PB RATIO ANALYSIS OF FORAMINIFERA TO OBSERVE PALEOCEANOGRAPHIC CHANGES DURING HOLOCENE IN ARAFURA SEA

ANALISIS PB RASIO FORAMINIFERA UNTUK MENGAMATI PERUBAHAN PALEOSEANOGRAFI SELAMA HOLOSEN DI LAUT ARAFURA

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ABSTRACT: Arafura Sea is influenced by several climatic dynamics, it is also a part of the coral triangle that provides most of marine organism diversity of the world. Therefore, this area is an important waters that impact the climatic dynamic so its paleoceanographic changes need to be understood. For that, we analyzed the foraminiferal PB ratio from marine sediment core ARAFURA-24 with a core length of 179 cm, collected from 47.4 m water depth, combined with that of Aru-07, taken from 276 m water depth (core length 152 cm). Both sediment cores were collected from the Arafura Sea using a gravity corer on board Geomarin III. ARAFURA-24 was sub-sampling in every 20 cm interval, while Aru-07 had been prepared in every 10 cm interval. PB Ratio values from ARAFURA-24 and Aru-07 ranged from 0,56% - 7,43% and from 29,89% to 82,66%, respectively. The age model was reconstructed by ^{14}C radiocarbon dating derived from organic sediment, combined with tie points of PB ratio records. The result indicates that ARAFURA-24 has been sedimented since the last 9.7 kyr BP. PB ratio records reveal three maximum sea level rises, which are before 7.4 kyr BP, at 5.86 kyr, and after 3 kyr BP (approximately at 2 kyr BP at Aru-07). From the age model reconstruction, sedimentation during the last 3 kyr BP was relatively slower than that in the older period. It can be concluded that the foraminiferal PB ratio during Late Holocene was not significantly impacted by sedimentation rate (hence detrital influence), in contrast, during Mid-Holocene detrital influence had more impact on the PB ratio record.

Keywords: Arafura Sea; foraminifera; PB ratio analysis; paleoceanographic changes; Holocene

ABSTRAK*: Laut Arafura dipengaruhi oleh beberapa dinamika iklim, dan juga merupakan bagian dari segitiga terumbu karang yang menyediakan sebagian besar keanekaragaman organisme laut dunia. Oleh karena itu, daerah ini merupakan perairan penting yang mempengaruhi dinamika iklim sehingga perubahan paleoceanografinya perlu dipahami. Untuk itu, kami menganalisis PB rasio foraminifera dari inti sedimen laut ARAFURA-24 dengan panjang inti 179 cm, diambil dari kedalaman air 47,4 m, dikorelasikan dengan inti sedimen Aru-07, yang diambil dari kedalaman air 276 m (panjang inti 152 cm). Kedua inti sedimen diambil dari Laut Arafura dengan menggunakan penginti jatuh bebas dari kapal Geomarin III. ARAFURA-24 dicuplik setiap interval 20 cm, sedangkan Aru-07 dicuplik setiap interval 10 cm (telah dilakukan oleh peneliti terdahulu). Nilai PB Ratio dari ARAFURA-24 dan Aru-07 masing-masing berkisar antara 0,56% - 7,43% dan dari 29,89% hingga 82,66%. Model umur direkonstruksi dengan*

penanggalan radiokarbon ^{14}C yang diukur dari sedimen organik, dikorelasikan dengan titik ikat nilai PB rasio. Hasilnya menunjukkan bahwa ARAFURA-24 telah terendapkan sejak 9,7 kyr BP. perhitungan PB rasio mengungkapkan tiga kenaikan permukaan laut maksimum, yaitu sebelum 7,4 kyr BP, pada 5,86 kyr, dan setelah 3 kyr BP (sekitar 2 kyr BP di Aru-07). Dari rekonstruksi model umur, sedimentasi selama 3 kyr BP terakhir relatif lebih lambat dibandingkan dengan periode waktu yang lebih tua. Dapat disimpulkan bahwa PB rasio foraminifera pada masa Holosen Akhir tidak terlalu dipengaruhi oleh laju sedimentasi (karena pengaruh detrital), sebaliknya pada masa Mid-Holosen pengaruh detrital memberikan dampak lebih besar terhadap perhitungan PB rasio.
Kata Kunci: *: Laut Arafura; foraminifera; analisis PB rasio; perubahan paleoseanografi; Holosen*

INTRODUCTION

Indonesian waters are known as a "mixed-master" that modify water mass derived from both north and south Pacific Oceans to feed the Indian Ocean (Gordon, 2005). The mixing process occurs in every sill of Indonesian water resulting in low salinity water characteristic of the Indonesian throughflow (ITF) that alters the Indian Ocean (Gordon et al., 2003; Talley and Sprintal, 2005). The ITF originated from both North and South Pacific Water, within the Indonesian sea are modified by vertical tidal mixing, upwelling, air-sea fluxes and freshwater fluxes before being exerted to the Indian Ocean (Ffield and Gordon, 1992; Koch-Larrouy et al., 2007). Intense vertical mixing has been observed particularly at Lifamatola Passage, over the Halmahera sill, the Aru Basin, Seram Sea, and between the Flores and western Banda Sea basins (Talley and Sprintal, 2005 and references therein). The ITF within Indonesian waters also interact with ENSO and Asian monsoon (Gordon and Tillinger, 2010) (Figure 1). As a consequence, a relatively isohaline Indonesian sea profile from the thermocline to near the bottom was formed altering the Indian Ocean (Ffield and Gordon, 1992; Waworuntu et al., 2000; Gordon et al., 2003; Koch-Larrouy et al., 2007).

