THE EFFECT OF PICKING UNCERTAINTY WINDOW INTERVAL (∆tp) ON HYPOCENTER MICRO-EARTHQUAKE (MEQ) LOCATION USING GEIGER METHOD

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ABSTRACT

Identification of the initial phase of the primary (P) waves at each seismic station is often inconsistent and implies the operator's subjectivity, due to the high noise level. Errors in identifying the initial phase of the P waves can significantly bias the location of the hypocenter. In this study, the data used is one micro-earthquake (MEQ) event recorded by 8 seismic stations. At each seismic station, the P waves arrival time was measured repeatedly, to obtain the picking uncertainty time window interval (Δtp) of the P waves arrival time. The P waves arrival time data was processed using the Geiger method to obtain the MEQ hypocenter location. Based on the processing results, the determination of the arrival time of the P waves depends on the width of the time window and the amplitude scale used. The picking uncertainty time window interval (Δtp) will be narrower for arrival time observations with an enlarged time window and amplitude scale. Δtp in the range of 0,007-0,049 seconds, in this study significantly refracted the MEQ hypocenter location. The results of determining the location of the MEQ hypocenter using the Geiger method only produced two variants of the RMS error value with a difference of 0.001 seconds. However, the difference in the RMS error value is associated with a shift in the epicenter in the range of 2 – 21,1 meters and a shift in the elevation of the hypocenter in the range of 3-15 meters.

Keyword: Arrival time, epicenter, Geiger, hypocenter, MEQ, picking, Δtp

Introduction

Consistent timing of seismic wave arrivals (Primary and Secondary waves) is very important but has received little attention [1]. Primary waves arrival time (P) is one of the fundamental data in the inversion procedure, one of which is in determining the location of seismic sources. Determination of the arrival time of high-quality seismic waves contributes more to the determination of the location of the seismic source (earthquake hypocenter) with a high degree of precision [2,3], so that it can provide a big picture that truly represents the dynamic conditions of an area [1,4,5,6].

The problem in identifying MEQ events is that the identification of the initial phase of the Primary (P) waves at each station is often inconsistent and implies subjectivity. This is because seismic recordings in geothermal fields generally have high noise levels [3, 4], which causes the initial impulse of the P waves to be obscured. The error in identifying the initial phase of the Primary (P) waves can significantly bias the hypocenter location and velocity model in the inversion method [8]. So, it is necessary to analyze the effect of the picking uncertainty time window interval (Δtp) of the arrival time of the P waves on the location of MEQ hypocenter using the Geiger method in the geothermal field area.

Methodology

This study used MEQ RAW (waveform) data derived from 8 seismic stations recordings in the geothermal field area. The distribution of the location of the seismic stations used in this study is shown in Figure 1 and 2, the coordinates of the locations in this study

