THE INFLUENCE OF SEA-LEVEL CHANGES ON SEA-BOTTOM MORPHOLOGY OF SINGKAWANG WATERS WEST KALIMANTAN BASED ON ANALYSES OF BATHYMETRIC AND SEISMIC DATA

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ABSTRACT

In the history of Quaternary geology, global climate changes influenced worldwide sea-level variations. On this study, these phenomena are tried to be assessed through sea-bottom morphology changes using bathymetric and seismic strata box data obtained during field survey in Singkawang Waters, West Kalimantan. Sea-level changes in this area are referred to global variations that had been studied by many researchers. Maximal depth attained during bathymetry mapping was -52 meters which take place as a depression between Lemukutan and Penata Besar Islands. General depths are - 30 m; thus, morphology reconstruction was done for sea-level positions - 10 m, - 20 m, and - 30 m from mean sea level. At the study area, sea-level dropped more than -30 m was only occurred in sea bottom morphology of isolated depressions. These isolated depressions are assumed as paleo-lakes which occurred throughout Sunda Land by some authors.

The study also shows that sea-level history in Singkawang's area span from approximately 10,000 years ago or Holocene time to Recent. During low sea-levels, the sea-bottom morphology was characterized by more extension of Singkawang land, formations of narrow straits between islands and developments of paleo-lakes assumed as fresh water lakes in the past. These events, based on Voris's Diagram, occurred about 10,200 up to 8,300 years ago. On the other hand, marine clays appeared on coastal area of Singkawang. These might be evidence of sea-level rise in this area. About + 5m sea-level rise flooded this area approximately 4,200 years ago.

Influences of sea-level changes to subbottom geological conditions were also assessed. The assessment was carried out by analyzing shallow seismic reflection records by using strata box. The records demonstrated that subsurface geology were characterized by truncation reflector configurations interpreted as fluvial environments.

Keywords : sea-level changes, sea-bottom morphology, bathymetry, strata box, Singkawang Waters, West Kalimantan.

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S A R I

Dalam sejarah geologi Kuarter, perubahan iklim global mempengaruhi variasi permukaan laut di seluruh dunia. Pada kajian ini fenomena tersebut dicoba dipelajari melalui perubahan morfologi dasar laut menggunakan data batimetri dan seismik pantul dangkal yang diperoleh selama survei lapangan di Perairan Singkawang, Kalimantan Barat. Perubahan muka laut di daerah ini mengacu pada variasi global yang telah dikaji oleh beberapa peneliti. Kedalaman tertinggi yang diperoleh selama pemetaan batimetri adalah 52 meter, yaitu berupa suatu daerah depresi antara Pulau Lemukutan dan Penata Besar. Umumnya kedalaman adalah -30 m; sehingga, rekonstruksi morfologi dilakukan pada posisi muka laut - 10 m, - 20 m, dan -30 m dari muka laut rata-rata. Di daerah kajian, muka laut turun lebih dari - 30 m hanya terjadi dalam morfologi dasar laut yang berupa daerah-daerah depresi yang terisolasi. Morfologi depresi terisolasi ini diduga sebagai danau purba oleh beberapa penulis yang terdapat pada Daratan Sunda.

Kajian ini juga menunjukkan bahwa sejarah muka laut di daerah Singkawang mulai dari sekitar 10.000 tahun lalu (Holosen) hingga saat ini (Resen). Selama turunnya muka laut, morfologi dasar laut dicirikan oleh semakin meluasnya daratan Singkawang, terbentuknya beberapa selat sempit dan berkembangnya danau-danau purba yang diduga sebagai danau air tawar di masa lalu. Peristiwa tersebut, berdasarkan diagram umur terhadap muka laut Voris, terjadi sekitar 10.200 hingga 8.300 tahun lalu. Sementara itu, keterdapatan lempung endapan laut dari data pemboran pantai di Singkawang merupakan bukti naiknya muka laut di daerah ini. Kenaikan muka laut sekitar + 5 m telah menggenangi daerah ini kira-kira 4.200 tahun lalu.

Tulisan ini juga membahas tentang pengaruh perubahan muka laut terhadap kondisi geologi bawah dasar laut. Kajian dilaksanakan dengan menganalisa rekaman seismik pantul dangkal. Rekaman menunjukkan bahwa geologi bawah dasar laut dicirikan oleh konfigurasi reflektor 'toreh dan isi' atau truncation yang ditafsirkan sebagai lingkungan fluvial.

Kata kunci : perubahan muka laut, morfologi dasar laut, batimetri, strata box, Perairan Singkawang, Kalimantan Barat.

INTRODUCTION

Issue on sea-level rise and fall related to global climate change has been widely discussed currently due to its influence to coastal zones, where most people lives. Study on local scale of this issue had been conducted in Singkawang Waters, West Kalimantan. Detailed bathymetry and shallow seismic reflection data were used to examine sea-bottom morphology and subbottom geological conditions of this area, especially during sea falls.

Maximal bathymetry depth obtained during field survey was -52 meters. The bathymetric contour pattern of this depth show as a depression area occured between Lemukutan and Penata Besar islands. In general, maximum depth in the study area is less than -30 m from mean sea level; while morphology reconstruction was done for sea-level positions -10m, -20m, and -30m. Overview of regional bathymetric data was also confirmed sea depth of the study area less than -30 m. Sea water depths more than 30 m at Singkawang Waters occurred in isolated and closed bathymetric patterns interpreted as morphology of depressions. These isolated depressions are assumed by some authors as paleo-lakes. According to Sathyamurthi and Voris (2006), this phenomenon occurred throughout Sunda Land. Under sea bottom, recognition of sea-level changes was done through identifications of Quaternary marine sediment deposition and erosional truncation patterns observed on shallow seismic reflection records.

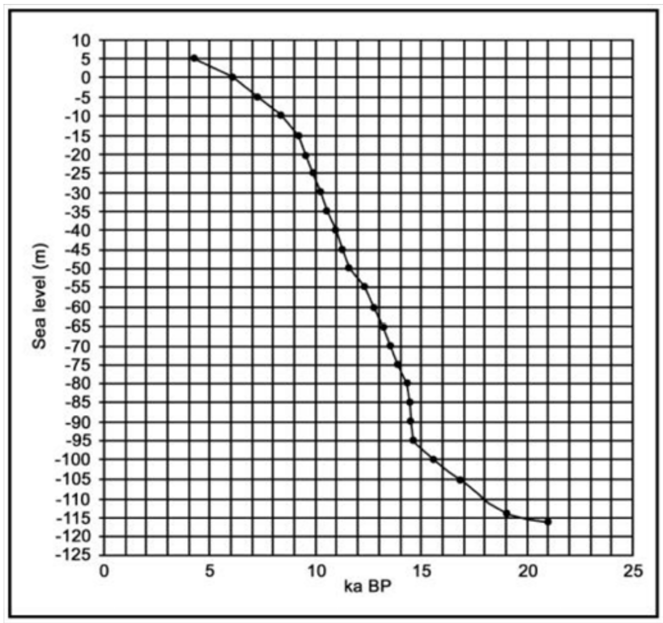

Figure 1. Curve of sea-surface rise from 21,000 up to 4,200 years ago used in this study. (Voris, 2000)

According to Voris (2000), Quaternary sea-level changes, especially Pleistocene, resulted from study of retreat coastline. This evidence is recorded from coral reef terraces migrations on tropical coasts or deviations of isotope oxygen records. It is based on the standard ratio $^{18}O/^{16}O$ in foraminifera shells obtained from deep sea core samples. The sea-level changes were presented in a sea-level estimation graph plotted against time in ka BP units or thousand years before present (Figure 1).

