The Relationship of Seafloor Surfacial Sediment with Seabottom Morphology of Lemkutan Island Water, West Kalimantan

Hubungan Distribusi Sedimen Permukaan Dasar Laut dengan Morfologi Dasar Laut Perairan Pulau Lemukutan, Kalimantan Barat

Hananto Kurnio* and Noor Cahyo Dwi Aryanto

Marine Geological Institute, Jl. Dr. Junjunan No.236 Bandung

Email : *hkurnio@yahoo.com

(Received 13 July 2013; in revised form 26 October2013; accepted 10 December 2013)

ABSTRACT: Sea floor sediment surrounding Lemukutan Island, West Kalimantan is distributed on rather steep sea bottom morphology. The steep bottom seems a continuation of rugged morphology of the island, especially at the northeast and southeast parts. This paper discusses the relation between sediment grain sizes and the steepness of sea bottom morphology. Grain size analyses of sediment shows various sediment types such as slightly gravelly muddy sand, gravel mostly composed of coral and lithic, and gravelly sand. Results show that steepness of sea bottom slope control deposited sediment types, coarse fraction sediments tend to settle on the area of high slope angle as at the northeastern and southeastern of the island. On the other hand, high energy marine environment, such as at the sea in front of north headland of Lemukutan Island, tends to accumulate coarse sediments. High percentages of organism shells in marine sediments obviously are deposited at those two domains.

Key words : sea bottom morphology, sediment, Lemukutan Island, West Kalimantan.

ABSTRAK: Sedimen dasar laut sekitar Pulau Lemukutan, Kalimantan Barat tersebar pada morfologi yang agak curam. Permukaan dasar laut yang curam tampaknya merupakan kelanjutan morfologi kasar pulau tersebut, terutama pada bagian timur laut dan tenggara. Makalah ini membahas hubungan antara besar butir sedimen dan kecuraman morfologi dasar laut. Analisis besar butir sedimen memperlihatkan jenis sedimen yang bervariasi, seperti pasir lumpuran sedikit krikilan, kerikil umumnya terdiri koral dan fragmen batuan, dan pasir krikilan. Hasil kajian menunjukkan bahwa kecuraman lereng dasar laut mengontrol tipe sedimen yang diendapkan, sedimen fraksi kasar cenderung mengendap pada daerah dengan sudut lereng tinggi seperti di bagian timur laut dan tenggara Pulau Lemukutan. Di samping itu, lingkungan laut enerji tinggi, seperti di bagian utara pulau, cenderung mengakumulasikan sedimen kasar. Prosentase tinggi dari cangkang organisma dalam sedimen laut tampak nyata diendapkan pada kedua lingkungan tersebut.

Kata kunci : morfologi dasar laut, sedimen, Pulau Lemukutan, Kalimantan Barat.

INTRODUCTION

An interesting phenomenon of seafloor morphology influences on sediment distribution off Lemukutan Island, West Kalimantan is studied in this paper. Lemukutan Island (Figure 1), is the biggest island among 12 and five of them occupied, which belongs to Bengkayang Regency territorial. This island is located approximately 38 kilometers from its district capital Sungai Raya – West Kalimantan mainland. The residences are 975 people with area approximately 12,520 hectare or 12.52 square kilometers.

With its small population, in average 77 people/ km^2 or 0.1 people/ha, natural condition of this island is relatively still pristine. In this island tourism destination for snorkeling is Melano Bay (at the south) and China Bay (at the north) of eastern coastal area.

This island has a unique morphology. At its northeastern and southeastern parts the morphology is steep hills (Figure 2). The steep morphology seems continued to sea bottom. Bathymetric data surround this morphology shows closed spacing contour which is an indication of steep seafloor. The steep morphology is developed due to resistance lithological condition of this island. Regional geology data, this island is composed of Raya Volcanics of Jura age according to Suwarna and Langford (1993), which is composed of andesite, dacite and pyroclastics. Granitic batholite rocks of Cretaceous age intruded Raya Volcanic units. This batholite known as Sintang Intrusives which consists of tonalite and granodiorite of calc-alcaline series.

By grain size, it seems that the sediment surrounding Lemukutan Island, West Kalimantan is

