Conference Paper

Tectonic Relationships and Structural Development between Arjosari, Pacitan, East Java and Tawangmangu, Karanganyar, Central Java

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Abstract

Java Island has volcanic arcs at the south and at the middle which are spread in a east-west pattern called Southern Mountains Zone and Quaternary Mountains Zone. The east-west pattern resembles the structural pattern produced by the Java tectonic subduction. Based on this, research was carried out to determine tectonic relationships and structural development in the Southern Mountains Zone and the Quaternary Mountains Zone. The study was conducted by structural mapping of each zone, namely the Grendulu Fault in Pacitan Regency which belongs to Southern Mountain Zone and the Cemorosewu Fault in Karanganyar Regency which belongs to Quaternary Mountains Zone. The mapping shows that the Grendulu Fault is a horizontal fault with north-south main stress, while the Cemorosewu Fault is a normal fault with nearly vertical main stress. Based on these, it can be concluded that there is no direct, but indirect tectonic relationship that works between the two: both structures developed due to Java Subduction. The structural development of the Grendulu Fault is strongly influenced by Java Subduction, which the subduction gives north-south main stress that forms this fault. While Southern Mountains formed, Kendeng Basin was formed due to loading from the mass of Southern Mountains. The formation of Kendeng Basin was continued with the formation of the Mount Lawu Complex (part of Quarternary Mountains) where the Cemorosewu Fault developed. This fault is formed as a result of mass loading of the Mount Lawu itself and triggered by the slope from Kendeng Basin to the north.

Keywords: grendulu fault, cemorosewu fault, tectonic relation, and the eastern part of java.

1. Introduction

Java Island, particularly the edge of the border between Central and East Java, is an area which has a unique geological structure. That is the change of the trend subduction zone in Cretaceous, from NE-SW to be E-W [1]. As consequence of the subduction, volcanoes are distributed along the length of the island [2]. The tectonic regime of Java with E-W trending still works on these days pushing Java Island to the north, so, there is a possibility of affecting the structure formed in both volcanic areas, Southern Mountains Zone and the Quaternary Mountains Zone.This system can be seen between the forming of geological structures in Mt. Lawu, which is north of Pacitan.

The geological structure that developed in Pacitan (Southern Mountains Zone) was dominated by the strike-slip fault, while in Karanganyar (Quaternary Mountains Zone) was dominated by the normal fault [3]. On the other hand, there are still fewer studies about the effect of tectonism in the Southern Mountains Zone toward the Quaternary Mountains Zone. As consequence, it is still unknown whether the stress that works in the Southern Mountain Zone also influences the development of geological structures in the Quaternary Mountains Zone. Based on the explanation, this study aimed to find out the correlation between these two zones. There are two faults as samples, Grendulu Fault in Arjosari, Pacitan, and Cemorosewu Fault in Tawangmangu, Karanganyar. Both locations were chosen because they are near and each one represented the Southern Mountains or the Quaternary Mountains Zone.

2. Scope of the Study

This research focused on the development of geological structures in Pacitan and Karanganyar Regency. It also discussed how the tectonic correlation occurred between these two areas.

3. Methodology

The study was conducted using geological structure mapping method. Its stages consist of literature reviews, preparation before field observation, reconnaissance, field data collection, data analysis, and report.

Equipment and materials used in this research are field equipment as in general. They are divided into two categories, primary and conditional. Furthermore, the list of equipment and materials is in

4. Results and Discussion

This study used primary data, which were the Grendulu Fault in Pacitan, and the Cemorosewu Fault in Karanganyar. Moreover, other features used for the geological structure analysis comprised of joint and shear fractures, fault plane, and striations.

TABLE 1: List of field equipment and materials.

Primary	Conditional
Fieldwork Suit	Chisel
Safety-shoes	Brush
Clothes	Webbing
Map	Scout Rope
Brunton Compass	Raffia String
Chisel-Tip Hammer	Penknife
Pointed-Tip Hammer	Lighting Tool
Sample Bags	Candle
Hand Lens	Scissors
Field Notebook	Matches
Stationery	Flysheet
Plastic Board	Whistle
Global Positioning System	Tent
Pocket camera	Coat
Hat	Cutlery
Raincoat	Laptop
First Aid Kit	Games
Watch	
Helmet	

4.1. Grendulu Fault in Pacitan

There are 18 stop sites distributed along the Grendulu Fault. Lithology around the fault was included in Mandalika and Arjosari Formation. For instance, there was andesite-porphyry (Mandalika Formation) which spread in the east of observation area, while the tuff-sandstone (Arjosari Formation) spread from the middle to the west (Figure 1).

