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Geological Study and Regional Development of Mamberamo Raya Disctrict of Papua Province, Indonesia

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Abstract. The goverment of Mamberamo Raya district was established through Act No. 19 of 2007 dated 15 March 2007 as part of the administrative area of Papua Province. The administrative age of this district is relatively young requires hard work of all components in facing development challenges so that necessary strategic steps of vision and mission of regional development to achieve ideal conditions of spatial which as direction of the desired embodiment in the future. Regional development covers all technical aspects including the geological aspect that the area is located on the morphology of the mountains and Mamberamo watershed. Strategic steps require policy as an action to achieve the goal with the elaboration of operational steps to realize the welfare of peoples equally and sustainably according to the potential physiogeography of Mamberamo watershed. The geological aspect as the consideration of technical that this region belongs to the regional tectonic which is divided into the difference of fault in the north there is Yapen fault and in the south is Mamberamo-Gauttier Fault and also a consideration on the stratigraphic structure of various rock types including the dominance of sedimentary rocks. This study examines geological aspects as an element of earth science in spatial planning in Mamberamo district, especially Kasonaweja and Burmeso. The analysis is presented based on field data, in the form of geographical map data of geological structure, geological map, and earthquake data described by cluster pattern indicating regional motion relationship and rock characteristics that make up Mamberamo watershed. It finds land characteristics controlled by geological structures, rock arrangements and landforms in response to landslide, flood and seismic changes.
Keywords: geological aspect,Gauttier Faut, Kasonaweja,Burmeso,Mamberamo

1. Introduction

Mamberamo River is a main river with a length of 670 km, as the largest and longest river in Papua province that flows from south to north to the Pacific Ocean, the river flows between Burmeso and Kasonaweja areas.

Mamberamo Raya district, Papua Province was established under Act No. 19, 2007 (15 March 2007) with an area of 23.813.91 km^2 (BPS, 2013) or 16.852.16 km^2 or 31.136.85 km^2 (in various sources). The boundaries of Mamberamo Raya as follows: North - Pacific Ocean, South - Puncak Jaya and Tolikara, West - Waropen and Yapen, East - Sarmi.

Although there are differences in the size of region, this district is very broad for a district government size with a population of 18.365 people [1] especially since the geology of the district connects mountain to coastal morphologies. Generally, land use in the area of Mamberamo Raya district consists of primary forests, secondary forests, primary mangroves, secondary mangroves, primary swamp forests, secondary swamp forests, community gardens, dry land farming, shrubs, and open land.

Certainly, to build a substantial district with uneven distribution of population required hard work for the government by involving stakeholders and various disciplines to build for the advancement of society. Multidisciplinary involvement is a necessity to provide much input to the government as a consideration of policies and decisions to build the physical area; this can be seen in the view of geological discipline regionally and locally to the location of the district in Mamberamo watershed and its relation to land carrying capacity, fault structures and morphological types.

2. Regional geology

Regionally, the location of Mamberamo Raya is influenced by active dynamic motion of Gautthers fault in the central part of Papua Island that impact can be seen with the emergence of several local faults that change the carrying capacity of rock. The territory of Mamberamo entered on the geology of the central mountains and the northern island of Papua with lithology in northern part composed by sediments (Formations of Unk, Mamberamo and Makats), it called North Irian basin [2] or Mamberamo basin [3]. Lithology of sediment spread following the morphology of mountains to the plains and also encountered metamorphic rock exposure in the southern part that spreads on the mountainous topography.

The condition of rocks distribution is closely related to the tectonic structure and the regional geological structure of New Guinea, which pose a sinistral shear fault structure. Northern part is fault zone of Mamberamo Raya towards East-West and in the Southern is Tarera-Aiduna (figure 1).

This paper is based on the results of research on geological mapping, mineral resource mapping and geological structure pattern mapping in the district of Burmeso and Kasonaweja in 2016. The benefits of this research can be used as a reference in regional development planning of Mamberamo district and geological disaster mitigation.