Arafura, Timor, and the Banda Sea are known to have a high productivity level as sources for major fisheries, due to the upwelling process particularly induced by the northern part of the Sahul continental shelf (Wyrtki, 1961; Ilahude et al., 1990; Atmadipoera et al., 2009; Alongi et al., 2011; Basit et al., 2022). Upwelling in the Arafura Sea is assumed as seasonal coastal upwelling that mostly occurs during the southeast monsoon (Wyrtki, 1961). Southeasterly monsoon wind leads to the westward and southwestward flow of the surface layer, thus colder water that is deeper and rich in nutrients would be upwelled to fill the void in the surface. As a consequence, it provides a large number of nutrients and food for marine organisms so that increases productivity. In contrast, during the Northwest monsoon (December-February), northwesterly wind induces downwelling in the Arafura and Banda Sea that allowing deep ocean oxygenation (>200 m depth), providing dissolve oxygen for benthic organism (van der Zwaan et al., 1990; Basit et al., 2022). In addition to that Arafura Sea is also a part of the Coral Triangle, the epicenter of all marine organism and diversity, Indonesia is considered the largest coral reef area in Southeast Asia (Allen & Werner, 2002; Coral Triangle Initiative, 2014). However, the Arafura Sea is also considered the most endangered tropical coastal and marine ecosystems in the world (Alongi et al., 2011).

The Arafura Sea also provides non-living marine resources, particularly oil and gas resources (e.g. Abadi and Tangguh gas field, Roberts et al., 2011). It is also a part

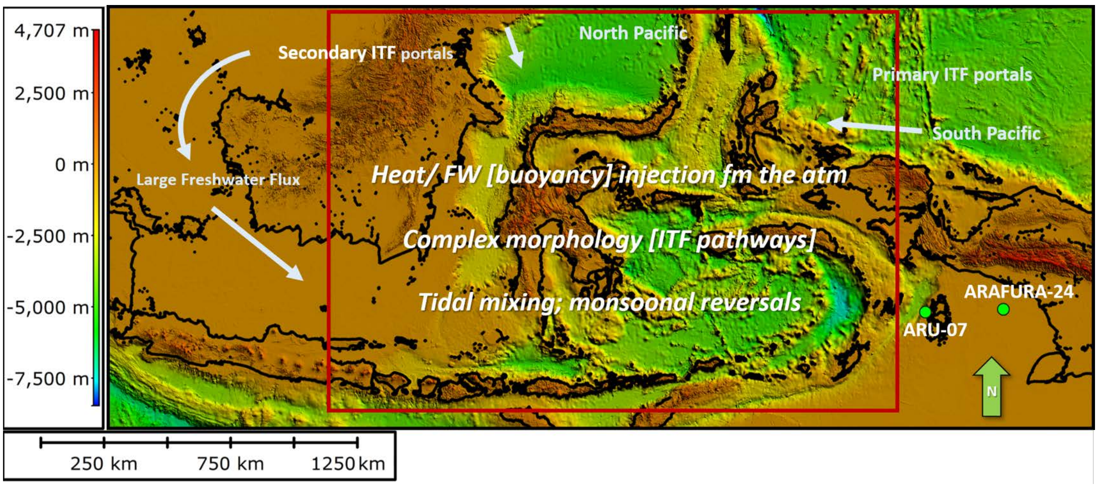

Figure 1. The Indonesian Throughflow routes, western route via South China Sea into Java Sea carrying freshwater altering the ITF in the eastern route at the Banda Sea. Green circle is the sediment core for this study (Modification from Gordon et al., 2005; 2010), on Indonesian bathymetric map (http://batnas.big.go.id/)

of important shipping routes, connecting some Australian ports to the Southeast and Northeast Asian ports, and the northern Pacific Ocean, and a major part of the maritime boundary between Australia, Indonesia, Timor Leste and Papua New Guinea (Alongi et al., 2011). We noticed that the Arafura Sea greatly impacts various aspects, including biodiversity, oceanography, economy and politics, that draw attention from many parties in the world. Therefore, we study marine sediment core from the Arafura Sea, to understand the paleoceanographic condition of eastern Indonesia, by studying PB ratio of marine organisms, particularly foraminifera.