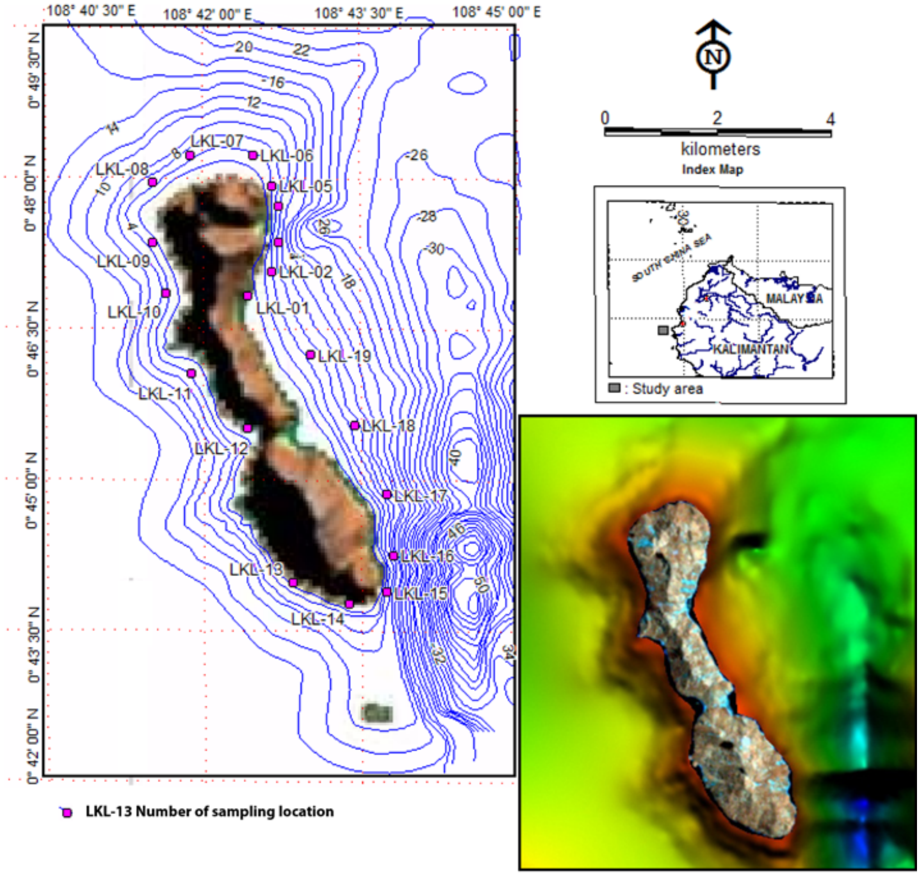


Figure 1. Location of study area and seafloor sediment sampling map

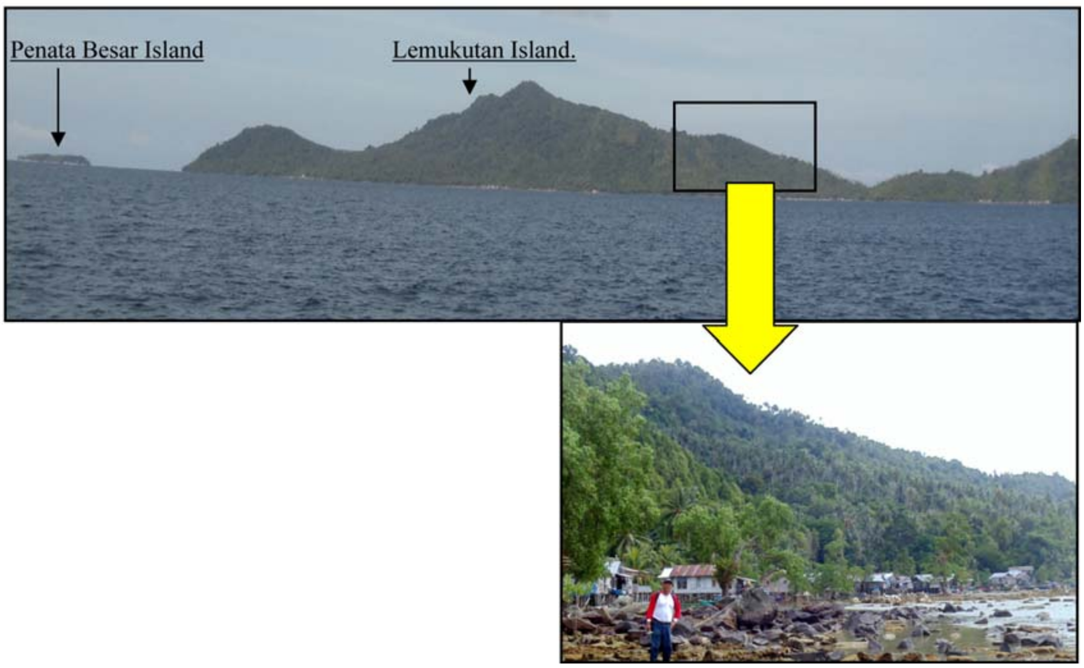


Figure 2. Steep hills morphology at eastern part of Lemukutan island

Figure 3. Strongly jointed massive lava outcrop at southeast of Lemukutan Island

distributed on rather steep sea bottom surface. The steep morphology is a continuation of rugged morphology of the island, especially at its northeast and southeast parts (Figure 3). The purpose of this paper is to investigate the relation between sediment grain size with conditions seabed morphology.

Studies on the relation between slope and sediment grain size have been done elsewhere. Reis and Gama (2010) had studied beach face slope and its relation with sand size based on various observations of beach characteristics in many areas. Their study revealed that there is a relationship involving sand grain size, beach face slope and open ocean wave height.

Briggs et al (2005) measured seafloor microtopography as a standardized element of geoacoustic characterization. They found out that much seafloor microtopography has been characterized alongside with sediment grain size; even though its empirical prediction of roughness from grain size remains problematic. This is due to sediment-water interface dynamic.

During field survey in June of 2012, especially at southeast of the island, the geology of coastal area is composed of massive lava outcrops which is strongly jointed (Figure 3). The lava is andesite with xenoliths of granodiorite and basalt.

