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The Control Of Geological Structure At Songgo River Dyke Intrusion In Nanggulan Formation, Western Part Of Yogyakarta-Central Java

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Abstract. This study to explain the presence of intrusive rocks in Naggulan Formation was carried out with a series of geological research methods. The method used in this research is through reference studies from previous research, observing the image of the study area and its surroundings, direct observation of Paleogenic rock bodies, and measurement of fault structures, joints, and folds in the field. Measurement of the elements of geological structure is used to determine the main structure and stress forming structure in Nanggulan Formation rock which is of Paleogene age and surrounding rocks which are Neogene age. The igneous rocks found in the study area is a dyke that cut the sedimentary rock layers of Nanggulan Formation. Dyke igneous rock distribution in the study area forms a northwest-southeast (NW-SE) direction. The distribution of igneous rocks is controlled by geological structures with the main stress direction of northwest-southeast which creates extensional vertical fractures in the direction of the main compressional stress source.

1. Introduction

The study area is in the Nanggulan area, the western part of the Yogyakarta Special Region-Central java (Figure 1). This area is very geologically interesting because it is one of the oldest sedimentary rocks found on the island of Java. This rock is the Nanggulan Formation which is an Eocene age rock according to [1] and [2]. In the western part of Yogyakarta, this rock forms a base for Oligocene - Miocene volcanic and sedimentary rocks at the top.

The presence of Nanggulan Formation rocks in this area has attracted many researchers including Van [3], [4], [5], [6], [7], [8] and [9]. Research by [10] described the presence of fold structure, strike-slip faults, and normal faults in the Songgo River area and surroundings. Research by [11], map the distribution of the Nanggulan Formation, and describe north-south trending anticlines and basalt intrusions in the Songgo River area.

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Figure 1. Research area location in Java Island.

2. Regional Stratigraphy

The Nanggulan Formation has a type location on the Songgo River, Nanggulan area. [3], explains that this formation is the oldest rock in the western part of Yogyakarta. The constituent lithology consists of sandstones with lignite, sandy marl, claystone with limonite, marl and limestone concretions, sandstones, tuffs rich in foraminifera and mollusks, estimated thickness up to 350 m. Based on the study of planktonic foraminifera, the Nanggulan Formation has an age range between the Middle Eocene to the Oligocene (Figure 2).

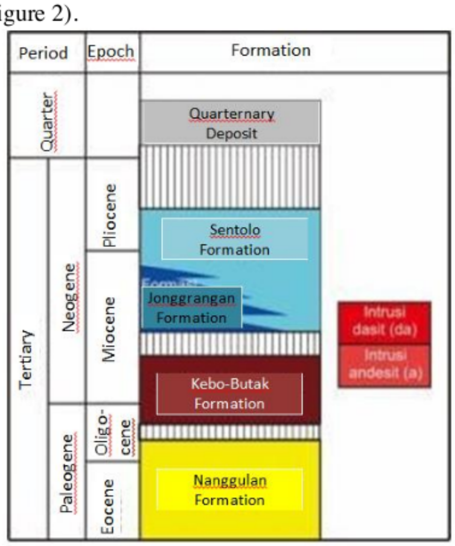

Figure 2. Stratigraphic column of study area according to [13] with modifications.

The volcanic rocks referred to by [3] as the Old Andesite Formation (OAF) are the same as those referred to as the Kebo Butak Formation (Figure 2) by [12] and [13]. [13] mentions the constituent rocks of the Kebo Butak Formation are andesite breccias, tuffs, lapilli tuffs, agglomerates and inserts andesite lava flows. Research of [14] describes the rocks that make up the Old Andesite Formation including volcanic breccias, lava, and intrusion. Volcanic breccias consist of volcanic breccias associated with lava; associate with lapilituf and tuff; with volcanic sandstone lenses; and alternating with finely layered sandstones. Lava is found around the center of the eruption (feeder) of the existing Oligo-Miosen volcano. Intrusion rocks consist of andesite, dacite, and basal intrusion.

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Publication of [15] states, this volcanic group are covered unconformably by the shallow marine deposits of the Jonggrangan Formation and Sentolo Formation. Based on [16] states that the first carbonate sedimentation occurred at the top of the Early Miocene and occupied high areas such as Kulon Progo and Karang Bolong (Kebumen) resulting in the Sentolo and Jonggrangan Formations of Early Middle Miocene. Reefs are built on the heights of former volcanic bodies. Result of [17] states that carbonate sedimentation formed at the top of the Early Miocene and took place in high areas such as at the height of the early Middle Miocene Kulon Progo.

