Enormous Mass Movements, and Gravitational Tectonics Model of the North Serayu Mountains, Karangkobar Area, Banjarnegara Regency, Central Java, Indonesia

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***Abstract*—North Serayu Mountains in the Central Java province, Indonesia, stretches with west - east axis, bordered by Slamet volcano to the Bogor Mountains in the west, and delimited by Ungaran volcano to the Kendeng Mountains in the east. In the north of these mountains there is coastal alluvial plain of Java, and in the south there is a depression zone of River Serayu. Overall geomorphostructures of the North Serayu Mountains form a faulted anticlinorium, which one of its flank relatively dipping to the south. In the bottom part of this ranges are such plastic, clastic, clayey sedimentary rocks, Eocene to Miocene aged. While at the upper portion there is a group of elastic, brittle, massive volcanic rocks, andesitic to basaltic composition, Pliocene to Pleistocene aged. A volcano, called Rogo Jembangan stands over the top of the North Serayu anticlinorium, with two of its eccentric cones, namely Mount Telagalele and Mount Pawinihan, situated in the Karangkobar District. North Serayu anticlinorium with a plastic bedrock, which is overlain by elastic, hard, and heavy rock has created such a tectonic model influenced by gravity. Parts of volcano's body and volcanic rocks blocks in the Banjarnegara Regency area generally move slowly but surely southward over a giant slip plane in the form of orographic fields. Locally, this gravitational tectonic is manifested as mass slides, glides, and creeps, occur any time in the study area. Orogenetics of the North Serayu Mountains is still on going in line with the active tectonism of the Java island, caused by subduction of Indian-Australian plate beneath the Eurasian plate. As long as that is the case, gravitational tectonic will continue to run, and mass movements in the research area will regenerate to happen.**

***Index Terms*—anticlinorium, gravitational tectonic, mass movement, North Serayu Mountains**

I. INTRODUCTION

Karangkobar and its surrounding area, Banjarnegara Regency, Central Java, are known as an area with unstable rocky conditions. It is located from 7 km to 30 km to the north of the Banjarnegara city, the capital city of the Banjarnegara regency. Astronomically it is situated at 109°40' - 109°45' East Longitude, and 7°15'- 7°20' South Latitude (Fig. 1). Rocks that exposed in almost every place of this region are a group of clay, marl, shale, silt, and sandstones with quite high carbonate content included in the Merawu formation, and a group of volcanic rocks. As it is known, the Merawu Formation has physical properties of impermeable, plastic, soft, and very sensitive to erosion, while the volcanic rocks behaves elastic, hard, and dense.

Due to this geological condition, Karangkobar and surrounding area is often subjected to relatively catastrophic rock mass movements in the form of landslides, subsidence, shifting, and creeping. In this region there are also several mountains or hills, which according to the results of previous geological researches, it is verified that the area really always disturbed by mass movements [1].

There are some mountains and/or hills in the Karangkobar area that very well known by local residents, namely Mount Telagalele (1291 m), Mount Pawinihan (1232 m), and Mount Lawe (about 700 m above sea level). Those mountains transfer slowly over the base rock, relatively to the south, toward the Banjarnegara Basin [2]. The travel of these mountains triggers the occurrence of smaller scale movements on their sides and/or slopes.

In the year 2006, a part of the foot slope of Mount Pawinihan collapsed and slided, burying many houses and killing 90 people in Sijeruk village. In the year 2012 landslide happened again on the southeast slope of Mount Pawinihan, and in 2014 landslide occurred at Jemblung village involving norteastern slope of Mount Telagalele, assassinating 108 people [3].

The occurences of mass movements in Karangkobar and its surroundings are not likely to cease this time, but will continue to happen. For this reason, it is necessary to study the characteristics of the geological dynamics and local tectonic of the area, so that it can be used as a reference for landslide disaster mitigation in the Karangkobar and surrounding areas.

Based on the rationales mentioned above, some, research in order to find out the characteristics, models, and force controlling mass movements in Karangkobar need to be done, with geological point of view.

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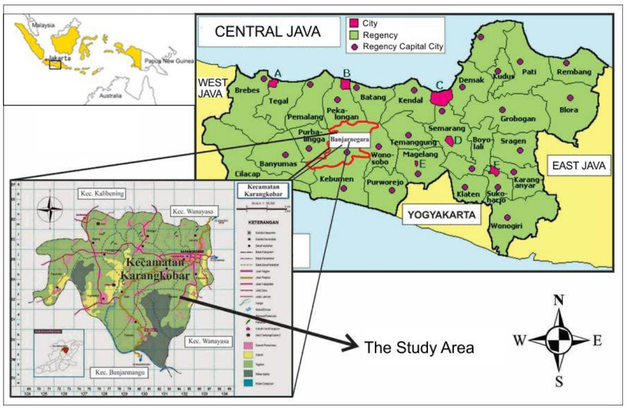


Figure 1. Location map of the study area.

