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Sunda epicontinental shelf and Quaternary glacial-interglacial sea level variation and their implications to the regional and global environmental change

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Abstract. Sunda Epicontinental Shelf occupies a large area between Asia and Indonesian Maritime Continent. This shallow shelf developed soon as stability of this area since Pliocene was achieved. Sedimentation and erosion started, following sea level variation of Milankovitch cycle that changed this area to, partly to entirely become a low lying open land. These changes imply a difference height of about 135 m sea level. Consequence of this changes from shallow sea during interglacial to the exposed low land during glacial period is producing different land cover that might influence to the surrounding area. As the large land surface, this area should be covered by low land tropical forest, savanna to wet coastal plain. This large low-lying land belongs an important river drainage system of South East Asia in the north (Gulf of Thailand) and another system that curved from Malay Peninsula, Sumatra, Bangka-Belitung and Kalimantan, named as Palaeo Sunda River. The total area of this land is about 1 million km², this must bring consequences to the environmental condition. This change belongs to the global change on which the signal may be sent to a distance, then is preserved as geological formation. Being large and flat land, it has a long and winding river valley so this land influences the life of biota as fauna and flora but also human being that may live or just move on the passing through around East Asia. Global sea level changes through time which is then followed by the change of the area of land or water have indeed influenced the hydrology and carbon cycle balance. Through studying the stratigraphy and geology dynamic, based on seismic images and core samples from drilling work, one can be obtained, the better understanding the environmental change and its impact to the regional but could be global scale.

1. Introduction

Geological formation had been formed through the process that involved some natural phenomena. The process takes place continuously, the previous formation outcropped in the land then can be reworked out which the material develops new geological formation. The marine process is relatively undisturbed producing thick preserved layer which the material component of the sediment can inform how, when and where the material derived from. Once the shallow marine formation had been developed then it emerged due to the sea level drops along the sea level variation history. The rise of sea level then allows the new sedimentation covers the older exposed sediment before. This change on sea level have been last since long time due to the periodically change of the solar energy that comes to the earth. The evaporated sea level during glacial time falls in the ice mass in the high latitude and being conserved as the ice stock that melts during the opposite period of the interglacial. The change of sea level column could involve to 135 m down below the present sea level along the Pleistocene [1].

The epicontinental shelf, named Sunda Shelf is a large shallow sea area that belongs mainly to the Indonesian territory. The depth varies down to about ~150 m in the edge of the deep sea. Sea level



change implies the change of part of this area become an exposed land which river basin covers large area and the river valley incises deeply the terrain. Low land tropical forest and weather as well the river system during low stand sea level bears an important hydrological and carbon cycles system in this region. All the material had been preserved as the geological formation in the sediment sequences, proposes a potential information of the past geological process. Though part of the sequence had been truncated, but the continuous sequence in the deeper basin still keep the sequences being undisturbed.

This manuscript tries to review the possible past process and the impact to the local but also to the more global environment. Better understanding to the past geological process could be achieved through the pilot geophysical sensing and analyzing sediment samples from the continuous undisturb cores.

2. Geology and morphologi of Sunda Platform

Present Sunda Epicontinental Shelf now days being an extended shallow sea of about 1 million km². Starting from the coastal plain of several big island gradually down to about -130 m depth of an edge of deeper front slope. This deep was a delta plain of some big rivers (co delta) during low sea level time. Some interstadial periods had not drained completely the platform and left a relatively large shallow sea or swampy area. Erosion took place in the exposed land which erosional material had been redeposited in the shallow marine. In the coastal plain, sedimentation took place under the different environment that produce multi facies of sediment sequences.

Evolution of Sunda Platform can be traced back from the Mesozoic Time when the plutonic intrusion took place. Relict of this plutonic rocks can be found as the fresh granitic outcrops. This pluton intruded older sedimentary and metamorphic rocks. Other explosive or intrusive rocks of younger period (Tertiary) also found in some island around southern rims of Sunda Platform. Plutonic rocks in Anambas Island mainly is granitic rocks as well granite adamellite which plagioclase crystal is more than 5 cm big and the date (K-Ar) gives 74-84 M years. Granite adamellite from Natuna Island in west of Anambas, gives the age of 71.56 M years (K-Ar). The close distant outcrop of granite in Pulau Laut gives 100 M years (K-Ar). Granite has an intrusion contact with the seafloor ultra-mafic rocks peridotite and gabbro. The granite has diabasic to andesitic rocks dykes [2]. Tertiary sequence of deep to shallow marine volcanic material was deposited forming layering sediment consists of quartz and tuff. There is a significant different geological evolution between west and east Natuna region. The basin of west Natuna does not show a tectonic influence while the east side. The west part shows the thick marine sequences which upperpart had been truncated during Upper Miocene, then left as the peneplain land and curved by the river valley before it was inundated by the high stand sea level. Shallow sea sedimentation continued interplayed with terrestrial sequences of fluvial, flood plain, swampy and coastal sedimentation. This sequences changes laterally either vertically through the change of sea level history. Seismic data reveals this geological evolution in the platform [3]. The eastern Natuna basin have been last which shallowing process continues. Along the relatively shallow and clear water environment, coral reef carbonate develops well that actually found as the carbonate reservoir for hydrocarbon and gas.

