Jurnal Penelitian Fisika dan Aplikasinya (JPFA) *Volume 11, Issue 02, December 2021*
p-ISSN: 2087-9946 DOI: [10.26740/jpfa.v11n2.p158-170](https://doi.org/10.26740/jpfa.v11n2.p158-170)
e-ISSN: 2477-1775 https://journal.unesa.ac.id/index.php/jpfa

ResearchArticle

Coulomb Stress Change of the 2004 Aceh Earthquake on Mount Sorik Marapi 2021

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Abstract

Sorik Marapi is an active volcanic mountain with an altitude of 2,145 meters located in Batang Gadis National Park, Sibanggor Julu Village, Mandailing Natal Regency, North Sumatra, Indonesia. Since the earthquake in Aceh on December 26, 2004, geological conditions in the western part of Sumatra Island have increased in stress. This affects the volcano in Sumatra, Mount Sorik Marapi, so it needs to be studied to find out the condition of changes in coulomb stress in Sorik Marapi. The method used in this study is a descriptive method with an analysis of the coulomb stress method. From the Aceh earthquake year of December 2004 to 2021, Mount Sorik Marapi experienced the highest average increase in coulomb stress in 2012, which was 0.171 bars. The highest average increase in shear in 2015 was 0.25 bars, and the highest average normal increase in 2018 was 0.202 bars. While at depth, Sorik Marapi mountain experienced an average change in coulomb stress highest of 0.368 bars, the average increase in the highest shear by 0.269 bars, and the average normal increase of 0.246 bars. All such increases are at a depth of 90 km below sea level. Based on the results of this study, it is stated that Mount Sorik Marapi experiences inconsistent changes in coulomb stress every year.

Keywords: *Earthquake; Sumatera; coulomb stress; Sorik Marapi*

Perubahan Coulomb Stress Pada Gempabumi Aceh 2004 di Gunung Sorik Marapi 2021

Abstrak

Sorik Marapi merupakan gunung vulkanik aktif dengan ketinggian 2.145 meter yang terletak di Taman Nasional Batang Gadis, di Desa Sibanggor Julu, Kabupaten Mandailing Natal, Sumatera Utara, Indonesia. Sejak gempa bumi yang terjadi di Aceh pada 26 Desember 2004, kondisi geologi di bagian barat Pulau Sumatera mengalami peningkatan tegangan. Hal ini mempengaruhi gunung berapi di Sumatera, Gunung Sorik Marapi sehingga perlu diteliti dengan tujuan agar dapat mengetahui kondisi perubahan coulomb stress di Sorik Marapi. Metode yang digunakan dalam penelitian ini adalah metode deskriptif dengan analisis metode coulomb stress. Sejak gempa Aceh Desember tahun 2004 hingga 2021, Gunung Sorik Marapi mengalami peningkatan rata-rata coulomb stress tertinggi pada tahun 2012, yaitu *sebesar 0,171 bar, rata-rata peningkatan shear tertinggi pada tahun 2015 adalah 0,25 bar dan rata-rata peningkatan normal tertinggi pada tahun 2018 adalah 0,202 bar. Sementara di kedalaman, gunung Sorik Marapi mengalami rata-rata perubahan coulomb stress tertinggi sebesar 0,368 bar, rata-rata peningkatan shear tertinggi sebesar 0,269 bar dan rata-rata peningkatan normal sebesar 0,246 bar. Semua peningkatan tersebut berada pada kedalaman 90 km di bawah permukaan laut. Berdasarkan hasil penelitian ini, disebutkan bahwa Gunung Sorik Marapi mengalami perubahan stres coulomb yang tidak konsisten setiap tahunnya.*

Kata Kunci: *Gempabumi; Sumatera; coulomb stress; Sorik Marapi*

PACS: 91.45.Xz; 91.30.Px

Article History: Received: 4 November 2020 Aproved with minor revision: 22 July 2021
Accepted: 20 November 2021 Published: 30 December 2021
Howtocite: Sinaga GHD, et al. Coulomb Stress Change of the 2004 Aceh Earthquake on Mount Sorik Marapi 2021. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*. 2021; **11**(2): 158-170. DOI: https://doi.org/10.26740/jpfa.v11n2.p158-170.