Based on the analysis, Grendulu Fault in Pacitan is a NE-SW reverse-left-slip fault in Rickard kinematic fault classification (1972). Figure 2 showed that Grendulu Fault had a dominant left lateral motion which had moved vertically upward. It was interpreted as a result of the main stress from south to north with the trend of N350^{0}E and plunge of 10^0. The stress was approximately from the tectonic regime of Java subduction, which located in the south of Java. Furthermore, this fault has a dip to the south so that relatively uplifted-rock blocks were blocks in the south of the fault plane.

Because it is the Reverse-left-slip fault, the shifting was dominantly left horizontal, and the uplifting was relatively small with the pitch of 12^0. Therefore, based on Rickard kinematic fault classification, the vertical shifting did not need to be described. This

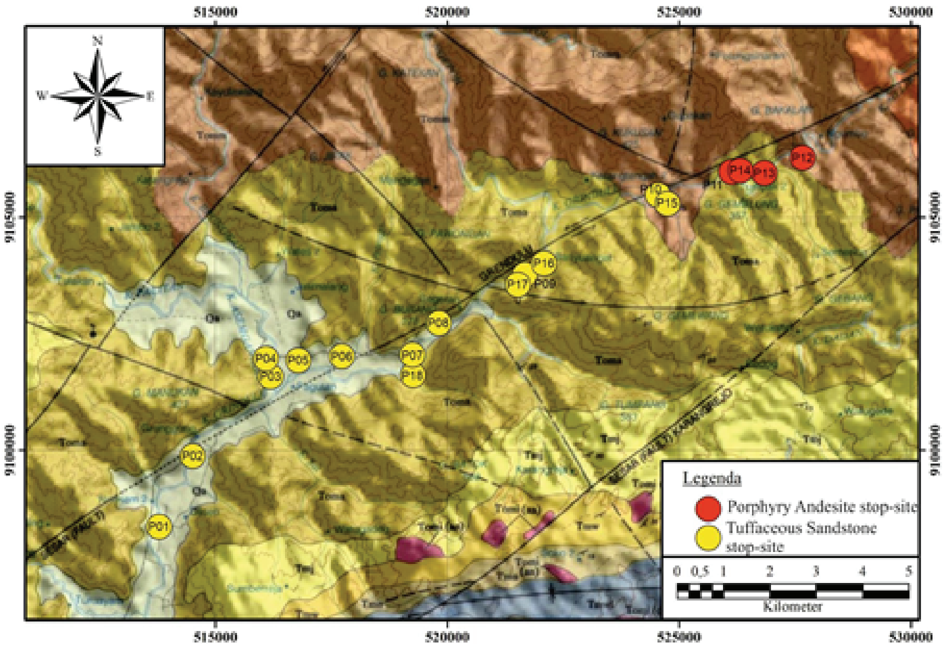
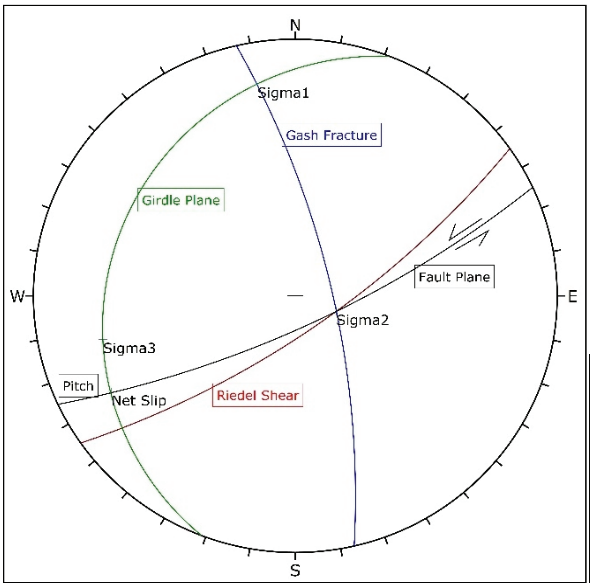


Figure 1: Plotted-stop sites in Grendulu Fault, Pacitan.

fault is from the stress in Middle Miocene and reactivated at Arjosari and Mandalika Formation due to the present stress that is still working [4].



