

The use of Radiolaria as index fossils

In 1927, and at several occasions thereafter, Tan Sin Hok expressed his doubts about the value of radiolaria as zonal markers, e.g. in Tan Sin Hok (1931, p. 95): *"From the point of stratigraphy the radiolaria are of but small importance"*. It is not clear what this strong statement was based on, because at that time very few radiolarian assemblages had been studied, and for most of these there was no good independent age information available. It was probably driven by his own misinterpretation of the Roti material, which made him conclude that many species ranged from Mesozoic to Neogene.

TABLE 1	NEW TAXA DESCRIBED BY TAN SIN HOK	
Calcareous Nannofossils (1927)	**Family**	Discoasteraceae
	Genus	*Discoaster, Eu-discoaster, Helio-discoaster, Hemi-discoaster*
	Species	*Discoaster brouweri, D. hilli, D. pentaradiatus, D. molengraaffi, D. triradiatus, D. barbadiensis, D. ehrenbergi , D. barbadiensis , D. barbadiensis var. bebalaini*
Radiolaria (1927)	**Genus**	*Cenolarcopyle, Hemicryptocapsa, Stylocryptocapsa, Holocryptocapsa*
	Species (138)	*Caenosphaera immanis, Sphaeropyle chonopora, S. nova, S. fallax, Carposphaera diversipora, C. haeckeli, Xiphosphaera tuberosa, Stylosphaera squinaboli, Conosphaera tuberosa., Ellipsoxiphus rugosus, Lithapium spinosum, Spongodiscus cribrosus, Cenolarcopyle fragilis, Stypolarcus laboriosus, Tripocalpis ellyae, Cornutella apicata, C. acuta, C. procera, C. nitida, C. facilis, C. adunca, Archicorys turgida, Cyrtocalpis operosa, C. pachyderma, C. digitiformis, Archicapsa guttiformi, A. mutila, Dictyophimus gracilis, Peromelissa crassa, Sethoconus cordayae, S. nashi, Sethocapsa martini, S. hastata, S. nobilis, Dicolocapsa verbeeki, D. cephalocrypta, D. exquisita, Stylocapsa pachyderma, S. pylosa, S. hastellata, Theocapsa urniformis, T. simplex, T. laevis, T. curata, T. elata, T. variabilis, Tricolocapsa parva, T. dispar, T. pachyderma, T. simplex, T. parvipora, T. nodosa, T. spinosa, T. frequens, T. triangulosa, T. riusti, Hemicryptocapsa capita, H. regularis, H. pseudopilula, Stylocryptocapsa verbeeki, S. fallax, H olocryptocapsa fallax, H. hindei, Lithostrobus erectus, L. nodosus, L. pseudomulticostatus, L. dignus, L. ornatus, L. parvus, Dictyomitra mediocris, D. lilyae, Stichomitra pseudoscalaris, Lithomitra excellens, L. pseudopinguis, Eucyrtidium parviporum, E. brouweri, E. deformis, E. thiensis, Eusyringium kruizingai, E. niobeae, E. ingens, Syringium ingens, S. molengraaffi, Lithocampe grutterinki, L. pseudochrysalis, L. hanni, Cyrtocapsa grutterinki, C. houwi, C. horrida, C. molengraaffi, C. ovalis, C. asseni, C. rottensis, C. piriformis, C. pseudacerra, C. gilseae, C. miserabilis, C. pseudinauris, C. molukkensis, C. pseudoreticulata, C. indonesiensis, Stichocapsa bebalainsis, S. wichmanni, S. rutteni, S. pseudornata, S. lageniformis, S. pseudopentacola, S. pseudodecora, S. pseudocincta, S. fallax, S. singularis, S. pseudapicata, Artocapsa bicornis, A. ultima*
Larger foraminifera (1932-1939)	**Family**	Miogypsinidae 1936
	Genera	*Katacycloclypeus* 1932, *Radiocycloclypeus* 1932, *Vacuolispira* 1936, *Conomiogypsinoides* 1936, *Eolepidina* 1939
	Species	*Cycloclypeus koolhoveni, C. oppenoorthi, C. eidae, C. posteidae, C. inornatus, C. postinornatuus, C. indopacificus, C. postindopacificus, Radiocycloclypeus stellatus, R. radiatus, Katacycloclypeus transiens, K. posttransiens, K. biplicatus, Heterostegina praecursor, H. bantamensis* (all 1932), *Lepidocyclina stratifera* 1935, *L. omphalus* 1935, *L. zeijlmansi* 1936, *Miogypsinoides ubaghsi, M. bantamensis, Miogypsina primitiva, M. borneensis, M. indonesiensis, M. musperi* (all 1936), *Miolepidocyclina excentrica* 1937
NEW TAXA named after TAN SIN HOK		
Calcareous Nannofossils	**Genus**	*Tansinius* Filipescu and Hanganu 1960
	Species	*Discoaster tani* Bramlette and Riedel 1954, *Discoaster tani nodifer* Bramlette and Riedel 1954, *Discoaster tani ornatus* Bramlette and Wilcoxon, 1967
Radiolaria	**Species**	*Minocapsa tansinhoki* Hull 1997, *Acanthocircus tansinhoki* Pessagno and Hull 2002
Larger foraminifera	**Genus**	*Tansinhokella* Banner and Hodgkinson 1991
	Species	*Miogypsina tani* Drooger 1952

