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by Rahmat Catur Wibowo

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Geomorphic Indices and Fault Segmentation Indication of Menanga Fault

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1

GEOMORPHIC INDICES AND FAULT SEGMENTATION INDICATION OF MENANGA FAULT AT PESAWARAN, LAMPUNG

PETUNJUK GEOMORFIK DAN INDIKASI SEGMENTASI SESAR PADA SESAR MENANGA DI PESAWARAN, LAMPUNG

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Abstract. Remote[1] sensing and GIS are playing[2,4] important[3] roles in geomorphology and hazard risks[2,4] analysis. Pesawaran[1] area located[5] near the Menanga Fault and recently[5] on[5] the risk[5] of earthquake[5] that happened[6] along this fault. Thus[1], it is essential to investigate the area actively affected by Menanga[7] Fault as preliminary research about hazard risk related to Menanga[7] Fault. The[1] morphometry method based on DEMNAS and Landsat 8 was applied to evaluate the zone affected by Menanga[8] Fault, and fracture data analysis was conducted[9] to consider the possibility of fault segmentation resulting from its mechanism. The[1] study area can be divided[10] into 3[11] zones;[12] zone A is greatly affected by Menanga Fault activity, zone B is affected by Menanga Fault and Mt. Pesawaran development, and zone C is tectonically less affected. Zone[1] A landforms were not only formed[13] as a result of Menanga[14] Thrust fault but also the strike-slip fault segment. Fault[1] segmentation exists in this zone with different mechanisms (strike-slip and dip-slip), producing lineaments with different trends,[15] and differentiation of river patterns.

Abstrak. Penginderaan jauh dan GIS memainkan peran penting dalam geomorfologi dan analisis risiko bahaya. Daerah Pesawaran terletak dekat dengan Sesar Menanga dan baru-baru ini berada pada risiko gempa bumi yang terjadi di sepanjang sesar ini. Oleh karena itu, sangat penting untuk menyelidiki area yang terpengaruh secara aktif oleh Sesar Menanga sebagai penelitian awal tentang risiko bahaya yang terkait dengan Sesar Menanga. Kami menggunakan metode morfometri berbasis DEMNAS dan Landsat 8 untuk mengevaluasi zona yang terpengaruh oleh Sesar Menanga yang digabungkan dengan analisis data rekahan untuk mempertimbangkan kemungkinan segmentasi sesar dari mekanismenya. Daerah studi dapat dibagi menjadi 3 zona; zona A sangat terpengaruh oleh aktivitas Sesar Menanga, zona B terpengaruh oleh Sesar Menanga dan perkembangan Gunung Pesawaran, dan zona C kurang terpengaruh secara tektonik. Landform di zona A tidak hanya terbentuk akibat patahan celah turun Menanga tetapi juga segmen patahan celah mendatar. Segmentasi sesar ada di zona ini dengan mekanisme yang berbeda (mendatar dan turun), menghasilkan kelurusan dengan tren yang berbeda, dan diferensiasi pola sungai.

INTRODUCTION

Remote sensing (RS) is[16] increasingly playing[16] an important role in earth observation over this decade. Geographic[1] Information System (GIS) was one of the practical parts of hazard risk assessment, especially for spatial aspects, geomorphology analysis, visualization, and modelling[17] (Ahmadi & Pekkan, 2021; Al-Ashkar et al., 2022; Moustafa et al., 2022; Ren et al., 2023; Van Westen, 2013) Digital mapping allows more efficient data collection and analysis nowadays (Fossen, 2019).

Geomorphology was a key component of hazard assessment because hazard events played a role in the dynamics of landforms and surface processes (Mohan et al., 2021; Gao et al., 2021; Van Westen, 2013; Keller & Pinter, 1996). Numerous[1] processes affecting the dynamics of landforms and surfaces can be potentially dangerous for a human being. Those[1] endogenic and exogenic processes can trigger hazardous processes, such as earthquakes, landslides, etc.[18] (Keller & Pinter, 1996).

A great[19] interest in remote sensing applications, earth dynamic modelling[20], and geomorphology has been observed[21] over the past years. Previous[1] research applied morphometry or geomorphic indices analysis on tectonically active regions, ongoing mountain building, river basins, and plate margins have been published recently (Yudhicara et al., 2017; Ganas et al., 2005; Rozycka & Migon, 2021). The[1] remote sensing and morphometry analysis approach helps the researcher to[22] solve the[22] problem[22] over[22] the[22] complex and weathered region.[22] It[1] is being[23] a critical part of the reconnaissance phase of tectonic and/or[24] disaster management research.

