E-ISSN : 2963-4946
Vol. 2 No. March 06, 2024

Asian Journal of Social and Humanities
https://ajosh.org/

Stereographic For Development of Stricture Pattern of Geological Alteration Zone in Atauro Island, Timor-Leste

Nazario Gomes[1*], Sutarto[2], Joko Soesilo[3], Heru Sigit Purwanto[4], James Christopher[5]
Universitas Veteran Yogyakarta, Indonesia
E-mail: alvianogomes@gmail.com

***Correspondence:** alvianogomes@gmail.com

KEYWORDS
Stereography, Development Pattern, Structure, Geological Alteration Zone, Atauro Island.

ABSTRACT
The geological structural patterns and hydrothermal alteration zones of Atauro Island, Timor-Leste, which are influenced by the collision mechanism between the Banda Arc and the Australian Continent, are the subject of this study. The study identifies fault types and alteration zones through stereographic analysis. It indicates the possibility of mineralisation in the area. Four alteration zones were identified in this study: argillic, Propylitic, calcosite, and geotite. The analysis results show that left-striking and normal faulting were essential in forming these zones. The mineralisation zones, mainly chalcopyrite and chalcocite, are related to the north-northeast trending left horizontal Fault. In addition, this study suggests additional research that includes mineralogy, geochemical, and geophysical analyses to understand more about the characteristics of hydrothermal alteration zones and possible mineralisation on Atauro Island. The results of this study are expected to improve our understanding of mineral resources in the region, and it is suggested that this information be considered by authorities responsible for the management of potential natural resources on Atauro Island, Timor.

Introduction

Geological structure is a science that studies essential aspects to determine the stress pattern in a research area. This paper discusses the geological structure of marginal basins in the South Banda Basin. It includes the northern parts of Alor, Atauro, Liran, Kisar, and Wetar Islands (Maneerat et al., 2022). The arc-continent collision mechanism between the Banda Arc and the Australian Continent influences this structure.

The study found that four areas at the Makili, Villa, Berau, and Bikeli sites in Atauro experienced hydrothermal alteration (Aisabokhae et al., 2023). Such changes are argillic; outer Propylitic, phillic, and advanced argillic changes are the types of changes produced by (Aisabokhae et al., 2023). The Villa, Makili, Pala, Berau, and Atauro sites are lithologically dominated by porphyritic, partly andesitic, dacitic, andesite rocks with silicic, propylitic, and argillic Filik alteration. Normal faulting is joint and shows a radiation pattern around the Pliocene-Pleistocene volcanic bodies, which still look ideal). Therefore, this four-region trend defines the left horizontal fault zone, which consists of both a strike-slip and a strike-slip zone. The left horizontal Fault is a mineralisation trapline that hosts significant sulphide mineralisation (Govil et al., 2021). Submarine Hydrothermal Systems: Dispersal Centers and Island Arcs interest researchers because of the hydrothermal fluid systems in the Island's arc (Pirajno, 2012). These characteristics suggest that the general process leads to hydrothermal fluids forming and transporting precipitates of metallic minerals such as Au, Ag, Cu, Zn, and Pb. However, these features are not yet diagnostic enough to generate a widely accepted genetic model. In the mineralisation zone map, two geological structure models are proposed to indicate the origin of Cu, Ag, Pb, and Zn elements. This model is the hydrothermal mineralisation zone model described in Figure 10 on the alteration and mineralisation zone model map of the study area, where mineralisation originates from magma, and the mineralisation model to determine the mineral elements originating from the earth's crust through meteoric and hydrothermal water fluids formed in brittle fault structures. This fluid pathway initiated the Cu, Ag, Pb, and Zn mineralisation in the Atauro Island study area. In the weak zone, hydrothermal fluids pass through faults and brittle zones. Stereographic programs are often used to determine the movement of structural patterns as traps in the formation of mineralisation and faults that occur in the study area. The results of geological structure modelling and analysis of general structural direction patterns, vein-style Cu, Ag, Pb, and Zn mineralisation are associated with significant N-S and B-T faults, particularly the Villa, Berau, and Makili Pala faults (Brookhian et al., 2020). Geological structures are still used to name faults and breccias at Atauro, Timor-Leste, to develop alteration and mineralisation models.

