Journal of Global Environmental Dynamics (JGED)

Contents list available at JGED website: https://jurnal.uns.ac.id/jged/index

# Characteristics of Sewu Mountain Karst as Geopark Area

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**ABSTRACT**. One of the Geopark area in Indonesia is Karst area of Sewu Mountain that is located on three regencies, which are Gunung Kidul, Wonogiri, and Pacitan. The uniqueness of the karst area in terms of geology, geomorphology, hydrology, and land wealth side is managed sustainably in a geopark package. Resources in karst area are very potential to support life, on the one hand it has a wealth of potential and abundant resources, but on the other hand it is vulnerable to the risk of environmental damage due to irresponsible use. This study aims to determine the characteristics of the karst area of Sewu Mountain as a geopark area. This research object is the karst area of Sewu Mountain and uses a qualitative descriptive method, with secondary data collection. Based on the geology side, Doline is found as a characteristic in the karst area, in the geomorphology side of the Sewu Mountain karst area it is divided into three subtypes, namely polygonal, labyrinth, and tower-cone, while from hydrology it uses a conduit system, and then from cultural condition there is land use (agricultural land), livestock, and also to take advantage of the function of the sea.

***Keywords:*** Karst, Sewu Mountain, Geopark.

**Article History**: Received: 16 October 2020; Revised: 29 October 2020; Accepted: 2 November 2020; Available online: 15 November 2020
**How to Cite This Article**: Hartawan, B.S., Erwandha, R., Irsyadi, M.B., Hidayat, M.R.A., and Sholih, D. (2020) Characteristics of Sewu Mountain Karst as Geopark Area, Journal of Global Environmental Science, 1 (1), 7-12.

## 1. Introduction

Karst is a surface form of the earth that is generally characterized by closed depression, surface drainage and caves. Karst is formed by dissolving rock, predominantly by limestone. The Sewu Mountain karst area is the largest karst area in Java Island. The area of Sewu Mountain karst reaches 800 $km^2$ -1,300 $km^2$ covering Yogyakarta Province, Central Java, and East Java Province (Chemistra *et al*, 2018). The Sewu Mountain karst area is characterized by a karst dome (Kegle Karst), or often termed sinusoidal with a positive blunt and non-steep formation (Lehman, 1936). The Sewu Mountain karst area has an altitude ranging from 300 - 500 meters above sea level and relief altitude between 50 - 150 meters. Limestone in the Sewu Mountain karst Area is of the same age as Miocene, karstified at the end of the pliocene untill the beginning of the Pleistocene.

Sewu Mountain karst is one of the largest karst area in Java Island as well as the most famous karst area because of its uniqueness of its landscape (Prakarsa and Ahmadin, 2017). Because of its uniqueness, the Sewu Mountain Karst Area is echoed as a *World Heritage*. There was an award from the *Asia-Pacific forum on Karst Ecosystem and World Heritage* as world natural heritage can be used as evidence of its uniqueness (Cahyadi *et al*., 2013). Its uniqueness includes regular cone-shaped hills, drainage valleys called doline which are always filled with water every rainy season which is then called a lake, with hundreds of caves and underground rivers that have great potential for subsurface water resources and various richness of flora on its surface and fauna in it (Santosa, 2015). The Sewu Mountain karst area is also a holokarst type karst filled with thousands of remaining hills of dissolution (Adji, 2006).

It is necessary to develop an area to support the community to develop in order to meet their needs in today's progress. One of the regional potential developments is carried out through area development with the geopark concept. Maybe lately we often hear news about "geoparks" or it can be interpreted as an earth park (Fahrudi and Wiratmoko, 2018). The Geopark Site is a concept that was coined by UNESCO in the early 2000s which was followed up in 2004 by the establishment of the Global Geopark Network (GGN).