Tan Sin Hok (1935) critically reviewed the Hojnos (1934) paper 'On age determinations based on radiolarians of E Sulawesi'. Hojnos had identified Late Jurassic- Early Cretaceous radiolaria in samples collected by Van Loczy in East Sulawesi, but Tan argued that all radiolaria species were long-ranging, should not be used for age determination, and that some of the Sulawesi species also occurred in the Neogene of Roti. As we know now, Tan was wrong in his age interpretation of the Roti samples and the Hojnos (1934) interpretation was probably quite reasonable.

Tan's misguided skepticism on the use of radiolaria as index fossils may have been the reason why he never conducted any further studies on radiolaria after his 1927 thesis work.

CALCAREOUS NANNOFOSSIL STUDIES

Calcareous nannoplankton (coccoliths) are a group of extremely small calcareous planktonic algae (2-30 microns), which require very high-magnification (x500 or more) for study. Studies of this group started with Ehrenberg (1836), but very little systematic work was done between their initial discovery and the routine use of these forms in biostratigraphy since the 1960's.

Discoasters from Roti

The papers and thesis of Tan Sin Hok (1926, 1927, 1931) on the star-shaped sub-group he named 'Discoasters' from Neogene marls of Roti and Timor were a pioneering effort. Discoasters are now the most important calcareous nannofossil group for biostratigraphic zonation of the Cenozoic of tropical and subtropical provinces. Several of the new names proposed by Tan are still in use today and some have become significant zonal marker species (*Discoaster brouweri*, *Discoaster pentaradiatus*, *Discoaster barbadiensis*, *etc ; Figure 5, 6*).

Most of Tan Sin Hok's nannofossil material was from Sample 168 from the Bebalain area of South Roti, collected by Brouwer in 1912. This sample from Roti was restudied several times. Kamptner (1955) described 99 additional new species of nannossils. Martini (1971) examined the material and placed it in zone NN10. Jafar (1975) also identified many additional species, including index species *Discoaster bollii, D. hamatus and Catinaster coalitus*, and the determined age of the sample as within zone upper NN9, late Middle Miocene. The sample also contains reworked Cretaceous, Eocene and Early Miocene nannoplankton.

Tan Sin Hok (1927) proposed eight new species of 'calcareous asterisks', which were all assigned to the genus *Discoaster.* Later workers have described over 200 additional species of this genus, of which about 100 are commonly used. Unfortunately, Tan was not very careful in his systematic descriptions of his proposed family Discoasteridae and its members, although, in Tan's defense, the rules of the Internal Commisions of Zoological and Botanical Nomenclature were not as well-defined then as they are today (and in 1927 it was not even known whether coccoliths were animals or plants). The genus name *Discoaster* was apparently used by Tan only as an informal name, without generic description and without designating a type species. All new species of discoasterids in Tan's 1927 paper were assigned to *Discoaster*, but they were also classified into three formally described (sub-)genera:

- *Eu-discoaster* (star-shaped discosterids; type species *Discoaster brouweri* Tan; other new species in this genus: *Discoaster hilli, D. pentaradiatus*). In Tan (1931) considered synonym of *Discoaster*;
- *Helio-discoaster* (rosette-shaped discoasterids; type species *Discoaster barbadiensis* Tan; other new species in this genus: *Discoaster barbadiensis* var. *bebalaini*, *D. ehrenbergi*);
- *Hemi-discoaster* (star-shaped discoasterids with arms welded together; type species *Discoaster molengraaffii* Tan; other new species in this genus: *Discoaster triradiatus*). The distinguishing feature is now believed to be a diagenetic variation of *Eu-discoaster*, so genus and species are invalid.