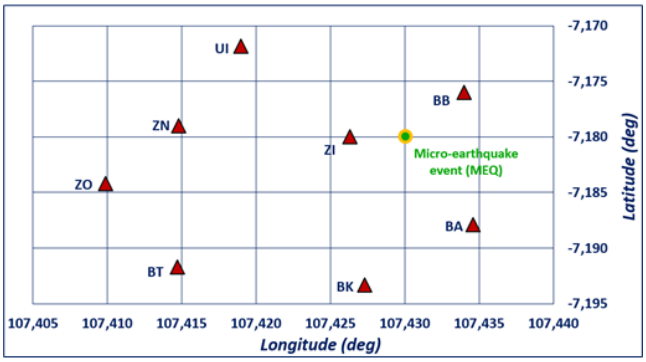

Figure 1. Epicenter and seismic station location

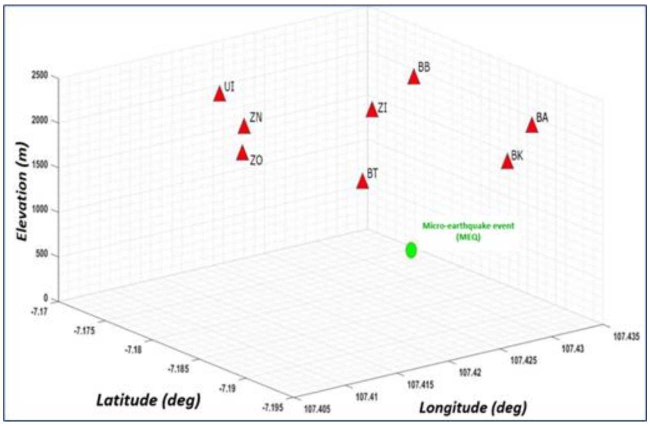

Figure 2. Hypocenter and seismic station location

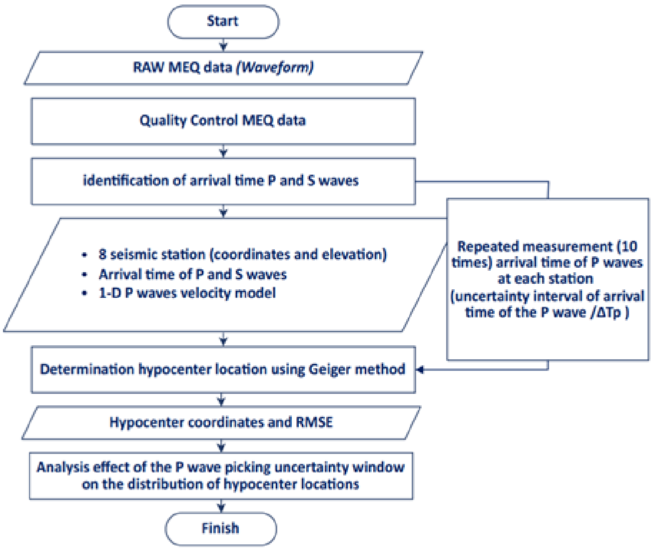

Figure 3. Flowchart

were disguised because they contained information about the geographic location of the geothermal field used, this is related to the regulations of the data owner company. So, the coordinates will be written with the letter 'x' for the number before the fraction separator (comma), and only include the number after the fraction separator (e.g., xxx,405 degree).

From the 8 seismic stations, one MEQ event was determined with the same recording time. In the MEQ event, treatment was given in the form of determining the arrival time of the P wave repeatedly (10 times) to obtain the uncertainty picking time window interval (Δtp). The seismic wave arrival time data was then processed using the Geiger method to obtain the MEQ hypocenter location, as shown in the flowchart Figure 3.

Determination of the picking uncertainty time window interval (Δtp) of Primary Wave Arrival Time (P)

There is no universal definition of wave arrival time, but it is generally possible to do this by manually observing the amplitude, known as the amplitude-based signal-to-noise ratio (ASNR). The arrival time is determined when a change in impulse amplitude (wave discontinuity) exceeds the noise threshold (background) on the seismogram [5, 6]. The determination of the arrival time in this study was repeated 10 times as shown in Figure 4, by adjusting the width of the time window and the amplitude scale. Thus, the uncertainty picking time window interval (Δtp) of the arrival time of the P wave for each seismic recording station can be determined as shown in Figure 5.

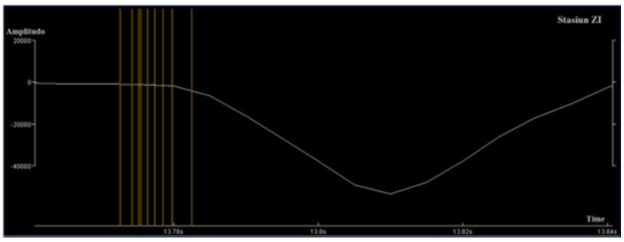

Figure 4. Repeated determination of the arrival time (Arrival Time) of the P wave (10 times) at Station ZI

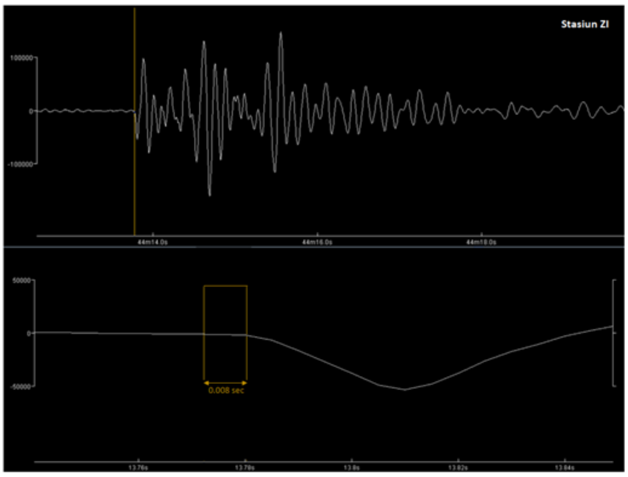

Figure 5. Picking uncertainty time window interval (Δtp) of the arrival time of the P wave at station Z

Determination of the location of the MEQ hypocenter using the Geiger method

The arrival time of the P wave from repeated measurements in the previous process were the main data in the next processing, namely, determining the location of the MEQ hypocenter using the Geiger method. The Geiger method is a method for determining a single hypocenter by calculating the residual time or the difference between the observed time and the calculated time [10]. The Geiger method is an inversion method that uses input data including arrival time, seismic station coordinates, 1-D seismic wave velocity model and MEQ parameters [8, 9]. The output generated from the processing using the Geiger method includes MEQ parameters in the form of the time of the earthquake (origin time), the RMS error value and the coordinates of the MEQ earthquake hypocenter [5]. These parameters were then analyzed as summarized in the flow diagram in Figure 3.