Menanga Fault was the active fault that is now believed[25] as[26,27] the source of the earthquake that happened earlier in the Pesawaran area (Nurfitriana et al., 2022). The[1] previous study revealed that Menanga[28] Fault was a relatively significant thrust fault (Nurfitriana et al., 2022; Mangga et al., 1993, 1994). This fault cuts through Paleozoic[29], Cretaceous, and Neogen Rocks. Pesawaran[1] area is located[30] near the shoreline and[31] the geothermal manifestation (Haerudin et. al.[31], 2016), most of the lithology was altered[32] (Haerudin et. Al.[31], 2016), and none of the fault plane outcrops has[31] yet been identified[33] in this area. Besides[1] that, it has a large population so[34] disaster management systems were fully needed to prepare society from[34] the hazard risks. No[1] previous research explains the distribution of the Menanga Fault, its damage zone, and specific movement. Thus[1], it is essential to investigate the area actively affected by Menanga[35] Fault by RS and GIS methods as preliminary research about hazard risk related to Menanga[35] Fault.

This research applied the GIS method and morphometry calculation to evaluate the geomorphic indices and zone[36] affected by Menanga Fault. Five[1] geomorphic parameters were assessed[37] in this research are[38] Bifurcation Ratio Analysis (Rb), Drainage Density (Dd), Drainage Basin Shape (Bs), Hypsometric Curves and Integral (HI), and lineament trends (Keller & Pinter, 1996; Strahler, 1952). The[1] geomorphic indices along[39] with the field structural data[39] will reveal the zonation of Menanga[39] Fault area which[39] can be a critical part for[39,41] the next[40] disaster risk assessment of this area[41].

LITERATURE REVIEW

The study area is located[42] in the Pesawaran[43] region, Lampung in the vicinity of[43,44] Menanga[43] Fault. Geographically[1], it is situated[45] between 105°07'30"-105°15'00" to 5°32'0"–5°35'0" (Figure 1).

Based on the Regional Geology Map of Tanjungkarang (Mangga et al., 1993, 1994), the study area was composed of 7 rock units, from old to young aged Paleogene to Recent, there were Undifferentiated Gunung Kasih Complex (Pzg), Menanga Formation (Km), Tarahan Formation (Tpot), Sabu Formation (Tpos), Hulusimpang Formation (Tomh), Pesawaran Young Volcanic Deposits (Qhvp), and Alluvium (Qa). Menanga Formation (Km) which aged Cretaceous has structural contact with Undifferentiated Gunung Kasih Complex (Pzg) (Figure 2). Geological structures that formed in this area are subject to the subduction and the northern block was the moving up part of the fault.

Figure 1. Location map of the study area, white box is the area of interest.

Figure 2. Geomorphological map of the research area.

MATERIAL AND METHODS

Digital Elevation Model Nasional (DEMNAS) with a spatial resolution of 8.25 meters and Landsat 8 taken between 2018/07/13 to 2020/08/31 with 30 meters resolution were the primary input data in this study. DEMNAS were the product combined from IFSAR data (5 meters resolution), TERRASAR-X (5 meters resolution), and ALOS PALSAR (11.25 meters resolution) from Geospatial

Information Agency (BIG) Indonesia. Regional geology data as the basic regional framework was taken from the regional geological map of Tanjungkarang (Mangga et al., 1993).

Lineament delineation, hill shade analysis, watershed analysis, and morphometry parameter quantification carried out using ArcGIS 10.8 software and Microsoft Excel. The ArcGIS processing was completed with white box tools for hypsometric analysis. QGIS and Semi-Automatic Classification Plugin were used in this research for atmospheric correction, clipping, and band composite of Landsat 8. Lineament extraction was applied in RGB band composite 5, 8, 2 ((Misra et al., 2020; Taoufik et al., 2016). In addition, PCI Geomatica 2018 was used to delineate the contour from hill shades and Landsat 8 automatically. This research includes the studio project for remote sensing and GIS analysis through the software mentioned before, a field visit, and a comprehensive analysis of stress. The GIS analysis was validated based on a field visit and geomorphological observation. Besides the geomorphological observation, shear fracture data were used for validation. The stress analysis of shear fracture data was done using WinTensor 4.0.3.