METHODS

The method used in this research, among others are: Position data acquisition for sea floor sediment sampling using Garmin GPS Map 235 was conducted, while measuring the depth of sea floor using a Reson echosounder 210.

Seafloor slope values were determined through bathymetric map resulted from the survey (Aryanto et. al., 2012), which is then combined with digital elevation map (DEM) data and Landsat image (RGB 457) to determine the form of its land topography, whereas the topography of the sea forms are processed using global mapper software and then was made cross-section of the eastern side of Lemukutan island eastward to assess changes in seabed morphology.

The angle was calculated on the following way (Figure 4):

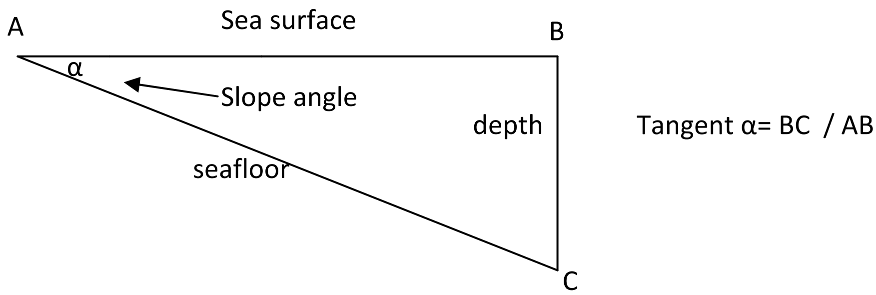


Figure 4. Diagram of seafloor slope angle calculation

Grain size analyses was applied for seafloor sediments. Sediment type classification is based on Folk (1980). The classification is also included statistic parameters such as mean (X(phi)), sortation, skewness and kurtosis; for each analyzed sediment sample (Table 1). Mean or average grain size is used to be correlated with seafloor slope angles at every sample location.

RESULTS

Seafloor sediments

The following table present granulometry data of seafloor sediments surround Lemukutan Island. The sediment was classified based on fractions of gravel, sand, silt and clay; and sediment types were using classification proposed by Folk (1980). Besides grain

Table 1. Seafloor sediment grain size data off Lemukutan Island, West Kalimantan

NO	SAMPLE NUMBER	X(phi)	Sortation	Skewness	Kurtosis	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	SEDIMENT TYPE (Folk, 1980)
1	LKL-01	-	-	-	-	-	-	-	-	Coral fragments
2	LKL-02	3.7	1.9	-0.2	3	1	52.6	46.2	0.2	Slightly gravelly muddy Sand
3	LKL-03	2.1	1.6	0.6	6	3.8	86.8	9	0.4	Slightly gravelly Sand
4	LKL-04	-	-	-	-	-	-	-	-	Coral fragments
5	LKL-05	-	-	-	-	-	-	-	-	Coral fragments
6	LKL-06	1.7	2.3	0.7	2.4	3.2	70.1	26.4	0.4	Slightly gravelly muddy Sand
7	LKL-07	0.7	1.9	0.3	4.1	19	76.7	4.4	0.2	Gravelly Sand
8	LKL-08	-	-	-	-	-	-	-	-	Coral fragments
9	LKL-09	2.8	1.8	0	3.3	2.2	65.6	31.5	0.6	Slightly gravelly muddy Sand
10	LKL-10	3.1	1.4	-0.3	3.1	0.2	65.2	34.5	0.1	Slightly gravelly muddy Sand
11	LKL-11	2.9	1.6	-0.1	3.2	0.9	69.2	29.9	0	Slightly gravelly muddy Sand
12	LKL-12	2.9	1.7	1.8	5.6	0	82.6	14.7	2.8	Silty Sand
13	LKL-13	2.4	2.4	0.5	2.6	2.7	60.7	33	3.6	Slightly gravelly muddy Sand
14	LKL-14	-	-	-	-	-	-	-	-	Coral fragments
15	LKL-15	1.7	1.9	1.4	4.4	0.4	83	16	0.6	Slightly gravelly muddy Sand
16	LKL-16	2.4	1.9	0.8	3.4	0.9	78.2	20.3	0.6	Slightly gravelly muddy Sand
17	LKL-17	1.3	2	0.1	3.5	14	76.2	10.1	0.1	Gravelly muddy Sand
18	LKL-18	2.7	1.7	0.1	3.3	1.9	74.6	23.4	0	Slightly gravelly muddy Sand
19	LKL-19	1.9	1.6	1.5	6.1	0.9	87.2	11.5	0.5	Slightly gravelly muddy Sand
20	LKL-20	-	-	-	-	-	-	-	-	Coral fragments

size, other parameters are statistic data for each sample such as mean, sortation, skewness and kurtosis.

Seafloor sediment distribution of the study area was drawn based on plotting of granulometry data on location base map. The area is dominated by slightly gravelly muddy sand. Other sediment units are corals (not discussed specifically, considered has not undergone a sedimentation process), slightly gravelly sand, gravelly sand, silty sand and gravelly muddy sand which are sparsely distributed; However, to simplify the discussion, some units that have similar appearance and content into two sea floor sediment types are: slightly gravelly muddy sand (e.g: gravelly muddy sand and silty sand) and gravelly sand including of slightly gravelly sand (Figure 5).

