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The influence of tectonics on underwater morphology of the Arafura Sea by using seismic refraction in West Papua, Indonesia

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Abstract

The Arafura waters are part of the northern edge of the Mesozoic Passive Margin of Australia. The movement of plates on the ocean floor results in the formation of reliefs on the seabed, these reliefs are commonly referred to as seabed morphology. Tectonic activity on the Tarera-Aiduna fault, until now still plays an important role and controls conversion tectonic activity in this area. The collision between plates or subduction is the eventuality quality of a collision between plates, where one plate plunges downwards, forming an ocean trench. The seabed is a very deep and narrow seabed, the walls are steep and steep with a depth of more than 200 m. The purpose of this study was to determine the morphological formations on the seabed caused by tectonic activity, so as to obtain what tectonic processes are working in the area. The method used in this research is to analyze the data generated by the survey ship Geomarine III, owned by P3GL, Ministry of Energy and Mineral Resources. The data used are Marine seismic data and Bathymetry data, analysis of seismic data is intended to determine rock layers, and the geometric shape of the structures that develop in the area, while Bathymetric data analysis is intended to determine the depth of seawater, which is also used to determine reliefs. Or morphology under the seabed. The results of the analysis are in the form of morphological formations on the ocean floor starting from the Exposure area to the Aru Trench.

1. Introduction

The waters of Aru are part of the northern edge of the passive margin of the Australian plate [1]. This area is very complex and has been active since the Paleozoic and continues today [2]. This area is an active zone that is influenced by the activity of the Tarera-Aiduna fault, which is a transcurrent fault that is estimated to have a left/sinistral shift [3]. Papua experienced a very complex and complicated tectonic process, where there are several main faults, namely: Sorong fault zone, Yapen fault zone, Memberamo fault zone, Lengguru fault and fold zone, Papua fault and fold zone, Tarera-Aiduna fault, Anjak Gauter fault zone, Through Aru, and the New Guinea trench [4]. The Tarera-Aiduna Fault plays an important role and controls the conversion tectonic activity in this area, formed during the conversion stage of the Oligocene-Middle Miocene as a consequence of the northward movement of the Australian Plate [5]. The Arafura waters are part of the northern edge of the Mesozoic Passive Margin of Arafura, Australia [6]. In Figure 1, a description of the tectonic elements that occur in Papua is given. This area is very complex and has been active since the Paleozoic and continues today [6].

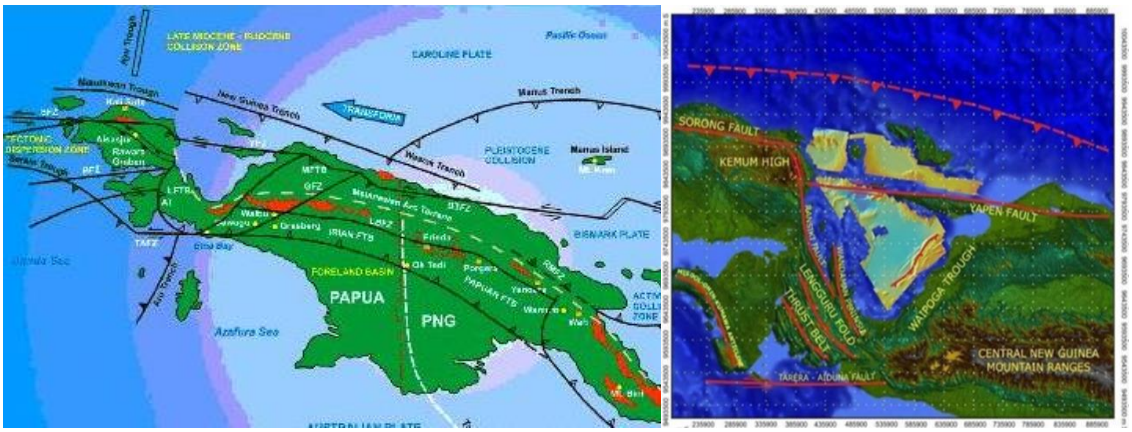

Figure 1. Tectonic element (left) (modified from [7]) and Tectonic settings (right) of the Papua Island [8]