RESULT AND DISCUSSION

Geomorphological map the of research area (Figure 2) presented 3 different geomorphology units. This location consists of a volcanic body in the western area along north to south, a fault block ridge in center area, and an alluvial plain. This phenomenon indicated that located composed of different endogenous aspects.

The area of interest is divided into 16 watersheds (DAS) and 6 river patterns; parallel in DAS 1, 3, 9, 10, 11, 15, and 16, sub-parallel in DAS 4, 6, 7, and 13, rectangular in DAS 8 and 14, dendritic in DAS 5, sub-dendritic in DAS 2, and pinnate in DAS 12 (Figure 3). The morphometric calculation was done for all watersheds. The[1] bifurcation ratio (Rb) is the ratio number[73] of river segments in each watershed that reflects the branching of the river (Keller & Pinter, 1996). The[1] more actively tectonic a zone, the higher number[74] of Rb in a watershed.[75] Rb[1] of 16 watersheds is ranging[76] from 1.04 to 6.35. Basin[1,77] shape (Bs) value defines the planimetric shape of a basin (Keller & Pinter, 1996; Yudhicara et al., 2017). High[1] Bs values provide the elongated basin and higher tectonic activity than the low Bs value. Bs[1,78] value of 16 watersheds are ranging[78] from 0.27 to 9.67. Drainage[1] density (DD) defines the amount of water stored in a catchment area (Keller & Pinter, 1996). DD[1] number or the research area is ranging[79] from 2.36-4.74.[79] Hypsometric[1,80] Curve and Integral (HI) show the elevation distribution that defines the stadium of morphology (Keller & Pinter, 1996). HI[1] of the research area ranging from 0.19-0.56. HI[1] describes the geomorphic condition quantitatively. Old[1] geomorphic stadium tends to have HI<0.4 while[81] 0.4<HI<0.6 is interpreted as mature geomorphic (Strahler, 1952).

Figure 3. Geological[1] map of the research area and the its[82] watershed delineation (Modified from Mangga et al., 1993).

The study area has two different geomorphic stadiums. Northern[1,83] and northwest area are belonging to mature stadium[83,84] while[83] the eastern and southeast areas is[83,84] old stadiums. The[1] data obtained from morphometry calculation cannot be directly interpreted[85] to divide the tectonic affected zone. It is essential to make[1][86] spatial observations to see the pattern of significant changes. Interpolation[1] is performed by[88] using Inverse Distance Weighting (IDW) and contouring methods to help the data visualization and compared[87,88] with landsat.[87] This[1] visualization (Figure 4) then[89,90] compared to the lineament taken from Landsat for further interpretation.

In general, the morphometry analysis from the parameters above shows that there are 2 zone, the eastern block[91,92] and the[92] western block.[92] Looking[1] into more detail[93], the eastern block can be divided into two other zones as it tends to have different patterns of the lineament and morphometric range values in the north and south. Thus[1], there are 3[94] zones with different structural effects in the research area, those[95] three zones are Zone A, Zone B, and Zone C (Figure 5). The[1] drainage bifurcation ratio (Rb) shows that Zone A has a greater[96] value than Zone B and C so[97] it can be interpreted[98] that the most significant level of fault activity is located[99] in Zone A (Table 1).

Figure 4. Contouring[1] map of the morphometry parameters.

Figure 5. Lineament[1] map of the research area.

Table 1. Zone Classification.

Morphometric Parameters

Zone A

Zone B

Zone C

DAS 2, 8, 11, 13

DAS 7, 9, 10, 12, 16

DAS 1, 3, 4, 5, 6, 14, 15

Bifurcation Ratio (Rb)

1.64-6.36

1.04-3.70

1.44-3.79

Basin Shape (Bs)

0.7-3.7

1.34-9.67

0.27-3.30

Drainage Density (DD)

3.06-3.97

3.16-4.08

2.36-4.74

Hypsometric Curves and Integral (HI)