Result and Discussion

Based on the repeated determination of the arrival time of the P wave, 10 times, at each seismic station, the determination of the arrival time of the wave depends on the width of the time window and the amplitude scale used. The picking uncertainty time window interval (Δtp) would be narrower for arrival time observations with an enlarged time window and amplitude scale. Based on this procedure, 80 P wave arrival time data were obtained from 8 seismic stations. The data was processed using the Geiger method to obtain the location of the MEQ hypocenter and information related to the MEQ earthquake parameters as summarized in Table 1 and Figure 6.

On Table 1, the uncertainty interval of the P wave arrival time varies greatly at the stations used in the study. However, if we pay attention to the direction of the shift in the epicenter location for each station, the trend is the same. The location of the epicenter as a result of the processing using the arrival time that is close to the largest arrival time value tpmax for each repeated measurement is always shifted away (opposite) from the location of the recording station as summarized in Figure 6.

Table 1. The results of 10 times repeated measurements of the arrival time of the P wave and the determination of the location of the hypocenter using the Geiger method

Station	**Δtp** (sec)	**tpmin** (sec)	**tpmax** (sec)	**Distance** (m) (tpmin and tpmax)	**RMSE** (sec) Repeated measurement (10times)
ZI	0.008	13.772	13.780	2.0122	0.118
UI	0.021	13.952	13.973	12.115	0.118
ZO	0.012	14.152	14.164	4.0295	0.118
ZN	0.010	14.035	14.045	2.8475	0.117
BA	0.020	13.812	13.832	5.8721	0.118
BT	0.007	14.145	14.152	2.2503	0.118
BB	0.009	13.767	13.776	5.0328	0.117
BK	0.049	13.895	13.944	21.1283	0.118

Description:

Δtp = P waves picking uncertainty time window interval (tp_{max}-tp_{min})

tp_{min} = Smallest P waves arrival time value

tp_{max} = Largest P waves arrival time value

Distance = The distance from the farthest epicenter of repeated measurements

Δz = Elevation difference tp_{max}-tp_{min}

RMSE = RMSE average

At station ZI, the picking uncertainty time window interval (Δtp) of the arrival time of the P wave is 0,008 seconds, with tpmin at 13,772 seconds and tpmax at 13,780 seconds. In the picking uncertainty time window interval (Δtp) the farthest distance of epicenter shift (tpmax dan tpmin) is 2 meters towards the southeast, while for the other stations, it is summarized in Table 1 and Figure 6.

Based on the graphs in Fig. 7 and Table 1, the change in the width of the picking uncertainty time window interval (Δtp) of the arrival time of the P wave is directly proportional to the shift distance of the epicenter location (tpmax dan tpmin). The smallest picking uncertainty time window interval (Δtp) is 0,007 seconds, resulting in a shift of the epicenter as far as 2,3 meters, and the largest picking uncertainty time window interval (Δtp) is 0,049 seconds, resulting in a shift of the epicenter as far as 21,1 meters. The furthest epicenter shifts occurred at UI and BK stations, both stations on the order of tens of meters. This is related to the less significant changes in the impulse amplitude of the incident wave recorded at the two stations, which then has an impact on the width of the picking uncertainty time window (Δtp).