The very active and complex tectonic activity in Aru's waters affects the structure of the sedimentary rock layers in the area (see figure 1), especially under the seabed. Tectonic processes can produce folds and faults, both in small and large sizes. Based on the analysis of geological and geophysical data, the general situation of seafloor tectonic conditions and morphological formation from the continental shelf to the Aru Trench is obtained. The location of the research area is the waters of West Papua in the southern part and is bordered by the northern part of the Aru Islands with an area of 39,340 km^2 or a length of 215 km to the northwest-southeast and a width of 180 km to the northeast-southwest. The location of the research area is the Aru Waters of West Papua in the southern part and borders the northern part of the Aru Islands with an area of 39,340 km^2 or a length of 215 km to the northwest-southeast.

2. Geological Setting

East Indonesia is tectonically located in the interaction zone between 3 main tectonic plates, namely the Eurasian, Indo-Australian, and Pacific Plates [6]. The three tectonic plates were broken, buckled, and squeezed before the Miocene (See figure 2). This area is very complex and has been active since the Paleozoic and continues today. Several microcontinents and oceanic fragments have separated and separated into the margin of the Late Cenozoic tectonic evolution of Eastern Indonesia. Tectonic elements of eastern Indonesia and the western edge of the Australian continent [1], [9].

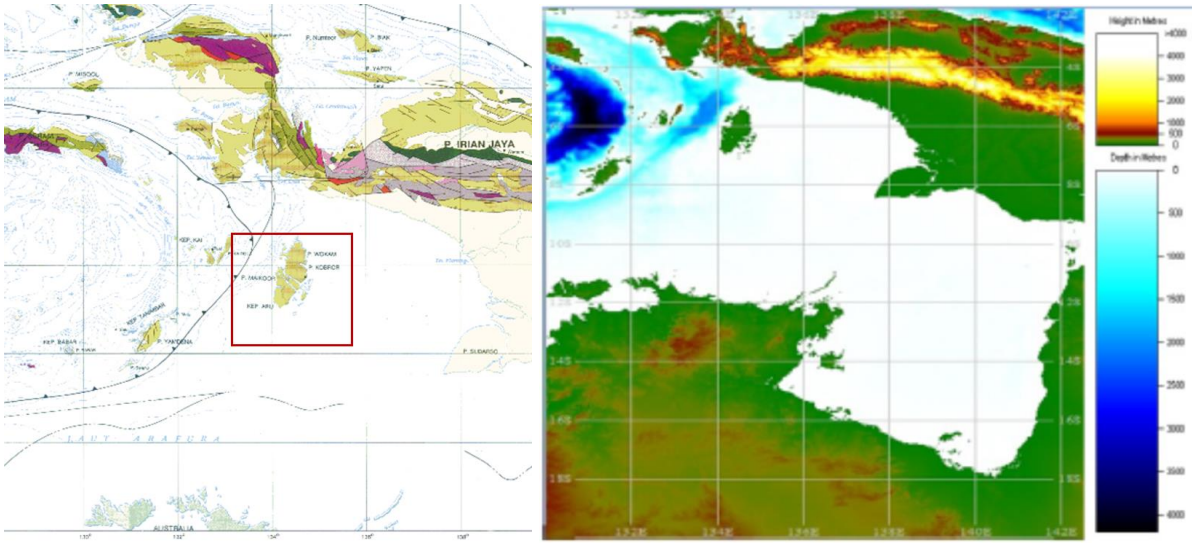

Figure 2. The research location with the background of the compilation of terrestrial geological maps and regional geological structures (left) (modification of PSG, 2011 in [10]), The Bathymetry of the Arafura sea with a spatial resolution of 30 arc-second (900 m) (GEBCO) [11]

