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Comparison of Grain-Size Profile and Depositional Process in Mandeh and Nyalo Bar, Mandeh Bay, West Sumatera, Indonesia

Rahmadi Hidayat* and Muhammad Fadli Rozamuri

Department of Geological Engineering, Gadjah Mada University, Yogyakarta, Indonesia

ABSTRACT. Shipwreck of MV Boelongan Nederland situated in offshore of Mandeh Bay of West Sumatera is announced as potential area for tourism destination. Many studies were produced in term of its archeological and historical side but there is no significant work in sedimentological aspect. It is critical to understand depositional process of study area regarding the design of construction to minimize the impact of dynamic activity of waves within the area. Moreover, some areas along Mandeh Bay are covered by Cubadak Island as a protection for wave action derived from Indian Ocean that can produce more complexity in depositional process and will reflect to its characteristic of grain-size profiles. Utilizing thirteen sediment samples in two areas that correspond to inside (Mandeh Bar) and outside (Nyalo Bar) coverage of Cubadak Island, this study attempted to compare and contrast both grain-size profiles as well as interpretation of depositional process based on well-known analysis such as bivariate scatter plots, Linear Discriminant Function plot (LDF), Log probability curves and C-M diagram. Result of this study can be integrated by other researches to gain better policy in maintaining the shipwreck conservation. High energy of Indian Ocean wave supported by strong current clearly dominated depositional process in Nyalo Bar with coarser grain-size; good sortation, lower Y2 of LDF plot; extremely high population of traction materials and lower range of C-M. By contrast, presence of Cubadak Island disrupted the wave effectively and created lower and fluctuated energy in Mandeh Bar. This phenomenon was clearly depicted in its characteristic of finer grain-size with higher Y2 value; high abundance of saltation materials and greater ratio of C-M value.

Keywords: Mandeh Bay · Grain-size analysis · Depositional process · Shipwreck conservation · High energy.

1 INTRODUCTION

Study area is located in downstream point-bars of Mandeh and Nyalo River within Mandeh Bay, West Sumatera Province, Indonesia (Figure 1). Mandeh Bay is being developed for new tourism destination. One of the potential destination is a shipwreck called MV Boelongan Nederland that has been surveyed and researched since 2006. However, most of works were related to archeological and historical studies. Nia *et al.* (2015) attempted to make major review of several studies related to the shipwreck in order to understand the degree of vulnerability against natural factors such as dynamic of the ocean and the effect of climate.

In term of sedimentology, depositional process within study area could produce pitfalls to build proper and effective maritime conservation concept. Moreover, occurrence of Cubadak Island in Mandeh Bay, that is located directly in front of Mandeh River, could be critical to reveal the sedimentation complexity in Mandeh Bay. As consequences, depositional process of Mandeh Bar would behave differently compare to Nyalo Bar that is situated in relatively more open marine environment. In such situation, it

*Corresponding author: R. HIDAYAT, Department of Geological Engineering, Gadjah Mada University. Jl. Grafika 2 Yogyakarta, Indonesia. E-mail: rahmadihidayat@ugm.ac.id