Subduction and accompanying volcanism spread systematically over an area that progressively expanded away from the continents towards the oceans during the tectonic evolution of the Indonesian Archipelago from the Late Paleozoic to the Pliocene Katili, (1975).

Research Methods

In this study, the phenomena observed were the following: The analysis was characterised by three specific zones: thrust zone, proto-thrust zone, and normal fault zone, where the boundary between frontal thrust and frontal deformation separates each zone.

Alteration zones: This study reports four altered zones at Makili, Villa, Pala, Berau, and Atauro, and all four zones have undergone hydrothermal alteration. The resulting alteration types are quartz and clay: argillic alteration, propylitic alteration, dolomitic alteration, and chloritic alteration of quartz, clay, and sericite—Filik (Figure 7d) (Govil et al., 2021) on Atauro Island, East Timor.

This research collects secondary data from several observation locations or samples to describe specific characteristics or phenomena. In this study, the data collected are on strike/dip measurements of bridles, faults, structural patterns, and geological alteration zones on Atauro Island, Timor-Leste (Fu et al., 2023).

The samples in this study are four geological alteration zones selected at the location and map of the alteration zone purposefully. A purposive sample was selected considering the geological alteration zone has different characteristics.

The instruments used in this research are geological maps and DEM (Digital Elevation Model) (Khalid et al., 2016). (Figure 8a dan 8b) to analyse kinematics and relate structures to each other and the tectonic setting, making it possible to determine the genetics of the geological structures developed in the study area. Fractures, volcanic breccias, slickensides, and variations in dip and strike over small distances, as well as uplift and depression structures, indicate the performance of faults acting in the area, which play an essential role in the geometry and distribution of mineralised masses (Brookhian et al., 2020) and satellite imagery and field data. Geological maps (Figure 11) were used to determine the characteristics of rocks on Atauro Island, Timor-Leste. Satellite imagery determines the pattern of geological structures on Atauro Island, Timor-Leste. Field data was used to observe geological alteration zones on Atauro Island, Timor-Leste, directly.

The research procedures carried out in this study are as follows:

Conduct a literature study to determine the characteristics of rocks and geological alteration zones. I am analysing geological maps to determine the distribution of rocks on Atauro Island, Timor-Leste, and satellite images to determine the pattern of geological structures on Atauro Island, Timor-Leste. Conduct field observations of geological alteration zones on Atauro Island, Timor-Leste. Data analysis will be conducted to analyse the structural pattern of the geological alteration zone on Atauro Island, Timor-Leste.

Results and Discussions

The geological structure pattern on Atauro Island, Timor-Leste, is dominated by normal Fault and shear fault structures. From the results of the alignment analysis, Atauro Island is dominated by the alignment with the general direction of east-northeast-west-west-west-west-west-west- -west southwest, followed by the relative alignment of north-south to northwest-southeast. The east-northwest alignment is due to the structure that developed the Escarpment Villa segment. The northwest-southeast alignment is a valley resulting from erosion along the fault line. The north-south alignment pattern may be related to structures developed in the island's northern part. After the collision at the Sunda-Banda Trough, the initial recession system formed from the mid-Miocene to the Pliocene subduction of the lithosphere from the Jurassic and Cretaceous oceans (Figure 2). When the most recent Pliocene Scott Plateau of the Australian continental margin entered the trench, accessory inflation increased significantly, transforming it into a new continental front fold and thrust belt (Figure 1).

Over the last 5 million years, subduction occurred where the Australian Oceanic Crust subducted beneath the Banda Arc and produced Banda Arc volcanism (Figure 2) Tate et al., (2015). Subduction of the continental crust produced natural basaltic magmatism, resulting in the volcanism of the Gunung Berau-Tutonair subduction volcanism zone Harris, (2011). The stresses acting in this phase are compression forces with a north-northeast-south-southwest orientation, such as the direction of movement of the subducted plate, in the appendix images of outcrops 4, 5a, and 5b.

Moving from subduction to collision in the Banda Arc, the global positioning system experiences a decrease in speed compared to the Sunda Shelf (backarc). Earthquake hypocenters are known as blue dots due to wedge collapse, white continental crust, black oceanic crust, Dutch striped terranes, green mélange, and yellow basins. The hypocenter of an earthquake outlines the subducting slab (Figure 6).