Slightly gravelly muddy sand is the most widespread sediment type at the study area. Megascopically description during field survey, this unit is mostly grey to brown color, some brownish white, greenish; soft, bad sorted, plenty of foraminifera shells. At certain location, such as at west part of north headland (LKL-09); quartz dominant (±75%), mafic (±15%), and shells (± 10%). At some locations, especially closed to steep coastal area, rock fragments could be observed; such as at LKL-15 and LKL-16 at southeast of studied area. This unit is characterized by range of mean grain size between 1.9 and 3.7 phi or ranges of medium size until very fine sand based on Wentworth grain size scale. Sand fraction content ranges between 52.6% up to 87.2%; silt 11.5 – 46.2%; clay less than 4%; while gravel 0.2 – 2.7%. Very few clay content of sea bottom sediment possibly due to high energy environment for deposition and no large river flows in the study area. The histogram (Figure 6), shows various grain sizes, from -1.0 phi (very coarse sand) until 8.0 phi (silt). The longest bars in the histogram are concentrated in 3.0 – 5.0 phi or very fine sand to silt. Dominance of fine fractions indicate that the deposition environment mostly is in a low energy or low agitation typical estuary environment.

As an example, this calm environment takes place in the middle of eastern study area. Masuk dalam jenis sedimen ini adalah Included in this sediment type is slightly gravelly sand that only spread at northeast of Lemukutan Island, at LKL-03. Megascopically, this unit is brownish color, soft and a lot of foraminifera shells. Mean grain size is 2.1 or fine sand according to Wentworth scale, sand fraction content 86.8%, silt 9.0%, gravel 3.8% and clay 0.4%. The gravel content in this location is quite high which mostly consisted of rock fragments and corals, indication of high energy (see also sediment distribution map, Figure 5). Gravelly muddy sand is spread at one location – LKL-17 of southeast area. Megascopically, it was described as coarse sand of brown color, bad sorted, a lot of corals and rock fragments. Sediment composition: sand