Analysis Result (Plunge, Trend)			
Sigma1	Sigma2	Sigma3	Net Slip
Fault Analysis			
10, 350	71, 111	16, 257	13, 242
Pitch		12	
Anderson (1951)		Slip Fault	
Rickard (1972)		Reverse Left Slip Fault	

Figure 2: Stereographic analysis of Grendulu Fault.

From all of 18 stop sites along the Grendulu river in Pacitan, the result of the geological structure analysis is various. However, there are only 3 faults data that are capable enough to be analyzed. The shifting of all minor faults is left horizontal (sinistral). Nevertheless, there is a stopsite which moved vertically and interpreted as a reverse fault (Stopsite P18), a normal fault (Stopsite P15), and a stopsite which relatively has no vertical move (Stopsite P12) (Figure 3).

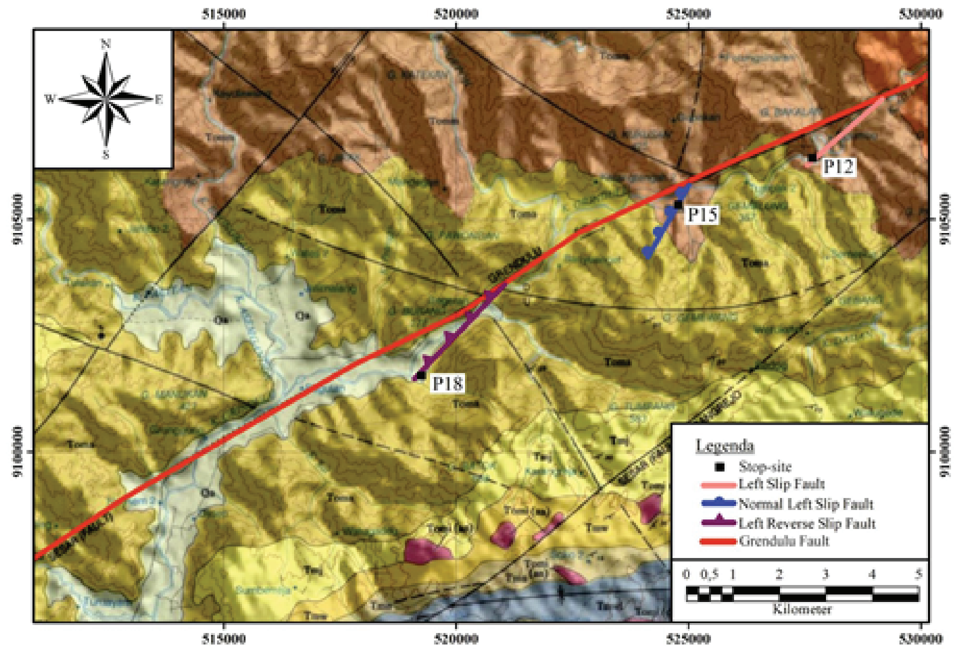


Figure 3: The distribution of small faults as additional structures of Grendulu Fault (modified from [8]).

Fractures will grow with the fault plane by showing the shifting from its fault plane. Based on Petit analogical model (1987), they consist of shear fracture (P), extension fracture (T), and riddle shear (R'). In a major fault, a micro-fault which is a fracture but has a shift will be formed. Names of these micro-faults depend on their orientation and kinematics on fault shifts (Figure 4). The difference in 3 types of faults as minor faults in the Grendulu Fault zone showed the fit shift dynamics with the fracture kinematic criteria.

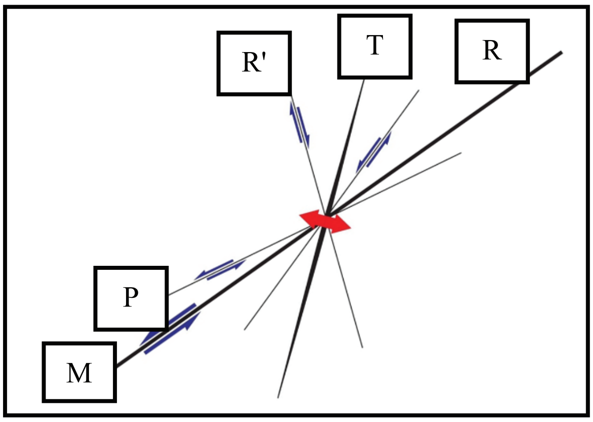


Figure 4: Kinematic criteria of fractures around the fault plane (M) = fault surface (P) = shear fracture; (T) = extension fracture; (R) dan (R') = riedel shear [6].

