State of knowledge on marine palynology in Indonesia

To cite this article: S H Nugroho 2018 IOP Conf. Ser.: Earth Environ. Sci. 118 012012

View the article online for updates and enhancements.
State of knowledge on marine palynology in Indonesia

S H Nugroho

1 Research Centre for Deep Sea, LIPI, Ambon, Indonesia
E-mail: sept006@lipi.go.id

Abstract. Pollen analyses of marine sediments contribute to reconstructions of the vegetation and climate, as well as to environment changes and human-environment interactions, which is reflected in marine sediments of Indonesian waters. Furthermore, factors controlling pollen deposition are of particular importance, like in the Indonesian region where the whole climate system is driven mostly by the monsoon reversal. In this paper, I review some palynology studies in Indonesia, and I found out that there were not any marine pollen studies during the Last Glacial – Holocene in Indonesia area, especially in the Eastern Indonesia. Review results show that during that time, although temperatures were lower, there were differences on humid-arid climate indications in each region which were characterized by discrepancy vegetation. Detailed analysis of past environmental, climate and land use history in the Indonesian region is essential to obtain better understanding of human-environment relationships and to prevent uncertainties in future development of the region.

1. Introduction

Palynology is a scientific study of pollen grains and spores. It is also called palynomorphs, a study of all organic-walled microfossils [2]. The word “Palynology”, first announced by Hyde and Williams in 1944, comes from the Greek language “palunein” meaning to sprinkle or scatter, and the Latin word “pollen” meaning to flour or dust [1]. The characteristics of pollen and spores are that they are microscopic and essentially unable to be destroyed. The pollen and spores are easily used to identify plant parts found in adjacent soils and water bodies. Pollen grains are produced by seed plants (Spermatophytes), and spores are produced by seedless plants, mosses, and ferns. The size of Pollen and spores grain ranges from around 10 to more than 200 microns.

In geology and paleobotany, palynology has a much broader meaning because it observes pollen grains obtained from sediments [1]. Palynomorphs in marine sediments incorporate natural remains related to pelagic production, for example, cysts of dinoflagellates, phycoma of prasinophytes, lorica and spores of tintinnids, and copepod eggs [1]. They additionally incorporate remains of benthic organisms, which act outstandingly as natural linings of benthic foraminifers and the amoebians. Marine sediments of neritic zones contain allochthonous palynomorphs beginning from the adjacent terrestrial vegetation and the freshwater biota, i.e., pollen grains of spermatophytes, spores of pteridophytes, bryophytes and fungi, organic walls of chlorococcales, etc. Palynomorphs may also incorporate reworked microfossils coming from the erosion of sedimentary outcrops [1].

Pollen and spores are valuable proxies for reconstructing vegetation change on the continent because of their good preservation and abundant presence in most terrestrial and marine sediments [3,4]. Their content in marine sediments can reflect both natural and anthropogenic induced vegetation changes as well as variations in runoff rates [5]. The sedimentary charcoal content can be used to provide information about the fire history of an area or region [6]. The fire-ecology can be studied when it is compared to palynological based vegetation reconstructions [7,8].
Several marine environment studies on the late Holocene in Indonesia (Figure 1) are available from the Banda Sea [9-15], Molucca Sea [16], Sulu Sea [17], Celebes Sea [11], Mahakam Delta, Kalimantan [18], the Makassar Strait [19,20], the western [21,22] and eastern Indian Ocean [23-26] and off Sumatra [27,28]. However, information of the Java Sea is almost missing [29, 30]. Nevertheless, there is only a little marine core used in palynological studies in Indonesia and almost all studies derived from eastern Indonesia, as the studies from the Java Sea are absent.