II. Method of Study

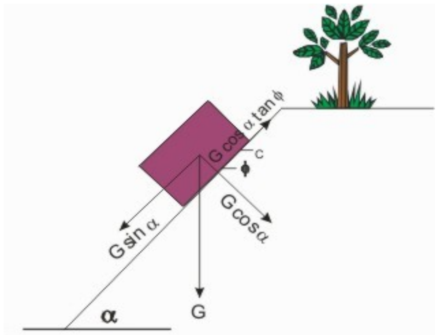
This research was conducted based on analytical methods using secondary as well as primary data from field surveys and mappings. Some aproaches applied in the study was topographic interpretation, remote sensing, surface geologic and geomorphologic mappings, petrologic analysis, rock/soil properties analysis, and geologic structure assessment. Data used for the analyses were derived from field surveys, mappings, and existing previous studies.The results are further discussed in this paper.

Survey and mapping were done to identify the variation of physical characteristics and distribution of the lithology. Geologic structure assessment and measurements were held for recording the strike and dip of bedding, folds, joints or fault planes. Survey and mapping were also used for identifying the morphology such as hills, ridges, and valleys. Topographic and image interpretation were utilized for identifying pattern and orientation of fracture system (joint, fractures, fault) also hills and valleys lineaments.

Petrological and petrographic analyzes were carried out to determine rock types [4], paleontological analysis was also carried out to decide rock geological age. Determination of rock age, especially in sedimentary rocks deposited in the marine environment, is based on plantonic foraminifer fossils (Blow, 1969) [5]. On the other hand, geological structures assessment was also done clopleeting this research by refering to the existence of field indicators such as lithological offset, fault plane, brecciation zone, milonitization, and morphological lineament or scarps [6], [7]

Related to rock and soil mass movements, it is ferivied that when there is a disturbance of force balance distribution in such a slope, mass movement will occur [8]. Force acting on a certain area is described as stress [8]. The distribution of stresses working on a slope can be illustrated as in Fig. 2.

In general, mass movements are able to be categorized into various types. The classification is based on the speed of movement, the presence or absence of slip plane, the character of slip plane, and the variety of involving materials. For example, if the speed of movement is rapid, there is a circular slip plane with rotational sliding, and the involving mass is soil, then it can be claasified into "slump" [10]. When the involving mass is hard or fresh rock, without any slip plane, then the mass movement is namely rockfall. Whereas if the velocity of mass transfer is slow, high water content, it usually in the form of flow, such as debris flow, soil flow, and mud flow (Fig. 3) [7].



G = Weight Force
α = Slope inclination
Φ = Friction Angle
c = Cohesion Force

Figure 2. Stress distribution acting on a slope [9].

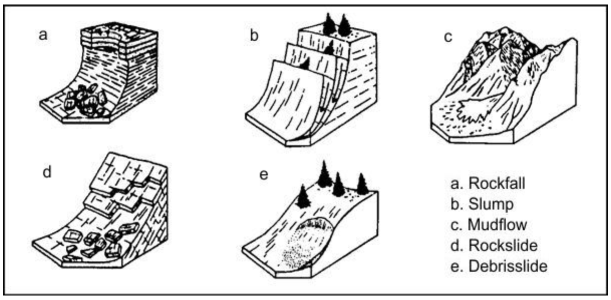


Figure 3. Types of mass movements [8], [11].

Classification of rock movement is totally difference from that of soil mass. Types of rock mass movement include planar slide, wedge, and topple (Fig. 4) [7]. Whatever the type of movement, stability of such a slope is quantitatively represented by its Factor of Safety (FS). Determining the factor of safety such a slope is based on the principle equation:

$$\text{FS (Factor of Safety)} = \frac{\sum \text{Resisting Force}}{\sum \text{Driving Force}} \quad (1)$$

Figure 4. Types of rock slope failures: (a) block gliding (planar sliding), (b) wedge, (c) toppling [8].

