PREDICTING THE LOCATIONS OF CAVES AND ROCK SHELTERS IN WESTERN PART OF ACEH KARST USING GEOGRAPHIC INFORMATION SYSTEM

Prediksi Lokasi Gua dan Ceruk di Karst Aceh Bagian Barat dengan Sistem Informasi Geografis

Taufiqurrahman Setiawan[1] and Azhari Fitra Nasution[2]
[1]Research Center for Archaeometry, National Research and Innovation Agency, Indonesia
[2]Department of Geological Engineering, Faculty of Mineral Technology,
Medan Institute of Technology, Indonesia
tauf030@brin.go.id

Abstract. *Geographic Information Systems (GIS) is a method used in archaeological research to provide information on landscapes and resources on the earth's surface, combined with phenomena, predict the location of sites. This paper revealed some results of using this method in the case of karst in the western part of Aceh to find the locations of caves and inlets with GIS data sources. Satellite imagery, DEM, Topographic Maps, and Geological Maps, which overlayed with the geological structures, and the lithology of the location of the caves and inlets. The analysis results obtained that there were 26 areas grouped into five clusters of possible locations for caves and rock-shelters..*
Keywords: *Prediction Model, Remote Sensing, Karst, Caves and Rock-shelter, Aceh*

Abstrak. Sistem Informasi Geografis (GIS) adalah metode yang digunakan dalam penelitian arkeologi untuk memberikan informasi tentang bentang lahan dan sumber daya di permukaan bumi, dikombinasikan dengan fenomena, memprediksi lokasi situs. Tulisan ini mengungkap beberapa hasil penggunaan metode ini pada kasus karst di Aceh bagian barat untuk mencari lokasi gua dan ceruk dengan sumber data GIS. Citra satelit, DEM, Peta Topografi, dan Peta Geologi yang ditumpuk dengan struktur geologi, serta litologi letak gua dan inlet. Hasil analisis menunjukkan 26 area, dikelompokkan ke dalam lima klaster yang mungkin merupakan lokasi gua dan ceruk.
Kata Kunci: Model Prediksi, Penginderaan Jauh, Karst, Gua dan Ceruk, Aceh

1. Introduction

As a result of the natural processes of karts, the cave or rock shelter shows its characteristic features in association with the surrounding environmental conditions. Therefore, the main parameters of this study are the cave and its environmental aspects, such as geological structure, lithology, and slope. Cave morphogenesis is to predict the existence of the cave mouth and access networks to or from the cave. Not all caves are settlements, only those with dry floors or no water flow. This type of cave is not in the vadose zone. The dry and relatively flat cave floor is very supportive of daily activities.

Caves in archaeological studies are unique objects for early detection tools related to a past life. Archaeological studies at the location have found evidence of its use as a residential location. Archaeological caves are natural cave formations that have indications of being used by humans in prehistoric times as a place to carry out various life activities. There are three parameters: morphology and morphogenesis, environment, and archaeological content (Yuwono 2005).

One of the digital technologies to be applied to find archaeological sites is Geographic Information Systems (GIS). It plays a role in generating information about landscapes and environmental resources on the earth's surface and plays a significant role in increasing the depth of analysis of the landscape and existing resources for past settlements. The GIS can predict the location of sites such as caves and rock shelters. However, GIS data (including satellite image data) does not directly reveal the existence of archaeological data contained therein. GIS's ability in database management, data analysis, and spatial modeling for archaeological purposes, including data presented in the form of maps, is also an advantage (Sharer and Ashmore 2003).

Remote Sensing can provide landscape-related information at various scales and over time. It is possible to obtain the existing condition of landscape overview and the landscape reconstruction in the past and its changes in a site or area.

