Determination Hypocentre and Focal Mechanism Earthquake of Oct 31, 2016 in Bone, South Sulawesi

Muhammad Altin Massinai, Muhammad Fawzy Ismullah M
Geophysics Dept., Hasanuddin University
E-mail: altin@science.unhas.ac.id

Abstract. Indonesian Meteorology, Climatology and Geophysics Agency (BMKG) recorded an earthquake with M4.6 on at October 31, 2016 at Bone District, around 80 Km northeast from Makassar, South Sulawesi. The earthquake occurred 18:18:14 local time in 4.7°S, 120°E with depth 10 Km. Seismicity around location predicted caused by activity Walennae fault. We reprocessed earthquake data to determine precise hypocentre location and focal mechanism. The P- and S-wave arrival time got from BMKG used as input HYPOELLIPSE code to determine hypocentre. The results showed that the earthquake occurred 10:18:14.46 UTC in 4.6380S, 119.9660E with depth 24.76 Km. The hypocentre resolved 10 Km fix depth and had lower travel time residual than BMKG result. Focal mechanism determination used Azmtak code based on the first arrival polarity at earthquake waveform manually picked. The result showed a reverse mechanism with strike direction 38°, dip 44°, rake angle 134° on fault plane I and strike direction 164°, dip 60°, rake angle 56° on fault plane II. So, the earthquake which may be related to a reverse East Walennae Fault.

1. Introduction

Monday October 31, 2016, tectonic earthquake occurred at Bone, South Sulawesi. The analyzed result from BMKG (Indonesia Meteorology, Climatology and Geophysics Agency) showed that earthquake occurred on 18:18:14 LT (Central Indonesia Time) with M4.6 and epicentre located at 4.7°S, 120°E with 10 km focus depth, 80 Km eastern Makassar. The earthquake impact felt in many areas like Makassar, Soppeng, Bone, Camming, Watanlamuru, Watampone, Mare’, Soreang, Maros, Mandai, Campae and Rala on intensity scale II SIG-BMKG (III MMI). Citizen of this area reported run out to rescue [1].

The epicentre located at Walennae depression, which located between West Walennae Fault (WWF) and East Walennae Fault (EWF) as part of Walennae Fault. Walennae Fault is reverse fault [2]. WWF is a sinistral strike-slip fault and EWF as a reverse fault with a dextral component of slip. This area covered by Camba volcanic and sandstone Neogene, volcanic and Salokalupang fm (sedimentary and volcanioclastic rock) Paleogene and plutonic and metamorphic rock, volcanic rock, sedimentary rock [3].

The first step to study about seismicity and his relations to fault is hypocentre determination. Hypocentre required to study structure, tectonic regime and processes that trigger seismic activity [4]. Hypocentre accuracy depends on factors, one of them is small travel time residual. Many techniques had developed to determine hypocentre become precisely. One of them is Geiger’s method [5]. The basic of this method are minimizing travel time residuals between observation data and calculated travel times by calculating using distant seismic networks by employing spherical earth travel time [6].
The second step are moment tensor analysis. Moment tensor described by focal mechanism, is method to know tectonic force regime which caused earthquake.

This research used seismogram data onto BMKG stations on Sulawesi. The aim at this research is to get more geological information on earthquake analysis: hypocentre determination and focal mechanism.

2. Data and Methods
We used HYPOELLIPSE [7, 8] code to determine hypocentre using arrival time data from BMKG. HYPOELLIPSE code locates a hypocentre based on Geiger’s method [5] which minimizes travel time residuals between observation data and calculated travel times [6]. This code also allows to calculate using distant seismic networks by employing spherical earth travel time tables [9]. We used IASP91 velocity model was adopted from [10].

Focal mechanism of the 2016 Bone earthquake was determined using Azmtak [11] code employed first arrival polarity data. We determined first arrival polarity data from seismogram by manual picking. A total of six stations were used to calculate the focal mechanism.

![Figure 1. BMKG shakemap of Earthquake of Oct 31, 2016 in Bone, South Sulawesi [1]. Red star is epicenter.](image-url)
Figure 2. (a) Tectonic map showing the distribution of plates, continents and island arcs in the eastern part of Indonesia. The area of the rectangle corresponds to South Sulawesi shown in (b). (b) Structural and topographic map of South Sulawesi [2].
3. Results and Discussion

Hypocentre of the Bone earthquake based on our inversion is 4.638°S, 119.9663°E with 24.76 km focus depth (figure 1). Our location is located 7.85 km northwest of BMKG location. Furthermore, our inversion is able to resolve the fix-depth. Our location showed lower travel time residual, 0.1385 ms, compared to the BMKG result, 1.318 ms. It showed that our hypocentre is more accurate because able to resolve the fix-depth and have lower travel time residual.