III. Results and Discussion

A. Geomorphology and Stratigraphy

The Karangkobar and surrounding areas are positioned in the physiographic zone of the North Serayu Anticlinorium [2], occupying elevation between 400 m, up to more than 1000 m above sea level. The highest point of the area occupies an elevation of 1291 m. The landscape in Karangkobar and its surroundings can be grouped into several geomorphological units, namely the Volcanic Hills morphology unit, the Undulating morphology unit, and the Homoclynal Mountains morphology unit.

The Volcanic Hills morphology unit occupies an altitude of 800 m - 1291 m, slope reaches 10^o – 30^o or about 18% to 58% (steep to very steep) with a height difference of 300 m to 500 m, generally built by volcanic rocks including breccia and lava. The Undulating morphology unit is situated at altitude of 405 m to 900 m, displaying slopes range from 2^o – 10^o or aproximately 5% to 20% with height difference between the lowest and the highest elevation of 10 m to 100 m. This area in general comprises soft clayey sedimentary rocks. In addition to volcanic hills and undulating morphology areas, there is also a Homoclynal Mountains morphology unit in the central and southern part of the study area. This morphology is characterized by slopes of 20^o – 70^o or more or less 36% to 275% (steep to extremely steep) with height difference varies 300 m to 900 m, compiled by Pleistocene aged of volcanic rocks.

Rocks that stratigraphically make up Karangkobar and its surrounding areas from the oldest to the youngest are Eocene deposits, Merawu Formation, Penyatan Formation, Bodas Formation, Ligung Formation, Jembangan Formation, and alluvial deposits, respectively (Fig. 5).

The oldest rocks in the study area are Eocene-aged deposits. These deposits consist of polymixed conglomerates with quartzite, igneous rocks, and schist fragments at the bottom part, and thick shale, marl, clay with sandstone intervals, and fossilized limestone insertions at the top part.

Unconformably overlaying the Eocene deposit, there is Merawu Formation. This formation consists of interlayering among claystone, marl, shale, and sandstone. This unit was deposited as a distal turbidite in the *middle fan environment to the outer fan*, at a depth of 300 to 1000 meters below the sea level (Batyal Zone). Its stratigraphic thickness reaches 2000 meters [2], while its geologic age is Early Miocene to Middle Miocene.

Above the Merawu Formation, there exists the Penyatan Formation, comprising volcanic deposits of marine environment, intersections between sandstones and breccia, with insertions of marl, agglomerates, and lava of basaltic and andesitic composition. The Penyatan Formation was deposited by gravitational flow mechanism in the *channeled supra fan* environment to the *depositional lobes on the supra fan* in the Batyal Zone, during the Middle Miocene to Late Miocene epoch. The Penyatan Formation and the formations below it were intruded by dioritic to diabasic dykes and sills.

The Bodas Formation shows unconformity relationship over the Penyatan Formation and other older rock units. This unit consists of limestone in the lower part, marl, limestone, and claystone in the upper part. The breccia and sandstone correlation to the limestone and claystone is different facies. The Bodas Formation was deposited in the *middle neritic* environment, and its geologic age is Pliocene, with 800 m thickness.

There is Ligung Formation that unconformably overlaying the Bodas Formation. It is composed of volcanic deposits from Mount Korakan [2]. The rock unit consists of andesite breccia with lignite insertions, 2 m thick, and there are also plant remains can be found. There is a cross - layering structure, indicating that the Ligung Formation sedimented in a fluvial environment. This formation is facies difference from the Jembangan Formation which is a volcanic deposit from Rogo Jembangan complex.

The Jembangan Formation consists of laharic breccia, pyroclastic breccia, agglomerates, and volcanic ash deposits. Their composition is generally andesite-basaltic, with an olivine content of 5% - 10%. The deposits are quite thick, reaching more than 500 meters. Some of the hills that built by this unit include Mount Telagalele (1291 m), and Mount Pawinihan (1232 m).

On the top of the stratigraphic column of Karamgkobar area is Alluvial deposits, generally occupy such plain area and/or river sides. The deposits consist of loose materials of various grain size including clay, silt, sand, cobble, pebble, and boulder. They are deposited in the Quaternary period, and unconformably overlaying all of the formations exposed in the research area (Fig. 5).

