Marine Information Technology

Curriculum Report

Extraction of tectonic lineaments from bathymetry DEM using GIS and Remote Sensing

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Declaration

I declare that the assignment here submitted is original except for source material explicitly acknowledged, and that the same or related material has not been previously submitted for another course. I also acknowledge that I am aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations.

Signature: 

Date: **2020-06-08**

Abstract

Tectonic lineaments are the linear features on the seafloor or Earth surface that can be mapped and they are morphological expression of geological structures. They are always related to tectonic processes and sometimes they are used to produce geological structural maps. Seafloor lineaments are important in recognizing geological structures on and inside seafloor that are related to the control and distribution of natural resources e. g. hydrothermal vents systems. Because the seafloor covers very wide area, it is difficult to find these natural resources on the seafloor. High cost and a very long period of time will be required to determine the potential areas. Therefore, seafloor tectonic lineaments extraction from bathymetry DEM which uses UWC is very important to narrow down exploration area. The objective of this study is to extract seafloor tectonic lineaments and hence producing lineament density map, from Bathymetry DEM using GIS and Remote Sensing. The extracted lineaments will help in identification of potential zones for the occurrence of prominent natural resources. The methods involved are calculation of slope and aspect, structures enhancement, multiple filtering, labelling of pixels and image skeletonization. The final result is seafloor tectonic lineaments and lineament density maps. The lineaments decrease the cost and time of the marine research as it facilitates the selection of potential searching zones prior to data acquisition or exploration. This method is applied on digital bathymetric images in an effort to recognize the geological structures. The identification of zones with presumed mineral potentiality is beneficial for pre-exploration mineral mining activities, so area that would be surveyed could be narrowed on those zones, and could be done faster, and used lower cost.

1 Introduction

1.1 Tectonic lineaments

Lineaments (Figure 1) are the linear features that can be mapped (Figure 2) on the Earth's and seafloor. They are morphological expression of geological structures such as fractures, faults and folds. Morphological lineaments have been studied by geologists since 19th century as they realized that the linear features on the surface of the Earth were the results of weak zones or structural displacement inside the Earth's crust (Hung et al, 2005; Nugroho & Tjahjaningsih, 2016). Lineaments are important in recognizing geological structures on and inside Earth's layers that are related to the control and distribution of natural resources, geo-hazards, geothermal energy and earthquakes. Tectonic lineaments are related to tectonic processes and sometimes are used to produce geological structural maps (Kokinou & Panagiotakis, 2020).

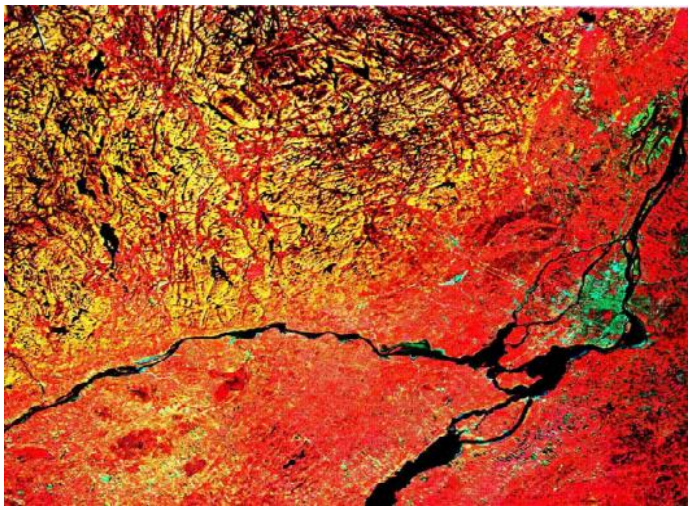

Figure 1: Lineaments (Gay, 2012)

Seafloor geomorphologic studies are important in the extraction and analysis of tectonic lineaments in sub-marine realm which comprise of many natural resources. Resources of importance under the ocean include hydrothermal vent systems, massive sulfides and hydrocarbon rich areas. The prediction of these resources potential zones under the ocean depend so much on the occurrence of tectonic lineaments (Kokinou & Panagiotakis, 2020). Geomorphologic techniques on bathymetric Digital Elevation

Model (DEM) can be used to extract and map tectonic lineaments from the seafloor.