4.2. Cemorosewu Fault in Karanganyar

There are 17 stopsites regarding the Cemorosewu Fault in Karanganyar. Overall, the lithology is the igneous rock from Lawu Volcanic Rock Formation, Breccia Jobolarangan Formation, and Lava Sidoramping Formation. Rocks distribution in one formation is irregular because of the many of interbedded rocks. Therefore, the lithology was getting from the most dominant lithology in the area. As a result, it was andesite lava from the Lawu Volcanic Rock Formation and Breccia Jobolarangan Formation in the east to the middle of the area (Figure 5).

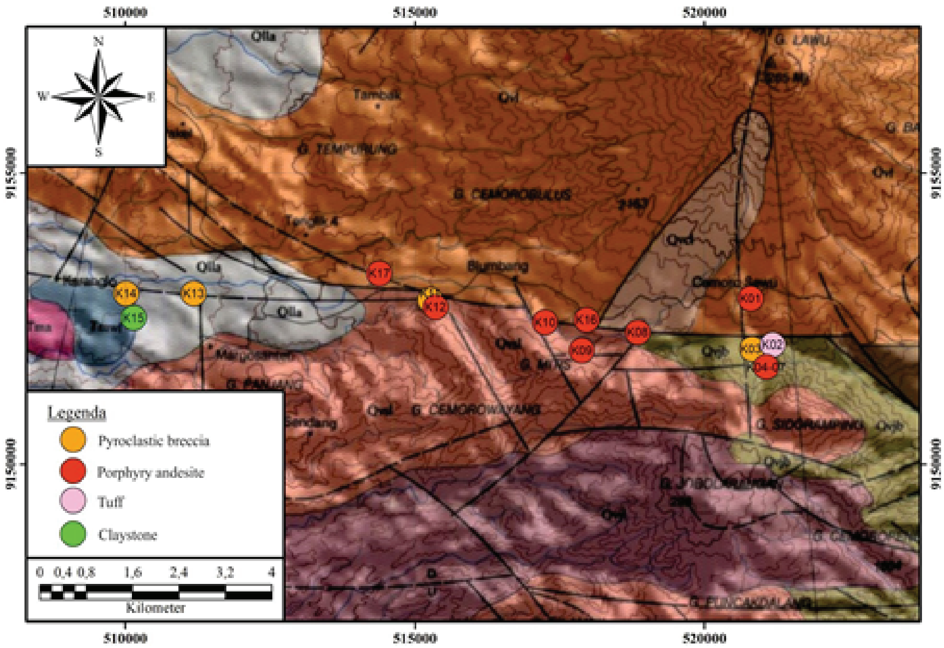
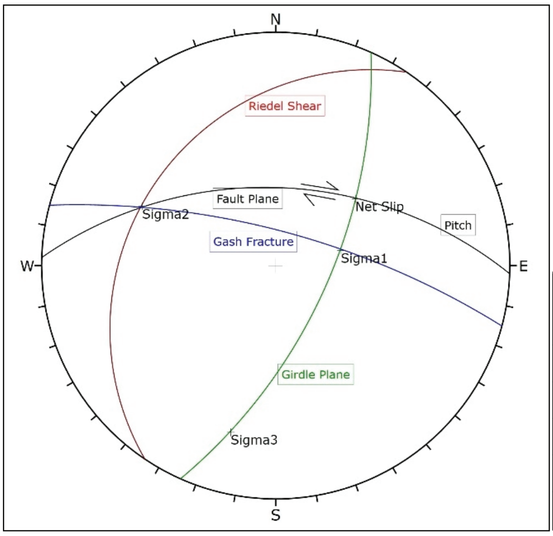


Figure 5: Plotted-stop sites in Cemorosewu Fault, Karanganyar (modified from Sampurno et.al., 1997).