0.19-0.32

0.35-0.47

0.25-0.56

Lineament

NW-SE, NE-SW

NW-SE

NE-SW

Geological Intepretation

Greatly affected by Menanga Fault

Affected by Menanga Fault and Mt. Pesawaran

Less Affected by Menanga Fault

Slope class

Gently slope (2-7%) – Steep (30-70%)

Moderately Steep (15-30%) – Very Steep (70-140%)

Flat – Moderately Steep (0-30%)

Lineament data from band 5, 8, and 2 RGB composite generally show NW-SE trending, but there are different patterns between zone A and B (Figure 5). Zone A is dominated by both NW-SE and NE-SW trends. Based on the cross-cutting relationship, NW-SE trends are cut through NE-SW trends. Compared with the regional geology maps, those NW-SE trends are defined as Menanga Fault. On the other hand, based on remote sensing analysis, Zone B has dominant NW-SE lineament trends. Based on those trends, supported by morphography and lithology distribution, the fault activities in this zone are not only affected by Menanga Fault but also volcanic process of Mt. Pesawaran which has eruption centre in the northwest part of the study area. Zone C in the northern part of the research area tends to have a NE-SW lineament pattern with less quantity of lineament. Zone C is relatively less affected by Menanga Fault.
The analysis is reinforced by six fractures as field data that were found in several areas representing each zone (green circle in Figure 5). Field data of zone A show shear fractures with a couple of plane directions (Figure 6) which are thought to have been formed due to the activity of the Menanga Fault. Rose diagrams of A.1 and A.2 revealed NW-SE and NE-SW trending, in line with the result of remote sensing analysis. The most striking feature is, even in stations affected by Menanga Fault, the stress pattern implied a different system based on Anderson's model (Anderson, 1951; Fossen, 2016), A.1 in the southeast area showed a strike-slip pattern with both maximum and minimum stress in the

horizontal axis while A.2 indicated a dip-slip pattern with minimum stress presented on the vertical axis. The[1] pattern of stress tend[116] to be sinistral strike-slip movement.

Figure 6. Stereograph[1] analysis of the shear fracture data from stations A.1 and A.2.

The analysis is reinforced[117] by six fractures as field data that were found[118] in[119] several areas representing each zone (green circle in Figure 5). Field[1] data of zone A show shear fractures with a couple of plane directions (Figure 6) which[120] are thought[121] to have been formed[122] due to the activity of the Menanga Fault. Rose[1] diagrams of A.1 and A.2 revealed NW-SE and NE-SW trending, in line with the result of remote sensing analysis. The[1] most striking feature is, even in stations affected by Menanga Fault, the stress pattern implied a different system based on Anderson's model (Anderson, 1951; Fossen, 2016), A.1[123] in the southeast area showed a strike-slip pattern with both maximum and minimum stress in the horizontal axis while A.2 indicated a dip-slip pattern with minimum stress presented on the vertical axis. The[1] pattern of stress tend[124] to be sinistral strike-slip movement.

Move to field data from zone B, B.1 is shear fractures that have two dominance fractures[125,126] trends, NE-SW and NW-SE (Figure 7). The[1] shear fractures are dip-slip but[127] the other one (B.2)[128] is tension joints with only one dominant trending,[127] thus[127] these kinds of tension are not the product of Menanga Fault activity but are interpreted as formed by the growth of Mt.Pesawaran. The[1] last zone is zone C, overall[129], the data shows only 1[130] major trend which[129] is NE-SW thus[129] it was not shear fracture related to tectonics but non-tectonically related fractures in the form of tension joints. The[1] data from zone C are displayed[131] as a rosette diagram only due to its type of tension joint (Figure 8).

In sum up, based[132,133] on both GIS and field data, it can be interpreted that Menanga Fault was a major[134] active tectonic process that affected the landform formation but it[132,135] was not the only process affecting its adjacent area. The[1] zone that was greatly affected by Menanga[136] Fault was zone A. The[1] landform formation in the research area is not only affected[138] by Menanga[137] Fault but also formed[137,138] by the growth of Mt.Pesawaran and other fault segments. Fault[1] segmentation exists in this zone with different mechanisms (strike-slip and dip-slip), producing lineaments with different trends,[139] and differentiation of river patterns. Fault[1] segmentation corresponds with the different mechanisms in the nearby area as shown by the stereograph analysis of the fracture. This[1] research is limited in asses the indication of fault segmentation, yet describes its boundary.