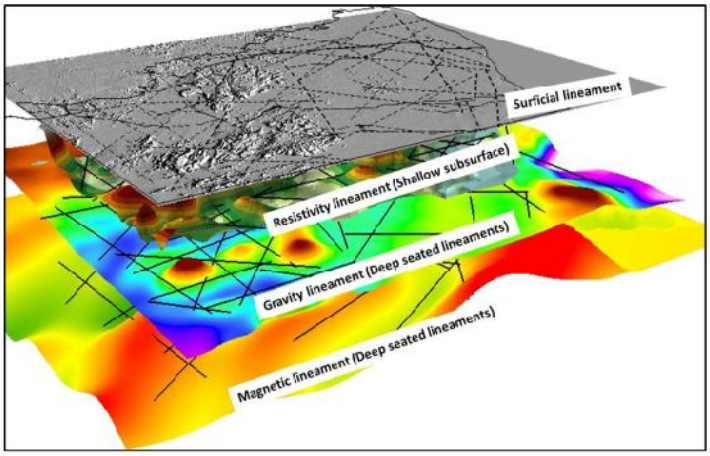

Figure 2: Mapped lineaments (Saravanavel, 2014)

1.2 Bathymetry

Bathymetric surveys (Figure 3) measure the depth of water body e. g. oceans as well as map the underwater features of a water body. Bathymetry is underwater equivalent to topography on the surface of the Earth. Bathymetry charts show seafloor relief or terrain as contour lines (Thurman, 1997).

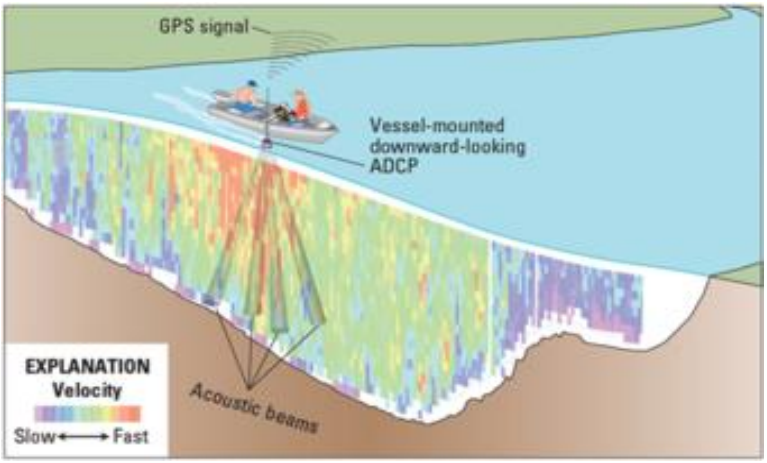

Figure 3: Bathymetry technique (USGS, 2019)

Bathymetry maps may also use DEM to produce Bathymetry DEM (Figure 4). Bathymetry technique uses an echo sounder (sonar) mounted beneath or over the

side of a boat, pinging a beam of sound downward at the seafloor. The amount of time it takes for the sound to travel through the water, bounce off the seafloor, and return to the sounder informs the equipment of the distance to the seafloor. Remote sensing LIDAR or LADAR systems which use light can also be used to make low resolution bathymetry maps. LIDAR/LADAR surveys are usually conducted by airborne/space borne systems (NOAA, 2018).

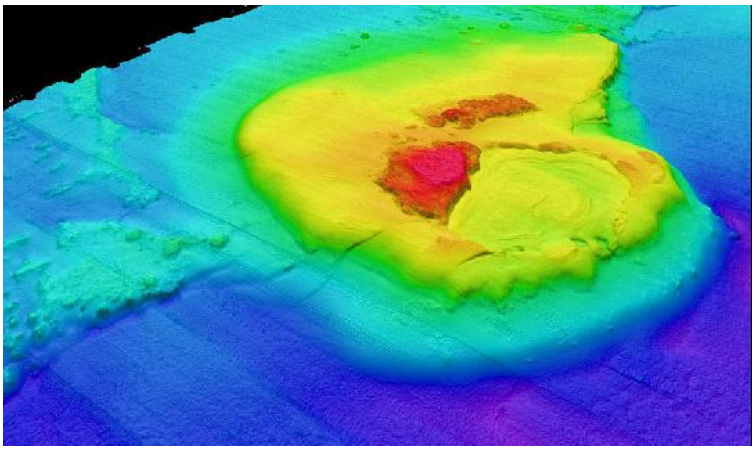

Figure 4: Bathymetry DEM (NOAA, 2018)