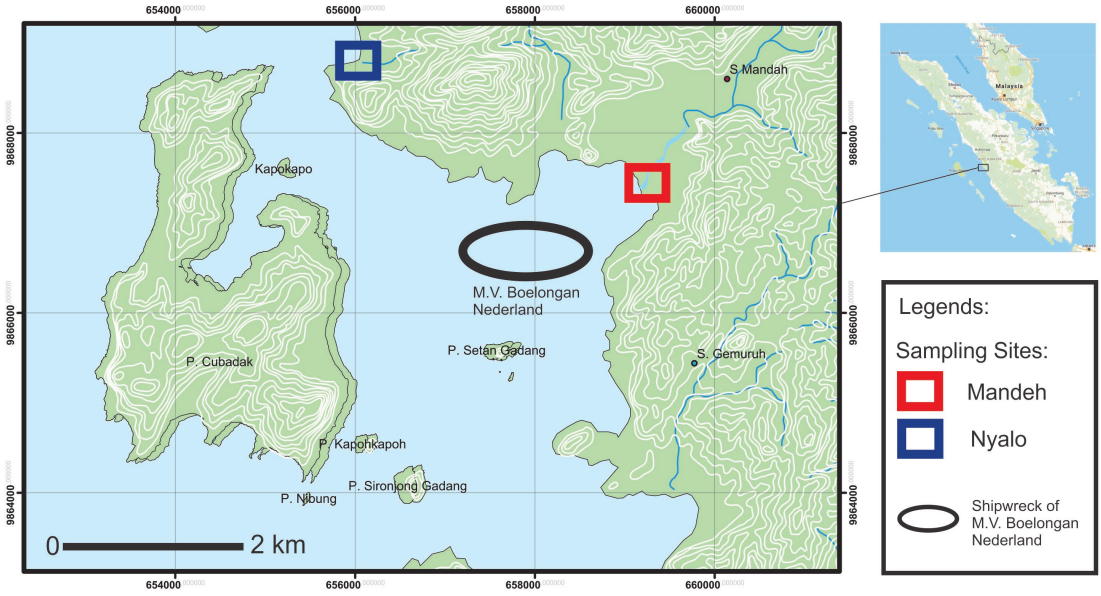

Figure 1: Location of Mandeh Bay with sampling sites.

should be reflected to the grain-size profiles of both river bars.

This research aims to compare and contrast grain-size feature characteristics as well as interpreted depositional process in recent sediment of Mandeh and Nyalo Point-bars. Collaborating this research with several previous study can be useful for constructing better policy for maritime conservation area to be long-lasting tourism destination (Nia *et al.*, 2015).

2 PHYSIOGRAPHY AND REGIONAL GEOLOGY

According to Van Bemmelen (1949), Mandeh Bay is regionally located on physiography of Central Sumatera. In a detailed scale, it can be included as subzonation of alluvial plain along West Sumatera coastline.

Alluvium sediments are widely distributed in Mandeh Bay. Those sediments commonly have silt-size to granule-size that was deposited along coastline and downstream of rivers, including Nyalo and Mandeh. Sampling sites were focused on this area. Further landward, Oligocene--Miocene of Painan Formation is exposed that dominantly comprises of both epiclastic sediment and volcaniclastic complexes such lava, tuff, ignimbrite and volcanic breccia (Rosidi *et al.*, 1996).

3 RESEARCH METHODS

Thirteen sediment samples were collected in two major point-bars along Mandeh Bay: Nyalo (six samples, Figure 2A) and Mandeh (seven samples, Figure 2B). Applying method carried out by Lewis and McConchie (1994), samples were taken at around 5-meter intervals with relatively upstream-downstream as well as inside-outside bar direction. In order to maintain the quality of results, samples were taken in naturally preserved area away from engineering structures (Alsharhan and El-Sammak, 2004).

Pre-treatment of sediment samples was established, especially coning-quartering and removing organic matter. After pre-treatment, a 100-gram of each sample was sieved with a shaker for fifteen minutes through ASTM mesh 18 to 270. Wentworth (1922) was applied for grain-size classification while Folk and Ward (1957) classifications were utilized for clustering sortation, skewness and kurtosis in this study. The distribution of sediment samples are depicted using statistical approaches. In previous studies conducted by Sahu (1964), adopting graphical method is the most suitable in delivering statistical analysis.

The grain-size parameters that will be described in this research are mean (Mz), sortation ($\sigma 1$), skewness (Sk1) and kurtosis (KG). These parameters are commonly utilized for constructing depositional process of linear discriminant function (Sahu, 1964), log probability curves (Visher, 1969) and identifying mechanism of transportation based on C-M diagram (Passega and Byramjee, 1957).