3. Approach

Being a flat lying low land or the shallow sea, the data coming from that site is still scarce to figure out its past environment. There is not enough clear how was geological evolution since this platform had been being stable since Pliocene passing through several glacial-interglacial cycle which sea level change under the rate of 8-10 cm/yr [1,4]. Continuous core of sediment sequence that can be obtained from the right geological section guided by seismic profile, may bring data that could open new insight of the past Quaternary to Present evolution of the platform. To the older time, Mio-Pliocene sedimentary rock from the edge of the platform is expected to bring signal of its tectonic evolution before this platform being stable. Further study to the outcropped of the ultra mafic and plutonic rocks in several island around Sunda Platform could bring new insight to the Mesozoic geological evolution of this platform. To obtain all the data needed for the whole study, both onland field geological investigation and marine research activity are necessarily needed. Shallow seismic profiling will be carried out to

obtain better insight on the stratigraphic profile as well better information of the paleo drainage pattern. Based on this information, the right choice can be taken where the site to obtain the most continuous and complete sedimentary sequence that contains data to study evolution of Sunda Platform.

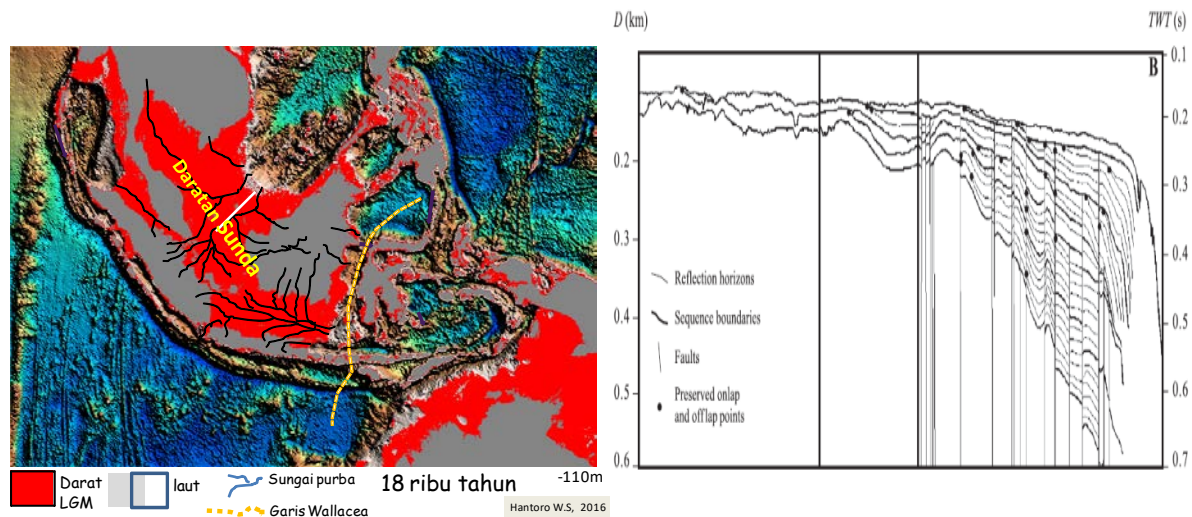


Figure 1. Map of the Paleo Sunda Land (red) and sedimentation process in the edge of the platform face to the South China Sea [5,6].

Based on the good material that can be obtained from the geological investigation in the whole Sunda Platform, the more detail study can be proposed under the various method to figure out past of natural process that had been last in this platform. The integrated study of the past climatic variability, hydrological balance and cycle, paleoceanography, paleobiogeography, paleovolcanology as well archeology may bring new achievement to the knowledge on the earth sciences.

4. Perspectives of the finding

4.1. Eustatic sea level

Sea level variation is induced and controlled by some reasons, change on the sea level volume due to the ice cap accumulation in the high latitude and the sea water expansion due to the temperature increase. Change on the basin's volume due to tectonic process may induce to the change on sea level too. Sediment input to the sea may change the basin volume then induce sea level change. Understanding of the sea level variation had been proposed before [1,7-10]. Sea level reconstruction had been deduced from the uplifted marine coral reef terraces and other geological formation as well the past ecosystem's relict close to the coast. Mangrove trunk is some time explored as the paleo sea level indicators as well beach sand or shell layer in the sediment. The most prominent uplifted marine terraces of Huon Papua and Tanjung Laundi Sumba inspired the long curve of sea level since almost 1 M years. (Figure 2).

High resolution data shows the increase of sea level about 16 m during 300 years from 14.6 k yrs to 14.3 tahun BP (before present) [11]. This find support data from Tahiti about 14-18 m sea level rise between 14.650 - 14.310 yrs [12]. Rebound due to impact of ice cap load or the change of water load is clearly shown in the different place [1,13].

An important contribution to our understanding of eustatic sea level was obtained from the last ODP which result figured out the interval of sea level during Oligo/Miocene (IODP 313, New Jersey Shallow Shelf). Other result delivered sea level's interfal of during Quaternary (IODP 310, Tahiti; IODP 325, Great Barrier Reef). There is still lack of data between Early Pliocene and Early Pleistocene related the development of the ice cap in North and South pole. Based on the model, the early stage of glacial cycle is indicated by $\delta^{18}\text{O}$ when temperatur drops as the strong cooling sea water. It was happen in the early phase of LGM [14]. Data from Sunda Land is expected to improve the sea level curve that had been obtained from Red Sea. Data from Sunda Land could bring an opportunity to fill the gap of data from

Pliocene to Recent. Samples from equator is the most representative to contribute high resolution data on sea level variation. Equatorial data is respectively free from the impact of glacioeustasy (rebound due to load of ice cap). Being a shallow platform, the obtained data is relatively free from the impact of hydroisostatic rebound. This rebound just gives the influence less than 2% [1].

