Earthquake In Palu Areas As An Indication Of Active Faults In Palu-Koro, Central Sulawesi, Indonesia

MURNI Sulastri, ASDANI Soehami and DICKY Muslim

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Abstract

Central Sulawesi is part of active tectonic as a product of subduction, which produce geological phenomena such as volcanism and tectonic activity. Palu-Koro fault section passing through the center of Sulawesi Island in Central Sulawesi town of Palu right divides into two parts, east and west. Central Sulawesi is one of the areas with a high level of seismicity in Indonesia. Geographically, the study area lies between 119^o 47' 31.891'' East Longitude to 120^o 1' 46.488'' East Longitude and 1^o 12' 15.714'' South Latitude to 0^o 50' 20.922'' South Latitude. The research aims to find geomorphological configuration in the study area, Geological structure of study area, relationship between earthquake epicenters with the fault in research area.

Mapping methods that used are measurement of geological data include strike/dip, megascopic rock description, taking photographs and field test of statistical data to prove there is a relation between seismic data and the Fault which is located in research area, and the preparation of the final report and making seismotectonic map.

Palu-Koro fault is one of the horizontal sinistral faults in the island of Sulawesi. Palu-Koro fault is expressed by the geomorphology aspects. The earthquake data and anykind of collected data in the research area show that the kind of faults in the field area are normal and sinistral faults. To support those data, authors used the epicenter of the earthquake record data from the USGS (United States Geological Survey), as well as the earthquake data from BMKG (The Meteorology, Climatology and Geophysics Council). The sliding-fault of Palu-Koro and the minor-fault around Palu-Koro are the indication caused the earthquakes in Palu and area surrounded. Based on the results of the study, Palu-Koro Fault is included the type of an oblique-active fault.

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1. INTRODUCTION

Sulawesi Island is an island which is complex because there is a junction of three tectonic plates between the Indian ocean plate-Australia plate, or often called the Eurasian plate and the Pacific plate exposure to Sunda (Surono, 2010). Central Sulawesi is part of the active tectonics. As a product of subduction, which produce geological phenomena such as volcanism and tectonic activities. This region is one of the Indonesia earthquake zone XIX numbers due to Palu-Koro faulting (Geological Research and Development Centre, 2003). Records mention seismicity in this region is very high (BMKG Palu, 2012).

Central Sulawesi Regional Tectonics

According to Hamilton (1979), there were some segmentation Faulting which give rise the huge earthquakes in Central Sulawesi and South Sulawesi. The Faulting is:

1. Palu-Koro Faulting
2. Saddang Faulting
3. Trench Faulting

In the observation area of the structure consists of the study, folds, and fracture. This fracture is said to be a fracture "transcurrent", further stated that the vertical fracture movement found primarily in the north, while in the western part of the horizontal direction movement is found to the left (Katili, 1970 in Soehaimi, 2005). Movement speed of the fracture to the left, which is estimated to 14-17 mm per year (Sudrad, 1981).

In Regional Palu-Koro there are 3 (three) types of facets namely; Triangular Facet Type A, B and C. The introduction was based on the level of activity of each and it is reflected by the growth rate of the erosion rate. Triangular Facet type A, was identified from a high erosion rate with debris material grows and moves to form new grooves. Triangular Facet erosion rate of type B are the most material debris appears on one side of the valley. Triangular Facet C looks more massive and stable with a low erosion rate, there is no any new material debris on the valley (Soehaimi, 2012).

Earthquake

The perpendicular point to hipocenter in the earth's surface is called epicenter. (Soehaimi, 2008) divided the depth of the earthquake hipocenter location of the earth's surface as follows:

A. Shallow earthquakes, hipocenter distance <30km.
B. Intermediate earthquakes, hipocenter distance between 31-100km.
C. Earthquakes in, hipocenter distance between> 100km.

Hunt (2005) described the factors that affect disaster and earthquake damage are magnitude, intensity, frequency and time of earthquake occurrences, distance point earthquake with area residents, local geological conditions, and the condition of construction building. Bellier et al.

(2001), examined the Palu-Koro Fault movement by dating the alluvial fan sediments. Results show that the horizontal movement of fauult is 35 ± 8 mm / year. Bellier concluded that the Palu-Koro Fault is a Fault which has a relatively fast movement, but with a low seismicity. Based on the analysis of the geomorphology aspects, Palu-Koro Fault could be divided into seven segments with a total length (measured in land) is 218 km.

Type and Parameter of Fault in Focal Mechanism Diagrams

Focal mechanism is the result of the analysis of waves in the record number of seismographs, mechanisms focal in the central segment of the NMSZ. This study shows a complex pattern of orientation of the fracture plane (Chiu et al., 1992; Brahman,2011). In the diagram of focal mechanisms, faulting plane depicted in the form of a ball with a focal plane orthogranal lines, in terms that we can determine the Faulting type focal mechanism diagram is as follows (Figure 1).