I. INTRODUCTION

Indonesia has the largest number of volcanoes in the world to have erupted in history (76), with more than 1100 explosion dates. Currently, there are 75 types A volcanoes in Indonesia, and 12 of them are in Sumatra, including Sorik Marapi. About one-seventh of the world's recorded eruptions have occurred in Indonesia, and four-fifths of historically active volcanoes have erupted in the last century [1]. Sorik Marapi is an active volcanic mountain with a height of 2,145 meters located in the Batang Gadis National Park area, which is administratively located in Sibanggor Julu Village, Puncak Sorik Marapi District, Mandailing Natal Regency, North Sumatra, Indonesia [2][3]. Mount Sorik Marapi has a crater lake peak. Volcanic centers are often located in stepovers and releasing bends, associated with normal faulting and the formation of pull-apart sedimentary basins [4][5]. In addition, Sorik Marapi is also one of the geothermal fields in Indonesia that was recently drilled, with the results indicating the presence of a high-temperature, mature, and neutral resource [6]. Several active solfatara fields and many phreatic explosions were recorded during the 19th and 20th centuries. The eruption in 1892 produced a lava that 180 people favored. Six activities are being reported since 1986 [1].

Looking at the number of victims and the time of the incident, there is a need for research on events before the volcanic eruption. Tectonic earthquakes preceded several cases of increased volcanic activity. Several cases of increased volcanic activity occurred in several volcanoes in parts of the world, including in Indonesia, such as Mount Sorik Marapi [7], Mount Rinjani [8], Mount Soputan and Gamalama [9], and Mount Merapi [10].

The Aceh earthquake with Mw9.0 and an earthquake with Mw>7, which resulted in positive Coulomb stress changes in the Mount Sorik Marapi area and its surroundings, triggered a powerful eruption on 27 August 2010. Shallow-medium earthquakes also generated positive coulomb stress changes and shallow earthquakes in which the epicenter was relatively close to Mount Sorik Marapi. The increase in seismicity after the 2004 Aceh earthquake resulted in unstable volcanic tectonic conditions in the surrounding area, causing Mount Sorik Marapi to be active [11].

Distribution value of the coulomb stress change originates from tectonic earthquakes with a magnitude scale >5 Mw. Based on the calculation results, the distribution value of the coulomb stress change has increased by 0.01 kPa with a direction toward the lower position of the peak of the Merapi volcano [10].

The static coulomb stress change model shows an extreme increase in stress distribution when an earthquake occurred on July 28, 2018, and areas experiencing increased stress again resulted in a major earthquake on August 5, 2018, and August 19, 2019. The results of PVMBG observations of major earthquake events do not affect the activity of Mount Rinjani. Still, based on the results of the DInSAR image, there is an uplift on the body of Mount Rinjani and Subsidence in the northern part [8].

Mount Soputan, Mount Gamalama, and several volcanoes in Indonesia, whose increased activity is influenced by increased coulomb stress, were indicated by the red lobe. Earthquakes in West Halmahera affects indirectly mountain Soputan and Mount Gamalama due to long distances for the coulomb stress to be observed, causing the transfer stress and stress fracture in Soputan and Gamalama [9].

Many researchers have been and are even researching the condition of an area and also volcanoes based on coulomb stress analysis, such as researches on Mount Sinabung, Mount Rinjani, Mount Soputan, Mount Gamalama, and Mount Vesuvius, Italy, and Mount Karymsky [12][13][14]. Although currently only a few volcanoes are associated with changes in coulomb stress, it is possible that some volcanoes in Indonesia will also be studied with the coulom.