Marine pollen studies are very important to reconstruct paleoclimates and to identify links between signals at sea and on land [31]. They pay attention to the relationship between sea and land, as they are crucial for such areas with monsoon climate as in Indonesia. The study can give essential information on continental vegetation and climate dynamics, as well as the direction of ocean currents and predominant wind, and it can show an alternative palaeoecological information on relatively dry areas. It has been described that detailed interpretations of palaeoecological are good for these regions by comparing marine core spectra and core top samples [32,33]. More study on palynological should be held due to its importance, since limited critical work was undertaken on a marine palynology for Indonesian paleo-environmental and paleo-climatic during Last Glacial. The study will provide information and data of climate change that occurred in the past, which can be a guide to understand the present climate conditions and predict the future ones. In this case, information and data play an important role in monitoring process of climate change, both locally and globally. Furthermore, the next research should attempt to fill the gap by making a comparative analysis of marine pollen records and stable isotope composition. The research is intended to leverage insights, knowledge and understanding of environmental and climate changes especially during the Last Glacial to Holocene.

2. Distribution of pollen and spores in the marine sediments

Some factors need to be investigated for explaining the assemblages of pollen and spore in the marine sediment, such as the pollen source area, flowering periods, distance to the pollen producing vegetation, river discharge, wind fields, marine currents and the time for pollen and spore transportation [34]. In the interpretation of pollen data, some aspects must be captured into account; these include source of
production of pollen, its transport to the sea and through the water column, displacement by ocean currents, sedimentation processes, fossilization and accumulation in the sediment [34]. Composition and production of pollen grains depend on the vegetation source. The pollen distribution pattern is greatly influenced by the distance from the source and the marine localities under study. The distribution of various types of pollen is individually impressed by production and transport mechanisms, due to the diversity in the source area, dispersal and production [35]. Thus, the distribution of different pollen taxa may control different causes and cannot be interpreted all in the same way.

Pollen grains are transported by wind and/or water currents to the ocean (Figure 2), and in the water column they sink to the ocean floor where they become incorporated in surface sediments [36]. Most pollen grains found in marine sediments have been transported over long distances (more than 100 km) and thus only represent an extremely small fraction of the pollen production at the source area [36]. Only taxa that release pollen grains in high quantities (abundant taxa and/or good pollen producers) provide us with a useful relationship between the position and extension of pollen source areas and pollen distribution patterns in marine sediments. In the surface layer of the sea, pollen grains and other small particles e.g. diatoms are lumped into aggregates (faecal pellets and marine snow) during the biological particle cycle [37]. These processes strongly increase the settling velocity of small particles to more than 100 m per day, enabling them to reach the sea bottom within short time [35].

Study of pollen and spores on recent sediments of continental shelves indicate the influence of both rivers input and sorting of particles, whereby the deposition of pollen grains can be distinguished to that of fine to medium silt-sized, because of its density and size [38].

![Figure 2. Model of pollen transport that occurred in the northwest African continent to offshore marine sediments [36]](image-url)

3. Marine palynology research in Indonesia
Since the early 1990s, study of pollen diversity in Indonesia is provided only in two publications, a study on the Late Pleistocene and Holocene vegetation in West Java [39] and an overview of pollen morphology as the main taxa in the Southeast Asian archipelago [40]. Regarding the marine pollen in the Indonesian Archipelago, available data and information are still very restricted. It is definite that marine palynology in Indonesia started to develop only in recent decades. The first study on the marine palynology in the region was from surface sediments in the Banda Sea [9], in which ‘a series of 27 pollen and spore types are identified and informally categorized’. However, the paper does not explain any analytical for palaeoecology. First pollen analyses for the Indonesian region were published at the early 1990s [11,17] and interpreted the prospective of marine palynology to reconstruct the vegetation in this region.
Regarding the information above, there are only several papers published in Indonesia. For example, publication in the Banda Sea area in 1989 and 2000 [9,13], Celebes Sea, in 1991 and 2000 [11,13], Molucca Sea in 1993 [16], Sulu Sea in 2003 [17], Mahakam Delta, Kalimantan in 1988 [18], Makassar in 2004 [19], as well as off Sumatra in 2010 and 2012 [27,41]. Previous marine palynology studies, mostly in the eastern Indonesia and parts of the northern Australia, showed significantly increased open forest (grassland) vegetation and a low of temperature and humidity for Southeast Asia during glacial periods [13,16]. Moreover, some studies indicated that the pollen settled in Indonesian Waters had been possibly transported from adjacent areas (e.g., northern Australia, southern China) that were an arid land during the LGM. Other study in Sumatra and West Java Highlands showed the decrease of forest altitudinal zones and the abundance increase of gymnosperms at moderate elevation (1300–1500 m a.s.l.) which implied a considerable fall of annual temperature down to 7°C lower than present day, but no dryness was observed during Last Glacial period (39,42,43). This highly variable character of the area reported that the northern shelf of the South China Sea experienced drier, colder conditions, while the Sunda shelf in the southern South China Sea (adjacent to Borneo) was continuously vegetated by a tropical humid rainforest during the LGM [44]. While the whole region cooled, the northern parts were more arid and the southern parts were at least as moist as they are today. Similar evidence for cooler and humid conditions in the equatorial region of South America during the LGM are now becoming widely accepted [45]. The result suggests a global distribution of this climatic regime.