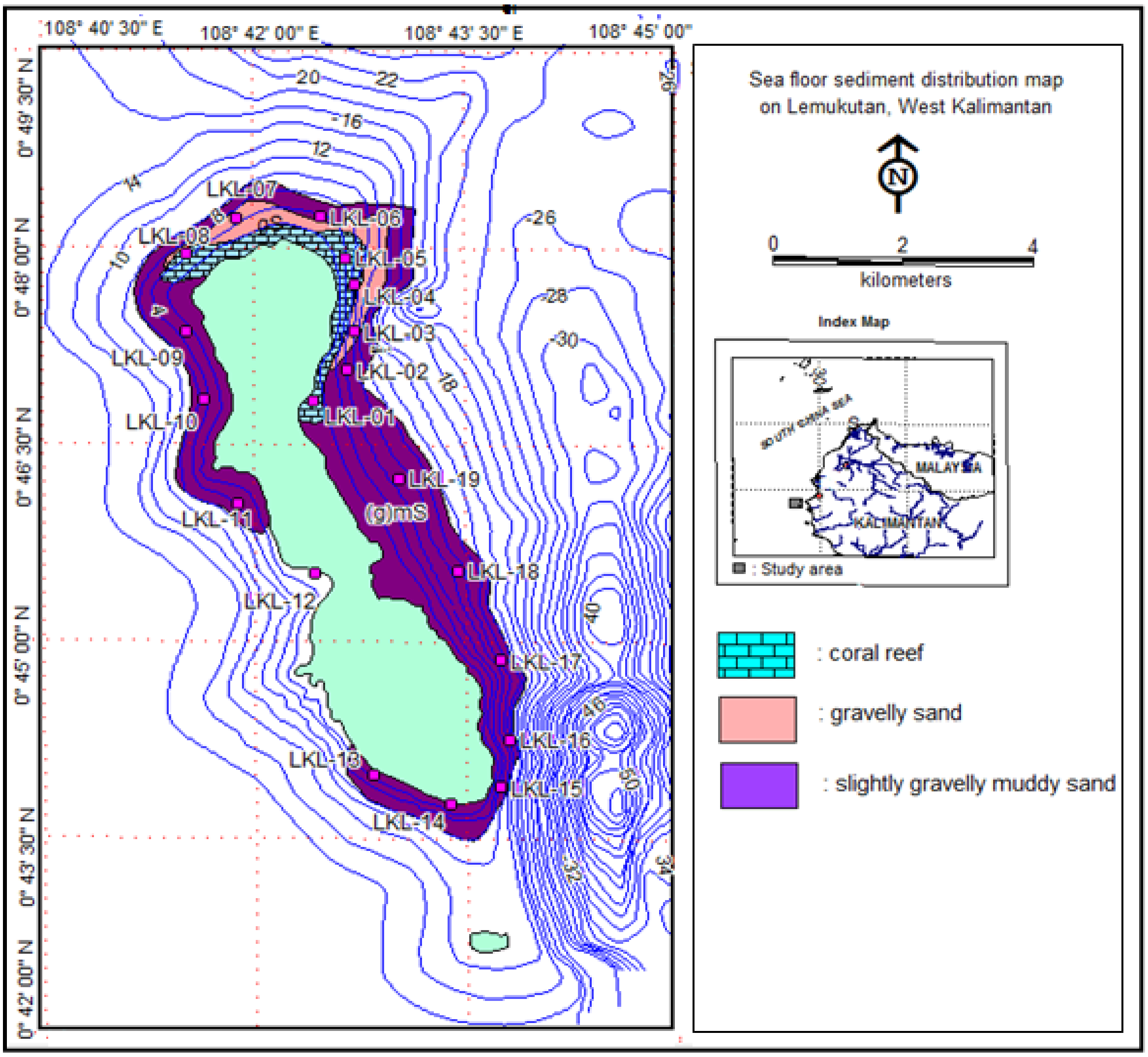


Figure 5. Seafloor sediment distribution map of Lemukutan Waters

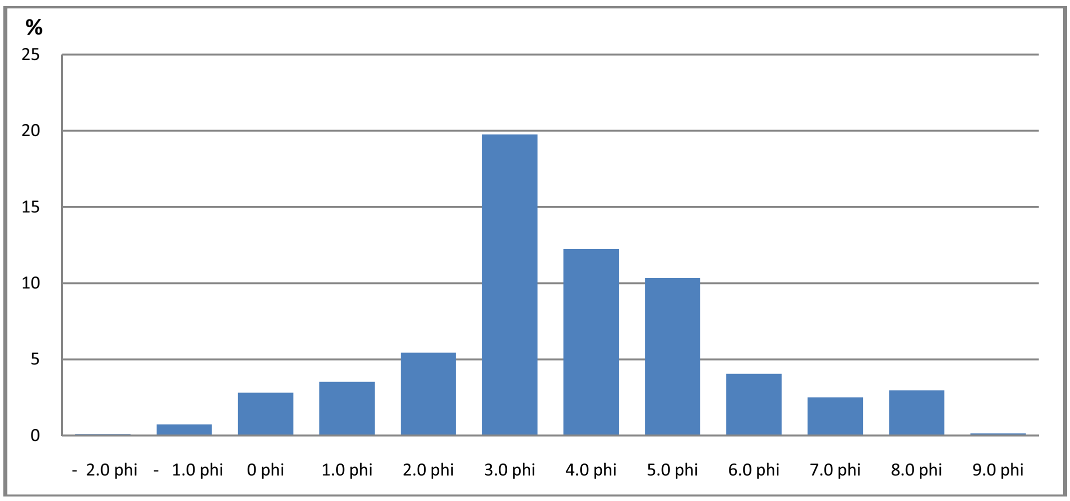


Figure 6. Histogram of slightly gravelly muddy sand.

76.2%, gravel 14%, silt 10.1% and clay 0.1%. This sediment type characterized by high percentages of sand (1.0 – 3.0 phi) and gravel (-2.0 - -1.0phi). High percentages of coarse fractions as shown in the diagram are indication of high energy environment, as location of LKL-17 is situated at an unprotected open area at southeast of the island.

Gravelly sand, This unit is only found at a location, north of headland of Lemukutan Island (LKL-07 and LKL-08). It is obvious that the environment deposition is very high energy, indicated by high content of gravel (19.0%) – the highest content in the whole study area; sand 76.7%, silt 4.4%, and clay 0.2%. Megascopic description, gravelly sand is greenish grey color, bad sorted, foraminifera shells; and a lot of rock fragments and corals. The Figure 7 demonstrates dominance of coarse fractions from -2.0 until 3.0 phi. The gravels are between -2.0 up to -1.0 phi or 2 – 4 mm; while the sands 0.0 – 3.0 phi or very coarse until fine sizes. The histogram mode which shows polymodal pattern could be interpreted that origin of the sediment is derived from many sources, as the area surround headland is the place of wave refraction from many directions.

Corals are mostly distributed at the north of survey area, surround north headland. The sea bottom samples were not analyzed. The corals are reddish color, only a few could be sampled from sea bottom. Observation through snorkeling during the survey, the corals mostly are in good condition and as habitat for many fishes.

Seafloor morphology at study area is obtained based on the results of batymetry data which is then overlaid with DEM data and geo-computation processed (Figure 8). Based on the picture, then was made the cross-section (Figure 9a and 9b), to determine variations in morphology.

Slope angle calculation of each sea bottom sediment location using Figure 3 method is presented in the following table together with its grain size mean values:

DISCUSSIONS

To understand relationship between parameters, correlation diagram were made for mean grain size and seafloor slope angles (Table 2). The correlation diagram applied MS excel. Control of sea depths to sediment distribution was also using correlation diagram.

Figure 10 shows the relation between mean grain size of sea bottom sediment samples and seafloor slope angles. It demonstrates negative regressive linier correlation; illustrated by increased mean values of grain size but lower seafloor slope. Due to log values of X(phi) or mean grain size, the greater the number, the finer grain size. Figure above could be interpreted that fine sediments such as fine sand (2-3 phi) and very fine sand (3-4 phi) tend to be deposited at sea bottom slope angle less than 3 . Agitation at seafloor of low slope angle seems less than at high angle, and locations of low slope angles are at east, north, west and southwest of Lemukutan Island.

