GEOTHERMAL POTENTIAL ON SUMATRA FAULT SYSTEM TO SUSTAINABLE GEOTOURISM IN WEST SUMATRA

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POTENSI PANAS BUMI PADA SISTEM SESAR SUMATRA UNTUK GEOWISATA BERKELANJUTAN DI SUMATRA BARAT

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Abstrak. Sumatra Island is an island is traversed an active ring of fire of Barisan Range which is related to the active Sumatra fault system and geothermal manifestations. It is associated with geothermal manifestations in Cubadak, Talu, Bonjol, and Rimbo Panti, Pasaman Regency, and West Pasaman Regency, West Sumatra Province, as an indication of a geothermal system connected to the Sumatra Fault System from the Sianok Segment and the Talamau Volcano Complex. Sustainable geotourism has become an effective for sustainable development of geotourism, the geothermal energy direct utilization. The purpose of this study is to provide sustainable geotourism from geothermal potential in the fault system, taking into account aspects of village geotourism, ecotourism, ecoculture, and education. The methodology used in this study is to collect data on geothermal manifestations from regional geological maps and field observations in geothermal manifestation areas by considering sustainable geotourism. A simple model of sustainable geotourism is made. Study result indicate several locations of potential geothermal manifestations to be used as sustainable geotourism associated with the Sumatra Fault System and the Talamau Volcano Complex.

Abstract. Pulau Sumatra merupakan pulau yang dilalui oleh jalur gunung api aktif pada Perbukitan Barisan yang berkaitan dengan keberadaan sistem sesar aktif Sumatra dan manifestasi panas bumi. Berhubungan dengan hal tersebut, terdapatnya potensi manifestasi panas bumi di Cubadak, Talu, Bonjol, dan

Rimbo Panti, Kabupaten Pasaman dan Kabupaten Pasaman Barat, Provinsi Sumatra Barat sebagai petunjuk adanya sistem panas bumi yang terkoneksi dengan Sistem Sesar Sumatra dari Segmen Sianok dan Kompleks Gunung Api Talamau. Dengan tatanan geologi yang demikian, menjadi suatu hal yang sangat baik dijadikan sebagai tempat wisata alam kebumian yang berbasis geowisata berkelanjutan. Geowisata berkelanjutan menjadi suatu hal penting dalam peranan geowisata pembangunan berkelanjutan dari pemanfaatan secara langsung energi panas bumi. Tujuan dari studi ini diharapkan dapat menyediakan geowisata berkelanjutan dari potensi panas bumi di sistem sesar, dengan mempertimbangkan aspek geowisata desa, ekowisata, ekobudaya, dan eduwisata. Metodologi yang digunakan pada penelitian ini, yaitu mengumpulkan data manifestasi panas bumi dari peta geologi regional dan observasi lapangan di daerah manifestasi panas bumi dengan mempertimbangkan geowisata berkelanjutan, selanjutnya dilakukan pembuatan model sederhana dari geowisata berkelanjutan. Hasil dari penelitian menunjukkan beberapa lokasi manifestasi panasbumi yang potensial untuk dijadikan geowisata berkelanjutan yang berasosiasi dengan Sistem Sesar Sumatra dan Kompleks Gunung Api Talamau.

1. INTRODUCTION

A large part of Indonesia's archipelago consists of islands is related the active volcano of Pacific ring of fire, including Sumatra of active continental margin (Entezari & Aghaeipour, 2014; N.T. Farsani et al., 2011; Neda Torabi Farsani et al., 2012; Hochstein & Sudarman, 2015). These have numerous implications for the existence of energy resource potential in Sumatra, particularly geothermal potential manifestation (Antić & Tomić, 2017; Hochstein & Sudarman, 2017).

Geothermal features manifestation on Cubadak, Talu, Bonjol, and Rimbo Panti, Pasaman Regency and West Pasaman Regency, West Sumatra, Indonesia are an indication to geothermal system the connected to Sumatra Fault System (SFS) and Talamau Volcanic Complex (TVC) (Hermawan & Rezky, 2010; Hochstein & Sudarman, 2017; Sardjam et al., 2010) (**Figure 1**). It is significant for study the utilization of direct and direct use.

