ISSN 2338-0152
Volume 3

Proceedings of the 3rd Annual

Basic Science International Conference 2013

Basic Science Advances in Energy, Health and Environment

April 16-17th, 2013 | University of Brawijaya
Malang, East Java, Indonesia

JOIN UB BE THE BEST
UB
UNIVERSITY OF BRAWIJAYA

BaSiC 2013

Faculty of Mathematics and Natural Sciences
University of Brawijaya

PHYSICS

Parallel Session Day TWO - 17 April 2013
Lontar 2 Room: Physics

Time	Paper ID	Author	Title	Moderator
10.00-11.00	P16	Muhammad Farid, Kirbani Sri Brotopuspito, Wahyudi, Sunarto, Wiwit Suryanto	Shoreline Changes and Seismic Vulnerability Index in The Earthquake Prone Areas (The Case of Coastal North Bengkulu, Bengkulu Province-Indonesia)	Saad M. Alshehri
	P17	Deassy Siska, Wiwit Suryanto	Array Technique Application to Determine Direction of Rupture of Tohoku's Earthquake, March 11th 2011	
	P18	Suprianto.A., Wahyud, Suryanto. W., Utama. W., Jaya. M.S., Deon. A., Grassner. A., Putrakusuma. T.M., Putriatni.D., Supoyo, and Erbas. K	Installing Surface Microseismic Monitoring in Mt. Lamongan Geothermal Field, East Java, Indonesia	
	P19	Chrystian Afiko, Sismanto and Taufik Anwar	Analysis of Petrophysics Properties Reservoir using Software Geolog 6.7 with Multimin Method and Calculate Volumetric Reserves Gas on "Sianturi" Field Reservoir G25 Kutai Basin East Kalimantan	
	P20	F. Virgo, A. Zaenudin, Suharno, W. Suryanto and Wahyudi	Magnetic Survey within Penantian Geothermal Area in Pasema Air Keruh, South Sumatra	
	Discussion/Questions/Answers			
	P21	Saad M. Alshehri and Tansir Ahamad	Silver Nanoparticles (AgNP) Loaded Hydrogels and their Antimicrobial and Burn Wound	

Array Technique Application To Determine Direction Of Rupture Of Tohoku's Earthquake

D. Siska and W. Suryanto

***Abstract*— We conduct a study using array technique to determine the rupture direction of Tohoku earthquake, Japan on March 11, 2011 at 05:46 UTC with *Mw* 9.0 (epicenter at 38,297°N ; 142,372°E). The research data was recorded at five stations using three components seismometer short-period type, in West Sumatera. This research began with Array Transfer Function (ARF) configuration *Yellowknife* and ARCESS type of array and then for array at West Sumatera. We use the Warangps from Geopsy software. Further more we used beam forming methode for analize the Fk-movie with MATLAB 7.10 (R2010a) to track the rupture direction of Tohoku's Earthquake. Based of our analysis the back *azimuth* of rupture is changing from 40.18^0 to 46.5^0 with slowness of 4 – 4.4 s/deg. The position of the rupture movement suffered deflection at time intervals of 20 seconds, the first from the epicenter to northeast and then undergo reverse direction toward the southwest. At 70 seconds time intervals, the rupture back turned to the northeast of the epicenter that is gone toward the position of the Japan trenches.**

Keyword—*array seismic, array response function, azimuth, beam forming, rupture, slowness*

I. Introduction

An earthquake is the release of energy in the event of a sudden in the earth that cause vibrations on the surface of the earth. The vibrations radiating in all directions as the seismic waves that propagate from the epicenter through the interior of the Earth. to the surface of the earth. Seismic array technique is a method of recording seismic data using at least three seismometers with a particular configuration. The advantage is that it can produce a signal that has a signal to noise ratio better than the results of the signal from a single seismogram. The using of seismic array techniques have not been popular in Indonesia, although this technique has been introduced since the 1960's [1]. Therefore, in this study will be introduced to an array of seismic techniques to determine the direction of the earthquake rupture in Tohoku, Japan on March 11, 2011.