This standard fault structure was formed due to a compression process that occurred in the Pliocene to present-day Kuarte, where the four islands of Atauro, Alor, Liran, Kisar, and Wetar in northern Timor were no longer volcanically active, and activity ceased around 3 million years ago. This compression process causes the formation of hydrothermal alteration zones rich in sulphur dioxide minerals, such as pyrite. The geological structure pattern on Atauro Island, Timor-Leste, significantly influences the formation of hydrothermal alteration zones. These hydrothermal alteration zones have the potential to be a source of metallic minerals such as gold, silver, and copper.

Control Geological and geothermal structures in the Makili segment include hot springs and altered rocks. In this segment, there are geological structures in the form of the Kalehura Descending Fault (station-9) and the Makili Left Flat Fault (station-5), with an additional Fatulela location Descending Fault produced due to loading (Figure 7c). The structural control of geothermal heat in this segment is interpreted to be caused by the Makili left-lateral fault system. The presence of the Kalehura Descending Fault allows for permeable zones, where hot sprays with Cu, Ag, Pb, and Zn mineralisation are found around the study site. At the same time, the mineralised hills are still cut by the Makili Fault. It is interpreted that the Makili Fault creates fractures in the subsurface that become permeable zones for geothermal fluids to propagate to the surface.

At the Makili study site, alteration types are argillic and externally propylitic, with the argillic type consisting of quartz minerals and mineral oxides that have extensively altered the lithology. (Figure 9) Quartz fills veinlets, where chalcopyrite and chalcocite are mineralised, and serves as a base-mass replacement for clay minerals. The formation temperature is thought to range between 100 and 300 degrees Celsius. Host rock ages range between 3.65 ± 0.18 million years and 3.27 ± 0.18 million years.

Cross section of alteration zone incision A-A' Yellow Argillic alteration type: composed of quartz and clay minerals that have altered the lithology (Figure 10). Pervasively, quartz is present as a base mass replacement accompanying clay minerals. It is also present in filling veinlets that host chalcopyrite and chalcocite mineralisation. The formation temperature is interpreted to be 100–300 ᵒC Pliocene–Pleistocene horsrock age Propylitic Outer Alteration Type in Green in Cross Section: consists of chlorite and minor calcite that alter the lithology in a selective pervasive manner, where chlorite replaces mafic minerals. Calcite is present as infilling in fractures. The interpretation of the alteration formation temperature is 200-300 ᵒC.

Geological structure patterns on Atauro Island (Aisabokhae et al., 2023), standard and thrust faults dominate Timor-Leste; normal faults form hydrothermal alteration zones, While the descending fault horizontal fault plays a role in forming the argillic alteration zone (Prabowo et al., 2018).

Based on the results of stereographic analysis, the hydrothermal alteration zone on Atauro Island can be divided into two, namely argillic alteration type with pyrite +jerosite -hematite mineralisation zone, propylitic another alteration type, Chalcopyrite+calcosite+geotite mineralisation zone (Honarmand & Shahriari, 2021). The mineralised zone develops on a northeast-northeast trending left horizontal fault plane. In contrast, the silica-alkali alteration zone develops on a southwest-northeast trending strike-slip and left horizontal fault plane (Aryanto & Kurnio, 2020).

Hydrothermal alteration zones on Atauro Island have the potential to be a source of precious metal minerals such as gold, silver, and copper (Setijadji et al., 2010).

To further optimise the potential of mineral resources on Atauro Island, further research must be done to determine the hydrothermal alteration zone in more detail (Aisabokhae et al., 2023). Such research may include mineralogical, geochemical, and geological analysis of structures. Here are some recommendations for further research that can be done:

Mineralogical analysis to determine the type of minerals formed in the hydrothermal alteration.

1. Geochemical analysis for precious metal content in hydrothermal alteration zones (Province, (2023).
2. Geophysical analysis to determine the prospects for mineral resources in the hydrothermal alteration zone Utama, (2020)
3. Further research is needed to determine the relationship between structural and geological alteration patterns. Further research can be conducted using geochemical, petrographic, and geophysical methods.
4. Further research is needed to determine the mineralisation potential on Atauro Island (Inoh et al., 2023). Further research can be carried out using geological exploration methods.

This research has provided an overview of the structural pattern of geological alteration zones on Atauro Island. This research has also shown that Atauro Island has mineralisation potential.