Geopark is an area with amazing geological phenomena, which include geomorphology, hydrology, geology, ecology, and surrounding culture (Wiratmoko and Fahrudi, 2017). The magnitude of the unique values possessed by the Sewu mountain Karst Area made it a strategic area to be designated as the Ekokarst area on December 6, 2004 by the then president, Mr. Susilo Bambang Yudhoyono. In early 2009, the Sewu Mountain karst Area was then managed sustainably in the form of a Geopark area. On May 13, 2013, the Ministry of Energy and Mineral Resources as well as the Ministry of Tourism and Creative Economy established a geopark for the Sewu Moutain Area which had previously been proposed by the Pacitan Wonogiri-Wonosari Cooperation Forum to become a National Geopark. The Gunung Sewu National Geopark advanced to the international level, namely becoming a member of the *Global Geoparks Network* UNESCO in 2015 (Hasibuan, 2006). This study aims to determine the factors regarding the characteristics of the Sewu Mountain karst area which make it a geopark area.

## 2. Materials and Methods

### *2.1 Research Locations*

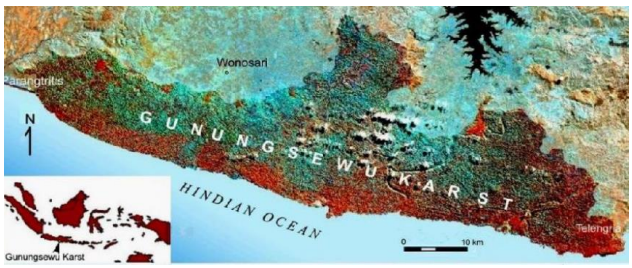


**Fig. 1** The Map of Karst Sewu Mountain Region
Source: Haryono (2011)

This research was conducted in the Sewu Mountain karst area which is located in the central part of the southern part of Java Island, Kanigoro, Kemadang, Tanjungsari Sub-District, Gunung Kidul Regency, Yogyakarta Special Region. Geographically, Sewu Mountain karst is located at coordinates 6°10 '- 6°30' latitude and 99°35 '- 100° east longitude, about 25 km from Yogyakarta to the southeast, 109 km from Pacitan to the north-west, and 20 km from Wonogiri to the southwest. The research was conducted in September 2020. Based on the map in Figure 1, administratively the Sewu Mountain karst area spans four districts, namely Bantul Regency and Gunung Kidul Regency (Yogyakarta Special Region), Pacitan Regency (East Java), and Wonogiri Regency (Central Java).

### *2.2 Data Analysis*

This research uses descriptive research methods with a qualitative approach. Research in secondary data collection using literature studies related to the karst area of Sewu Mountain. The object of this research is the condition of geology, geomorphology, hydrology, and the community around the geopark of the Sewu Mountain karst area.

## 3. Result and Discussion

### *3.1 Geological Conditions of the Sewu Mountain Karst Area*

The highland area of the Sewu Mountain karst area has an elevation ranging from 200-300 height above sea level. There is an uplift caused by tectonic movements at the height of the southern mountains, making the southern mountainous region there are many caves and karst hills. Half spherical hills and convex slopes are the characteristics of this type of tropical karst. The process of forming a landscape is dominated by geological elements, such as fractures and cracks. Based on Figure 2, it is known that there are many sediments in the Sewu Mountain karst area, for example sediments of beach-rocks and sea-stacks which are found on the seven southern coasts of Java. The low-elevation Sewu Mountain karst area is in the alluvial plain which is an alluvium area and a coastal area (Najib, 2010).