Consider to the shallow water column of the present platform and the long time existence since Lower Miocene being under the sea level change, the erosion and sedimentation had produced a lateral variation on its stratigraphic sequence. Vertical both lateral discontinuity is observed in the relatively shallow part but more continuous marine sequence in the deeper part. The deeper part offers best opportunity to obtain good data that represent continuous history of Sunda Platform evolution. The right site to find the best samples could be done firstly by using seismic data. The profiles may indicate the continuous sedimentation without any rupture due to truncation during erosional phase. Rapid sedimentation in tropical environment may bring finer resolution but it may produce coarser sediment.

Samples from long and continuous sedimentation process may represent the variability of the original zone where sediment comes from. Climatic variability either tectonic activity of the area may be reflected in the clay mineralogy in the samples. If the obtained samples represent the complete sequence of the glacial-interglacial cycles, it can be expected to reveal how the cycle have happened in the area that was free from the direct influence of the ice melting process. How much volume of ice in the high latitude that had been involved in this cycle then can be modeled.

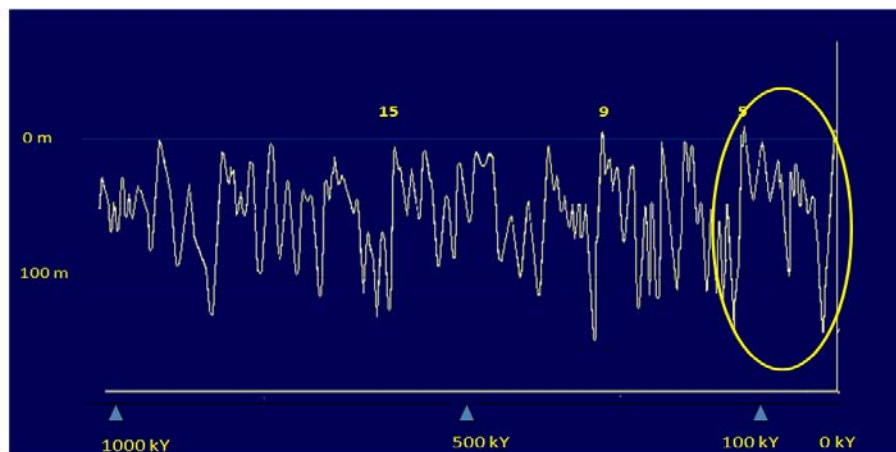


Figure 2. Curve of eustatic sea level variation based on the age data and elevation of the coral samples from Cape Laundi, East Sumba, Indonesia. Curve was corrected to the isotopic data obtain from ODP 677 [1].

Uplifted coral reef terraces [1,10] as well sediment sequences from Tahiti just support limited data to figure out the history of global sea level variations (Figure 2). The curve is being under the correction by using other source of data, that could be come from the different geological formation that conserves continuous data about sea level variatio since Lower Pliocene to Recent. Samples from Paleo Sunda platform is expected to support the needed data. The questions related to the sea level should be assess:

- Clarify the previous theory whether the lowest sea level achieved so far about -141m [1,15] or just -125 m previously expected.
- Highest sea level during (MIS) 5a or 80 kilo years BP is about 1 m above present sea level [16]. Possible during (MIS) 7.3/4 m at was about 229 kilo years BP.
- Clarification this stage is not related to the 100 kilo years cycle of ice age that had been inferred by strong solar energy during warm season. (Edwards, 2010).
- Discussion of the high sea level of MIS 5e that had been proposed about 4-6 m, 10 m or 15 m [8] and 20 m [16].

- Expected low sea level on MIS 6 (ca. 135-185 ka) related to the extended in Eurasia and North [17].
- Predicted sea level +5m during MIS 9 (325 k years [1], MIS 11 (400 k years), data Bermuda and Barbados proposed +20 m high while other data just +10 m [18].
- Correlation between high sea level with the change of monsoon [19-21].
- Change of sea level related to the melting of ice at MIS 31 (~1.07 M years) when the collapse of West Antarctic ice cap induce the Sea Ross was free from the ice covers [22,23].

5. River drainage pattern and hydrology of Paleo Sundaland

There are now days some large river drainage systems in the world tropical area, as Amazon in the South America, Congo in Africa that play an important role in the hydrological balance and cycle. The biggest river in the world, Amazon, brings about 209,000 m³/sec. Along the 6400 km length of the stream. This river contributes 20% fresh water so the biggest of the largest world tropical river basin. Congo river the longest 9th in the world (4700 km) releases about 42.800 m³/sec. fresh water to the sea from tropical forest basin, so the presently second fresh water contributor after Amazon. Both two big river's basin that belongs to the important fresh water contribution is comparable to the Paleo Sunda Land's contribution on fresh water input during lowstand sea level. The most fresh water contribution of this land to the world was being about the largest exposed land, during The Low Glacial Maximum was about 20 to 15 k yr. That large space of the exposed land that contributes fresh water could be larger than ever if it considers East Paleo Sunda river basin too. The two rivers basin gave ¼ of the total world epicontinental land during low stand sea level. The whole epicontinental shelf that emerged during LGM attained almost 1/5 the total land surface in the world. This number may bring the idea how important was the contribution of the Paleo Sunda Land (North and East) during low land tropical forest in the fresh water balance in the world.