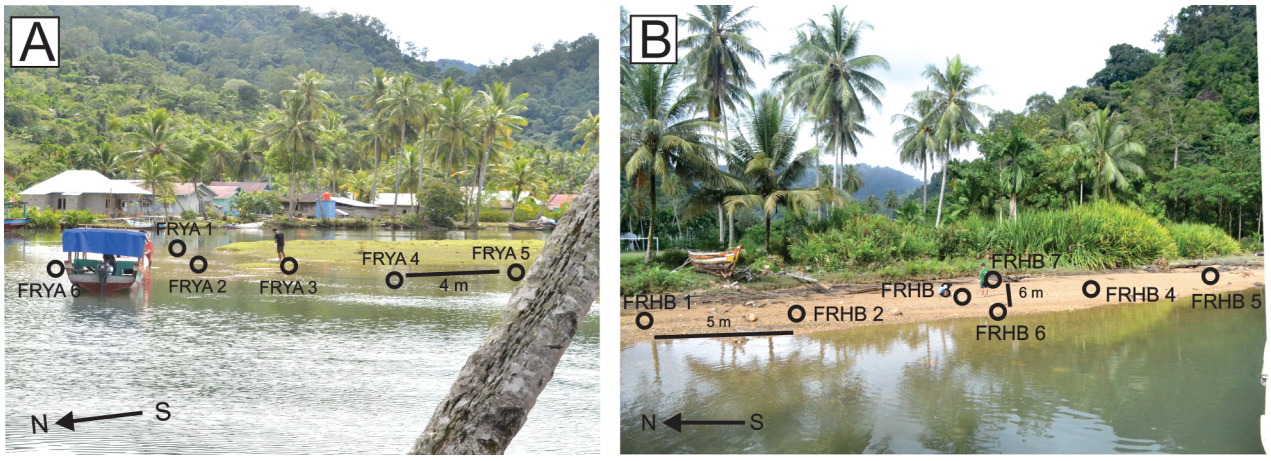

Figure 2: Sampling site of (A) Nyalo Bar and (B) Mandeh Bar.

4 RESULTS AND DISCUSSION

Bivariate scatter plots

Grain-size parameters perform a basic scheme for classifying sedimentary environments. Recent studies often explore advanced statistical techniques with several graphical plots (Alsharhan and El-Sammak, 2004). Bivariate scatter plot comparing each of grain-size parameter is a viable method that widely utilized by many researchers for comparing depositional settings (Srivastava and Mankar, 2009; Rajganapathi *et al.*, 2013; Martins, 2013; Jitheshkumar *et al.*, 2015).

Griffiths (1967) explained that relationship of mean grain-size and sortation related to its hydraulic control of sediments. Bivariate scatter plot of mean grain-size and sortation depicts significant cluster between Mandeh and Nyalo Bar Figure 3A. Nyalo Bar has coarser grain-size (-0.23 phi to -0.40 phi) and tends to have well to moderately well sorted (0.46 phi to 0.57 phi). By contrast, Mandeh Bar is distinguished by smaller particle size (-0.10 phi to 0.77 phi) and moderately sorted (0.69 phi to 0.82 phi).

Plotting of sortation against skewness can provide grouping for further sedimentary analysis (Alsharhan and El-Sammak, 2004). Figure 3B describes a wider range of skewness in Mandeh Bar (-0.02 to 0.46). It tends to have high variation from near symmetry to very fine skewed. By comparing to samples taken from Mandeh Bar, samples from Nyalo Bar has specifically narrow range and categorized as very fine skewed (0.41 to 0.67).

Bivariate plotting of skewness against kurtosis corresponds to similar characteristic between both bars Figure 3C. Samples in Mandeh Bar show wider range of kurtosis (0.92 to 1.39). It is included in two groups that are mesokurtic to leptokurtic. In Nyalo Bar, the value of kurtosis is higher and strictly lower in term of variation (0.29 – 0.59).

Three bivariate scatter plots concluded major distinction of depositional processes of Nyalo compare to Mandeh Bar. Characteristic of Mandeh Point-bar indicates lower and relatively fluctuated energy. It corresponds to Cubadak Island that breaks wave energy derived from Indian Ocean to construct the sedimentation of Mandeh Bar. Compare to Nyalo Bar, wave action directly controls the depositional process without any interruptions of Cubadak Island. This phenomenon also reflects grain-size parameter of Nyalo Bar with typically coarser grain-size, better sortation and relatively low variation of both skewness and kurtosis.

Linear discriminant function

Sahu's linear discriminant function (LDF) is a powerful method to determine sedimentation process that controls the area. According to Sahu (1964), variation of energy and fluidity factor that produce different profile of grain-size parameters leads to different sedimentary processes as well as depositional environments.

