Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Identification of Fracture Zones in Geothermal Field Based On Microseismic Events

Bambang Mujihardi[1,2], Andri D. Nugraha[3], Sri Widiyantoro[3], Djedi S. Widarto[1] and Tommy Hendriansyah[1]

[1]PT. Pertamina (Persero), Jakarta, Indonesia

[2]Geophysical Engineering Study Program, Faculty of Mining and Petroleum Engineering, ITB, Bandung, Indonesia

[3]Global Geophysical Research Group, Faculty of Mining and Petroleum Engineering, ITB, Bandung, Indonesia

E-mail address, bambang.mujihardi@pertamina.com

Keywords: Fracture, Geothermal, Microseismic, GAD.

ABSTRACT

This paper describes the identification of fracture zones in geothermal fields based on microseismic events with see hypocenter distribution. An important step in hypocenter determination is how to determine the phases of P- and S-wave arrival times at all stations. In this study, we applied filtering techniques (i.e. band-pass and low-cut filters) to suppress noise and conducted S-transform analysis to improve the picking quality of unclear P- and S- wave arrival times. The initial locations of microseismic events were determined using the Geiger Adaptive Damping (GAD) method. We selected microseismic events with time residuals (i.e. the difference between S-wave arrival time (ts) and P-wave arrival time (tp)) of less than 2 seconds. Our preliminary results show that the initial events are distributed in the central southwestern parts and northeastern parts of the seismographic station network. The events seem to be more clustered in the same region at depths of 0-1 km below the mean sea level (MSL) in the central part, at depths of 0-2 km below MSL in the northeastern part and at depths of 0-8 km below MSL in the southwestern part of the station network. Epicenter distribution has a pattern which can be interpreted with predominantly NE-SW strike direction as shown by the rose diagrams. A major fracture is observed at depths of about 1200-1300 m. For future work, we will add more data coverage and conduct seismic tomography to determine 3D seismic velocity structure. We expect to be able to further improve the accuracy of the hypocenter relocation by using the resulting 3D velocity model and to identify detailed fracture zones in the study area.

1. INTRODUCTION

Microseismic waves caused by a local movement in the subsurface with a low magnitude usually have travel time difference of P and S waves between 0.02-2.6 seconds with duration of less than 10 seconds. Examples of movement that can be categorized as generating microseismic waves include fracture, fluid injection processes, drilling activity, and fluid migration.

Determination of the location of microseismic sources can be done using the arrival time of P and S waves recorded at seismographic stations. The accuracy of the arrival time picking of P and S waves is crucial to obtain an accurate hypocenter location. Application of filters to the microseismic data recording is necessary to reduce the presence of noise. Recordingmicroseismic events using instruments with 3 (three) components will provide data in the vertical direction (Z), the North-South (N-S) and East-West (E-W) directions. P-wave arrival times can be easily estimated by observing the data on the vertical component (Z). To determine S-wave arrival times requires transformation to the frequency domain to help pick more accurately.

Epicenter and hypocenter distributions form patterns that can be interpreted as affecting activity of the geological setting in the study area of Pertamina geothermal field in West Java, Indonesia. Fluid injection activities can affect the condition of the subsurface. These patterns can be confirmed from the data of geology and Formation Microscanner (FMS) wells.

2. PRELIMINARY RESULTS AND CONCLUDING REMARKS

Data used in this study are 3 components, P waves with vertical components (Z) and S waves with horizontal components (N-S and W-E) were installed on the surface and were recorded at six stations . In total 465 events, of P- and S- waves arrival times were recorded during 2011. We used a velocity reference based on the field data as initial velocity.

In this study, we determined P-wave arrivals beforehand based on the earlier phases coming at all stations. Once the P-wave arrival times were obtained, generally S-wave arrival times can be determined subsequently. Here, S-transform analysis was applied to improve the picking quality of unclear/biased arrival times. The initial locations of microseismic events were determined using the GAD method (Geiger, 1910; Nishi, 2005).

Interpretation of fractures in the study area was conducted based on the epicenter and hypocenter distributions. Then our interpretation results were compared with the results of FMS data interpretation and structural map available for the study area.

2.1 Preliminary Results

An important step in hypocenter determination is how to determine earlier phases of P- and S-wave arrival times to all stations. In this study, we applied filtering techniques (i.e. band-pass filter) in order to reduce noise. We also conducted S-transform analysis to improve the picking quality of unclear P- and S-wave arrival times. Determining earlier phases of P- and S-wave arrival times to all stations is an important step in hypocenter determination. In this study, we applied filtering techniques (i.e. band pass and low cut filters) to reduce noise. In addition, we conducted S-transform analysis to improve the picking quality of unclear P- and S-wave arrival times. Figure 1 shows a map depicting the geological structures in the study area, which are dominated by NE-SW trending structures. Our preliminary results show that the initial events are distributed in the central, southwestern and northeastern parts of the station network (Figure 2). The epicenter distribution has a pattern, which can be interpreted as fractures (Figure 3) similar to those shown in Figure 1 (i.e. with a predominant strike in the NE-SW direction).

