Fabric study in metamorphic rocks in Karangsambung, Kebumen, Central Java

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Abstract. Process of deFormation has an effect on both dynamic and regional metamorphic rocks. Metamorphic rock of Manunggal Formation can be found as large outcrops in Karangsambung, Central Java. In this research, we did geological mapping in the Manunggal Formation outcrop area and took rock samples. The rock samples are then analysis macroscopically to determine their metamorphic facies. From our study, we are able to identify the various degrees of metamorphism within the study area. This variation are concluded from the detailed macroscopic of mineral composition and rock texture of the rock samples from Manunggal Formation. The metamorphism process in rocks produced foliation textures on metamorphic rocks that are either foliated like phyllite and schist, or non-foliated such as green rock, serpentinite, and hornfels. All of this variation are plotted into the geological map and showing specific trend that might be related to past tectonic activity in the study area.

Keywords: Metamorphic rock, metamorphism, texture, structure

1. Introduction

Metamorphic rocks are origin rocks that the mineralogy and chemical composition has been changed, due to elevated temperature and pressure during the geological process below the surface, called metamorphism [1]. Metamorphic rocks are divided into two categories, foliated, and non-foliated. The existence of foliation in metamorphic rocks is a result of recrystallization minerals and the variation of stress or strain which produces the compositional layering during metamorphism process. This layering will be on a cm or smaller scale, or any planar orientation of inequant minerals grain. The existence of foliation in metamorphic rocks is a key to better understand the metamorphic deFormation history of an area [2, 3].

This research conducted in Manunggal Formation is a part of Luk Ulo Mélange Complex, located in Karangsambung, Kebumen, in Central Java (figure 1). From the previous researchers, this Luk Ulo Mélange Complex interpreted as a product of subduction between Indo-Australian and Eurasian plates during late cretaceous to early Paleocene, which consist of a mixture pre-tertiary rocks (exotic block) and tertiary rocks (native block) such as greywacke, pillow lavas, argillite and associated with cherts and pink limestones, turbidite clastic and ophiolite, which inserted between metamorphic terrane with greenschist to blueschist facies. This group of rocks is called mélange, which is the result of tectonic mixing of oceanic crust and terrestrial rocks. Mélange has a very complex deFormation, that produces rocks in a block with a sclay clay groundmass as a result of destruction, separation, which then
followed by tectonic mixing. The tectonic occurrence in this area produced a discontinue direction of lateral distribution and various metamorphic facies from the very low to highest grade [4].

In research area (figure 1) consist of ultramafic rocks and metamorphic rocks such as amphibole, mica, glaucophane schist, and phyllite as tectonic inclusions [4]. This research aims to determine the characteristics of the lowest to highest grade metamorphic rock, which focus on mineral composition and the presence of foliation orientation from each sample. Through these two data, it can be used to support or complete the interpretation of the geological history of a Manunggul Formation.

2. Methodology
The research method was carried out by geological surface mapping to collect primary data from the field and petrology analysis using the classification of metamorphic rocks (figure 2). The sample of metamorphic rocks had taken along Manunggul Formation, Karangsambung, Kebumen, in Central Java (figure 3).

Based on its texture, metamorphic rock is divided into two classifications. There are rocks with a foliation or have no foliation. Foliation is the fabrics element or usually minerals grains which have a planar arrangement in the body of rock. In taking a sample, the existence of minerals and foliation are necessary to indicate the facies of metamorphic rocks. On the sample which has foliation,

Figure 1. Research location

Figure 2. Sampling activities in the field.
This will measure the direction of orientation using a compass. The data of orientation foliation in each area will be plotted in maps and use to complete and prove the geological history that had just made previously.

The petrological analysis was carried out in the geology laboratory, Universitas Indonesia. The petrology analysis is a macroscopic analysis of rock using a loupe and stretcher, which contains color, mineral composition, structure, and texture of each sample. Through this data, the facies metamorphism can be determined.

3. Results and discussion

3.1. Facies metamorphism and mineral composition

From the maps above (figure 4), at least there are six dominant facies metamorphism that is cropped out along Manunggul Formation. In the Northeast-part was found blueschist and serpentinite, the Central-part was found phyllite, hornfels, greenschist, and green rocks, and greenschist in the Western-part. Detail explanation delivered in the section below.

|Blueschist facies. Blueschist Facies is high-grade rock metamorphism with schistose structure, formed at high pressure and low temperature that associated with subduction zones. This facies is dominated with blue alkali-amphibole with a high proportion of glaucophane, which results in the blue colour in rocks. The minerals assemblages were commonly found with these two minerals are lawsonite, zoisite, epidote, garnet, chlorite, phengite, paragonite, chloritoid, talc, kyanite, jadeitic pyroxene, ankerite, and aragonite. This facies was frequently found as blocks in tectonic melange, these blocks are separated by a matrix either sediments or serpentinite [1, 2].

