

Image side-scan sonar segmentation for seafloor detection in Lembah strait, Bitung, North Sulawesi

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Abstract. Segmentation is the process of dividing and grouping the pixel of an image into a segments or objects with the similar characteristics into homogenous areas. This method is expected to get better result with relatively faster result compared to manual (digitation) method. Side-scan Sonar image segmentation using Multi-resolution segmentation algorithm with considered many parameter and using pixel based threshold. The segment grouping using spectral reference by emphasizing the degree of brightness and texture where the two parameters are related to each. Segmentation with two parameters (brightness and texture) is effectively used for targets located near a towfish because of higher target spectral heterogeneity. TVG (Time Varried Gain) correction deliver more detailed result, image with TVG have highest accuracy of 0.987. This proves that the TVG correction that regulates the backscatter to affect the hue in the image has an important role in the seafloor classification process, in addition it can sharpen the appearance of the target which is far from the tow-fish range. Weakness of energy during measurement caused by angle and distance from instrument to target far from the towfish will affect the value of brightness and texture.

1. Introduction

Seafloor mapping with acoustic instruments have been done with many different method. One of the method using Side-scan Sonar instrument [1]. The images produced by acoustic instrument is difficult to interpret because its complexion of characteristic and processes during propagation and reflection in marine seafloor. Manual interpretation of Side-scan Sonar imagery usually take long processing due to data coverage and spatial resolution depending the instrument's frequency. The appearances of various target in different location affected by dynamic of seawater. Thus, more effective and efficient method are necessary to classify each target by taking into account the factors affecting characteristic of target. One method that can be used in this target classification is segmentation.

Segmentation is digital classification which divide data into homogenous area [2]. Generally, segmentation on Side-scan Sonar is performed on numerical data by applying processing signal using frequency variable, time, and other numerical data. In this research, image processing is tried to the raster data of Side-scan Sonar. The aim of this research to found the method that faster and efficient [3] to process Side-scan Sonar data with segmentation method.



2. Study Area & Data

The data uses in this research is a Side-scan Sonar measurement data, seafloor sampling with grab sampling method and underwater photograph/video. The instrument uses Side-scan Sonar Starfish 990F with 1 MHz frequency, with acquisition software is Scan-line Starfish version 2.1. This instrument mounted on ship and following the pre installment track using GPS. Measurement carried by four areas and each area contain five survey path. For preprocessing Side-scan Sonar data using Hypack 2015. The measurement conducted in April 2016 on Lembah Strait, Bitung, North Sulawesi. The measurement is in collaboration with Marine Geological Research and Development Center, Ministry of Energy and Mineral Resources in the framework of research and development of marine potential energy in Lembah Strait.