Many authors in Indonesia had also conducted research on the past sea-level changes. Yulianto and Sukapti (1998) studied sea-level variations generated by climate change through palynological data. They assumed that every climate alteration will give impact either directly or indirectly to flora or vegetation. Pollen fossils preserved in sediments could be used to reconstruct paleo-vegetation community. While palynology assessment in complete sediment sequence could give records of paleo-vegetation community. It has various fluctuations at certain time interval, which then this data is used to predict climate change that occurred. Their results show that before Holocene, earth temperature immediately was decreasing as the last maximum glacial period. In Indian Ocean Quaternary sediments of this period is characterized by proportion abundances of Graminae and Cyperaceae pollens. The abundances of Graminae occured around 35,000 up to 16,000 years ago, which related to dry climate and extension of Sunda Shelf. This extension was arisen due to lowering of sea-level, causing Sunda Land exposed. Palynology study at paleo-delta of Mahakam was also confirmed obvious increased of Graminae pollen approximately 18,000 years ago. Graminae domination, beside Cyperaceae and prairie taxa, is the most observable palynological phenomena during the last maximum glacial period; especially for marine, transition and low land sediment study.

Premonowati (1998) used reef elevation changes to study sea-level fluctuations from Paciran Formation at north coast of East Java. The assessment was based on ‘caliche’ elevations and slope breaks of carbonate facies of Paciran Formation, which reached highest elevation 157 m and lowest 12,5 m above Recent sea-level. Unfortunately, the age range was quite wide, 940,000 up to 5.4 million years ago. The age range is difficult to be applied at the present study area of Singkawang which only in thousand years.

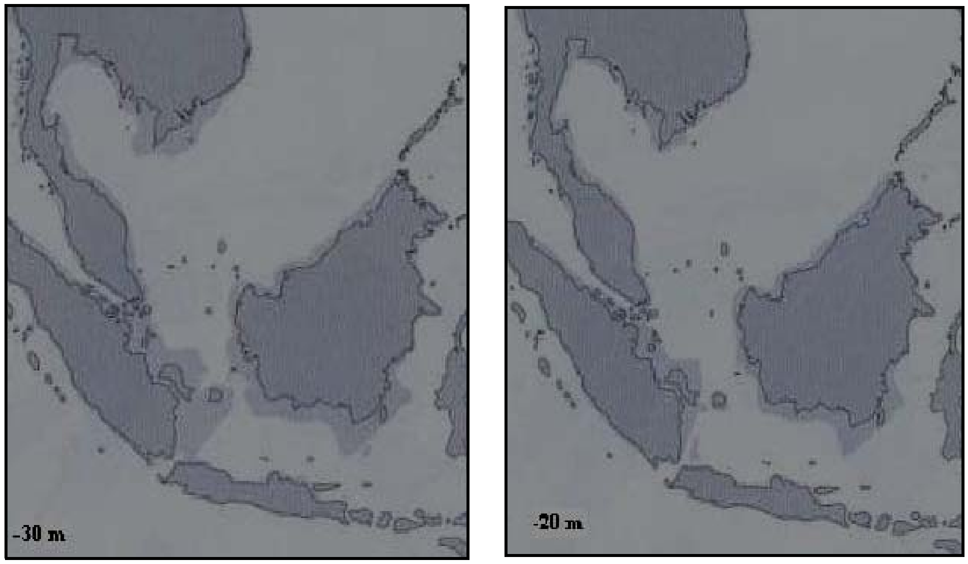

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Figure 2. Land mass condition of Sunda Shelf at sea-surfaces -30, -20 and -10 m below present sea-level (Voris, 2000).

Sea-level change which started at the last maximum glacial, approximately 21,000 years ago, influenced to an area extension of emerged Sunda Shelf. Figure 2 illustrates land area changes at each sea-level -40m, - 30 m, - 20 m and –10 m below present sea surface. It is obvious that Sunda Land area and its paleo-river pattern adjusted to sea-level rise. While paleo-coastline changes appeared as termination of paleo-rivers. At sea level - 40 m, most paleo-channels were drawn; while at - 30 up to -10m Kalimantan, Sumatra and Java lands were already separated. Offshore area of West Kalimantan was characterized by two distributary channels of paleo-North Sunda river, where the south distributary as a continuation of present Kapuas River and the other north assumed as a prolongation of Singkawang River.

Hanebuth, *et al* (2000, in Sathiamurthy and Voris, 2006) gave descriptions of sea-level rise stages between 21,000 up to 11,000 years ago: Lowest Glacial Maximum (LGM) occurred at 21,000 years ago. Then, at 19,000 years ago sea-level slowly rise from -116 m with average velocity 0.10 m / 100 years until -114 m from present sea-level. Between 19,000 and 14,600 years ago, sea-surface increased from -114m able to -96 m at velocity 0,41 m / 100 years. Sea-surface rise accelerated from 14,600 until 14,300 years ago, started from -96 up to -80 m at velocity 5.33 m / 100 years. This acceleration was associated with rapid polar ice melt or polar melt water pulses.

In between 14,300 and 13,100 years ago, sea-surface increased from -80 until -64 m with rate 1.33 m / 100 years. While between 13,100 and 11,000 years ago, sea-level increased about 8 m in 700 years.

Sea-level rise at Holocene Epoch took place between 10,000 years ago until modern time. Among 10,000 and 6,000 years ago, sea-level was rise from -51 until 0 m. Between 6,000 and 4,200 years ago, sea-surface increased from 0 to +5 m, known as a high sea-level of Mid-Holocene. At this level low coastal plains and deltas were drawn. After this level, sea-surface gradually decrease and reached the modern surface about 1,000 years ago.

In relation to tectonic activity, the Sunda Shelf generally is a stable tectonic area since Early Tertiary. Nevertheless, Tjia, *et al* (1983 in Sathyamurti and Voris, 2006) indicated that sea-level rise in this area could be correlated to a combination of real sea-level rise and vertical plate movement.

The decreased Holocene sea-level in Sunda Shelf gave impact to climate change, formation of land bridge between big islands in Sunda land, major reconfigurations of Sunda river system, and greater separation of Indian Ocean and South China Sea (Voris, 2000; Sathiamurthy and Voris, 2006).

According to Steinke, *et al* (2003), based on their study in South China Sea (SCS), the exposure of the Sunda Shelf at the last glacial maximum (LGM) led to an increased terrigenous input to the basin of up to 10 times when sea level was -120 m lower. This was caused by erosional processes on the emerged shelf and by centralized discharge of fluvial sediment via major river systems of North Sunda River, onto the slopes and the deep sea. On the other hand, the subsequent rise of sea level during LGM was paralleled by a marked decrease of sediment supply to the continental margin and the deep sea due to a shift of the depositional centers from shelf break and slope to proximal shelf seas. This kind of proximal deposition take place in northern area of Singkawang Waters, as this place is the location of sediment deposited from Kalimantan hinterland.

They also pointed out that temporal and spatial variations in the flux of terrigenous sediment from shelf margin down to the lower continental slope of the southern SCS in response to the morphological evolution on the Sunda Shelf.

The study area, off Singkawang, belongs to Northern part of Sunda Shelf. This area was characterized by a paleo-river system of North Sunda, the largest paleo-river system in the shelf, flowed to the north from northeastern coasts of Sumatra (Indragiri, Batanghari and Musi rivers) to combine with big Kapuas River from Kalimantan before entering the sea, at northeast of Natuna Island. Most authors agree with this North Sunda river system. At sea-level below 75 m from present sea-surface (Figure 2), this river mixed some rivers of Kalimantan and Sumatra and largely influenced the distribution of fresh water fishes (Voris, 2000).