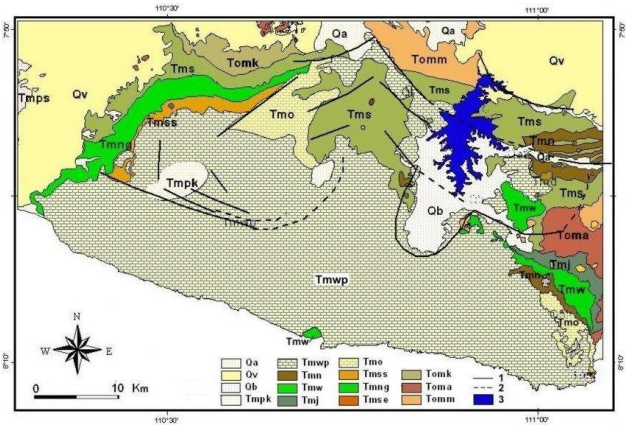


**Fig. 2** Geology Map of Karst Sewu Mountain Region
Source: Permadi,R., P.Rachwibowo, dan W.K.Hidayat (2014)

The characteristic of doline in the Sewu Mountain karst area has a hole or vertical system. The Karst type in the Sewu Mountain area does not have impermeable rocks, which means that it extends massively pure carbonate rock from the surface to the base rock. Based on PP Number 26 of 2008, geological sites in the Sewu Mountain area received national protection because Sewu Mountain is a karst area. The Sewu Mountain area has 33 sites, both geological and non-geological sites that are superior (Permadi *et al*., 2014). There are 30 geological sites and 3 non-geological sites. These sites are spread across various segments. In the western segment (GeoAre Gunung Kidul) there are 11 geological sites and 2 non-geological sites. In the middle segment (GeoArea Wonogiri) there are 7 geological sites. Then in the eastern segment (GeoArea Pacitan) there are 12 geological sites and 1 non-geological site. Sites in karst areas are protected and developed as objects and attractions for geotourism (Parno, 2018).

Government Regulation of the Republic of Indonesia Number 26 of 2008 concerning the national spatial plan, the Geological sites located in the Sewu Mountain National Geopark receive National protection because they are in the Karst area. This regulation serves as a guide for the implementation of legal regulation Number 26 of 2007 regarding spatial planning. The meaning and function of Karst in spatial planning can be understood through Article 60 section (2) letters c and f, article 53 section (1) letter b, article 52 section (5) letter, and article 51 letter e. contains that cave and karst landscapes are unique and protected areas, (b) unique scenic areas are geological reserves, (c) geological reserves are geological areas, and (d) geological protected areas are national protected areas. The Ministry of Energy and Mineral Resources has established several geological sites on Sewu Mountain to protect geodiversity and geoheritage objects (Permadi *et al*., 2014). Nowadays, in the spatial planning of each region (Gunung Kidul, Wonogiri, Pacitan regencies), karst is positioned as the main function space as a protected area (Anggraini *et al*., 2018).

