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MULTIPLE DEFORMATION OF JOKOTUWO FAULT ZONE, EAST JIWO HILL, BAYAT, KLATEN, CENTRAL JAVA

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Abstract
Jokotuwo fault zone was first mentioned as the sinistral transpression Jokotuwo fault by Jatmika Setiawan (2002). The trending of fault zone can be traced on four directions. The first direction is ENE –WSW in northern part of Jokotuwo hill to Konang hill. The second direction is E – W in southern part of Jokotuwo hill to southern part of Semangu hill. The third direction is NNW – SSE in central part of Jokotuwo hill to Temas hill, and the fourth direction is NE – SW in central part Jokotuwo hill to Gunung Gajah hill. The fault zone area show evidence for four successive structure episodes. The first generation (D1) is deformation in northern part of Jokotuwo hill to the Rondonom hill. This zones is manifested by a variety of structures for well-developed mylonite foliations. The second generation (D2) is deformation in southern part of Jokotuwo hill to southern part of Semangu hill. This zone is manifested by shearing structure for cataclasite flow. The third generation (D3) is deformation in central part of Jokotuwo hill to Temas hill. This zone is manifested by a variety of structures, which may include drag folds, fault plane,and fault breccia. The fourth generation (D4) is deformation in central part of Jokotuwo hill to Gunung Gajah hill. This zone is manifested by a variety of structures, which may include fault plane, and fault breccias. The earliest structures in the Eastern Jiwo hill was generally showed that D1 structures are rotational and non-coaxial in semi-ductile character. The deformation was dextral thrusting involving WNW shortening with a significant component of thrust-parallel slip movement that continued into the Pra-Tertiary Orogeny. The D2 and D3 are rotational and non-coaxial in brittle character. The deformation were sinistral transpressive with a significant component of sinistral-strike slip movement that continued into the Tertiary Orogeny.

INTRODUCTION

Jiwo Hills (Bayat) is the one of three places that outcrop of pra-Tertiary and Paleogen rock is occurred in Java Island. The rest are Ciletuh, which is located at southeast of Pelabuhan Ratu (West Java) and Karangsambung, at Central Java, located at the north of Kebumen.

Many geologist has done doing research at Bayat area, there are : Bothe (1929), who made stratigraphy column of Jiwo Hills and also proposed the name of Wungkal Formation and Gamping Formation which aged Eosen; Sunu Sumosusastro (1956), researching in more detail the geology og East Jiwo Hills, study of biostratigraphy is ever conducted by Sumarso and Ismojowati (1974), Soeria Atmaja *et al.* (1991) and Sutanto *et al.* (1994), researching volcanic stone in Java Island, consists of age of many stones with radiometric method (Isotrophic K/Ar dating method) some igneous stones at Bayat and surrounding areas; Soesilo, dkk. (2000), researching about nomenclature of crystalline rock at West Jiwo Hills; Setiawan (2000), researching about paleostress of geological structures at Jiwo Hills; Prasetyadi and Maha (2004), researching the stratigraphy analysis associated with probability of ancient high at Jiwo Hills.

GEOLOGY OF EASTERN JIWO HILL

Until today, naming the rock units at Jiwo Hills basically use the nomenclature which is proposed by Bothe (1929) vide Setiawan (2000). Based on stratigraphy, Bayat area is composed by rock units as mentioned below (Setiawan, 2000) : (1) Pra-Tertiary-aged metamorphic rock, (2) Gamping – Wungkal Formation; (3) Oyo Formation. (Figure 1)

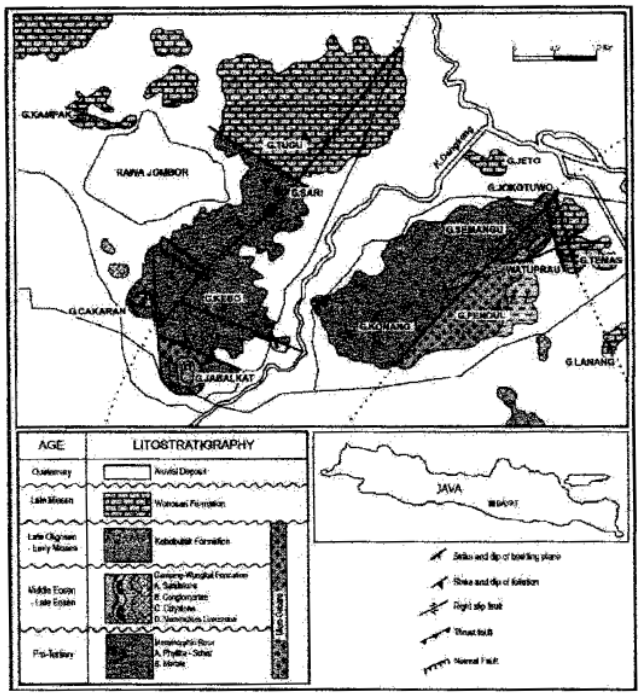

FIGURE 1. Geological Map of Jiwo Hill, Bayat, Klaten (Setiawan, 2000)

Soesilo, *et al.* (2000) suggested nomenclature based SSI (1996) for crystalline rock at West Jiwo Hills to be Bayat Phyllite Lithodemic, Bayat Gabbro Lithodemic and Bayat Basalt Lithodemic.