Predictive modeling can track archaeological sites in an area. Prediction modeling is an experimental technique to predict the existence of archaeological sites in an area based on samples or ideas related to human behavior. Prediction modeling starts from the assumption that the location of archaeological remains in a landscape is not random but correlated with various natural environment characteristics (Verhagen 2007). Conolly and Lake (2006) mention that the development of an archaeological estimation model usually goes through four main stages, namely: 1) data collection, 2) statistical analysis, 3) application of the model, and 4) model validation. Data collection is generally related to the known or tracked location and distribution of sites. An archaeological site can sometimes be detected directly by visual observation of the image. For example, it appears in a building or a specific pattern. However, many archaeological sites cannot be detected directly by visual observation. It requires an approach to environmental aspects or certain landscapes that can provide clues about the existence of a site. Therefore, it is necessary to understand that the existence of archaeological sites is related to specific environmental aspects or landscapes, and landscape attributes, such as elevation, geology, and soil. These data can be in the form of thematic maps or derived from the interpretation of satellite imagery.

The basis used is the equation of the spatial paradigm (spatial). By using Remote Sensing, the data information about the object, area, or phenomenon can be analyzed without having direct contact. This data can present information on various appearances of phenomena on the earth's surface and the archaeological remains. They can be remotely

sensed, including Satellite Imagery and Aerial Photography. The remote sensing data is investigated and analyzed using GIS to track the possible existence of locations that have the potential (Kuswanto 2016).

The existence of archaeological caves in karst areas is interesting to trace at the site location—an estimation model to track the existence of sites. One of the locations that we can try is the western part of Aceh Karst in Aceh Province.

The province of Aceh has a vast karst landscape potential for caves or rock shelters, but more data needs to be collected. Of course, it is wildly disproportionate to the inventoried cave data. Karst in the west of Aceh which extends from north to south, Lam Badeuk, Mata Ie, Lampuuk, Lhok Nga, Leupung, Lamno, Teunom, Labuhan Haji, and Tapak Tuan until now only obtained information on the whereabouts of the cave as many as 46 locations. The information is from the page "Caves-ID: Let's Map Karst Distribution in Indonesia" in 2013 and the "Sumatra Speleolog Expedition" expedition conducted by Dr. Louis Deharveng (MNHN, France) and DR. Francois Brouquisse (Wanadoo, France) in the 1990s, followed by Drawhorn (2000) with the title Indonesian-International Sumatran Cave Research and Exploration Expedition. The vast area of the karst landscape in the western part of Aceh is certainly not comparable to the cave data inventoried. Other information obtained from UKM PA Leuser (2004) mentioned caves in the Aceh karst such as Lhok Mata Ie Cave, Apamani Cave, Mon Cave, Kameng Cave, Landak Cave, Gap Cave, Lima Cave, Lontie Cave (little bats), Needle Hole Cave, Green Cave, Babah Ie Cave, Pari Cave, Sagop Cave, Gle Glungku Cave, Tanoh Anoe Cave, Teumbiga Cave, Pinto Tujoh Cave, Tiger Cave, Loyang Koro Cave, Loyang Putri Pukes Cave, Loyang Datu Cave, Loyang Kameng Cave, Weih Lop Cave, Demer Hanging Cave, Umah Atu Cave,

Limestone Cave, Frankincense Cave, and Atu Janggut Cave.

The North Sumatra Archeology Center researched to survey the archaeological potential of caves and inlets in the karst region of western Aceh, the administrative area of Aceh Besar Regency, in 2018. It found nineteen caves and rock shelters and surveyed eleven locations. Seven caves have potential as residential caves, and three (Mabitce Cave, Tuandigedong Cave, and Ek Leuntie Cave) have residential and research potentials (Setiawan 2020).

Cave explorations at Mabitce Cave in 2018 led to the follow-up excavations in 2019. This cave was inhabited by people who supported Hoabihian culture, as indicated by the findings of Sumatralith stone tools. Other information found was evidence of ancient tsunamis recorded in stratigraphic layers and features of shells of mussels and snails found in the cave (Setiawan *et al*. 2020, 2021).

Based on the background above, the problem discussed in this paper is: Where are the locations that have the potential for caves in the western part of Aceh karst region? This location information determines the potential distribution of caves in the area and also becomes a starting point to determine locations for future surveys and research. The analysis results are used as signs for karst conservation in the western region of Aceh, given the high economic value of karst areas, especially for the industrial sector.