Geothermal energy potential is not only used for electricity, but well to direct used geothermal energy as tourism object. Geothermal features on Cubadak, Bonjol, Rimbo Panti, Talu the associated with Sumatra Fault System to become interesting for the sustainable geotourism on geothermal potential of tourism object.

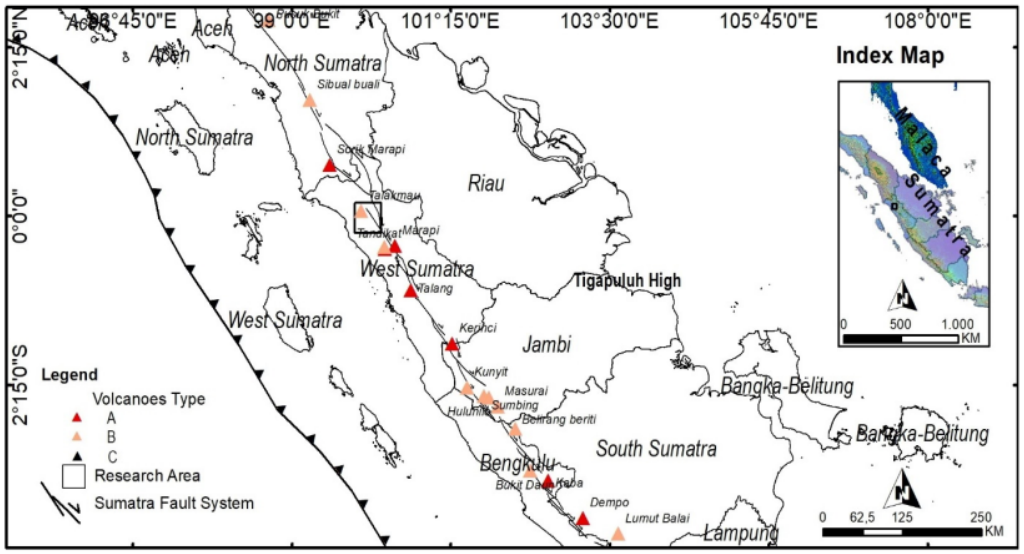

Figure 1. Geothermal geotourism on Pasaman Regency and West Pasaman Regency, West Sumatra, Indonesia. SFS and TVC are associated to geothermal potential to sustainable geotourism (modified from Hochstein & Sudarman, 2017).

Geotourism on geothermal energy is a natural tourism utilized to resource geothermal features potential, and linkage to geothermal landscape, lithology, structural geology, and historical geology. Geothermal geotourism implicates the study an active volcano, geothermal landscape, and structural geology (Cooper, 2010; Prasetya et al., 2017; Suharcahyo et al., 2017).

Sumatra Fault System is an active structure associated with geothermal manifestation and volcanic of Barisan Range (Hall, 2011, 2012, 2013; Hall & Spakman, 2015; Muraoka et al., 2010). It have formed Neogene of counterbalance the collision India Continental to Asia Continental, and activity continued to Quarternary volcanism. Sianok Segment and Barumun Segment are fault system the appear of geothermal features manifestation potential on Rimbo Panti and Bonjol, where Talamau Volcanic Complex part of western of Sumatra Fault System.

Sustainable geotourism has become significant for sustainable development of geotourism. The organize geothermal geotourism will aid geothermal manifestation become education of geothermal potential (Chen et al., 2015; Moufti & Nemeth, 2016; Utama, 2015; Utami et al., 2013). The purpose study is expected to providing significant sustainable geotourism of geothermal potential a fault system, indeed regard several aspects, who consider of geotourism village, ecotourism, ecocultural, and education based on local wisdom.