North Sunda Platform is a large low lying land, where three big river systems North Sunda, Chao Pray and Mekong were developed during low stand sea level. The three rivers end up the flow to the deep South China Sea basin. Regarding the large of the lowland tropical forest in the Sunda Platform during lowstand sea level and its huge volume of the water involving its hydrological balance, this platform must be considered as the important earth's tropical pool that regulated the earth climatic system.

Existence of burden river paleochannel in this Sunda platform had been identified [24]. Hydrocarbon exploration in this region had contributed geophysical either stratigraphical and other geological data. It may reveal the deep incised valley then had been filled by younger sediment sequences [25]. There are two main drainage patterns that flow to the north to the South China Sea and the other to the east to Flores deep sea. One system that developed in the Java Sea basin was controlled by structural pattern of fault system either fold axis lineament.

- North Sunda Paleo River
One of the big river drainage in the Sunda Platform is the drainage that runs from Sumatra and Kalimantan as well other tiny island Bangka and Belitung. This system is named as North Sunda River. This river system brought derived materials from volcanic, sedimentary, metamorphic to plutonic rocks.
- Mekong river
This Mekong river system could be the largest drainage system starting far from the highland of South East Asian mountain system (Thailand, South China, Burma, etc.). This river just shortly flew along the platform which total length of the river is about 4350 km and brings about 457 km³ fresh water yearly to the sea. This river has salt waterlake in the down stream.
- Chao Phraya River
One of the river drainage system is Chao Pray that flows from Asian Land and come into the shallow sea Sunda Platform. This is the biggest river system in Thailand, brings heavy suspended load to the Gulf of Siam. During the lowstand sea level, this system passed through

the exposed Sunda Land, finished the river by forming delta complex in the edge of the platform as the co delta together with North Sunda River. Length of the river is about 1200 km, which catchment area is about 1.350.000 km², become one of the river system in Asia.

- East Sunda Paleo River

One of other important large river system develops during lowstand sea level, developed in the present Jawa Sea basin. The system received fresh water and sediment load from Kalimantan and Jawa, flows to the east brings it to the Flores Sea.

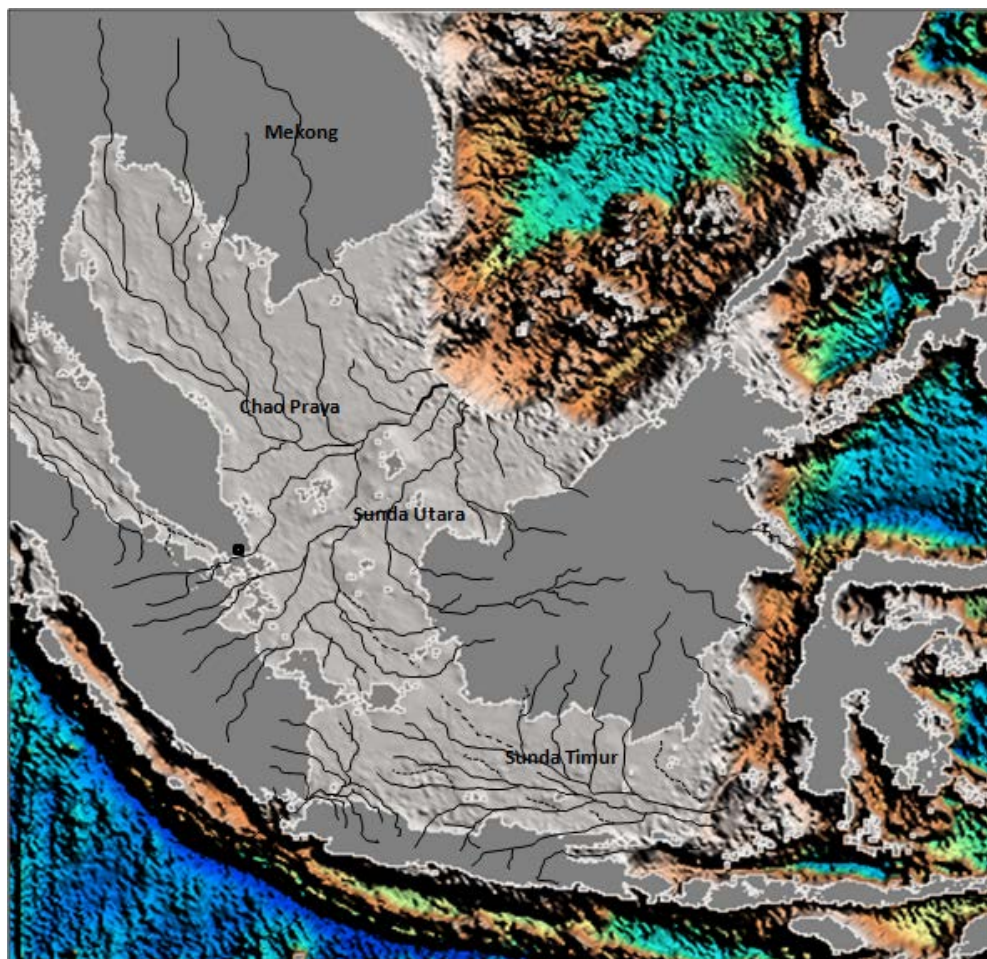


Figure 3. Epicontinental Shelf Sunda and the expected drainage river system. The drainage was reconstructed based on the seismic and bathymetric profiling done by mineral and hydrocarbon exploration (modified after [5]).