According to the nomenclatural rules of today, the name *Discoaster* and all of Tan's new species are legally invalid because they lack type species designation, holotypes and type localities (Prins 1971, Theodoridis 1983, Doweld 2014). One of the new species (*Discoaster triradiatus*) was never figured. Some of these omissions were 'fixed' by Loeblich and Tappan (1963, 1966). Today it is common practice to include all discoasterid species in *Discoaster* and ignore Tan Sin Hok's other three genus names, although this is historically incorrect. A proposal by Doweld (2014) intends to legitimize this practice.

The use of Calcareous nannofossils as index fossils

Tan Sin Hok (1927) did not realize how successful discoasterids were going to be in future biostratigraphic applications when he claimed that *"Discoasteridae, etc. are of little value from a stratigraphic point of view"*. Part of the reason may have been that some of his samples apparently contained mixed assemblages with reworked species (e.g. Middle- Late Eocene *Discoaster barbadiensis* Tan associated with Miocene species). Subsequent work, starting with Bramlette and Riedel (1954) and expanded by Bukry, Martini, Gartner, Perch-Nielsen, etc., has proven that nannofossils are very useful biostratigraphic indicators, and are now one of the primary tools for high-resolution age dating of Cretaceous-Cenozoic marine sediments. As noted for radiolaria, Tan's misguided skepticism on the use of calcareous nannofossils as index fossils may have been the reason why he never conducted any further studies on this group after his 1927 thesis work.

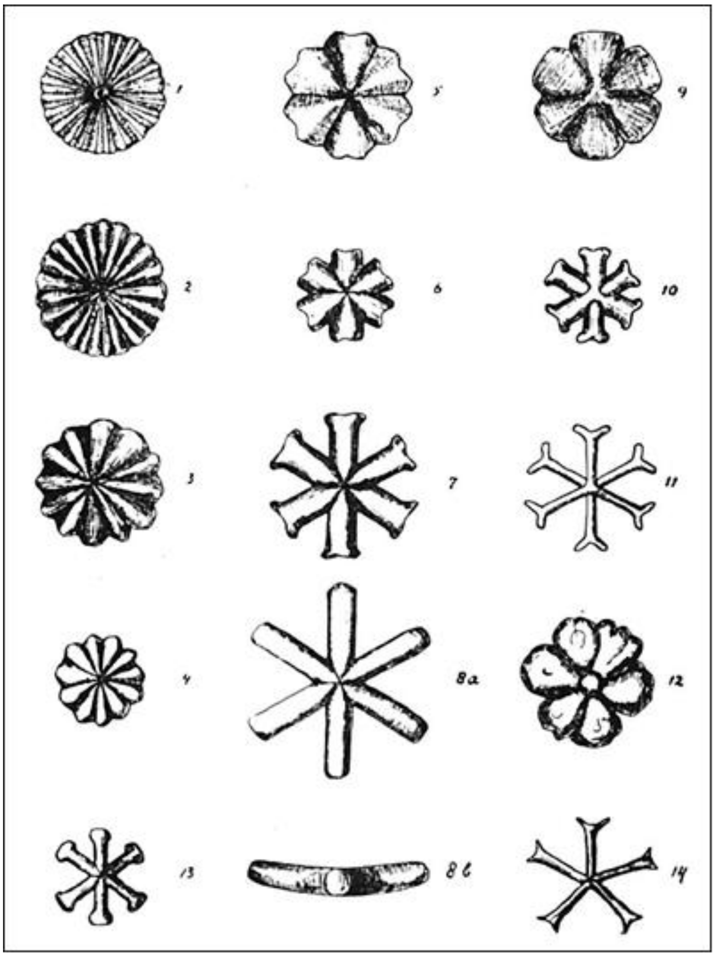


Figure 5. *Calcareous nannofossils of Discoaster group from Neogene of Roti (Tan Sin Hok 1927): 1. Coccolithophora leptophora, 2-3 Discoaster ehrenbergi (= D. multiradiatus= reworked Paleogene), 4 D. barbadiensis var. bebalaini (= reworked Eocene?), 5-8 D. brouweri var. beta, gamma (= D. challengeri), theta, 9-11 D. molengraaffi (= D. brouweri), 12 'coccolith', 13. D. brouweri var. alpha, 14 D. pentaradiatus.*

