Opak fault: a comparative review

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Abstract. The term of Opak fault as commonly used today refer to the subsurface rupture beneath Opak river, which is covered by young Merapi volcano sediment, located in Bantul Region southeast of Yogyakarta within the entire of southern mountain. The early concerning to the existing of Opak fault appear to be awakened since Dr. S.W. Visser reported Yogyakarta earthquake of 1867 which epicenter located near opak river. Since the Yogyakarta earthquake on 27 May 2006, Opak fault become famous and researcher believe that the earthquake caused by this fault. Further more, the conclusions regarding fault position remain equivocal are due to difference in each idea which resulting from their researches. It is understood because the main fault body exposure is limited and not available data at all to collecting due to covering by young Merapi sediment. However, as ontologically it is still remain question mark and has not being met the essence of opak fault existence. This paper proposes a preliminary result of the comparative review taking from the conclusions of the last several researchers regarding its opak fault existence. In order to determine either aspect of structure elements which have been conformed or still remain the uncertainties. Previous studies have reported some results regarding opak fault as summarized: 1) Opak fault system striking from Southwest to the Northeast; 2) The lineament of Poncosari – Taman Tirto was identified as a fault which has striking parallel to opak fault; 3) Between Poncosari Tamantirto lineament and opak fault trending create a zone with corridor at approximately 10 km; 4) Different ideas of opak fault dip direction resulting from researchers, either opak fault has dip direction toward the Northwest or the Southeast. At least two group of ideas arising based upon the list explained above which have been identified.(1) Although they have coincident in the trending SW-NE of the opak fault. Yet in kinematic aspects appear different opinion due to yielding from different methods. Either they concluded in trending left lateral strike slip fault or thrust fault with dip direction to the Southeast. (2)The lineament Poncosari Tamantirto is still need to find field evident while this fault was interpreted from InSar to reveal surface deformation.(3) Poncosari-Tamantirto fault is shown in gravity pattern starting from Kasihan toward Glagah Jatinom, Klaten. (4) Updating of new opinion regarding dip direction to resulted the Southeast of dip direction and directed to the hanging wall area in Wonosari Gunung kidul. In the next stage of research, it is required an investigation in the field within corridor of opak fault zone to determine the areas where need to clarify and to find the evident at the edge of hills .

Keywords: comparative review, Opak fault, fault position and dip direction
1. Introduction
Based on catalog documented by the Center of Volcanology and Geological Disaster Mitigation, Yogyakarta Region and surrounding areas experienced several earthquake events that damaged buildings and claimed casualties among them; (1) In 1840 an earthquake was recorded (2) An earthquake on June 10, 1867 claimed the lives of 5 people, at approximately of the intensity scale was IX MMI with the damage to the building over the entire areas of Yogyakarta, Klaten and Surakarta. (3) Furthermore, the occurrence of tectonic earthquakes on July 23, 1943 with the same intensity scale of IX MMI damaged buildings in Yogyakarta, Klaten and Surakarta. Swallowing 213 lives and 2096 people injured. (4) Tectonic earthquakes again originated from subduction activity on January 13, 1981. As a result of this earthquake, the foundation of Ambarukmo Hotel suffered a fracture, and some buildings experienced wall cracks. Earthquake intensity was estimated at VI MMI. (5) The last earthquake occurred on land on 27 May 2006, resulting in severe damage to buildings in the Bantul, Prambanan and Klaten areas including the city of Yogyakarta. The death toll reached more than 5,600 people. In 2010 (6) and 2015 (7) also earthquakes were still felt in Yogyakarta.

History of the Yogyakarta earthquakes which recorded 7 times above, 3 events including 1867, 1943 and 2006, the estimated occurrence of the earthquake caused by the fault movement system striking from southwest to northeast, namely the opak fault because the epicenter is on land and shallow. Likewise, the earthquake that occurred on September 25, 2015 epicenter was on land and shallow (Supartoyo et al., 2014).

