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Geoheritage and cultural heritage overview of the Toba caldera geosite, North Sumatra, Indonesia

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Abstract: Geoheritage is recognized as a component of cultural heritage, especially in the Toba Caldera Geopark area. The aim of the research is to determine the relationship between geoheritage and cultural heritage in the concept of abiotic ecosystems. The research method used in this research is empirical, juridical, or non-doctrinal, with a sociological or empirical approach using a non-positivist approach, including reference studies and observations. The research results describe sarcophagi and megaliths carved from Toba tuff rock estimated to be 73,500 years old during the Pleistocene period and andesite lava 33,000 years old from the eruption of the Toba volcano.

Keywords: geoheritage; cultural-heritage; geodiversity; geosite; Toba caldera

1. Introduction

Geoheritage focuses on the appreciation and protection of the diversity of minerals, rocks, and fossils, as well as geomorphological features that illustrate the effects of present and past climatic and environmental changes [1] and landforms created by natural processes during prolonged intervals of geological evolution; these terms have never been separated [2–4]. From the cultural heritage, several scientific papers have explained the definition of including cultural significance [5,6]. The relationship between geoheritage and cultural heritage is multiple: spatial, conceptual, causal, and thematic [7]. Similarly, part of geo-conservation lies in the encounter with cultural heritage, as the introduction of certain conservation measures requires a good understanding of the local cultural context, including the intangible heritage of indigenous peoples [8], while on the other hand, the preservation of built heritage requires adequate consideration of heritage buildings. Geoparks as a means of transferring geoscience knowledge to society and raising awareness of geoheritage strongly emphasize the concept of highlighting the interrelationships between abiotic, biotic, and cultural components [9]. Geologically, Samosir Island is generally formed on volcanic rocks dominated by tuff in addition to andesitic rocks [10]. The research area is located in the Toba caldera area, which has 16 unique and interesting geosites with different ages and geological histories for each geosite. Today, this geodiversity is enjoyed continuously by society, including culture as a resource for tourism, recreation, and as part of the natural heritage, in addition to fulfilling matters of spiritual importance. Most of the geosites recognized by UNESCO are also directly related to aspects of cultural heritage [11], linking very well with research focusing on natural hazards and risk reduction, not least in the context of the Anthropocene

conversation [12] where vulnerability emerges in the context of community history [13], emphasizing that risk assessment is largely culture-dependent. The main problems of cultural and heritage values in the research area are (1) how geological processes and geoheritage influence culture; (2) how culture influences the perception and management of geoheritage; and (3) how culture and geology integrate cultural heritage [11]. The research aims to present geocultural issues in the Toba caldera area and to evaluate the geodiversity of the of the cultural ecosystem area using an abiotic ecosystem phenomenon approach [14]. Supporting data for this research is supported by the results of an inventory of 36 geosite sites, which are scattered in the Toba Caldera region [15]. The results of research on geosites and community culture show that the value of geoheritage gives a significant meaning to the development of cultural history in the study area, such as in Siallagan village, Limbong village, and Simanindo District, Samosir Regency, where megalithic structures were found. The sarcophagus in the Huta Siallagan area was also carved using Tuk-tuk Rhyolite volcanic rock around 33,000 years ago. Geosite Pusuk Buhit, namely Hobon Stone, is also a lava dome located in Pusuk Buhit, which is indicated to have formed around 33,000 years ago. While the Silalahi Sabungan geosite is Sigadap stone and Sijongjong stone, Panukunan village, Silalahi I Silahisabungan District, Dairi Regency. Tugu Silalahi (Silalahi Monument) is a volcanic rock from the eruption of Toba, including the type of andesite volcanic rock estimated to be 840,000 years ago. Here (**Figure 1**) is an integrated geodiversity-culture heritage relationship in the concept of abiotic ecosystems [16].