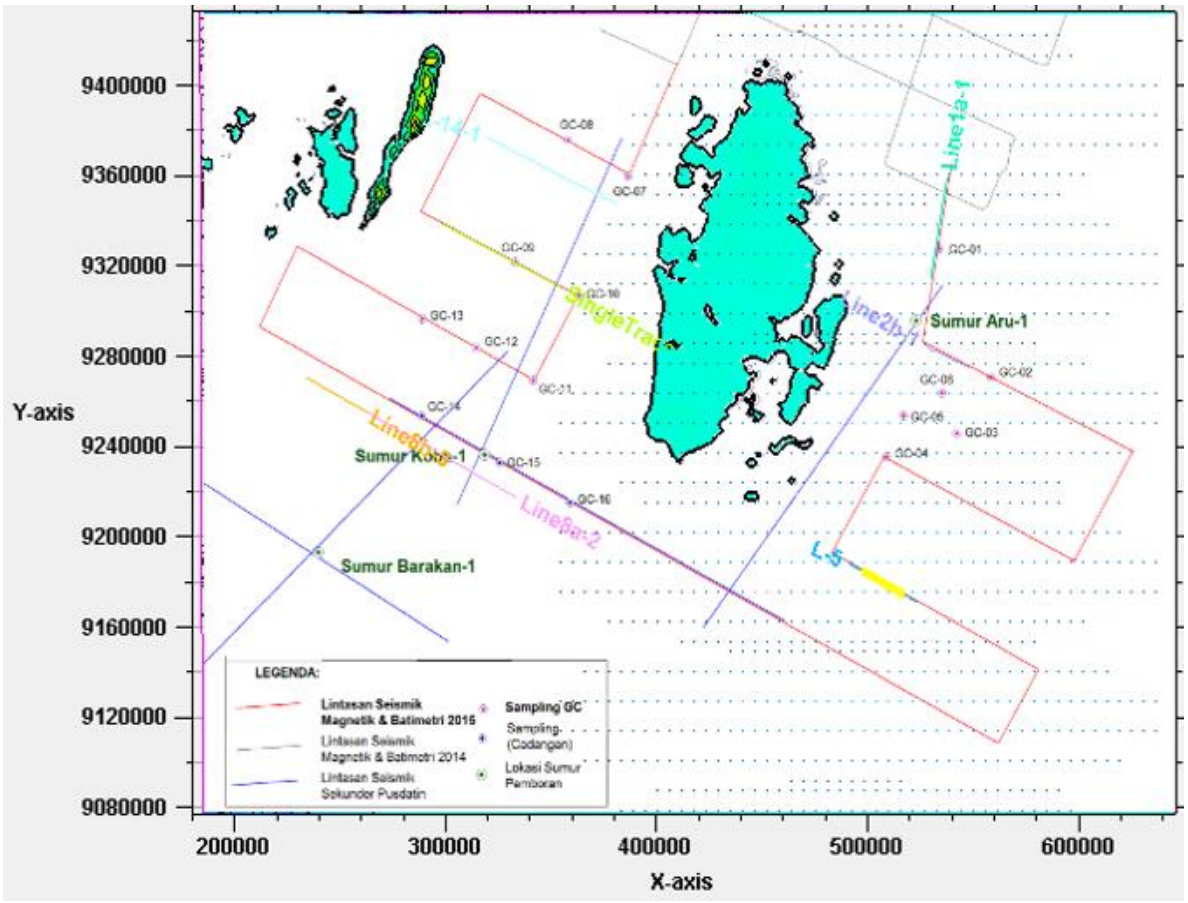

Figure 3. location of seismic trajectories and research sampling

The results of this tectonic interaction can be seen from the configuration of the basin in the area at this time, where the Northwest Australian (NW) and Arafura/Barakan basins in Indonesia are dominated by Paleozoic to Mesozoic basins associated with a strain tectonic system [12]. The Bird's Head region is dominated by the Tertiary basin, which has been affected by the compression of the tectonic system. The main tectonic activities can be summarized as follows:

a. Paleozoic (Permian), Paleozoic graben rifting trend of northwest-southeast fault direction in The Berau Wells was recorded in the Australian Sea Salt Flats, Money Shoal, and Bonaparte Basin.
b. Late Jurassic unconformity (Fitzroy Movement), compression (shortening), and regional erosional surfaces of the Late Triassic unconformity plane.
c. Early Euler stretching in the northeast occurred mainly in the northwest of the Australian continental shelf.
d. Central Eula (Callovian) unconformity of well datum and chronostratigraphy.
e. Late Cretaceous (Cenomanian) unconformity fields based on wells datum, chronostratigraphy.
f. Passive marginal sequence: Paleocene-Miocene The Neogene and Miocene collisions between Australia and Indonesia resulted in the onset of Neogene tectonic transpression, local uplift, and flexural extension.