There are different methods that can be used in bathymetry surveys. A multi-beam echo sounder sends out a hundreds of very narrow adjacent beams across a "swath" of the seafloor. As the beams are bounced back from the seafloor, data is collected and processed. Multi-beam surveying are much useful in larger water bodies. A single-beam bathymetry measures the water depth directly under the boat using a single beam of sound. They are generally used for smaller water bodies. Acoustic Doppler Current Profiler (ADCP) measures water velocity by transmitting sound waves which are reflected off sediments and other materials in the water. Sub-bottom profilers are most commonly used to view the layers of sediment and rocks under the seafloor. Eco-mapper Autonomous Underwater Vehicle (AUV) can collect detailed bathymetric data, down to 30cm contours, in places that are difficult to reach with boats (NOAA, 2018). Satellites can also be used for bathymetry survey. LIDAR/LADAR maps deep-sea topography by detecting the subtle variations in sea

level caused by the gravitational pull of undersea mountains, ridges, and other masses.

Geologists use bathymetry data to study rocks and minerals, underwater earthquakes or volcanoes, hydrothermal vents fields, massive hydrothermal sulfides, hydrocarbons rich area, early life formation and search for extraterrestrial life on other planets.

1.3 GIS and remote sensing

The extraction of seafloor tectonic lineaments from the bathymetry DEM can be performed using Geographic Information Systems (GIS) and remote sensing (RS) techniques, together enhance analysis knowledge in geology and geomorphology (Kokinou & Panagiotakis, 2020). GIS is a computerized system which is capable of capturing, storing, managing, analyzing and dissemination of geographical data. RS is integrated into GIS as one of the data source into a system. Example of RS data is bathymetry DEM.

In my research direction, the Bathymetry technique which uses Underwater Wireless Communication (UWC) will be used to extract tectonic lineaments.

1.4 Problem statement

Seafloor tectonic lineaments are the manifestation at the seafloor of deeper geological structures, indicating important tectonic units under the seafloor and zones favorable for the formation of minerals, hydrothermal vents systems, massive sulfides, hydrocarbon rich areas and early life forms (Kokinou & Panagiotakis, 2014). However, there are difficulties of finding the favorable zones as the seafloor consists of a very wide coverage area (More than 75% of the earth’s surface is covered by oceans). A very long period of time will be required to determine the prospect areas, which will have direct impact on the financial of exploration activities (Kokinou & Panagiotakis, 2020). Therefore, in order to curb these problems, in-depth studies on seafloor tectonic lineaments extraction from bathymetry DEM are of theoretical significance and practical value.

1.5 Objectives

1.5.1 Main objective

The main objective of this study will be to extract tectonic lineaments from Bathymetry DEM using GIS and RS.

1.5.2 Specific objectives

i. Calculation of slope and aspect
ii. Faults enhancement using RS techniques
iii. Filtering and Curvilinear detection using RS techniques
iv. Lineaments generation
v. Creation of lineament density map

1.6 Significance of the study

This type of study will be useful into the determination of potential zones of the following:

i. Hydrothermal vents fields
ii. Massive Sulfides
iii. Hydrocarbons rich areas
iv. Early life forms

It can also be useful in searching for life on extraterrestrial planets and studies on the origin of life on earth.

2 Literature review

Many researchers have conducted the study on lineament extraction from DEM and satellite images on the Earth's surface. However, there are very few studies on geological lineaments extraction from Bathymetry DEM on the seafloor. A framework (Figure 5) was proposed for automatic enhancement and detection of active sea faults using bathymetric images (Kokinou & Panagiotakis, 2014). They computed the slope and aspect images as well their derivatives and then efficiently combined a rotation and scale invariant filter and a pixel labeling method, providing

a robust detection of the sea faults. Experimental results and their correlation with recent earthquake activity indicated the reliable performance of the proposed scheme.