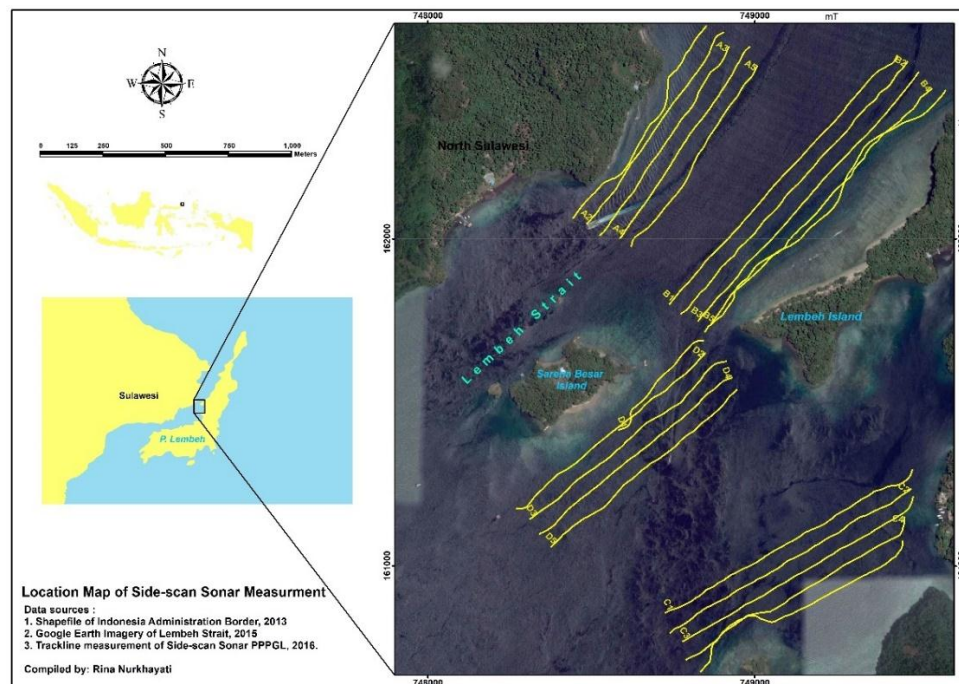


Figure 1. The location of research. Survey track line tagged by yellow line

Table 1. Specification of Starfish 990F

System Part Number	BP00181
Frequency	1 MHz CHIRP
Operating Range	35 m (115 ft) per channel
Horizontal Beam Width	0.3°
Vertical Beam Width	60°
Tranducer Angle	Tilted Down 30° from horizontal
Length	378 mm (14.88")
Width	110 mm (4.33")
Height	97 mm(3.81")
Depth Rating	50 m (164ft)



Figure 2. Starfish 990F instrument

3. Method

Side-scan Sonar image interpretation using digital processing by placing pixel into target class based on visual image. Digital classification can distinguish target by similarity of spectral characteristic and target geometry. Segmentation process are disintegrating and grouping the pixel with the same characteristics, and describes the segments into a particular class. Segmentation of Side-scan Sonar images using multi-resolution segmentation algorithm. This algorithm consider several parameter and using pixel-based threshold for grouping the segment [4]. The parameter in this research is brightness and texture. In the process of segmentation, there is a parameter scale determination in the formation of segments that group the targets based on the range of adjacent homogeneous pixels.

Segmentation with multi-resolution algorithm using pixel-based threshold to identified the direction of color change and pixel texture in the image to the segment [5]. For identification, the borders of color and texture change are influenced by the resolution affecting the pixel size. The higher the resolution will be gentle edge border between segments, for image Side-scan Sonar is used a high resolution image, each pixel size of 0.5 x 0.5 meters for frequency 1 MHz so that the results of segmentation for all three data has the degree of edge changes between segments are smooth or details.

In this research the test data conducted in Block A line 1 data. The data processing differ 3 categories are original image with water column, image with water column correction, and image with Time Varried Gain (TVG) correction. Processing data using E-Cognition software begin by design tree processing of class hierarchical with the analogy of decision tree [6]. The design tree processing shown below :

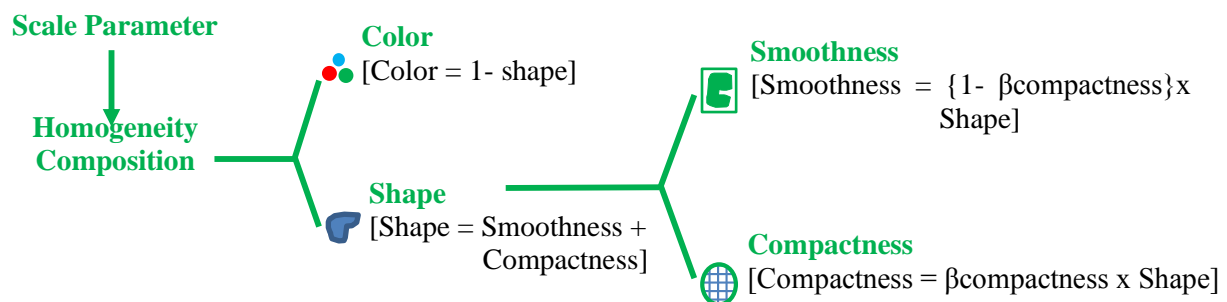


Figure 3. Multi-resolution method concept, E-cognition, Trimble [7]