This study focused on LDF plot of Y2 against Y3. Y2 is a discriminant value for contrasting beach to subtidal (agitated marine) characteristic while Y3 is clustering the influence of fluvial to shallow marine (Alsharhan and El-Sammak, 2004). Sahu (1964) suggested fixed values for discriminating values of Y2 and Y3: (1) Y2 less than 65.3650 gives indication of beach than sub-

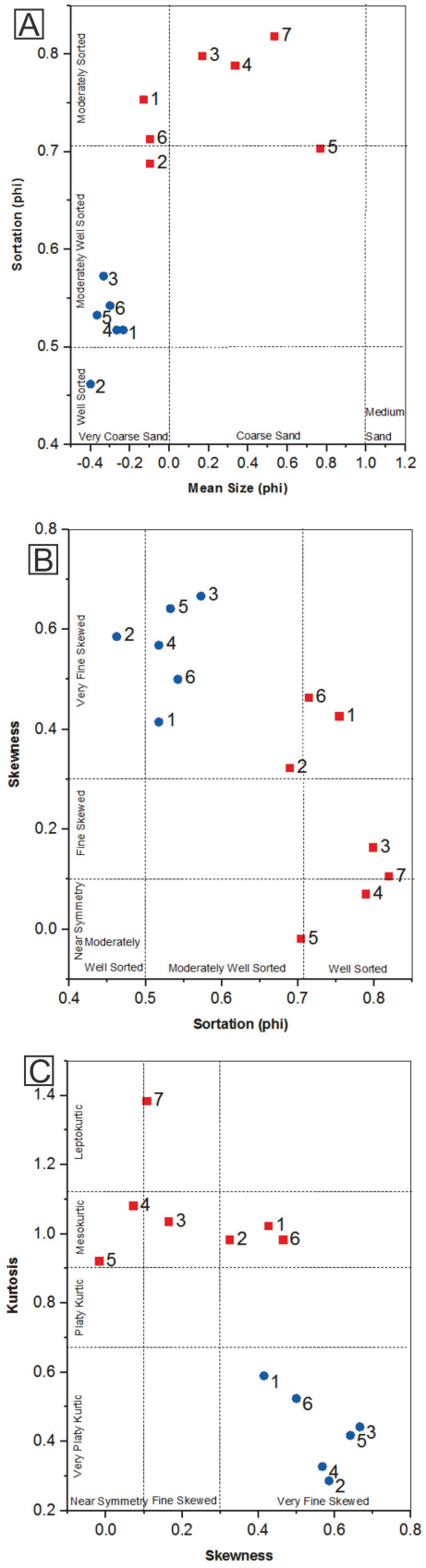

Figure 3: Bivariate scatter plots: (A) mean grain-size against sorting, (B) sorting against skewness and (C) skewness against kurtosis.

tidal process and (2) Y3 less than – 7.4190 indicates that fluvial is more dominantly controlling the depositional process than marine. By applying this discriminant, process of sedimentation in transitional area can be interpreted whether it is dominated by fluvial, wave action (shallow marine) or tidal.

Plotting of Y3 shows no significant cluster in Mandeh Bar (-7.0233 to -3.9590) or Nyalo Bar (-4.3986 to -6.1917). However, Y2 plot depicts significant contrast between both areas. Moreover, these values remain consistent for grouped samples (Figure 4). Nyalo Bar commonly comprises of lower Y2 value (23.6856 to 36.5978) than Mandeh Bar (53.6578 to 79.9753). It indicates that both bars were experienced slightly different depositional process. Lower value of Y2 suggests that depositional process of Nyalo Bar is more influenced by wave action than Mandeh Bar. As a result, the presence of Cubadak Island covering Mandeh Bar clearly disrupted the wave activity derived from Indian Ocean. In contrary, Nyalo point-bar is relatively open to Indian Ocean without any disturbances from Cubadak Island. It allows wave action to control more dominantly.

Log probability curves

Log probability curve is a representative of cumulative grain-size distribution that is quite useful for clustering the sediment samples to the mode of transportation mechanism such as traction, saltation and suspension (Srivastava *et al.*, 2009). Visher (1969) classified the characteristic of depositional environment based on percentage of population in transportation mechanisms, sortation, the coarse truncation point (CT) as well as the fine truncation point (FT).