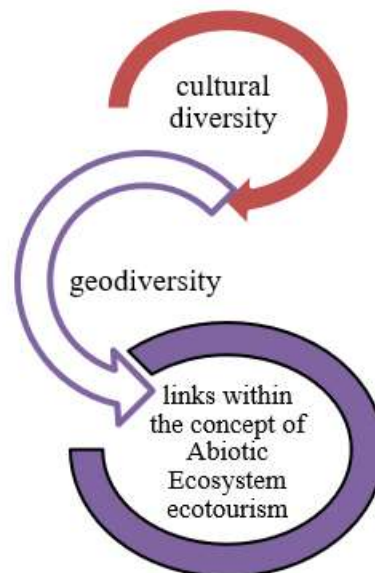


Figure 1. Geodiversity-cultural diversity in the abiotic ecosystem concept.

1.1. Theoretical background

Lake Toba is located in North Sumatra Province and is one of the most beautiful tectonic volcanic lakes in Indonesia. With an area of 1145 square kilometers, Lake Toba looks like an ocean at an altitude of 900 meters above sea level. Apart from being called 1837, it is the largest lake in Southeast Asia and this lake is 450 meters deep and the deepest lake in the world. Apart from that, there is an island in the middle of

Lake Toba, namely Samosir Island. Samosir Island has a small lake above it, namely Lake Aek Natonang and Lake Sidihoni, which provides a very beautiful panorama. Samosir Island is home to the Samosir Batak tribe ethnic group. The Batak people who live on Samosir Island still adhere to their ancestors confidence. They also still carry out various rituals that were usually carried out by their previous ancestors. It's not only Samosir Island that is the attraction.

The Lake Toba tourist attraction is also surrounded by pine forests, several waterfalls, and warm springs in the forest. The scenery around the lake is very beautiful, with relatively cool air, so you feel at home for a long time.

The Toba Caldera region, North Sumatra Province, has many natural resources and cultural heritage included in the UNESCO list. The research location includes three geosites, namely: Ambarita-Tuk Tuk-Tomok geosite, Simanindo District; Pusuk Buhit geosite, a volcanic cone located in Pangururan District; and Silalahi-Sabungan geosite, the Western Caldera Wall, located in Silahisabungan District, North Sumatra Province. Currently, Lake Toba has been submitted to UNESCO [17] as a world heritage site. According to the needs so that good development is maintained. The development of Lake Toba must have a cool climate so that the environment is not affected by pollution. The community participates in maintaining cleanliness and environmental sustainability, organizing tour packages between tourist attractions in Parapat and tour packages with the Samosir tourist area in Tomok and Tuk Tuk, and involving institutions in managing tourist attractions and cultural tourism by utilizing online media for promotion [18]. This positive value is in line with future per capita economic development, especially the value of cultural heritage.

The Faro Convention [19] emphasizes important aspects of cultural heritage related to human rights and democracy. It promotes a broader understanding of cultural heritage and its relationship to communities and society. This convention encourages us to realize that historical objects and places are important to preserve. Chesner [20] explained that the eruption of the Toba super volcano occurred 74,000 years ago through the De Silva [21], Chesner et al. [22], and Chesner [10], their Youngest Toba Tuff (YTT), volcanic-tectonic explosion process. The results of the field description show that the type of volcanic rock that is widely used to make sarcophagi and megaliths in the Samosir tourist area is andesite tuff volcanic rock resulting from the eruption of the Toba volcano. This material is durable and relatively easy to work with, which was an important consideration for ancient civilizations in the region.

2. Methods

The method used in this writing is qualitative. Moleong [23] states that the data analysis method used in this research is from Matthew and Miles [24], namely: (1) collecting data (data collection), namely collecting data from interviews and documentation; (2) reducing words (data reduction), namely summarizing data by selecting important things; (3) presenting data (data display), namely organizing and arranging relationship patterns so that they are easy to understand; (4) confirming, namely drawing initial conclusions that are temporary and will change if supporting evidence is found in the form of written or spoken words from people and observed

behavior. Qualitative methods can be used to explore and understand the meaning derived from social or humanitarian issues [25] related to interpreting data found in the field [26]. Focus group discussions were conducted using discussions with community leaders and local government, in this case the reference building of the Toba Caldera Geopark Information Center and the Tourism Office, and related sources, journals, bulletins, and others.