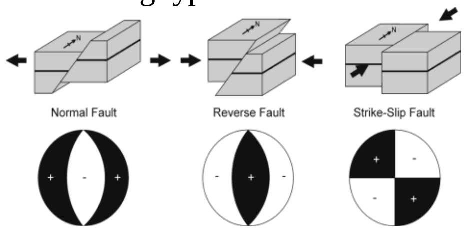

Figure 1 Interpretative of Fault type in Mechanism Diagram

a) Mechanism of vertical fault (Dip-slip faulting).
b) Mechanism of horizontal fault (Srike-slip faulting)
c) Describe focal mechanism diagram when the diagram is right in the center of the intersection of the two lines.

Seismotectonic

Geotectonic and seismic (seismotectonic) is the study of the connection between geological structure with earthquake occurrence. Therefore seismotectonic studies should include the study of geology and geological structures associated with the occurrence of historical earthquakes in the region (Soehami, 2005). Seismotectonic is the earth science related to the connection between the characteristics of earthquake seismology or tectonic current (Brahman, 2011).

2. Research Methods

Studio Method

The first method is the determination of research area that carried out by the satellite image of DEM, Alignment withdrawal of DEM, making topographic maps, and other library studies, as preparation to the field. **Field Work**;The second method is preparation tools for geological mapping such as below :Base map scale of 1: 25,000 (used also as studio equipment), GPS devices (Global Positioning System), Compass (used to perform the measurement of geometry field – structures of geological field, and geological of Hummer).

Analysis of Laboratory Data

ASTERGDEM of the data is processed using Global Mapper program aims to get the alignment pattern that will be used to estimate the geological structure of the pattern.

Processing of Joint Data (1);All joint data of the field are processed using the Dips program defined field - the field maximum, generally moves toward the diagram roses (*rose diagrams*) and also known the value of the conjugate joint. **Statistical Data Analysis (2);**Statistical data analysis is divided into two data such as quantitative and qualitative data. Those data include normally test and difference test (t-test) statistics: population of joint data, lineaments, rivers and seismicity.

3. Results and Discussion

Geological Structure Analysis.

At this stage, the analysis of geological structure done by analyzing the study result based on the joint data. The result of ASTER DEM lineament analysis in the research area determined the patterns of deformation and the direction of the main affirmation that occurred in the study area. These interpretation also support the joint data of the field to know the structure. Processing and data analysis using projection dip. Dip projection is one of the method that used in the analysis of geological structures in three dimensions presented in the form of a two-dimensional of field data. Each pole contouring using Net Counting of Kalsbeek will produce the maximum peak field which is the largest of the plotted data density. The process of plotting data is assisted by using Dips program.

Assessment of Earthquake Data

At this step, seismic assessment is conducted in accordance with the deployment of the earthquake epicenter and focal mechanism of the earthquake epicenter which has above 5 on the richter scale. This kind of movement could be seen through the direction of the fault.The preparation of the reports and any updated seismotectonic map are used to display the results of the study. The interpretation of DEM lineaments are conducted to determine the type of geological structures developed as a result of tectonic and also to know the lithology.

Variables to be compared are based on the comparison of the topographic in DEM maps image, field data, and seismic data. Based on three data above which are compared using normality, homogenity, and the difference test show an association between muscular and river segments and also lineaments of DEM. Palu-Koro Fault is a fault which is still active until now on. It could be seen through the morphology of local area. These morphology data could be represented as data of DEM lineaments, field data, and the river segments data (Figure 2).

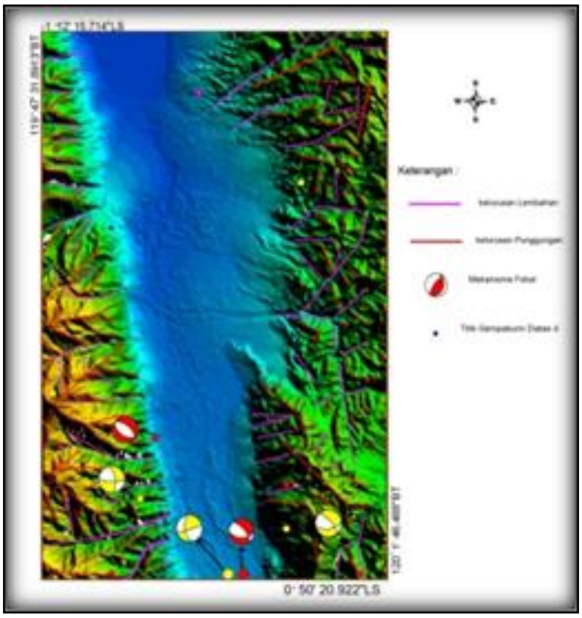

Figure 2 Lineaments Interpretative Using ASTER-DEM Image

The morphology of study area could be seen from the shape of triangular facets and wineglass canyons. The active fault is divided into two parts, which are western and eastern part. In the western part is indicated through triangular facets and wineglass canyons surface characterized by steep straight bay, which are composed of granite. The differences could be seen between the river lithology characterization in the western and eastern section. Western section is characterized with metasediment lithology and granite breakthrough, while the eastern section is characterized with Molasa Sulawesi. Beside that the terrace of beach deposits is filled up with fragile rocks of Molasa Sulawesi and marine fossils. From the observation, (Tjia, 1974) determined that coral near the northern city of Palu Tondo experienced vertical movement which has average speed of 4.5 mm / year.The lithology of terrace eastern coast as well as molasa sandstones are easily eroded. While the morphology of the molasa conglomerate and sandstone lithologies with pyrite mineral are included the type of slopping hills.