The research use two data types, parameter data of earthquake source (Tohoku's earthquake, March 11th 2011) and seismogram recorded data from array stations seismometer that area is located in the Padang Panjang District, West Sumatra. The stations are located at 0,69° to 0,98° South Latitude and 100,32° to 102,42° East Longitude.

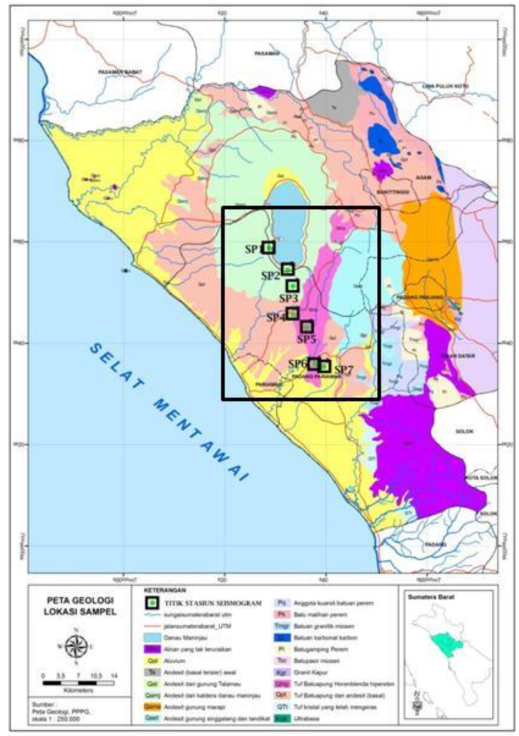

Figure 1. The Research area mapping. Black box indicates areas that the pattern of the station array in West Sumatra is SP2, SP4, SP5, SP6 and SP7.

The earthquake occurred in Tohoku, Japan on March 11, 2011 at 05:46 UTC (14:46 local time) is a large-magnitude earthquake with magnitude 9.0 Mw. This earthquake caused tsunami in the Tohoku region. In addition to the tsunami, the earthquake of March 11, 2011 was also caused rupture area large enough that began in the epicenter of the region along the fault plane.

The Using seismic array techniques have not been popular in Indonesia, although this technique has been introduced since the 1960's [1]. Therefore, in this study will be introduced to an array of seismic techniques to determine the direction of the earthquake rupture in Tohoku, Japan on March 11, 2011 by using beam forming techniques.

The purpose of this study was to determine the direction of the earthquake rupture Tohoku, Japan on March 11, 2011 through the movement direction of the back azimuth and slowness determine the range of values through the array response function of the five-station seismograms recorded data to the configuration of the array in the West Sumatra earthquake in Tohoku case study , Japan on March 11, 2011 at 05:46 UTC.

D. Siska is student of Magister Program, Faculty of Mathematics and Natural Science, Gadjah Mada University, Yogyakarta, Indonesia and Architecture Department, Engineering Faculty, Malikussaleh University, Nanggroe Aceh Darussalam, Indonesia. Yogyakarta, Indonesia. (e-mail: deassy@ymail.com, deassy.siska@mail.ugm.ac.id).

W. Suryanto is with Department of Physiscs, Faculty of Mathematics and Natural Science, Gadjah Mada University, Yogyakarta, Indonesia (email: ws@ugm.co.id, wiwit@gadjahmada.edu, maswiet@gmail.com)

II. BASIC THEORY

Array Seismic

Array seismic is an arrangement of three or more different seismometers as well as the same type with a certain distance according to the application [1]. Array methods can be classified by its aperture, the distance between the instrument and the number of stations. Based on the aperture or size, seismic array methods can be classified into three; large array, medium array dan small array [1].