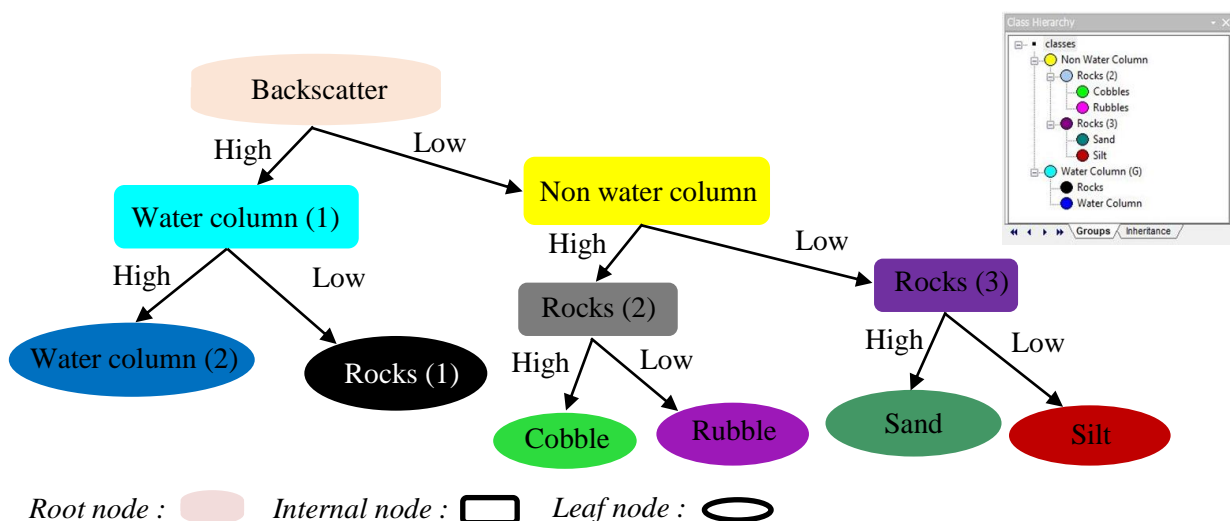


Figure 4. Decision tree analogy for seafloor classification

The decision tree analogy using backscatter force as the node root in decision-making. Seafloor backscattering phenomenon related to surface roughness and hardness [8]. Relatively strong backscattering associated with more roughness target and weak backscattering associated with low roughness target. The strong backscattering data is spelling into three level data classification: (1) water column and non-water column, (2) water column with the rock classes, and (3) rock classes classified into more specific as the seafloor classes.

Multi-resolution segmentation is tested on all three data using brightness and texture based on the pixel value where the pixel value is inversely proportional to the backscatter strength. The amount of pixel value between one data and the data may be different due to the correction of the water column and TVG. Figure 5 showing a technical processing of Side-scan Sonar which have two steps, first is segmentation and second is seafloor classification.

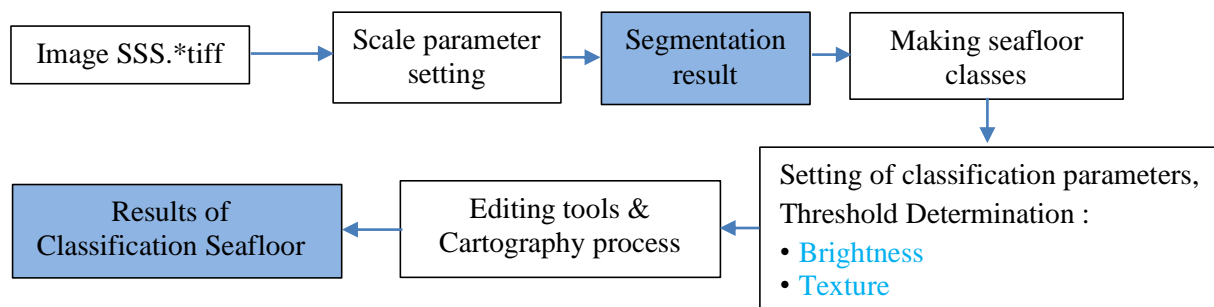


Figure 5. Technical processing of Side-scan Sonar which have two step, first is segmentation and second is seafloor classification