*3.2 Geomorphological Conditions of the Sewu Mountain Karst Area*

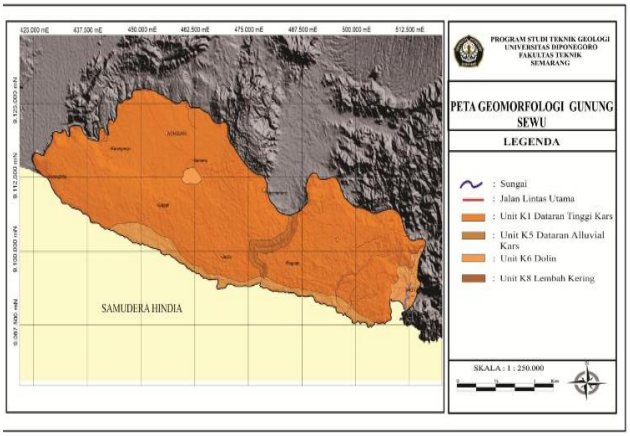


**Fig. 3** Geomorphology Map of Sewu Mountain Karst Region
Source: Brahmantyo (2006)

The karst area of Sewu Mountain is a limestone hill about 2 million years ago which experienced uplift from the seabed to the surface (Wiratmoko and Fahrudi, 2017). This process causes the limestone to undergo a dissolving process by water which forms the karst (karstsification). The karst landscape of Sewu Mountain is a tropical karst type hill (Wiratmoko and Fahrudi, 2017) with limestone hills that form many cones with a height of several tens of meters, half a ball and convex slopes (Chemistra *et al*, 2018). The geomorphological model of Sewu Mountain karst consists of aspects of morphography, morphometry, and morphogenesis. Morphogenesis involves passive morphostructures, physical properties of lithology, active morphostructures including tectonics, and morphodynamics. This also includes exogenic process such as erosion, dissolution, and mass wasting. Geomorphological diversity involves both positive and negative factors. Positive support consists of hills as high as 10 m to 90 m. Variations in this shape consist of a cone (Figure 4), a dome (Figure 5), a round cone or *convex-cone* (Figure 6), convex, and a *ridge* (Figure 4). While negative support consists of doline, uvala, polje, and poros, or caves (Kusumayudha *et al.,* 2015).

**Fig. 4** Cone Karst
Source: Kusumayudha, S. B., J. Setiawan, A. N. Ciptahening and P. D. Septianta (2015)

**Fig. 5** Dome Karst
Source: Kusumayudha, S. B., J. Setiawan, A. N. Ciptahening and P. D. Septianta (2015)

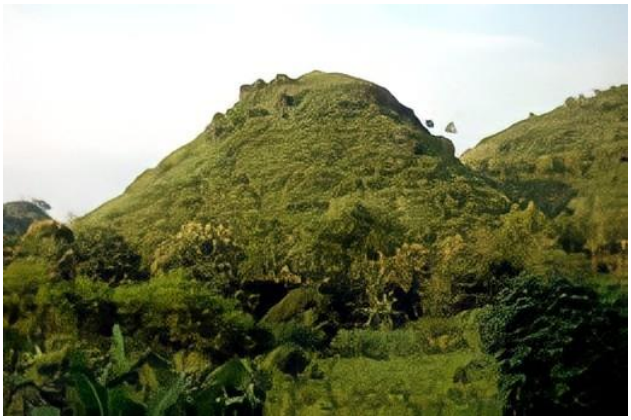

**Fig. 6** Convex-Cone Karst
Source: Kusumayudha, S. B., J. Setiawan, A. N. Ciptahening and P. D. Septianta (2015)

**Fig. 7** Karst Ridge
Source: Kusumayudha, S. B., J. Setiawan, A. N. Ciptahening and P. D. Septianta (2015)

Based on the karst typology classification, the karst area of Mount Sewu is categorized as a holokarst type (Santosa, 2015). According to Haryono and Adji (2017), the holokarst type is the karst with the most perfect development, starting from the shape of the land to the hydrological aspects of its subsurface. This area is also characterized by exokarst morphology, because it is found on a naturally occurring on the surface, as well as endokarst due to the existence of a river system and subsurface ground flow.

The Karst topography of Sewu Mountain is in the form of thousands of remaining hills of dissolution. In the world, only the Sewu Mountain karst area has the characteristic of karst formation in the form of *conical hills* (Haryono and Adji, 2017) and is the only karst area in Indonesia with an open type (*bare/nackter karst*). This type of open karst is a *residual karst cone* or *karst tower* with a plain followed by karst domes in the middle. Themorphology of the *residualkarst cone is* formed from the continuation of the development of thetype *polygonal-karstkarst*. The karst section of Sewu Mountain can be categorized into three subtypes, including polygonal, labyrinth, and tower-cone (Dibyosaputro and Haryono, 2020).

(1) The karst labyrinths in the Sewu Mountain karst area are characterized by longitudinal dry valleys in the form of overlapping linear interfluvial residues, clear and unclosed and predominantly controlled by major faults or fractures.
(2) Polygonal-karst is characterized by a dense depression or cockpit and a network of irregular meandering valleys. The polygonal karst in the Sewu Mountain karst area is influenced by fluvial process and slope factor.
(3) Residual karst cone is characterized by isolated cones which are scattered over the corrosion plain. Karst morphology the residual karst cone is not hard and can be dissolved in high amounts (chalky limestone).

