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Microearthquake relocation hypocenter using Modified Joint Hypocenter Determination (MJHD) method. (case study: Opak fault)

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Microearthquake relocation hypocenter using Modified Joint Hypocenter Determination (MJHD) method. (case study: Opak fault)

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Abstract. Earthquakes with small magnitude and shallow depths are one form of manifestation of existence a fault line in Yogyakarta. Accurate hypocenter determination is needed to identify tectonic and fault conditions based on earthquake hypocenter distribution recorded by seismograf. Hypocenter was determined by using two methods Geiger's Adaptive Damping for early hypocenter and Modified Joint Hypocenter Determination (MJHD) for relocate hypocenter, we used 2 weeks aftershock data after main quake occurred on June 10-14 2006 with total of 625 events earthquake obtained from the results of picking waves. The difference of hyposenter result on the longitude and latitude is about 2 -25 km and depth change around 0.3-5 km with major distribution to the east from the fault. The final result of this relocation shows that the area is more easily releases energy is in the eastern section of the fault consisting of sedimentary rocks.

1. Introduction

Earthquake Fault appear in Opak River Yogyakarta is result of some movement between the plates. These plates move in different directions and different speeds to each other, the movement of these plates causes the onset of deformation in the Earth's crust around it either horizontally or vertically. The existence of interactions between the plates puts Indonesia as the region with highly vulnerable to earthquakes.

The earthquake caused active fault movement occurred in Yogyakarta on 26 May 2006 was followed by aftershocks that occur continuously. Hypocenter determination of earthquakes is very important in seismology to analyze the tectonic structure in detail, such as fault zone identification as well as the pattern of sub-duction zones. However, the result hypocenter parameters is still unoptimal because it only to provide the information as soon as possible for mitigation. Further studies need to be done to relocate earthquake hypocenter parameters.

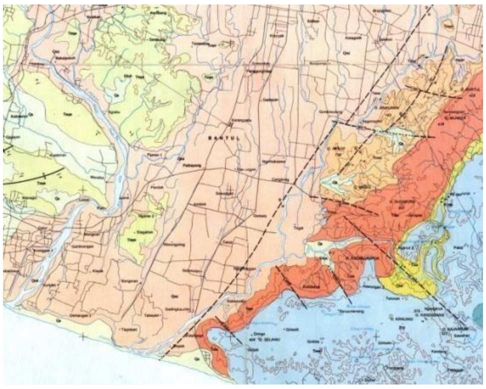
2. Data & Method

This research using secondary data from aftershock opak fault for 5 days started from 10 until 14 June 2006 using MJHD method. Main earthquake occured on May 27 2006 with hypocenter location are near from Opak fault. The process starts with processing data of picking waves of the earthquakes from 10 June until 14 June and retrieved as many as 625 earthquakes.

Yogyakarta is one of the provinces in Java island contoguos to subduction zone Australia plate against the Eurasian plate activity where there are active [1]. In addition, Yogyakarta is also prone to earthquakes due to activities of some local geological fault on the Mainland [2]. Complex conditions tectonic structure causes Yogyakarta region and the surrounding area became active with high seismicity frequency.

Refer to the geological map of Yogyakarta, some areas of Opak fault line surround Kretek, Pundong, Imogiri, Jetis, Piyungan, Pleret and Prambanan. This Opak fault has same direction with Opak river where there are 2 areas East block and West block with a width fault approximately around 2.5 km [3]. Field observations on fault zone suggests that the Opak fault is active, this semi detail has given an idea that the fault zone is characterized by the presence of segments of smaller sizes a few cm to a few dozen metres [3].

The area around Opak fault is Wonosari formation it showed in **figure 1**. The formation consists of Wonosari subzona Wonosari and Sewu Mountain subzona Wonosari, to consist of the part of the South Mountain with limestone as a bedrock, while clay deposits of material surface is black and the ancient Lake. On the sub mountain zones are present, have the characteristics of limestone rocks that make this area into a region with landscapes of karts.



Tmn	Nganglaran formation	Breksi mt merap, breksiflow, lava,tuf andesit
Tmse	Semilir formation	Mix between breksi and tuf, pumice, tuf dasit, tuf andesit and clay tufan
Tmwl	Wonosari formation	Limestone, kalkarenit, kalkarenit tufan
Qmi	Mount Merapi sedimentation	Tuf, breksi,konglomerat, lava

Figure 1. Geological map of Yogyakarta [4]

2.1 Picking

Picking process use for obtaining primary earthquake wave arrival time (tp) and secondary wave (ts) then it can be acquired origin time (to) of each event earthquake, origin time value can be used to be known earthquake waves t ravel time from the source to the stations. This process was done for 3 components i.e. x, y and z. In conducting the process of picking (**figure 2**) from 12 station, at least 3 stations that recorded the earthquake waves on a range of time scales of 1-6 seconds.