As reviewed, there were not any marine pollen studies during the Last Glacial – Holocene in Indonesia area, particularly in the Eastern Indonesia. During the time, temperatures were lower, but there were differences on humid-arid climate indications in each region which characterized by discrepancy vegetation. The stable isotopic composition of vascular plant fatty acids (δ13CFA) and pollen data from a core indicated expansion of C4 herbs during the last glaciation, implying enhanced aridity and water stress during the dry season [46]. The previous research results are important and topical because limited critical work had been undertaken on a marine palynology for Indonesian paleoenvironmental and paleo-climatic during Last Glacial - Holocene. Future research attempts to fill the gap by making a comparative analysis between marine pollen records and stable isotope composition. These researches are intended to leverage insights, knowledge and understanding of environmental and climate changes especially during the Last Glacial to Holocene. Furthermore, it could be a guidance on knowing present climate conditions and on predicting future climate.

Referring to the study on the distribution of modern pollen in the surface sediments in the South China Sea off Borneo, it has been interpreted that pollen is mainly transported from the south islands by rivers, e.g. Borneo [47,48]. Pollen grains discovered in the modern South China Sea are very little because of the long-distance transport from the coast [49]. Analytical work for pollen in the box-core samples, obtained from deep-sea surface sediments along a three transects in the Banda Sea [50], showed that assemblages of palynodebris, palynomorphs and diffuse organic aggregates essentially consist of zooplanktonic and terrigenous constituents. Analytical of pollen on box-core sediment was obtained by transect from the south-eastern Indonesian waters [51]. The author indicated general trends in pollen transport, and interpreted that pollen grains and spore tend to have reduced in size with increasing distance from the shore line. In spite of the involvement of vegetation types and patterns of pollen transport in the area, it was proven that the distribution of taxa and major vegetation characters are well reflected in marine deposits. Low percentages of mangroves were interpreted as their proportion in the source area tend to reduce along with distance to shore line [13,35,47,51].

4. Conclusions
Study of marine palynology are very important to reconstruct palaeovegetation and palaeoenvironment. However, in the interpretation of pollen data, several aspects must be taken into account: these include the source of production of pollen, its transport to the sea and through the water column, displacement by ocean currents, sedimentation processes, fossilization, and accumulation in the sediment. Marine palynology studies in the Indonesian waters are still very limited and only a few are available for robust interpretation of the regional environmental and climatic changes in this vast and complex region. The
review results showed that there were not any marine pollen studies during the Last Glacial – Holocene in Indonesia area, especially in the Eastern Indonesia.

Acknowledgments
I acknowledged comments and revisions from the reviewer and the editor of GCGE2017.