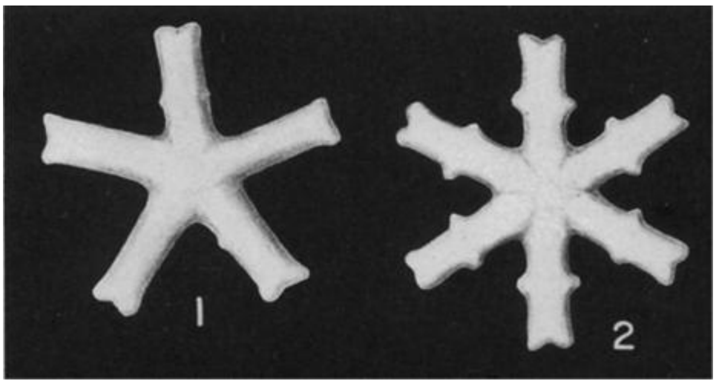


Figure 6. *Discoaster tani and Discoaster tani nodifer; a new species and subspecies named after Tan Sin Hok by Bramlette and Riedel (1954).*

Another apparent weakness in Tan's (1927) work is his interpretation of depositional environments of the nannofossil marls from Roti and Timor, which he interpreted as 'low-energy, lagoonal deposits', instead of the deep marine pelagic sediments that most workers today would view these as.

FORAMINIFERA STUDIES

A pioneer of evolution of Cenozoic larger foraminifera (1930-1939)

When Tan Sin Hok arrived at his first job at the Paleontological Laboratory of the Geological Survey ('Dienst Mijnwezen') in Bandung in 1928, he found a significant collection of Cenozoic larger foraminifera from Indonesia, built by his predecessors I.M. van der Vlerk and J.H.F. Umbgrove. Both of them had already published multiple papers on larger foraminifera, including their milestone 1927 joint paper proposing the larger foraminifera biozonation now known as the 'East Indies Letter Classification', which is still in use for dating shallow marine carbonates in SE Asia.

Van der Vlerk and Umbgrove, and most micropaleontologists before and after Tan Sin Hok, initially used the traditional, 'typological' approach to taxonomy in larger foraminifera: new species were defined on morphological criteria, and a holotype was designated and illustrated. Species are then identified as to similarity with the selected holotype. Such classification is generally artificial as it does not capture normal variability within populations, and has led to a proliferation of species names, based on difference is size, shape, ornamentation, etc. Many of which are 'normal' variants in single populations, which do not deserve separate species names.

From 1931-1941 Tan Sin Hok published a series of papers demonstrating the existence of more-or-less gradual evolution in several lineages of Cenozoic larger foraminifera from Indonesia. These evolutionary series of *Heterostegina* to *Cycloclypeus, Heterostegina to Spiroclypeus, Pararotalia* to *Miogypsina and Lepidocyclina* show similar, parallel changes over periods of 12-30 million years. A review of Tan's larger foram work by the Swiss NKPM/Stanvac paleontologist in Palembang Hans Thalmann (1938) is one of many papers to endorse the merits of Tan Sin Hok's novel approaches to larger foraminifera. Several examples of Tan's work were also discussed in Lunt and Allan (2004) and Van Gorsel, Lunt and Morley (2014).

Several new genera and species of larger foraminifera were described by Tan. Some of these are still in use, including *Katacycloclypeus, Radiocycloclypeus* and *Cycloclypeus koolhoveni* (see Table 1).

1. On the genus Cycloclypeus Carpenter (1932)

Tan Sin Hok's first major work on larger foraminifera was the 1932 book on the genus *Cycloclypeus*, mainly from SW Java, a work called 'an outstanding monograph' by Drooger (1955).

Its main merit is that it documents (1) the evolution from an earliest Oligocene large *Heterostegina* ancestral species into *Cycloclypeus* by acquiring a concentric growth pattern, (2) how through this concentric growth is reached progressively earlier in the ontogeny from Oligocene-Recent (Figure 7), (3) classified the successive stages of the main lineage into species based on their degree of evolution; (4) documents the existence of two side-lineages *Katacycloclypeus* and *Radiocycloclypeus*.