Log probability profile of Mandeh Bar depicts saltation population in range of 19 to 50.8 % with 0.8–1 phi of CT and 2.9–3.1 phi of FT (Figure 5A). This profile is clearly different to Nyalo Bar that commonly has maximum of 12.6% of saltation population (Figure 5B). In term of suspension population, Mandeh Bar has slightly higher number (0.5 to 1.1 %) than Nyalo bar (0.1 to 0.4 %). Parameter of traction population of Mandeh Bar is 25.1 to 82.2 % while Nyalo Bar has significantly larger value (87.3 to 92.9 %).

Log probability profile of Nyalo Bar can be referred to typically nearshore zone area with an

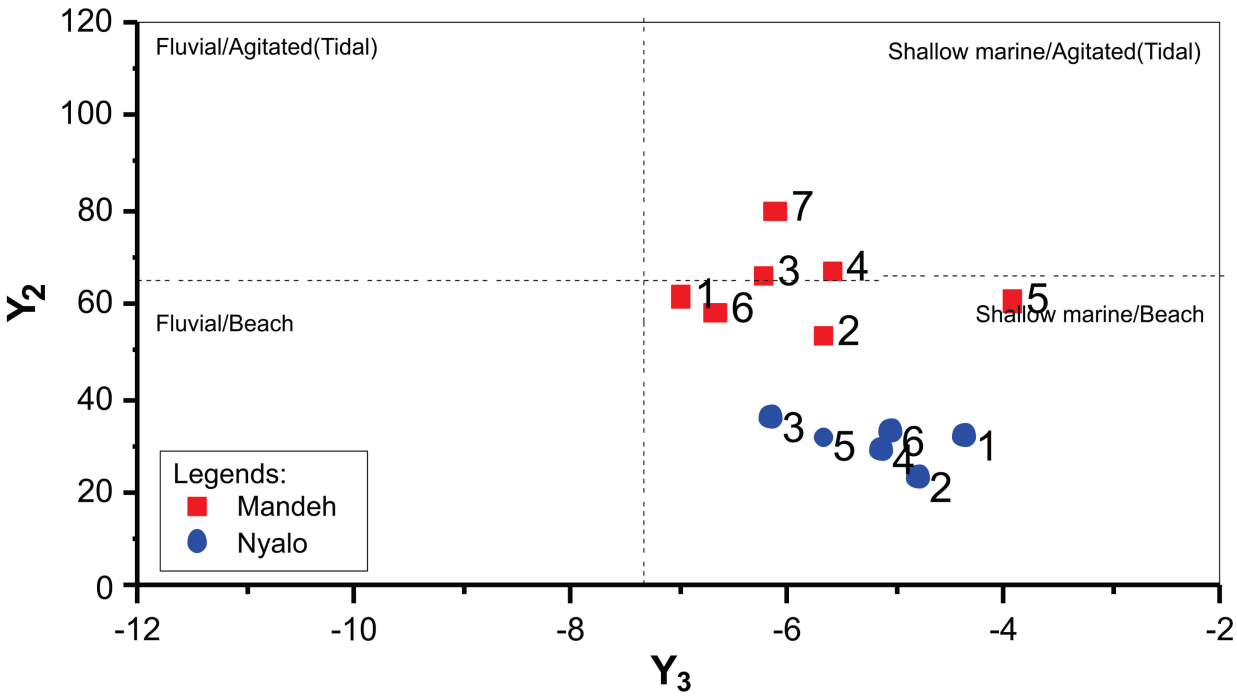

Figure 4: Linear Discriminant Function Y_2 - Y_3 plot adopted from Sahu (1964) in Mandeh and Nyalo sediment samples.