Tectonic settings

The tectonic setting of the Papua Region has been widely discussed by geologists and is used as a frame of reference in discussing the tectonic history of Papua. According to [10], the tectonic configuration of Papua is on the northern edge of the Australian plate, which is the result of the meeting between the Australian Plate and the Pacific plate. The Australian plate is moving northward, while the Pacific plate is moving west [10]

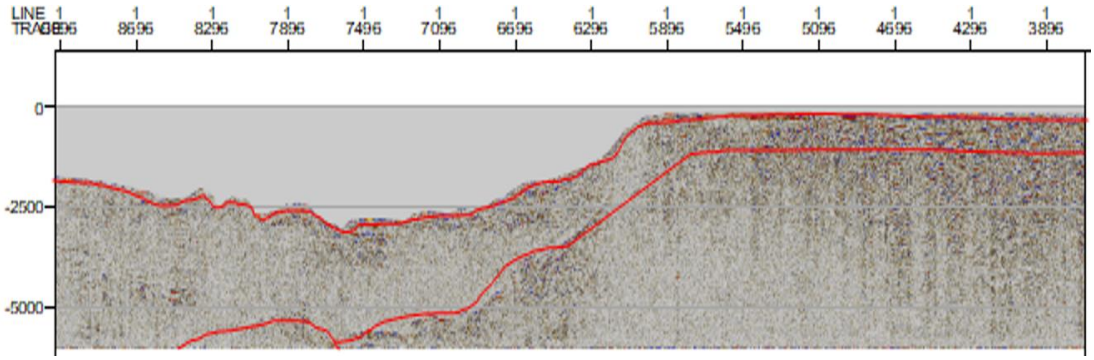

Figure 4. Seismic trajectory 01

3. Methodology

The data acquisition was carried out using the Geomarin III vessel, owned by P3GL of the Ministry of Energy and Mineral Resources. The data used are bathymetry, marine seismic, and other supporting data. The research method consists of several research stages, namely understanding the depth of the sea through bathymetric data. Analysis of the structure of the rock and the geometric shape of the layers of sedimentary rock under the seabed used marine seismic data. In addition, based on the results of the tectonic process, the morphogenesis of the seabed was analyzed.

4. Results

Bathymetric Data, Analysis

From the results of measuring the depth of the seabed using an echo sounder, corrections are made with bathymetry comparisons using GEBCO, (General Bathymetric Chart of the Ocean) images. GEBCO imagery is used as correction data and depth trend patterns on the seafloor (Bathymetry) so that a contour map of the depth of the seafloor can be produced.

Seabed morphology is a picture under the seabed that has similarities to conditions on land. Morphology in the form of underwater mountains, underwater volcanoes, slopes, plains, valleys, ditches, and channels (see figure 4 and 5). Underwater morphology in Aru waters is influenced by geologic processes, especially tectonic processes from plate movement under the ocean. The Tarera-Aiduna Fault plays an important role and controls the conversion tectonic activity in this area, formed during the conversion stage of the Oligocene-Middle Miocene as a consequence of the northward movement of the Australian Plate. The morphological patterns of the seafloor usually follow the shoreline and tectonic patterns. The highlands show the shape of sharp narrow ridges and valleys that are the main characteristics of bedrock. The stratigraphy or topography was affected by the collision of the inner Australian microcontinent with the Banda Arc. The bathymetric data of the Arafura Sea was extracted from the General Bathymetric Chart of The Ocean (GEBCO), with a spatial resolution of 30 arc-seconds (900m), positive values represent land, negative values represent seabed.