Foraminifera is a single marine organism that exhibits a high response to environmental changes, hence it is a great proxy for paleoceanographic reconstruction and has been widely used in paleoceanography and paleoclimatological study. It is found very abundant in marine sediments, with low cost and simple sample preparation. Geochemistry of foraminiferal shells is the most basic for paleoclimatological proxy, particularly their shells oxygen isotope record which coupled with their Mg/Ca ratio value, may represent seawater temperature and salinity, revealing the air-sea interaction and their correlation to the global climate (e.g. Anand et al., 2008; Elderfield & Ganssen, 2000; Gustiantini, 2018; Hollstein et al., 2017; Zuraida et al., 2009). Furthermore, foraminiferal assemblages also provide comprehensive data for determining paleoceanographic reconstruction. Singh et al. (2017) reconstructed fertility variation in the Sulu Sea from foraminiferal assemblages during 40 kyr BP, resulting in eutrophic conditions during 26 – 17 kyr and Holocene. Ding et al. (2006) revealed significant differences in foraminiferal assemblages group occupying different marine conditions (Java upwelling region, Java – Banda region, Indian monsoon Sumatra region, Timor region, and NW Australian margin region). The previous study of paleoceanographic reconstruction of Arafura Sea derived from foraminiferal assemblages (Gustiantini et al., 2018, will be discussed further later) also resulted in a significantly different group of foraminifera representing distinctive different paleoceanographic condition during older than 3.9 ka BP, 3.9 – 2 ka BP, and younger than 2 ka BP. PB ratio analysis is one statistical analysis of foraminifera that calculate the percentage of planktonic type to the total of benthic and planktonic foraminifera (in %). PB ratio has been known related to water depths (Phleger and parker, 1951; van Marle et al., 1987; van der Zwaan et al., 1990). Furthermore, the PB ratio is also known related to productivity and organic matter flux (Berger and Diester-Haass, 1988; van der Zwaan et al., 1990), and in modern studies, the PB ratio is considered a

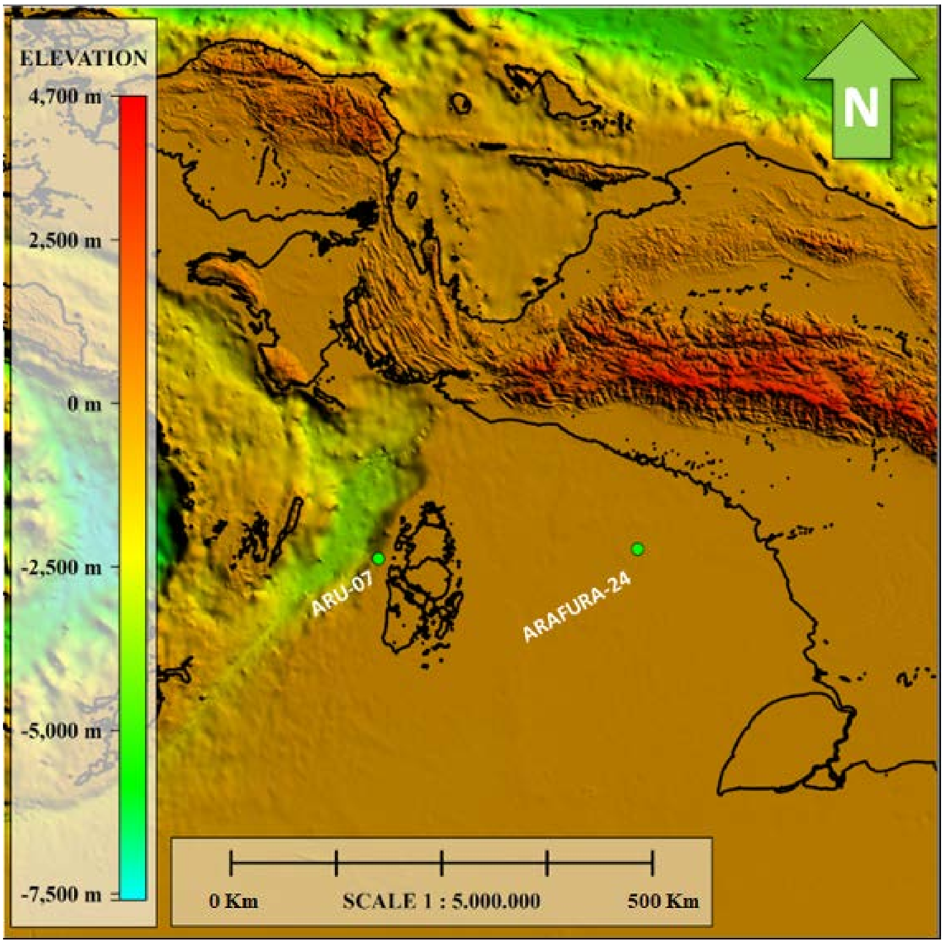

Figure 2. The location of marine sample sediments (ARAFURA-24 and ARU-07)

potential proxy for sea ice indicator (Polyak et al., 2013; Almgren, 2020).

METHODS

This research was analyzed from one marine sediment core ARAFURA-24 (Figure 2). This marine sediment sample was taken from a water depth of 47.4 meters with a core length of 179 cm, located in the northeast of Aru Island, Arafura waters (coordinate of 136° 21' 54.81" E and 5° 49' 38.79" S). The marine sediment core was collected by using a gravity corer on board Geomarin III Vessel in 2017, by the investigation team of the Marine Geological Institute. To have a better comprehension result, we also analyzed marine sediment core ARU-07, which have been collected from nearby location (coordinate of 134° 00' 33.6" E and 5° 55' 51.59" S), from a water depth of 276 meters with a core length of 152 cm, located on the west of Aru Island, Arafura. Foraminiferal assemblages from this marine sediment core has been published (Gustiantini et al., 2018).