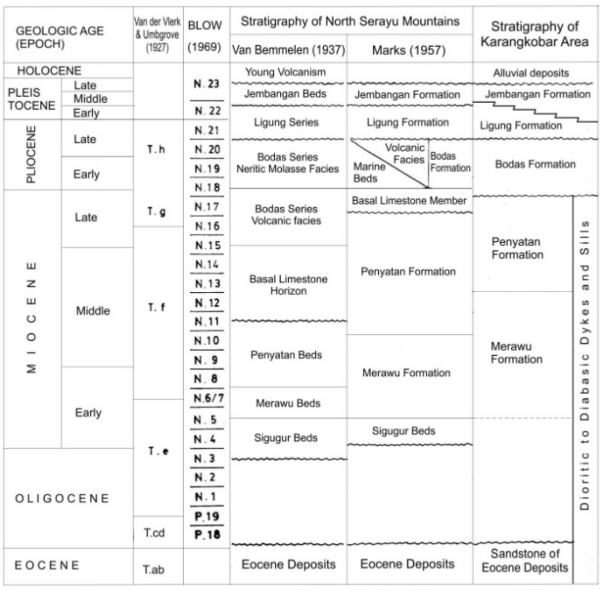


Figure 5. Stratigraphic correlation of the study area and North Serayu Mountains Zone.

B. Geologic Structures

The Karangkobar and its surrounding areas display a quite complex geological structure setting. Geological structures, such as joints, faults and folds are easy to be discovered in this area. Mountains which built by volcanic formations such as Mount Telagalele and Mount Pawinihan are chopped by normal step faults. The normal step faults of the two mountais generally show Northeast – Southwest strikes. On the other hand, some reverse faults are observed in locations that compiled by the Merawu Formation. One of the reverse faults is Kali Merawu Fault which striking Northwest – Southeast and then curvely turning to West – East direction. In spite of the existence of normal and reverse faults, there is also a lateral fault, namely Kaliurang Fault and Pagerpelah Fault. The Kaliurang Fault is Northeast – Southwest lining, besides cutting the diorite sill, it also interpreted as chopping the body of Mount Pawinihan. On the other hand, Pagerpelah fault is West – East strike, crosscuting the diorite sill in Paweden village. The two faults belongs to right lateral slip fault. The geologic structures involve all of the rock units in the study area, therefore the age can be pointed as post Pleistocene (Fig. 6), and the tectonic process is allegedly active until now.

Despite the presence of faults, microfolds are also obtained in Karangkobar area, for example that found in the sites of around Kaliurang and Merawu rivers. The folds are normally following and used to be one of the indicators for the occurence of a reverse fault.

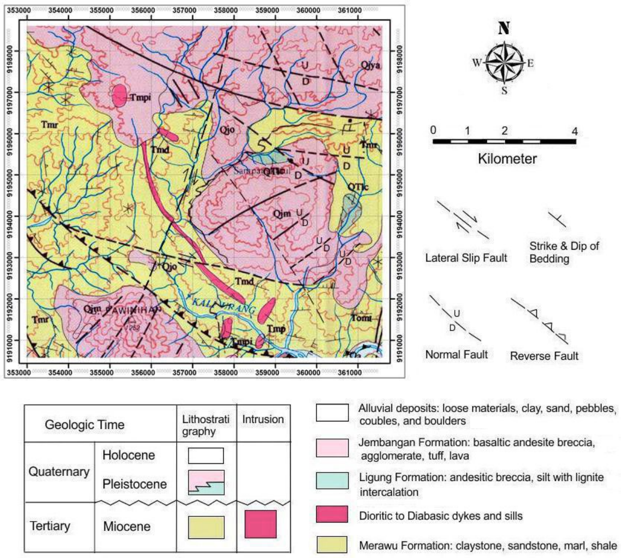


Figure 6. Geologic map of the Karangkobar area.

C. Geologic Hystory

The geological history of the Karangkobar and its surrounding areas began from Eocene epoch. At that time sandy-clayey deposits were formed in marine environment. The deposition process of marine environment took place until the Pliocene epoch, displayed by the establishment of Merawu Formation, Penyatan Formation, and Bodas Formation. During the period of Eocene to the Pliocene there are two sedimentary unconformity relationships, which exist between the Eocene deposits and the Merawu Formation, and between the Penyatan Formation and Bodas Formation. This condition convinces that the North Serayu Basin was tectonically unstable and experienced to several times of sea level changes. In Plio-pleistocene epoch the North Serayu Basin arose above sea level, marked by the occurrence of volcanism activities in fluvial environment.

The development of North Serayu Mountains was in line with the process of uplifting, starting about two million years ago [2]. Uplifting and folding (the process of orogenesis) produced an anticlinorium structure, with a West-East general fold axes direction. Then the glyptogenesis started to action up to now. This process includes erosion and denudation, bringing about the existing reliefs, in the shape of a relatively gently sloping plain. Then North Serayu Mountains transformed into a wavy landscape largely sloping to the south.