The large array is an array configuration with a large aperture sizes above 200 km, an example of this type is the NORSAR array in Norway and LASA in the United States. Array is the array configuration with a medium size of 100 km, an example of this type is the Grafenberg array Array (GRF), which was founded in the 1970s and placed in the frankonian Jura, southern Germany. while the array is an array that has a small aperture with a size below 30 km, a small sample of the array is an array ARCESS and NORESS in Norwegian, Finish Experimental Seismic System in Finland, GERESS in Germany, Yellowknife Array (YKA) in Canada and the Array which is the object of research in West Sumatra (Figure 2).

Slowness and Back Azimuth

Most array methods assume a plane wave arriving at the array. This is a good approximation for wavefronts from teleseismic events but is a restriction for the study of near-receiver structures. The propagation direction of elastic waves traveling in a spherical Earth and arriving at a seismological array can be described by two parameters (Figure 3):

a) (1) vertical incident angle i and (2) back azimuth θ. In practice, not the incident angle i but the inverse of the apparent velocity of the wave front across the array $1/v_{app}$ is used. This parameter is called slowness u and is written as_: [1]:

$$u = \frac{1}{v_{app}} = \frac{\sin i}{v_0} \qquad (2.1)$$

with v_0 as the medium velocity beneath the array.

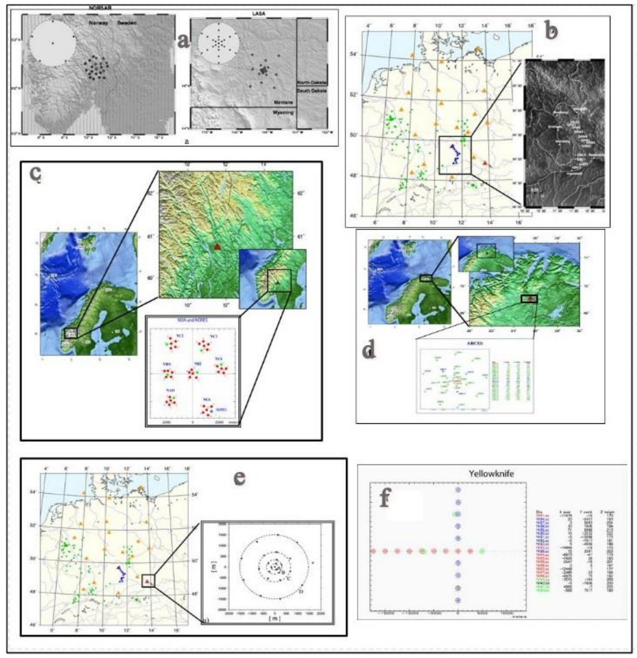

Figure 2. Based on the aperture or size, seismic array methods can be classified into three; large array, medium array dan small array: a. NORSAR array in Norway and LASA in Montana, USA; b. Array medium GRF in Germany; c. NORES array in Norwegia; d. ARCESS array in Norwegia; e. GERESS array in Germany; f. Yellowknife array in Canada.

b) back azimuth θ is the angle of the wave front arriving at the array measured between north and the direction to the epicenter in degrees. Both parameters are combined in the slowness vector u. In a spherical geometry this is written as [1]:

$$u = \frac{1}{v_0}(\sin i \sin \theta, \sin i \cos \theta, \cos i). \qquad (2.2)$$

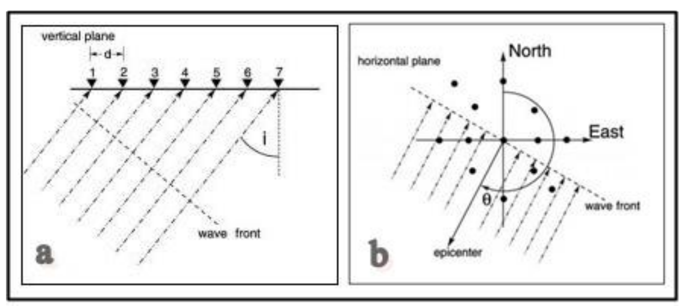

Figure 3. The vertical plane of an incident wave front crossing an array at an angle of incidence i. (b) Sketch of the horizontal plane of an incident plane wave arriving with a back azimuth θ.