3. Research Method

The study was conducted through a series of reference studies from previous research, observation of the image of the study area and its surroundings, direct observation of the rock body, and measurement of fault structures, joints, and folds in the field. Measurement of the elements of geological structure is used to determine the main structure and the main stress of structure formation in the Nanggulan Formation rock which is of Paleogene age and the surrounding rocks which are of Neogene age.

4. Research Result

Nanggulan folds develop on the Nanggulan Formation rocks (Figure 3) in the Girimulyo and Kalibawang areas, Kulon Progo. The anticline fold has a Southwest-Northeast-directed axis. Anticline limb facing to the southeast can be seen in the coal seam on the Watupuru River with dipping 25°. The limb that leads to the northwest has a slope between 7°-17°. Limb in the southwest is found with dipping 35° and 24°.

Figure 3. Outcrops of Nanggulan fold limb. a. The northwestward view of the anticline limb on sandstone was inserted by claystone dipping to the NW. b. Westward view of the southeast anticline limb on claystone intercalated by siltstone.

The results of the stereographic analysis of the Nanggulan Folds data (Figure 4) resulted in the position of the northwest limb is N228°E / 13°. Southeast Limb domiciled N4°E / 29°. The Nanggulan fold is formed by the main stress (T1) 7° / N105°E. The formed axis has the position N196°E / 83° with the axis line 07° / N015°E. Based on the results of the analysis, the Naggulan Fold is an Upright Horizontal Fold type according to Rickard's Classification, 1971. This fold is formed by the maximum main stress of T1: 7° / 105°E or stress from the southeast with an almost horizontal of plunge.

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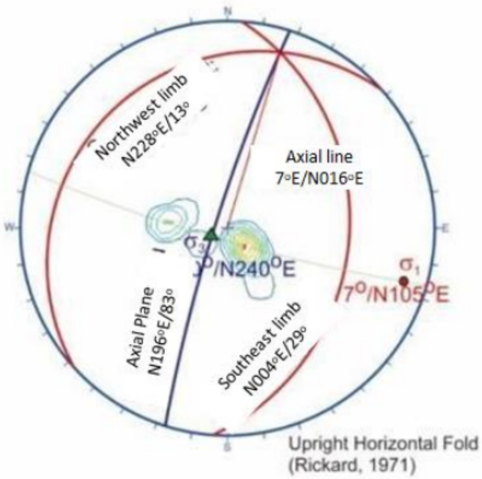

Figure 4. Stereographic analysis of Nanggulan folds.

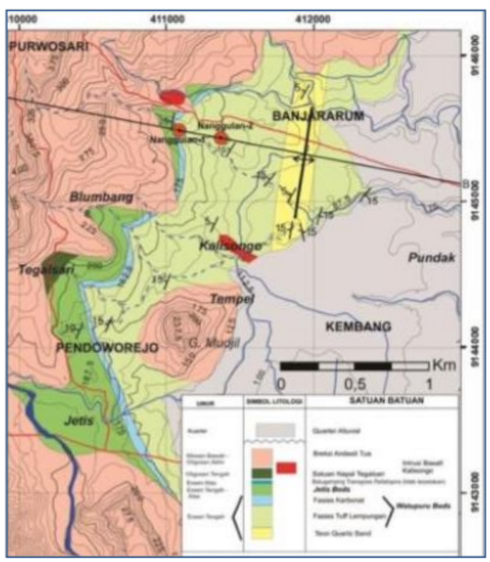

Figure 5. Geological map of the study area according to [15]. Songgo River dyke is in the center of the map.

Field observations show the distribution of igneous rocks as shallow intrusions (Figures 5 and 6). These rocks are slightly light gray to dark gray, fine afanite-porphyritic textures, vesicular structures (the structure of holes in dyke), and scoria structures. The vesicular structure only develops in the middle part of the body of intrusion rock that forms a columnar joint.

Figure 6. The appearance of basalt igneous rock in the study area [7].

5. Discussion

Based on fault kinematics, dyke is possible to form due to maximum extension, which allows magma to flow into the low-pressure zone. The relationship between the dyke pathway and the anticline structure shows its relationship with normal faults or extensional fracture and magmas fill spaces in the strain zone produced by the fault [18]. Magmatism activities are closely related to local area tectonic activities. As long as the area's tectonic activities are still ongoing, it can cause reactivation of magmatism activities [19].