2. LITERATURE REVIEW

Sumatra is a part of Sundaland with numerous experienced tectonic; it is consist of Pre-Tertiary tectonic processes the early with the collision of East Sumatra to East Malaya Terrane on Mid-Permian, then transitional system of East Sumatra Terrane to West Sumatra Terrane during Late Permian-Triassic, and terminated to obduction Woyla Arc to West Sumatra Terrane during Jurassic-Cretaceous (Metcalfe, 2011, 2013, 2017; Zahirovic et al., 2014, 2016). Pre-Tertiary tectonic is composed of stratigraphy and structural geology in Sundaland. The

preliminary Paleogene tectonic is Sumatra clockwise rotation which is formed of magmatic arc, volcanic arc, and volcanic sedimentary on Barisan Range and continued Neogen tectonic of Sumatra counterclockwise as the response of collision Australia to eastern margin of Sundaland; it is consequence of magmatic arc, volcanic arc, and active Sumatra Fault System on Barisan Range (Advokaat et al., 2018; Carey, 1955; Hutchison, 2010, 2014). Qaurternary tectonic is related to active volcano and geothermal features manifestation. Geological situation of Paleogene to Quaternary have experienced on Barisan Range the related to geothermal manifestation.

The physiography zone in Sumatra divided into 1) Barisan Range the related to geothermal and volcanic, 2) Sumatra Fault System the associated to volcanic and geothermal, 3) Tigapuluh Hills, 4) Sunda Shelf, 5) Low Hills and Wavy Plain, 6) Outer Arc (Utama et al., 2021). The geothermal features manifestation the related to Sumatra Fault System (**Figure 2**).

3. METHODS

This paper explains about the geothermal potential of Sumatra Fault System for sustainable geotourism. The early study is indirectly geological mapping through the regional geological map with 1:250.000 scale map, then recognize to geothermal manifestation and fault system the supported digital elevation model Aster Gdem 30 m of overlapping to regional geological map, and then the accompanied geological analysis of geothermal manifestation for understanding characteristic geothermal features potential manifestation, what is associated to volcanic hydrothermal or volcano-tectonic. Its purpose is the sustainability of geothermal potential to geotourism (Antić & Tomić, 2017; Suharcahyo et al., 2017). Sustainability geotourism concept is very important for geothermal manifestation area developed and utilized for tourism. Sumatra Fault System have numerous geothermal feature manifestation, therefore need sustainability geotourism who consider of geotourism village, ecotourism, ecocultural, and edutourism.

Geological surface collecting data only geothermal manifestation potential from the geological investigation, several locations such as Bonjol, Cubadak, Talu, and Rimbo Panti on Pasaman Regency, West Sumatra. Geological and tourism analysis of potential geothermal site to comprehends the characteristics of geotourism village, ecotourism, ecocultural, and edutourism. The final integration to these data geological mapping with the determination of geothermal manifestation potential to sustainable geotourism with simplified block model geotourism.