Each sea-level position at a certain location below present sea-surface, had its

Table 1. Estimation of time amount for each sea-level interval at Pleistocene until Holocene started 17,000 years ago (Voris, 2000).

Sea-level at or below current sea-level (m)	Estimation of year amount in each sea-level time period at or below present sea-surface (year)	Estimation of year amount percentage at every time period (%)
120	1.000	6
100	4.000	24
75	5.500	32
50	7.000	41
40	7.500	44
30	8.400	49
20	9.200	54
10	11.000	65

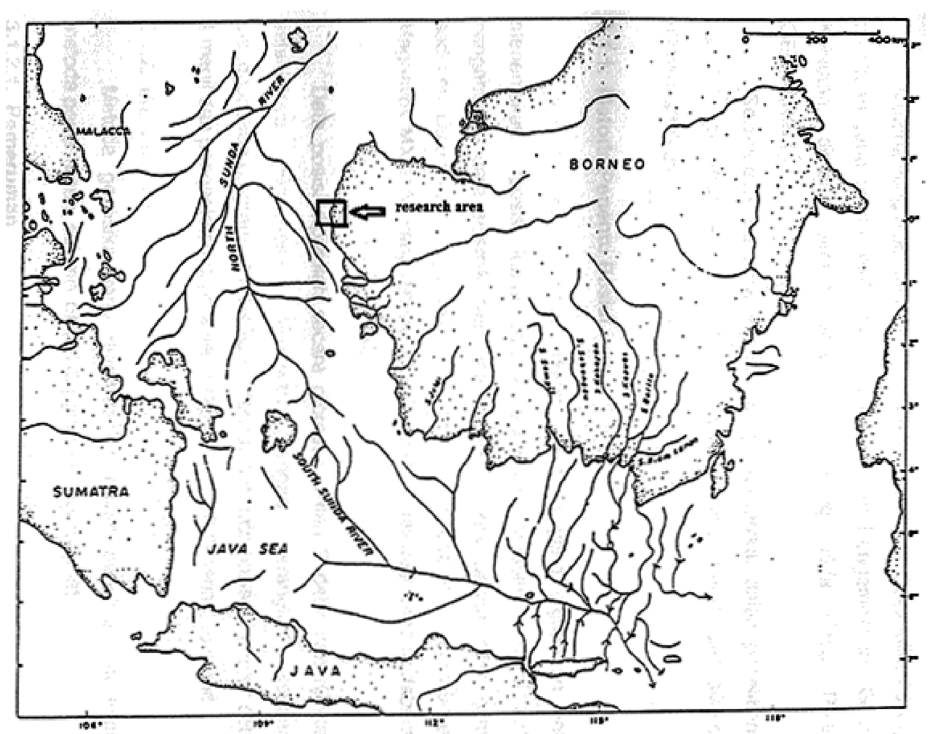

Figure 3. Research area in Sunda Shelf paleo-river map of Molengraff.

own time period, which differ its time duration for every level. Voris (2000) made estimation of time amount started from 17,000 years ago based on changes of oxygen isotopes deviations as shown in Table 1. It is clear that the largest percentage of year amount took place at sea-level -10 m from Recent sea-surface; while at maximum glacial -120 m, the percentage of amount year is the lowest; thus, it is interpreted that time period for each level is longer for sea-levels closed to present sea-surface.

METHOD

Research method used in general was marine geology and geophysics. Four sediment cores were collected by hand auger drilling in order to recognize any evidence of marine deposits in coastal areas of Singkawang. On the other hand, geophysical method applied was a shallow seismic reflection system of strata box to assess subsurface geological conditions.

For the purpose of sea-level change study, about 300 km length of seismic lines was made. This seismic was done in parallel with bathymetric mapping at an area of 1400 square kilometers where two-third or approximately 900 square kilometers is open sea.

Strata box is a water resistant under seabed high resolution seismic equipment, using low power and portable. This tool is capable to identify sediment layers resolution up to 6 cm with penetration reached 40 m below seabed and specially designed for coastal survey up to 150 m sea depth which operating at 10 kHz frequency (Ocean Data Equipment Corporation, 2002).

Bathymetric map was used for reconstruction of sea-bottom morphology at sea-level dropped -10 m, - 20 m and – 30 m. Each level was determined its age in thousand years before present (ka BP) using diagram of Figure 1. This method was first developed by Sathyamurthi and Voris (2006) to study sea-bottom morphological change affected by sea-level variation in Sunda Land in age range between 21,000 up to 4,200 years ago. These authors used the curve to estimate the age of each sea-level position either above or below Recent sea-level. Some assumptions were made for the analyses; it is assumed that present topographical and bathymetric condition nearly closed to physiographic condition 21,000 years ago. But, due to sedimentation and erosion had already influence bathymetry of Sunda Shelf; this method is an only estimation. Thus, it should be pointed out here that depths and geometry of Sunda Shelf and other submarine depressions were not accurately described the past.

RESULTS

Topographical contour 5 m above present mean sea-level was used as a based contour to show the influence of sea-level rise at Singkawang’s coastal area (Figure 4). Coastal elevation was obtained from earthgoogle elevation data, at about 15 feet height or 5 m over Recent mean sea-level. At this level, most of coastal area north of Singkawang City was inundated; due to its physiographic condition as an alluvial plain. On the other hand, the influence of sea-level rise at the middle coastal area of study area was not so significant due to high relief morphology. This part was constructed by old, massive and resistance lithology of Raya Volcanics of Upper Cretaceous and Sintang Intrusives of Oligo-Miocene age. At south of study area, the inundation area was quite significant observing its alluvial plain extension. Suwarna and Langford (1993) named lithology unit occupied this sea-level rise inundation area as Littoral Deposit which consisted of mud, sand, gravel, locally calcareous and vegetation remnants.

Sea level rise was recorded by Yoshikawa (1987) based on 14 carbon dating of dead