On the other hand, the highest value of slope angle is 5.7 found at sample number LKL-15. Mean grain size of this sample is 1.7 phi, or medium sand. Sediment classification of LKL-15 is slightly gravelly muddy sand. The sample is consisted fractions of sand (83%), silt (16%), clay (0.6%) and gravel (0.4%). LKL-15 is located at southeast tip of Lemukutan Island, which is the steepest seafloor observed from its very dense contour lines (Figure 1). Other three points above the trend line of correlation figure above are also located at the steepest seafloor, as shown in the sampling location map of Figure 1. Those are LKL-03, 16 and 17.

Plotting of X(phi) to sea depths shows tendency of fining of grain size at lower sea depths (Figure 11). This tendency opposes to general condition that at open seas, grain size should be finer at deeper seas; while at shallow seas grain size becoming coarser due to influence of waves, especially at breaker zone closed to coastline. This anomalous condition possibly due deposition environment of Lemukutan Island is influenced by many islands nearby, such as Penata Besar, Penata Kecil, and Kabung. This condition is causing marine energy, such as waves and currents, tend to distribute amongst the islands which further generate phenomenon of fining grain sizes at shallow seas close to coastal zone.

CONCLUSIONS

Sea floor slope of the study area actually control the deposited sediment types, coarse fraction sediments tend to accumulate at high slope angles such as at southeast and northeast. Nevertheless, marine energy also has its role for sediment distribution in the study area. Areas of high energy, such as at the north of Lemukutan Island headland, is likely to deposit coarse fraction sediments. Furthermore, high shell content percentages of sea bottom sediments are also settled down at those two domains.

ACKNOWELEDGEMENT

The authors would like to thank to the management of Marine Geological Institute in supporting us to conduct marine and coastal mineral research in Lemukutan Island and the surroundings. Thanks also dedicated to all scientists and technicians involved in data acquisition, especially during field survey. Special thanks to local residences for their hospitality during our stay in the island, and local government who sincerely serve us, especially to Pak Asmadi – Security Chief of Lemukutan Island.

