A field survey for the rupture continuity of Palu-Koro fault after Donggala earthquake on September 28th, 2018

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Abstract. The 28 September Mw 7.5 Donggala earthquake has generated the fault trace now able to be seen using satellite image on Google Earth especially in the Palu western zone. However, a field survey must be conducted in order to discover the decisive rupture continuity direction since it inspected not the entire trace for outside Palu areas in contrast. The survey result shows this rupture crosses Sigi, Palu, Palu Bay, and Donggala about 156 km in south-north directed. Yet, some slipping parts experienced dip-slip as oblique fault besides sinistral strike-slip/left-lateral fault type as currently inferred. Moreover, the liquefaction-affected areas were only occurred in the fault border zone such as in South Dolo, Sigi; Balaroa, Palu; and some areas of Donggala. Besides, this event reinforces evidence that Palu-Koro fault trace is the geothermal system components referred to what was happened to the villages of Pulu and Mantikole, Sigi. In sum up, this fault can be categorized as a disaster when significantly active it can cause massive damage to buildings and other infrastructures above the rupture even though the left-right side did not experience the same severe damage, and fatalities struck down by collapsed debris.

1. Introduction

The central and eastern part of Indonesia is a region that is always deformed because it is related to 3 major meetings of the world's plates, there are the Indo (Hindi) -Australia plate, Eurasian plate, and the Pacific plate, and 1 small plate namely the Philippine plate [21]. This region is also known as the triple junction that makes a variety of complex geological processes works in this area and one of the impacts is to form the island of Sulawesi such as the letter "K" [10]. According to Harris and Major [9], there are around 13 structures such as faults, trenches, troughs, and thrust are active in this region. One of the existing faults is the Palu-Koro fault which has long and straight dimensions and able to provide super shear cracks. The length of Palu-Koro fault according to Tjia [19] is 300 km, according to Bellier, et al. [4] the length is ± 218 km, and according to Watkinson and Hall [21], it is 200 Km and overall 500 km. The Palu-Koro Fault is a sliding fault zone stretched from north northwest-southeast, the southeast end of this fault segment continues to the Matano fault segment to the east, and some researchers said there is a continuous section towards Bone Bay [4, 10, 19, 21]. While viewed from the Palu Valley to the north-northwest direction, this fault continues into the Makassar Strait waters leading and connected to the North Sulawesi Trench [7, 9, 10]. The Palu-Koro Fault is considered to represent the greatest risk of seismicity among all faults in the triple junction region [21] because earthquake epicenter always occurs in a fault area which represents the boundary between two rigid media that can move relative to one another. It appears on the surface as if there is a side part of a block that moves against other parts [1, 5, 16]. However, the Palu-Koro fault is an active fault, because it proved there is a left shift lateral strike-slip each year at a rate of 34-58 mm / year [8, 14], and there are several hot springs around the track [17, 19].
According to Cipta, et al. [7] along the Palu-Koro fault line can provide earthquake risk to the X level scale Modified Mercalli Intensity (MMI) according to the United State Geology Society (USGS) scale. Additional risks from the Palu-Koro fault are liquefaction quarter sedimentary basin in the Palu Valley, landslides, and a tsunami-prone move towards the mouth of the narrowed Palu Bay [7,21]. One of the earthquake events that was triggered by the Palu-Koro fault was the 7.5 Mw earthquake occurred on September 28, 2018, the epicenter is around Sirenja District Donggala Regency about 70 km to the north of Palu City. The Palu-Koro Fault and the earthquake event also produced derivative phenomena such as tsunamis and ground-effect liquefaction movements, exactly as some researchers had predicted before the event.