Figure 7. Stereograph[1] analysis of the fracture data from station[141] B.1 and B.2.

Figure 8. Rossete diagrams of the fracture data from station C.1 and C.2.

CONCLUSION

GIS processing and geomorphic indices calculation are suitable to evaluate the actively tectonic affected zone of Menanga Fault. The Pesawaran area can be divided into three zones, zone A located in the southeast greatly affected by Menanga Fault, zone B in the west is affected by both Menanga Fault and Mt. Pesawaran, while zone C is tectonically less affected. Furthermore, this study found the possibility of Menanga Fault segmentation that there are dip-slip faults and strike-slip faults in this area. Further research is recommended to consider the movement of each fault segment. It will be useful for the assessment of seismic hazards in the next steps because possibly the segmentation boundary behaves as the main point of shocks or rupture.

AUTHOR CONTRIBUTION

RNH performed the conceptualization, GIS processing, data interpretation, analysis, and wrote the manuscript, WAD performed the data interpretation, analysis, and wrote the manuscript, AYB performed the GIS processing, layouting, and wrote the manuscript, AJW performed the geological data for validation and wrote the manuscript.

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1.	*. Remote; . Pesawaran; . Thus; . The; . Zone; . Fault; . Geographic; . Numerous; . Those; . Previous; . It; . This; . Besides; . No; . Thus; . Five; . Geographically; . Menanga; . Geological; . Location; . Geomorphological; . DEMNAS; . Regional; . QGIS; . Lineament; . In; . This; . Rb; . Basin;...*	Text inconsistencies	Correctness
2.	*Remote sensing and GIS are playing important roles in geomorphology and hazard risks analysis.*	Ungrammatical sentence	Correctness
3.	~~important~~ → essential	Word choice	Engagement
4.	*Remote sensing and GIS are playing important roles in geomorphology and hazard risks analysis.*	Unclear sentences	Clarity
5.	*Pesawaran area located near the Menanga Fault and recently on the risk of earthquake that happened along this fault.*	Ungrammatical sentence	Correctness
6.	~~that happened~~	Wordy sentences	Clarity
7.	*Thus, it is essential to investigate the area actively affected by Menanga Fault as preliminary research about hazard risk related to Menanga Fault.*	Ungrammatical sentence	Correctness
8.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
9.	*was conducted*	Passive voice misuse	Clarity
10.	*be divided*	Passive voice misuse	Clarity
11.	~~3~~ → three	Improper formatting	Correctness
12.	~~zones;~~ → zones:	Incorrect punctuation	Correctness
13.	*were not only formed*	Passive voice misuse	Clarity

14.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
15.	trends,	Punctuation in compound/complex sentences	Correctness
16.	*Remote sensing (RS) is increasingly playing an important role in earth observation over this decade.*	Ungrammatical sentence	Correctness
17.	~~modelling~~ → modeling	Mixed dialects of English	Correctness
18.	*etc.*	Inappropriate colloquialisms	Delivery
19.	~~A great~~ → An excellent, A fantastic	Word choice	Engagement
20.	~~modelling~~ → modeling	Mixed dialects of English	Correctness
21.	*been observed*	Passive voice misuse	Clarity
22.	*The remote sensing and morphometry analysis approach helps the researcher to solve the problem over the complex and weathered region.*	Incorrect phrasing	Correctness
23.	~~being~~	Wordy sentences	Clarity
24.	~~and/or~~ → and, or	Inappropriate colloquialisms	Delivery
25.	*is now believed*	Passive voice misuse	Clarity
26.	~~as~~ → to be	Incorrect phrasing	Correctness
27.	*Menanga Fault was the active fault that is now believed as the source of the earthquake that happened earlier in the Pesawaran area (Nurfitriana et al., 2022).*	Unclear sentences	Clarity
28.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
29.	the Paleozoic	Determiner use	Correctness