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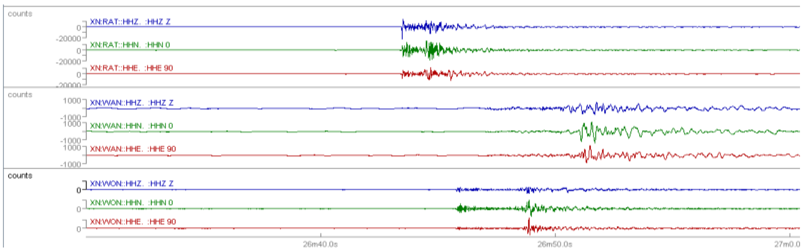

Figure 2. Picking earthquake wave, data processing start with picking earthquake waves and obtains total 625 earthquakes with small intensity

Picking result need to compare between Vp and Vs, at the time the earthquake occurred the area around the epicenter theoretically will experience in pressure change. This pressure can be observed from the changes while the speed of seismic waves revealed by the change of the Vp/Vs. According to Hurukawa Vp/Vs ratios ranging from 1.73 on the outside crust of the Earth where a lot occurrence of an earthquake, but when the circumstances are not met then the magnitude of Vp/Vs would decline or increase in relative [5]. Wadati diagrams (**figure 3**) can actually be used for determination of hypocenter assuming the Earth layer is homogeneous,. On this research Wadati diagram used to ensure that data at the time of the earthquake wave picking manually been good or have no large error values by looking at the comparison of the Vp/Vs.

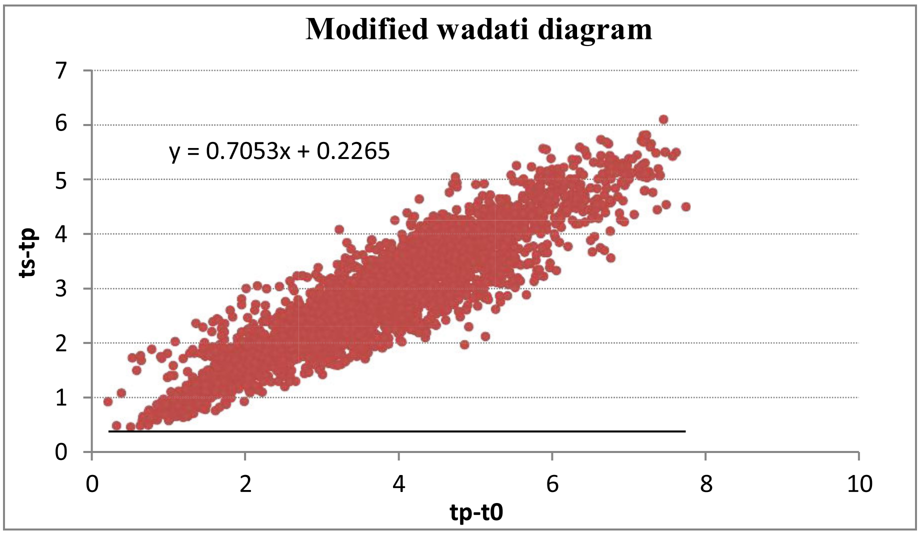

Figure 3. Result of wadati diagram

2.2 Geiger's Adaptive Damping (GAD)

Earthquake hypocenter is a position where the strain energy stored in the rocks was first released, and is the point where the Ridge/cracks begin to burst. It occurred at a depth of hypocenter under epicenter. On the determination of hypocenter required recording earthquake need someparameters such as time arrived P wave (tp), time arrived S waves(ts) at each station of the recorder.

Initial hypocenter determination using Single Event Determination (SED) with Geiger method and GAD (Geiger's Adaptive Damping) for software that used to locate the hypocenter [6], synthesis model used to verification GAD program. The principle of this method is iteration procedures with least square optimization where the square of minimum residual travel time of seismic wave at each seismometer are used. Parameters are used in the processing of data including time of arrival at the seismic wave, location of seismometer and velocity model are used.