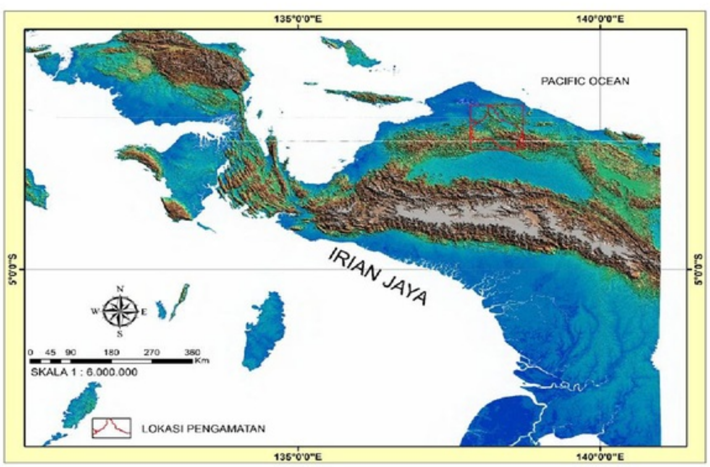

Figure 1. Regional geological map of Papua (*after* [4]) and the research site.

3. Methods

A quantitative research is done directly in the field by descriptive and measurement which include (a) morphological data collection, flow pattern recorded in the map and then followed by observation at

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the representative descriptive point (b) completeness of morphological data also combined with the symptoms of mass movement such as landslides, creep or fallout (c) geological structure data measurement is done on rocks that record the type of structure, and generally occur in sandstone sedimentary rocks.

Furthermore, field data is processed through making slope map through a method of landform interpretation, land use interpretation, recording on slope table, making digital slope map with *Arcgis 10.0* and 3D Analyst tool.

The data obtained in the field, also equipped with earthquake data recording from the Agencies of Meteorology, Climatology and Geophysics and then processed using statistica v.10 software to obtain a model form that represents the condition of field.

4. Results and discussions

4.1. Mamberamo watershed

Mamberamo River has a catchment area of 138.877 km². The depth of river ranges from 8 to 33 m. According to research in 1983, the water debit was able to reach 5.500 m^3/sec. The landscape around this river varies.

Generally, watersheds condition in the southern part are upstream of bermeander river such as S. Apauwar, S. Tor, S. Baedasifu, S. Roufaer, S.Verkam, S. Tariku, S. Burmeso and S. Kasonaweja towards S. Mamberamo which flows to the northern whose estuary is in contact with the Pacific Ocean. A number of rivers are upstream from fault structures and downstream along the Mamberamo River. The geological structure control of Mamberamo watershed is characterized by the presence of some well-known rapids among geologists; Marina Vallen, Marvalen and Batavia. The Mamberamo River downstream into the Pacific Ocean and Yapen where it is also used as water traffic by public and goverment shipping.

4.2. Geomorphology

The morphology of plains is located in the north and south of this district that separated by the mountains of Foja and Rouffaer. In northern part, the plain lies between the coastline and the mountains that extends to west-east in the central part of the district with the highest peak of 2.164 m above sea level. In southern part, the plain lies in the sedimentary basin situated above a basin flanked by the mountains of Foya and Nassau to Jayawijaya.

The southern plains lie between Mamberamo watersheds and flowed by large rivers, such as Tariku River (Rouffaer River) flowing from west to east and Taritatu River (Idenburg River) flowing from east to west. The two rivers then merge into one and become Memberamo River flowing to north through the Foja-Rouffaer Mountains.

Generally, the morphology of study area is controlled by the geological structures of fault and regional folds that characterized by a denritic flow pattern.

4.2.1. Morphology unit of lowland. The morphology of lowland enters residential areas of Kasonaweja and Burmeso with a slope of 10% to 12%. These morphological constituent rocks consist of strongly laid sandstones and alluvial sediment deposits (figure 2).

4.2.2. Morphology unit of hillside. This morphology enters residential areas of Anggreso Baru and Trimuris with a slope of 15% to 20%. The constituent rocks of this region are high-decaying in contact with the mud deposits.