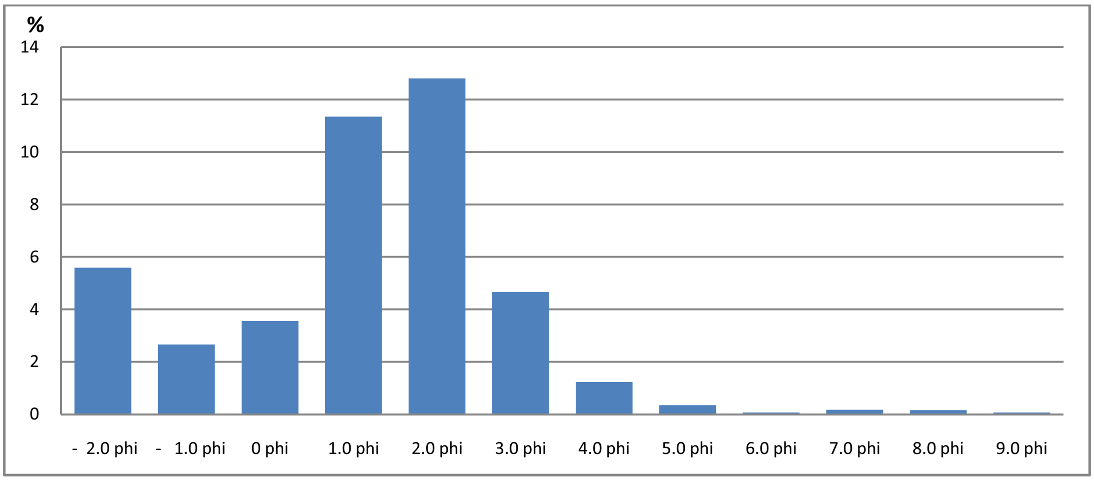


Figure 7. Histogram of gravelly sand

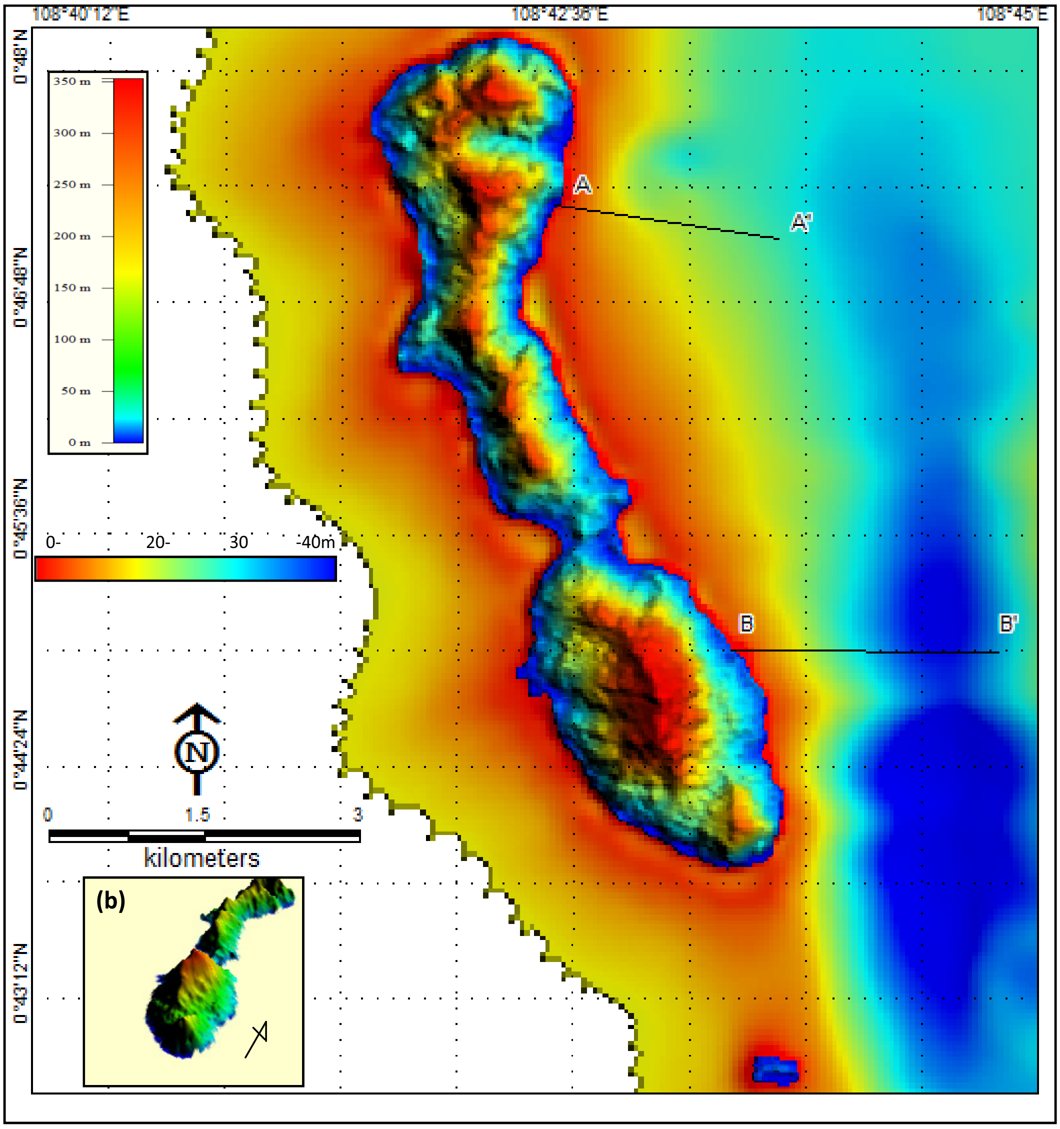
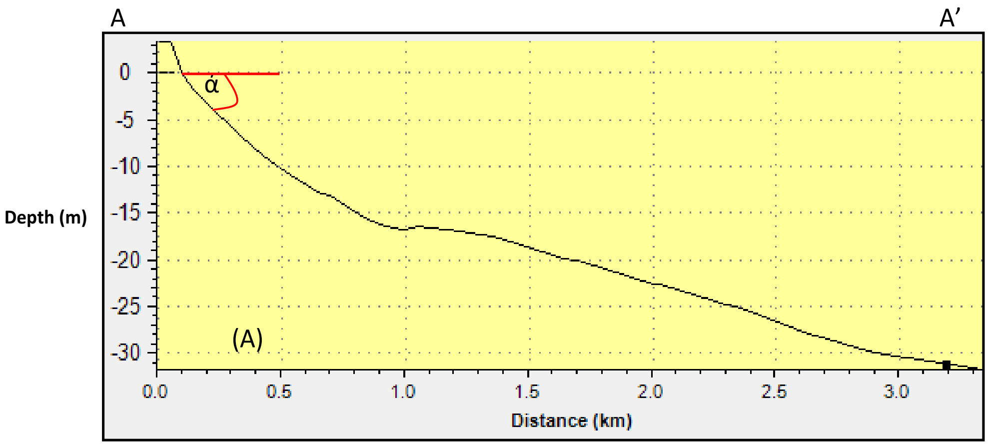


Figure 8. Lemukutan seabed morphology and cross section map; (b) inset- morphology Lemukutan Island



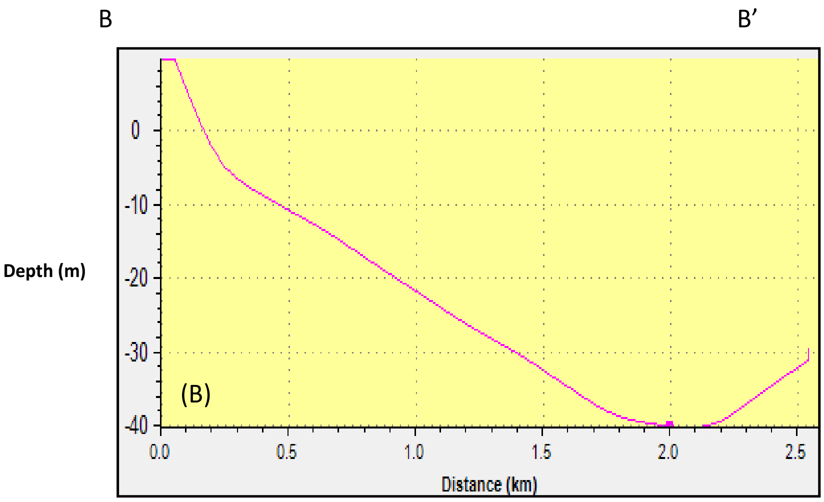


Figure 9. Lemukutan seabed morphology and cross section map;(A) northeast of Lemukutan and (B) southeast of Lemukutan section