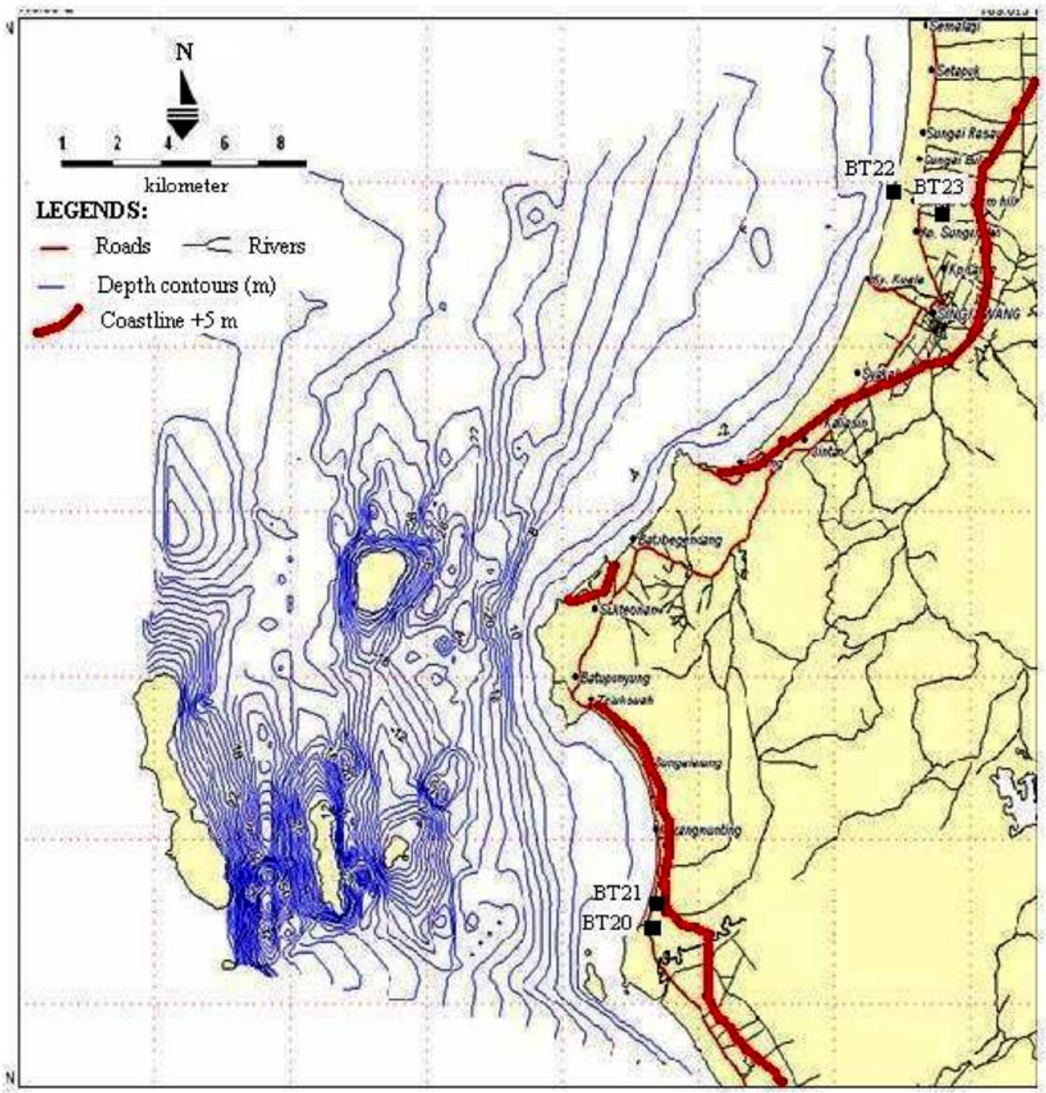

Figure 4. Singkawang's area at sea-level + 5 m from present sea-surface, approximately 4,200 years ago. At that time Singkawang City was drawn. BT20, BT21, BT22 and BT23 are hand auger drilling locations.

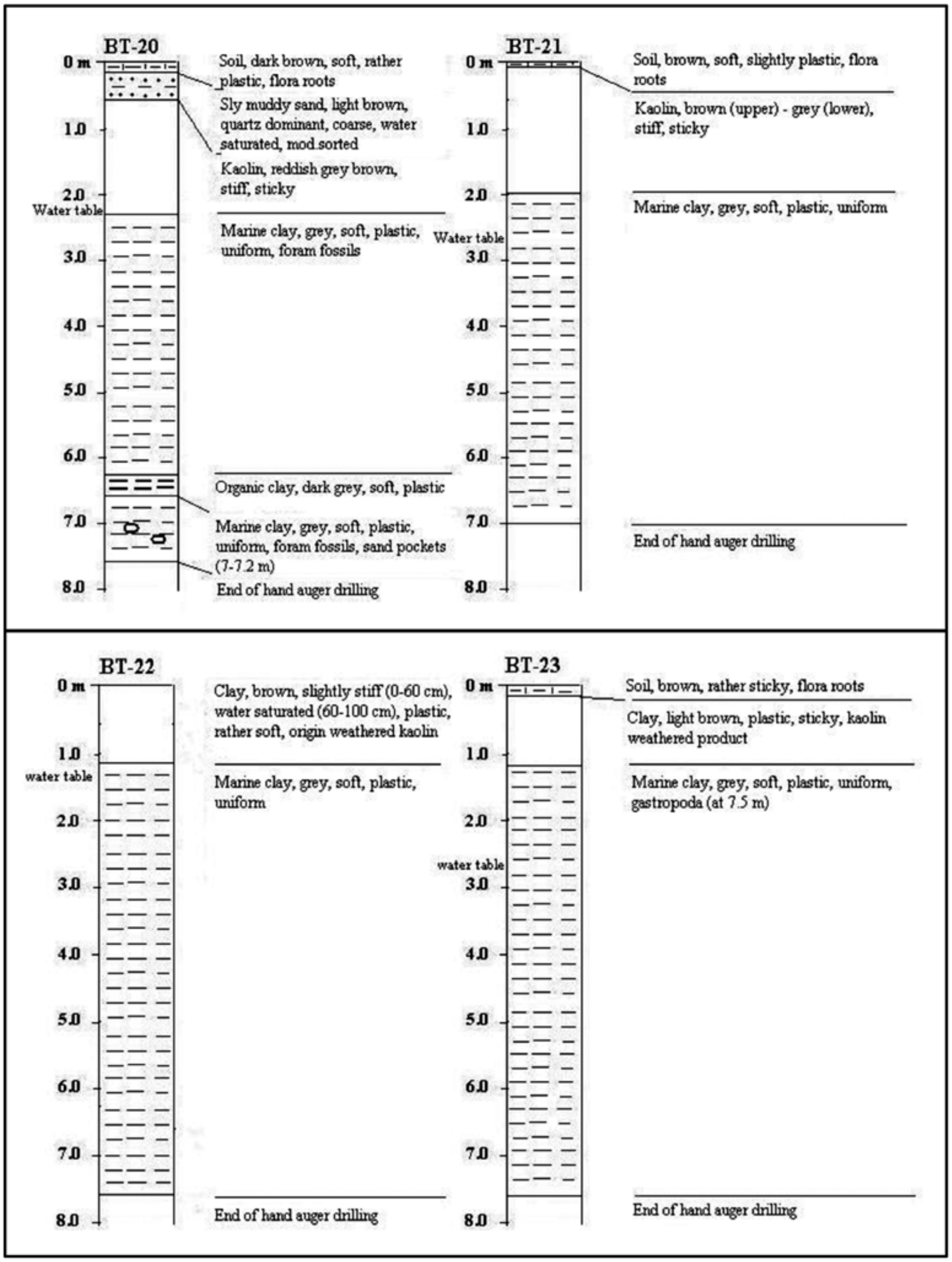

Figure 5. Hand auger data of the north and south of study area, locations on Figure 4, demonstrated marine clay, as an evidence of sea-level rise in this area.

algae and oyster found in six locations in Bangka Belitung Island. They collected from 1.6 to 3.3 m above sea level and their calculated age were between 4.820 and 1.490 year BP.

Hand auger data at coastal of study area (Figures 4 and 5) showed marine mud. At the north (BT22 and BT23) the marine clay is thicker, about 6 m, compared to drilling data (BT20 and BT21) of the south (5 m). This is possibly inundation area at the north was more extensive than the south which resulting in thicker marine clay.

In Singkawang area, sea-bottom morphology resulted from marine transgression-regression developments at 10 m intervals could only be reconstructed at time range between 10,200 and 4,200 years ago. Even though maximum sea depth 52 m from bathymetric data; seafloor morphology could only be reconstructed at sea-levels – 10 m,

- 20 m, and - 30 m. Beyond this depth, the study area had already becoming land and formation of depressions isolated from open sea were taken place.