The high river flux to the South China Sea influences the diversity and the individual abundance of foraminifera. Hydrological evolution since the development of the Paleo Sunda river along the sea level variation may induce the evolution and change of the individual species foraminifera assemblage. The successfully prevailing of the complete sediment sequence that represent the whole Quaternary period may figure out better on the sea level variation history as well its fresh water hydrological regime and balance.

Existence of the deep incised river channel during lowland sea level may reduce and block the fauna and hominid movement traversing across the river system. But, open space along the river valley

may give an advantage to the migration along the river bank. Movong along upstream and downstream was possibly done since the stream is relatively gentle along the low lying Sunda Land.

6. Sunda Land and carbon stock

Hydrological and carbon balance are the two systems that work in an integrated process. When the hydrological balance keeps working to regulate climate and weather in the platform during low stand sea level, while the dense forest that was supported by warm climate and high precipitation played an important role to produce carbon as regional stock in the platform [26]. Forest is about 92% of the global terrestrial biomass and 2/3 of its stock is the tropical forest [27]. Large part of present tropical forest spreads out in the South America (49%), sub Sahara (25%) and South East Asia (26%). This amount of biomass in South Asia has supplementary large to about 40% during low stand sea level from the Sunda Land [28,29]. Tropical rain forest plays an important role in the biogeochemical system of the earth, as it provides 20% oxygen in the world. It is named as the lung of the world. Forest and carbon stock that had been formed as the carbon cycle system. It can be released anytime to the atmosphere. Though the present days carbon stock seems apparently limited to be produced, other primary productivity that yields carbon may be formed and conserved in the sea as carbonate precipitation by developing presently large carbonate bank of the coral reef. Present and past Sunda Epicontinental Sea was known as the large carbonate formation too. The peat deposit under the present large wetland around Sunda Platform is one of the potential carbon stock in the tropical region. Peat bog deposit in South East Asian region is estimated to contribute about 77% of the total global carbon stock. To the region that belongs to the shallow epicontinental shelf, sea level variation in this area implies to how much large the change of the aerial exposed had been attained between low and high stand sea level of glacial interglacial cycle [30]. The past LGM low stand sea level, Sunda Land and other South Asia epicontinental land bears almost equal large to the Amazon's present tropical rain forest. This addition of the world carbon sequestration in the coastal area must be generated by the additional tropical rain forest. This carbon was stocked and preserved as the thick layer of peat in the shallow epicontinental land. Terrestrial ecosystem of rain forest that absorb CO₂ had been stabilized at about 2.5 PgC/yr [27,28].

Rain forest in the Paleo Sunda Land plays an important role and influences strongly to the global carbon cycle either to the hydrological cycle and balance. Being its important role, the contribution to the natural process also brought new insight on the approach in archeological research to understand possible past migration and occupation during lowstand sea level. Hypothesis and questions could be arisen related to the role of Paleo Sunda Land to the development of the nation around the Sunda land (Asia and Indonesia Maritim Continent). Idea and hypothesis could be proposed and discussed:

- What was the environment and its ecosystem's diversity develops during low stand sea level's period? Where and how those ecosystems were? Are those flood plains area or alluvial plain? Low and undulating beach ridges? Wet land? Coral reef platform or terraces?
- What are the rock's outcrop can be found in the emerged and immersed land? Type of soils?
- What is the vegetation's cover and living biota that found at those different ecosystem?
- Was there low land tropical forest? Interplay with savanna? Density? Type of trees and other dominant flora?
- Fauna flora association and its assemblage. Was it enough support to the ancient people's life. Was that the reason why was people lived in this land?
- Was there appropriate shelter to the ancient people found suitable place to live? Caves? Dry sandy ridges? Caves

Reconstruction of the ancient environment will bring positive impact to inspire further archeological study.

6.1. Climate and biogeography

Sunda epicontinental platform is being an important area of “Western Pacific Warm Pool” (WPWP) which SST is close to 28°C. This situation allows to induce thermal circulation of three important air mass movements, those are monsoon, Hadley and Walker circulation. The convection in “WPWP” and Walker circulation, during interaction to the other weather anomaly ENSO and Asia-Australia monsoon, will induce strongly to local weather. Models reveal that intensity of Walker circulation is sensitive to the change of the water in the shallow Sunda Epicontinental Sea. It must be happened in the past during Sunda Platform was being an open exposed land [31,32]. Changes of the platform through glacial and interglacial must be followed by change on the influence intensity to the local or regional climatic variability and other weather anomaly as ENSO, IOD and MJO.