Research design and rational framework

In order to achieve the expected research objectives, a design and research rationale were prepared which are graphically depicted as follows (**Figure 2**):

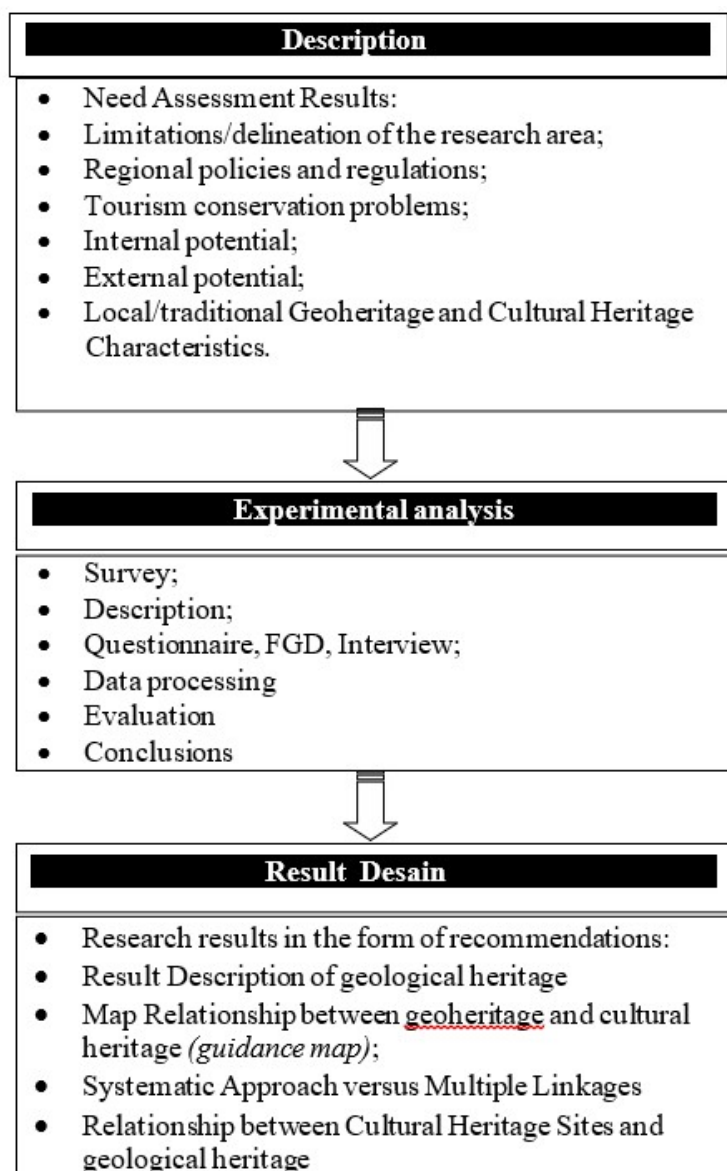


Figure 2. Research design framework.

3. Results

The Toba region in North Sumatra is famous for its volcanic activity and geological significance. Cultural heritage such as Megalithic and Sarcophagus, found

in the Toba region are made from locally available volcanic rocks.

3.1. Geology

As the largest tectonic-volcanic lake in the world, Lake Toba is 87 km long and 27 km wide. Lake Toba has a height of 906 m and a depth of 530 m. The depth of the steep caldera wall ranges from 400 m to 1200 m, and the total relief is recorded at 1700 m from bottom to top, becoming evidence of Toba's ancient volcanic geomorphology. Lake Toba is the largest lake in the world and was formed from a super volcanic eruption in the Late Pleistocene, 73,500 years ago. The lake is located in North Sumatra Province, between latitude $2^{\circ}35'$ – $2^{\circ}58'$ and longitude $98^{\circ}50'$ – $98^{\circ}83'$. Based on stratigraphic and paleomagnetic studies, the Toba eruption can be divided into four eruption periods as described by Chesner and Luhr [27], with the following results: known as the Haranggaol Dacite Tuff (HDT) (**Figure 3**), it was formed 1.2 million years ago, then the Oldest Toba Tuff (OTT) was formed 840,000 million years ago, the Middle Toba Tuff (MTT) was formed 450,000 years ago, and the Youngest Toba Tuff (YTT) [27], as made clear by Chesner et al. [22], was formed 73,500 thousand years ago.