If we trace the natural disaster event, then the indirect cause is the Palu-Koro fault that causing an earthquake when actively, and then triggers a tsunami due to landslides around the coast and ground movement by the effects of liquefaction. However, natural disasters here are not only from earthquakes, tsunamis, and ground-effect liquefaction movements but surface rupture of the Palu-Koro fault also directly acts as a disaster. This can be identified from Google Earth satellite imagery on October 2, 2018, that is in the western part of Palu City around the Balaraq liquefaction ground effect area there is an oddity in the shape of the road becomes curved as the letter "S", even though before September 28, 2018, the road is straight. This oddity stretches almost straight in the direction of around N320°E and N350°E, where along this path people's houses and other buildings are severely damaged and it does not occur in other buildings that are not right on the path. In the lane that makes the winding road, it appears that the eastern block shifts significantly toward to north as the Palu-Koro fault character that known for its left or lateral or sinistral sliding motion [4, 8, 10, 19, 21].

Here we suspect that the path that appears in the image is a Palu-Koro fault trace as a sign of the occurrence of the 7.5 Mw earthquake. But the path is only clearly seen in the image for Palu City and parts of the Sigi Regency that close to the city, and unclear for other regions. So the direct continuity of this path cannot be known certainty both to the south and especially to the north towards the earthquake epicenter. Therefore, we conducted a field survey to obtain an accurate geographical position, informations of the character and the impact caused by the pathway, as well as ensuring that the pathway was an existing surface rupture of the Palu-Koro fault.

2. Method
The study began with the observation image from google earth, that we use as the map information reference for surface rupture path of field survey. The starting point for this survey is around 119°50’51.36"E - 0°54’00.00”S in the administrative area in DonggalaKodi Village Ulujadi Sub-district Palu City, where there are winding roads that are shaped like an "S" letter and damage people's houses (Figure 1). From this point, the survey then continues northward to the earthquake epicenter around 119°50’46.32”E - 0°15’21.24”S based on the USGS earthquake catalog (https://earthquake.usgs.gov/earthquakes/search/), and searches for to the south until the surface rupture trail is no longer traces. Surface rupture tracing is quite easy to identify for Palu City and Sigi Regency because surface rupture is visible and adjacent to the road access. Whereas in the Donggala Regency, on the other hand, because the surface rupture pathway has been separated by the waters of Palu Bay which cannot be ascertained its continuation path to the north, besides that the route is quite far from the main access road. Therefore, in conducting this survey we are also guided by the results of depictions by Valkaniotis, et al. [20] who released the surface rupture pathway in October 2018 based on the correlation of sentinel-2 optical image data and planet imagery.

In this surface rupture path traces, we are quite careful to consider that not all the cracks in the surface phenomenon is the result of a shift fault expression. So if we encountered cracks, which only with a straight line pattern that have experienced rock displacement or rock blocks significantly that we consider to be a surface fault rupture [11,12].

In a densely populated area, a building or road infrastructure is very good to be used as a marker to identify surface rupture. Meanwhile, in a location that no infrastructure, we identified through marker-dip slip component, splash fault, fracture, or deformation of the surface due to the liquefaction effects in the border region of the fault. At each surface rupture location that we encountered, we took pictures using a camera and the geographical coordinates using GPS, after that plotted the location points and then connected them to the continuity lines that are displayed on the map.
3. Field Survey Results

A field survey conducted in the north Donggala Regency, then Palu City and in the south Sigi Regency. After that, our survey location plots at the administrative boundary, and it is identified that this surface rupture route crosses 33 villages or 7 sub-districts in the northern part of Donggala Regency, then crosses Palu Bay, then 10 villages or 4 sub-districts in the Palu City area and then in the south, it is Sigi Regency that has 31 villages or 5 districts. In Table (1) we mention the names of villages, sub-districts and cities/regencies, and the position of the Palu-Koro fault rupture. The purpose of the route path interpretation shown in the table is the location that we estimate is also traversed by the surface rupture path, based on the correlation of the closest observation positions.

The results of overlaying the surface rupture path in the field are shown in Table (1) with the path that released by Valkaniotis, et al. (2018) shows a good precision scale, but the accuracy of its position does not match between the two results, perhaps it is because of the regional scale of the optical image correlation map that Valkaniotis did compared to our direct field survey. In this case it is certainly important to make comparisons of previous releases, to obtain more accurate actual data. However, at this time the local community needs detailed information on the surface rupture pathway so that they can know whether the area is crossed by a fault or not.