Another characteristic of the Sewu Mountain karst is the topography of steep sloped steps dominating the southern edge which is directly adjacent to the Indian Ocean (Wiratmoko and Fahrudi, 2017). The northern part is bordered by mountains composed of volcanic rocks, karstica from volcanic origin, and igneous rocks from the remains of ancient volcanic activities.

No less interesting morphological forms and karstsification processes are under the surface of the ground or in caves (Wiratmoko and Fahrudi, 2017). Below the surface of the ground, a cave system develops, either a horizontal cave or a vertical cave, or a combination of the two. Dissolving underground for hundreds of thousands years has also produced various types of cave ornaments or decorations such as stalactites, stalagmites, pillars, sinteres, and flowstones (Kusumayudha *et al*., 2015).

The formation of this endokarst is also influenced by the existence of structural fractures and the stalactite layer is always found in longitudinal raw after fractures, namely cutting walls or cave roofs. This is controlled by variations in the physical properties of the lithology and the presence of geological structures. The fractures and cracks of these rocks facilitate the entry of rainwater into deeper limestone layers. The Sewu Mountain karst area in Pacitan is included in the Wonosari formation which consists of reef limestones, layered bioclastic limestones and marl (Chemistra *et al*, 2018). This formation is a form of exposure carbonate deposits (*carbonate plateform*) in the Middle Miocene to the Late Miocene. In addition, this formation also joins the Punung Formation in the eastern part because the two are difficult to separate, so this formation is called Wonosari-punung. The thickness of this formation is thought to be more than 800 meters.

*3.3 Hydrology of the Sewu Mountain Karst Area*

Generally, the potential of surface water in the karst area is influenced by geological structures such as cracks in the structure, rock texture, and surface morphology. This geological influence can determine the size of the coefficient of water flow and groundwater reserves. There is also rain water where rainwater falls into runoff and some of it seeps into the ground (Adji, 2005). Karst also receives input from underground water which then flows into the subsurface system as well as from other areas.

The rivers around the Sewu Mountain karst area have a unique drainage system. The river in the karst area usually enters the ground into an invisible *river (sink river)*, then becomes an underground river flow, referred to as a basinal flow pattern (Amrin *et al*., 2018). The water drainage system that is only found in karst area is the conduit system and the diffuse system (White, 1988). The conduit system is a river flow system that directly enters an underground cave, while the diffuse system is a flow system that flows downward through fractures (Haryono *et al*., 2017). The level of karstification development will affect the characteristic of groundwater input, storage capacity, and water release.

The development type of Sewu Mountain karst is a holokarst with a perfect level of karstification development so that the constituent rocks are relatively easy to dissolve, this causes the water drainage system in Sewu Mountain karst to be a conduit system. . The conduit drainage system will form an underground river that flows through the gaps in the limestone dissolving cave (Sulastro, 2013). The underground river system in the Sewu Mountain area is a large water resource, but its usage is not optimal because there are obstacles in reaching the water (Ford and Williams, 1992). Karst area has unique geohydrological conditions with secondary porosity and anisotropic flows that are the main characteristics of the area. There are 3 parts of the hydrological system of the Sewu Mountain karst area, namely insurgence, underground river and resurgence.

The sad thing is that the karst area itself is dominated by a hollow surface and the lack of a natural filtering system from the karst surface so that water that enters the soil is susceptible to contamination from foreign objects from outside (Adji, 2006). In addition, it is also in line with sampling in several springs that there is bacteria *E. coli* in the water content because many of the local residents have their disposal sites or their septic tanks are still on direct soil without cementing the bottom of their septic tanks, this is what makes their water waste products can seep to underground (Cahyadi *et al*., 2013). The susceptibility of karst is also influenced by several factors including conduit flow which dominates compared to the diffuse flow so that the frequency of incoming water is large, the soil layer is thin so that the naturally occurring filters in the form of soil and microbacteria are not maximally supported by the dominating conduit flow system, in the presence of heavy underground rivers flow also affect the quality of underground water in the karst, although the surface of the karst is thick (Adji, 2006).