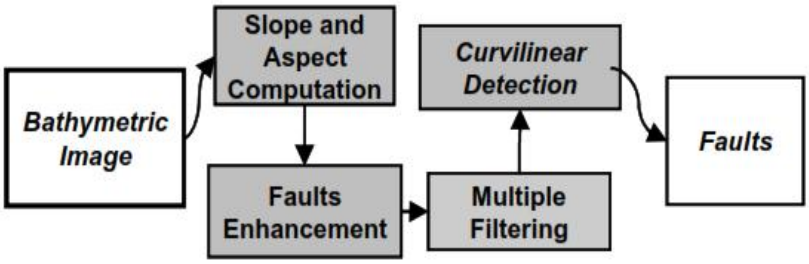

Figure 5: Scheme of the proposed system architecture (Kokinou & Panagiotakis, 2014)

In (Toprak & Suzen, 1998) the authors developed an algorithm which consists of a combination of large smoothing filters and gradient filters in order to decrease the artificial lineaments which are out of interest and to determine discontinuous and/or closely spaced regional lineaments.

3 Materials and Methods

3.1 Materials

Medium- and high-resolution bathymetric DEM which can be downloaded freely from the open-file database EMODNet (European Marine Observatory and Data Network) can primarily be used in the study.

3.2 Methods

The methodology continues the work of (Kokinou & Panagiotakis, 2020) and other scholars that has been applied in previous published geological studies. But it can also be summarized as follows:

i. Calculation of slope and aspect
ii. Structures enhancement
iii. Multiple filtering
iv. Labeling of pixels

v. Image skeletonization

vi. Data Interpretation

4 Results and discussion

The automatic extraction of the lineaments (Figure 6) from bathymetry DEM allows the interpretation of the most important seafloor morphological features. But the focus is on the tracing of tectonic lineaments and hence producing a lineament density map as a final result. The proposed methods have low computational demand and decreases the cost of the marine research because it facilitates the selection of potential zones prior to data exploration and acquisition (Kokinou & Panagiotakis, 2014, 2020).

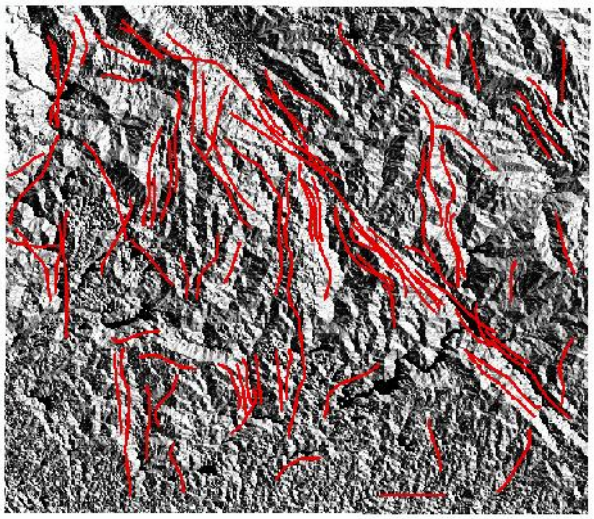

Figure 6: Extracted lineaments from DEM (Nugroho & Tjahjaningsih, 2016)

Litho-structural concept can be used to connect between lineament density information (Figure 7) with mineral potential zone. This concept describes generally that mineral resources can exist on areas having very strong structure intensity, so the water could pass through with sediment precious metal mineral on that area. This approach can be approximated by lineament density analysis by using general lineament parameter connected to geological structure (Nugroho & Tjahjaningsih, 2016).

Based on relationship between lineament density information with mineral potentiality, the study areas can be grouped into different zones (Figure 7) with presumed mineral potentiality. The grouping can be based on high density value and the existence of intersection between two zones of lineament density. The identification of zone with presumed mineral potency is beneficial for pre-exploration mineral mining activities, so area that would be surveyed could be narrowed on those zones, and could be done faster, and used lower cost (Nugroho & Tjahjaningsih, 2016).