2. Methods

The archaeological cave genesis is a residual structure of the cave system in limestone. Tectonic events raised the entire rock formation to a specific height position, followed by a decrease in the groundwater level through a base leveling period. The horizontal passages of the water table cave, which initially played an active role as a subterranean stream, then dried up and changed the role of a

vadose cave in the unsaturated zone above the new groundwater table. Gradual denudation, either by external processes (dissolution and erosion) at the surface or by seismic activity leading to collapse, eventually resulted in the cutting of vados passageways and blockage by accumulation of talus and rock slides (Yuwono 2004). The cave used as a residential location also had several requirements, such as sufficient morphology to accommodate group members, a horizontal cave floor that is dry and not humid, adequate lighting and air circulation, and its position with supporting resources. This study tracks the alleged location of archaeological cave sites still conjectured without surveys and excavations.

To be able to do this, we must prepare the data, such as:

a. Landsat 8 OLI/TIRS satellite imagery level 1 C1 Level 1 downloaded from https://earthexplorer.usgs.gov/
b. Digital Elevation Model (DEM) or Surface Radar Terrain Model (SRTM) downloaded from http://tides.big.go.id/DEMNAS/
c. Digital Topographic Map of Sumatra 1:50,000 scale from the Geospatial Information Agency

d. Geological Map of 1: 250,000 scale as many as five sheets, namely the Banda Aceh sheet (0421-0521); Calang (0420); Takengon (0520); Tapaktuan (0519); and Sidikalang (0518-0618)
e. Cave data for model testing

These materials analysis using computer software, including:

a. *Windows 10 64-bit*, for computer operating systems;
b. *QGIS 3.10.10* for processing vector and raster data consisting of satellite images, geological maps, digital topographic maps, and Geographic Information System equipment;

Various factors influenced the formation and development of caves—the Cave morphology results from a combination of the work of these various factors. Therefore the morphology of one cave to another is always different. Several factors influencing cave morphogenesis are geology, lithology, chemical conditions, paleokarst, hydrology, climate, and time. Those factors influence the early stages of cave formation, while paleokarst, hydrological conditions, climate, and time of influence appear in subsequent cave developments. The
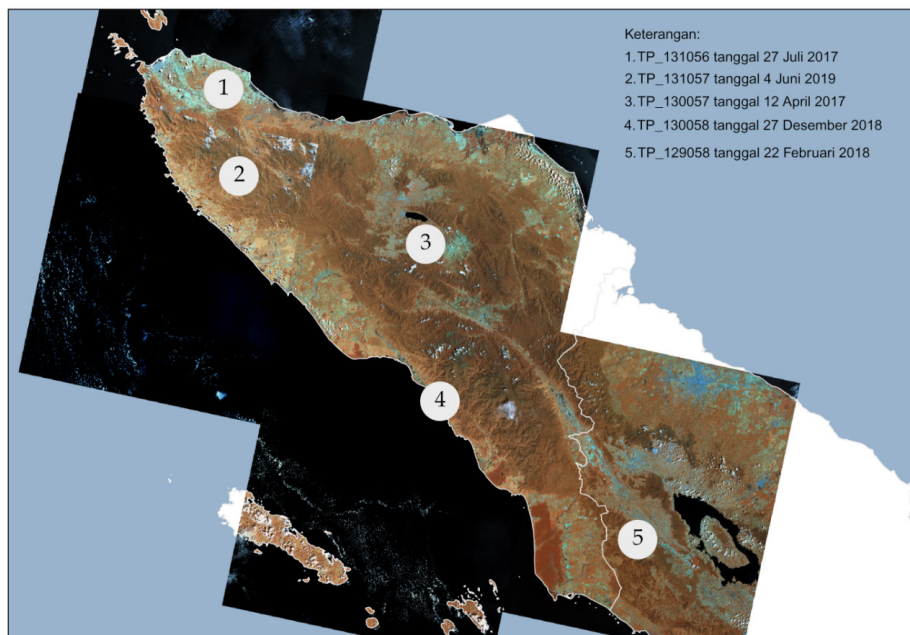
Figure 1. Landsat 8 OLI/TIRS level 1 C1 Level 1 satellite image used in this study
(Source: Setiawan and Nasution, 2023)

geological structure is a factor that affects the shape of the cave at an early stage, and then the shape is modified in its development due to the influence of other factors (Gillieson, 1996).