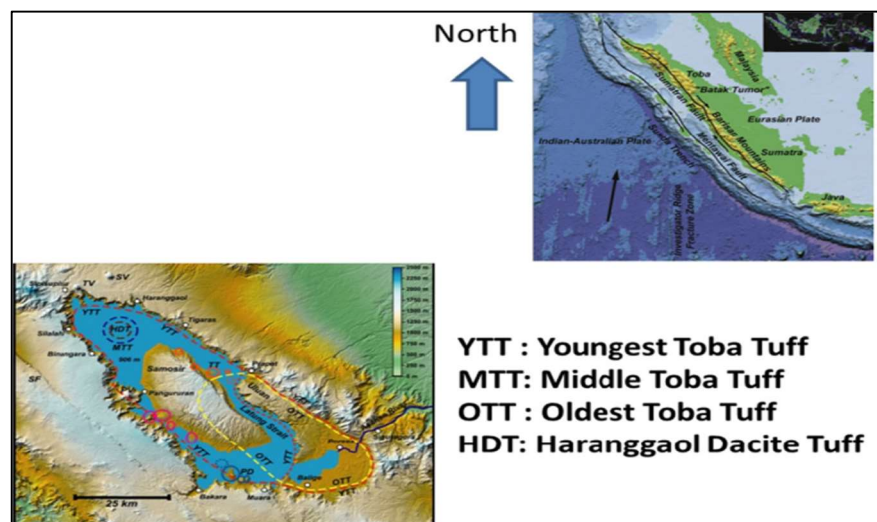


Figure 3. Map Relationship between geoheritage and cultural heritage.

The supervolcano eruption occurred 74,000 years ago through the Youngest Toba Tuff (YTT) [27], a volcanic-tectonic explosion process that occurred in Toba [21]. The results of the field description show that the types of volcanic rock that are widely used for making sarcophagi and megaliths in the Samosir tourist area are tuff andesite volcanic rocks resulting from the eruption of the Toba volcano. This material is durable and relatively easy to work with, which was an important consideration for ancient civilizations in the region.

3.2. Description of geological heritage

The results of research that has been carried out on three Geosites located in the research area with the method of description, location plotting, conducting interviews, and discussion results, are contained in (**Table 1**).

Table 1. Description geological heritage and culture heritage.

1.	G 1	Ambarita-Tuk Tuk-Tomok	Geo-Archeo-Anthropology	Coordinate
		Includes Batu Parsidangan–Siallagan Geopoint, Batuan Tuktuk Geopoint, Old Tomb Geopoint Sidabutar-Sigale-gale, Huta Bolon Museum in Simanindo	1.1 Entrance to Huta Siallagan Village, Samosir 1.2 Stone Chair of King Siallagan, (Batu Kursi Raja Siallagan), Village 1.3 Stairs in one of the Hotalagan Village settlements 1.4 Carvings on the stone fence walls of megalithic sites have human faces. formed from rhyolite tufa rock 1.4.1 Stone rhyolite, Ambarita Tuktuk. 1.5 King Siallagan’s Parsidangan Stone, AmbaritaTuktuk 1.5.1 Tuffa rhyodacite stone 1.6 The Megalithic Site of the Stone Tombs of the Sidabutar Kings in Samosir Inherits the Character of the Tolerant Batak People 1.6.1 A large group of humanoid statues alongside the royal graveyard in Tomok, Samosir	2°38’39.7” N 98°50’10.352” E 2°38’39.7” N 98°51’52.9” E 2°38’39.7” N 98°51’52.9”E 2°38’39.7” N 98°51’52.9” E 2° 39’4.842” N 98°51’37.908” E 2° 39’4.903” N 98°51’37.512” E
		Animist tourist attraction, Parulubalangan (swearing statue with a frog) and Sira stone chair, in Huta sipalakka Siallagan.	1.7 The entrance to the Parulubalangan Sira Stone Chair Huta Sipalakka Siallagan, Samosir. 1.8 Sira stone chairs, food serving places and statues 1.9 Swearing statue with a frog of Rhyolite 1.10 Ancient tombs were built with rhyolite stone 1.11 Rhyolite ancient cemetery near Ambarita	2°40’36.926” N 98°50’22.214” E 2°40’36.685” N 98°50’22.578” E 2° 40’36.865” N 98°50’22.697” E 2°40’37.034” N 98°50’22.567” E
2.	G-2		Geo-Culture diversitys	
		Pusuk Buhit, Volcanic cone	2.1 The Hobon Stone is a souvenir from King Uti, Sianjur Mula-mula 2.2 Batu Hobon is also lava dome situated in Pusuk Buhit, made of andesite	02°31’49.8” N 98°44’04.2” E 02°31’49.8” N 98°44’04.2” E
3.	G-3	Silalahi-Sabungan, Western Caldera Wall	Geo-Culture Diversity	
		Sigadap Stone and Sijongjong Stone consist of two stones. is the Stone of Judgment. or Stone of Justice King Silahi Sabungan, fragment of Middle Toba Tufa (MTT).	3.1 Sigadap Stone and Sijongjong Stone consist of two stones in Panukunan, Silalahi village	2°40’36.948” N 98°50’22.834” E 2°48’4.26” N 98°31’39.32” E