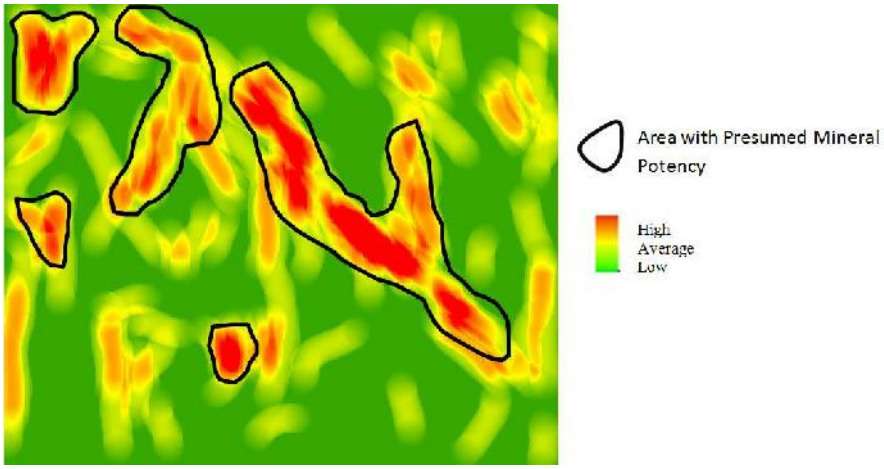

Figure 7: Lineaments density computed from extracted lineaments (Nugroho & Tjahjaningsih, 2016)

5 Conclusion

In this report, a framework for extraction of tectonic lineaments using bathymetric DEM (Underwater Wireless Acoustic Communication product) was presented. This method is applied on digital bathymetric images in an effort to recognize the geological structures. The determined geological structures are very important in geological marine research because it facilitates the identification of potential zones prior to exploration of different geological phenomena e. g. hydrothermal vents, hydrocarbons rich areas and earthquakes prone zones.

References

Gay, S. P. (2012). Joints, Linears, and Lineaments – The Basement Connection. AAPG Rocky Mountain Section.

Hung, L. Q., Batelaan, O., & De Smedt, F. (2005). Lineament extraction and analysis, comparison of LANDSAT ETM and ASTER imagery. Case study: Suoimuoi tropical karst catchment, Vietnam. Proc. of SPIE, 5983. doi: 10.1117/12.627699.

Kokinou, E., & Panagiotakis, C. (2014). Automatic enhancement and detection of active sea faults from bathymetry. Paper presented at the International Conference on Pattern Recognition.

Kokinou, E., & Panagiotakis, C. (2020). Automatic Pattern Recognition of Tectonic Lineaments in Seafloor Morphology to Contribute in the Structural Analysis of Potentially Hydrocarbon-Rich Areas. Remote Sens., 12(1538). doi: 10.3390/rs12101538

NOAA. (2018). *What is bathymetry?* [Online]. Available: https://oceanservice.noaa.gov/facts/bathymetry.html.

Nugroho, U. C., & Tjahjaningsih, A. (2016). Lineament density information extraction using DEM SRTM data to predict the mineral potential zones. International Journal of Remote Sensing and Earth Sciences, 13(1), 67-74.

Saravanavel, J. & Ramasamy, S. M. (2014). GIS Based 3D visualization of subsurface and surface lineaments / faults and their geological significance, Northern Tamil Nadu, India. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* XL.

Thurman, H. V. (1997). Introductory Oceanography. New Jersey, USA: Prentice Hall College.

Toprak, V., & Suzen, M. L. (1998). Filtering of satellite images in geological

lineament analyses: an application to a fault zone in central turkey. International Journal of Remote Sensing, 19(6), 1101–1114. doi: 10.1080/014311698215621.

USGS. (2019). *Bathymetric Surveys* [Online]. USA: U. S. Geological Surveys. Available: https://www.usgs.gov/centers/oki-water/science/bathymetric-surveys?qt-science_center_objects=0#qt-science_center_objects [Accessed 5/30 2020].