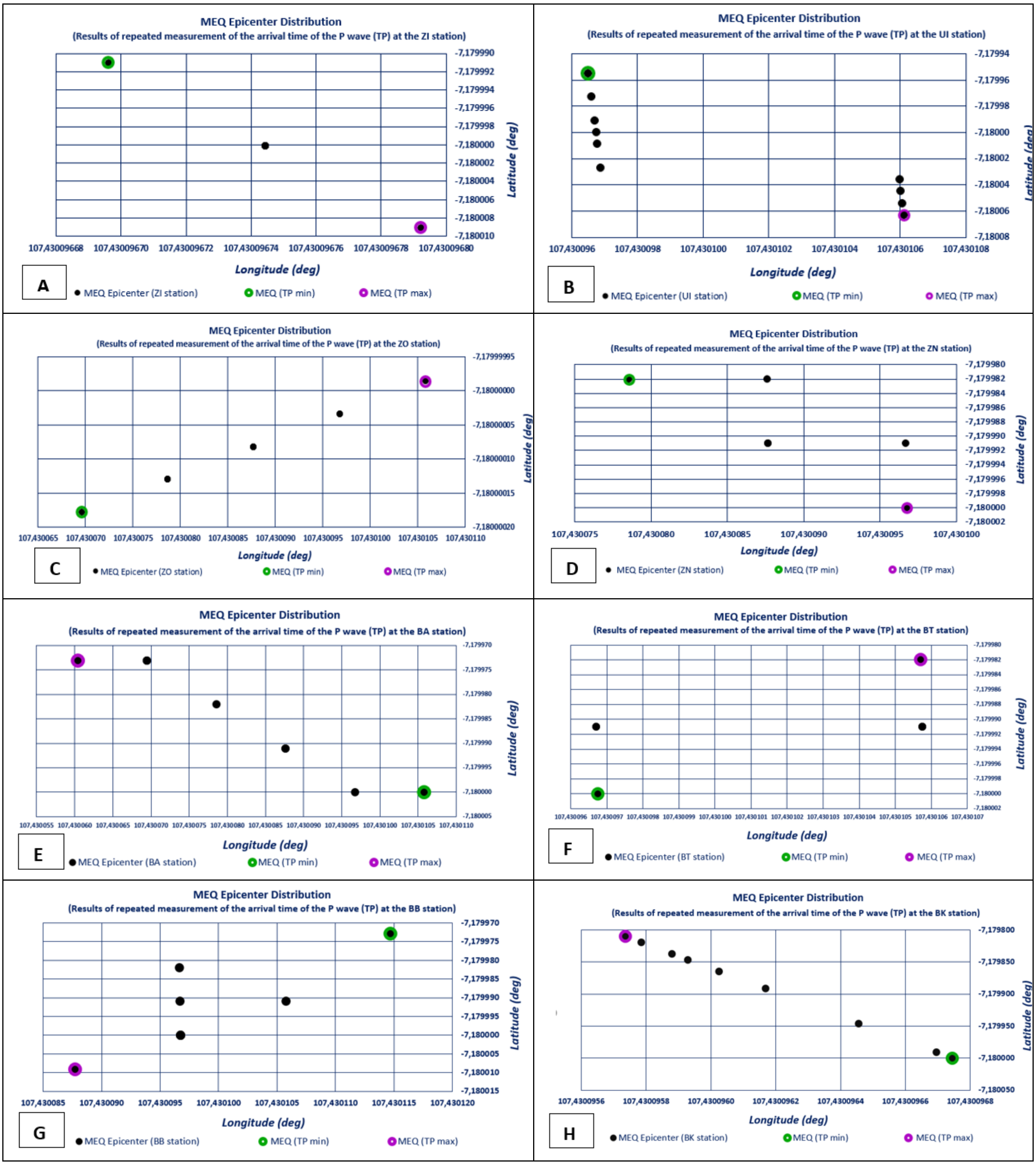

Figure 6. Picking uncertainty time window interval (Δtp) of P wave arrival time at station ZI

Based on the MEQ elevation histogram in Fig. 9, the skewness value is > 0 which means that the distribution of the elevation values is not symmetrical because the elevation values extend to the right. This is because the elevation mean value is greater than the median value and the mode value, therefore the elevation data graph has a right skewed distribution. This shows that the elevation value is concentrated to the left of the mean value with the largest distribution being at an elevation of 321-324 meters (69% of the total data).

While the value of the MEQ RMS error resulting from the determination of the location of the hypocenter using the Geiger method from 80 hypocenter points only has 2 variants of the RMS error value. Although the picking uncertainty window interval (Δtp) of the

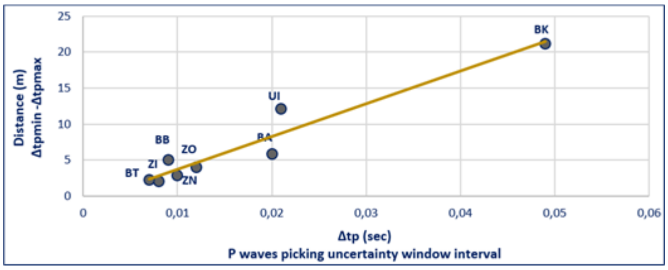

Figure 7. Graph of the P wave picking uncertainty time window interval (Δtp) to the shift distance of the epicenter point