Since the earthquake that occurred in Aceh on December 26, 2004, it has had a very big impact on the condition of an area that has experienced an increase in stress, especially in 13 volcanoes in Sumatra. Hence, researchers want to know the condition of changes in coulomb stress in Sorik Marapi, where Sorik Marapi is one of the active volcanoes in Sumatra [15].

II. METHOD

The method used is descriptive-analytical, with an explanation through the coulomb stress model. The model used in this study is the Coulomb Stress model. The data needed in the analysis and simulation is earthquake data in the form of the earthquake location, magnitude, depth, earthquake type, strike, slip, dip, and moment tensor. The 2004-2021 earthquake data was analyzed in coulomb 3.3 software, resulting in a coulomb stress change in bars in positive or negative form and vector directions in 2D and 3D maps [16].

Failure of faults is thought to be caused by a combination of normal (reduced) and shear stress conditions, generally measured as static coulomb stress criteria [17]. Changes in static coulomb stress caused by earthquakes may help explain the aftershock distribution [18], since aftershocks will occur when coulomb stress exceeds the collapse strength of the fault surface. Changes in coulomb stress status (ΔCFF) are defined as

$$\Delta CFF = \Delta_\tau + \mu\,(\Delta_\sigma + \Delta p) \qquad (1).$$

Δ_τ represents the change in shear stress on the fault (positive in the direction of the slip), Δ_σ is the change in normal stress (positive for unclamping fracture), Δp is the change in pore pressure, and μ is the coefficient of friction, which ranges from 0.6 to 0.8 for most intact rocks [19]. In Oklahoma, where the fluid injection is as deep as 1-2 km near the epicenter, this has been used for disposal since 1993 [20]. In addition, the effect of pore pressure cannot be ignored. Changes in pore pressure after stress change, in which there is no fluid flow (undrained condition), is

$$\Delta p = \frac{\beta \Delta \sigma_{kk}}{3} \quad (2)$$

where the β is the Skempton coefficient and σ_{kk} is the sum of diagonal elements of the stress tensor [21]. The Skempton coefficient describes changes in pore pressure resulting from externally applied stress changes, and often their values range from 0.5 to 1.0 [22][23][24].

For fault zone rheology, where fault zone material is more resilient than the surrounding material, $\sigma_{xx} = \sigma_{yy} = \sigma_{zz}$ [25] [26] [19]; so, $\frac{\Delta\sigma_{kk}}{3} = \Delta_\sigma$. Equations (1) and (2) combined with this assumption, making

$$\Delta CFF = \Delta_\tau + \mu \, \Delta_\sigma \quad (3),$$

where $\mu' = \mu\ (1-\beta\ )$, an effective friction coefficient. The effective coefficient of friction generally ranges from 0.0 to 0.8, but it is usually found to be around 0.4 ($\mu = 0.75$, $\beta = 0.47$) for horizontal faults or faults whose orientation is unknown [18]. These values are usually used in calculations of coulomb stress changes to minimize uncertainty [17, 27-29]. The location and geometry of the fault source, as well as the distribution of the slip above the source plane, play an important role in calculating coulomb stress changes. Based on the magnitude of the earthquake, we modeled the source of geometry with the empirical relationship for the strike-slip fault [30], which was built into Coulomb Software 3.3 [16].

III. RESULTS AND DISCUSSION

Coulomb Stress Changes from 2011-2021

Modeling ΔCFS is done to determine the distribution of static stress by an earthquake event. In addition, this method can also be used to look at the relationship of earthquakes that can trigger the next earthquake, both between mainshock-mainshock and mainshock-aftershock and the relationship between tectonic and volcanic earthquakes [8]. Earthquake data in the form of magnitude moment, depth, longitude, and latitude were obtained from the website of the Geophysical Meteorology and Climatology Agency (BMKG), while the focal mechanism was downloaded from the United States Geological Survey (USGS). The input data analyzed was an earthquake that occurred from May 2004 to May 2021 with a magnitude of at least 5.5.