Source: own processing, 2023.

Field description data on (**Table 1**) geosites, megalithic objects, and sarchopagus built from volcanic rocks resulting from the eruption of Toba volcano, such as tuff and andesite lava domes, is divided into three geosites, namely Ambarita-Tuk Tuk-Tomok geosite, Pusuk Buhit Volcanic cone geosite, and Silalahi-Sabungan Western Caldera Wall geosite. The following map shows the distribution and relationship between *geodiversity* and *cultural heritage* (**Figure 4**):

3.3. Relationship between cultural heritage sites and geological heritage

3.3.1. Geosite (G-1) Ambarita-Tuk Tuk-Tomok

The Ambarita-Tuktuk-Tomok Geosite covers the area of Simanindo District, Samosir Regency, which is famous for its many megalithic objects such as chairs, tables, stone stairs, the tomb of King Sidabutar, and artifacts stored at the Huta Bolon Simanindo Museum in the form of buildings carved from the products of the Toba volcanic eruption produced 73,500 years ago and then referred to as the Young Toba Tuff (YTT) Pleistocene Period. Huta Siallagan Area The megalithic culture in Huta Siallagan was formed around 400 years ago during the reign of the first Huta leader, King Laga Siallagan (**Figure 5**). After that, it was continued by his heir, King Hendrik Siallagan, until the descendants of King Ompu Batu Ginjang Siallagan. Today, a number of descendants of King Siallagan still reside here, particularly in the village of Siallagan Pinda Raya, where Huta Siallagan is located. The graves of their ancestors can also still be found in Huta Siallagan. Huta Siallagan is one of the villages located in Simanindo District, Samosir Regency. Huta Siallagan is limited by a perimeter wall, with the entrance equipped with a guard statue (pangulubalang) and several traditional houses on stilts. The result of the research is that the megalithic culture in Huta Siallagan in the past functioned as a place to convene or deliberate to decide everything, both regarding society, customary law, and crime cases, a form of local wisdom, because it is one of the actual knowledges of a society that comes from the noble values of cultural traditions and regulates the way of life of the community, according to Sibarani [28] and Siregar [26].



Figure 5. Geoheritage context of selected UNESCO World Heritage cultural properties in Huta Siallagan village (**A**), Entrance to Huta Siallagan Samosir Village, statue in the form of Toba Tuff. volcanic rock, (**B**) Legend of Batu Parsidangan “Stone Chair” of King Siallagan area, Village, (**C**) The stairs in one of the Huta Siallagan Village settlements are made of tuff rock, estimated to be 73,500 years old, (**D**) A Carving on A Stone Wall rhyodacite tuff, (**E**) The basic building material in the Huta Bolon Simanindo Museum is rock resulting from the eruption of the Toba volcano in the form of rhyodacite tuff Tuk-tuk is, estimated to be 73,500 years old, with a grain size of between 4–32 mm referred to as the Young Toba Tuff (YTT) during the Pleistocene [10].