Based on the analysis, Cemorosewu Fault in Karanganyar is an E-W right-normal-slip fault in Rickard kinematic fault classification (1972). It is interpreted at the beginning of Pleistocene, there was an activity of Jobolarangan Mountain or Old Lawu Mountain and followed by the collapse of the volcano's northern slope along the Cemorosewu Fault in about Middle Pleistocene. As a result, the next magmatism activity formed the Young Lawu Cone in the main periphery of the fault [3].

The stereographic analysis (Figure 6) showed that Cemorosewu Fault is a dominant vertical downward and relative right-horizontal slip fault with the trend of N77^{0}E and the plunge of 58^{0}. The main stress was approximately a result of the loading force of Old Lawu Mountain. Meanwhile, material from Young Lawu Mountain, which continues volcanic activity after the forming of Cemorosewu Fault, has completely covered the Old Lawu Mountain. Old Lawu Mountain has the same age as Sidoramping Mountain and Jobolarangan Mountain. The north shifting to the north was also caused by the existence of the Paleogene flexural basin as a basement which began to concave on the slopes of Old Lawu Mountain.



Analysis Result (Plunge, Trend)			
Sigma1	Sigma2	Sigma3	Net Slip
Fault Analysis			
58, 77	26, 294	17, 195	42, 50
Pitch		44	
Anderson (1951)		Normal Fault	
Rickard (1972)		Right Normal Slip Fault	

Figure 6: Stereographic analysis of Cemorosewu Fault.

From all of 18 stop sites along the Cemorosewu Fault Zone in Karanganyar, the result of the geological structure analysis is various. However, there are only 6 stopsites faults data that are capable enough to be analyzed. The shifting direction of the fault structure is very diverse; the normal fault formed in Stopsite K01, K12, and K17, the reverse fault in Stopsite K02 and K08, while the strike-slip fault in K15 (Figure 7).

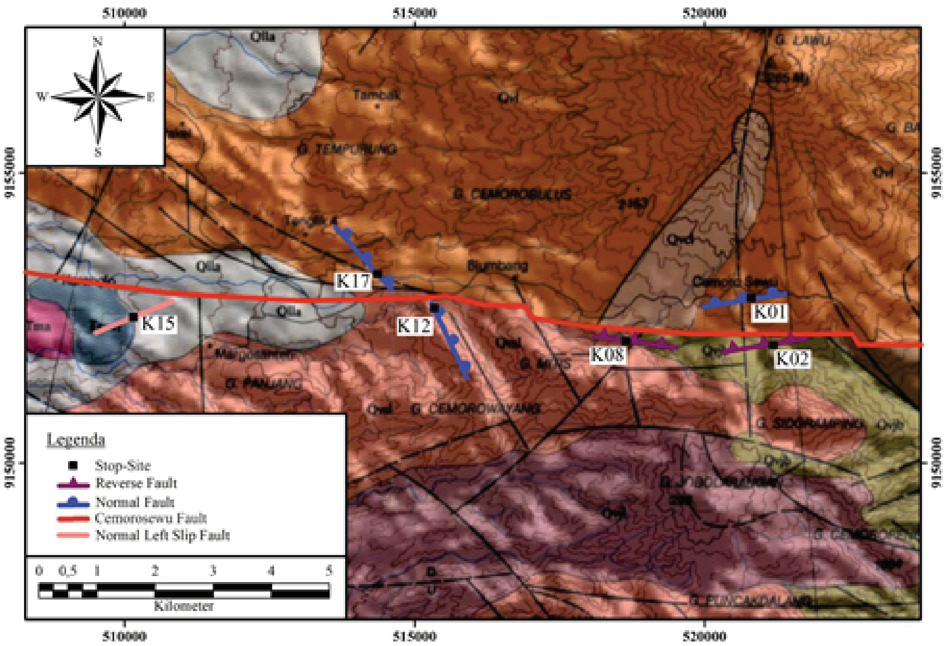


Figure 7: The distribution of small faults as additional structures of Cemorosewu Fault (modified from [3]).

It is quite difficult to find out the exact number of the age of those faults, but most likely are about Quartenary. Only the Cemorosewu Fault itself was estimated to be in the middle of the Pleistocene [3] and others were unknown. As a conclusion, the minor faults were formed after the Middle Pleistocene and interpretively generated by the vertical stress of the loading force of Young Lawu Mountain. The existence of the reverse fault was a result of horizontal strikes which restrained by Jobolarangan Mountain.