Table 1. Normal, Shear, and Stress average Values at Mount Sorik Marapi in 2004-2015 (Bar)

	2004-2011	**2004-2012**	**2004-2013**	**2004-2014**	**2004-2015**
Normal	0.103	0.086	0.121	0.162	-0.204
Shear	0.125	0.136	0.107	0.077	0.250
Coulomb	0.167	0.171	0.155	0.142	0.169

Table 1 displays the average value of normal, shear, and coulomb stress changes that occur on Mount Sorik Marapi at a depth of 0-100 km. The highest average normal value occurred in 2014 was at 0.162545 bar, while the lowest normal average value occurred in 2015 was at -0.204 bar. The highest shear average value occurred in 2015 was at 0.250636 bar, while the lowest shear average in 2014 was at 0.077636 bar. The average value of the largest coulomb stress change that occurred in 2012 was at 0.171545 bar, while the average value of the smallest coulomb stress change that occurred in 2014 was 0.142545 bar. Lastly, the average value of the largest coulomb stress change that occurred in 2015 was caused by an earthquake that occurred on March 3, 2015, with a magnitude moment criteria of 6.2, a depth of 23.6 km, and at the location of 98.58° longitude, and -0.72° latitude with type focal mechanism reverse fault (Figure 1).

Changes in coulomb stress that occur in one area are very different, especially when comparing a volcano with an a non-volcanic area. The change in coulomb stress that occurs on Mount Sorik Marapi is different from the change in coulomb stress that occurs in Pidie-Aceh. The change in coulomb stress that happened in Mount Sorik Marapi that occurred in 2013 has a value that is not much different from what happened in Pidie-Aceh. If the average change in coulomb stress in Sorik Marapi 2013 is 0.155 bar, then the average change in coulomb stress in Pidie-Aceh is 0.01-0.1 bar [31]. The comparison of changes in coulomb stress is not too far, probably because the position of Pidie-Aceh is more prone to earthquakes than the position of Mount Sorik Marapi and is also still in the position of the Sumatra Fault.

Table 2 shows the result of an analysis of coulomb stress changes from 2004 to 2021, including the average values of normal, shear, and coulomb stress changes that occurred on Mount Sorik Marapi at a depth of 0-100 km.

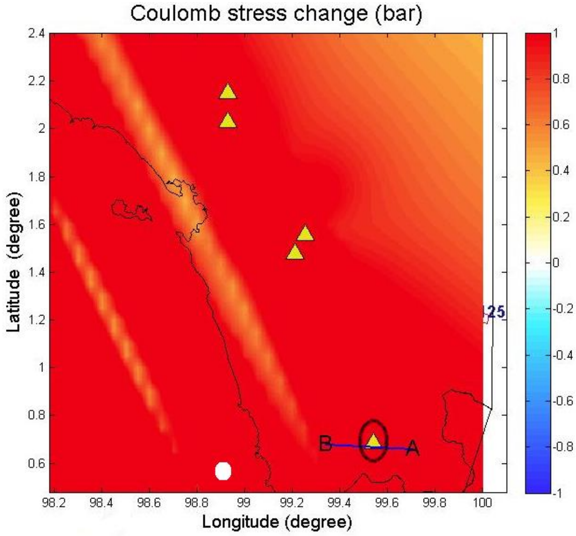

Figure 1. Coulomb Stress Change in Mount Sorik Marapi 2015 (black ring) and March 3, 2015 Earthquake (White ring)

Table 2. Normal, Shear, and Stress Values at Mount Sorik Marapi in 2004-2021 (Bar)

	2004-2016	**2004-2017**	**2004-2018**	**2004-2019**	**2004-2020**	**2004-2021**
Normal	0.185	0.192	0.202	0.150	0.172	0.116
Shear	0.086	0.054	0.064	0.079	0.074	0.110
Coulomb	0.160	0.131	0.141	0.139	0.144	0.157