At sea-surfaces -10 m, Singkawang's coastal area was more extended to the sea with paleo-coastline about 1 km to 10 km from present coastline. The islands were also expanded following bathymetric depth – 10 m (Figure 6), and the straits between the islands were narrowing.

Overview of bathymetry data combined with islands and coastal geology, marine area in center of study area is assumed as a stable area, compared to northern part. This opinion was based on geological condition in the central area that constructed by resistant hard rocks of Raya Volcanics and Sintang Intrusives; while the north part is an accumulation place for sediments deposited from Singkawang River (Figure 6). Stable bathymetry condition was also supported by thin sediment cover data from isopach map.

At receded sea-level – 10 m from present sea-surface, Singkawang land was extended toward the sea, as illustrated in Figure 6. It was also occurred for islands of Kabung, Lemukutan, Penata Besar and Penata Kecil that enlarged to the sea; due to their high elevations. Analyses of strata box seismic record (Figure 7, for location see Figure 6), paleo-coastline – 10 m was identified, and it reveals that the record demonstrated repetitions of cut and fill reflector configuration that could be interpreted as fluvial environments.

At the record was also shown that the Holocene sediment which is interpreted from sea-bottom up to underlying erosional surface boundary (Figure 7), was thin; 1 to 2 m thickness. Sediment types based on 77 surficial sediments show that the study area is dominated by silt, sandy silt and silty sand. Coarse fraction sediments of sand and gravelly sand were sporadically distributed around islands of Kabung, Lemukutan and Penata Besar.

Below erosional surface that separated the Holocene sediments with older sequences was found Pleistocene sediments which demonstrated cut and fill configuration pattern interpreted as fluvial environment. Ringis (1979) found out that these Pleistocene sediments are more solid and compact that consisted of sticky grey clay, sandy clay and sand. Basement of this unit was possibly Raya Volcanics of Upper Cretaceous age.

The -10 m paleo-shoreline environment was also supported by existence of gas charged sediment as shown in Figure 8 (record location on Figure 6). Considering the proximity of its location closed to paleo-shoreline, it is interpreted that the gas indication location was a transision environment possibly grown by mangroves in the past.

Sea-level condition below -20 m of Singkawang's area in the past is as shown in

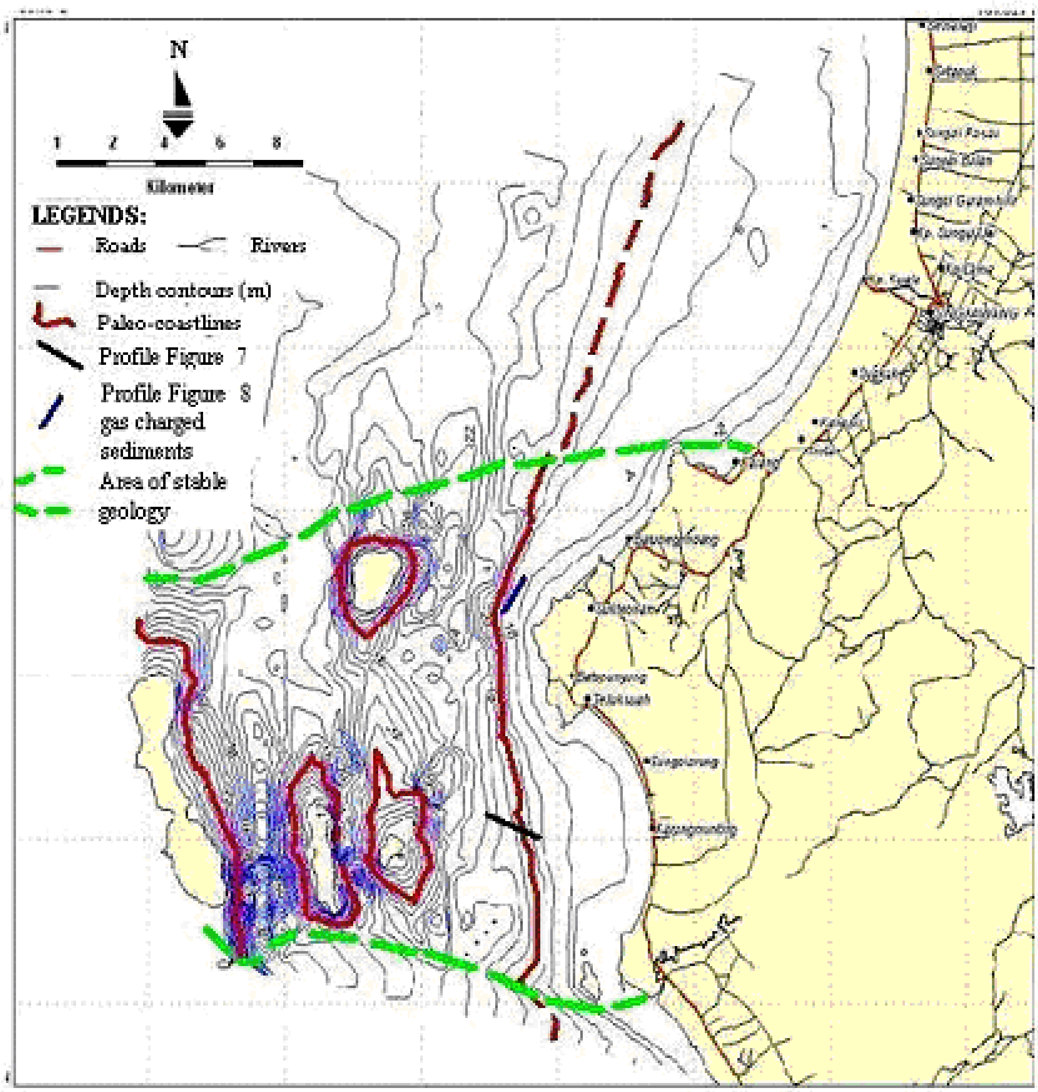

Figure 6. Singkawang area at sea-level below 10 m from present sea surface. Thick red contour was assumed as paleo-shorelines which occurred approxi-mately 8,300 years ago. Area of stable geology consisted of Upper Cretace-ous Raya Volcanics and Oligo-Miocene Sintang Intrusives was delineated.

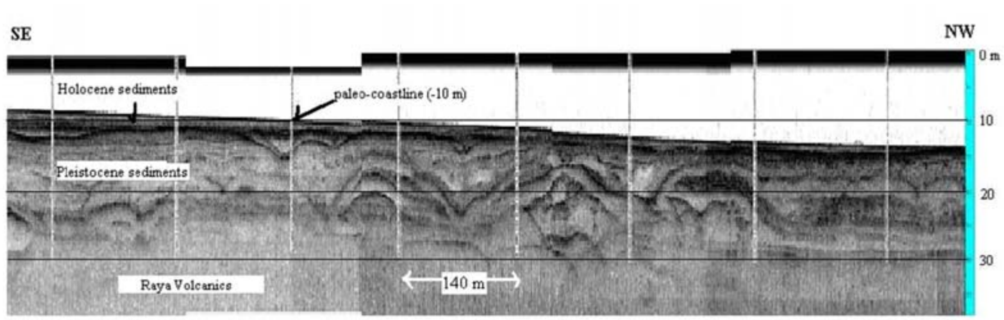

Figure 7. Repetition of distinct cut and fill reflector patterns of strata box seismic profile at the south of study area (see Figure 6 above for location) which reflects very intense fluvial sedimentation during Pleistocene. It seems that this phenome-non was taken place as a response of dropped sea-level many times. The -10 m paleo-shoreline is identified.