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2.3 Modified Joint Hypocenter Determination (MJHD)

Parameter to calculate hypocenter using MJHD is origin time, latitude, longitude, depth, magnitude and number of phases in the event of earthquake. and there is still information on Registrar stations along with its parameters, namely within arrived P wave on the station with origin time in the order of seconds, the value of the residue, the distance and azimuth. Input data in this software starts by determining value of MEQ and MNST. MEQ is minimum number of earthquakes were recorded at all stations while MNST is minimum number of stations that recorded an earthquake occurrences, goals in the specify value MEQ and this in order to eliminate MNST earthquake data that does not fit, so after set value of MEQ and this event MNST earthquake there will be reduced. This research process is done using the hypocenter relocation value MEQ 4.5 and 6, it is because the consideration that there are total of 12 stations on the earthquake recorder so that the addition value MEQ and MNST 1/3 up to ½ of the total value of the station recorder.

3. Result and Discussion

3.1 Initial hypocenter

Total 625 events micro-earthquake in early hypocenter, result can be seen on image of initial distribution hypocenter of earthquake fault area collected in the Opak part formation of Wonosari, Opak sesar at the mark with a thick line on the map. seen the position of earthquake recording stations still in the neighborhood area of Opak sesar that can be very clearly record the existence of vibration caused Opak fault movement.

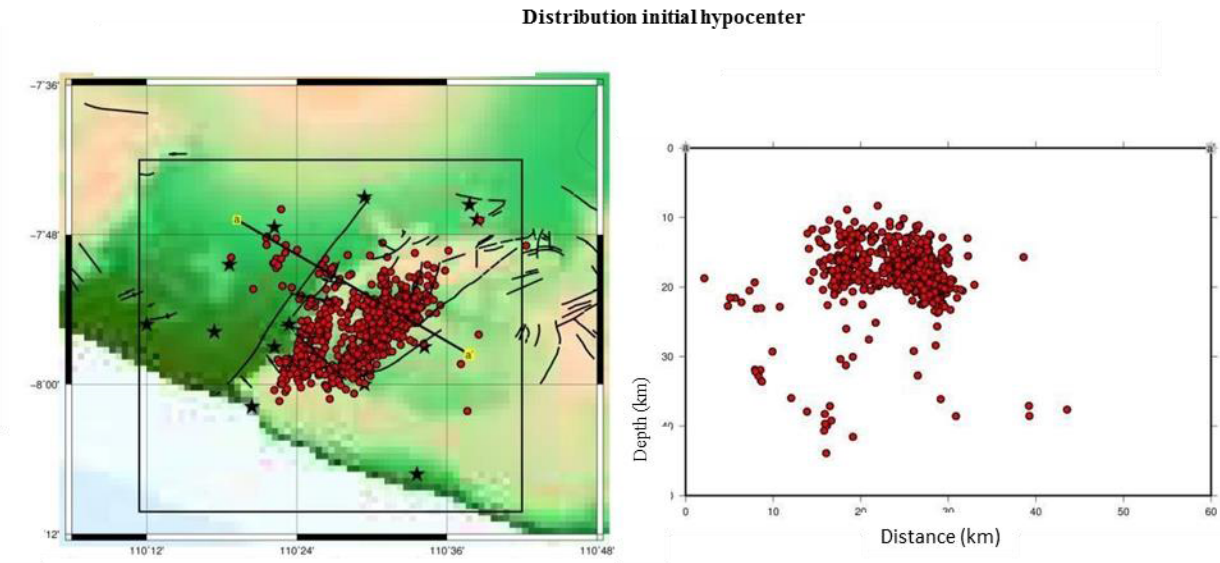
Hypocenter distribution results using GAD software showed several points which are not at the epicenter of the trend point other epicenters, it can be due to timing errors wave arrive in a capture station manual with process of picking waves. Naturally the Earth's surface is always experiencing seismic vibration with range of amplitude 10^{-4}-10^{-2} (mikrotremor). and the mikrotremor vibe caught by seismogram with variable intensity of vibration that can be caught on a seismogram vibration can be either human activities such as the car drove up the tree, vibration etc, determination of wave arrived first (tp) on the data a seismograph can be influenced by the presence of noise.

The result showed distribution of hypocenter using velocity model aka135 in line with path of opak fault (northeast- southwest). It showed that the occurrence of energy release is derived from a set points of epicenter and occurred at a depth of 10-25 km beneath the surface (**figure 4**). The use models of subsurface speed greatly influence the results of the distribution of epicenter, aftershock data including magnitude earthquake are small and relatively shallow depths (< 70 km) [7].