References
[1] De vernal A 2009 Marine palynology and its use for studying nearshore environments IOP Conf. Series: Earth & Env. Sci. 5 012002
[2] Morley R J 1990 Short Course Introduction to palynology with emphasis on Southeast Asia (Purwokerto: Fakultas Biologi UNSOED)
[3] Dupont L M 1999 Pollen and spores in marine sediments from the East Atlantic. A view from the ocean into the African continent (Use of Proxies in Paleoceanography: Examples from the South Atlantic) eds Fischer G, Wefer G (Berlin Heidelberg: Springer Verlag)
[4] Anshari G, Kershaw A P and van der Kaars S 2001 A Late Pleistocene and Holocene pollen and charcoal record from peat swamp forest, Lake Sentarum Wildlife Reserve, West Kalimantan Indonesia Palaeogeogr Palaeoclimatol. Palaeoecol. 171 213-28
[5] Donders T H, Wagner-Cremer F, Visscher H 2008 Integration of proxy data and model scenarios for the mid Holocene on set of modern ENSO variability Quat. Sci. Rev. 27 571-79
[6] Higuera P E, Gavin D G, Bartlein P J and Hallet J D 2010 Peak detection in sediment-charcoal records: impacts of alternative data analysis methods on fire-history interpretations Int. J. Wildland Fire 19 996-1014
[7] Colombaroli D, Marchetto A and Tinner W 2007 Long-term interactions between Mediterranean climate, vegetation and fire regime at Lago di Massaciuccoli (Tuscany, Italy) J. Ecol. 95 755–70
[8] Kaltenrieder P, Proacci G, Vanniere B, and Tinner W 2010 Vegetation and fire history of the Euganean Hills (Colli Euganei) as recorded by Late Glacial and Holocene sedimentary series from Lago dalla Costa (northeastern Italy) Holocene 20 679–95
[9] Van Waveren I M 1989 Palynofacies analysis of surface sediments from the northeastern Banda Sea (Indonesia) Neth J Sea Res 24 501-09
[10] Ahmad, S.M., Guichard, F., Hardjawidjaksana, K., Adisaputra, M.K., Labeyrie, L., 1995. Late Quaternary Paleoceanography of the Banda Sea Mar. Geol. 122 385-97
[11] Van der Kaars S 1991 Palynology of eastern Indonesian maritime piston-core: a late Quaternary vegetational and climatic record for Austral-Asia Palaeogeogr. Palaeoclimatol. Palaeoecol. 85 239-302
[12] Van der Kaars S and Dam R 1997 Vegetation and climate change in West Java, Indonesia during the last 135,000 years Quat. Int. 37 67-71
[13] Van der Kaars S, Wang X, Kershaw A P, Guichard F and Setiabudi D A 2000 A Late Quaternary palaeoecological record from the Banda Sea, Indonesia: patterns of vegetation, climate and biomass burning in Indonesia and northern Australia Palaeogeogr. Palaeoclimatol. Palaeoecol. 155 135–53
[14] Van der Kaars S 2001 Pollen distribution in marine sediments from the south-eastern Indonesian waters Palaeogeogr. Palaeoclimatol. Palaeoecol. 171 341–61
[15] Spooner M I, Barrows T T, De Deckker P and Paterner M 2005 Palaeoceanography of the Banda Sea and Late Pleistocene initiation of the Northwest Monsoon Glob. Planet. Change 49 28-46
[16] Barmawidjaja B M, Rohling E J, van der Kaars S A, Vergnaud G C, and Zachariasse W J 1993 Glacial conditions of the northern Molucca Sea region (Indonesia) Palaeogeogr. Palaeoclimatol. Palaeoecol. 101 147-67
[17] Beaufort L, de Garidel-Thorot T, Linsley B, Oppo D and Buchet N 2003 Biomass burning and oceanic primary production estimates in the Sulu Sea area over the last 380 kyr and the East Asian monsoon dynamics Mar. Geol. 201 53-65
[18] Caratini C and Tissot C 1988 Paleogeographical evolution of the Mahakam Delta in Kalimantan, Indonesia during the Quaternary and Late Pliocene Rev. Palaeobot. Palynol. 55 217-228
[19] Yulianto E, Sukapti W S, Rahardjo A T, Noeradi D, Siregar D A, Suparan P and Hirakawa K 2004 Mangrove shoreline responses to Holocene environmental change, Makassar Strait, Indonesia Rev. Palaeobot. Palynol. 131 251-268