Phyllite Lithodemic consists of phyllite, schist, serpentinite, and marble. Phyllite is the most important metamorphic rock at Jiwo hills, that has been exposed at Konang hills and Semangu hills. Schist is exposed at Padasan hills at East Jiwo, although it is not wide, and marble is the lense of phyllite, it is exposed at Jokotuo hills. In phyllite lithodemic, there is no fossil appeared, so the certain age of phyllite is unknown, but because of tertiary-aged formation covered phyllite, the age of phyllite is set on pra-tertiary.

Both of Wungkal Formation and Gamping Formation (Bothe, 1929), represent Eosen-aged rock formation. **Wungkal Formation** consists of polimic conglomerate, quartz sandstone, claystone and big foraminifera limestone (*Assilina* and *Camerina*) that show Early Eosen Age (Ta). This rocks unit is exposed at West Jiwo Hills, Wungkal Hills, Sekarbolo Village. This rocks unit is location type that is suggested by Bothe (1929). **Gamping Formation** consists of big foraminifera limestone (*Camerina* and *Discocyclina*) which is Late Eosen aged (Tb), sandstone and claystone. There is nonconformity above metamorphic rock group, exposed around Pendul hills and Watuprahu (East Jiwo Hills) is located at Gamping Village, and it is the location type.

Gabbro lithodemic consists of many basaltic dykes (Winong, Brumbung, Bukit Merak, Pager Jurang, etc) and gabbroic stock (Bendungan Village, Pendul hills, and Kebo hills). Those gabbroic rocks with earlier researcher are called Diorite, but with chemical analysis and its texture show Gabbro. At Temas Hill and Bendungan Village, eocene-aged rock formation is covered with nonconformity by reef limestone of Oyo Formation. Radiometric dating with isotropic Potassium-Argon method showing that the Gabbro at East Jiwo Hills is 31,3 Ma or Early Oligosen (Sutanto, *et al*, 1994). Oyo Formation consists of the layers of calcarenite and marl, that has Middle Miosen Age (N11 – N13), well exposed at Temas Hills and Lanang, This Formation covered unconformity with phyllite and gabbro lithodemic.

Geological structures that has been observed at East Jiwo are fault that cut Jokotuwo Marble hills. Fault evidences are fault plane with slickenlines, fault breccia and also sistematic joint, which is caused by its fault. Folliation structure can be observed at phyllite rock and schist rock (Jokotuwo) and layered bed rock at Gamping Formation around Watuprau Village. Fault breccia is located at Konang Hills, and also there is fault evidence appeared at Temas Hills.

METHODOLOGY

This research is mainly a field-based research. Fieldwork was conducted in two methods. The first method is Detailed Mapping at scale 1 : 500., and the second method is used grid systematic structural analysis have focused on small localized selected areas (Mary, 2005). Structural orientational data were analysed by means of manual stereographic plot hemisphere projection and software DIPS Version 3.7., and Paleostress Version 3.11.

Petrographic study under microscope was carried out to unravel the more detail information on identity of rocks based on mineralogical composition, texture, structure and petrogenesis. (Fossen, 2010) An investigation of the cleavage types and others related fabrics, and metamorphic petrogenesis was accomplished by thin section studies. (Pluijm and Marshak, 2004).The relationship between Sb, So, S1, and S2 (Almendinger, 2010), relationship on crenulation cleavage, relationship to fold and cleavage (Alsop et al, 2004), relationship fold to fold on superposed (Nemcok, et al 2009), relationship internal and external structure on porphyroclast or porphyroblast have comparable to overprinting relationships, structural vergences, tectonic transport directions and stratigraphic relationship in field investigation. (Hirth and Hovius, 2007)

EVIDENCE FOR MULTIPLE DEFORMATION

The fault zone of Jokotuwo area show evidence for four successive dynamo metamorphic structure episodes (Figure 2).