In the Pleistocene epoch, a volcanism actions occurred, producing breccia, agglomerate, and lava of Bodas, Ligung, and Jembangan formations. Therefore, over a weak zones of this pathway, the clayey dominated by Merawu Formation as the basement, such volcanic cones grew up, the biggest one is namely Rogo Jembangan (2177 m). These volcanoes develop on the upper part of North Serayu anticlinorium. Rogo Jembangan has several excentric cones, two of which are Mount Telagalele and Mount Pawinihan on the south wing of North Serayu anticlinorium [2].

D. Mass Movements Analyses

Various local mass movements occur in Karangkobar and surrounding areas almost every rainy season, and regional mass movements happen throughout the period [12]-[14]. Types of mass movements that involve Merawu Formation are soil avalanches, debris avalanches, soil creeps, and debris flows [13]. The specific movement type is translational sliding through discontinuity planes such as bedding and joint. While types of mass movement commonly involving volcanic rocks are landslides, debris slide, and complex. Landslides usually occur in soil with a thickness of more than 5 m. Some times not only part, of the land or rocks that move, but also in some places, even a body of hill moves above the sliding plane of Merawu Formation [13].

Usually, extreme rainfall have triggered landslides in the Karangkobar and surrounding areas. Before the landslide in Jemblung hamlet, the daily rainfall reached above 100 mm. According to information from local residents, heavy rains have occurred from Wednesday to Friday (December 10-12, 2014) respectively [12], [13], [15], [16].

Based on data and inform ation related to natural conditions of the study area, derived from field surveying, it can be concluded that there are three main factors influencing the occurrence of landslides, namely [12], [13], [15], [16]:

- Heavy / extreme rain for 3 consecutive days with daily rainfall > 100 mm.
- Morphology at the source of the formation of landslides has a steep slope (>25^o or > 55%).
- Weathered volcanic breccia rocks that form very weathered weathered soils (more than 5 meters), have very high water absorbing properties so they are easily saturated and create slope instability.

The natural conditions of landslide sites are as follows:

- The site is in an overdraft with steep to very steep slope. In such conditions some hamlets or villages are located in areas prone to landslides.
- The dimensions of the landslide commonly have a width ranges 10 m - 35 m, height varies 15 m - 20 m, and slope reaches 20^o – 70^o (36% - 275%).

- The slopes are composed by volcanic breccia of the Jembangan Formation, has been weathered, forming thick soil (> 5 m)
- The sites are generally located in the fault zones, fault lines, or close to the fault lines.
- Rotational and translational are the dominant types of landslides that involving weathered volcanic rocks.

Thus it turns out that the geological conditions, such as slope, lithology, and geological structures, namely bedding plane, joints, and faults, are very influential on the occurrence of landslides. The majority of landslide locations were in the faults zone and the alignments zone.

The following is the result of analysis on the occurrence of some landslides in the Karangkobar and surrounding areas (Table I). Locations of landslides being assessed are Paweden, Slatri, Gintung, and Jemblung villages (Fig. 7).

TABLE I. TYPES OF MASS MOVEMENTS IN KARANGKOBAR AND SURROUNDING AREAS [15] (REVISED)

No	Location (Village)	Coordinate X,Y (UTM)	Material being involved	Type of Movement
1	Paweden	356949, 9192436	Soil and Debris of volcanic rock	Complex (combination of rotational, translational, slide, and flow)
2	Jemblung, Sampang	358965, 9194599	Soil and Debris of volcanic rock	Complex (combination of rotational, translational, slide, and flow)
3	Paweden	359285, 9194674	Soil and Debris of volcanic rock	Creep
4	Paweden	358399, 9192565	Soil of volcanic rock	Rotational Slide
5	Slatri	357424, 9193507	Soil of volcanic rock	Creep
6	Gintung, Binangun	357431, 9197637	Soil and Debris of volcanic rock	Rotational Slide

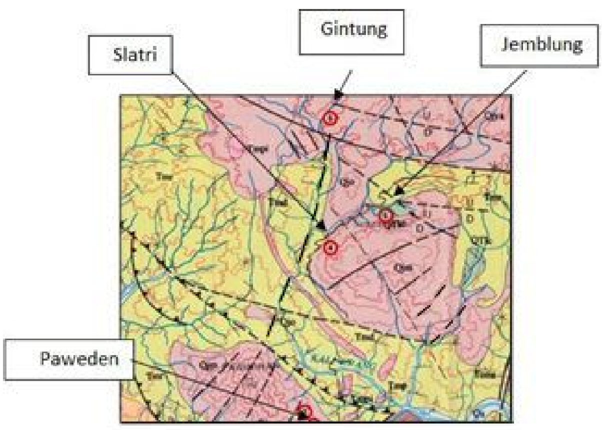


Figure 7. Locations of mass movements being analysed.