Up to now there is no one that can ensure the clarity of the opak fault line and its position associated with measurable dimensions and kinematics. So that the definition of opaque fault is only based on the interpretation which is still weak.

This paper presents an investigation from several previous researchers related to conclusions regarding opak fault as well as methodology of comparative review. It is intended to determine in the next opak fault researches.

2. Method

2.1. Location
Java Island is one of the products of archipelagic arcs from the convergent interactions mentioned above which took place from the Cretaceous Period (100-65 million years) until now is still valid. As is well known and revealed by researchers that, plate tectonic activity in the form of convergent interactions between the Indian-Australian Ocean Plate slides down the Sunda Shelf which is part of the Eurasian continent's plate forming an archipelago (Asikin, 1974; Katili, 1975; Hamilton, 1979)

Opak River is located in Bantul District Yogyakarta of Java Island general trending from Southwest to Northeast, where occupies on the fluvio volcanic of Merapi sediment at the west of Gunung Kidul. Where the existing of this river is believed in representing of a fault.
2.2. **Comparative Study**

Library study by collecting and comparing the results of previous conclusions of researchers for this location. Where the dynamics of opinions regarding opak faults appear when experts discuss the Yogya earthquake, among the researchers regarding the source of the earthquake and the position of the fault structure are described below:

The Opak Fault is an active fault in South Yogya with strike N 231 E and 87 of dip (Supartoyo, 2006); based on the above data, it means that the trending fault is southwest-northeast with a dip direction to the northwest.

Supartoyo's research used the observation methodology of the Yogya earthquake effect on May 27, 2006 on damage which includes aspects; (1) damage to buildings, landslides and soil cracks. (2) morphology, Quaternary soft rocks and weathered Tertiary rocks (3) geological structure inspection, measurement of deformation stakes including installation for aftershocks.

To understand the Opak fault activity, Supartoyo's attention was also aimed at the historical record of the earthquake events in Yogyakarta contained in the catalog. Where the history of this region had experienced destructive earthquakes in 1867, 1943, 1981 and 2006.

The final result of Supartoyo's research presents a map of the intensity and acceleration of earthquakes in the Yogyakarta and Central Java regions. However, in describing the fault line, Opartoyo still uses the map version of Raharjo et al 1995.

Research on liquefaction was carried out by Dwi Sraha and Eko Soebowo in 2006 under the LIPI Geotechnology Research Center. The study was conducted in the Bantul area using a drilling methodology in the Patalan Bantul area and mapping included the area of geotechnical investigation based on the Cone Penetration Test (CPT) by Robertson and Waste (1998).

Results; (1) The loose layer of liquafaction potential contains silt and sand is at a depth of 0.2-12.8 m. (2) the results of the liquefaction analysis indicate that the liquefaction potential of the soil layer thickness is 0.2-5.2 m. (3) Settlement induce with liquefaction 1.0-10.8 cm. (4) concentration at the center of the opaque fault.

Furthermore Bambang S Widijono & Budi Setyanta JSDG Geological Survey Center vol. XVI No. April 2007, published the publication of the results of gravity research to determine the delineation of element structure using the Bouger method and the residual gravity produced; (1) East-West folding trend. (2) Trending thrust fault Southwest-Northeast NE-SW. (3) Northwest-Southeast. NW-SE is a trending Slip Fault Strike. (4) North-South N-S is a Normal fault trending. (5) All structural elements
are indicated in the basement and Tertiary rocks. (6) Bogowonto, Nangulang, Sentolo, Imogiri and Opak faults are interpreted as reactivity faults and cut quaternary deposits.

Research on determination of fault and geometric position based on Surface deformation was carried out by Takeshi Tsuji, Katsuya Yamamoto, Toshifumi Matsuoka, Yasuhiro Yamada, Kyosuke. The results of the study have been published through online published (August 7, 2009).

The research methodology of Takeshi Tsuji et al used Analyzed synthetic aperture radar interferometry (InSAR) to obtain surface deformation associated with Yogya earthquake 27 May 2006.