The highest average of normal value occurred in 2018 was at 0.202455 bar, while the lowest normal average value occurred in 2021 was at 0.116455 bar. The highest shear average value occurred in 2021 was at 0.110727 bar, while the lowest shear average value occurred in 2017 at 0.05491 bar. The average value of the largest coulomb stress change in 2016 was at 0.160455 bar, while the average value of the smallest coulomb stress change that occurred in 2017 was 0.131273 bar. The average value of the largest coulomb stress change in 2016 was a continuation of earthquakes that occurred in 20 years caused by small earthquakes occurring at an average depth below 40 km. However, it is shown that the coulomb stress change in table 1, compared to table 2, achieved the highest coulomb stress change in 2015. So the average value of coulomb stress changes from 2011 to 2021 has increased and decreased inconstantly. Non-constant coulomb stress changes caused by earthquakes that have magnitude moments, depth, location, and focal mechanisms vary from time to time, especially the type of focal mechanism normal fault occurs in 2016 and the following year that affects or spreads stress horizontally around Mount Sorik Marapi.

Table 2 shows that, after 2015, the average value of coulomb stress decreased until 2021, even though the decrease in the average value of the coulomb stress change was inconsistent. Compared to Table 2, the value of the change in coulomb stress Sorik Marapi in 2015 still had a higher value in the following and the previous year. It was also the highest average value from 2011 to 2021. Changes in coulomb stress in Sorik Marapi 2016 also occur in Pidie-Aceh. However, the average value of the change in coulomb stress is different, and the average value of coulomb stress change in Pidie-Aceh is much lower than the previous year, which is less than 1 bar [32].

For the average value of coulomb stress changes, Sorik Marapi in 2017 has an average value of coulomb stress changes that are different from the Deli Serdang [33] and Poso[34]. The average value of Sorik Marapi's coulomb stress change in 2017 was 0.131 bar. Meanwhile, the average value of the change in coulomb stress in Deli Serdang was 0.1-0.5 bar [33]. This is because the value of changes in coulomb stress in Deli Serdang is still not averaged with shear or normal values. Meanwhile, the value of the change in coulomb stress that occurred in Poso was >0.2 bar [34]. This is also because the number of earthquakes that occur around Poso is not as many as the earthquakes that occur around Mount Sorik Marapi.

The average value of Sorik Marapi's coulomb stress change in 2018 has an average value that is different from the average value of coulomb stress change that occurred in Palu – Koro [35][36][37], Palu – Donggala [38][39], Palu [40][41][42][43], Lombok [44], Rinjani [8], Minahasa [45], and Sumatra [46]. The average value of coulomb stress change in Sorik Marapi 2018 was 0.141 bar, while the average value of coulomb stress change in Palu-Koro was ±0.5 bar. This is due to the proximity of Palu to the location of the earthquake on August 18, 2012. The average value of the Palu-Donggala coulomb stress change was ±1.0 bar. This is also due to the close proximity of Palu-Donggala to the location of the earthquake on August 18, 2012. The average value of the Palu coulomb stress change was ±1.0 bar, with the same cause as the change in coulomb stress in Koro-Palu, Palu-Donggala, and Palu. This was in contrast to the average value of changes in coulomb stress in Lombok, which was 0.1-1 bar. This is due to the fact that the number of earthquakes that occurred in Lombok was not as many as those in Sorik Marapi. The average value of coulomb stress change in Rinjani is ≤0.1 bar. Minahasa's coulomb stress change value is in the range of 0.007-55.282 bar. The value of this large coulomb stress change is due to the location of Minahasa, which is close to the intersection of two major earthquake locations, namely the 7.9 Mw earthquake in 1996 and the 7.5 Mw earthquake in 2018. The last change in coulomb stress in the Sumatra Fault has only spread along Sumatra's west coast. This is due to the requirement to include earthquakes that occurred on the west coast of Sumatra, but the software used has limitations, so the average value of coulomb stress on the island of Sumatra is not yet known.