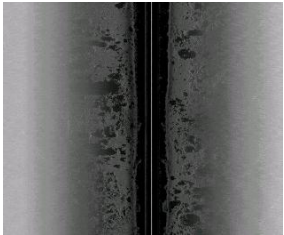
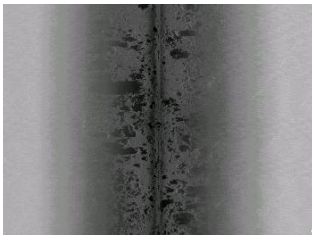
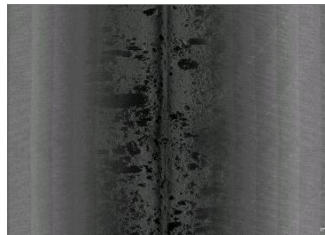
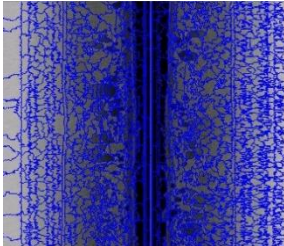
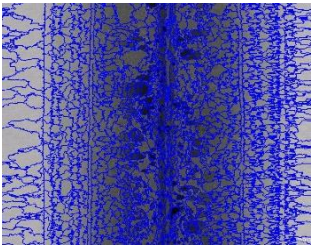
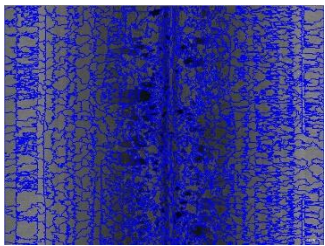
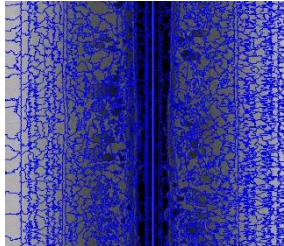
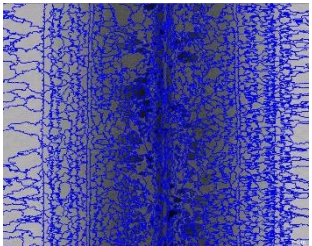
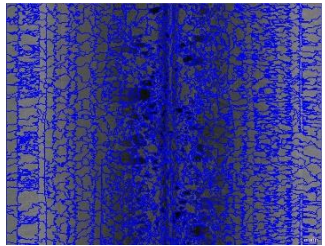
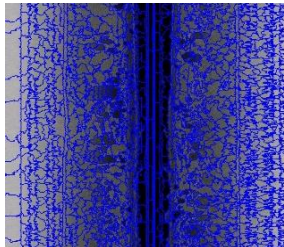
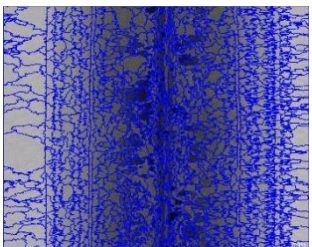
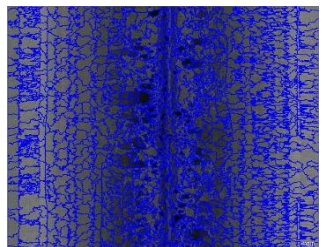
4. Result and Discussion

This is segmentation result (table 3) shown the difference Side-scan Sonar image and segmentation result each level of classification. Scale parameters for all three levels of data are determined by numbers that are differently ranging from 20 to 25, scale parameter numbers will further shrink or decrease the third iteration of segmentation more and more. In this research, iteration is done 3 times to produce 3 levels of data, iteration is done in order to detail the result of segmentation and classification. The segmentation result for three image shown that image with applied TVG have more segment than image with water column correction. Presence of water column can be determining factor of segmentation result. The table 2 is total the segment from all three images.