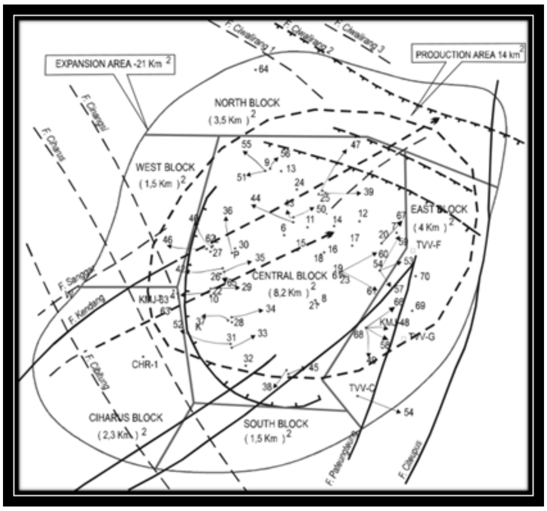

Figure 1: Structural map of the study area.

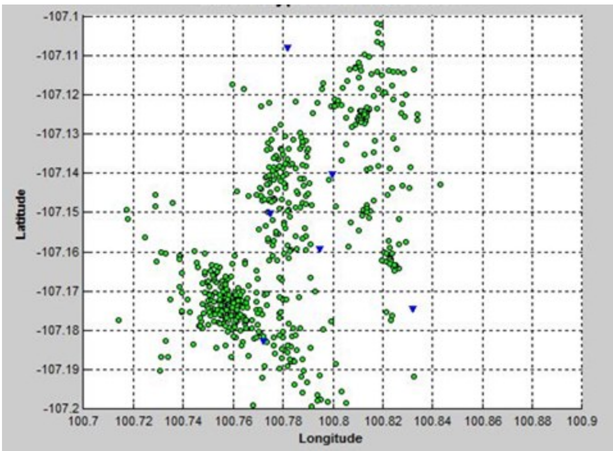

Figure 2: Epicenter distribution. Blue triangles depict seismographic stations.

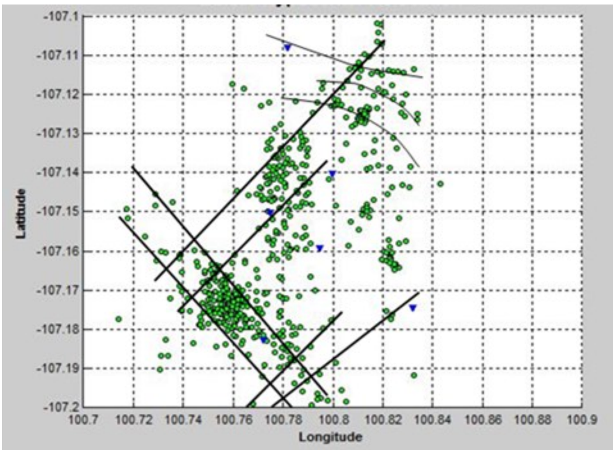

Figure 3: Epicenter distribution overlayed by interpreted fractures (black lines). Blue triangles depict seismographic stations.

Our interpretation is supported by the rose diagrams displayed in Figures 4 and 5. In Figure 6 FMS data show that there is a major fracture at a depth of approximately 1200-1300 m with a dip of less than 90 degrees. The events seem to be more clustered in the same region at depths of 0-1 km below MSL in the central part, 0-2 km below MSL in the northeastern part, and 0-8 km below MSL in the southwestern part of the station network (Figure 7). When interpreted in the W-E hypocenter cross sections (Figure 8), it is seen that the hypocenter distribution pattern forms structures with a dip of less than 90 degrees.

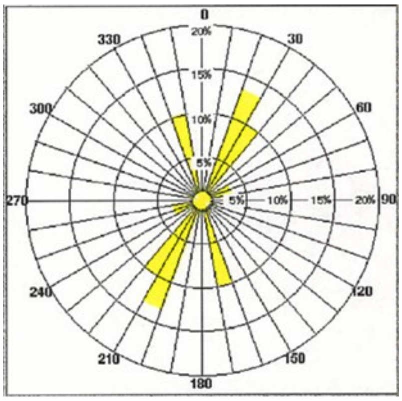

Figure 4: Rose diagram depicting minor fracture strike.

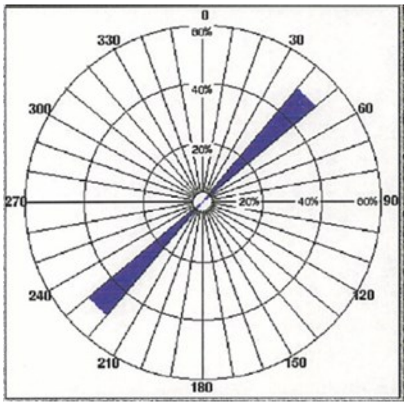

Figure 5: Rose diagram depicting major fracture strike.