The value of changes in the coulomb stress of Sorik Marapi 2019 has decreased by 0.139 bar. In contrast to the value of changes in coulomb stress that occurs in the Molucca Sea, which is in the range of -0.5-1.8 bar [47][48]. The value of this coulomb change was caused by a single earthquake that occurred on 7 January 2019, in which the earthquake was still not averaged with other earthquakes. In addition, the Molucca Sea earthquake case of September 26, 2019, and November 14-15, 2019, still has not happened as many earthquakes as in Sorik Marapi, so the average value of the Molucca Sea coulomb stress change is still greater than Sorik Marapi. The value of coulomb stress change in Tugu Hilir is in the range of ≤1.0 bar. This was caused by the mite earthquake on August 2, 2019, that occurred in Tugu Hilir [49]. Changes in coulomb stress that occurred in Sorik Marapi 2020 cannot be compared with other studies because there is no comparison with the same year, namely 2020.

The average value of coulomb stress changes in Sorik Marapi 2021 was 0.157 bar. The value of this change in coulomb stress is different from the average value of changes in coulomb stress in Mamuju-Majene [50] which was 78 bars. This huge change in coulomb stress is due to the location of Mamuju-Majene, which was at the intersection of three major earthquakes, namely the 7 Mw earthquake on February 23, 1969; the 7 Mw earthquake on January 8, 1984; and the 6.2 Mw earthquake on January 14, 2021. Meanwhile, the value of the change in coulomb stress in Central Molucca is 0.2-0.6 bar. This is because the average number of earthquakes in Central Molucca is not as many as in Sorik Marapi. Hence, the value of changes in coulomb stress in Central Molucca is greater than that of Sorik Marapi [51].

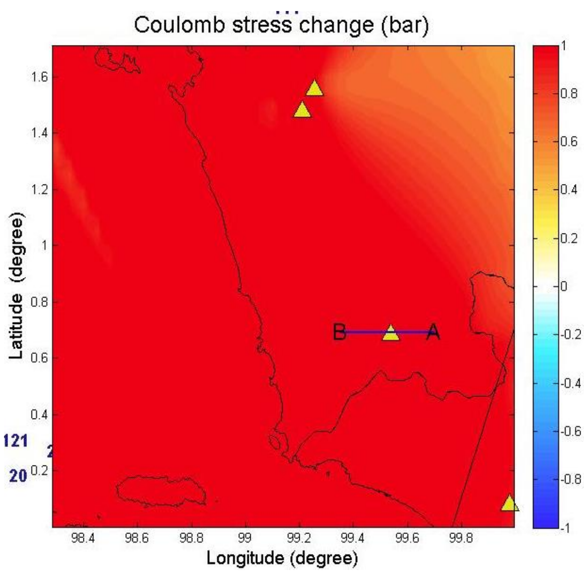

Figure 2. Coulomb Stress Change in Mount Sorik Marapi 2021

Figure 2 shows coulomb stress changes in Sorik Marapi in 2021. Coulomb stress changes have a normal average value of 0.116455 bar, a shear average value of 0.110727 bar, and an average coulomb change value of 0.157273 bar. Although coulomb stress changes are inconsistent, coulomb stress changes in 2021 have the smallest normal average since 2004 and the highest shear average since 2004. The decrease in the value of coulomb stress changes is caused by the number of earthquakes that occurred in 2020-2021, which has the least number of events compared to previous years. The most frequent earthquakes from 2020 to 2021 are predominantly located in the northern part of Sumatra Island. Coulomb stress changes in 2021 are predominantly heading east, southeast, and south. Red lobes characterize increased changes in coulomb stress, while decreased changes in coulomb stress are characterized by blue lobes. Changes in coulomb Stress on depth 0-100 km. Figure 3 shows a map of the spread of earthquakes with a centroid tensor moment of every event in 2021 on the island of Sumatra and surrounding areas.