Before further analysis, sediment core ARAFURA-24 was sampled at 20 cm intervals using syringe method, which gives a total of 10 subsamples that must be prepared first. The preparatory stage was continued by washing with flowing water and sieved through a 4 phi sieve. Furthermore, the samples were dried at < 60° C temperature for 24 hours. Afterward, we started to pick foraminifera (± 300 individu) from the sample using a binocular microscope, at this stage the separation between foraminifera from other grains was carried out using a small brush. If the sample volumes are too large, the samples were firstly splitted several times until they contained only approximately 300 individu of foraminifera, picked foraminiferal test will be multiplied by the split number afterwards. The number of foraminiferal abundant was then applied to the planktonic benthic ratio (PB ratio) equation:

$$\textbf{PB ratio (\%)} = P/(P+B) \times 100\%$$

P = Total Planktonic,

B = Total Benthic.

PB ratio is the planktonic percentage of the total foraminiferal community. PB ratio of foraminifera gives information about seawater depth, which at normal marine conditions, the deep water PB ratio will have a higher value than in shallower water (Table 1).

The geochronology of the sediment was estimated based on radiocarbon AMS ^{14}C dating, analyzed from organic samples collected from 1 sample horizon (163-179cm). It was carried out at the Quaternary laboratory of Center for Geological Survey, Ministry of Energy and Mineral Resources, and has been described in Tim Arafura report (2017).

To refine the age model, we analyzed PB ratio data from sediment core ARU-07, located to the west of the studied core, whose age model has been reconstructed (Gustiantini et al., 2018). The Geochronology of ARU-07 was also estimated based on radiocarbon AMS ^{14}C dating, and also analyzed on organic sediments. The calendar age from ARU-07 was calculated by CALIB 7.0.4 (in 2018, Stuiver et al., 2018, the latest version is Calib 8 which uses the 2020 international dataset), an online software by Stuiver and Reimer (1993) can be downloaded at http://calib.org/calib/download/. This software used the Intcal13 calibration data set (Reimer et al., 2013, in conjunction with Stuiver and Reimer, 1993). Intcal13 is commonly used for the no-marine sample, derived calendar age is presented in Before Present (BP), where "present time" is defined as AD 1950 (Currie, 2004; Reimer et al., 2013). According to the age model, ARU-07 was deposited since the last 8000 BP (Gustiantini et al., 2018).

PB ratio data from this studied core ARAFURA-24 will be correlated to that of the ARU-07 sediment core. We correlated similar events of both PB ratio pattern, to get the age derived from the ARU-07 age model. The calendar age of those similar events will be used as a tie point. Combined with radiocarbon dating data of this core, we further interpolate and extrapolate the age to reconstruct the age model.

Table 1. Environmental Classification based on PB ratio (modified from Grimsdale and Morkhovern, 1955 in Manuhuwa et al., 2021)

PB RATIO	ENVIRONMENT	Depth
< 20 %	Inner Neritic	0 – 50 m
20 – 60 %	Middle Neritic	50 -100 m
40 – 70 %	Outer Neritic	100 – 200 m
> 70%	Upper Bathyal	200 – 1000 m
> 95%	Lower Bathyal	1000 – 1500 m

RESULTS AND DISCUSSION

PB ratio of Foraminifera

The results indicated that the 10 sediment samples of core ARAFURA-24 contained foraminifera with benthic foraminifera type is more abundant and dominant than planktonic foraminifera. The total number of foraminifera obtained from the core sediment of ARAFURA-24 was 8768 individual foraminifera with the number of benthic foraminifera approximately 8468 individuals and the number of planktonic foraminifera as many as 282 individuals.

Based on the PB ratio calculation of the sediment core ARAFURA-24 (Table 2, figure 3), the minimum value with the percentage of 0.56% occurred at 160 cm depth interval, and at 20 cm depth interval with PB ratio of 1.32%. The maximum value is observed at the top of the core (depth interval 0 cm) with a percentage of 7.43%, at a depth interval of 80 cm (PB ratio 6.55%), and at the bottom of the core (179 cm depth interval) with PB ratio 5.77%. This finding indicates that the depositional environment of the area is an inner neritic marine environment.

Furthermore, PB ratio calculations from 16 samples of core sediment ARU-07 (Table 3, figure 3) show the minimum value of 29.89% at 110 cm depth interval. Another minimum PB ratio value is recognized at 30, 80 and 122 cm depth intervals with PB ratio value of 44.09%, 42.12%, and 41.96% respectively. While the maximum value is observed at a 10 cm depth interval with PB ratio value of 82.66%. Relatively other higher value of PB ratio is identified at three depth intervals, which are the core top (0 cm), 70 cm, and 140 cm, with PB ratio of 67.51%, 65.31%, and 68.8% respectively. This indicates the depositional environment of the area is mostly middle to outer neritic, except the depth interval of 10 cm indicates an upper bathyal marine environment.