*3.4 Resources and Culture of the Sewu Mountain Karst Community*

Resources are everything that exists on earth and can be used to fulfill life necessities. The Sewu Mountain karst area deserves to be named a geopark area because it has many resources that can be used as well as resources that must be protected. In general, the resources in the Sewu Mountain karst area can be classified into four. The four resources found in the Sewu Mountain karst area are water resources, mineral resources, landscape resources, and land resources (Yuwono, 2009).

Regarding land resources, shallow soils or bedrock outcrops are generally found on the surface in the Sewu Mountain karst area. Locally, thick soil occupies the bottom of a depression or dry valley, some of the land in the Sewu Mountain area consist of Haplustalf, Haplustoll, and Eutropept (Siswanto, 2006). Haplustalf as top soil is characterized by dark gray color, fine texture, hard consistency (dry) to medium sticky consistency (wet). The depth of the soil in the Sewu Mountain karst area is shallow-medium (less than 50 cm), so that this soil is described as Lithic Haplustalfs.

Next comes Haplustolls, which is shallow soil. This soil is characterized by a grayish brown color (in both the top and bottom soils), fine and slightly fine texture, very hard when dry, very soft when moist, sticky and easy to form when the soil is wet, neutral or slightly alkaline in nature. An area of 92% of Haplustolls land, not suitable for seasonal or annual plants (Siswanto, 2006).

Plants that can still be planted by people in the Sewu Mountain karst area include wetland rice, upland rice, corn, sweet potatoes, soybeans, peanuts and grass for animal feed. They are only marginally suitable for planting in dry valley floors and bumpy areas. The main limitations faced are the availability of water, thin soil solum, conditions of high erosion roots and the availability of small amounts of soil nutrients. To overcome the thin and shallow soil solum, farmers in the Sewu Mountain karst area create terraces on the hillside and trap sediment or runoff during the rainy season. The value of plant productivity in the Sewu Mountain karst area is very low. Because of this, the community overcame this by cultivating several types of seasonal plants and several types of annual plants simultaneously, most importantly for woody plants. This is a form of land use for agriculture (Pianto, 2016). Apart from agriculture, village farmers usually also raise livestock as savings that can be bought and sold at any time, and in the area around Sewu Mountain, many also work in coastal waters.

The next resource that is owned by the Sewu Mountain karst area is water resources. In the Sewu Mountain karst area, there are many underground rivers and caves. The underground river in the Sewu Mountain Krast area has a large water discharge. The rivers in the area are the Bribin River which has a discharge of 1500 l/s, the Baron River which has a discharge of 8000 l/s, the Ngobaran River which has a discharge of 150 l/s, and the Seropan River which has a discharge of 800 l/s (Cahyadi *et al. al*., 2013). The river is often used by the local community as a source of raw drinking water. Apart from rivers with large discharge, hundreds of rivers with discharge below 100 l/s are also found in this area (Cahyadi *et al*., 2013).

Apart from land and water resources, the Sewu Mountain karst Area also has mineral resources. Karst areas are generally dominated by carbonate rocks. The upper slopes of the Sewu Mountain karst Region are dominated by labradorite, hornblende, augite, and hyperstene. While in the doline section, quartz and opaque minerals are dominated (Mulyanto, 2008). The presence of these minerals is influenced by different levels of weathering.