		(a/an/the/this, etc.)	
30.	*is located*	Passive voice misuse	Clarity
31.	*Pesawaran area is located near the shoreline and the geothermal manifestation (Haerudin et. al., 2016), most of the lithology was altered (Haerudin et. Al., 2016), and none of the fault plane outcrops has yet been identified in this area.*	Ungrammatical sentence	Correctness
32.	*was altered*	Passive voice misuse	Clarity
33.	*been identified*	Passive voice misuse	Clarity
34.	*Besides that, it has a large population so disaster management systems were fully needed to prepare society from the hazard risks.*	Ungrammatical sentence	Correctness
35.	*Thus, it is essential to investigate the area actively affected by Menanga Fault by RS and GIS methods as preliminary research about hazard risk related to Menanga Fault.*	Ungrammatical sentence	Correctness
36.	~~zone~~ → zones	Incorrect noun number	Correctness
37.	*were assessed*	Passive voice misuse	Clarity
38.	*Five geomorphic parameters were assessed in this research are Bifurcation Ratio Analysis (Rb), Drainage Density (Dd), Drainage Basin Shape (Bs), Hypsometric Curves and Integral (HI), and lineament trends (Keller & Pinter, 1996; Strahler, 1952).*	Ungrammatical sentence	Correctness
39.	*The geomorphic indices along with the field structural data will reveal the zonation of Menanga Fault area which can be a critical part for the next disaster risk assessment of this area.*	Ungrammatical sentence	Correctness

40.	~~next~~ → following	Word choice	Engagement
41.	*The geomorphic indices along with the field structural data will reveal the zonation of Menanga Fault area which can be a critical part for the next disaster risk assessment of this area.*	Unclear sentences	Clarity
42.	*is located*	Passive voice misuse	Clarity
43.	*The study area is located in the Pesawaran region, Lampung in the vicinity of Menanga Fault.*	Ungrammatical sentence	Correctness
44.	*The study area is located in the Pesawaran region, Lampung in the vicinity of Menanga Fault.*	Unclear sentences	Clarity
45.	*is situated*	Passive voice misuse	Clarity
46.	*Menanga Formation (Km) which aged Cretaceous has structural contact with Undifferentiated Gunung Kasih Complex (Pzg) (Figure 2).*	Ungrammatical sentence	Correctness
47.	~~that~~ formed	Wordy sentences	Clarity
48.	, and	Punctuation in compound/complex sentences	Correctness
49.	~~of the~~ → of the	Improper formatting	Correctness
50.	~~area,~~ → area:	Incorrect punctuation	Correctness
51.	~~to~~ → and	Incorrect phrasing	Correctness
52.	~~were~~ → was	Faulty subject-verb agreement	Correctness
53.	~~basic~~ → primary	Word choice	Engagement
54.	were carried	Incorrect verb forms	Correctness

55.	*Lineament delineation, hill shade analysis, watershed analysis, and morphometry parameter quantification carried out using ArcGIS 10.8 software and Microsoft Excel.*	Incomplete sentences	Delivery
56.	*was completed*	Passive voice misuse	Clarity
57.	*were used*	Passive voice misuse	Clarity
58.	*was applied*	Passive voice misuse	Clarity
59.	and 2	Conjunction use	Correctness
60.	*was used*	Passive voice misuse	Clarity
61.	*In addition, PCI Geomatica 2018 was used to delineate the contour from hill shades and Landsat 8 automatically.*	Unclear sentences	Clarity
62.	stress analysis	Wordy sentences	Clarity
63.	*were used*	Passive voice misuse	Clarity
64.	*was done*	Passive voice misuse	Clarity
65.	*Geomorphological map the of research area (Figure 2) presented 3 different geomorphology units.*	Ungrammatical sentence	Correctness
66.	~~3~~ → three	Improper formatting	Correctness
67.	the center	Determiner use (a/an/the/this, etc.)	Correctness
68.	~~located~~ → the location is	Incorrect verb forms	Correctness
69.	*is divided*	Passive voice misuse	Clarity
70.	~~6~~ → six	Improper formatting	Correctness
71.	~~patterns;~~ → patterns:	Incorrect punctuation	Correctness