Table 2. PB ratio of ARAFURA-24

NO	DEPTH (m)	DEPTH INTERVAL (cm)	PB RATIO (%)	Interpolated AGE (kyr BP)
1	47.4	0	7.43	0
2	47.6	20	1.37	3.28
3	47.8	40	2.6	4.14
4	48	60	2.92	5.0
5	48.2	80	6.55	5.86
6	48.4	100	3.12	6.27
7	48.6	120	1.74	6.67
8	48.8	140	2.12	7.07
9	49	160	0.56	7.47
10	49.19	163-179 (171)	5.77	9,71

Table 3. PB ratio of ARU-07

NO	DEPTH (m)	DEPTH INTERVAL (cm)	PB RATIO (%)	AGE (kyr BP) Gustiantini et al., 2018
1	276	0	67.51	0
2	276.1	10	82.66	2.02
3	276.2	20	53.3	3.28
4	276.3	30	44.09	3.95
5	276.34	34	47.38	4.18
6	276.4	40	58.06	4.51
7	276.5	50	47.56	5.01
8	276.6	60	53.62	5.46
9	276.7	70	65.31	5.86
10	276.8	80	42.12	6.23
11	277	100	45.96	6.87
12	277.1	110	29.89	7.14
13	277.2	120	48.66	7.40
14	277.22	122	41.96	7.45
15	277.4	140	68.8	7.88
16	277.5	150	53.36	8.12

Geochronology

The age result from the radiocarbon dating analysis conducted from intervals 163 - 179 cm of ARAFURA-24 indicates the age of 9710 BP. As mentioned before, we correlated the PB ratio from the studied core to ARU-07 (Figure 4). We correlate similar patterns, that consider

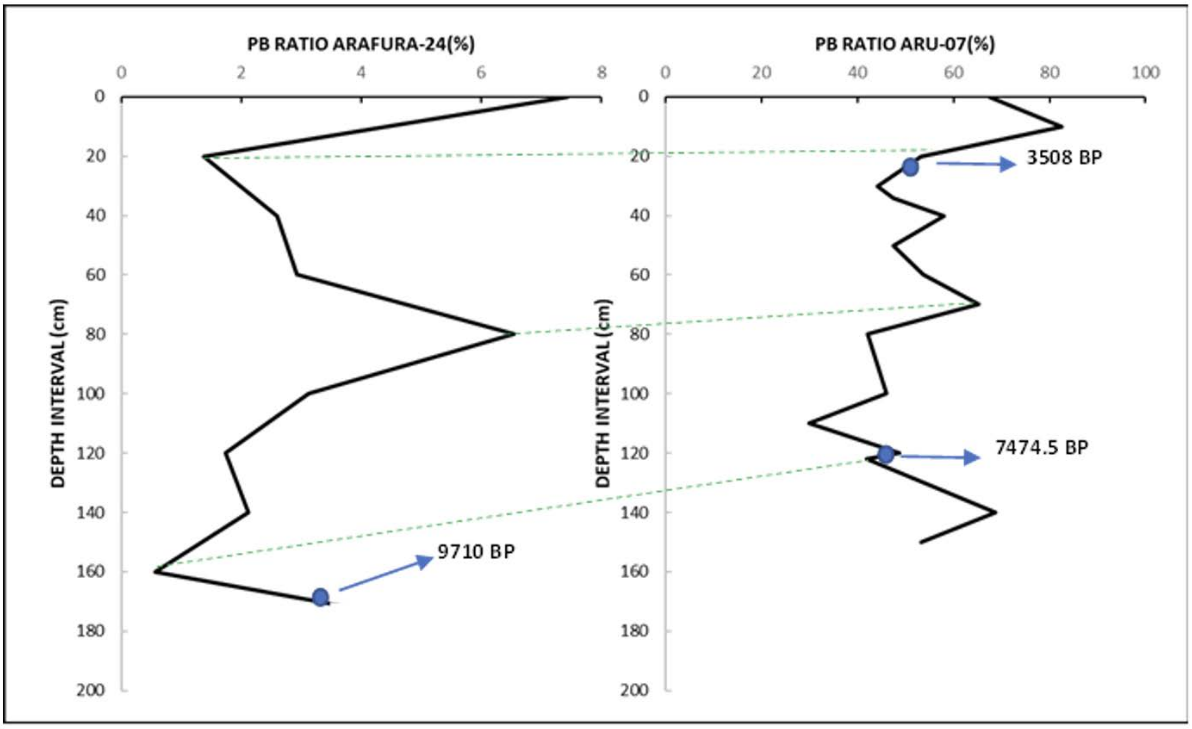

Figure 3. PB ratio versus depth interval at marine sediment core ARAFURA-24 and ARU-07, blue dots are interval sample for 14C dates analysis and the ages are indicated, dash green lines connecting tie points.