Beam Forming Formulae

For a specific back azimuth and apparent velocity combination, we can define a "delay and sum" process to calculate the array beam. In the following we will use the shorter vector syntax of Eq. (2.3) to calculate time delays. The calculated delay times can be negative or positive. This depends on the relative position of the single sites with respect to the array's reference point and to the backazimuth of the seismic signal. Negative delay times correspond to a delay and positive delay times correspond to a signal arriving earlier than at the reference site. Where $w_j(r_j, t)$ is the digital sample of the seismogram from site *j* at time *t*, then the beam of the whole array is defined as: [2]

$$b(t) = \frac{1}{M}\sum_{j=1}^{M} w_j(t + r_j.s) = \frac{1}{M}\sum_{j}^{M} w_j(t + \tau_j) \qquad (2.3)$$

This operation of summing the recordings of the M instruments by applying the time delays $r.s$ and then dividing by the number of traces M is called beamforming.

Array Response Function

The array transfer function describes sensitivity and resolution of an array for seismic signals with different frequency contents and slownesses. The Array response will be identical with the seismic energy of this beam can be calculated by integrating over the squared amplitudes: [2]

$$E(t) = \int_{-\infty}^{\infty} b^2(t)dt = \int_{-\infty}^{\infty} \left[\frac{1}{M}\sum_{j=1}^{M} w_j(t + r_j.(s_0 - s))\right]^2 dt. \qquad (2.4)$$

This equation can be written in the frequency domain by applying Parseval's theorem and then the shifting theorem:

$$E(\omega, s_0 - s) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \left|\overline{w}(\omega)\right|^2 . \left|\frac{1}{M}\sum_{j=1}^{M} e^{i\omega r_j.(s_0 - s)}\right|^2 d\omega. \qquad (2.5)$$

previous research

On 26 December 2004, a moment magnitude M_w 9.3 earthquake occurred along Northern Sumatra, the Nicobar and Andaman islands, resulting in a devastating tsunami in the Indian Ocean region. The rapid and accurate estimation of the rupture length and direction of such tsunami-generating earthquakes is crucial for constraining both tsunami wave-height models as well as the seismic moment of the events. Compressional seismic waves generated at the hypocenter of the Sumatra earthquake arrived after about 12 min at the broadband seismic stations of the German Regional Seismic Network (GRSN), located approximately 9,000 km from the event. The Rupture can be seen at Figure 4:

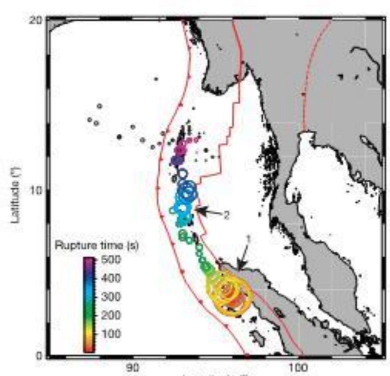

Figure 4. Rupture trace of the Sumatra earthquake [3].

III. METHODOLOGY

This array seismic research using two types of data, the first data source parameters Tohoku earthquake, Japan March 11, 2011 and the second is a short period seismometers recording data from the three components of the five stations non-permanent array in West Sumatra.

Before processing the data signal seismograms, first testing the array response function of the array is in western Sumatra through the array response function testing has been done before, which is to Yellowknife array and the array ARCESS. Testing array response function using the menu warangps from geopsy software (Figure 5). After obtaining the array response function then proceed to the stage of processing of the data signal (Figure 6).