The following is a complete description of three (3) landslide occurrences in Karangkobar area, which claimed as the most victims and losses disasters:

1) Jemblung landslide

This landslide hapenned in 2014, on apart of Mount Telagalele body. The topography mostly shows bumpy sloping that is around 45^{o} -50^{o}. The composing lithology is volcanic breccia of the Jembangan Formation, weathered, forming quite thick soil (> 5m). The geological structure found at that location is a fault. Allegedly landslide area is a fault zone. Type of movement include rotational slides [14], (Fig. 8). But based on lastly field assessment, it is identified that the type of landslide is a combination of rotational and translational, which then develops into flow, therefore it belongs to complex movement (Fig. 8 and Fig. 9).

Figure 8. Landslide on the southwestern slope of Mount Telagalele at Jemblung Village, 12th December 2014 (www.liputan6.com/news/read/2147024/).

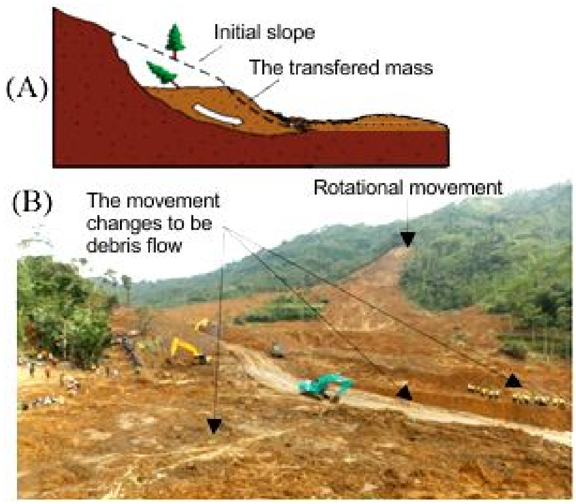


Figure 9. Analysis on Jemblung mass movement [15], modified.

2) Sijeruk landslide

The landslide occurred in 2006, situated is on the side of a road and a residential area. There was steep slope conditions with an inclination of about 45^{o}-60^{o}. Lithology of the site is in the form of layered tuffaceous sandstone, tuff and volcanic breccias of the Jembangan Formation in weathered conditions. Movement type is a complex type, including combination of rotation, translation, and flow (Fig. 10), [18] (http://www.tzuchi.or.id/read-berita/tzu-chi-bergerak-ke-sijeruk-lokasi-longsor/538).

Figure 10. Landslide on the slope of Mt. Pawinihan at Sijeruk, Paweden Village, 6th January 2006 [19] (http://www.kompasiana.com/cariefswomba/54f9264ea333115f378b4cbf).

3) Gintung landslide

The mass movement in Gintung village happened in 2014, displayed a dimension of 55 m wide by 40 m high (Figure 11). The slope inclination is 60°. The involving material is in the form of sandy soil. When the landslide happened, materials passing through a river with a width of 10 meters. The dimension of the landslide material that passes the river is 45 meters wide and about 75 cm thick, the volume of the landslide is around 5,000 m^3. When observing the field, small landslides still take place. The landslide can be classified into translational [14] with the boundary beetwen fresh rock and the soil act as the sliding plane.

Figure 11. Mass movement in Gintung Village, translational [15].

E. Gravitational Tectonics

Earthcrush dynamics that manifested in various surface processes, influenced by gravity, is categorized as gravitational tectonics [17]. In the North Serayu Mountains, especially Karangkobar and surrounding areas, this phenomenon occurs and can be observed. The study area occupies the southern wing of North Serayu Mountains. In this region, the orographic field stretches sloping to the south, towards Serayu River in the Banjarnegara Basin, with a general slope inclines ranging 2^o – 10^o or 5% to 20% (gently to moderately incline).

Although it is not an active tectonic region, Karangkobar and its surrounding areas can be categorized to be an area with unstable local tectonics. The tectonic symptoms are known as gravitational tectogenesis [2], [17], expressing in the form of mass movements that occur as the influence of gravity or gravitational force. This symptom is also often called gliding tectonics. The volcanic hills of Karangkobar move at an average speed of 24 cm to 40 cm per year [2].