4.2.3. Morphological unit of steep hill. This morphology spreads in Saromaja and Pisano areas, Van Rees, Gauttier and Siduarsi mountains were characterized by a slope of 22° to 45^0 degrees. Although the constituent rocks are generally old geological ages, they are compact and hard but in some places exhibit their brittle properties especially on fracture compiled by siltstone, mudstone, sandstone, and

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conglomerate, elevation 50 m to 75 m above sea level, the slope between 10% to 12%. Fracture morphology control is spreading in the Middle East Mamberamo, Mamberamo Hulu and Roufaer, west and southeast Mamberamo, Burmeso, Kasonaweja with the general direction North-Northwest-South-Southeast and Southwest-Northeast.

Figure 2. Lowland morphology.

4.3. *Structure*

4.3.1. Folds. The structure of major and minor folds as anticline and syncline, the slope of wings 30° to 50°, the general direction of axis is irregular northwest-southeast to east-west, steep corner. This structure is found in sedimentary rock of Unk Formation that make up Burmeso and Kasonaweja districts.

4.3.2. Fault. Regional fault pattern of Roufaer-guinea-Gauttier mountain-and Van Ress affecting local faults spreads in Kasonaweja-Burmeso and the middle parts-benuki-bira lake-marvalen rapids-batavia rapids-marina valen until downstream Mamberamo.

4.4. *Lithology*

Distribution of sedimentary rocks consisting of claystone, sandstone, siltstone that dominate the residential area. Claystone shows the fresh color of gray-blackish, fragments: clay, matrix: clay, cement: clay, N3250E/350 in position. Sandstone, grayish-white, fragments: very coarse sand, matrix: medium sand, cement: claystone and coal insertion (lignite). Siltstone shows fresh gray to brown, fragment: silt, matrix: silt, cement: silt, strong decay.

4.5. *Potential of mineral resources*

Result of inventory of metallic and non-metallic mineral resources by the Department of Energy and Mineral Resources of Mamberamo Raya district that mining in 2014 found some potential of excavation materials as follows:

- Fine sand, sirtu, coal, clay, gold, copper and iron, stibnit, black lead, zinc and energy.
- Coal, fine sand and clay are found in Roufaer District.
- Coal is found in Middle-East Mamberamo district.
- Sirtu (sand and stone), gems, gold, copper and iron, stibnit, lead and zinc are found in upstream Mamberamo district.

- Sirtu (sand and stone), gold, gemstone and coal are found in Central Mamberamo district.
- Indications of energy found in downstream Mamberamo and Sawai districts.

Especially the coal in the area of Mamberamo Raya district, where based on the results of laboratory analysis has a calorific value with a range of 5000 cal/gr, it is suitable as a raw material of Steam Power Plant. In addition to Steam Power Plant, the coal in Mamberamo Raya is also suitable to be made as coal briquettes which have the potential and distribution of coal in this region has a wide distribution.

Based on the potential data of metallic and nonmetallic resource above that related to the size of region, geologic location of rock variation as mineral source is estimated there are still some potency of other excavation material that has not been disclosed.

4.6. Slope

The slope has a variable angle that is affected by rock layer resistance and the location of region within the regional fault zone. This factor plays an important role in the formation of soil movement so it should be used in planning the construction of roads and bridges.

Based on the slope calculation is known that there are three slope classifications, namely: (1) steep (30% to 40%), (2) slight steep (15% to 30%), (3) ramps (8% to 15%). Generally, the steep slope has a greater gravity effect than the slight steep and ramps, which is due to the property of gravity is proportional to the sloping surface of the horizontal plane. This gravity is an absolute requirement of the process of detachment, transportation, and sedimentation (Wiradisastra, 1999).

Slope analysis of Kasonaweja-Burmeso region using morphometric parameters, quantitative assessment of landform as supporting aspects of morphographic and morphogenetic. These closely parameters are characterized by the properties of contour lines. The density of the contour lines on the map indicates that the slope is steeper and vice versa if the contour line is looser then the slope will be more ramps.

Data collection and interpretation approach of topographic map are used as morphometric data using slope formula (α):

$$\text{slope } (\alpha) = \text{Arc Tan (high difference-scaled distance)}$$

Based on the calculation using the above formula, it is known that there is a difference of slope in the district area which is described in the form of slope map (figure 3). Generally, the slopes distribution of flat slope, almost flat is located in the north or downstream area of Mamberamo River and in the northeast which borders Sarmi district. While, the slope of 9^{o} to 15^{o} spreads in Kasonaweja - Burmeso, where the spreads is limited by slight steep to steep.