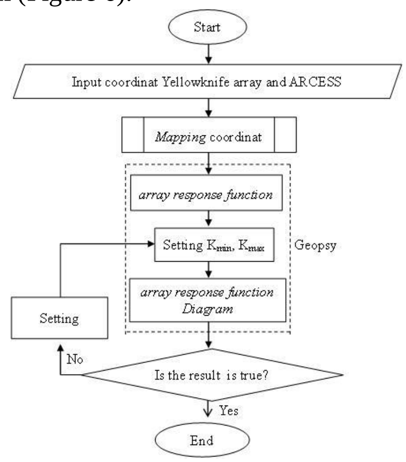

Figure 5. Flowchart the process of testing an array YKA array response function and ARCESS

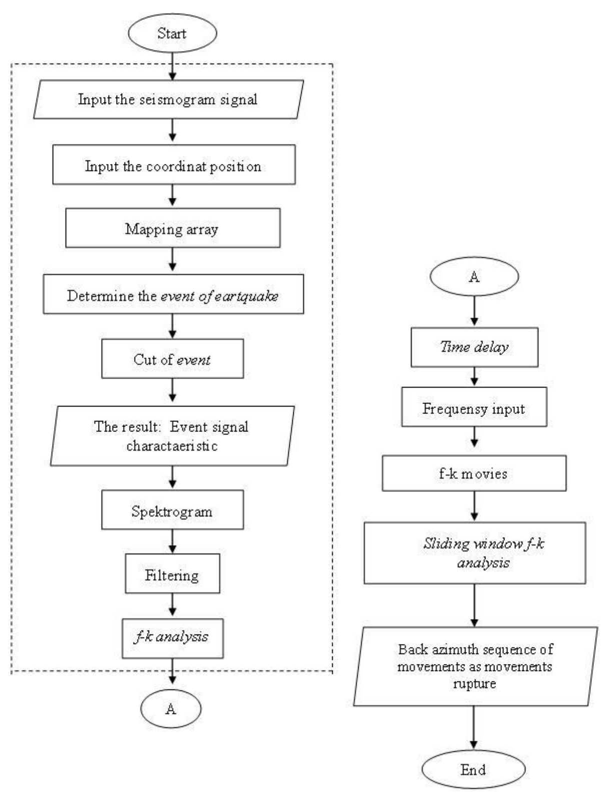

Figure 6. Flowchart of data processing array signal

Based on the data processing of the obtained results in the movement of the back azimuth array. back azimuth movement can rupture represented a movement in the epicenter area.

IV. RESULT

The research using P wave arrival time at each station arrays in western Sumatra. Seismograms recorded signal is Z component from five stations at West Sumatera. Characteristics the Z components signal events of March 11 earthquake, 2011 at 05:46 UTC were taken from five stations in West Sumatra can be seen in Figure 7.

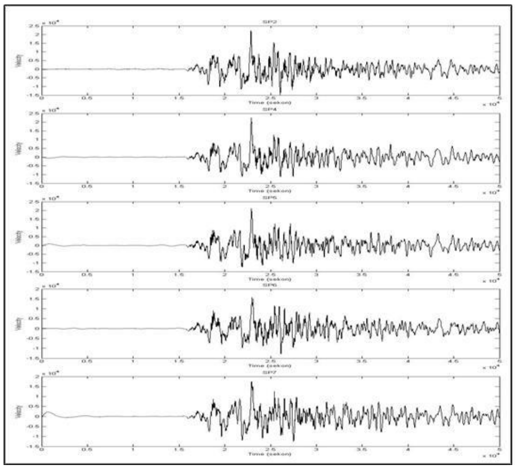

Figure 7. Characteristics the Z components signal events of March 11 earthquake, 2011 at 05:46 UTC were taken from five stations in West Sumatra. The stations are located at 0,69° to 0,98° South Latitude and 100,32° to 102,42° East Longitude

After going through the process of beam forming, Time movie FK analysis is then performed with a time window every 10 seconds for duration 100 seconds (Figure 8).