Focal mechanism solution showed a reverse mechanisms with strike direction 38°, dip 44° and rake angle 134° on fault plane I and strike direction 164°, dip 60° and rake angle 56° on fault plane II. This result agree with [3] that said the EWF is reverse fault. We chose strike direction 164° based on fault feature of the topography map of South Sulawesi.

Figure 3. BMKG station (yellow triangle), Epicentre of BMKG (orange circle) and result of this research (blue star).
That is the last earthquake in several years later. This can give information about EWF activity nowadays. The tectonic activity still active until now in this area. EWF dimension can be assumed have activity on 24.76 km. It means activity of EWF is very shallow and can be affected on human activity in surface. It’s possible if EWF activity can make other bigger earthquake in shallower depth. The direction of EWF signed tectonic force activity that created characteristic of EWF.

There was collision of East Sulawesi with the Banggai-Sula and Buton-Tukangbesi blocks, includes thrusting in the northern part of Sulawesi Island, and folding and uplifting in some parts of Bone Basin during the Pliocene. The convergence directions of the micro-continents have persisted in an approximately E-W direction at a high angle to the Walennae fault systems since the Late Miocene. This collision event could have affected the South Sulawesi and activated the EWF [3].

This result showed the activity of EWF caused this earthquake, although this location is in Walennae depression. Sandstone and other sedimentary rock made damage to this earthquake spread into surrounding EWF, but volcanic rock from Bone mountain and Walennae depression can be solved hold the shaking. So, the government and citizen must carefully planning city development around Walennae depression.

4. Conclusions
The Bone earthquake with magnitude 4.6 occurred on October 31, 2016 and located 4.638°S, 119.9663°E with 24.76 km depth. The mechanism of Bone earthquake is reverse with strike 38°, dip 44° and rake angle 134° on fault plane I and strike direction 164°, dip 60° and rake angle 56° on fault plane II. We suggest that this earthquake is may be related to EWF.

Acknowledgements
We gratefully acknowledge the BMKG for arrival time and waveform data. We thank to geophysics dept., Faculty of Mathematics and Natural Science Hasanuddin University (UNHAS) for supporting this research. Figures in this manuscript were created using Generic Mapping Tools [12].

References
[1] BMKG 2016 Gempabumi Darat Guncang Makassar, Dipicu Sesar Aktif www.bmkg.go.id
[2] Massinai M F I, Lantu, Aswad S and Massinai M A 2014 AIP Conf. Proc. 1658 030013-1 – 030013-10
[3] Jaya A and Nishikawa O 2013 Journal of Structural Geology 55 34-49
[4] Massinai M F I, Nugraha A D, Ramdhhan M and Wandono 2017 IOP Conf. Series: Earth and Environmental Science 62 012056
[5] Lahr J C 1979 HYPOELLIPSE: A Computer Program for Determining Local Earthquake Hypocentral Parameters, Magnitude and First Motion Pattern Open-le Report 79-431 US Geological Survey Menlo Park California 310
[6] Lahr J C 1999 HYPOELLIPSE: A Computer Program for Determining Local Earthquake Hypocentral Parameters, Magnitude and First Motion Pattern (Y2K Compliant Version) Open-File Report 99-023 (US Geological Survey Golden Colorado paper and on-line editions) 112 pp
[7] Geiger L 1912 Bull. St. Louis. Univ. 8 60-71
[8] Lahr J C and Snoke J A 2002 Handbook of Earthquake and Engineering Seismology Chapter 85 7
[9] Nugraha A D, Supendi P, Shiddiqi A H, Widiyantoro S 2016 AIP Conf. Proc. 1739 020001-1 – 020001-4
[10] Kennett B L N and Engdahl E R 1991 Geophys. J. Int. 105 429-465
[11] Suetsugu D 1997 Source Mechanism Practice Lecture notes International Institute of Seismology and Earthquake Engineering, Tsukuba, Japan
[12] Wessel P, Smith W H F, Scharroo R, Luis J and Wobbe F 2013 EOS Trans. American Geophys. Union 94 45 409 – 410