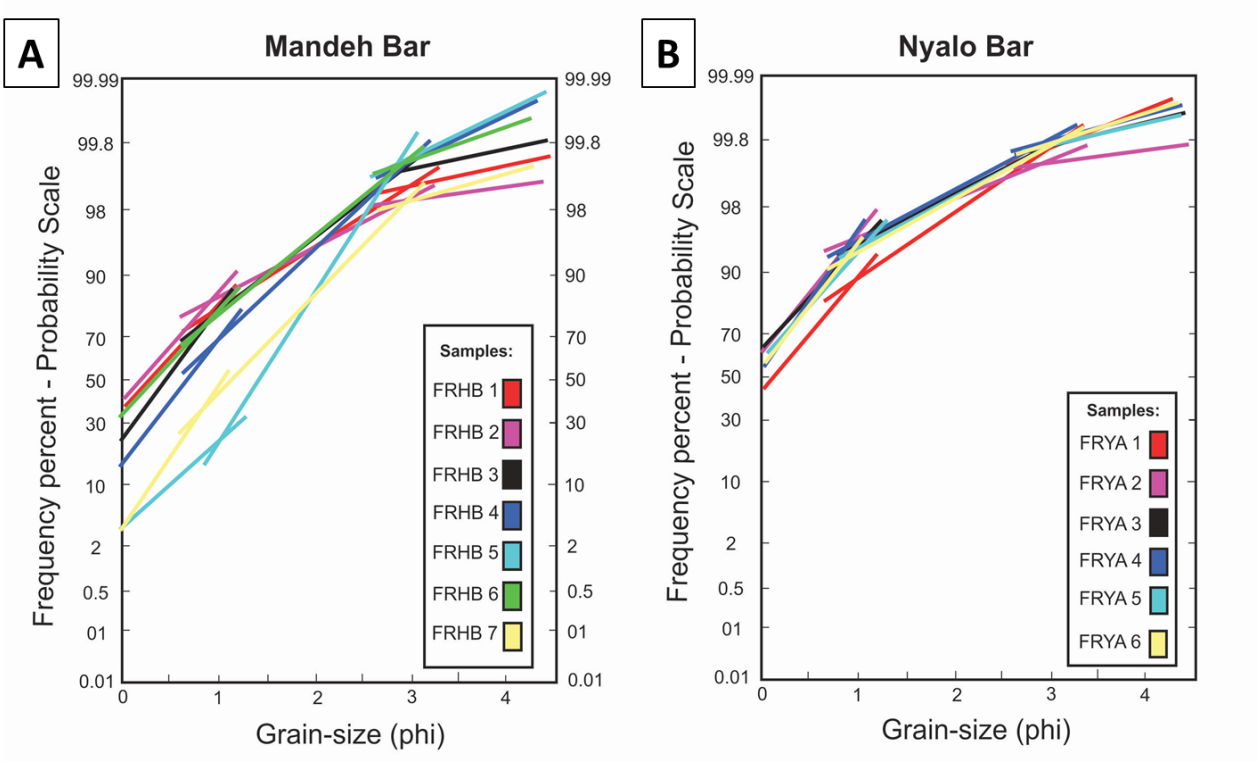

Figure 5: Log probability curves of (A) Mandeh Bar and (B) Nyalo Bar.

extremely high percentage of traction materials. This environment is produced by processes of breaking waves interacting with strong currents (Visher, 1969). Little suspension materials reflect to winnowing activities as well as seaward transportation by this strong currents. The population of saltation material in Mandeh Bar is much higher than Nyalo Bar. It suggests an environment that has limited control of wave action and tends to be tidal-controlled area. Visher (1969) stated that high percentage of traction materials in similar environment corresponds to high period of maximum current flow velocity. Based on this situation, the nature of Cubadak Island is effective to disintegrate wave activities in Mandeh Bar.

C-M diagram

Advanced method in determining depositional process of sediments was developed in years. Passega (1964) stated that sedimentary deposits were formed by graded suspension when turbulence decreases which can be determined by a value of C (one-percentile) of grain-size proportional to the M (median or 50-percentile). Many sedimentologists adopted C-M diagram for defining depositional process (Natesan *et al.*, 2012; Rajganapathi *et al.*, 2013; Jitheshkumar et al., 2015). Figure 6 described the result of this analysis. All samples collected in this study are included in sector I that have more typically rolled sediments (Passega and Byramjee, 1969) rather than suspension sediments. In term of depositional environment developed by Passega (1957, 1964), both bars are suggested to fall in between beach and tractive current.

There is significant difference in M value of both bars while C value is quite similar. Nyalo Bar has M value at around 1100 microns to 1400 microns. Compared to Mandeh Bar, the size of M is much lower (500 microns to 1000 microns). This phenomenon describes a larger ratio of C-M in Mandeh Bar that indicates a more fluctuation in term of depositional process. Both bivariate scatter plots and log probability curves also have the similar indication.