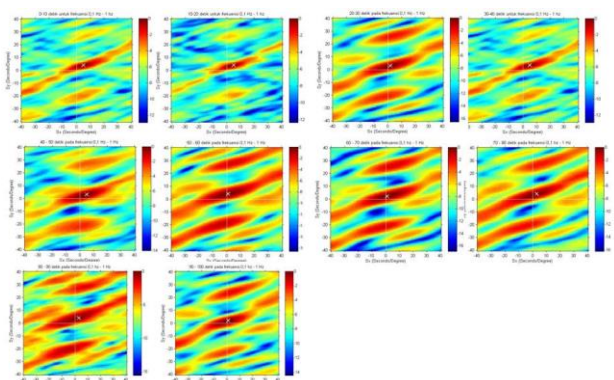

Figure 8. Time movie analysis for a duration of 100 seconds with a time window every 10 seconds.

From the analysis F-K Movie sort of the movement back azimuth every 10 seconds for a duration of 100 seconds. based on the movement of back azimuth can be represented at the epicenter of the movement patterns of rupture as shown in Figure 9.

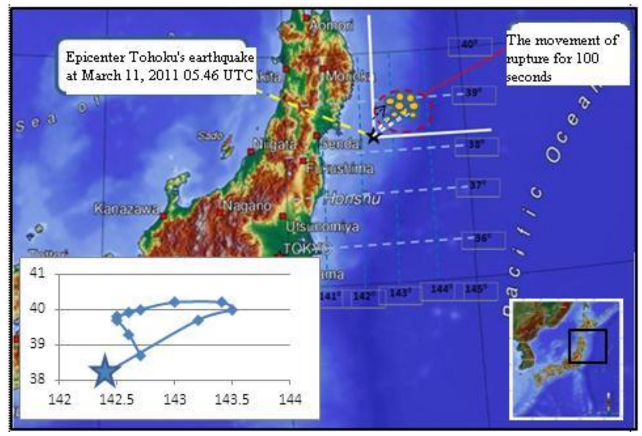

Figure 9. Representation of movement Tohoku earthquake rupture, Japan on March 11, 2011, from the north of the epicenter of the first rupture once moving in the direction of 40.18 ° to 46.5 ° to the east of the epicenter, blue star on the graph is the epicenter.

At first earthquake occurred at the epicenter (Latitude 38.29° ; Longitude 142.37°), 10 seconds later I moved as far rupture of 40.18 ° north of the epicenter in the coordinates (latitude 39.7 ; longitude 143.2), and so on until the last second to 100 back as far as the movement of rupture in a position back azimuth 46.5° (Latitude 38.7 ; Longitude 142.7).

V. CONCLUSION

Based of our analysis the back *azimuth* of rupture is changing from 40.18^0 to 46.5^0 with slowness of 4 – 4.4 s/deg. The position of the rupture movement suffered deflection at time intervals of 20 seconds, the first from the epicenter to northeast and then undergo reverse direction toward the southwest. At 70 seconds time intervals, the rupture back turned to the northeast of the epicenter that is gone toward the position of the Japan trenches.

ACKNOWLEDGMENT

I extend many thanks to the Directorate General of Higher Education Ministry of National Education through the Graduate Scholarship academic year 2010 - 2012, which has funded this research. And also, I am grateful to the team work of Geophysical Laboratory of Gajah Mada University Theodosius Marwan Irnaka Prima Wira Kusuma Ward who had been helping the processing of data to complete the research.

REFERENCES

[1] S. Rost, C. Thomas, "*Array Seismology. Methods and Applications, Rev. of Geophysics*," California, USA, 2002, pp. 2.1–2.27

[2] Schweitzer, J. Fyen, J. Mykkeltveit, S. Gibbons, J,S. Pirli, M. Kuhn, "*Seismic Arrays"*. DOI: 10.2312/GFZ.NMSOP-2_CH9. Norway, 2011, pp. 2-70

[3] F. Kruger, M. Ohnberger, " *Tracking The Rupture Of The M_w = 9,3 Sumatra earthquake over 1,150 km at Teleseismic Distance"*. Vol 435/16 June 2005/doi:10.1038/nature03696. Institute of Geosciences, University of Potsdam, Germany, 2005, pp. 937-939