4.3. Tectonic Correlation of Geological Structure in Pacitan and Karanganyar

The tectonic correlation between these two areas, Pacitan and Karanganyar, is that both are affected by the tectonic regime of Java subduction. The process started from the forming of the Southern Mountains Zone, which pushed the construction of the Kendeng Basin. In addition, the geological events of these studies simply explained as follows:

1. The Southern Mountains was formed in Oligocene, and it affected the forming of the flexural basin of Kendeng Basin [7];
2. Then, the tectonic deformation in Miocene set up the Grendulu Fault in Pacitan, the reverse-left-slip-fault which has a northeast-southwest trend and was reactivated on Plio-Pleistocene tectonism phase;
3. Tectonic deformation in south Pacitan generated the north-trending geological structure features that spread out to Karanganyar;
4. The next was Pleistocene tectonism phase which formed the Old Lawu Complex in Karanganyar (Old Lawu Mountain, Sidoramping Mountain, and Jobolarangan Mountain);
5. Finally, Cemorosewu Fault, the west-east trending normal fault, was constructed by the vertical stress of Lawu Mountain compressional force and by the Kendeng Basin basement configuration just like what happened at Arjuno Mountain [8].

5. Conclusion

In conclusion, there are some points about the correlation of tectonic deformation in Pacitan and Karanganyar as follows:

1. Grendulu Fault is a strike-slip fault with dominant left lateral shifting which has moved vertical upward (known as reverse left slip fault), while, Cemorosewu Fault is a fault with dominantly vertical downward and relatively right-lateral slip (known as right normal slip fault).

2. Grendulu Fault is a strike-slip fault in which the principal stress is 200, N3530E, and the micro-fault has developed as riddle and tension shear. Meanwhile, Cemorosewu Fault is a normal fault in which the principal stress is 530, N810E. and has other faults that associated with compressional forces of Lawu Mountain.

3. There is no direct, but indirect tectonic relationship that works between the Grendulu Fault and Cemorosewu Fault: both structures developed due to Java Subduction. According to the geological time scale, Grendulu Fault was active in Miocene and reactivated in Plio-Pleistocene tectonism phase, as an effect of compressional stress of Java subduction. At the same time, the vertical stress from Mount Lawu loading forces and the basement configuration from the flexural loading caused the forming of Old Lawu Complex, then followed by Cemoworsewu fault deformation.

References

[1] Sribudiyani, N. M., Ryacudu, R., Kunto, T., et al. (2003). The collision of the East Java Microplate and its implication for hydrocarbon occurrences in the East Java Basin. In *Indonesian Petroleum Association 29th Annual Convention Proceedings*.

[2] Samodra H. and Sampurno. (1997). *Peta Geologi Lembar Ponorogo, Jawa*. Bandung: Pusat Penelitian dan Pengembangan Geologi.

[3] Petit, J. P. (1987). Criteria for the Sense of Movement on Fault Surfaces in Brittle Rocks. *Journal of Structural Geology,* vol 97. no. 5-6, pp. 597-608.

[4] Samodra, H. Gafoer, S. and Tjorkosapoetro, S. (1992). *Peta Geologi Lembar Pacitan, Jawa.* Bandung: Pusat Penelitian dan Pengembangan Geologi.

[5] Rickard, (1972). *Classification of Translation Fault Slip,* 2545-2546. New York: Geology Society of America.

[6] Anderson, E. M. (1951). *The Dynamics of Faulting and Dyke Formation with Applicants to Britain*. Edinburgh: Oliver and Boyd.

[7] Romario, I. F. B., Mindasari, D., Suprapto, R. E., et al. (2015). Oligo-Miocene Tectonic of Java and The Implication for Flexural Basin of Southern Mountain in Affecting Depositional System in Kerek Formation. *Proceedings Joint Convention Balikpapan 2015 HAGI-IAGI-IAFMI-IATMI.*

[8] Van Bemmelen, R. W. (1949). *The Geology of Indonesia Vol. IA General Geology of Indonesia and Adjacent Archipelagoes*. Den Haag: Government Printing Office Hague