The Rogo Jembangan complex produces deposits of volcanic rock called the Jembangan Formation. Unlike the physical properties of the Merawu Formation, the Jembangan Formation is a group of hard, rigid, massive, and heavy rocks. Because the Jembangan Formation is quite thick. The Merawu Formation which acts as a basement is unable to withstand the load of the Jembangan Formation. Supported by the presence of an orographic field tilted to the south, there are symptoms of displacement as discussed above. Manifestations of tectonic symptoms include displacement, subsidence, and rock mass creeps including Mount Telagalele, Mount Pawinihan, and Lumbung Hill.

In the study area the occurrence of rock mass movement capable to involve very large masses. As happened to the body of Mount Telagalele and Mount Pawinihan. The two mountains are subjected to step faulting and creeping with a slip plane in the form of a stratigraphic boundary between the Jembangan and Merawu formation, as illustrated below (Fig. 12 and Fig. 13).

Figure 12. Step faulting and sliding of Mt. Telagalele. Volcanic body that overstands on predominantly clay composing formation.

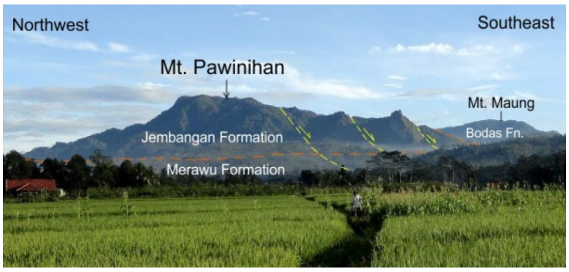


Figure 13. Step faulting and sliding of Mt Pawinihan. Volcanic body that overstands on predominantly clay composing formation.

Besides apart of its body experienced a collapse, Mount Telagalele is also creeping over the Merawu Formation. The collapse of Mount Telagalele body is pressumed to trigger reactivation of Pagerpelah fault and Kali Merawu fault. Such a similar process hapens on Mount Pawinihan. Apart of its body is step faulted down while crawling. Whereas another volcanic body namely Lumbung hill, which is much smaller compared to the previous two mountains, only experienced to creeping.

All movements of the hills are lead to the depression of Serayu River in the Southeast and Southern of the study area.

Refering to the entire discussion mentioned in the previous chapters, it can be established a model of mass movement found in the North Serayu Mountains in general, and Karangkobar in particular as shown in Fig. 14.

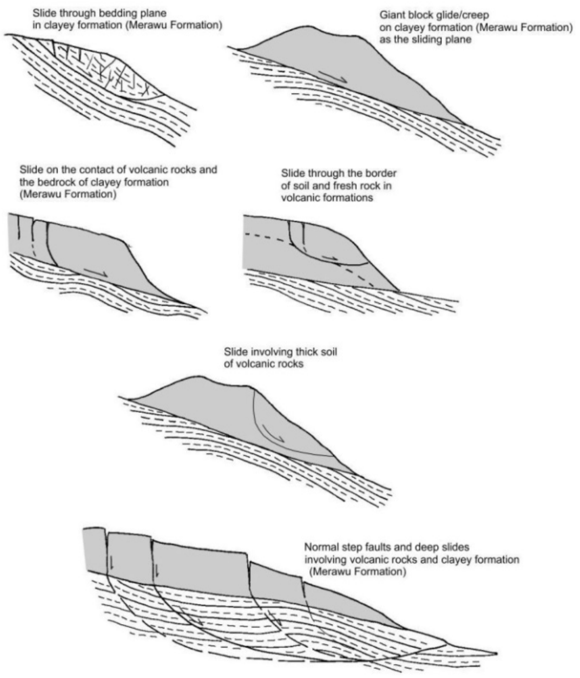


Figure 14. Model of mass movements in Karangkobar Region [1], [14] revised, reactualized.

IV. CONCLUSIONS

Based on the dicussions writen above, it can be concluded as follows:

1) The Karangkobar region and its surrounding areas are stratigraphically from the oldest to the youngest comprises Eocene sediments consisting of conglomerates, clayey sandstone, and shale, Merawu Formation of Middle Miocene to Upper Miocene, Penyatan Formation of Upper Miocene, Bodas Formation of Pliocene, Ligung Formation of Pleistocene, Jembangan Formation of upper Plestocene, and alluvial deposits that are Holocene in geological age.
2) The geological structures that develop in this area are normal step faults of Northeast-Southwest strikes, reverse faults of Northwest-Southeast lines, right lateral slip faults of relatively West-East lineament, and microfolds with Northwest-Southeast general axes.
3) Mass movements discovered in Karangkobar and surrounding areas in general can be modelled as slide on discontinuities (bedding and joint planes), giant block glide/creep, slide on the contack of volcanic rock and the bedrock, slide through the boundary of soil and fresh rock, thick volcanic soil sliding, and step faulting and deep slide.
4) Symptoms of gravitational tectonics in the Karangkobar and surrounding areas are characterized by the frequent occurrence of rock mass movements. Factors affecting tectonics include topographical conditions that show a very big gap, from gently sloping to extreemly steep (2^o -70^o or 5%-275%), stratigraphic position of heavy, hard, and brittle rocks over soft rocks (clay), and the number of fracture structures (joints and faults).