Figure 5. Seismic trajectory 02

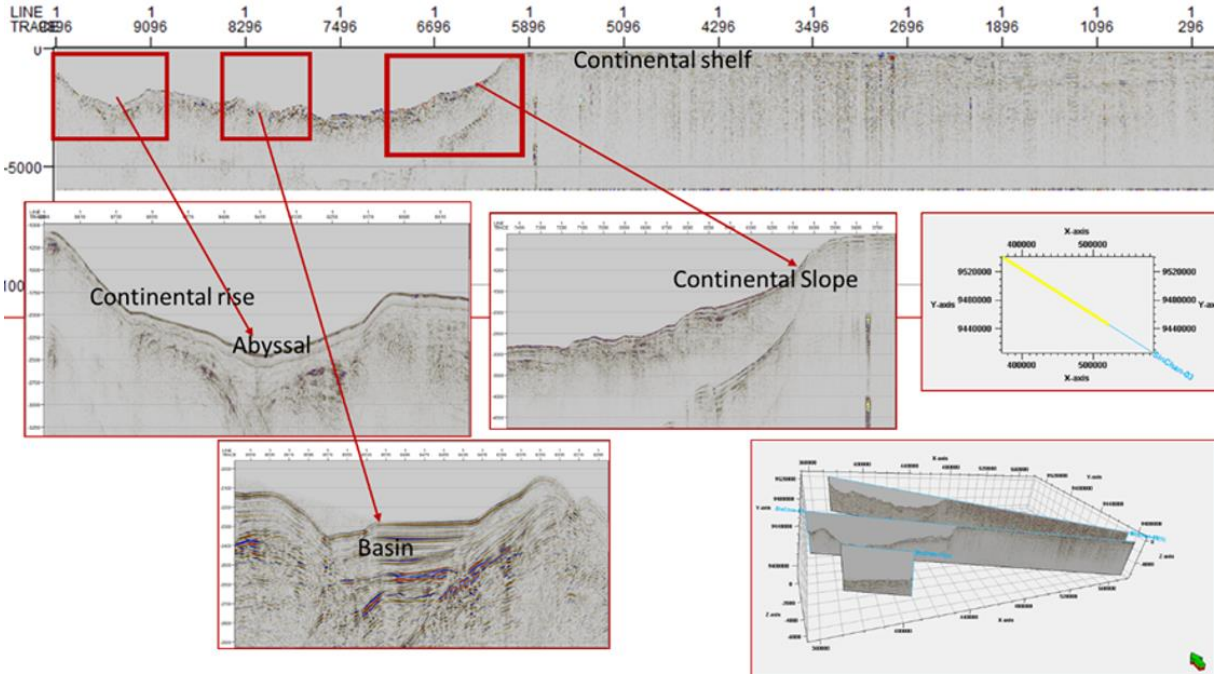

Figure 6. Morphological formations of the seabed

Seismic Data Analysis

There are several seismic trajectories at the study site, then horizon picking is performed to connect the horizons to get an image of the subsurface, resulting in geometric stratigraphy that describes the structure and morphology of the seabed. Here, we provide a map of seismic trajectories and sampling locations in the study area, as shown in Figure 3 below:

The morphological components, continental shelf, which is a large land under the seabed, slightly inclined, with an average depth of 200m, 2. Continental uplift, the part of the continent that is directly adjacent to the seabed, usually has a slope that slopes gradually to flat. Tens of kilometers wide, usually an accumulation of sediment deposits from above, 3. Continental slope, usually the end of sediment deposition, 4. Sea bottoms, caused by deep subsidence of the seabed caused by folds, the seabed here is already filled with thick sediments (see figure 6).