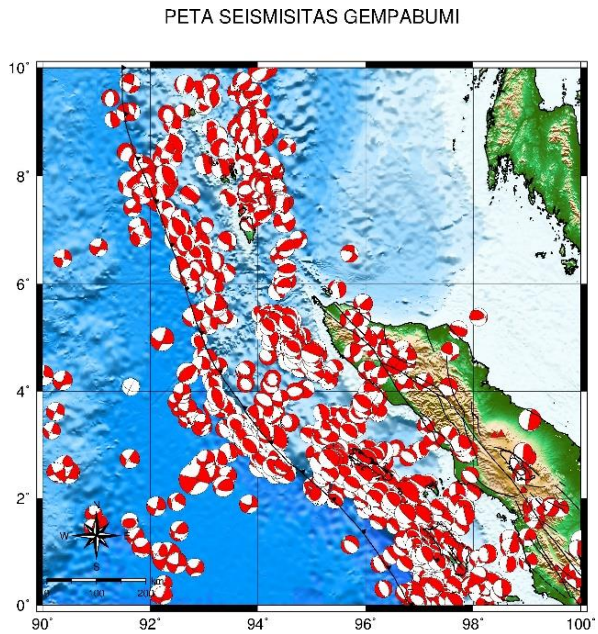

Figure 3. Earthquake distribution map with Centroid Moment Tensor in 2021

The centroid moment tensor shows strike-slip fault, reverse fault, and normal fault. The reverse fault is the centroid tensor moment that most often occurs around Mount Sorik Marapi. The geological conditions of the region influence the spread of earthquakes.

Changes in Coulomb Stress on depth 0-100 km

In addition to the changes in coulombs

stress studied from year to year, we also examined changes in coulomb stress at a depth of 0-100 km. This is done because coulomb stress changes also affect the geological and seismic conditions of Mount Sorik Marapi. Coulomb stress changes from year to year and continues to experience erratic changes within 0-100 km.

Table 3 displays shear, normal, and coulomb changes in Sorik Marapi from 2004 to 2021. Coulomb stress changes in Sorik Marapi have a different average value at each depth. The lowest average shear value is at a depth of 0 km of -0.16585 bar, while the highest average shear value is at a depth of 90 km of 0.269917 bar.

Table 3. Normal, Shear, and Stress Values at Mount Sorik Marapi 2004-2021 in depth 0-100 km

Depth	shear	normal	coulomb
0	-0.16583	0.129583	-0.11442
10	-0.12158	0.035833	-0.10783
20	-0.08108	0.005917	-0.07925
30	-0.00608	0.0065	-0.00392
40	0.07825	0.039667	0.093833
50	0.15625	0.103167	0.19725
60	0.214167	0.166917	0.280917
70	0.249	0.214583	0.334583
80	0.265583	0.239667	0.36125
90	0.269917	0.2465	0.368083
100	0.265167	0.23925	0.3605

It can also be identified that the lowest normal average value is at a depth of 20 km of 0.005917, while the highest normal average value is at a depth of 90 km of 0.2465 bar. The average value of the lowest coulomb change is at a depth of 0 km of -0.11442 bar, while the average value of the highest coulomb change is at a depth of 90 km of 0.368083 bar. Based on the depth of Mount Sorik Marapi, it can be concluded that the average value of the highest coulomb stress change is 90 km, but the average value of the lowest coulomb stress change (strain) is at a depth of 0-20 km.

The value of this coulomb stress change is caused by a large earthquake that occurred on September 30, 2009, with a magnitude of 7.6 Mw at a depth of 77.8 km and a longitude of 99.67°, the latitude of -0.79. The 6 Mw magnitude earthquake also influences it happened on 22 February 2002 at a depth of 50 km, a longitude of 100.31°, and a latitude of -1.68°. The updated coulomb stress value on Mount Sorik Marapi in 2021 has the highest average value of coulomb stress change occurring at a depth of 100 km by 0.314 bar, while the average value of the lowest coulomb stress change/strain is at a depth of 0 km of -0.008 bar. The highest average shear value is also at a depth of 100 km by 0.219 bar, while the lowest average shear value is at a depth of 0 km by -0.024 bar.