CONFLICT OF INTEREST

This research was conducted without a conflict of interest with anyone, both individuals and institutions.

AUTHOR CONTRIBUTIONS

In this research and publication, the first author plays the role as the team coordinator, contributing in engineering geology, rock mechanics, and hydrogeological fields. On the other hand, the second author provides a role as structural and tectonic geologist, supporting this study by his expertise. All the authors had approved the final version.

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REFERENCES

[1] S. B. Kusumayudha and S. Koesnaryo, "Landslide fenomenon of central java – DIY from engineering geological point of view: Social-cultural mitigation is required," *Buletin Teknologi Mineral*, 2001.

[2] R. W. V. Bemmelen, *The Geology of Indonesia*, The Hague, 1949, p. 761.

[3] Wikipedia Indonesia. (2014). [Online]. Available: https://en.wikipedia.org/wiki/Indonesia

[4] H. Williams, F. J. Turner, and M. Gilbert, *Petrography*, San Francisco: W. H. Freeman & Co, 1974.

[5] W. H. Blow, "Late middle miocene to recent planktonic foraminiferal biostratigraphy," in *Proc. First International Conference on Planktonic Microfossil*, Geneva, 1967, vol. 1, pp. 119-442.

[6] M. T. Billings, *Structural Geology*, New Delhi: Prentice Hall of India, 1979.

[7] M. L. Hill, *Fault Tectonics*, California: Atlantic Richfield Co, 1976.

[8] E. Hoek and J. W. Bray, *Rock Slope Engineering*, 3rd ed., London: The Institution of Mining and Metallurgy, 1981.

[9] B. N. K. Citrabhuwana, S. B. Kusumayudha, and Purwanto, "Geology and slope stability 27 analysis using markland method on road segment of Piyungan-Patuk, Sleman 28 and Gunungkidul Regencies, Yogyakarta Special Region, Indonesia," *International Journal of Economic and Environmental Geology,* vol. 7, no. 1, 2016.

[10] W. K. Hamblin and E. H. Christiansen, *Earth Dynamic Systems,* 10th ed., Prentice Hall, 2003.

[11] T. S. Dewi, S. B. Kusumayudha, and H. S. Purwanto, "Landslide vulnerability zonation based on GIS analysis: Case study Bagelen

District, Purworejo Regency, Central Java," *Jurnal Mineral Energi dan Lingkungan*, vol. 1, no. 1, pp. 50-59, 2017.

[12] Hutomo and I. A. Maryono, "Prediction model of landslide in Karangkobar District," *Jurnal Pembangunan Wilayah Dan Kota*, vol. 12, no. 3, pp. 303-314, September 2016.

[13] B. Geologi, *Report on Mass Movement Investigation of Karangkobar District, Banjarnegara Regency, Central Java*, Kementrian Energi dan Sumberdaya Mineral, 2018.

[14] S. B. Kusumayudha, "Geomechanical characteristic of landslides in central java and DIY," *Buku Sumberdaya Geologi DIY dan Jawa Tengah*, 2002.

[15] R. Hidayat, "Engineering geological condition of the landslide vulnerable area of Karangkobar, Banjarnegara Regency," in *Proc. Seminar Nasional Teknik Sipil*, Universitas Muhammad Diah Surakarta, 2018.

[16] H. S. Naryanto, "Analysis on landslide disaster of Jemblung Village 12 December 2014, Karangkobar District, Banjarnegara Regency, Central Java," *Jurnal Alami*, vol. 1, no. 1, 2017.

[17] K. A. D. Jong, *Gravity and Tectonics*, John Wiley 7 Sons Inc, 1973, p. 502.

[18] Tzu Chi Bergerak ke Sijeruk, Lokasi Longsor. (2016). [Online]. Available: http://www.tzuchi.or.id/read-berita/tzu-chi-bergerak-ke-sijeruk-lokasi-longsor/538

[19] Beyond Blogging. [Online]. Available: http://www.kompasiana.com/cariefswomba/54f9264ea333115f378b4cbf

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