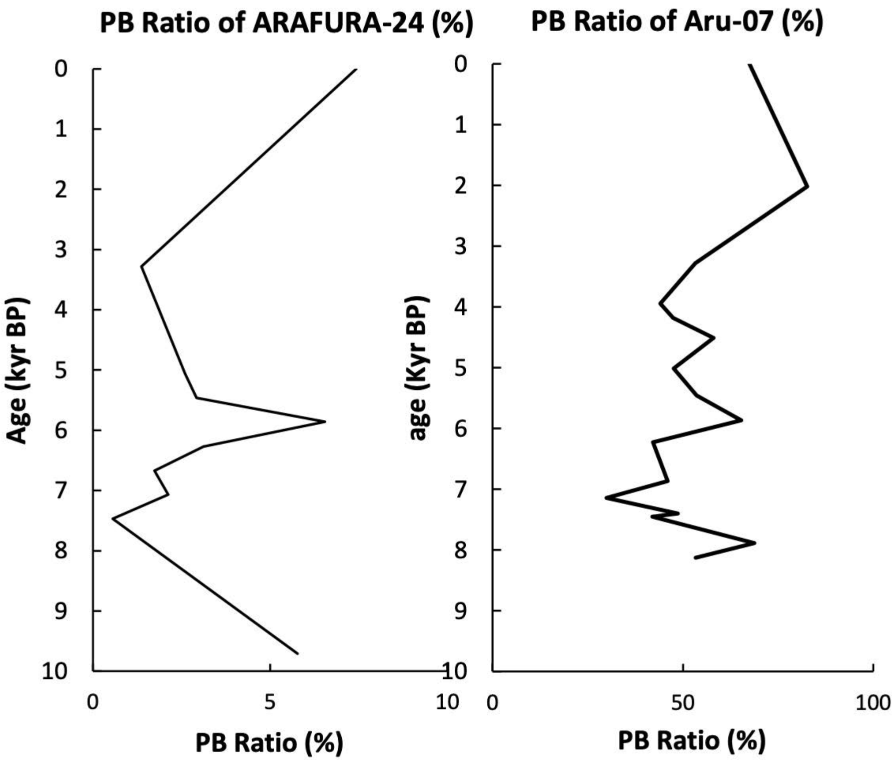

Figure 4. PB ratio of ARAFURA-24 vs interpolated calendar ages, correlated to that of ARU-07

representing similar events as tie points. From the figure, it is observed that intervals 20, 80 and 160 cm of ARAFURA-24 indicate a similar significant increase pattern in PB ratio with that of ARU-07 (interval depths of 20, 70, and 122 cm, respectively). According to ARU-07 calendar age, the age of the 20 cm depth interval is 3.28 kyr BP, depth interval of 80 cm indicates calendar age of 5.8 kyr BP, all tie points are displayed in Table 4. Then the age of the whole interval of the ARAFURA-24 was reconstructed by interpolating and extrapolating depth interval and radiocarbon dating using a linear regression equation (Table 2).

Table 4. Age and sedimentation rate estimation, derived from radiocarbon dating and correlation between ARAFURA-24 and ARU-07

NO	SAMPLE INTERVAL (cm)	CALENDAR AGE (Kyr BP)	REFERENCES	SEDIMENTATION RATE (cm/Kyr BP)
A	20 cm	3.2	Tie point, PB ratio of Aru-07	6.10
B	80 cm	5.86	Tie point, PB ratio of Aru-07	23.21
C	160 cm	7.45	Tie point, PB ratio of Aru-07	50.39
D	171 cm (163 - 179 cm)	9.7	Organic sediment dating	4.87
Average Sedimentation Rate				**21.14**