Table 2. Total segment from different methods

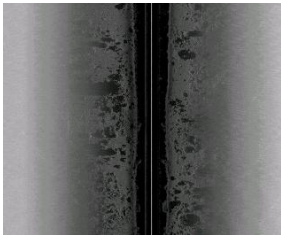
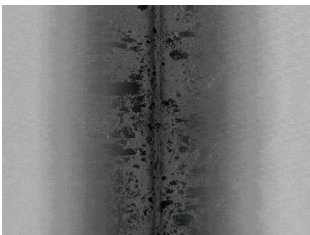
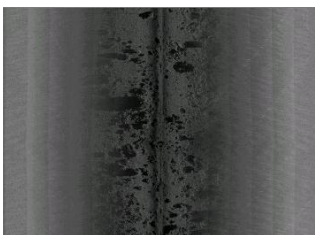
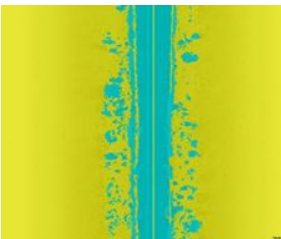
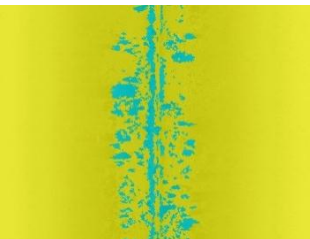
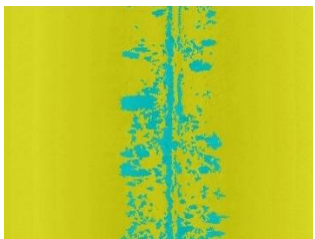
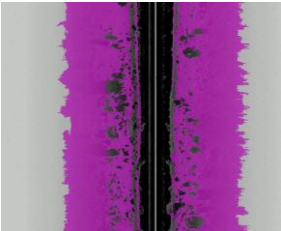
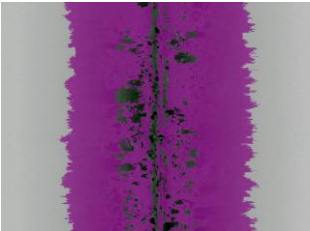
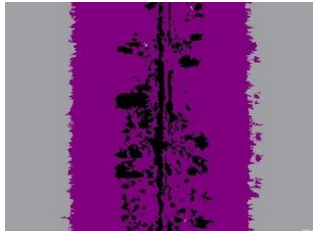
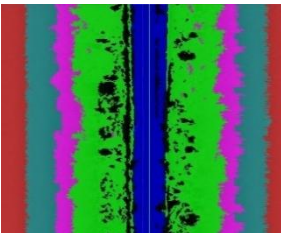
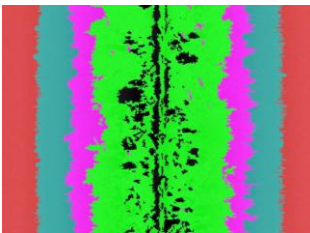
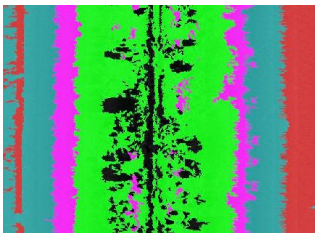






Image	Scale Parameter LV 1	Object Level 1	Scale Parameter LV 2	Object Level 2	Scale Parameter LV 3	Object Level 3
Original image with water column	25	15822	22	16153	20	16623
Image with water column correction	25	15305	22	15570	20	15820
Image with TVG correction	25	17362	22	17648	20	18014

Table 3. Segmentation result each level data classification:

Process	Side scan-Sonar with water column	Side scan-Sonar with water column correction	Side scan-Sonar with TVG correction
Before processing			
1st Segmentation			
2nd Segmentation			
3rd Segmentation			

The segmentation result will affect the classification, the higher level of segmentation more detailed result, done by 3 time iteration to produce 3 classification level.. The three level data classification: (1) water column and non-water column, (2) water column with the rock classes, and (3) rock classes is classified into more specific as the seafloor classes; this classes is divided into water column, rock, cobble, rubble, sand, and silt. TVG correction deliver more detailed result compare to original image and image with water column correction. The accuracy of segmentation and classification for three classes, image with amplified (TVG) have highest accuracy of 0.987.