Table 2. Mean values of each sediment with its seafloor slope angle

NO	MEAN VALUE	SLOPE ANGLE (°)	EXPLANATION
1	-	1.6	No grain size analyses
2	3.7	2.3	
3	2.1	4.3	
4	-	3.4	No grain size analyses
5	-	2.5	No grain size analyses
6	1.7	1.4	
7	0.7	1.5	
8	-	1.6	No grain size analyses
9	2.8	1.6	
10	3.1	1.9	
11	2.9	1.7	
12	2.9	1.7	
13	2.4	2.0	
14	-	1.8	No grain size analyses
15	1.7	5.7	
16	2.4	4.9	
17	1.3	4.3	
18	2.7	2.0	
19	1.9	1.5	
20	-		No grain size analyses

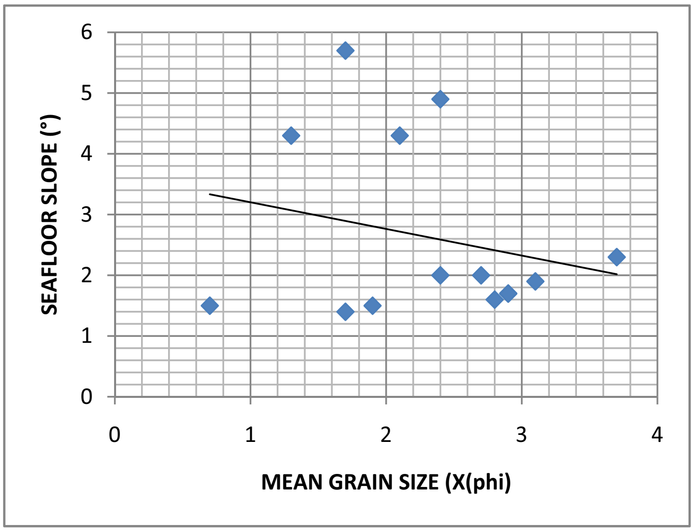


Figure 10. Correlation between mean grain size of marine sediments and seafloor slope

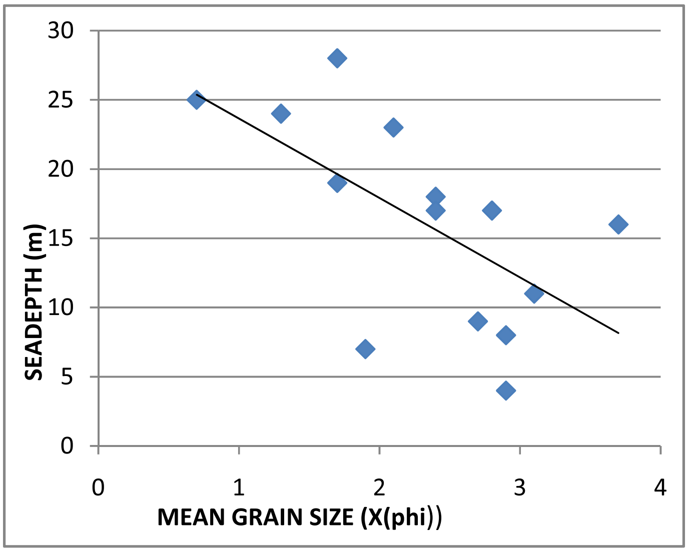


Figure 11. Correlation diagram between X(phi) and sea depths.

REFERENCES

[1] Aryanto, N.C.D., Kurnio, H., Wahib, A., dan Sutardi, 2012; Kajian Mineral Logam & Unsur Tanah Jarang (REE) di Pantai dan Perairan Kepulauan Lemukutan, Kalimantan Barat, Laporan Internal, *Puslitbang Geologi Kelautan, Bandung.*

[2] Briggs, K.B., Lyons, A.P., Pouliquen, E., Mayer, L.A., Richardson, M.D., 2005, Seafloor roughness, sediment grain size, and temporal stability. *Proceedings of the International Conference "Underwater Acoustic Measurements: Technologies & Results"* Heraklion, Crete, Greece, 28th June – 1st July 2005.

[3] Folk, R.L., 1980, *Petrology of Sedimentary Rocks.* Hemphill Publishing, Austin, TX, 184 p.

[4] Reis, A.H. and Gama, C., 2010, Sand size versus beachface slope – An explanation based on the Constructal Law. *Geomorphology*, vol.114, pp. 276-283. Journal homepage: www.elsevier.com/locate/geomorph.

[5] Suwarna, N., and Langford, R.P., 1993, "*Geology Map of Singkawang Quadrangle Kalimantan*," Scale 1:250.000, P3G, Bandung.