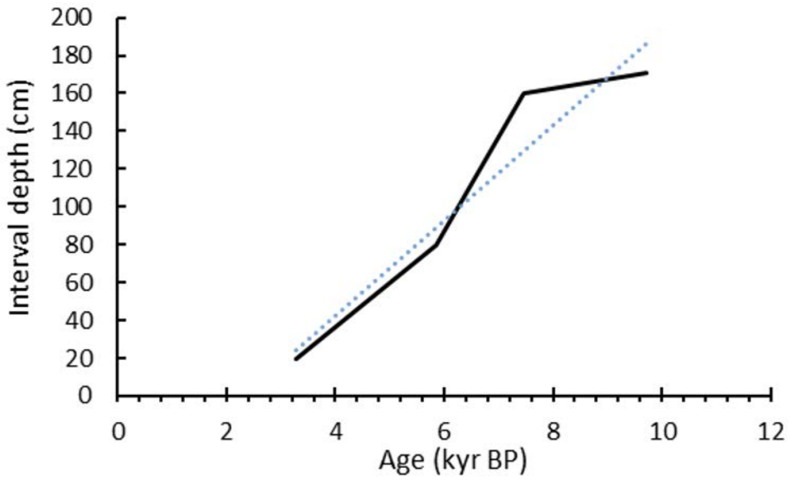

Figure 5. Age model reconstruction of marine sediment at core ARAFURA-24

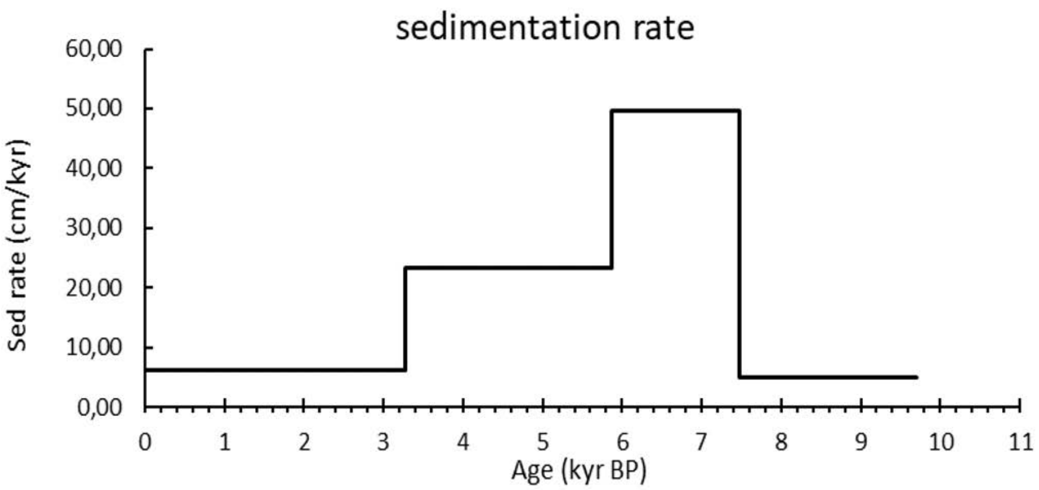

Figure 6. Sedimentation rate of marine sediment at core ARAFURA-24

The age model reconstruction and sedimentation rate estimation reveal that at the age of 3.28 kyr BP the average sedimentation rate was 6.10 cm/Kyr BP, then increased rapidly at 5.86 kyr BP to 23.22 cm/kyr BP. At the age of 7.45 kyr BP the sediment rate was 50.39 cm/kyr and 4.87 cm/kyr in the year 9.71 kyr BP (Table 4, Figure 5 and 6).

DISCUSSION

Marine sample sediment core ARAFURA-24 was acquired at a depth of 47.4 m, categorized as the inner neritic zone, while ARU-07 was classified as a bathyal zone taken at a depth of 276 m. Despite these two marine sediment samples were taken from different zone of water depths leads to different oceanography and marine ecology, both cores demonstrate similar PB ratio and sedimentation rate variability. The distance between the two cores is relatively close (307.3 km), thus both core parameters (particularly PB ratio and sediment geochemistry) apparently preserved the impact of global paleoceanography and paleoclimatic dynamics very well, although some local forcing modified the records. It is observed that before 3.28 kyr BP, the sedimentation rate average of ARAFURA-24 was 26.16 cm/kyr, with distinct slower sedimentation rate before 7.4 kyr BP (sedimentation rate was 4.87 cm/kyr), which is rather similar with that of younger than 3 kyr BP (sedimentation rate was 6.10 cm/kyr). This indicates that the sedimentation rate of ARAFURA-24 after 3.2 kyr BP was relatively slower compared to that before 3.2 kyr BP. This variability is similar to the finding of ARU-07, which indicated a sedimentation rate of 6.56 cm/kyr BP during 3.5 kyr, clearly lower than before 3.5 kyr BP with sedimentation rate of 25.2 cm/kyr BP (Gustiantini et al., 2018). Similar variability of sedimentation rate was also observed from the south of Sumba Islands, as described by Ardi et al. (2021), which revealed relatively slower sedimentation rate (7.602 cm/kyr) at the depth interval 0 – 25 cm (which corresponds to calendar age younger than ~3.2 kyr), compared to that from depth interval samples between 25 – 105 cm (~3.2 kyr – 6.97 kyr) with sedimentation rate 17.28 – 24.8 cm/kyr. Hyun et al. (2018) described that between ~7 – 3 kyr BP in Aru Sea (from similar core used in this study, ARU-07) and in Mahakam Delta were highly influenced by riverine input or influx of terrestrial organic matter, revealed from relatively high CPI (Carbon Preference Index) value, that may be related to paleoclimatic variability.

Another proxy that clearly preserves the impact of similar global paleoceanography and paleoclimatic dynamics of both cores (ARAFURA-24 and ARU-07) is the elemental composition, particularly the log ratio of Ti/Ca (Piranti, in press; and Zuraida et al., in press). We compared both records as displayed in Figure 7. From the figure, both graphs demonstrate relatively coherent variability, which is relative increase down the core. Thus, this data corroborates the hypothesis that global impact clearly influences the two areas and well preserved in the proxy.