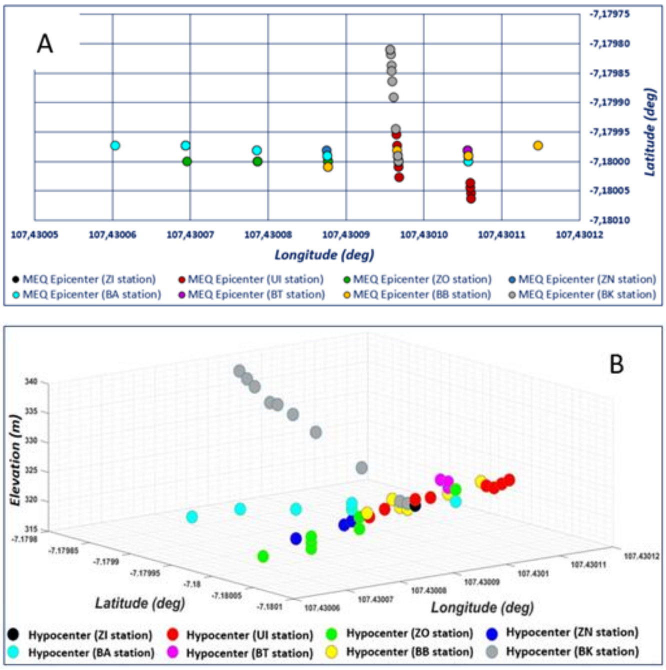

Figure 8. (A) Distribution of MEQ 2D epicenter locations (Results of repeated measurements of P wave arrival time for each station) and (B)) Distribution of 3D MEQ hypocenter locations (Results of repeated measurements of P wave arrival time for each station)

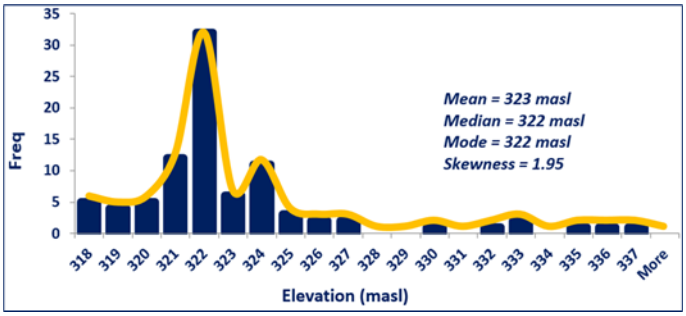

Figure 9. Histogram of MEQ elevation

arrival time of the P wave reaches 0.049 seconds (the widest Δtp in this research), the RMS error value still has two value variants, 0,117 and 0,118 seconds. However, the difference in the RMS error value was 0,001 seconds followed by a shift in the location of the epicenter as far as 21,1 meters and a depth of 15 meters. This becomes the basis for determining the location of the hypocenter with large seismic data (long recording time and a large number of stations) requiring quality control of the hypocenter resulting from the inversion method which is not only based on the RMS error value, but other control parameters are necessary to be added, such as suitability with the geological conditions of the area and other supporting data. The results of this study indicate that the picking uncertainty time window interval (Δtp) of the arrival time of the P wave significantly biases the location of the MEQ hypocenter as a result of Geiger's method processing. The shift of the epicenter is at the interval of 2,0 – 21,1 meters and the shift of the elevation of the hypocenter is at an interval of 3-15 meters, the shift in the location of the hypocenter indicates a biased hypocenter location.

Conclusion

The determination of the arrival time of the P wave depends on the width of the time window and the amplitude scale used. The picking uncertainty time window interval (Δtp) will be narrower for arrival time observations with an enlarged time window and amplitude scale. Δtp in this study ranged from 0,007-0,049 seconds, significantly biasing the MEQ hypocenter location. The results of determining the location of the MEQ hypocenter using the Geiger method only produced two variants of the RMS error value, 0,117 and 0,118 seconds (0,001 seconds difference). Although the difference in the value of the RMS error is very small, it is associated with a shift of the epicenter in the range of 2 - 21,1 meters and a shift in the elevation of the hypocenter with an interval of 3 - 15 meters. Thus, to determine the location of the hypocenter with large seismic data (long recording time and large number of stations), the quality control of the hypocenter as a result of the inversion method is better not only based on the RMS error value, but other control parameters are necessary to be added such as suitability with geological conditions of the area and supporting data such as the location of injection and production wells.

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