72.	*was done*	Passive voice misuse	Clarity
73.	of the number	Incorrect phrasing	Correctness
74.	the number	Determiner use (a/an/the/this, etc.)	Correctness
75.	*The more actively tectonic a zone, the higher number of Rb in a watershed.*	Incomplete sentences	Delivery
76.	*Rb of 16 watersheds is ranging from 1.04 to 6.35.*	Incorrect phrasing	Correctness
77.	The basin	Determiner use (a/an/the/this, etc.)	Correctness
78.	*Bs value of 16 watersheds are ranging from 0.27 to 9.67.*	Ungrammatical sentence	Correctness
79.	*DD number or the research area is ranging from 2.36-4.74.*	Ungrammatical sentence	Correctness
80.	The Hypsometric	Determiner use (a/an/the/this, etc.)	Correctness
81.	, while	Punctuation in compound/complex sentences	Correctness
82.	~~the~~ its	Determiner use (a/an/the/this, etc.)	Correctness
83.	*Northern and northwest area are belonging to mature stadium while the eastern and southeast areas is old stadiums.*	Ungrammatical sentence	Correctness
84.	*Northern and northwest area are belonging to mature stadium while the eastern and southeast areas is old stadiums.*	Unclear sentences	Clarity
85.	*be directly interpreted*	Passive voice misuse	Clarity

86.	*It is essential to make spatial observations to see the pattern of significant changes.*	Unclear sentences	Clarity
87.	*Interpolation is performed by using Inverse Distance Weighting (IDW) and contouring methods to help the data visualization and compared with landsat.*	Ungrammatical sentence	Correctness
88.	*Interpolation is performed by using Inverse Distance Weighting (IDW) and contouring methods to help the data visualization and compared with landsat.*	Unclear sentences	Clarity
89.	is then	Incorrect verb forms	Correctness
90.	~~then~~	Wordy sentences	Clarity
91.	*In general, the morphometry analysis from the parameters above shows that there are 2 zone, the eastern block and the western block.*	Ungrammatical sentence	Correctness
92.	*In general, the morphometry analysis from the parameters above shows that there are 2 zone, the eastern block and the western block.*	Unclear sentences	Clarity
93.	*Looking into more detail*	Misplaced words or phrases	Correctness
94.	~~3~~ → three	Improper formatting	Correctness
95.	~~, these~~ → ; those, . Those	Punctuation in compound/complex sentences	Correctness
96.	~~greater~~ → more excellent	Word choice	Engagement
97.	, so	Punctuation in compound/complex sentences	Correctness
98.	*be interpreted*	Passive voice misuse	Clarity

99.	*is located*	Passive voice misuse	Clarity
100.	~~zone~~ → zones	Incorrect noun number	Correctness
101.	*Zone A is dominated by both NW-SE and NE-SW trends.*	Passive voice misuse	Clarity
102.	*are cut*	Passive voice misuse	Clarity
103.	*are defined*	Passive voice misuse	Clarity
104.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
105.	*Based on those trends, supported by morphography and lithology distribution, the fault activities in this zone are not only affected by Menanga Fault but also volcanic process of Mt. Pesawaran which has eruption centre in the northwest part of the study area.*	Ungrammatical sentence	Correctness
106.	*Based on those trends, supported by morphography and lithology distribution, the fault activities in this zone are not only affected by Menanga Fault but also volcanic process of Mt. Pesawaran which has eruption centre in the northwest part of the study area.*	Unclear sentences	Clarity
107.	~~a NE-SW~~ → an NE-SW	Determiner use (a/an/the/this, etc.)	Correctness
108.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
109.	*is reinforced*	Passive voice misuse	Clarity
110.	~~that were~~	Wordy sentences	Clarity
111.	*were found*	Passive voice misuse	Clarity
112.	, which	Punctuation in compound/complex	Correctness

		sentences	
113.	*are thought*	Passive voice misuse	Clarity
114.	*been formed*	Passive voice misuse	Clarity
115.	~~, A.~~ → ; A. , . A.	Punctuation in compound/complex sentences	Correctness
116.	~~tend~~ → tends	Faulty subject-verb agreement	Correctness
117.	*is reinforced*	Passive voice misuse	Clarity
118.	~~that were~~	Wordy sentences	Clarity
119.	*were found*	Passive voice misuse	Clarity
120.	, which	Punctuation in compound/complex sentences	Correctness
121.	*are thought*	Passive voice misuse	Clarity
122.	*been formed*	Passive voice misuse	Clarity
123.	~~, A.~~ → ; A. , . A.	Punctuation in compound/complex sentences	Correctness
124.	~~tend~~ → tends	Faulty subject-verb agreement	Correctness
125.	~~fractures~~ → fracture	Incorrect noun number	Correctness
126.	*Move to field data from zone B, B.1 is shear fractures that have two dominance fractures trends, NE-SW and NW-SE (Figure 7).*	Unclear sentences	Clarity
127.	*The shear fractures are dip-slip but the other one (B.2) is tension joints with only*	Ungrammatical sentence	Correctness