The next resource that the Sewu Mountain karst area has is landscape resources. There are many caves and beaches in the area. The caves and beaches in the area have beautiful and exotic views to enjoy. Caves and beaches in the area have the potential to be used as tourist attractions and educational facilities. In the Sewu Mountain karst Area, there are 30 Geosites and 3 Non-Geosites. 30 Geosites in the area are Miocene Volcano Site, Miocene Sea Depth, Pindul Cave Geosite, Luweng Kali Suci Complex, Luweng Jomblang, Siung-Wediombo Beach, Purba Sadeng Dry Valley, Sri Gethuk Waterfall Geosite, Baron-Kukup Beach Geosite -Krakal, Luweng Cokro Geosite, Ngingrong Cave Geosite, Giri Tontro Dry Valley, Sodong Cave Geosite, Tembus Cave Geosite, Luweng Sapen Geosite, Mrico Cave Geosite, Potro-Bunder Cave Geosite, Sembukan Beach Geosite, Klayar Beach Geosite, Buyutan Beach Geosite, Panai Watu Karang Geosite, Srau Beach Geosite, Pacitan Bay Geosite, Gong Cave Geosite, Tabuhan Beach Geosite, Luweng Jaran Geosite, Songontin Geosite, Luweng Ombo Geosite, Baksoka River Geosite, Guyangwarak Lake Geosite. Meanwhile, the 3 non-geosites in the area are Wanagama Geoforest Biosite, Derivative Geoforest Biosite, Ngrinjangan Culturesite. Biosite in the region has succeeded in converting critical land into forest and conservation areas, while cultureite is a place where historical artifacts and stone pieces are found (Parno, 2018).

### *3.5 Mount Sewu Geopark Area*

The karst of the Sewu Mountains is declared as a geopark area. Geopark is defined as an area that has a different or unique side to an area which will be developed sustainably for the benefit of local community empowerment, science, and forms of conservation. Geopark is a form of appreciation for the uniqueness, rarity and beauty of the Sewu Mountain karst area. In the Geopark area of Pacitan Regency, there are thirteen tourist objects in the form of geological sites such as; Klayar Beach, Srau Beach, Watu Beach, Teleng Ria Beach, Sacks, Gong Cave, Luweng Ombo Cave, Luweng Jaran Cave, Wasp Cave and Song River. Cultural sites tourism objects include wayang beber and ceprotan ceremony (Wiratmoko and Fahrudi, 2017).

Some of the most famous areas of Sewu Mountain karst are Pindul Cave, Gunungkidul GeoArea (Middle Miocene Marine Sediment); Kalisuci, 7 sites in Wonogiri GeoArea (Dry Valley) Tembus Cave, Mrico / Mrica Cave, Potro-Bunder Cave, Sodong Cave, Purba Girintontro, Luweng Sapen, Sembukan Beach and 12 in Pacitan GeoArea (Klayar Beach, Mbuyutan Beach, Watukarung Beach, Srau Beach, Pacitan Bay, Luweng Jaran, Luweng Ombo, Tabuhan Cave, Songontin Cave, Gong Cave, Baksoka River, and Guyangwarak Lake Followed by 3 Non-Geological sites such as Derivative Forest, Wanagama Forest and Ngrinjangan Archaeological Site.

As a geopark area, The Sewu Mountain karst has many resources that can be utilized as well as resources that must be protected. In general, the resources in the Sewu Mountain karst area can be classified into four. The four resources found in the Sewu Mountain karst area are water resources, mineral resources, landscape resources, and land resources. It is hoped that this Geopark area can be utilized properly so that it can support the development of community culture, as well as increase community income and also for tourism development of the region itself.

## 4. Conclusion

Karst of the Sewu Mountains is declared as a geopark area. Geopark is defined as an area that has a different or unique side to an area which will be developed sustainably for the benefit of local community empowerment, science, and forms of conservation. From the geological aspect, there are beach-rocks and sea-stacks deposits found on the seven southern coasts of Java. Doline karst region of Sewu Mounatin also has special characteristics. Seen from its geomorphology, the karst section of Sewu Mountain can be categorized into three

subtypes, including polygonal, labyrinth, and tower-cone, the Sewu Mountain karst area is a holokarst type of karst, because the type of development is holokarst with a perfect level of karstification development so that the constituent rocks are relatively easily dissolves, this causes the water drainage system in Sewu Mountain to be a conduit system.

**Acknowledgments**

Authors would like to thank Mrs. Siti Rachmawati, SST., M.Si as a lecturer The Karst Environment Course instructor who helped produce this article, to parents and friends who have provided support and advice.

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