Furthermore, we still could reconstruct the sea level changes during the 9 kyr BP, it is observed three times of maximum sea level rises, before 7.4 kyr BP (at 7.8 kyr BP at ARU-07), at 5.82 kyr, and after 3.28 kyr BP

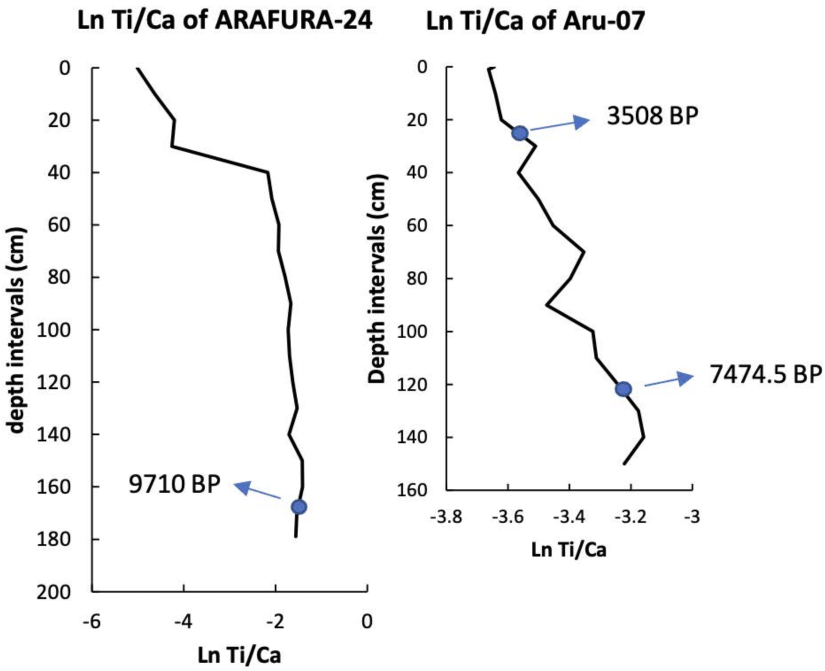

Figure 7. Comparation of elemental proxy (Ln Ti/Ca) from ARAFURA-24 (Piranti, in press) and Aru-07 (Zuraida et al., in press) which demonstrate coherent variability.

(approximately at 2 kyr BP at ARU-07). Significant sea level rise occurred after 3.28 kyr BP which transformed the outer neritic bathymetry zone into a bathyal zone at ARU-07. In contrast, the sedimentation rate decreased after this time and became slower compared to the older time period. This indicates that the sedimentation rate (hence detrital influence) does not significantly impact the PB ratio during Late Holocene, which is mostly more impacted by sea level changes at the Arafura Sea. However, at the time ~7.5 kyr BP, the PB Ratio of Arafura Sea demonstrates relatively abrupt increase trend until ~6 kyr BP, then abruptly decrease up to ~3.2 kyr BP, this pattern displays rather coherent with the increase of sedimentation rate during this interval time. This time interval might represent the warm middle Holocene global climate (Walker et al., 2012). According to Stott et al., (2004) observed from Western Pacific (MD98-2176 at the eastern Banda Sea), during this middle Holocene, particularly before 5 ka, persisted La Niña like condition occurred. NOAA (2021) also reported that sometime during mid-Holocene (7 – 6 ka) the climate was warmer than today.

Van Marle et al.(1987) noted that various parameter influence foraminifera PB ratio, including salinity decrease by river input, turbidity, downslope transport, productivity, sediment accumulation rates, current transport, etc., that might be some factors lead to the discrepancy between paleodepth estimation with the actual water depth. The author described how upwelling leads to nutrient enrichment and could increase planktonic foraminiferal abundance, in contrast this condition might lead to oxygen depletion at the bottom water, which might decrease benthic type abundance. Or vice versa, the upwelling process could increase typical species of benthic that favourable from eutrophic and anoxic conditions (e.g. *Bolivina, Bulimina, Uvigerina*) (e.g. Boltovskoy and Wright, 1976; Jorissen, 1987; Murray, 1991; Bernhard and Sen Gupta, 1999; Fontanier et al., 2003; Martins et al. 2015; etc.), in contrast decrease typical species of planktonic that prefer to live in oligotrophic condition, such as *Globigerinoides ruber* and *Globigerinoides sacculifer* (e.g. Fairbanks et al., 1982; Field D.B., 2004; Ding et al., 2006). Therefore, it is actually will be better to compare the PB ratio analysis result with the study of both benthic and planktonic taxonomy (Van Marle et al., 1987).

CONCLUSIONS

The relatively coherent pattern of the PB ratio of ARAFURA-24 to that of ARU-07 gives us access to be able to reconstruct the age model of ARAFURA-24 by correlating tie points of similar events combined with dating data from both cores. Therefore, we are very optimistic with our age models, however further analysis is necessary to get a better result of age model reconstruction.

PB ratio result indicates three times of maximum sea level rises, which are before 7.4 kyr BP (at 7.8 kyr BP at ARU-07), at 5.86 kyr, and after 3.28 kyr BP (approximately at 2 kyr BP at ARU-07). While sedimentation rate reconstruction exhibits a slower rate value after 3.28 kyr BP compared to that of the older time period. Thus, it can be concluded that during Late Holocene, the sedimentation rate (hence detrital influence) does not significantly impact the foraminiferal PB ratio at the Arafura Sea. Furthermore, during Mid-Holocene, sedimentation rate more influence foraminiferal PB ratio.

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