4.7. Geological disaster mitigation

Mitigation in disaster terminology is defined as human efforts with the main objective of reducing the risks or impacts of natural disasters caused by natural or human activities (Sudibyakto, 2011). If an event that has a potential hazard occurs in an area with a vulnerable condition, then the area can be categorized as at risk of disaster [5].

The general potential of geological disasters is tectonic movement, tropical climate, soil movement and human activities that tend to change topography. In terms of regional geology, Mamberamo Raya district is flanked by regional fault of Gauttier located in the south and Yapen fault in the north and some local fault. Both of these regional faults are relatively active. Based on geological history, the dynamic tectonic motion of the past can be seen in the traces of local fault structures and folds recorded on sedimentary rocks. The impact of this structure, although it is local but can evolve to form a labile zone that characterized by the formation of a steep slope to a very steep, reduced rock compaction gradually change the size (fragmentation) from coarse to fine and even the size of clay and the formation of the slip due to layer changes and rock slope.

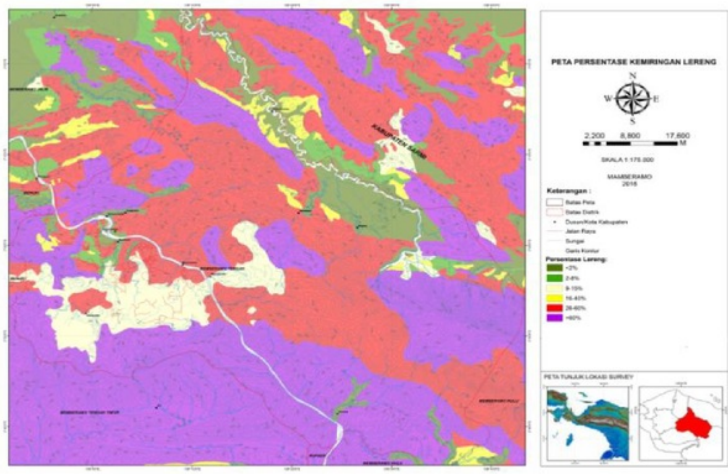

Figure 3. Map of slope percentage of Mamberamo Raya district. (1) 0°-2° = flat to almost flat, green (2) 2°-8° = slightly angled, light green (3) 9°-15 ° = angled with higher magnitude, yellow (4) 16°-40° = slightly steep, orange (5) 26°-60 ° = steep, pink (6) 35°-55° = very steep, red (7) > 60° = very steep, purple.

The data of soil movement potential is seen from the slope difference and seems to have a different kind of material contribution as well. Tilt of slope 0° to 15° although the topography is relatively flat but enough potency to cause sheet and groove erosions. Then, groove erosion that develops into landslides that also occur on the slope of slightly steep. The denudation process that occurs in rocks is quite active on steep conditions so it can increase the intensity of land motion. The condition of the soil movement develops on a very steep until very-very steep, which is composed by rock sediment (colluvial).

Data (1950-1990) average rainfall Mamberamo region in one year for each month is about 262.5 mm. Average rainfall above 200 mm every month and above 250 mm occurred in December, January, February, March and April [6]. Based on the accumulation of rainfall data, it quite high and influential as a trigger for the emergence of symptoms of mass movement, this is correlated with field conditions where usually after the rainfall activity found real erosion. Another trigger is the change in the compactness structure of rocks that occur in silt and sand that causes the development of real erosion into large-scale erosion or gully.

The high rainfall also affects several changes in Mamberamo watershed, namely the increase in surface water volume, the rising water levels of the river branches and Mamberamo River and the erosion of river walls. The above change factor can be used as an agenda in preparing the concept of regional development, another consideration is the field data of floods in 2015 which is an unusual event by the overflowing of Mamberamo River and inundating several houses located a few meters from the riverbank.