As evidence of the survey results, we display some photos of surface rupture conditions in the field from north to south (see Figure 2), according to the village code name as shown in Table (1).
| No | Village | Districts | Long (X)  | Lat (Y)  |
|----|---------|-----------|-----------|----------|
| 1  | Lombonga* | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 2  | Lende | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 3  | Tompe | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 4  | Belutumma 1 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 5  | Belutumma 2 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 6  | Belutumma 3 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 7  | Tanjung Padang* | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 8  | Tomoko | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 9  | Sikesa Tobata | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 10 | Sikesa Tobata* | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 11 | Oti | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 12 | Tamarenja 3 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 13 | Tamarenja 1* | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 14 | Tamarenja 2 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 15 | Tamarenja 3 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 16 | Oki | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 17 | RutuyawaGo'o | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 18 | TamosunaGo'o | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 19 | TamosunaGo'o* | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 20 | CalbanuKala | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 21 | Talbo | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 22 | Soko1 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 23 | Soko2 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 24 | Soko3 | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 25 | Kavaya | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 26 | Kavaya | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 27 | Kavaya | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 28 | Kavaya | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 29 | Kavaya | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |
| 30 | Sumari | Donggala | Interprestaksenmeranun | Interpretasikemenerusan |

(*) Several locations of surface rupture conditions in the field shown in this paper
| No  | Village          | Districts | Long (X)    | Lat (Y)    |
|-----|------------------|-----------|-------------|------------|
| 59  | Kabonena 1       | Palu      | 119.843     | -0.888     |
| 60  | Kabonena 2       | Palu      | 119.843     | -0.889     |
| 61  | Kabonena 3       | Palu      | 119.844     | -0.891     |
| 62  | Kabonena 4       | Palu      | 119.844     | -0.891     |
| 63  | Kabonena 5       | Palu      | 119.844     | -0.892     |
| 64  | Kabonena 6       | Palu      | 119.844     | -0.892     |
| 65  | Kabonena 7       | Palu      | 119.844     | -0.892     |
| 66  | Kabonena 8       | Palu      | 119.844     | -0.893     |
| 67  | Kabonena 9       | Palu      | 119.845     | -0.894     |
| 68  | Kabonena 10      | Palu      | 119.845     | -0.895     |
| 69  | Kabonena 11      | Palu      | 119.845     | -0.895     |
| 70  | Kabonena 12      | Palu      | 119.845     | -0.896     |
| 71  | Kabonena 13      | Palu      | 119.845     | -0.897     |
| 72  | Kabonena 14      | Palu      | 119.845     | -0.897     |
| 73  | Kabonena 15      | Palu      | 119.845     | -0.898     |
| 74  | Kabonena 16      | Palu      | 119.846     | -0.898     |
| 75  | Kabonena 17      | Palu      | 119.846     | -0.899     |
| 76  | Kabonena 18      | Palu      | 119.846     | -0.900     |
| 77  | Kabonena 19      | Palu      | 119.846     | -0.900     |
| 78  | Kabonena 20      | Palu      | 119.846     | -0.901     |
| 79  | Kabonena 21      | Palu      | 119.846     | -0.901     |
| 80  | Kabonena 22      | Palu      | 119.846     | -0.902     |
| 81  | Kabonena 23      | Palu      | 119.846     | -0.902     |
| 82  | Kabonena 24      | Palu      | 119.846     | -0.903     |
| 83  | Kabonena 25      | Palu      | 119.846     | -0.904     |
| 84  | Kabonena 26      | Palu      | 119.846     | -0.906     |
| 85  | Kabonena 27      | Palu      | 119.846     | -0.906     |
| 86  | Kabonena 28      | Palu      | 119.846     | -0.907     |
| 87  | Kabonena 29      | Palu      | 119.846     | -0.907     |
| 88  | Kabonena 30      | Palu      | 119.846     | -0.908     |
| 89  | Kabonena 31      | Palu      | 119.846     | -0.910     |
| 90  | Kabonena 32      | Palu      | 119.846     | -0.913     |