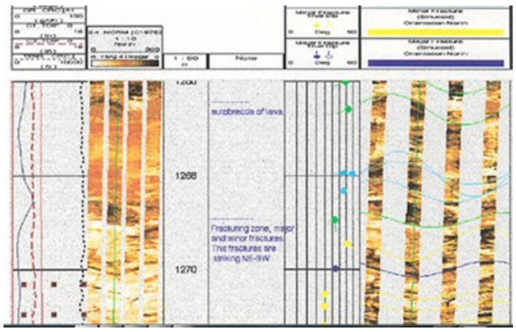

Figure 6: Formation Microscanner (FMS) interpreted fracture zone.

Table 1: 1D Velocity reference.

Layer Number	Layer Thickness (Km)	P-Wave Velocity (Km/Sec)
1	1	3.35
2	4	3.99
3	3	4.37
4	4	4.62

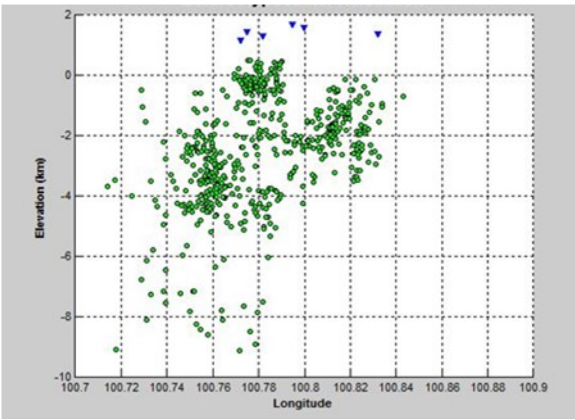

Figure 7: Hipocenter distribution along longitude. Blue triangles depict seismographic stations.

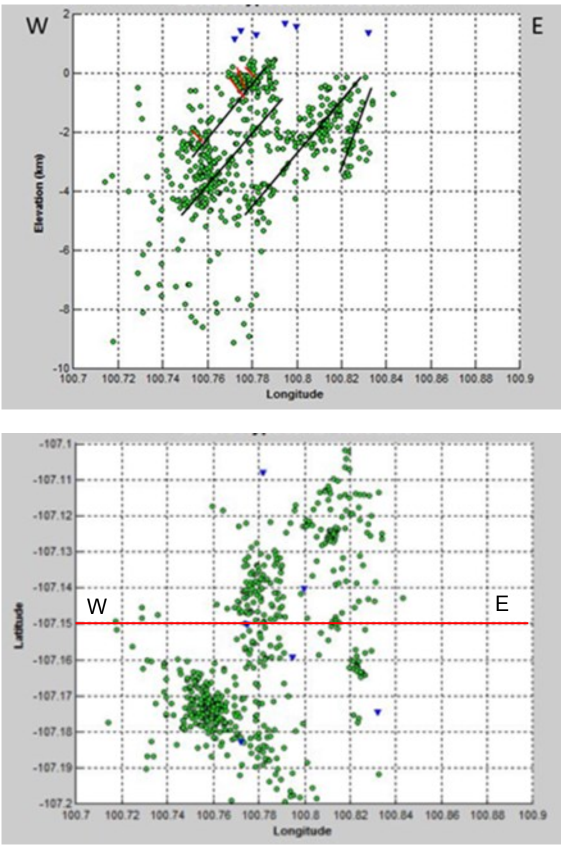

Figure 8: Hipocenter distribution along longitude overlayed by interpreted fracture zone (black lines). Blue triangles depict seismographic stations.

2.2 Concluding Remarks

In this study, filtering is the most important step to suppress noise, and S-transform analysis is useful to improve the picking quality of unclear P-and S-wave arrival times. Limitation was applied to the data with time residuals less than 2 seconds. The initial locations of microseismic events were determined using the GAD method. Epicenter distribution has a pattern which can be interpreted as predominantly strike in the NE-SW direction as depicted by the rose diagrams. The major fracture exists in the depth interval of approximately 1200-1300 m with a dip of about 60 degrees.

REFERENCES

Geiger, L., 1910, Herdbestimmung bei Erdbeben aus den Ankunftszeiten. Nachrichten von der Koniglichen Gesellschaft der Wissenschaften zu Gottingen, Mathematisch-Physikalische Klasse, 331-349.

Errington, A., 2006, Sensor Placement for Microseismic Event, A Thesis Submitted for the Degree of Master of Science in the Depatrment of Electrical Engineering, University of Saskatchewan, Saskatoon.

Nishi, K., 2005, Hypocenter calculation software GAD (Geiger's Method with Adaptive Damping), ver 1 JICA report – May 2005.

Pertamina, 1998, Formation Micro Scanner Report.

Pertamina, 2004, Sructural Geology Study in Geothermal Field Report.

Wolfe, J. E., 2007, Microseismic Measurement of Fracture Geometry using Synchronized Three Component Geophone Extended Arrays, CSPG/CSPE Geoconvention 2007, Calgary, Alberta, Canada, May 14-17, 2007