Although the district is included in watershed and the morphology of the plains, it cannot be said that the abundance of water can meet the needs of clean water. It is well-founded that the results of some field observation points on the outcrop of sedimentary rocks with the layered structure indicate *impermeable* physical properties. Because the distribution of sedimentary rock is wide enough it is necessary to note the availability of aquifer layer as a consideration material in preparing regional

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development planning. Given that the availability of groundwater as a need for clean water is a major and increasing need.

4.8. Synergy

Efforts to integrate spatial plans and regional development are undertaken by the Government of Mamberamo Raya district of Papua Province, but these efforts require maximum implementation due to constraints, technical and non-technical, and budget availability.

4.8.1. The role of stakeholder. The success of spatial planning will be determined by how much society can be involved in planning activities, spatial use, and spatial use controls facilitated by the Government. As the first stage of spatial planning, participatory planning provides greater opportunities for the creation of integrated and synergic space utilization, as well as effective and efficient spatial controls.

4.8.2. The role of central and provincial governments. Planning and development target of Mamberamo district need to synergize with various disciplines including the target of how the geology database. (First): the coordination, integration and communication of the Government of Mamberamo Raya district of Papua Province, (Second): Principal target of Metallic and Non- Metallic Resources Management, (Third): Mapping vulnerable zone of geological disasters, (Fourth): mapping ground water fluctuations, (Fifth): performing mapping of river characteristic, chemical properties and flow patterns of Mamberamo watershed.

4.8.3. General planning. (1) Government efforts to open roads, should be continued by prioritizing road openings, hardening connecting the districts to the villages that allow the passage of four-wheeled vehicles (2) plan a wider Airport from now, or look for a wider airport location alternative (3) availability of economic facilities for the community in utilizing river and estuary potentials.

4.8.4. Watershed management. The function of Mamberamo River for communities and government is as a source of livelihood of fisheries and transportation routes that connect the economy between villages, districts and other districts. Along with the development of uncontrolled land use in the upper river, it also disrupted the mechanism of river function and river hydrological behavior in Mamberamo watershed. Initially influenced by nature properties as a watershed system but gradually influenced also by humans. Therefore, a planned and integrated participatory watershed management should be undertaken in order to maintain and improve the continuity and quality of river water resources by maintaining upstream areas and their zones including: (1) plan to remove wood residual that embedded in Mamberamo river from Kasonaweja to downstream (2) plan to making dam along the riverbank in Kasonaweja - Burmeso to prevent erosion of river walls.

4.8.5. Agricultural planning. The planning of mapping program is an early step for realizing the characteristics of the land for the determination of the type of plant, mapping of agricultural land and its designation and establishing the type of mainstay.

4.8.6. Planning of estuary and coastal areas. Large coastal areas contain natural resources such as fisheries and mangrove forests to oil and gas so that guidance is required for the management of estuarine and coastal areas development. Several alternatives that can be conducted such as making industrial development centers, ports and shipping, tourism, agribusiness, human settlements and activities, both within the coastal and outer (upper land and high seas) systems. The development of tourism aspect is quite prospective and promising for example mangrove ecosystem tours in the form of views of various types of mangrove trees and biota supported by the thick atmosphere and Rombebai Lake tourism inhabited by various types of freshwater fish, endemic and marine biota.

4.8.7. Mineral resource management. The management of metallic and non-metallic mineral resources including rocks involves the local community which leads to the original income of the Mamberamo Raya district of Papua Province. Despite the enactment of Act No. 23 of 2014 regarding re-withdrawing decentralized mining management authority to the Central and Provincial Governments. However, it is necessary to review and involve the local community given the geographical conditions and hierarchy of land ownership.

5. Conclusions

The study concludes that (1) the application of geological-based regional development is fully undertaken (2) the provision of thematic maps containing technical information of a rock, soil, or land; information on the prevention and prevention of potential geological hazards (3) implementation of community-based mineral center development as an optimization step (4) availability of plain morphology as land that can grow agriculture and involve transmigration in developing area (5) necessary strong spatial development to geological disasters by arranging and mapping geomorphology of regional zoning according to zoning and constituent rocks (6) integrated-planning of coastal and estuarine areas requiring multi-disciplines and stakeholder integrity.

Acknowledgments

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