Conclusion

The results show that geological structure and fault patterns are essential in forming hydrothermal alteration zones. This study confirms that Atauro Island has significant mineralisation potential, including valuable mineral resources such as gold, silver, and copper. However, further research is needed to gain a more in-depth understanding of the types of minerals formed in the alteration zone, the precious metal content, and the overall mineral resource outlook. Further research recommendations include mineralogical, geochemical, and geophysical analyses to understand hydrothermal alteration zones better. In addition, further geological exploration research could help identify the mineralisation potential in detail. The data and information generated from this study have great potential. They should be presented to the local government and the Timor-Leste Energy and Mineral Resources office to take the mineral resource potential of Atauro Island more seriously. As such, this study provides a solid foundation for further development in the geological exploration field and an understanding of the potential mineral resources in this region.

References

Aisabokhae, J., Alimi, S., Adeoye, M., & Oresajo, B. (2023). Geological structure and hydrothermal alteration mapping for mineral deposit prospectivity using airborne geomagnetic and multispectral data in Zuru Province, northwestern Nigeria. *The Egyptian Journal of Remote Sensing and Space Science*, *26*(1), 231–244.

Aryanto, N. C. D., & Kurnio, H. (2020). Tectonics of volcanogenic massive sulphide (VMS) deposits at Flores back-arc basin: a review. *Bulletin of the Marine Geology*, *35*(2).

Brookhian, M., Golkar Hamzee Yazd, H. R., & Tavousi, M. (2020). 3D modelling of faults and stability analysis of Dardvey mine in Sangan iron skarn complex, Iran. *SN Applied Sciences*, *2*(12), 2098.

Fu, S., Qiu, M., Shi, L., Liu, Z., Yang, X., Liu, T., & Zhang, L. (2023). Information Fusion and Metallogenic Prognosis of Gold Deposits in the Qixia Area, Northern Shandong Province, China. *Minerals*, *13*(9), 1125.

Govil, H., Mishra, G., Gill, N., Taylor, A., & Diwan, P. (2021). Mapping hydrothermally altered minerals and gossans using hyperspectral data in Eastern Kumaon Himalaya, India. *Applied Computing and Geosciences*, p. *9*, 100054. https://doi.org/10.1016/j.acags.2021.100054

Honarmand, M., & Shahriari, H. (2021). Geological mapping using drone-based photogrammetry: An application for exploration of vein-type Cu mineralisation. *Minerals*, *11*(6), 585.

Inoh, H. A., Rajji, A., Eddardouri, M., & Tayebi, M. (2023). Structural and mineral mapping using multispectral images in the Central High Atlas of Morocco. *Estud. Geol.(Madr.)*, *79*(1), e148.

Khalid, N. F., Din, A. H. M., Omar, K. M., Khanan, M. F. A., Omar, A. H., Hamid, A. I. A., & Pa'Suya, M. F. (2016). Open-source digital elevation model (DEM) evaluation with GPS and LiDAR data. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, pp. *42*, 299–306.

Maneerat, P., Bürgmann, R., & Betka, P. M. (2022). Thrust Sequence in the Western Fold-and-Thrust Belt of the Indo-Burma Range Determined from Fluvial Profile Analysis and Dynamic Landform Modeling. *Tectonophysics*, *845*, 229638. https://doi.org/10.1016/j.tecto.2022.229638

Pirajno, F. (2012). *Hydrothermal mineral deposits: principles and fundamental concepts for the exploration geologist*. Springer Science & Business Media.

Prabowo, B. B., Harefa, V. P., Senduk, S. E., Wowor, A. A. E., Tae, Y. D., & Seran, R. R. (2018). Investigation of the Structural Controlled Mineralization: Integrated

Geology, Geophysics and Remote Sensing in Kulonprogo. *EAGE-HAGI 1st Asia Pacific Meeting on Near Surface Geoscience and Engineering*, *2018*(1), 1–5. https://doi.org/10.3997/2214-4609.201800394

Setijadji, L. D., Basuki, N. I., & Prihatmoko, S. (2010). Kalimantan mineral resources: An update on exploration and mining trends, synthesis on magmatism history and proposed models for metallic mineralisation. *Proceedings 39th IAGI (Indonesian Geologists Association) Annual Convention and Exhibition, Lombok.*, *14pp*.