The genesis of karst development in an area influences the morphology and placement of archaeological cave mouths. Therefore, to trace the existence of archaeological caves in karst areas, it is necessary to consider the developmental genesis of each type of cave. Based on their character, the cave was formed by several environmental variables correlated with the presence of archaeological cave mouths. Are archaeological cave mouths or rock shelters generally located on hillsides and facing toward the valley? The accessibility of the cave considers the relative elevation class (height difference) of the cave mouth from the valley floor and the large class of single slopes. The mouth position of a cave-type cave and niche is at the intersection of a hill and a valley. The existence of a niche is very likely to be in a cliff formation. Rock-shelter genesis is not related to the presence of an underground river but can form due to the intensive dissolution of the cliff by the vados flow. The role of geological structures (faults and joints) in forming horizontal cave mouths (Kuswanto 2016).

In this paper, the variables used are only geological structures. Variables of hillsides, valleys, dolines, and cliffs are represented by Landsat and DEM image data. However, considering the area to be analyzed, this variable is not used at this stage. These three variables will be used further at the next stage when the suspected locations have been discovered.

Satellite image processing by compositing and image sharpening is the next step that must be ensured, the same as the processing of DEM and SRTM (Figure 1). Next, mapping of each research variable. It maps each variable and its parameters, compiling thematic work maps for each parameter. In the single variable thematic working maps, each parameter is from the interpretation of satellite imagery, analysis of existing reference maps, or a combination of both. This process includes interpreting, grouping, and grading the existing parameters. The cave distribution data in previous studies was used to see the phenomenon of cave formation in northern Sumatra.

3. Results and Discussion

Karst is a field with specific landforms and hydrological characteristics that develop in soluble rock and has a secondary porosity field (Ford and Williams, 2013). Furthermore, Samudra (2005) defines karst as an area generally composed of limestone, with a topography formed by the dissolving process or characterized by Karren, with closed grooves, underground flow patterns, and many caves. So karst areas are characterized by the presence of closed basins and or dry valleys in various sizes and shapes, scarce or no surface drainage or rivers, and caves from underground drainage systems. Four factors influence karst landforms, namely: 1) climate, 2) limestone, 3) regional topography, and 4) geological structure field (Ahmad *et al.* 2005). Regarding the geological structure, dissolution will occur in a plane with high porosity and the field in areas that experience faults and joints. (Asikin, 1978).

Karst topography is a product of the karstification process. The dissolution process dominates karstification or the process of forming karstic landforms. Addison stated that karstification is the process of dissolving and underground infiltration that gives rise to surface features and underground drainage networks in karst areas. Therefore, dissolution is essential in forming karstic landforms (Sweeting, 1968).