The direction tendency of dyke is likely to be concentrated in the direction of the maximum compressional stress (T1) with the opening towards the minimum compressional stress (T3). The T1 direction is usually horizontal in the contractional tectonic region which is characterized by the presence of a strike-slip fault or thrust fault that is not in line with the vertical dyke intrusion. The trajectory can be controlled by the arrangement of stress-field lithospheric and local stress fields and fractures caused by such as normal faults, thrust faults, and strike-slip faults [20]. According to [21], [22] and [23] mentioned the presence of anticline and thrust faults as controllers for the emergence of the Nanggulan Formation in western Yogyakarta.

Figure 7 shows the movement of magma in the crust along the plane of the thrust fault, illustrating that magma can spread to the surface in a tectonic regime characterized by contractional deformation. If the thrust fault is below the surface with a gentle angle in a flat view, vertical tension fractures can form in the shallow part of the hanging wall subparallel to the imposed shortening. These structures can be formed due to local loading, due to uplifted areas in regional stress fields [24].

Dyke which intrudes into an area can be simplified into a vertical plane, better known as the dyke plane, as the main magma escape route. Normal-tension is perpendicular to the dyke plane. Volumetric changes around the magma sac may be related to the influence of magma overpressure as a source of magma. Active fault zone can cause wider swelling in the magma reservoir which allows volcanic eruptions [25].

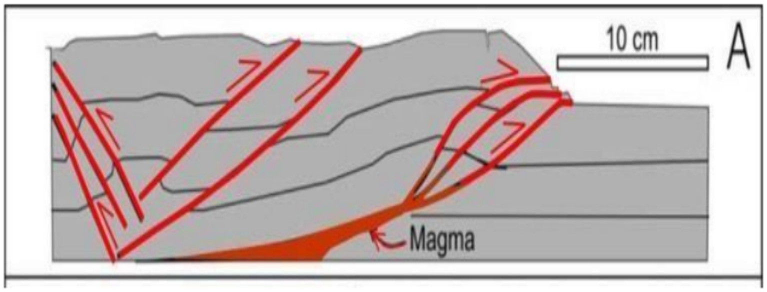

Figure 7. Intrusion models in contractional tectonic settings [24]. Shows the movement of magma under the surface along the plane of the thrust fault.

Magmatism in the study area is of the same age as northwest-southeast-directed local compression. The maximum main stress is horizontal T1 and the minimum main stress is vertical T3 creating a horizontal / almost horizontal thrust fault structure. Magma flows through the composite system of sub-horizontal tension fractures and thrust fault planes.

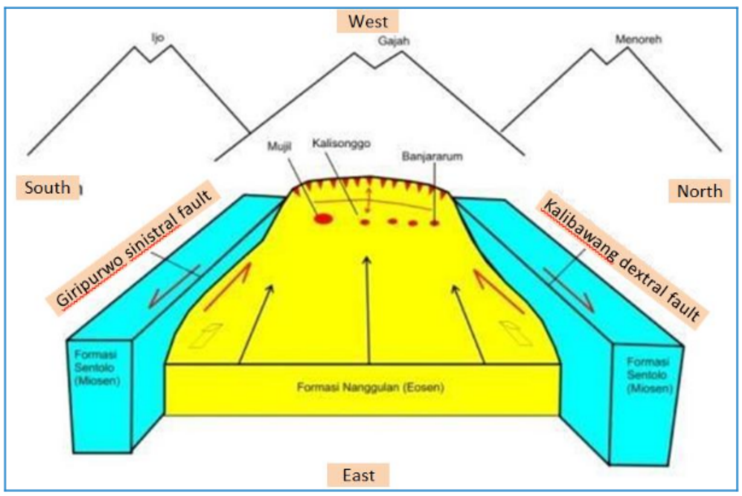

Figure 8. Schematic block diagram showing the uplift process of the Nanggulan Formation due to strike-slip and thrust fault.

The block diagram scheme (Figure 8) shows the thrust fault and anticline that gave rise to the Nanggulan Formation. In this picture, the rising of the Nanggulan (Eocene) Formation rock is drawn up to cut the young rock of the Sentolo Formation (Middle Miocene). To the north and south of the Nanggulan Formation, the Sentolo Formation is found. So it can be said that laterally the Naggulan Formation is flanked by the Sentolo Formation in the north and south. While in the west there is contact with the Old Andesite Formation [3] or the Kebo Butak Formation [13] or the Gajah Volcano rock according to [26] and [15].

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6. Conclusion

The igneous rock found in the study area is a dyke that cuts anticline structures of the Nanggulan Formation sedimentary rocks. Dyke igneous rock distribution in the study area forms a northwest-southeast direction. The distribution of igneous rocks is controlled by geological structures with the main direction of stress is southeast-northwest which creates an extensional vertical fracture in the direction of forming stress.

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