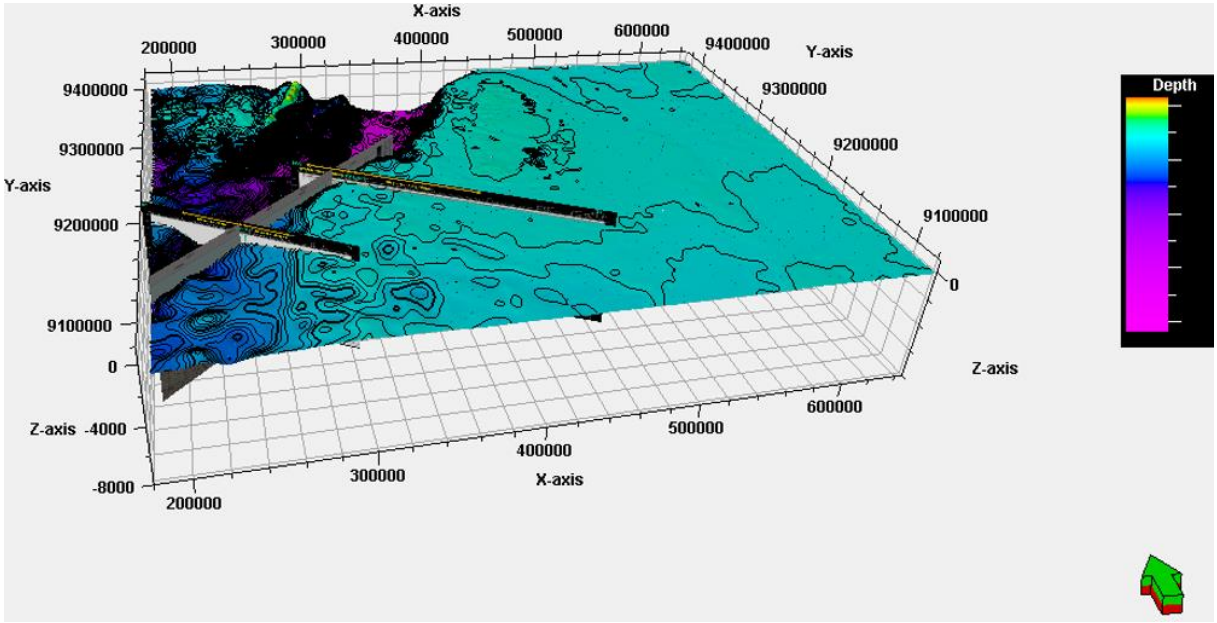

Figure 7. the results of the analysis of the morphology of the seabed

5. Discussion

The study site is a highly tectonic active area, resulting in a tectonic pattern developed at the study site. The activity of the Tarera – The Aiduna fault plays an important role in the formation of the tectonic framework in this area [1], [3], [4], [6], [10]. Based on the results of the analysis using bathymetric data and seismic data [13], it can be concluded that using bathymetric and seismic data for data analysis [14], describes the geomorphic formation of the seabed, showing the location of the continental shelf to the Aru Trench. Tectonic activity plays an important role in the formation of seabed morphology [15], where the area adjacent to the Aru Trench shows morphological formations due to tectonic activity [16]. Morphological formations are strongly influenced by tectonic activity so that in locations adjacent to the Aru Trench, various morphological formations can be seen developing (see figure 7).

6. Conclusion

Based on the results of the analysis using bathymetric data and seismic data, it can be concluded that using bathymetric and seismic data for data analysis, describes the geomorphic formation of the seabed, showing the location of the continental shelf to the Aru Trench. Tectonic activity plays an important role in the formation of seabed morphology, where the area adjacent to the Aru Trench shows morphological formations due to tectonic activity [16]. The morphological components are; 1) Continental shelf, which is a large land under the seabed, slightly inclined, with an average depth of 200m, 2) Continental uplift, the part of the continent that is directly adjacent to the seabed, usually has a slope that slopes gradually to flat. Tens of kilometers wide, usually an accumulation of sediment deposits from above, 3) Continental slope, usually the end of sediment deposition, 4) Sea bottoms, caused by deep subsidence of the seabed caused by folds, the seabed here is already filled with thick sediments.

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References:

[1] P. Bird, "An updated digital model of plate boundaries," *Geochemistry, Geophysics, Geosystems*, 2003, doi: 10.1029/2001GC000252.