Table 4. Classification result each level of classification

Process	Side-scan Sonar with water column	Side-scan Sonar With water column correction	Side-scan Sonar with TVG correction
Before processing			
1st Classification			
2nd Classification			
3rd Classification			
<div> <div> Water Column</div> <div> Rocks</div> <div> Cobble</div> <div> Rubble</div> </div> <div> <div> Sand</div> <div> Silt</div> </div>			

This proves that the TVG correction that regulates the backscatter to affect the hue in the image has an important role in the seafloor classification process, in addition it can sharpen the appearance of the target which is far from the tow-fish range. Water column presence become consideration in the process of segmentation and classification.

Table 5. Error Matrix based on TTA Mask (Image Side-scan Sonar with water column)

User\Reference Class	Silt	Sand	Rubble	Cobble	Rocks	Water column	Sum
Confusion Matrix							
Silt	137047	1973	0	0	0	0	139020
Sand	4256	6539	1742	0	0	0	16228
Rubble	527	2164	13185	5532	0	0	21410
Cobble	2174	0	6346	20552	508	0	29580
Rocks	0	0	0	18	4186	48	4494
Water column	0	0	0	0	573	3579	21728
Unclassified	0	0	0	0	0	0	0
Sum	144004	10676	21273	26104	5267	25136	
Accuracy							
Producer	0.951	0.612	0.619	0.787	0.794	0.841	
User	0.985	0.403	0.615	0.694	0.931	0.973	
Totals							
Overall Accuracy	0.871						
KIA	0.783						

Table 6. Error Matrix based on TTA Mask (Image Side-scan Sonar with water column correction)

User\Reference Class	Silt	Sand	Rubble	Cobble	Rocks	Sum
Confusion Matrix						
Silt	28286	4286	0	0	0	32572
Sand	1393	12430	0	0	0	13823
Rubble	0	3771	7234	1631	0	12636
Cobble	121	0	3221	16000	1346	20688
Rocks	289	0	0	133	6496	6918
Unclassified	0	501	0	0	0	501
Sum	30089	20988	10455	17764	7842	
Accuracy						
Producer	0.940	0.592	0.692	0.900	0.828	
User	0.868	0.899	0.572	0.773	0.939	
Totals						
Overall Accuracy	0.808					
KIA	0.747					

Table 7. Error Matrix based on TTA Mask (Image Side-scan Sonar with TVG correction)

User\Reference Class	Silt	Sand	Rubble	Cobble	Rocks	Water column	Sum
Confusion Matrix							
Silt	15507	0	0	0	0	0	15507
Sand	627	27796	500	0	0	0	28923
Rubble	0	0	16655	0	0	0	16655
Cobble	0	0	0	23865	0	0	23865
Rocks	0	0	0	0	6015	48	6063
Water column	0	0	0	0	0	3579	3579
Unclassified	0	0	0	0	0	0	0
Sum	16134	27796	17155	23865	6015	3627	
Accuracy							
Producer	0.961	1	0.970	1	1	0.986	
User	1	0.961	1	1	0.992	1	
Totals							
Overall Accuracy	0.987						
KIA	0.984						

Comparison of the accuracy of original image with accuracy of water column correction shown that the image with water column correction has a higher accuracy. Water column and the rock are a critical sample in the classification process. The pixel values of the two classes has no significant difference

and equally high (dark), seen in the second level classification results for the original image (in the presence of the water column), the water column target known as rocks shown in black. Critical samples show the similarity of spectral characteristics of the target will affect the value of the target stability, critical samples show the target that will affect the results, showing which samples will be similar / critical and the number of samples.

The result of seafloor classification has been validated by integration of grab sampling distribution map and bathymetry of study area taken adjacent to Side-scan Sonar measurement, although the sediment distribution map is made in larger scale so it is more general. Map of sediment distribution shows sedimentation in the form of gravel material where the seafloor classification of segmentation result is in the range of sand class to cobble. Deep classes in bathymetry map indicated that large grain will be in the shallower depth class, the smoother and smaller grain sediment will be in the deeper depth class.