5 CONCLUSIONS

Characteristic of sediment samples collected in Nyalo and Mandeh Bar indicates significant constrast in grain-size profiles. It related to different depositional process that controls both areas.

Bivariate scatter plots revealed that Nyalo Bar is characterized as larger grain-size (-0.23 to -0.40 phi), well to moderately well sorted and low variation of skewness and kurtosis. It exhibits a higher and less-fluctuated energy of wave action. It confirmed by lower Y2 value of LDF (23.6856 to 36.5978). Sahu (1964) categorized this group as a dominantly wave-controlled sediment rather than tidal activity. An extreme high population of traction materials (87.3 to 92.9 %) as well as low ratio of C-M suggested that strong current also supports the depositional process in Nyalo Bar.

Mandeh Bar displayed a relatively contrast characteristics. It is characterized by finer grain-size (-0.10 to 0.77 phi), moderately sorted and high variability of skewness and kurtosis. LDF depicts higher Y2 value (53.6578 to 79.9753) that indicates a significant reduction in wave activities. Moreover, high abundance of saltation (19 to 50.8 %) supports a limitation of wave action to control depositional process in Mandeh Bar. This was also strengthened by larger C-M ratio. It is interpreted that the presence of Cubadak Island covering Mandeh Bar disrupted the Indian Ocean wave effectively and coincidentally produced more fluctuated energy.

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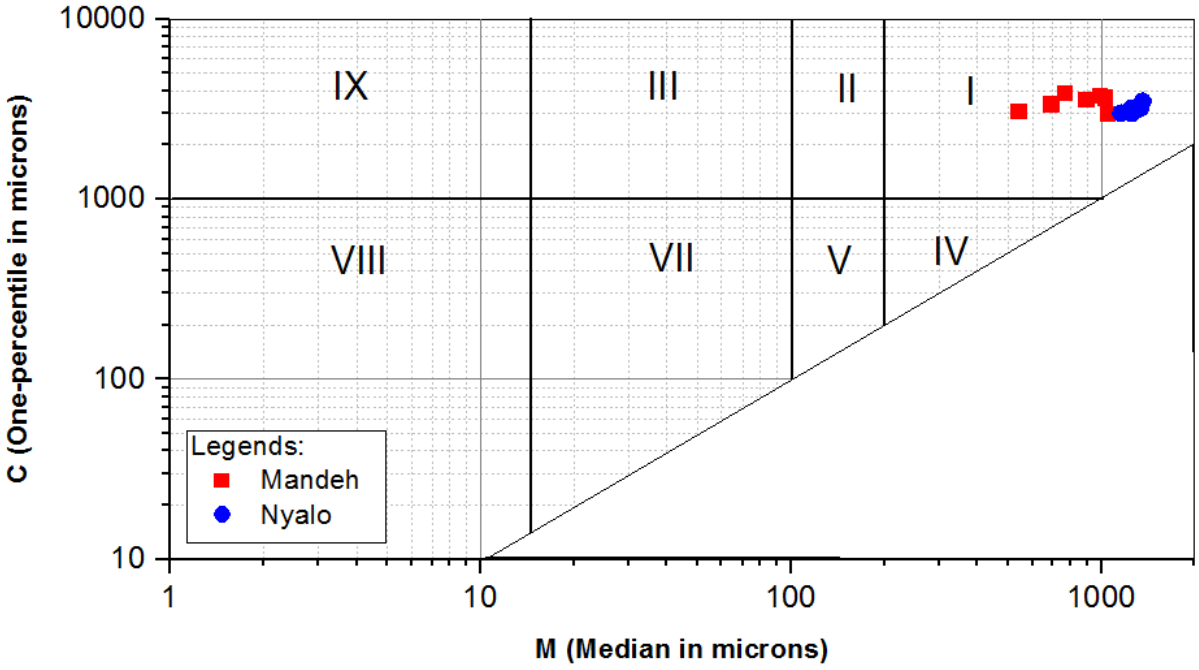

Figure 6: C-M diagram of Mandeh and Nyalo Bar.

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