Several articles have been written about the legend of the *parsidangan* stone, including by Debora et al. [29], Syahfitri et al. [30], and Sinamo et al. [31]. If you want to visit Samosir Island, remember to visit this historical and cultural site of Huta Siallagan Zizydmk [32].

The Raja Siallagan Stone Chair (locally known as Batu Parsidangan, which means “Trial Stone”) (**Figure 6**) is a historical and ancient object in the form of a chair and stone table that is located right in the center of Huta Siallagan (Siallagan village). The hariara tree, which is considered a sacred tree by the Batak tribe, is believed to be more than 200 years old. The building carved into tables and chairs consists of tuff rock with an age of around 73,500 years, which is used as an official meeting place.



Figure 6. (A) Parsidangan rocks of King Siallagan, Ambarita Tuktuk explained that King Siallagan always cared about his people by meeting and greeting them [26]. There is King Siallagan’s Stone Chair (in the regional language called Batu Parsidangan) which functioned as a place of execution [33]. (B) It is a rock resulting from volcanic eruptions in the form of Toba tuff, light gray to pink at the bottom and light gray at the top, high-SiO₂, Chesner and Luhr [27] estimated to be 73,500 years old, referred to as Young Toba Tuff (YTT) during the Pleistocene.

3.3.1.1. The megaliths and tomb of the Batak King’s Sidabutar

Batu Raja Sidabutar Tomb (**Figure 7A**) is located in Ambarita Village, Simanindo District, Samosir Regency. As the name suggests, This district is located on Samosir Island, an island in the middle of Lake Toba. A volcanic island formed from an ancient volcanic eruption, this lake is 100 kilometers long and 30 kilometers wide. The largest lake in Southeast Asia. The tomb of the “new” King OP Soribuntu Sidabutar, 460 years old, which is classified as a sarcophagus, is located in Ambarita village, Samosir, including the Ambarita-Tuktuk-Tomok geosite. In **Figure 7B**, there is a large group of humanoid statues. These statues were carved from Toba tufa rock (riodacite tuff). Geologically, it was built from volcanic rock; this lava dome also erupted 74,000 years ago [4], and it is assumed to represent residual magma YTT. The condition of the gravestone already looks black. There is a lot of hardened moss growing on the rock surface, as required by the Faro Convention [19]. Megaliths and the tomb of Sidabutar Raja Batak. A large group of humanoid statues is next to the royal grave in Tomok. The statues are carved from Toba tuffa rock (riodacite tuff), estimated to be 73,500 years old.



Figure 7. (A) Megaliths and the tomb of Sidabutar Raja Batak (B) A large group of humanoid statues next to the royal grave in Tomok. The statues are carved from Toba tuffa rock (rhyodacite tuff) estimated to be 73,500 years old.

3.3.1.2. The entrance to the Parulubalangan Sira Stone Chair

The entrance building (**Figure 8A**) has two statues carved from the Toba Tuffa volcanic rock material. (**Figure 8B**), a set of table chairs called Sira Stone, made of rhyodacite tuff. (**Figure 9A**), called the Sarapah Frog Statue, carved from Toba tuff stone. The megalithic era is found in Siallagan village and Sipalakka village, Ambarita Samosir. In **Figure 9B**, at the entrance to the building, there are two statues carved from rhyodacite tuff. Meanwhile, **Figure 9C** shows the Frog Oath Statue carved from Toba tuffa rock aged around 73,500 (YTT) during the Pleistocene era, the result of the eruption of the Toba volcano.



Figure 8. (A) The entrance to the Parulubalangan Sira Stone Chair; (B) Sira stone chairs, food serving places, and statues.