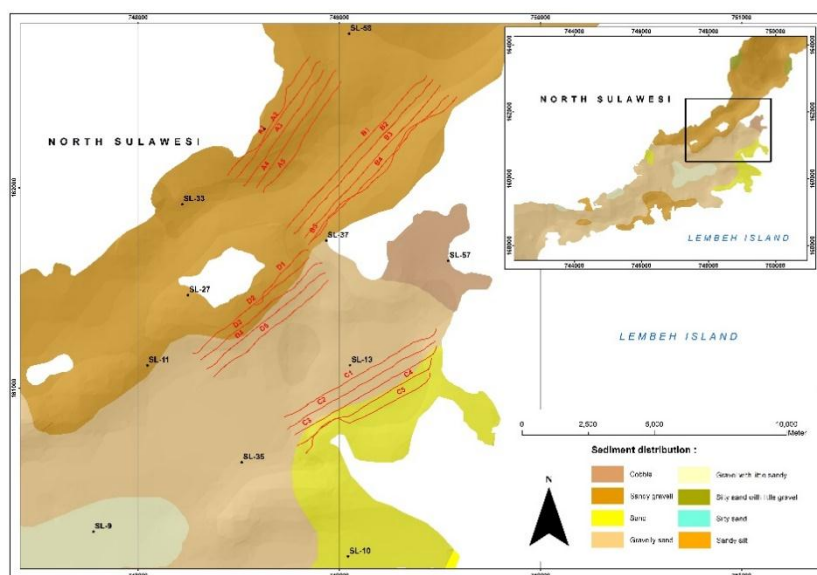
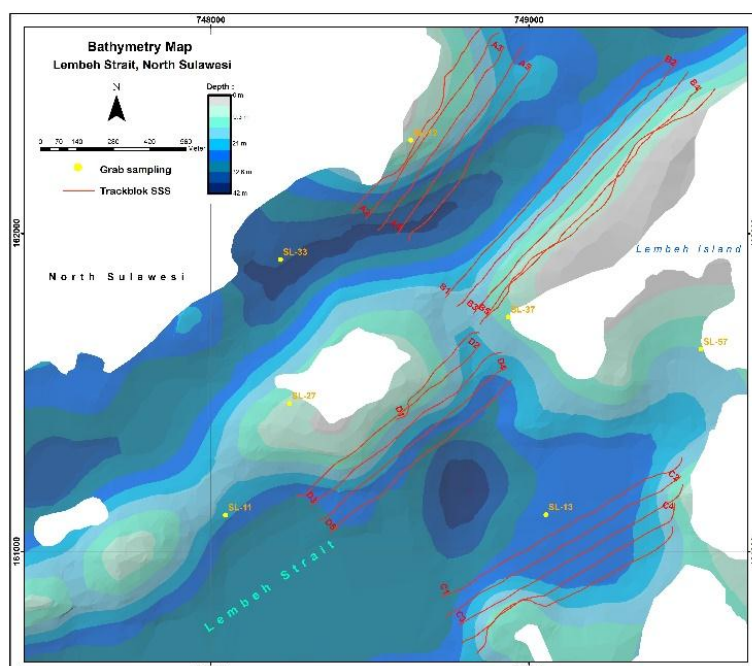


Figure 6. Sediment distribution map in Lembeh Strait, Bitung, North Sulawesi, grab sampling in April 2016



5. Conclusion

Segmentation and classification of Side-scan Sonar can be done using integrating backscatter power and image processing with difference pixel value of target. Backscatter associated with the target material of hardness and roughness can be correlated in multi-resolution segmentation method using smoothness and compactness values. However, every pixel value each correction level varies for each type of data so that in the segmentation and classification process it is necessary to retrieve the training area to find out the critical target or target with a high probability of bias. The classification results of the segmentation process would be better if the data validation is done on the same scale.

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