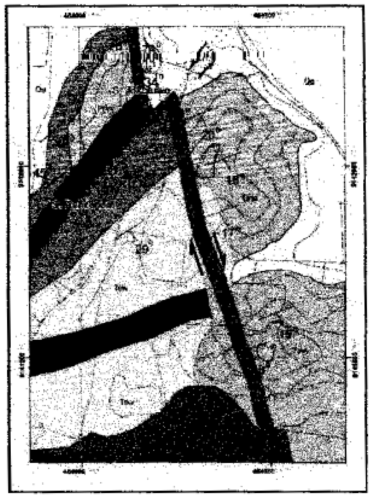

FIGURE 2. Geological Map of Gajah Hills (Rodhi, 2019)

The first generation structures (S_1) is varies of mylonite foliated fold structures, those are from recumbent to overturned folds with fold axes generally gently plunging to the ENE or WSW. Their axial surfaces ranging from low to horizontaly dipping and commonly associated with bedding parallel cleavage (C_1). They are commonly closely associated with refolded and chevron folds. Most of the cleavage transects not only the axial surface but also the fold hinge. The NNW cleavage trend cut off by the NW cleavage. The cleavage cuts counterclockwise relative to roughly synchronous fold hinges, indicates component of dextral lateral thrusting. Transposition of layering during the first deformation (D_1) is not uncommon and the occurences of high-strain zone of thrust faults suggest that the D_1 deformation were derived from intense NW-SE compression with significant shouthern block thrusting of Jiwo Hill has undergone N-S oblique deformation (Figure 3).

The second generation structures (S_2) that grow within a synshearing structures zone during deformation are generally called growth structures, they include the second generation folds (F_2) and E - W Larger Foraminifera Limestone Blast orientation in cataclasite flow zones. The (F_2) varies folds from low plunging asymmetrical to horizontaly plunging symmetrical folds. In graphite slate or phyllite with strong bedding-plane foliation was formed crenulation cleavage. It is typically an S_2 foliation that has been superimposed on an earlier (S_1) foliation. These evidence suggests that the D_2 deformation was dextral lateral thrusting. The predominance of Larger Foraminifera Limestone Blast orientation asymmetric pinch and swell structure as well as asymmetric boudinages and the non-coaxial superposition of S_2 cleavages. Dextral lateral thrusting deformation of D_2 produced zones of high flattening strain and E-W-striking fault zones. The deformation orientation of D_2 is N-S, and different with the first deformation (D_1). (Figure 4).

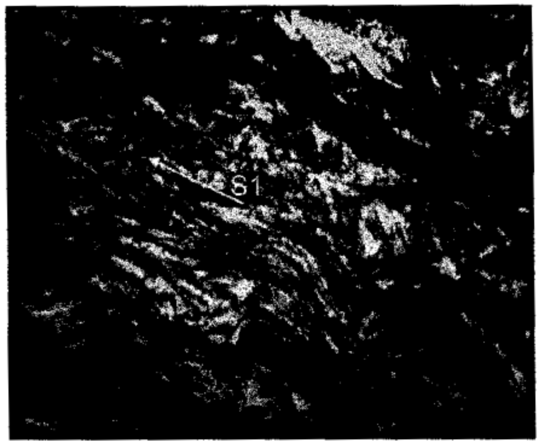

FIGURE 3. Superpost fault (S1)

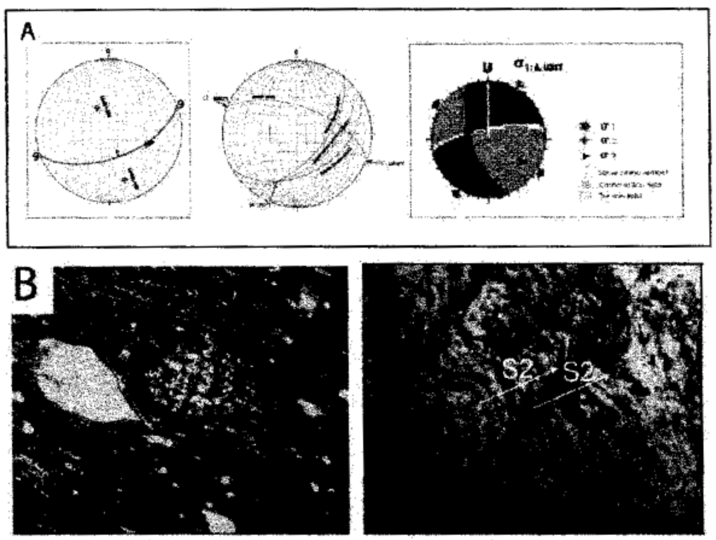

FIGURE 4. (a) Dips and Paleostress stereometric analysis; (b) Pinch and swell structure on petrography section; (c) hinge line cross cutting S1 and S2 microfault.