This blueschist-facies dominantly found in the North-East of the research area. This facies (figure 5) has greenish-blue, but in some sample has a dark blue colour. Foliation in blueschist is composed of glaucophane minerals arranged in the same direction, which shows the schistose structure. Minor minerals that also found are muscovite, garnet, and green minerals that might exist in rocks sample which has a greenish colour.

|Phyllite facies. Phyllite facies has a parallel arrangement of phyllosilicates minerals which shows the perfect schistosity [2]. This facies consist of fine-grained rock with a low metamorphic grade (under...
300 °C), which commonly found in a lighter or darker shade of grey, but sometimes has a greenish colour. This facies Mineral assemblages in phyllite are mica + quartz + chlorite ± biotite ± feldspar, with mineral accessories such as tourmaline, zircon, pyrite, and iron oxide. In weathered phyllite, the mineral commonly found are Iron oxide, hydroxide, and clay minerals [5, 6].

Phyllite-facies in research area found in the middle part of Manunggul Formation. We can see in figure 6, phyllite-facies commonly found with the dark grey colour and green colour in some sample. Each sample has a phyllite structure that represents the perfect foliation with different orientation. Minerals that found in this sample are muscovite, quartz, pyrite, green minerals that might exist in phyllite with green colour, and clay mineral in highly weathered phyllite.

**Hornfels facies.** Hornfels Facies is a non-schistose with a very fine-grained rock. The mineral assemblage is silicate ± oxide minerals [3]. Hornfels is a massive metamorphic rock, which formed close to the contacts of igneous intrusion with temperatures above 650 °C. Contact metamorphism occurs when igneous rocks intrude the country-rock as a result of magma heating, which the minerals formed in a random interlocking as an impact of strain during the Formation process. In Manunggul Formation, hornfels found in the southern part. We can see in figure 7, this facies has a dark grey colour and has no-foliation. The minerals found in this sample are quartz and clay minerals [5, 7].

![Figure 4](image-url)  
**Figure 4.** Map of facies metamorphism distribution in Manunggul Formation.

![Figure 5](image-url)  
**Figure 5.** (a) Blueschist with glaucophane mineral that shows the perfect foliation in sample D02/07, (b) Blueschist with garnet mineral in sample D02/10.
Greenschist facies. Greenschist facies is high-grade rock metamorphism with schistose structure, formed at temperature range 300–500 °C with low to intermediate pressure [2, 7]. The presence of minerals in these facies influenced by the origin rocks, but there are some minerals which commonly found such as actinolite, chlorite, epidote, albite, and quartz, where the first three minerals produced green colour in this facies [8].

Greenschist-facies dominantly found in the central part of Manunggul Formation. This facies shown in figure 8 has a green color, but some samples have a greenish-gray color. This facies has a foliation with different orientation of each sample. Minerals that found in each sample are muscovite, green minerals, which chalcopyrite and quartz found in a small amount of sample.

Figure 6. (a) Green phyllite with clay minerals and green minerals in sample D01/07 and shows the perfect foliation, (b) Grey phyllite with muscovite, pyrite, and quartz minerals in sample D01/03.

Figure 7. Hornfels with clay and quartz minerals in sample D05/04.

Figure 8. Greenschist with chalcopyrite, muscovite, and green minerals in sample D03/04 and shows the perfect foliation.
Green rocks facies. Green rocks facies is low-grade metamorphism, which has very fine-grained as a result of altered or metamorphosed mafic igneous rock. This facies has a green colour, due to the presence of green minerals (e.g. chlorite, actinolite, epidote, zoisite, prehnite, or pumpellyite) and has no foliation. The mineral assemblage that also common in these rocks are albite, sphene, and some carbonate minerals, which partially replaced as a result of metamorphism [8]. Green rocks (figure 9) dominantly found in the middle part of Manunggul Formation. The minerals that found are green minerals which represent the dark green colour of each sample, and a small amount of muscovite and quartz in several samples.

Serpentinite. Serpentinite is low-grade metamorphism, which occurred in all ancient orogenic belt. This rock is a part of sub-greenschist facies, which formed by the hydration of olivine-rich ultramafic rocks (peridotite) with low temperature and has a green colour [9]. Serpentinite was found dominantly in the Northeast part of Manunggul Formation, which closes to the presence of blueschist facies. We can see in figure 10 the sample has a green colour, which produced by the serpentine mineral group.

3.2. Distribution of foliation orientation

The map below (figure 11) shows the direction of foliation obtained at each sample point [10]. The results of measuring the direction of foliation at each sample point divided into three levels of certainty, there are low, medium, and high. Foliation with a high level of certainty found in metamorphic rocks with low weathering rates, where the foliation is representative to the research area. At the medium level, fairly weathered metamorphic rock with clear foliation. The metamorphic rock from the lower level is very weathered, and the presence of foliation is less clear.

Figure 9. Green rocks with muscovite and quartz mineral which is seen in sample D04/06.

Figure 10. Serpentinite in sample D02/01.
Furthermore, the presence of foliation is also quite influenced by the presence of geological structures in the study area. The sampling area which close to the presence of structure, shows the direction of foliation variation which will affect the result of the interpretation of continuity in each sample. Based on the data obtained, foliation from low to the high level of certainty in each sample have a dominant trend. The resulting dominant trend indicates that there is a lateral continuity in metamorphic rocks in the Manunggul Formation.

4. Conclusion
Foliation study can be useful to find the correlation between each rock. Metamorphic rocks in the Manunggul Formation has a continuous direction of foliation and shows the dominant trend. The presence of the dominant trend indicates that there is a lateral continuity in metamorphic rocks. Further study is needed, to define the foliation pattern, Formation stage and the relation to the occurrence of metamorphic rock in Karangsambung.

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