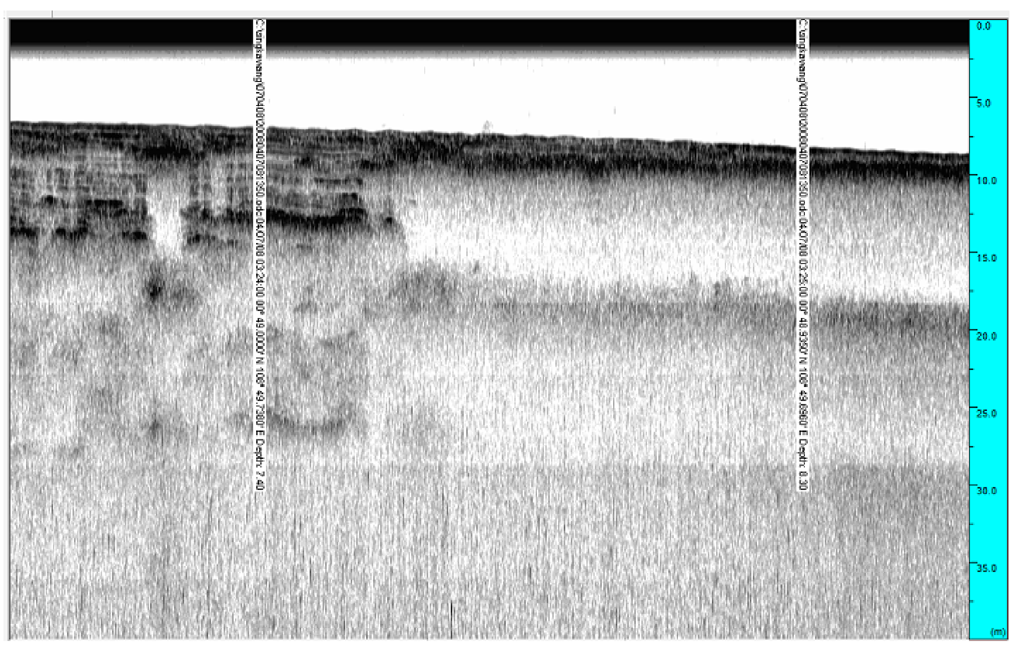

Figure 8. Gas charged sediment indication around Batubelah Cape (record location on Figure 5). It is obvious that the indication is existed in Holocene sediment. It gave 'pulling down effect' where the underlay sediments were not properly recorded due to reduce acoustic signal velocity by gas absorp-tion. This environment was possibly a mangrove coastal area in the past.

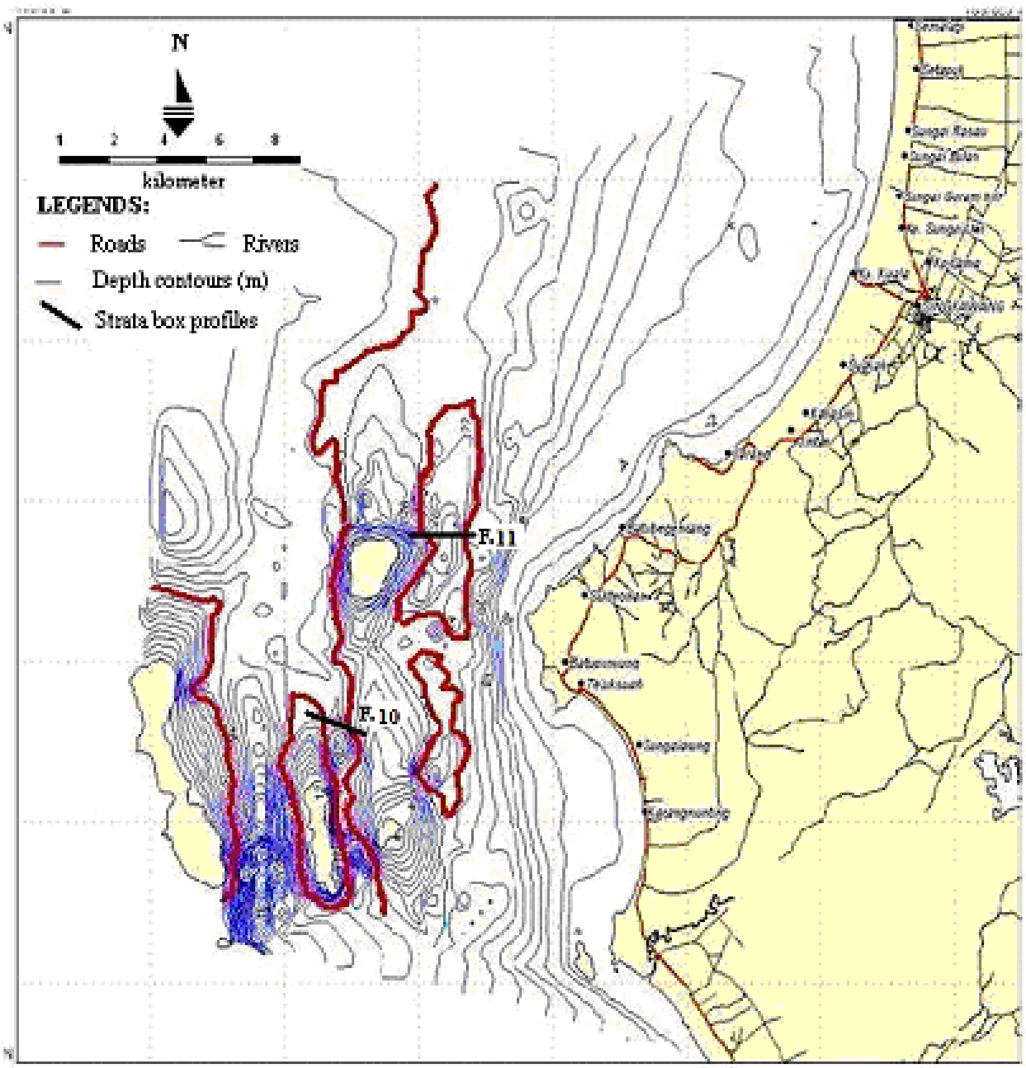

Figure 9. Singkawang's area at sea-level -20 m from current sea-level. Paleo-coastlines formed closed bathymetry contours east and southeast of Kabung Island occurred as depressions interpreted as paleo-lakes; while Singkawang's -20 m coastline relatively parallel to current coastline was moving further west. Narrower strait was also formed between Singkawang's paleo-coastline and Penata Besar Island coastline which was also extended seaward following sea-level dropped.

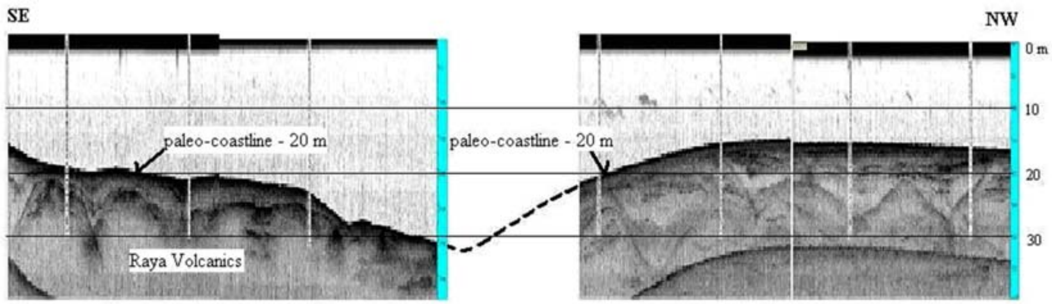

Figure 10. Strata box record show narrow strait between Singkawang's land (SE) and Penata Besar Island (NW) which reached sea depth more than 30 m. More active erosi-onal process than sedimentation was demonstrated by thin surficial sediment. The sea-bottom and its sub-surface geological conditions were not changed much during the past -20 m sea-level dropped due to high resistance lithology of Raya Volcanics. The high resistance rock was also demonstrated by multiple feature of the strata box record. Record location at Figure 9.