[20] Visser K, Thunell R, Goni M A 2004 Glacial–interglacial organic carbon record from the Makassar Strait, Indonesia: implications for regional changes in continental vegetation Quat. Sci. Rev. 23 17–27
[21] Kuhntert H, Kuhlmann H, Mohtadi M, Meggers H, Baumann K-H and Pätzold J 2014 Holocene tropical Western Indian Ocean sea surface temperatures in covariation with climatic changes in the Indonesian region Paleoeceanography 29 423–37
[22] Niedermeyer E M, Sessions A L, Feakins S J, and Mohtadi M 2014 Hydroclimate of the western Indo-Pacific Warm Pool during the past 24,000 years Proc. Natl. Acad. Sci. U.S.A. 111 9402-06
[23] Wang X, Van der Kaars S, Kershaw A P, Bird M and Jansen F 1999 A record of vegetation and climate through the last three glacial cycles from Lombok Ridge core G6-4, eastern Indian Ocean, Indonesia Palaeoecogr. Palaeoclimatol. Palaeoecol 147 241–56
[24] Mohtadi M, Steinke S, Lückge A, Groeneveld J and Hathorne E C 2010 Glacial to Holocene surface hydrography of the tropical eastern Indian Ocean Earth Planet. Sci. Lett 292 89-97
[25] Mohtadi M, Oppo D W, Lückge A, De Pol-Holz R, Steinke S, Groeneveld J, Hemme N and Hebbeln D 2011 Reconstructing the thermal structure of the upper ocean: insights from planktic foraminifera shell chemistry and alkenones in modern sediments of the tropical eastern Indian Ocean Paleoeceanography 26 PA3219
[26] Chen W, Mohtadi M, Schefuß E and Mollenhauer G 2014 Organic-geochemical proxies of sea surface temperature in surface sediments of the tropical Eastern Indian Ocean Deep Sea Res I 88 17-29
[27] Van der Kaars S, Bassinot F, De Deckker P and Guichard F 2010 Changes in monsoon and ocean circulation and the vegetation cover of southwest Sumatra through the last 83,000 years: the record from marine core BAR94-42 Palaeogeogr. Palaeoclimatol. Palaeoecol 296 52-78
[28] Van der Kaars S, Williams M A J, Bassinot F, Guichard F, Moreno E, Dewilde F and Cook E K 2012. The influence of the ~73 ka Toba super-eruption on the ecosystems of northern Sumatra as recorded in marine core BAR94-25 Quat. Int. 258 45-53
[29] Boely Y T, Lining M, Cremoux J L, Petit D, Potier M, Nurhakim S and Sujuaneto S 1991. Estimation of the abundance of pelagic fish in the central part of the Java Sea (Indonesia) (Indonesia: Marine Fisheries Research Institute) pp 58-107
[30] Suryantini I A, Kuncoro I A, Saputri D and Helfinalis F 2011 Marine Sediment Characteristics at Karimun Java Sea Based on Stratigraphic Profile Analysis, Total Suspended Solid (TSS) and Grain Size Analysis (Granulometry) J. ITKT 3 26-51
[31] Van der Kaars S and De Deckker P 2003 Pollen distribution in marine surface sediments offshore Western Australia Rev. Palaeobot. Palynol. 124 113-129
[32] Hooghiemstra H 1998 Palynological records from northwest African marine sediments: A general outline of the interpretation of the pollen signal Philos. Trans. R. Soc. Lond. B 318 431–49
[33] Hooghiemstra H and Agwu C O C 1988 Changes in the vegetation and trade winds in equatorial Northwest Africa 140,000-70,000 yr BP, as deduced from two marine pollen records Palaeogeography, Palaeoclimatology, Palaeoecology 66 173-213
[34] Poliakova A, Rixen T, Jennerjahn T and Behling H 2014 Annual High Resolution Pollen and Spore Sedimentation Record off SW Java in the Indian Ocean Mar. Micropaleontol. 111 90-9
[35] Dupont L M and Agwu C O C 1991 Environmental control of pollen grain distribution patterns in the Gulf of Guinea and offshore NW-Africa Geol Rundsch 80 567-89
[36] Hooghiemstra H, Le´zine A-M, Leroy S A G, Dupont L M and Marret F 2006 Late Quaternary palynology in marine sediments: A synthesis of the understanding of pollen distribution patterns in the NW African setting Quat. Int. 148 29–44