(*) Several locations of surface rupture conditions in the field shown in this paper
| No | Village | Districts | Long (X) | Lat (Y) | No | Village | Districts | Long (X) | Lat (Y) |
|----|---------|-----------|----------|---------|----|---------|-----------|----------|---------|
| 121 | Padende | Sigi | 119.860 | -0.963 | 151 | Rogo 2 | Sigi | 119.889 | -1.187 |
| 122 | Sibedi | Sigi | 119.861 | -0.980 | 152 | Rogo 3 | Sigi | 119.890 | -1.187 |
| 123 | Beka 1 | Sigi | 119.860 | -0.985 | 153 | Baluase | Sigi | 119.897 | -1.191 |
| 124 | Beka 2 | Sigi | 119.860 | -0.989 | 154 | Bulubete | Sigi | Interpretasi kemenerusan |
| 125 | Beka 3 | Sigi | 119.860 | -0.997 | 155 | Walatana | Sigi | Interpretasi kemenerusan |
| 126 | Beka 4 | Sigi | 119.860 | -1.000 | 156 | Bangga | Sigi | Interpretasi kemenerusan |
| 127 | Beka 5 | Sigi | 119.860 | -1.002 | 157 | Pakuli 1* | Sigi | 119.946 | -1.231 |
| 128 | Bomba 1 | Sigi | 119.860 | -1.004 | 158 | Pakuli 2 | Sigi | 119.949 | -1.232 |
| 129 | Bomba 2 | Sigi | 119.860 | -1.006 | 159 | Pakuli 3 | Sigi | 119.950 | -1.233 |
| 130 | Bomba 3 | Sigi | 119.860 | -1.007 | 160 | Pakuli 4 | Sigi | 119.952 | -1.243 |
| 131 | Sibonu | Sigi | Interpretasi kemenerusan | 161 | Simoro 1 | Sigi | 119.953 | -1.253 |
| 132 | Pewunu 1 | Sigi | 119.863 | -1.025 | 162 | Simoro 2 | Sigi | 119.955 | -1.262 |
| 133 | Pewunu 2 | Sigi | 119.863 | -1.031 | 163 | Omu | Sigi | 119.956 | -1.276 |
| 134 | Kaluku Tinggu | Sigi | Interpretasi kemenerusan | 164 | Tuwa | Sigi | 119.960 | -1.306 |
| 135 | Balumpewa | Sigi | 119.864 | -1.053 | 165 | Salua | Sigi | 119.966 | -1.347 |
| 136 | Balamoa 1 | Sigi | 119.864 | -1.066 | 166 | Namo | Sigi | Interpretasi kemenerusan |
| 137 | Balamoa 2 | Sigi | 119.864 | -1.067 | 167 | Bolapapu 1 | Sigi | 119.983 | -1.427 |
| 138 | Mantikole 1* | Sigi | 119.864 | -1.081 | 168 | Bolapapu 2 | Sigi | 119.983 | -1.428 |
| 139 | Mantikole 2 | Sigi | 119.864 | -1.085 | 169 | Bolapapu 3 | Sigi | 119.984 | -1.431 |
| 140 | Bobo | Sigi | 119.864 | -1.085 | 170 | Bolapapu 4 | Sigi | 119.984 | -1.431 |
| 141 | Jono* | Sigi | 119.874 | -1.112 | 171 | Bolapapu 5* | Sigi | 119.984 | -1.432 |
| 142 | Sambo | Sigi | Interpretasi kemenerusan | 172 | Bolapapu 6 | Sigi | 119.984 | -1.433 |
| 143 | Wisolo 1 | Sigi | 119.876 | -1.123 | 173 | Bolapapu 7 | Sigi | 119.987 | -1.438 |
| 144 | Wisolo 2 | Sigi | 119.876 | -1.127 | 174 | Bolapapu 8 | Sigi | 119.987 | -1.439 |
| 145 | Balongga | Sigi | Interpretasi kemenerusan | 175 | Bolapapu 9 | Sigi | 119.987 | -1.439 |
| 146 | Poi* | Sigi | 119.880 | -1.147 | 176 | Bolapapu 10 | Sigi | 119.990 | -1.441 |
| 147 | Pulu 1 | Sigi | 119.88106 | -1.16568 | 177 | Bolapapu 11 | Sigi | 119.991 | -1.442 |
| 148 | Pulu 2* | Sigi | 119.882 | -1.165 | 178 | Bolapapu 12 | Sigi | 119.992 | -1.443 |
| 149 | Pulu 3 | Sigi | 119.882 | -1.167 | 179 | Bolapapu 13 | Sigi | 119.993 | -1.444 |
| 150 | Rogo 1 | Sigi | 119.885 | -1.180 | 180 | Bolapapu 14 | Sigi | 119.994 | -1.445 |