3.2 Hypocenter Relocation

Hypocenter initial coordinates that has been gained from GAD used as data input for the relocation process using MJHD. The difference is determination of hypocenter using GAD all data results were used in determining the picking coordinates hypocenter, whereas at MJHD done some filters so that out of total 625 earthquake events, after a filter then the program produces only 413 MJHD earthquake event. There are 212 events that is filtered, it is due to the determination of MEQ value and input on program MJHD. The value of MEQ is 5 so if there’s a number of earthquakes recorded stations less than 5 then the event will not be included in the calculation of the program as well as the value of the specified MNST, if an event is recorded only less earthquake of the five stations that event then the recorder will not enter into the calculation program MJHD. Relation between the number of earthquakes with a value MEQ and MNST is inversely proportional.

MJHD program has parameter value of longitude, latitude and the maximum value of Z, which was the value of the midpoint or the center cluster from result of initial hypocenter. As in **figure 5** the asterisk symbolizes midpoint value of the overall position result of hypocenter either from longitude, latitude and the depth value is also limited to 50 km considering the early results showed the depth of the hypocenter of the earthquake the maximum is at 45 km.



(a) (b)

Figure 4. (a). Result of initial hypocenter using GAD showed hypocenter distribution around the fault. (**b).** Hypocenter distribution beneath the surface accumulates at depths of 10-25 km.

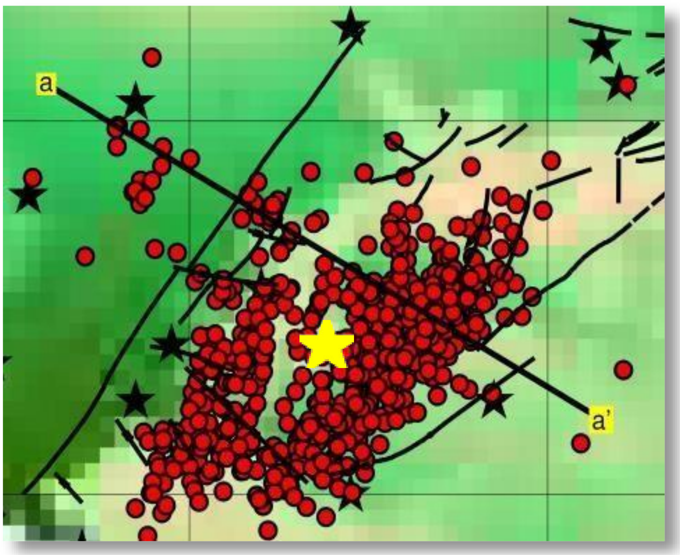


Figure 5. Episenter distribution around opak fault (center cluster of epicenter showed as asterisk symbol, line a to a' showed the slicing that used to obtain the depth of epicenter).

Results showed the epicenter distribution with northeast-southwest and parallel position with Opak fault, this event indicates that the earthquake is influenced by the activity of the subduction zone (**figure 6**). The position of the hypocenter relocation that have showed the presence of shifting position on either the value of longitude, latitude or depth value, distribution direction are leaning towards the East, collected on a minor fault which is also located in the East of the fault ruptured along the minor. East Opak areas more brittle and easier to release energy when the pressure is below the surface while the area to the West fault tend to be composed of rocks that have a high compaction.

Energy release below the surface a lot happened on East and Southeast during the Wonosari formation and showed the area has high seismic activity. Southern part mountains with surface material deposition is black clays and ancient lakes and rocks are essentially composed of limestone..

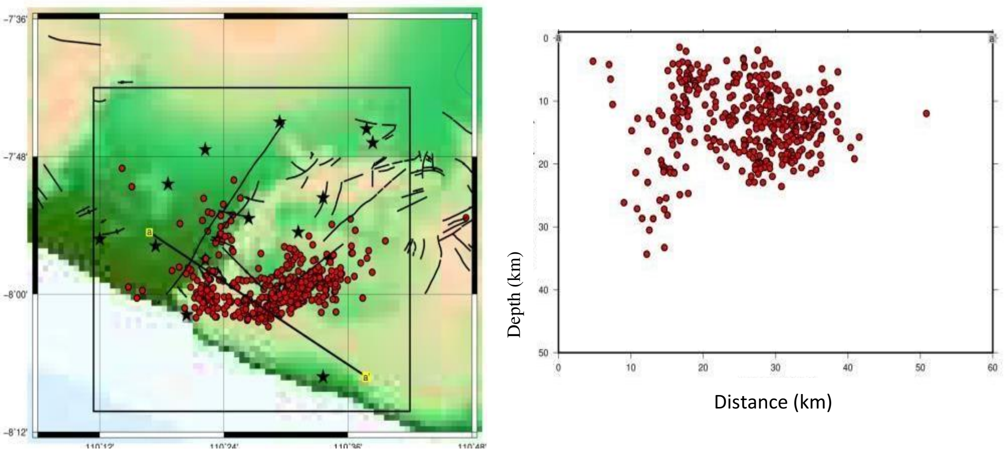


Figure 6. Result of initial hypocenter using MJHD showed hypocenter distribution around the fault