This work also contains a discussion of the mechanism of the evolutionary processes. Evolutionary change was viewed as being independent of environment, caused by genetic shifts, with each genetic shift resulting in a mutational step. Tan argued that evolution in *Cycloclypeus* was not entirely gradual, but that distinct abundance peaks of 32, 30, 27, 24, 21, 19, 17, 15, 12, 6, 4 and 3 pre-cyclic nepionic stages suggested stepwise small mutations. Subsequent workers have been unable to confirm such peaks and distinct mutational steps in *Cycloclypeus* (Drooger 1955, MacGillavry 1962) or in other larger foraminifera (e.g. Van der Vlerk and Gloor 1968). Instead, larger foram workers tend to not find only gradual shifts in progress in successive populations, primarily towards reaching more efficient radial symmetry (Drooger, 1993).

2. Studies on Lepidocyclina (1934-1936)

Earlier workers like Douville, Rutten, Van der Vlerk and others had already done much work to describe and name Oligocene-Miocene *Lepidocyclina* species from Indonesia. Lepidocyclinids are generally viewed as immigrants from The Americas into SE Asia in Early Oligocene time, but Tan Sin Hok (1936) described the primitive species *Lepidocyclina (Polylepidina) zeijlmansi* from the Eocene of the upper Kutai Basin, C. Kalimantan, which shows similarities to *Orbitosiphon* species from NE India (Rutten 1950).

3. Studies on Spiroclypeus (1937)

In the 1930's the *Spiroclypeus* larger foram group was known only from the Late Oligocene- Early Miocene in the Indo-Pacific province (but not Europe), except for some disputed occurrences in North Borneo. Tan Sin Hok (1937) was the first to describe the Late Eocene species *Spiroclypeus vermicularis* from beds with *Pellatispira* and other Eocene marker fossils in the upper Kutai Basin of Kalimantan. *Spiroclypeus* is now known to represent two parallel evolutionary developments, one in Late Eocene and the other within the Late Oligocene, both evolving from *Heterostegina* ancestors by the acquisition of lateral chambers (see also Lunt and Renema, 2014).