[2] J. K.-E.-S. Reviews and undefined 1971, "A review of the geotectonic theories and tectonic maps of Indonesia," *Elsevier*, Accessed: Mar. 03, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/0012825271900067

[3] H. Darman, "An Outline of The Geology Indonesia," *Journal of Chemical Information and Modeling*, 2000, doi: 10.1017/CBO9781107415324.004.

[4] B. H. Harahap, A. S. Hakim, and D. B. Dow, "Geological map of the Enarotali sheet, Irian Jaya," Bandung, 1990. Accessed: Mar. 14, 2022. [Online]. Available: https://drive.google.com/drive/u/2/folders/1IREfy_bxm4PjBJ8xLqjK7tSD0r5s06C_

[5] W. R. Buck, F. Martinez, M. S. Steckler, and J. R. Cochran, "Thermal consequences of lithospheric extension: Pure and simple," *Tectonics*, 1988, doi: 10.1029/TC007i002p00213.

[6] R. Soeria-Atmadja, R. C. Maury, H. Bellon, H. Pringgoprawiro, M. Polve, and B. Priadi, "Tertiary magmatic belts in Java," *Journal of Southeast Asian Earth Sciences*, 1994, doi: 10.1016/0743-9547(94)90062-0.

[7] S. L. Baldwin, P. G. Fitzgerald, and L. E. Webb, "Tectonics of the New Guinea Region," *http://dx.doi.org/10.1146/annurev-earth-040809-152540*, vol. 40, pp. 495–520, May 2012, doi: 10.1146/ANNUREV-EARTH-040809-152540.

[8] R. W. van Bemmelen, "The Geology of Indonesia. General Geology of Indonesia and Adjacent Archipelagoes," *Government Printing Office, The Hague*. 1949. doi: 10.1109/VR.2018.8447558.

[9] F. R. Widiatmoko, A. Zamroni, M. A. Siamashari, and A. N. Maulina, "Rekaman stasiun GPS sebagai pendeteksi pergerakan tektonik, studi kasus: bencana Tsunami Aceh 26 Desember

2004," in *Prosiding Seminar Teknologi Kebumian dan Kelautan*, 2019, vol. 1, no. 1, pp. 236–240. [Online]. Available: https://ejurnal.itats.ac.id/semitan/article/view/856

[10] "Seismic stratigraphy analysis of 2D seismic cross-section in Arafura sea, Papua | Naufal | Journal of Geological Sciences and Applied Geology." http://journal.unpad.ac.id/gsag/article/view/29153 (accessed Mar. 14, 2022).

[11] P. Weatherall *et al.*, "A new digital bathymetric model of the world's oceans," *Earth and Space Science*, vol. 2, no. 8, pp. 331–345, Aug. 2015, doi: 10.1002/2015EA000107.

[12] "Fault Classification: Discussion | GSA Bulletin | GeoScienceWorld." https://pubs.geoscienceworld.org/gsa/gsabulletin/article-abstract/83/8/2545/7688/Fault-Classification-Discussion (accessed Mar. 07, 2022).

[13] A. N. Saerina, I. F. Romario, and H. Nugroho, "Central Java Hydrocarbon Potential: North Serayu Petroleum System from Source to Trap Based on Geology, Geochemistry, and Geophysics Analysis," 2016. doi: 10.2523/iptc-18654-ms.

[14] P. S. Schultz, S. Ronen, M. Hattori, and C. Corbett, "Seismic-guided estimation of log properties Part 1: A data-driven interpretation methodology," *Leading Edge*, 1994, doi: 10.1190/1.1437020.

[15] A. Ismail-Zadeh, A. Soloviev, V. Sokolov, I. Vorobieva, B. Müller, and F. Schilling, "Quantitative modeling of the lithosphere dynamics, earthquakes and seismic hazard," *Tectonophysics*, 2018, doi: 10.1016/j.tecto.2017.04.007.

[16] A. Gualandi, Z. Liu, and C. Rollins, "Post-large earthquake seismic activities mediated by aseismic deformation processes," *Earth and Planetary Science Letters*, 2020, doi: 10.1016/j.epsl.2019.115870.