The climate dynamic around WPWP including Sunda Land during LGM has not been yet figured out well, as related to the decreasing of sea level and atmospheric temperature. Reconstruction (CLIMAP) based on the microfossil indicates the slight of lowering temperature. To reduce ice cap in the highland of tropical island as Kinabalu and Jayawijaya Mountain, certainly needs about 3°C cooler of WPWP [33]. Lowering temperature during LGM around 2°C in WPWP [34] is coincide to the lowering of sea temperature in the North Part of Sunda Platform close to South China Sea, at about 6°C cooler [35]. Many hypothesis had been proposed as the change of the cloud formation in the equator may induce the lowering of temperature [36].

The decreasing humidity on Paleo Sunda Land presumably happened during the decreasing precipitation along LGM for the whole rea of Maritime Island and Australia. [31,36-39]. Polen analysis from the slope of South China Sea [40,41]. shows a significant forest cover in the land during LGM that shows similarity to the tropical surrounding area [42-46].

Biographically, Sunda Platform is part of *Wallace* Line in the triangle Pacific and Indian Ocean that is rich on its biodiversity [47,48]. This area become important since some new finding improve data on tropical knowledge. Sediment data from core drilling samples is necessarily needed to open more presently hidden figure how the tropical forest and sabana was on its large and density during LGM. [49]. Sabana gaps and deep incised river valley in Palaeo Sunda Platform may reduce the fauna and flora interconnection between Asia and Malaya Peninsula to East and North Kalimantan [48].

6.2. Impact of the past extreme event to the Paleo Sunda Land

Epicontinental shelf is a stable geological zone in the Maritime Continntental Island. Volcanism that related to the tectonic activity in Sunda Land had been ceased sice Upper Miocene which the last product was mainly tuffaceous marine sediment and dykes that intruded granite in Anambas Island. The influence of the volcanism activity to this area just the drops of tuffaceous particulate that had been injected during eruption. It was brought and dispersed in the atmosphere into the large area. This tuffa layer may be left in the sediment sequence as the marker or signal of volcanic activity. The Recent (Antropocene) big volcanic eruption (Tambora, Krakatau, Rinjani, east lesser island volcano, etc) may left the tuff layer. This tuff may bring data of the volcanic eruption type as well source of the magma.

Since the last interglacial (MIS 5e), some prominent big volcanic eruption happened in the surrounding Paleo Sunda Land. Toba is the well known as magmatic explosion which injected material. It may be dispersed far away and cover large area including Sunda Platform. Based on the relict of its explosion in the sediment sequence, some big volcano in Jawa and Sumatra may send its injected tuffaceous product and reach Sunda Platform. This left of volcanic product may be still well preserved and produces good signal to reconstruct past volcanism along the ring of fire. Geologically, Sunda Platform is a stable tectonic region but other tectonic event may produce such calamity in this region during lowstand sea level. Seismic shock in Phillipine and North Kalimantan may induce tsunami which big waves could reach and destroy the edge of Sunda Land [50].

6.3. Sunda Land: perspective in the dispersion and development Indonesian population

Consider to the role of Sunda Platform in the dispersion of the population in the surrounding area, that is the physical condition of the enviroinment that may support the migration during low stand sea level.

The obstacle and other difficulty as well hard environment to be traversed may be the reason to be avoided during the migration. Scarcity of the resources may also being a main pressure to the people have to avoid to settle down building the occupation. Mapping of the past environment of this land may bring the better understanding why, where and how the ancient people use this land as the choice in the path of the migration and the occupation [23,51]. Living in the hard land which resources are scarce and full of the threat may influence then develops a better self human capacity to be adaptive to the environment [23,47]. Knowledge that people developed through this adaptation may be shared to other group and being implemented as the new experience to increase the ability to come over the obstacle in their life.

During maximum sea level drop, this area under the certain reason, that is the path of the faunal and human migration, or the destination to go to settle down as the new living occupation [5]. Two main hypothesis of human occupation in Indonesia had been proposed related to the Austronesia diaspora [52,53]. Diaspora, including Austronesia, is presumed starting from Asia land [53] through Taiwan, cruised along the sea to Philippine than continued to the Indonesian Island in the south. Other theory of migration from Asia land to Indonesian island had been done by passing through the land bridge during low stand sea level [5,51]. The large land bridge should be Paleo Sunda Land. Those migrations may happen during LGM but could be earlier during other older glacial or stadial period. The question then, where or which path had been taken for the migration. The open land along the river valley could be the suitable track for the people passing through the land than traversing dense tropical forest. River stream was relatively gentle in the low lying land of Sunda Platform where floating tree trunk may be used to cross the river from side to the other or to move down stream easily. Moving along the stream may continue following the enhancement of the people to produce floating mass and its navigation along down or upstream river.

DNA mapping of different tribe in Indonesia [54] reveals that distribution their occupation along the stream has a good correlation to the distribution of their DNA type cluster [5]. The movement of people in the Maritime Island could be influenced by some reasons that induce people decides to leave the former habitat. Strong climatic deterioration in Asia land could be one of the people leaving out to the south to find better and warmer climate.

7. Perspectives

Based on the discussion above, it is clear that Sunda Platform potentially bears important data and its role as the climate regulator in the regional and global scale.