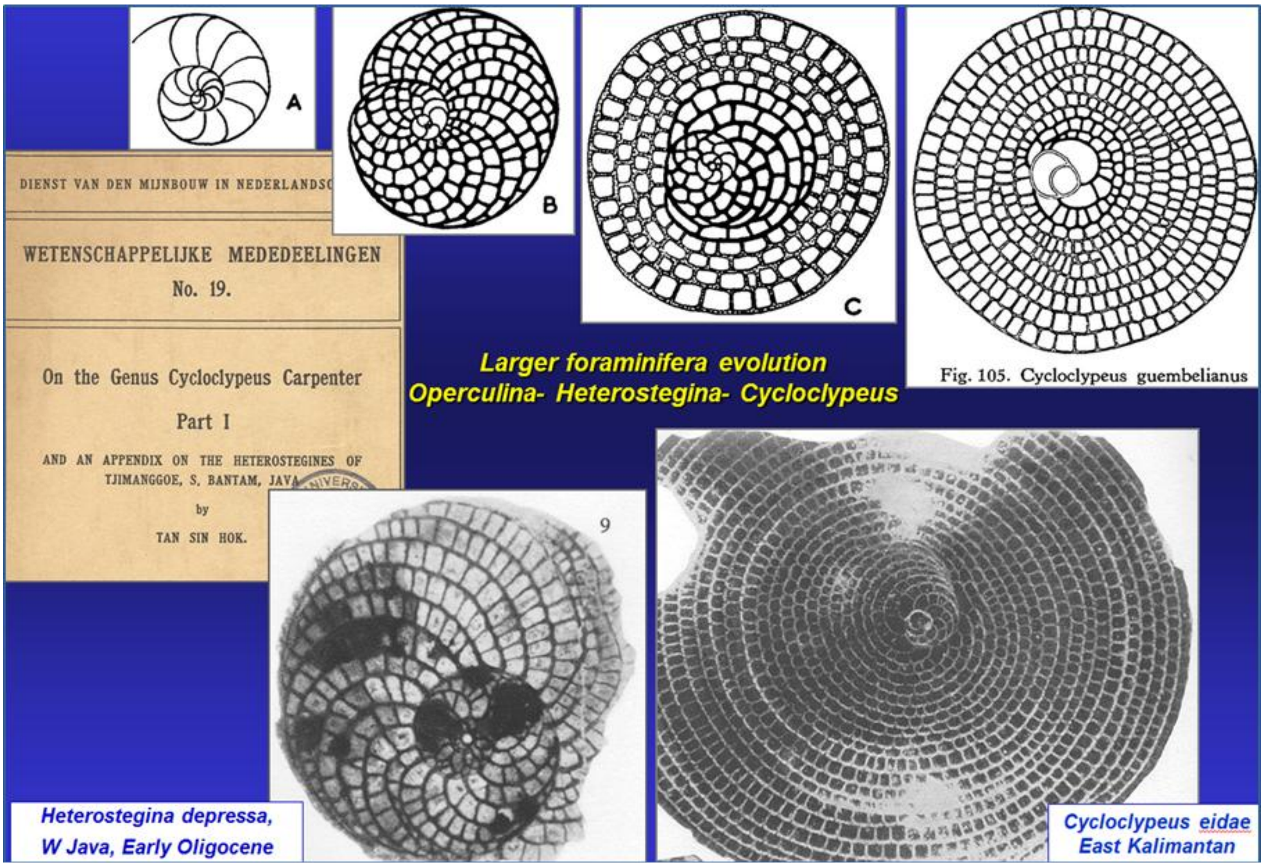


Figure 7. *Composite figure with illustrations from Tan Sin Hok (1932) On the genus* Cycloclypeus. *Drawings of horizontal sections on top row show evolution from Operculina with spirally arranged chambers (A) to Heterostegina with subdivided-spiral chambers (B) to Cycloclypeus with concentrically arranged chambers (C) and Recent C. guembelianus. Photos on bottom row Early Oligocene Heterostegina depressa from SW Java and microspheric Miocene Cycloclypeus eidae from East Kalimantan.*

4. Studies on Miogypsinidae (1936-1937)

A series of six papers in the journal 'De Ingenieur in Nederlandsch Indie' ('The Engineer in the Netherlands Indies') documents the evolution and distribution of species of the important Late Oligocene- Middle Miocene miogypsinid group. In it Tan Sin Hok documented the evolution from a small benthic *Rotalia* species to primitive *Miogypsinoides* in the Late Oligocene by the development of partial concentric growth of chambers. This is followed by a gradual reduction in the number of spiral chambers prior to concentric growth (*Miogypsinoides complanata* to *M. bantamensis* to *M. dehaartii*) (Figure 9). At the start of the Miocene, miogypsinids starts to acquire lateral chambers, which then defines them as members of the genus *Miogypsina* (Figure 8). The main Early-Middle Miocene *Miogypsina* lineage is further subdivided into evolutionary stages of successively shorter initial spiral nepionic stages (*Miogypsina gunteri- M. tani- M. globulina- M. cushmani* or *M. indonesiensis- M. antillea*) (Figure 9).

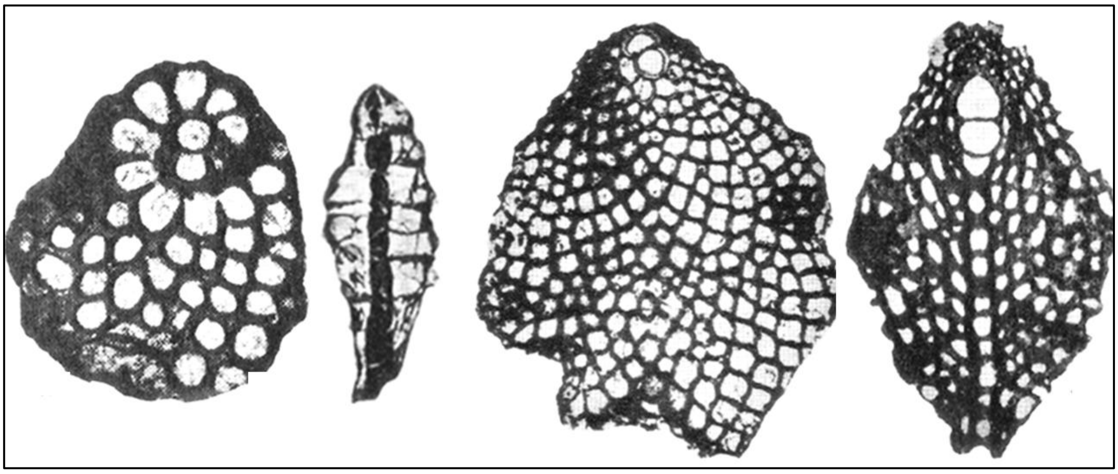


Figure 8. *Left to right: 1. Miogypsinoides bantamensis Tan 1936- horizontal section, 2. Miogypsinoides- vertical section;3. Miogypsina kotoi- horizontal section, 4. Miogypsina musperi Tan- vertical section (all from East Kalimantan).*