(*) several locations of surface rupture conditions in the field shown in this paper
Figure 2. Image locations surface rupture of Palu-Koro fault: (a) Tanjungpadang, (b) Tamarenja 1, (c) LeroTatari, (d) Pantoloan 3, (f) DonggalaKodi 11, (g) Baliase 4, (h) Mantikole 1, (i) Jono, (j) Pulu, (k) Pakuli 1, (l) Bolgapu.
Figure 3: (a) Peta topografi, (b) Peta distribusi manifestasi air panas (hot springs), dan (c) Peta geologi regional (modifikasi dari Sukamto, dkk., 1973; dan Sukido, dkk., 1993) di sekitar jalur surface rupture sesar Palu-Koro.
4. Character of Palu-Koro Fault Surface Rupture

The Palu-Koro Fault has 4 segments, namely the Palu segment, the Saluki segment, the Moa segment, and the Meloi segment [8]. From the survey results, the surface rupture of the Palu-Koro fault appears in the Saluki segment and the Palu segment then is estimated to cross the Palu Bay, turn eastward and then continue northward in the Donggala Regency. The picture of the fault traces between surface rupture from survey results with references is quite different. The first difference is that some researchers describe the main lane of the Palu-Koro fault crossing the BanawaDonggala Regency area from the northern end of the Palu segment, continuing through the Makassar Strait waters and converge with the northwestern Sulawesi trench [9, 10]. The second difference is that the main lane of the Palu-Koro fault around the city of Palu is mostly depicted passing around the foot of the Gawalise Mountains even though it is now seen crossing in the middle of the Palu City, although previously the middle lane of the city was described by Daryono [8] and Watkinson and Hall [21], but it is still an estimate because it is described by the "dotted line" description. These differences are a natural thing, maybe because of the scale factor or technological factors and the methodological approach used. But the most important thing is that we know that the Palu-Koro fault line surface rupture is that the main lane of the Palu-Koro fault does not continue in the direction of Banowa, does not pass around the foot of the Gawalise Mountains but firmly crosses in the middle of the city, and does not go directly through Makassar strait waters but towards the land to Donggala Regency area in the north of Palu City (Figure 3).

As for the results of our field survey, we describe the surface rupture Palu-Koro fault character from north to south with the following description:

- In the northern part, around the Donggala Regency area, the surface rupture of the Palu-Koro fault is ± 70 km. Based on the surface rupture identifier, it is difficult to find that the fault type is sliding because the slip size is short or ≤ 1 m. Bao, et al. [2] also states that the slip in the north is between 0.5 - 1.5 m. In the Labuan Subdistrict to around Sindue Tobata Subdistrict area, surface rupture shows cracked to open soil, the western side of the block is down, and the eastern side of the block is slightly shifted relative to the north. around Tompe Village in Sirenja Subdistrict, the surface rupture appeared only as a cracks that not as large as the previous area in the south. In this village, the western fault block also appears to be descending and rupture faults also affect liquefaction at the surface. Most of the villages in the coastal area of Donggala Regency other than those mentioned in Table (1) are not included as the risk area from the Palu-Koro fault surface rupture.