Conclusion of Takeshi Tsuji et al can be summarized as follows; (1) Surface deformation occurs about 10 km east of the Opak River. (2). The source of fault causes the May 2006 earthquake to be delineated consistently with the position of aftershock epicenters which is determined by temporary seismic tissue. (3). The western part of Yogyakarta occurs subsidence.

Hasanuddin Z. et al (2009) analyzed the 2006 Yogya earthquake coseismic deformation in a horizontal and vertical motion of about 10-15 cm. Horizontal deformation after seismic ranges from 0.3-9.1 cm.

The methodology used by Hasanuddin et al. Was the Okada dislocation model which was compromised by the coseismic slide vector calculation based on geodetic GPS data from 1998 to 2008 and aftershock depth data.

Hasanuddin et al. Concluded the location of the fault causing the Yogya earthquake was in the east of the Opak river about 5-10 Km. This fault has an upright dip of almost 90 degrees with the direction of N48E as the strike, moving as a strike slip fault.

The appearance of the opaque fault surface was also examined by C. Prasetyadi, Achmad Subandrio, Jatmika Setiawan and Hanif Ibadurrahman Sulaeman published as PROCEEDINGS Jogja Earthquake in Reflection 2016 24-26 May 2016.

The methodology used by C. Prasetyadi et al is field mapping by measuring the structure of dividing the three segments as the results are broken down below; (1) The Northern Segment covering the Prambanan area shows indications of activity faults with vertical strike-slip faults cutting alluvial deposits and river sediments, possessing trending N350E-N004E and N010E-N014E. (2) the middle segment in the Trimulyo region, Bantul found the N200 / 85 ° E slip fault and (3) South Segment at the junction of the Opak river and Oyo trending river (N20E-N29E).

Supartoyo again carried out the publication in 2016 from the results of opak fault research using a combination of morphotectonic methodology and field observation by measuring geoelectricity.

1. Morphotectonic methodology to predict specifically the active faults of opak fault in Quaternary tectonic include fault scarps, warped and tilted slope, subsidence features: sag ponds, and offset streams in channels
2. Field observations using 4 geoelectric measurement pathways to verify morphotectonic analysis results in selected locations, focused along the Opak fault zone stretching in the area; Parang Tritis, Jetis, Plered, Berbah and Prambanan.

The indications shown by 4 geoelectric cross sections are used as a basis for drawing conclusions about the position of the opak fault which can be described below; (1) Parangeritis cross section shows dipping of fault plane towards northwet. (2) Reisitivty profile Srimantiri is estimated to show a fault with a slope towards southeast, where the fault is not an opak fault. (3) resistivity path G. Bangkeng Klenggotan Srimulyo shows an opak fault with a dipping towards the west. (4) cross section of resistivity G. Candi Abang, Blambangan, Jogotirto shows Opak faults by dipping towards the West.

Danny Hilman Natuwidjaja expressed his research findings on GEOMAGZN VOL. 6 | NO.2 | June 2016. Where Hilman research was carried out some time after the Yogya earthquake occurred around August 2006. The methodology used was to conduct surveys & documentation of field observations including; (1). indication of liquefaction process (2) Mole-track small mound lengthwise often zigzag, typical of fault surface ruptures. (3). Morphotectonics at SRTM 30 and IFSAR 5m.
The conclusions submitted by Hilman can be described below: (1) This tectonic fracture strongly indicates the existence of the Opak Active Fault site as a source of the 2006 earthquake along the Opak River flow, trending southwest-northeast. (2) Based on the data of tectonic fracture patterns and morphotectonic analysis on SRTM 30 & IFSAR 5m, an approximate map of the location of Opak Faults and the source of the 2006 Earthquake Fault was occurred. (3) Fault dipping to the east to a depth of 8-10 Km then upright has a dip of 45-50 degrees.