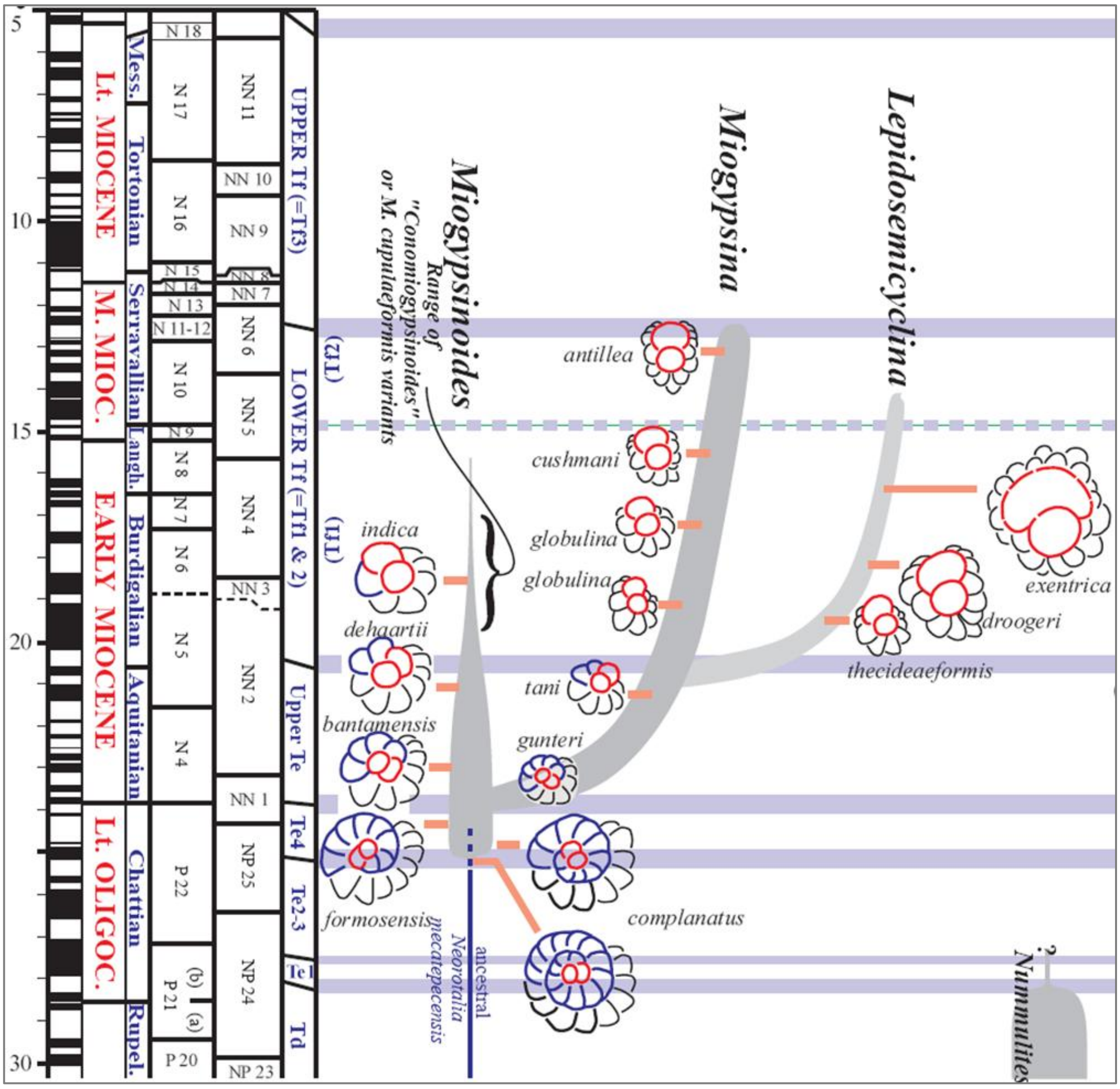


Figure 9. *Schematic view of Late Oligocene-Middle Miocene evolutionary development of miogypsinid embryonic stages, mainly based on work of Tan Sin Hok (from Lunt and Allan 2004).*