[37] Silver M W, Shanks A L and Trent J D 1978 Marine snow: microplankton habitat and source of smallscale patchiness in pelagic population Science 201 371-73

[38] Rossignol M 1961 Analyse pollinique de sédiments marins quaternaires en Israel 1. Sédiments récents Pollen et Spores 3 303-24

[39] Stuivjs I 1993 Late Pleistocene and Holocene vegetation of West Java, Indonesia (Modern Quaternary Research in South-East Asia 12) ed Stuivjs I (Rotterdam: A. A. Balkema)

[40] Van der Kaars S A 1993 Pollen morphology of main taxa from the Southeast Asian archipelago. Unpublished internal document (Amsterdam: Institute of Earth Sciences, Free University of Amsterdam and Hugo de Vries laboratory) including 20 plates

[41] Van der Kaars S, Williams M A J, Bassinot F, Guichard F, Moreno E, Dewilde F and Cook E K 2012 The influence of the ~73 ka Toba super-eruption on the ecosystems of northern Sumatra as recorded in marine core BAR94-25 Quat. Int. 258 45-53

[42] Stuivjs I 1984 Palynological study of Situ Bayongbong, West Java (Modern Quaternary Research in South-East Asia vol 8) eds Bartstra GJ and WA Casparie (Rotterdam: A. A. Balkema) pp 17-27

[43] Stuivjs I, Newsome J C and Flenley J R 1988 Evidence for Late Quaternary vegetational change in the Sumatran and Javan highlands Rev. Palaeobot. Palynol 55 207-16

[44] Sun X, Li X, Luo Y and Chen X 2000 The vegetation and climate at the last glaciation on the emerged continental shelf of the South China Sea Palaeogeogr. Palaeoclimatol. Palaeoecol. 160 301–16

[45] Colinvaux P A and de Oliveira P E 2000 Palaeoecology and climate of the Amazon Basin during the last glacial cycle J. Quaternary Sci 15 347–356

[46] Dubois N, Oppo D W, Galy V V, Mohtadi M, van der Kaars S, Tierney J E., Rosenthal Y, Eglinton T I., Lucke A, Linsley B K. 2014. Indonesian vegetation response to changes in rainfall seasonality over the past 25,000 years Nat. Geosci DOI: 10.1038/NGEO2182

[47] Sun X and Li X 1999 A pollen record of the last 37 ka in deep sea core 17940 from the northern slope of the South China Sea Mar. Geol. 156 227–44

[48] Sun X J, Luo Y L and Huang F 2003 Deep-sea pollen from the South China Sea: Pleistocene indicators of East Asian monsoon Mar. Geol. 201 97-118

[49] Wang X M, Sun X J, Wang P X and Stattegger K 2007 A high-resolution history of vegetation and climate history on Sunda Shelf since the last glaciation Sci. China. Series D-Earth Sci. 50 75-80

[50] Van Waveren I and Visscher H 1994 Analysis of the composition and selective preservation of organic matter in surficial deep-sea sediments from a high-productivity area (Banda Sea, Indonesia) Palaeogeogr. Palaeoclimatol. Palaeoecol. 112 85-111

[51] Van der Kaars, S. 2001 Pollen distribution in marine sediments from the south-eastern Indonesian waters Palaeogeogr. Palaeoclimatol. Palaeoecol. 171 341-61