The method section identifies geological structures on Landsat 8 images by observing the lineament pattern of geological structures (faults and joints). The lineage pattern of the
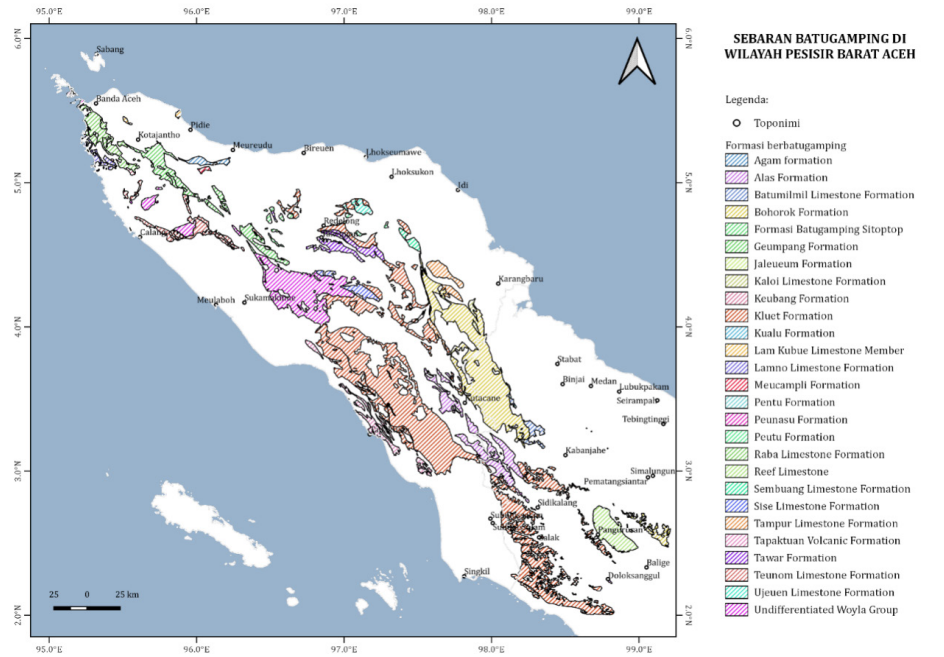
Figure 2. Distribution of Limestone Formation on the West Coast of Aceh
(Source: Setiawan and Nasution, 2023)

geological structure was observed from the pattern of the valley network or the intersection of the hill with the valley network with an elongated pattern controlled by the geological structure. For better results, the interpretation of lineament patterns was assisted by geological maps and DEM data. With the DEM data, the appearance of the morphology of the geological structure lineage pattern will become more evident.

The geological structure that developed based on the geological map of the Takengon Sheet (1982) is in the form of folds and faults traversed by the main Sumatran fault (Semangko Zone). The fold axis is generally in a northwest-southeast and almost north-south direction. Normal and rising faults generally have a northwest-southeast to almost north-south, while horizontal faults generally have a northeast-southwest and west-east direction.

Geological structure analysis and geological map data reveal more information on geological conditions, lithology, and other geological information. For this reason, the geological formation data found on the 1:250.000 Geological map with limestone content discover to facilitate the process of analysis and estimating the location of the existence of the cave.

The distribution of geological formations (see Figure 2) containing limestone on the west coast of Aceh consists of the Peuteu Formation, Dusun Members (Tmpd), consisting of sandstone, siltstone, mudstone, and limestone. The Tampur limestone formation (Totl) consists of reef limestone and dolomite. The Sise Limestone (Musl) Formation consists of modified limestone. Limestones In the Indivisible Woyla Group (Muwl) consist of modified solid limestones. The Alas Formation, Limestone (Ppal) Member, consists of solid limestone and recrystallized limestone of the Bahorok Formation (Pub), consisting of schist, phyllite, and genes. The Kluet Formation, Limestone Member (Pukl), consists of meta-limestone and marble (Raja, Muksin and Labaik, 2014).

Another formation is the Lamno Limestone (Mull) Formation, in the form of clastic limestone, black in color, hard and solid, generally regenerated, with calcite veins found. These rocks are found in the northeastern

inventory area (Kecamatan Jaya), forming steep hills (Ge Gueruthe). Reef members, Lamno Formation (Mullr), are limestone-like reefs. These rocks in the northeastern part of the inventory area, including in Jaya District, are gray to black in color, hard and solid, and calcite veins discover, forming steep hills. Reef member, Teunom Limestone Formation (Mutlr), in the form of massive limestone, generally has undergone recrystallization resembling a reef, solid, hard, black in color, marbled by the Sikuleh Batholith (Sayekti and Raja, 2011).