1. Change on the fresh water hydrological balance and the humidity in the atmosphere. Fresh water during low stand sea level was trapped in the aquifer then covered by aquitard sediment during high stand sea level sedimentation. This huge under water reservoir being important as the future stock of fresh water.
2. Change on the terrestrial carbon stock during lowstand sea level. This stock had been preserved soon it was blanketed by shallow sea sediment.
3. As large low lying land, it belongs to the large wet land tropical forest. Its carbon stock was kept safely as the bituminous layer under the following clay sedimentation during high stand sea level.
4. Front edge of the platform faces to the deeper basin was a large deltaic ecosystem of several big important drainage system in the world during low stand sea level. Co delta system developed and produced thick sediment sequence that could be free from the truncation during lowest sea level ever.
5. During low stand sea level, the coastal plain was under the unstable weather of South China Sea that bring excessive rain and then flood. Strong wind and high wave induce the development of high sandy beach ridges which vertical sequence become a potential fresh water reservoir.
6. Change of coast line in the clean and agitated water may induce the development of the large coral reef platform. This past ecosystem may provide the paleo environment and sea level data.

Intensive reefal carbonate sequence may help to stock carbon in the carbonate rocks and preserved well in the stratigraphic sequence.

7. Though this land is relatively far from the volcanic rims, the past volcanic activity might left its dispersed material producing during eruption as the tuff layer or tephra.
8. The paleo Sunda Land had been potentially under the threat of sea calamity as well tsunami that was generated and might strike. Neighbouring area (Serawak and Philippine) had been under the tectonic activity that may produce strong seismic shock.
9. During the lowest and longest low stand sea level, the climate could be different than present day, giving fresher and dryer weather that induce more open ecosystem as well sabana. Sabana belongs to the open grass land that was suitable to the mamalian mainly grazers lives. The wide river valley which stream was deep and strong could be an obstacle to the movement of the animal and hominid crossing the river.
10. To the hominid, the more open space free from the dense tropical low land forest give an advantage to their moving or migration. The path could be the open river bank or sabana along where the food stock is available (mamalia, fish and fruits or tubers).

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References

- [1] Hantoro W S 1992 *Etude des terrasses récifales quaternaires soulevées entre le détroit de la Sonde et isle de Timor, Indonésie Mouvements Verticaux de la Croûte terrestre et variations du niveau de la mer* (Marseille : Univ. d'Aix Marseille II. France).
- [2] Hakim S, Suryono N, 1994 *Peta Geologi Lembar Teluk Butun dan Ranai, Sumatera* (Bandung: Pusat Penelitian Pengembangan Geologi).
- [3] Darmadi Y, Willis B J and Dorobek S L, 2007 *Journal of Sedimentary Research* **77** 225–238 DOI: 10.2110/jsr.2007.024
- [4] Hantoro W S, Faure H, Djuwansah R, Faure-Denard L, Pirazzoli P A, 1993 *IGCP 253-274 workshop, Dakar, Senegal, May 3-5, 1993*.
- [5] Hantoro WS 2016 *Proceeding International Seminar Austronesia Diaspora 18-23 Juli, 2016* (Denpasar: Pusat Arkeologi Nasional).
- [6] Zhong G, Geng J, Wong H K, Ma Z and Wu N 2004 *Earth Planet. Sci. Lett.* **223** 443–459.
- [7] Chappel J, 1983 *Nature* **302**, 406-408.
- [8] Pirazzoli P A, Radtke U, Hantoro W S, Jouannic C, Hoang C T, Causse C, Borel Best M, 1991 *Science* **252** 1834-1836.
- [9] Pirazzoli P A, Radtke U, Hantoro W S, Hoang C T, Causse C, Borel Best M, 1993 *Mar. Geology* **109** 221-236.
- [10] Hantoro W S, Pirazzoli P A, Jouannic C, Faure H, Hoang C T, Radtke U, Causse C, Borel Best M, Lafont R, Bieda S, and Lambeck K 1994 *Coral Reef* **13** 215-223.
- [11] Hanebuth T, Stattegger K, Grootes P M, 2000 *Science* **288** 1033-1035.
- [12] Deschamps P, Durand N, Bard E 2012 *Nature* **483** 559-564.
- [13] Clark P U, Mitrovica J X, Milne G A and Tamisiea M E, 2002 *Science* **295** 2438–2441
- [14] Bintanja R, van de Wal R S W, Oerlemans J, 2005 *Nature* **437** 125-128
- [15] Lambeck K, Rouby H, Purcell A, Sun Y, Sambridge M, 2014 *PNAS* **111**(43) 15296–15303
- [16] Dorale J A, Onac B P, Fornós J J, Ginés J, Ginés A, Tuccimei P, Peate D W, 2010 *Science* **327** 860-863.
- [17] Svendsen J I, et al., 2004 *Quaternary Science Reviews* **23** 1229–1271
- [18] Raymo M E and Mitrovica J X, 2011 *Nature* **483** 453-456.
- [19] Yin Q, Berger A, Crucifix M, 2009 *Clim Past* **5** 229–243.
- [20] Muri H, Berger A, Yin Q, Voldoire A, Salas D, Méliá Y, Sundaram S, 2012 *Clim Dyn* **39** 1739–1761.