In his writings Hilman explained based on publication of S.W Visser 1922, in the De Locomotief newspaper, that the first Yogyakarta earthquake recorded, when occurred in 1867 with a magnitude of 6.9 from an opak NW-NE fault, so S.W. Visser was the expert who first stated the existence of the Opak fault.

Table 1. The results of the opak fault.

| No. | Title of Paper Year | Metodology | Results |
|-----|---------------------|------------|---------|
| 1   | GEMAPADU YOGYAKARTA TANGGAL 27 MEI 2006 (Oka: Suparto Sya) | Inventarisasi & pemeriksaan kerusakan : 1. Bangunan dan kerusakan geologi (bongkahan, retakan tanah dan pelukan). 2. Penguatkan koordinat GPS, pada daerah yang pernah mengalami kerusakan gempa, 3. Pemetaan morfologi, 4. Pemetaan sebaran batakan laku berumur kurang 5, pemeriksaan batakan berumur tenaga yang telah lusuk. 5. Pemeriksaan struktur geologi, 6. Pemetaan batuan lindung portal untuk Gp susun, 7. Pengukuran palu deformasi sekitar zona sesar. | Gempaannya yang terjadi tanggal 27-5-2006 : 1. berupa diri datar, 2. alat pengukuran sesal aktif 3. bentuk dari susut dinding tanah. 4. Gempa 2006. 5. Kerusakan geologi retakan tanah, pelukan (liquefaction) dan longsor. |
| 2   | International Symposium on Earth Science and Technology, ONSET 2012 | 1. Mapping of liquefaction along with geotechnical investigation in Belitung region, YogyaKarta. 2. Geotechnical Investigation of zone prementation and drills and drilling in Palembang region, Belitung, YogyaKarta. 3. Analysis of liquefication potential by using CPT data by Robertson and White (1989) method. | 1. Loose layer consists of silty sand and sandy silt at depth 0.2-1.2 m are potentially liquefied. 2. liquefaction analysis indicated the thickness of potentially liquefied soil layer varies 0.2-1.2 m. 3. total settlement induced by the liquefaction is from 10-18 cm. 4. concentrated at the middle part of Opak Fault. |
| 3   | Anomali Gaya Berat, Kegempaan Serta Kelumpuan Geologi Dari Adas Yogyakarta dan Seintengan Bambang S.Wolfgang & Budi Setyawan Pustat Survey Geologi: JISG vol XVI No. 4 April 2007 | Gravity data analysis to defineate geologic structure element using Beuger and residual gravity. | | |
| 4   | Earthquake Fault of the 26 May 2006 Yogyakarta earthquake observed by SAR interferometry Takashi Tsumura, Katsuyu Yamamoto, Hoshiyama Matsumo, Yasuhiko Tanode, YokoYokono | 1. Analyzed synthetic aperture radar interferometry (InSAR) to reveal surface deformation associated with the 26 May 2006 Yogyakarta earthquake. 2. determined the fault location and geometry. | 1. Demonstrate that surface deformation occurred ~5 km east of the Opak River 2. fault thought to be the source of the May 2006 fault, delineated consistent with aftershock epicenters determined by a temporary seismic network. 3. West of Yogykarata mass subsidence. |
| 5   | Jurnal Geologi Indonesia, Vol. 4 No 4 Desember 2000 Hasanuddin Is, Aditya, H. Arief, H. Slawisni, M. Sigit, H. Ginting dan C. I. Abdullah | Levelling GPS pada tahun 1998, 2006, dan 2008. Methodik dikelompokkan kategorikan berdasarkan penderapan deformasi kategori: 1. Kedalaman gempa gempa susulan. | Deformasi kromosomi gempa Yogyakarta 2006 berdasarkan antara 30-35 cm dalam lapisan horizontal dan vertikal (susul). Sebaran penyebaran gempa 2006 adalah aerasi snesor (left-lateral) dengan siture kejadian M4.3 dan sudut 90. Sebaran penyebaran gempa Yogyakarta 2006 yang diketentukan dari lapisan 10-12 km. \( L \) tema lokal Sumber Opak. |