- It is not possible to obtain a firm path of the Palu-Koro surface rupture in the waters of Palu Bay, other than interpreting the continuity path (Figure 17). However, we are sure that after surface rupture from the south arrived in Palu City, about ± 20 m to the west from the Palu Grand Mall Shopping Center (PGM) at Cumi-Cumi street, rupture leads around N320°E then turn and go upright in the Pantoloan Village, continue to Pantoloan Boya Village, Wani Lumbupetigo Village, Wani III Village, Labuan Kungguma, and so on. The interpretation of this rupture pathway phenomenon is similar to that found in the South Dolo District of Sigi Regency. The surface rupture length of the Palu-Koro fault in Palu Bay is estimated to be ± 20 km.

- A surface rupture in Palu City characterizes a block slip in the east relative to the north and the west block slip relative to the south, indicating a sinistral/left/ lateral-type fault. This appearance is very clearly seen in the Palu City and several Sigi Regency areas that close to Palu City. The largest shift of all surface rupture lines is in Palu City around ± 4.5 - 5 m [2, 14, 20]. As a result of this shift, many buildings and people's homes were destroyed and the shape of the streets turned like the "S" letter. Then around the surface rupture path, there is stagnant water that sourced from shallow groundwater which is pushed out through cracks then rises to the surface. This phenomenon can be seen starting from Samudera, Lasoso, up to Kelor Street. The length of the Palu-Koro fault surface rupture in Palu City is ± 6 km.

- In the southern part, in the Sigi Regency area, the surface rupture of the Palu-Koro fault is ± 60 km. It is the most dominant area affected by surface rupture, because this path also crosses over densely populated areas,
especially Marawola Subdistrict, Dolo Selatan Subdistrict, and some from Gumbasa Subdistrict and Kulawi Subdistrict. Around South Dolo Subdistrict, surface rupture fault forms such as cracked and exposed land, the surface of the land are turned bumpy and descending like a ladder following elevation from the west to the east due to the effect of liquefaction on the surface from the fault line influence. In this region, there appears to be a left-lateral shift, and the eastern side of the block appears down, the size of the slip identified around 3-5 m. In this area subsidence and/or down lift has also taken place, starting from West Dolo District such as Mantikole Village and Bobo Village which are close to South Dolo District. In South Dolo Subdistrict, all villages have had subsidence in the eastern part of the surface rupture pathway, which is not difficult to identify. Starting from Jono Village, Sambo Village, Wisolo Village, Balongga Village, Poi Village, Pulu Village, Rogo Village, Baluase Village, Bulubete Village, Wasaranan Village, and Bangga Village. Among these villages, the rupture had the worst impact on Jono Village, Wisolo Village, and Rogo Village, which crossed at densely populated areas. Wisolo village is like the term splay strike-slip faults [12], which destroys almost all roads and houses.

The fault type around this region is not purely strike-slip but rather oblique, because it is very visible fault scarp as a dip-slip component. This type of oblique fault was previously identified by Bellier et al. [4] based on an analysis of morphological features along the Palu-Koro fault line in the southern part of the Palu Valley. Palu-Koro fault has morphological characteristics of steep slopes, marked by triangular facets and tectonic hills. At some left-lateral strike-slip sites, there are vertical components that intersect between the strike-slip component and the normal component. In this region there has also been a surface rupture of fault from east to west, which starts turning from Pakuli Village, Gumbasa Subdistrict, into Dolo Selatan Subdistrict namely Bangga Village, Wasaranan Village, Bulubete Village, Baluase Village, and Rogo Village, then continue towards the north. Among these villages, surface rupture damaged parts of the houses and roads in Pakuli Village and reduced the land and road surface ± 3.5 m in Rogo Village. Between the two deflections in Rogo and Pakuli Village have the same shift direction, in the middle, it will develop a pull that will produce down faults and create a basin from subsidence drawn by both sides of the sliding fault.