	one dominant trending, thus these kinds of tension are not the product of Menanga Fault activity but are interpreted as formed by the growth of Mt.Pesawaran.		
128.		Incorrect citation format	Correctness
129.	*The last zone is zone C, overall, the data shows only 1 major trend which is NE-SW thus it was not shear fracture related to tectonics but non-tectonically related fractures in the form of tension joints.*	Ungrammatical sentence	Correctness
130.	~~1~~ → one	Improper formatting	Correctness
131.	*are displayed*	Passive voice misuse	Clarity
132.	*In sum up, based on both GIS and field data, it can be interpreted that Menanga Fault was a major active tectonic process that affected the landform formation but it was not the only process affecting its adjacent area.*	Ungrammatical sentence	Correctness
133.		Tone suggestions	Delivery
134.	~~major~~ → prominent, central, primary, significant	Word choice	Engagement
135.	~~but it~~ → . However, it	Hard-to-read text	Clarity
136.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
137.	*The landform formation in the research area is not only affected by Menanga Fault but also formed by the growth of Mt.Pesawaran and other fault segments.*	Ungrammatical sentence	Correctness
138.	*The landform formation in the research area is not only affected by Menanga Fault but also formed by the growth of Mt.Pesawaran and other fault segments.*	Unclear sentences	Clarity

139.	trends,	Punctuation in compound/complex sentences	Correctness
140.	, as	Punctuation in compound/complex sentences	Correctness
141.	~~station~~ → stations	Incorrect noun number	Correctness
142.	~~station~~ → stations	Incorrect noun number	Correctness
143.	the Menanga	Determiner use (a/an/the/this, etc.)	Correctness
144.	*The Pesawaran area can be divided into three zones, zone A located in the southeast greatly affected by Menanga Fault, zone B in the west is affected by both Menanga Fault and Mt. Pesawaran, while zone C is tectonically less affected.*	Ungrammatical sentence	Correctness
145.	~~while~~ → and	Conjunction use	Correctness
146.	, that	Punctuation in compound/complex sentences	Correctness
147.	~~faults~~	Wordy sentences	Clarity
148.	*is recommended*	Passive voice misuse	Clarity
149.	~~useful for~~ → helpful in, helpful for	Word choice	Engagement
150.	~~next~~ → following	Word choice	Engagement
151.	~~possibly~~	Misuse of modifiers	Correctness
152.	*It will be useful for the assessment of seismic hazards in the next steps because possibly the segmentation boundary behaves as the main point of shocks or rupture.*	Unclear sentences	Clarity

153.		Tone suggestions	Delivery
154.	*RNH performed the conceptualization, GIS processing, data interpretation, analysis, and wrote the manuscript, WAD performed the data interpretation, analysis, and wrote the manuscript, AYB performed the GIS processing, layouting, and wrote the manuscript, AJW performed the geological data for valid...*	Ungrammatical sentence	Correctness
155.		Incorrect citation format	Correctness
156.	~~with an emphasis on~~ → emphasizing	Wordy sentences	Clarity
157.	~~Advices~~ → Advice, Pieces of Advice, Bits of Advice	Incorrect noun number	Correctness
158.		Incorrect citation format	Correctness
159.	Attica ,	Improper formatting	Correctness
160.	Greece ,	Improper formatting	Correctness
161.	...	Misuse of semicolons, quotation marks, etc.	Correctness
162.	*Radon and thoron mapping to delineate the local-fault in the way Ratai geothermal field lampung Indonesia.*	Ungrammatical sentence	Correctness
163.	*Radon and thoron mapping to delineate the local-fault in the way Ratai geothermal field lampung Indonesia.*	Unclear sentences	Clarity
164.	~~Kothyari~~ → Kothari	Misspelled words	Correctness
165.		Incorrect citation format	Correctness
166.	~~Identification of~~ → Identifying	Wordy sentences	Clarity
167.		Incorrect citation format	Correctness

168.		Incorrect citation format	Correctness
169.		Incorrect citation format	Correctness
170.	Data :	Improper formatting	Correctness
171.		Incorrect citation format	Correctness
172.		Incorrect citation format	Correctness