The section of beach terrace is divided into 3 phases, which are near to the ocean or bay. The terrace western section looks flat and found some fossils, these trace fossils indicated as a movement of fault. In the terrace eastern section looks a triangular facet. Based on the reconstruction data, authors could determine the relative movement of the fault system. From the data above the ancient sharpness (paleostress) is indicated in the western part of study area, while the eastern part of study area looks the tendency known as geological structure patterns developed in Palu-Koro. Lithological types are not visible in the eastern fracture, because there are Molasa Sulawesi in the eastern part which indicates the lithology is too compact, so the cracks does not look obviously (Figure 3).

Figure 3 Teras Western

Tectonics in the eastern part of the Palu Bay in Central Sulawesi called neotectonic. This could be seen along Palu city and the surrounding valley. This is also influenced by the presence of Palu-Koro active faults (Soehami, 2012). Palu valley on both sides (western and eastern), found a fracture escarpment with triangular facets phase varies in the height from 25 to 300 meters (Soehami 2012).

DATA GEMPA BUMI DIATAS 4 SCALA RICHER DARI USGS

Year	Month	Day	Time(hhmmss.mm)UTC	Latitude	Longitude	Magnitude	Depth		Catalog
1987	6	21	193013.86	-1.2	119.84	4	28	mbGS	PDE
2005	7	13	113013.34	-1.2	120.01	4.2	10	mbGS	PDE
1990	12	4	14720.15	-1.08	119.8	4.8	33	mbGS	PDE
1987	6	21	193013.86	-1.2	119.84	4	28	mbGS	PDE
1985	2	10	174557.66	-0.97	119.84	4.7	105	mbGS	PDE
2004	11	2	214818.48	-1.15	119.86	4.9	55	MwHRV	PDE
2009	3	2	339.74	-1.11	119.87	5.6	11	MwGCMT	PDE
2004	1	1	135324.62	-0.88	119.9	4.4	70	mbGS	PDE
2001	11	30	152205.99	-1.2	119.92	5.2	38	MwHRV	PDE
2005	1	23	201012.15	-1.2	119.93	6.3	11	MwHRV	PDE
2005	7	9	235917.03	-1.17	119.96	5.9	32	MwHRV	PDE
2005	1	24	2243.61	-1.14	119.96	4.8	10	mbGS	PDE
1981	10	19	95112.32	-0.94	119.97	4.6	33	mbGS	PDE
2005	7	13	113013.34	-1.2	120.01	4.2	10	mbGS	PDE

Table 1 Earthquake Data above 4 SR (USGS, 2012)

The triangular escarpment on the western facet has a height greater than the triangular escarpment on the eastern facet, as well as the slope of the valley. The lithology is constituent in the eastern part of Sulawesi. The earthquake data collected from BMKG (The Meteorology, Climatology and Geophysics Council) determine the western part of Palu in Central Sulawesi has more active tectonic movement with lithological constituent of granite rocks.

Determination of the earthquake fracture movement is often called the focal mechanism. The focal mechanism of the earthquake would occur if the fault related to the area which has earthquake over 5 Scala Richter. It also damage the areas sorrounded. The data recorded in the focal mechanism (Figure 4).

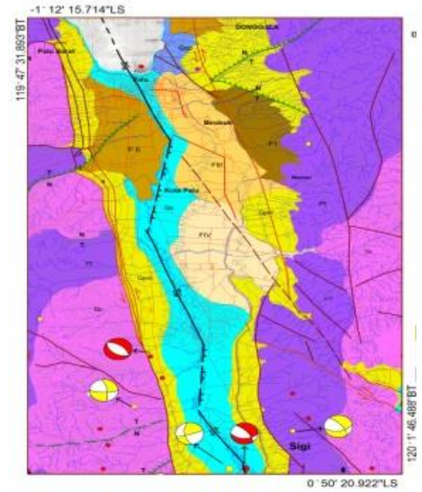

Figure 4 Maps of seismotectonic in Palu areas - Central Of Sulawesi, Indonesia

From the all analysis data above look that the Palu-Koro Fault is an active fault which has important role as an indication of the earthquake in Central Sulawesi, while it is also controlled by minor faults at the western and eastern part of Palu-Koro Fault. Palu-Koro Fault could be determined as an active faults, as shown by the activeness of the morphology product and earthquake data in Central Sulawesi.

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