Figure 9. (A) Swearing statue with a frog, a statue carved from Toba tuff rock material around 73,500 years old, near Ambarita, Samosir, (B) Swearing statue with a frog of Rhyolite, (C) near Ambarita Ancient tombs were built with rhyolite stone.

3.3.2. Geosite (G-2) Pusuk Buhit, Volcanic Cone

Pusuk Buhit Mountain is an inactive quaternary volcano located in Panukunan Village, Silalahi I Silahisabungan District, Dairi Regency, North Sumatra Province, which is very unique due to the potential geosite and its relation to cultural aspects, Cultural heritage objects in the form of Pusuk Buhit Andesite Lava rock units (Teraltered). The geosite is located in the Samosir Geoarea, which was formed around 33,000 years ago. The geosite and cultural heritage of the study area, such as Hobon Stone, is said to be a gift from King Uti. Hobon Stone is a lava dome formed during the formation of Samosir Island located in Pusuk Buhit. The type of andesite rock that popped out of the surface due to the eruption of Pusuk Buhit Mountain (Figure 10A) is estimated to have been created 22,000 years ago. There may be other uses of rocks by humans, but most in the Toba region use rhyolite and lava andesite (Figure 10B).



Figure 10. (A) The Hobon Stone is a souvenir from King Uti, **(B)** Batu Hobon is also lava dome situated in Pusuk Buhit, made of andesite rocks.

3.3.3. Geosite (G-3) Silalahi-Sabungan, Western Caldera Wall

This area occupies the north-western part of Toba Caldera; it is a road that connects Tongging to Sumbul and Sidikalang (the capital of Dairi Regency). There are outcrops of a Toba Caldera wall sequence, beginning with Paleozoic basement rocks, which are the ruins of the caldera wall (debris), and the caldera wall consists of Middle Toba Tuff (MTT) fragments. estimated to have occurred 500,000 years ago. The results of research, field descriptions, and reference information indicate that Batu Sigadap and Batu Jonjong Silahisabungan inscriptions are a cultural heritage inherited by the King of Silahisabungan. Batu Sigadap is in the form of two sacred stones that are believed to have mystical powers. This stone is elongated with two positions, one standing (jongjong) and the other lying down (gadap), hence the names Sijongjong stone and Sigadap stone (**Figure 11**). This stone used to function as a place for the Supreme Court Court used by the King of Silahisabungan to try guilty people. The people of the location of the stone, which is located in the Sidabariba Toruan area of Silalahi I Village, about 300m from the center of Silalahi I Village, refer to the two stones as Batu Panungkunan. Silahisabungan District, Dairi Regency. The rock is a type of andesite volcanic rock estimated to be 840,000 years old (first Toba eruption).



Figure 11. Sigadap Stone and Sijongjong Stone, fragments of Middle Toba Tuff (MTT).

4. Conclusion

In conclusion, the relevance of culture and geoheritage has been widely recognized as an important concern, has become a very popular subject of study, and is important to geotourism and tourism education. There are cultural heritage sites integrated with geodiversity materials such as sculptures, tables, stairs, and sculpted graves. Geoheritage represents an additional value associated with cultural heritage. This can be seen in many UNESCO World Heritage sites, which are listed in recognition of their cultural value and the presence of interesting rock outcrops used for megalithic and sarcophagus. There is a relationship between the volcanic materials (*geoheritage*) of Young Toba Tuff (YTT), Middle Toba Tuff (MTT), and cultural heritage (*cultur heritage*) of the Sarcophagus building in the Megalithic Age. Increased awareness of geoheritage values among the visitor community and a lack of attention by local communities and the government to cultural heritage sites have left them mossy and unmaintained. Cultural heritage management is still far from being considered a ‘shared responsibility’ between citizens and authorities as required by the Faro Convention [19].

Author contributions: The following is the author’s contribution, A, geologist understands the ideas presented, B. develops theory and verifies analytical methods, and D regional mapping, E, reviewing regional access and local government policies. and All authors discussed the results and contributed to the final manuscript. All authors provided critical feedback and helped shape the research, analysis, designed the model and computational framework for regional mapping and compiled this research and was responsible for the overall results of the research.

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