- The Palu-Koro Fault scanned from surface rupture also correlates with the presence of hot spring points in the vicinity. This hot spring is a manifestation of geothermal on the surface, scattered around Sigi Regency in Pulu Village, Mantikole Village, and Bora Village, then around Donggala Regency in Wani III Village (MapaneWani), Marana Village, Masangi Village, Tamarenja Village, Ombo Village, Lompio Village and Tambu Village (Figure 3). The manifestation did exist before the earthquake, but after the Palu-Koro fault, it could be scanned after the earthquake. Here we are sure that between faults and geothermal have a close relationship, due to the appearance of cracks on the surface that may be caused by the presence of faults around it, hot water can appear on the surface.

- The surface rupture overlay of the Palu-Koro fault with the surrounding regional geological order shows the surface rupture path passing through almost the boundaries or contact between sediment and metamorphic igneous rocks (Figure 3). Then physiographically, it appears that the Palu region consists of an east and west dyke, both have north-south direction separated by the Palu Valley (Fossa Sarasina). West dike height is more than 2,000 m.asl., While east dike height is between 400 - 1,900 m.asl [17]. In the south, the high elevation is in the west and low elevation in the east is the location of land subsidence (down). While in the north, the high elevation is in the east and low elevation in the west is also the location of land subsidence (down). Dimensions of land subsidence in the south are larger than those in the north.

- Palu-Koro fault is not one hundred percent straight, but there are parts that appear to be the phenomenon of the fault bending (Figure 4). In the south, deflection occurs around the Pakuli Village, GumbasaSubdistrict in the east, then turns or there is a force pointing to the west, precisely in Rogo Village, South Dolo District. This region is a releasing bend that can form a pull-apart feature, it is evident that the eastern part of the block has decreased (subsidence), which is identified from the shape of the surface rupture that shows fault scarp. Furthermore, the surface rupture route continues from Rogo Village to around Silae Village, Palu City, then crosses in Palu Bay then turns or pushes back towards the east, which has been identified in Pantoloan Village, Tawaeli District. In this region known as a restraining bend area that can form a push-up feature, this is the reason why in the neck region of Sulawesi the western side of the fault line experiences subsidence, where pressure from the south makes the east look as if it is rising.
Figure 4 The formation of Palu Basin which is influenced by the Palu-Koro fault system concept model

The two western and eastern embankment heights are slowly separated due to the possibility of two forces that pushing westward on the south and pushing eastward on the north. These forces require a long time to form the Palu Valley. The evidence is that there is a decrease in the eastern part of them, so gradually the lowlands are formed and the elevation in the east which was probably as high as the elevation in the west, is now even lower based on the mean sea level datum. This is estimated by the character of rock types namely breakthrough and metamorphic rocks contained in these two embankments. From this decline phenomenon, so that eventually forming this region resembles a basin, so that there are openings from two separate bunds that allow shipments of seawater from the Makassar Strait. Then filled with sediment deposits through exogenous processes such as erosion, landslides, river sedimentation, or liquefaction.

5. Conclusions
At the conclusion of this paper, we would like to convey that the surface rupture of the Palu-Koro Fault was included in the Natural Disaster at the time of the September 28, 2018, in Palu City and its surroundings incident. At present, the Palu-Koro fault has identified its route of path based on the appearance of surface rupture which stretches relatively north-south along ± 156 km, across 3 densely populated areas namely Sigi Regency, Palu City, and Donggala Regency. This existence fault is a real threat to people's lives and greatly affects the economic growth in Central Sulawesi Province because the fault passes right in the capital region. For example, a significant land-shifting in the fault field on September 28, 2018, has triggered various phenomena such as earthquakes, tsunamis, and ground-effect liquefaction movements that had caused thousands of lives and trillions of material losses. However, without these derivative phenomena the Palu-Koro fault also directly damaged buildings and other infrastructure along it surface rupture path. So, it is better for each geological mapping record need to include the distinguishing fault legend (in general) and active fault legend if the mapping is related to hatred. Therefore, we will know that in a location there is actually a potential danger from the active fault of surface rupture, which will provide us with the knowledge base for making decisions about what risk reduction efforts are best carried out around the active fault border area.

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