Figure 9. The thick red lines in the east of Kabung and Penata Kecil islands form closed contours which are interpreted as depressions of maximum depths -28 m at the north and -30 m at the south. These two depressions were possibly fresh water lakes in the past (Sathyamurthi and Voris, 2006). On the other hand, narrow straits were formed between paleo-coastline of Singkawang's land (SE part of Figure 10) and Penata Besar Island (NW part of Figure 10). Between Lemukutan and Penata Besar islands, the strait reached -52 m depth which is the deepest spot of study area. These straits were formed due to extension of land and islands generated by -20 m sea dropped, and this event was taken place about 9,500 years ago.

The strata box record of Figure 10 also shows more intense erosional activity than sedimentation, especially at paleo-river valleys below sea-bottom. This phenomenon was also supported by thinner surficial sediments. At the figure, multiple of sea-bottom below shows hard rock interpreted as part of Raya Volcanics of Upper Cretaceous.

Researchers at Exxon Company Production Research (EPR) had done a revolutionary breakthrough using reflection seismic profiles to identify sequences and then used these sequences to estimate age and magnitude of sea-level change in the past. Although continental margin stratigraphic records are complicated due to subsidence changes, it is still possible to evaluate subsidence history using method known as 'backstripping'. This method progressively disposed of influences of compaction, sediment loading, and thermal reduction; and left behind an estimation of eustatic sea-level. Backstripping method also requires information on age estimation, sediment type (for decompaction), and paleo – bathymetry (Kenneth, 2005) which usually are obtained from benthic foraminifera and lithology data. These two data are great sources of uncertainty. Thus, it is pointed out here that although seismic record data was used by many researchers to estimate sea-level changes in the past; it remains that its uncertainty still huge as mentioned above. The authors try to discuss seismic record data as it

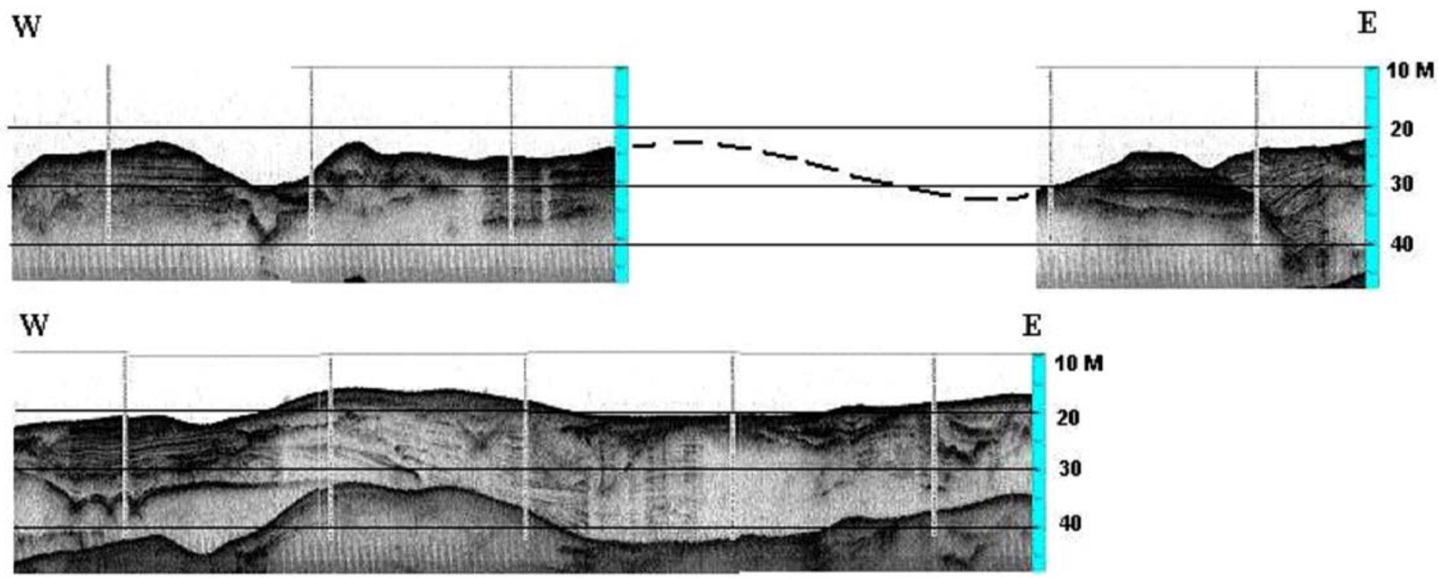

Figure 11. Two dimensional sea-bottom morphology of a depression located east of Kabung Island from strata box record (record location in Figure 9). Again, this record shows resistance hard rock of Sintang Volcanics of Upper Cretaceous; no Holocene sediment could be observed here; and this condition seems the same when sea-level dropped -20 m about 9,500 years ago. Sub-seabottom geological structure was shown by rock deformation and folding; hard sea-bottom was also supported by multiple feature of strata box record.