| 6   | SURFICIAL FEATURES OF OPAK FAULT ZONE C. Prapatady, A. Chandra, S. J. Abahyuy, B. I. Setiawan, S. M. B. Darsuna, L. C. Abdullah | Field mapping | Three locations 1. North segment is at Pambanan area: show indication of activity fault with vertical post-fault. cut-and-fill and over embankments. trending N70°D000 and N00°D00. 2. Middle segment: Timbul, Banjar is founded slip fault N20°E 3. South segment is at junction of Opak and Oyo Rivers: trending N80°D05. |
| No. | Title of Paper Year | Data on Maps | Remarks |
|-----|---------------------|--------------|---------|
| 1   | GEMPABUMI YOGYAKARTA TANGGAL 27 MEI 2006 | ![Map](image1.png) | Peta Bencana Gempabumi |
|     | Oleh : Supartoyo *) | ![Map](image2.png) |         |
|     | *Jurnal Pemanaan Muka di Baling, Penggerakan Gempabumi dan Gisasi Tanah, Puslit PBBN, BNPB, 2006 | ![Map](image3.png) |         |
|     | PVMBG, Hal 36 - 55 | ![Map](image4.png) |         |
| 2   | Anomali Gaya Berat, Kegempaan Serta Kelurusan Geologi Daerah Yogyakarta dan Sekitarnya Rambang S Widijono & Budi Setyanto | ![Map](image5.png) | Difference pattern |
|     | Pusat Survey Geologi JSUG | ![Map](image6.png) |         |
|     | vol XVI No. April 2007 | ![Map](image7.png) |         |
| 3   | International Symposium on Earth Science and Technology, CMMIT 2012 | ![Map](image8.png) | Geotechnical analysis suggested that the liquefaction had occurred within the upper Quaternary sediment filling the Bantulgraben. |
|     | Liquefaction Due to the 2006 Yogyakarta Earthquake: Field Occurrence and Geotechnical Analysis | ![Map](image9.png) |         |
|     | Dwi Satria and Eko Soebowo,a* | ![Map](image10.png) |         |
|     | aResearch Centre for Geotechnology, [LPJ], Bandung 40135, Indonesia | ![Map](image11.png) |         |
| 4   | Earthquake fault of the 26 May 2006 Yogyakarta earthquake observed by SAR interferometry | ![Map](image12.png) | Consistent to Foxmach Poulusion |
|     | Takeshi Tujii, Katsuya Yamamoto, Toshimi Matsumo, Yashiro Yamada, Kyouko (Online published August 7, 2009) | ![Map](image13.png) |         |
| 5   | Jurnal Geologi Indonesia, Vol. 4 No.4 Desember 2009 | ![Map](image14.png) |         |
|     | Hasanuddin Z. Abidin, H. Andreas, I. Mellanoi, M. Gomel, I. Gumilar, dan C.E. Abdullah | ![Map](image15.png) |         |
Figure 2. Opak fault map from previous research of results.

Conclusion
Previous Researchers agreed, Trending opak faults is SW-NE directed, but some had the opinion that the fault dipping towards Northeast (NE) and other opinions towards the Southeast. Some researchers say that Opak river is a rising fault with HW in the Southeast.
The problem of surface manifestation requires static data in the form of structural elements including data strike dip, plunge, bearing and accompanying structures. Also requires kinematics data in the form of morphotectonic and geodetic slip rate to determine active faults.

Subsurface manifestation problems require paleoseismotectonic (geoelectric and trenching) data for Holocene and seismic focal mechanism data and tensor for resonance.

The results of the literature research on opak fault from the conclusions of previous researchers which have been described in the above chapter, are used as a tool to look for items that will be raised, by comparing all the conclusions submitted by the researchers. Produces the following two problems:

1. Fault Type Problems
2. Fault Line Continuity Problems

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