The third generation structures (S_3) was represented by varies structures, which may include drag folds, fault plane with lineation and slickensite, and fault breccia with shear and gash fractures. The structures typically form with fracturelike rapidity, indicating a brittle behavior. Both fault plane and fault breccia commonly associated with minor to major drag folds. Stereographic plot hemisphere projection on software DIPS and Paleostress have NNW trending dextral strike slip fault deformation. The association of NNW dextral fault and SW trending drag folds indicates that the D_3 deformation was the result of NNE-SSW compression with dextral transpressive. (Figure 5)

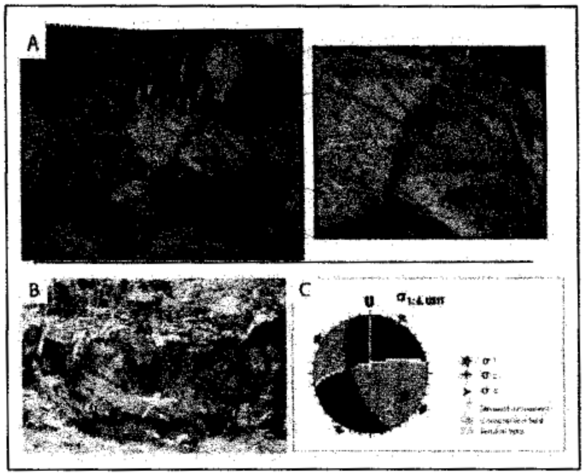

FIGURE 5. (a) Petrography of Fault Breccia, (b) Slump structure, (c) Paleostress stereographic analysis

The fourth generation structures (S_4) was represented by brittle SW-NE fault plane related striation and slickensite, commonly closed associated with SW-NE fault zone, shear and gash fracture. Stereographic plot hemisphere projection on software DIPS and Paleostress have NE-SW trending dextral strike slip fault deformation. The association of NNW dextral fault and NE-SW dextral fault indicates that the D_4 deformation was from ENE-WSW compression with dextral transpressive resulting NNE-SSW compression with dextral transpresive. (Figure 6).

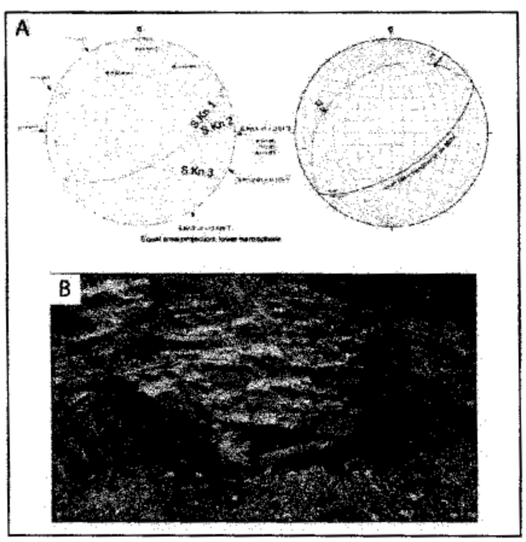

FIGURE 6. (a) Dips sereographic analysis, (b) Fault zone at Gunung Gajah

THE AGE OF DYNAMO METAMORPHIC

The timing of deformation is difficult to constrain due to lack of paleontological data. However, based on the unconformable relationship between Gamping Formation and the pra-Tertiary phylitic metamorphic lithodem. The first deformations (D_1) typically from ductile to semi-ductile behavior of low grade mylonite metamorphic facies. Both phylite and mylonite developed at the same depth and time. It could be inferred that the age of D_1 was pra- Tertiery. Synshearing or growth fault structures on Late Eosen Foraminifera Limestone have suggested that the age of D_2 was Late Eosen. The fault zone of S_3 was cutting all lithology at Jokotuwo areas. Based on the unconformable relationship between Oyo Formation and the Gamping Formation. or Gabbro Lithodem and growth fault structures indicators on Oyo Limestone Formation, it could be suggested that the age of D_3 was Middle Miocene, same with age of the Oyo Formation. The fault zone of S4 was cutting all of lithology and another fault zones at Jokotuwo areas, but it's not uncommonly synshearing or growth structures. It can be speculated that D_4 would have resulted from strong dextral transpressional deformation (D_3) during Middle Miocene to Late Miocene.

CONCLUSION AND TECTONIC HISTORY

The earliest deformations of Eatern Jiwo Hill was NNW compression involving ENE-shortening with a semi–ductile significant component of thrusting movement during late Mesozoic to that continued into the early Tertiay East Java micro continent Orogeny.

The growth of the thrust fault zone mainly controlled by coaxial refolding and reactivation dextral thrust zone. Based on the type of superposed fold that the semi-ductile fault zone showed at least two deformation periods (D_1 and D_2).

The brittle deformation of Eastern Jiwo Hill (D_3) was NNE dextral transpression during Middle Miocene after the Gabbroic intrusion have exposed and eroded or post Oligocene-Miocene volcanic activity.

The last deformation (D_4) was NNE sinistral transpression during post Late Miocene, and it was maked carbonate sedimentary exposed .

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