5. Larger Foram Zonation and the 'Letter Classification' (1936, 1939)

In 1936 and 1939 Tan Sin Hok published two papers on zonation of larger foraminifera, in which he was critical of the latest version of the 'East Indies Letter Classification' as proposed by Leupold and Van der Vlerk (1931). He questioned the validity of certain zonal definitions, like Top *Assilina* = Top Ta, Base *Lepidocyclina* = Base Td, base *Spiroclypeus* = base Te2, base *Miogypsina* = base Te5, etc. Tan's objections are partly valid, but despite these, the Letter Stage zonation has held up quite well as a 'first-pass' zonation and age interpretation tool for Indonesian limestones.

6. Evolution and the phylomorphogenetic classification of larger foraminifera

In and after 1936 Tan further elaborated the principle of 'nepionic acceleration' in several lineages of larger foraminifera. It states that in successive populations the ancestral initial stage of spirally-arranged chambers becomes progressively shorter, and the concentric growth stage is reached progressively earlier in the ontogeny.

These well-documented evolutionary trends formed the basis of Tan's 'phylomorphogenetic analysis' approach to Cenozoic larger foraminifera classification and zonation. Instead of classifying foraminifera into morphotypes populations can now be characterized based on evolutionary development of the embryonic stages. Instead of names populations may now be characterized by measurements or counts of parameters that characterize the embryonic chamber arrangements. These parameters show consistent changes through time, which then allow much finer biostratigraphic refinement than the popular 'Letter Classification'. These parameters are also independent of paleoenvironmental factors, which is important because a 'base' or a 'top' of a larger foram genus/species in a stratigraphic profile is rarely its true evolutionary appearance or extinction level, but is usually marks a change in facies.

Although subsequent workers refined and modified the work started by Tan Sin Hok (mainly by Dutch Schools headed by Van der Vlerk in Leiden, Drooger in Utrecht and MacGillavry in Amsterdam), the basic trends identified by Tan remained unchanged. I.M. van der Vlerk was a good example of a larger foram specialist who changed his approach to *Lepidocyclina* after Tan Sin Hok's work, evolving from the traditional naming of species based on morphologic types in the 1920's to characterizing lepidocyclinid populations by measured parameters of the embryon in the 1950's and later (Van der Vlerk (1955, 1959), Van der Vlerk and Gloor (1968)). The main contributions of modern workers include improved calibrations of larger foram zones and evolutionary stages to other biozonations like planktonic foraminifera and to the standard time scale.

FINAL THOUGHT

The 'Modern Paleontology' of Tan Sin Hok: where did it go?

Mohler (1938) wrote a glowing review of Tan Sin Hok's ongoing larger foraminifera work. Translated from German, he wrote "*Each insightful paleontologist will agree that the hitherto followed traditional method of species identification must be abandoned unconditionally in favor of the evolutionary-morphogenetic method. The old method will not lead to progress, but will at best complicate the nomenclature. It is now no longer only about an inventory of foraminifera in sediments, but about a direct phylogenetically oriented chronology....The modern paleontologist will gradually be liberated from the shackles of purely descriptive systematics. The aim of paleontologists is not only in distinguishing and describing new systematic units, but to find, develop and interpret laws...to complete deciphering of the essence fossil documents. The future and development of foraminifera paleontology lies solely in morphogenetic phylogenetic, biostratigraphically-paleontologic analysis and synthesis of fossils*"

Unfortunately, the Tan Sin Hok approach of biometrically classifying larger foram populations has not been universally followed, except by the Dutch micropaleontology 'schools' and occasional other workers like Papp and Kupper in Austria and Chaproniere in Australia. British, Japanese, American, etc. workers tended not to think in these new terms. This is probably not because of negative perceptions of the validity of Tan's approach, but mainly because most his work was relatively inaccessible to much of the world outside The Netherlands and Netherlands Indies, due to languages in which most papers were written (Dutch, German) and to the limited distributions of the journals in which they were published. Another limiting factor is undoubtedly the time-consuming preparation of a statistically significant number of oriented thin sections required for this type of analysis.

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