The value of changes in Sorik Marapi's coulombs stress at depth is also different from some changes in coulomb stress analyzed in the position of volcanoes in Indonesia. As explained above, the largest Sorik Marapi coulomb stress value is at a depth of 90 km, compared to volcanoes in Indonesia, such as Mount Rinjani [8], which has the highest change in coulomb stress in the range of 0-150 km at depth. It is different from Mount Soputan and Mount Gamalama, which have the largest change in coulomb stress at a depth of 10 km with an average change in coulomb stress of 0.023 bar and 0.007 bar [9]. It is possible that the change in Sorik Marapi's coulomb stress, which is at a depth exceeding the depth of the magma, does not affect the activity of Sorik Marapi.

The highest normal average value has the same depth as the average value of coulomb and shear, which is 100 km of 0.237 bar, while the lowest normal average value is at a depth of 10 km of -0.006 bar. The highest coulomb stress change was caused by two earthquakes that occurred, namely, the earthquake that occurred on June 17, 2019, (5.1 Mw, depth 51.2 km, longitude 98.92°, and latitude -0.46°)

and the earthquake that occurred on August 10, 2019 (5.2 Mw, depth 40.1 km, longitude 99.2°, and latitude -0.87°).

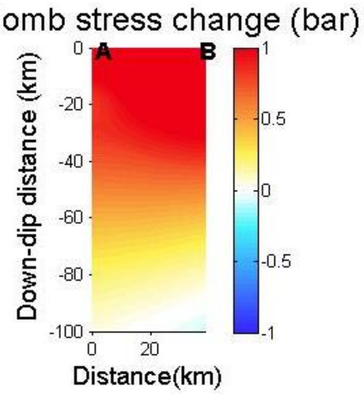

Figure 4. Cross Section of Coulomb Stress Change in Mount Sorik Marapi 2021 on depth 0-100 km

Based on the analysis of coulomb stress and its spread, it can be concluded that the stress movement is disseminated towards the southwest. The direction of the spread of positive coulomb stress can be seen in Figure 4, where the direction of spread is converted to vector and then displayed on Google Earth, right at the position of Mount Sorik Marapi. If the direction of the coulomb stress vector on volcanoes in North Sumatra, especially Mount Sinabung, is compared to the direction of change in coulomb stress in Sorik Marapi, the difference in Sorik Marapi's coulomb stress is not too large for Mount Sinabung. This is because the amount of earthquake activity and earthquake impacts on the west coastline is smaller than earthquake activity in the northwest of the island of Sumatra. However, if traced further, the shape and position of Sorik Marapi may have changed due to changes in coulomb stress to the southwest.

Based on the results of research on changes in coulomb stress on Mount Sorik Marapi, it is hoped that the results of this study will continue to be deepened and developed again, especially in terms of the magnetic properties of rocks and also gravity, as the researchers suspect that there is a relationship between stress and the magnetic nature of rocks. This study can be used as a reference for all concerned, especially natural disaster mitigation data, and can also advance and develop science, especially geophysics.

IV. CONCLUSION

Coulomb stress on Mount Sorik Marapi is constantly changing every year. The average value of the highest coulomb stress change on Mount Sorik Marapi occurred in 2012 was at 0.171 bar, while the average value of the lowest coulomb stress change on Mount Sorik Marapi occurred in 2017 was 0.131 bar. For 2021, the average value of the highest coulomb stress change on Mount Sorik Marapi is 0.157 bar. The average value of the highest coulomb stress change also occurs at a depth of 90 km, while the average value of the lowest coulomb stress change (strain) is at a depth of 0 km. The positive and negative stress change in the coulomb is influenced by earthquakes around Mount Sorik Marapi.

ACKNOWLEDGMENT (OPTIONAL)

The authors want to sincerely thank the Agency for Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), Global CMT, and PVMBG for the information on Sumatra earthquake given for this research. The authors would also like to thank Shinji Toda, Ross Stein, Jian Lin, and Volkan Sevilgen as the author of Coulomb 3.3 software. Thank you also for the help during the research completion.

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