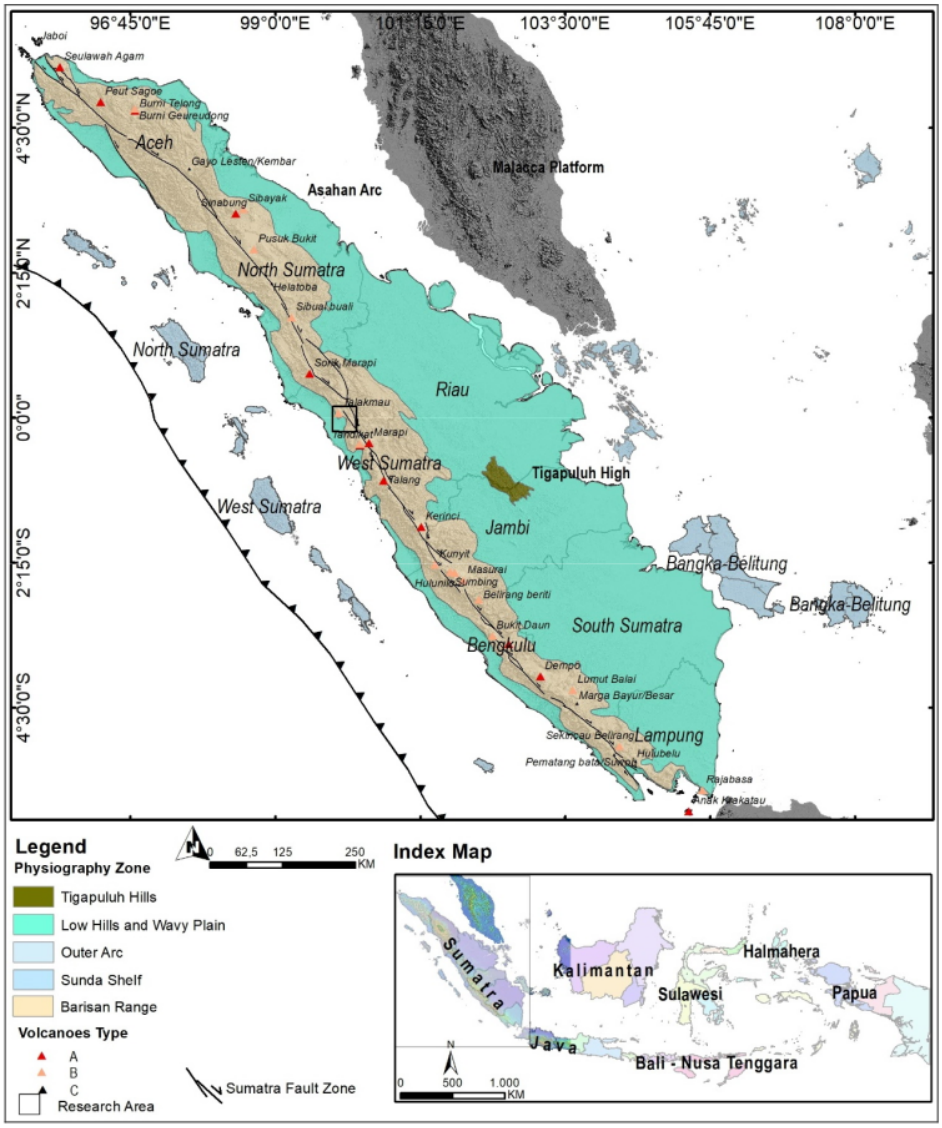

Figure 2. Tectonic and physiography in Sumatra, after Utama et al.. (2021).

4. RESULTS AND DISCUSSION

4.1. Result

Geothermal potential in Bonjol, Cubadak, Talu, and Rimbo Panti on Pasaman Regency, West Sumatra have numerous geothermal manifestations become to geotourism sustainablity, such as hot spring, hot pool, mud pool, steaming ground, and hydrothermal alteration rock. Below, the category of geothermal geotourism in West Pasaman Regency and Pasaman Regency, West Sumatra.

4.1.1. Rimbo Panti Geotourism

Geothermal features manifestation consist of the hot pool, mud pool, hot spring, hydrothermal alteration rock. This location has

made tourism, but not yet signboard as guidance for understanding about appear geothermal features, so that significantly for tourism object become to sustainable geotourism with aspect education with signboard about historical geothermal manifestation (**Figure 3**). Geothermal features manifestation on Sumatra Fault System, between of Barumun Segment and Sianok Segment. The existence of geothermal manifestation on Miosen hydrothermal alteration andesitic lava.

4.1.2. Bonjol Geotourism

Geothermal appear manifestation divided to the hot pool, hot spring, hydrothermal alteration rock, and stream to Bonjol River of irrigation (**Figure 4**). The existence of geothermal manifestation on Sianok Fault Segment. Detachment of bedrock as proof of the linkage geothermal feature manifestation to Sumatra Fault System. Public facilities such as maoques and gazebo can use tourism object, but have not signboard about education geothermal manifestation. Manifestation appears of Quaternary volcanic product and Miosen lava.