Based on the Surono reasearh which have 800 meters thickness of Wonosari formation, and earthquake hypocenter distribution seen beneath the surface tends to be collected at dept of 10-25 km indicates that the source of the quake did not come from the Wonosari formation but comes from another of the older formations under Wonosari (Tmwl) such as the formation of Oyo (Tmo), Breezy (Tms), Sambipitu (Tmss), Nglanggaran (Tmng), Kebobutak (Tomk), Limestone Wungkal (Tew) and Malihan (Ktm) [8]. Hypocenter of the earthquake that is estimated. To be associated with Wungkal and Malihan Limestone formations that have old age as shown in **Figure 6.** Research on geological condition of surrounding Opak ever done by Walter, et al, in his research say that the west part of Opak fault consists of igneous rock which is caused by deposition of lava originating from the eruption of Mount Merapi, while in the east part of deposition of lava in the volcano found on Opak fault [9]. Viewed in terms of the depth earthquake distribution focused on depth range of 10-25 km which is far below the estimated

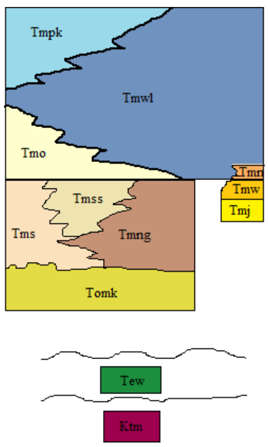


Figure 7. Litologi formation on the east area of sesar opak [4]

Wonosari formation is composed of soft sedimentary rock and also be seen from **Figure 6** there is minor fault in East part of Opak fault.Research on geological condition of surrounding Opak ever done by Walter, et al, in his research say that the west part of Opak fault consists of igneous rock which is caused by deposition of lava originating from the eruption of Mount Merapi, while in the east part of deposition of lava in the volcano found on Opak fault [9]. Viewed in terms of the depth earthquake

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distribution focused on depth range of 10-25 km which is far below the estimated Wonosari formation(**Figure 7**) is com sedimentary rock and also be seen from **Figure 7** there is minor fault in East part of Opak fault.

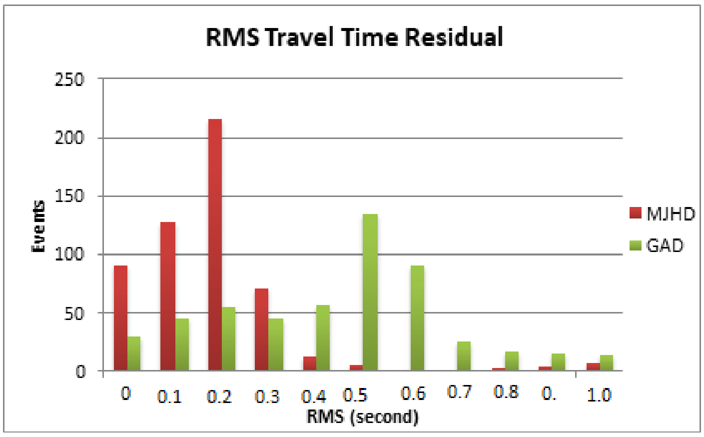

Figure 8. RMS Travel Time Residual Histogram.

Distribution hypocenter after relocation has better RMS value when compared with initial hypocenter. Residual rms value average obtained around 0.11318 seconds (**Figure 8**). Time arriving P wave (tp) of the local earthquake will give the value of the rms travel time small residual, Cause timing of wave arrived at station recorder will affect magnitude value of travel P time wave observation and generate residual time travel which is close to zero.

4. Conclusion

Hypocenter relocation method using MJHD results experienced a shift from the hypocenter distribution of hypocenter relocation early, shifted to the East and has a distribution of residual traveltime rms the dominant range 0.0-0.3 seconds. The rms value of small shows the hypocenter relocation results more accurate. Hypocenter focused on the eastern part of sesar Opak showed the area more vulnerable to experiencing a discharge of energy and becomes a collection of dots epicenter.

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