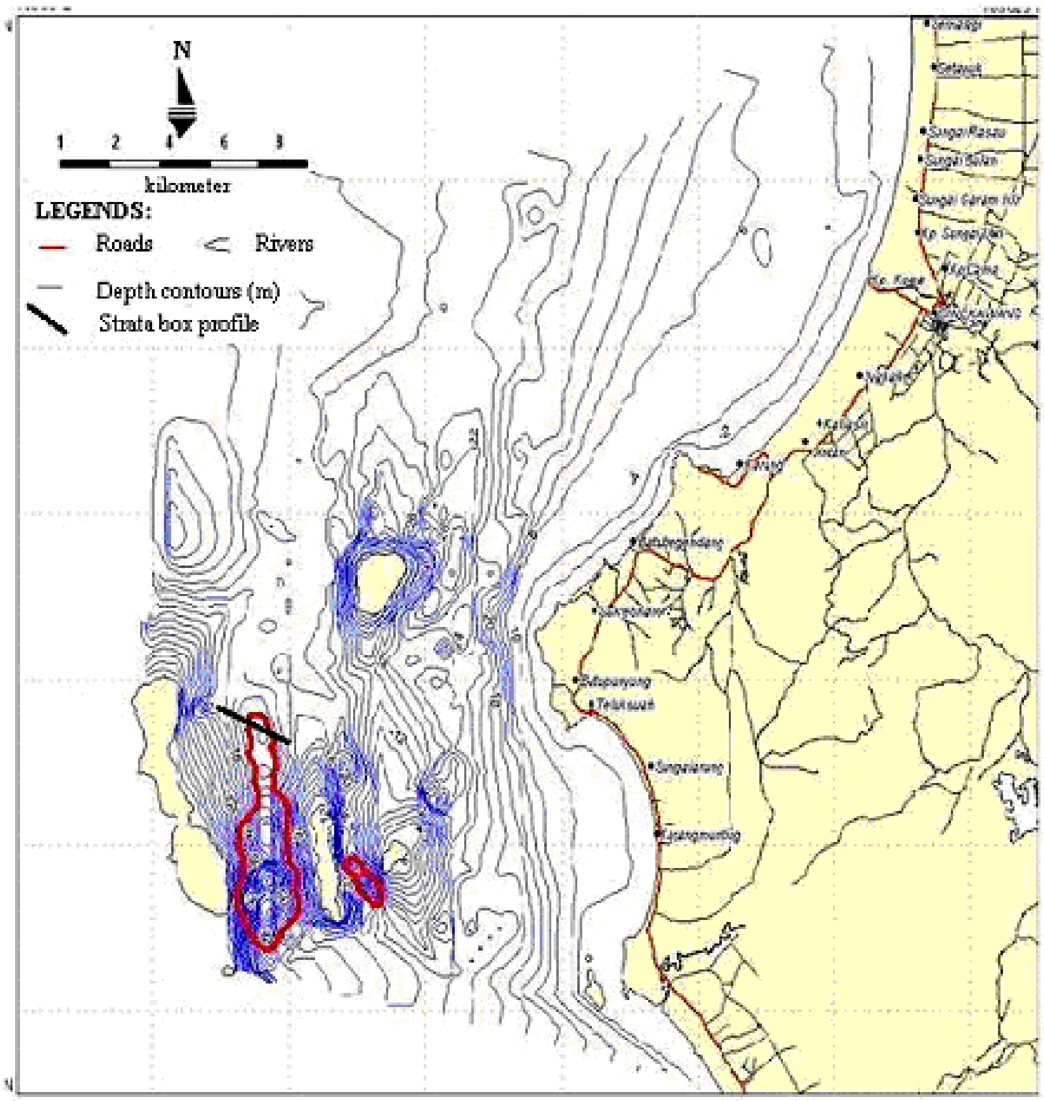

Figure 12. Singkawang's area at sea-level dropped -30 m from current sea-level (about 10,200 years ago) which only left two depressions that possibly fresh water lakes located between Lemukutan and Penata Besar islands and between Penata Besar and Penata Kecil islands.

is, without further related it with sea-level changes.

Velocity of acoustic signal propagation used at strata box seismic system for media of sea water and under sea bottom sediments are differ. At sea water, assumption of the velocity used is 1,500 m/second; while for under sea bottom sediments 1,600 m/second. Depth values displayed at right side of strata box records are meant for water column, for sediments due to velocity difference; at water depth 10 m, calculated sediment thickness is 9.375 m. For sea depth 20 m is comparable with sediment thickness 18.750 m. Hard rock require another different acoustic signal velocity greater than 1,600 m/second. Budhi et al (2001) used acoustic velocity 1,750 m/second to calculate thickness of coal-bearing sediments in South Kalimantan Waters. By using this value to calculate thickness of hard rocks of Raya Volcanics and Sintang Intrusives in the study area, was obtained 8.571 m rock thickness comparable with 10 m water depth; and 17.143 m comparable to 20 m sea depth. Thus, it is obvious that depth values on the right side of strata box records were not accurate to determine neither sediment nor hard rock thicknesses; due to acoustic velocity of different media.

At sea-level decreased up to -30 m (Figure 12), all the study area had became vast land, except a depression located between Lemukutan and Penata Besar islands. This depression morphology is assumed as a paleo-lake possibly filled with fresh water. Further sea-level dropped until -50 m would not effect Singkawang's area that already had become part of Kalimantan main land; only the paleo-lakes remained.

DISCUSSION

Assumption used for delineations of paleo-coastlines from bathymetry data of Singkawang's Waters at sea-levels dropped -10 m, -20 m and -30 m from current sea-surface seems only appropriate for middle part of the study area. This is based on consideration that this part more stable due to geologically composed of compact and rigid old rocks of Upper Cretaceous Raya Volcanics and Oligo-Miocene Sintang Intrusives. Another consideration is that in this part

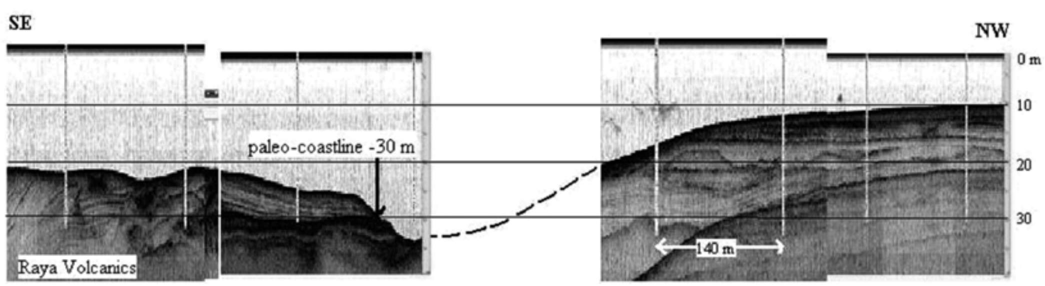

Figure 13. Strata box record of a seismic line passing through north part of a depression formed between Lemukutan and Penata Besar islands. Lowering sea-level up to -30 m was causing the depression, assumed as a paleo- fresh water lake consi-Dering its closed bathymetry contour pattern, to become narrow. Hard rock sea-bottom condition of Raya Volcanics would come to interpretation that morphology in the past remain the same as it is today.

sedimentation is almost neglected, compared to the northern part of Singkawang River mouth area. At the north due to very active sedimentation, morphological conditions always changed from 10,200 years ago.

Existence of depressions in the study area without outlet to open sea is interpreted as fresh water paleo-lakes. Sea-level change study by Sathyamurthi and Voris (2006) at Sunda Shelf found out many depressions that possibly in the past were fresh water lakes, when Sunda Shelf becoming land.

Question on weather in the past these lakes filled with fresh water or salt water depend on what kind of sea-level changes affected them. Is it generated by a sea-level rise? If it is the case, then the lake in the past possibly filled with fresh water, because the depressions belong to fluvial system of land environment. On the other hand, if the lakes were resulted from sea-level retreat, then the basins might be filled with salt water because it acted like trap. The authors believe that the depressions were resulted from sea-level rise.

Analyses of strata box seismic records of the study area for sea-level change could not be applied back-stripping method due to lack supportive data such as compaction, sediment loading, and thermal decrease. Other parameters such as age estimation, sediment type (for decompaction) and paleo-water depth were also could not be available.

Our study, valuable offshore minerals such as tin and gold were much trapped in under seabed paleo-channels. These mostly buried paleo-channels were controlled by sea-level changes. Thus, study of sea-level variation would be useful to understand offshore mineral distribution especially placer minerals. It is already reported that offshore tin surround Bangka, Belitung and Singkep islands were trapped in paleo-channels closed to granitic intrusive bodies.

CONCLUSIONS

The reconstruction of sea-level change from bathymetry data was done at positions -10 m, -20 m, and -30 m. Even though maximum sea depth is 52 m; at more than -30 m, almost all parts of the study area was becoming land and depressions isolated from open sea were also formed. These lower sea-level events, based on Sathiamurthy and Voris (2006) diagram, were taken place around 8,300 up to 10,200 years ago. Therefore, sea-level changes affected the study area only during Holocene time, approximately 10,000 years ago until now. Reconstruction results found out Singkawang's land extension, formation of narrow straits between islands, and formation of depressions possibly fresh water lakes in the past.

Analyses of strata box records found out many 'cut and fill' reflector configurations interpreted as fluvial environment when sea-level dropped from Recent position. On the other hand, sea-level rise above 5 m from present sea-level, occurred about 4,200 years ago, is recorded as marine clay from hand auger sample in the coastal area of Singkawang which was inundated during that time.

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