4.1.3. Cubadak Geotourism

Geothermal manifestation on Cubadak is composed of warm stream, hot spring, hydrothermal alteration rock, and hot pool. This location is the northern part of Talamau Volcanic Complex and the western part of Sumatra Fault System.

Figure 3. Geothermal features manifestation on Rimbo Panti Geotourism consist of a) hot pool and hot spring, b) welcome board to geotourism, but not only education signboard, c) mud pool and small pool the can use to egg boil, d) bridge above mud pool.

The relevance for sustainable geotourism, so that signboard for a lesson to tourism in the destination in there, requires signboard about historical geology of existence geothermal features manifestation (**Figure 5**). Manifestation appears on Miocene Volcanic Product such as andesitic lava and volcanic breccia.

Figure 4. a) Public facilities of gazebo on geothermal manifestation, b) hot pool and alteration rock, c) masque as muslim worship, d) warm stream of irrigation.

Figure 5. a) Warm stream and hydrothermal alteration rock, b) public facilities form street to geothermal manifestation destination, c) hot pool for geotourism.

4.1.4. Talu Geotourism

Geothermal manifestation consists of mud pool, hot spring, warm stream, hydrothermal alteration rock. This geothermal features on Talu is the northern part of Talamau Volcanic Complex, the western part of Sumatra Fault System, and near Cubadak Geothermal manifestation (**Figure 6**). Holocene volcanic

product and Miosen andesitic lava product is consist of lithology on geothermal manifestation. This location have not a signboard to lesson about geothermal manifestation for tourism destination.

4.2. Discussion

Geothermal manifestation related to SFS of Sianok Segment and Barumun Segment and the associated to TVC. Appear of geothermal manifestation on the Rimbo Panti, Bonjol, Cubadak, and Talu are refer to as volcanic-tectonic (**Figure 7**). Geothermal manifestation is stratigraphy composed of Miosen andesitic lava and volcanic breccia (Tmv) and Quatenary Holocene volcanic (Qh and Qvgn) (Kastowo et al., 1996; Rock et al., 1983). Geological settings on the geotourism in these area has historical geology involve Quatenary volcanic activity of volcanic dormant type B of Talamau Volcanic Complex (See **Figure 2**) as the heat source of the geothermal system, whereas Sumatra Fault System as permeability zone of fracture system the channel way fluid geothermal the appear to surface as geothermal features manifestation.

Sustainable geotourism of geothermal manifestation is required local culture, including ecotourism and ecoculture, which is caring to local people and surrounding, environment conservation, traditional culture, with priority to entrepreneur. For applied the ecotourism, ecoculture, and geotourism village is required signboard with complete lesson about geothermal features manifestation, historical geology related to geothermal landscape, and structural geology as channel way of exposure/appear geothermal manifestation, in order to achieve education for tourists (**Figure 8**).

Conseptual model of geotourism is perspective model of geotourism on Rimbo Panti, Bonjol, Cubadak, Talu, of Pasaman Regency and West Pasaman Regency, West Sumatra. It is to examine of geotourism village, ecotourism, ecocultural, and edutourism. It is including of sustainable geotourism. Therefore to the recommendation of guidance of geotourism on potential geothermal site in Sumatra.

Figure 6. a) Mud pool on warm pool shelter, b) warm pool shelter and hydrothermal alteration rock, and c) warm stream of geothermal.

5. CONCLUSION

Geothermal manifestation on Rimbo Panti, Bonjol, Cubadak, and Talu, Pasaman Regency and West Pasaman Regency, West Sumatra consist of hot spring, mud pool, warm pool, hydrothermal rock alteration. Several locations of geothermal manifestation has made natural tourism. Therefore need to examine geotourism village, ecotourism, ecoculture, and education.

Geothermal potential on Sumatra Fault System of Sianok segment is significantly sustainable geotourism with the consider environmental, which is geotourism village, ecotourism, ecoculture, and education. Geotourism on Rimbo Panti, Bonjol, Cubadak, and Talu is very entirely for sustainable geotourism based on local wisdom and lesson historical geology of signboard.

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