- [21] DiNezio P N, Tierney J E, 2013 *Nature Geoscience* **6** 485-491, doi: 10.1038/NGEO1823.
- [22] Scherer R P, Bohaty S M, Dunbar R B, 2008 *Geosc. Res. Lett.* **35** L03505 doi:10.1029/2007GL032254.
- [23] Pollard D, DeConto R M, 2009 *Nature* **458** 329-333.
- [24] Molengraaff G A F, Weber M 1921 *Proceedings of the Royal Academy of Amsterdam* **23**: 395-439.
- [25] Alqahtani F A, Johnson H D, Jackson C A-L, Som MRB, 2015 *Sedimentology* **62**, 1198-1232, ISSN:0037-0746.
- [26] Heaney L R, 1991 *Climatic Change* **19**, 53–61.
- [27] Pan Y, Birdsey R A, Phillips O L, Jackso R B, 2013 *Annu. Rev. Ecol. Evol. Syst.* **44** 593–622.
- [28] Avitabile V, et al., 2016 *Global Change Biology* **22**, 1406–1420, doi: 10.1111/gcb.13139
- [29] Saatchi S S, Harris N L, Brown, S., 2011 *PNAS* **108**, 9899-9904.
- [30] Prentice I C, Harrison S P and Bartlein P J 2011 *New Phytol.* **189**, 988_998.
- [31] Bird M I, Taylor D, Hunt C, 2005 *Quat. Sci. Rev.* **24**:2228–2242
- [32] Dayem K E, D C Noone and Molnar P., 2007 Tropical western Pacific warm pool and maritime continent precipitation rates and their contrasting relationships with the Walker Circulation, *J. Geophys. Res.*, 112, D06101, doi:10.1029/2006JD007870.
- [33] Hostetler S W, Clark P U, 2000 *Science* **290**, 1747– 1750.
- [34] Martinez J I, De Deckker P, Barrows TT, 2002 Palaeoceanography of the Western Pacific Warm Pool during the lase glacial maximum: Long-term climatic monitoring of the maritime continent *Bridging Wallace's Line: The Environmental and Cultural History and Dynamics of the SE-Asian-Australian Region* ed Kershaw et al. (IUSS) pp 147-172.
- [35] Jian Z, Tian J, Sun X, 2009 *Paleoceanography and Sedimentology* 297-394.
- [36] De Deckker P, Tapper N and van der Kaars W 2002 *Global and Planetary Change* **35** 25-35.
- [37] Gagan M K, Hendy E J, Haberle S G and W S Hantoro 2004 *Quaternary International* **118** 127-143.
- [38] Griffiths M L, Drysdale R N, Vohnof H B, Gagan M K, Zhao J -x, Ayliffe L K, Hantoro W S, Hellstrom J C, Cartwright I, Frisia S and B W Suwargadi 2010 *Earth and Planetary Science Letters* **295** 30-36.
- [39] Griffiths M L, Drysdale R N, Gagan M K, Zhao J -x, Hellstrom J C, Ayliffe L K and Hantoro W S 2013 *Quaternary Science Reviews* **74** 273-279.
- [40] Post V E A, Groen J, Kooi H, Person M, Ge S, Edmunds W M, 2013 *Nature*, **504**, 71-78.
- [41] Sun X J, Li X, Luo Y L 2002 *Acta Bot Sin.* **44** 746–752.
- [42] Wang X, Sun X, Wang P, Stattegger K 2009 *Palaeogeogr Palaeocl* **278** 88–97.
- [43] Voris H K 2000 *J. Biogeogr.* **27** 1153–1167.
- [44] Slik J W F et al. 2011 *Proc Natl Acad Sci* **108** 12343–12347.
- [45] Wang P, Li Q, Tian J 2014 *Marine Geology* 381–396.
- [46] Raes N, Cannon C H, Hijmans R J, Piessens T, Saw L G, van Welzen P C, Slik J W F 2014 *PNAS* **111** 16790–16795.
- [47] Hanebuth T J J, Stattegger K 2003 The stratigraphic evolution of the Sunda Shelf during the past fifty thousand years *Tropical deltas of Southeast Asia – sedimentology, Stratigraphy, and petroleum geology* ed Sidi F H et al. **76** (SEPM) 189–200.
- [48] Briggs, 1992 *Proceedings of the National Academy of Sciences*.
- [49] Lim H C, Rahman M A, Lim S L H, Moyle R G, Sheldon F H, 2011 *Evolution* **65** 321–334.
- [50] Wurster C M, Bird M I, Bull I D, Creed F, Bryant C, Dungait J A J, Paz V, 2010 *PNAS* **107** 15508–15511.
- [51] Latief H, 2015 Pers.com. Propagasi gelombang tsunami di paparan tepi kontinen Sunda dan Laut China Selatan.
- [52] Hantoro W S 2006 *Procedings of the International Symposium Indonesian Institute of Sciences International Center of Prehistoric and Austronesian Studies* (Jakarta: LIPI Press) 438p.

- [53] Belwood P 2006 *Procedings of the International Symposium Indonesian Institute of Sciences International Center of Prehistoric and Austronesian Studies* (Jakarta: LIPI Press) 438p.
- [54] Jacob T 2006 *Procedings of the International Symposium Indonesian Institute of Sciences International Center of Prehistoric and Austronesian Studies* (Jakarta: LIPI Press) 438p.
- [55] Marzuki S and Sadoyo H 2006 *Procedings of the International Symposium. Indonesian Institute of Sciences. International Center of Prehistoric and Austronesian Studies* (Jakarta: LIPI Press) 438p.