There is enormous potential in several previous studies conducted in the Benermeriah karst area and Lut Tawar Lake. The survey found 13 caves and inlets (Setiawan 2013). The distribution of the cave findings, when superimposed with the Landsat imagery, geological structure, and lithology, found the following data: 1) The distribution of caves in zones of the geological structure, both faults, and joints, and 2) The caves in the formation boundaries and lithology (see Figure 3). In another study conducted in 2018 in the West Coast region of Aceh in Aceh Besar District, 11 caves were also found (Setiawan, 2020). In addition to these data, some cave information from other secondary sources. Based on the distribution of the caves and inlets found, the phenomena are almost similar to those found in the Benermeriah karst and Lut Tawar
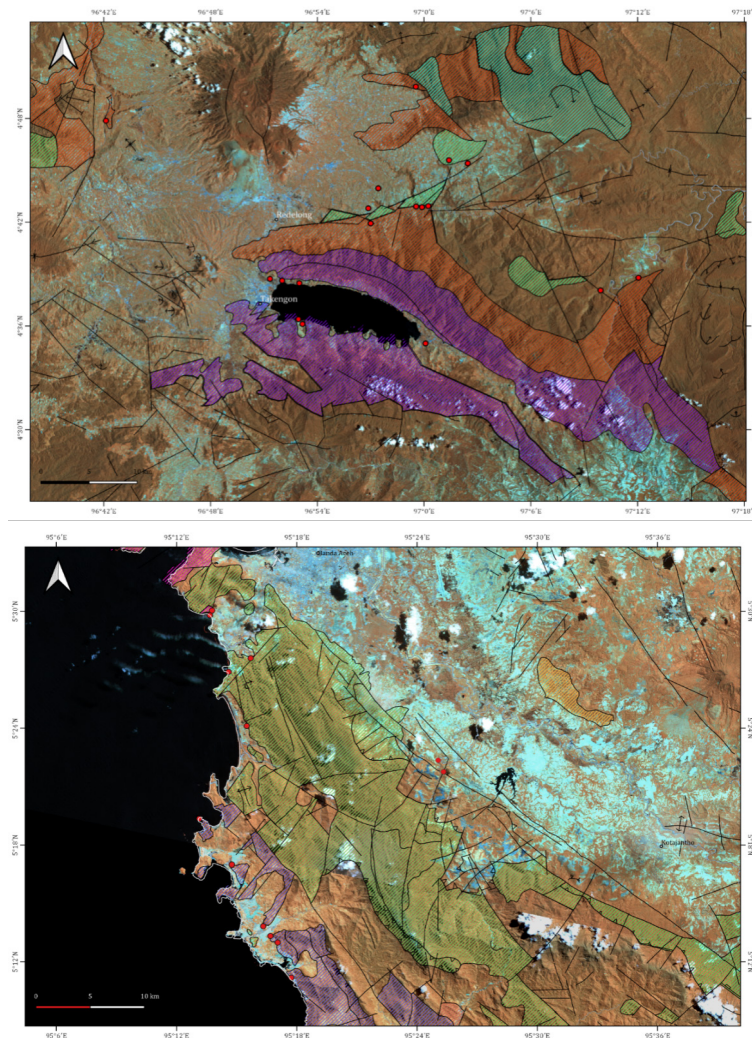
Figure 3. Position of Caves and Rock-shelters concerning geological structures
and research lineages at Bener Meriah and Lut Tawar Lake in 2012-2013
(above) and Aceh Besar (2018)
(Source: Setiawan and Nasution, 2023)

Lake. The phenomenon of finding caves in the karst region of the western part of Aceh, Aceh Besar, is also found in locations with limestone formations that have straight lines and geological structures crossed in one lithological unit (see Figure 3).

By paying attention to the phenomena found from the results of the two studies and the analysis of lineament data and geological structures, there are 26 possibilities distributed from the West Coast and Central Mountains of Aceh Province. The locations that have the potential for the existence of these caves show that there are groupings at several locations. At least five clusters can be found (see Figure 4).

a. Cluster I

This group consists of eight locations that are currently under the administrative area of Aceh Besar Regency (3 locations), Aceh Jaya Regency (2 locations), and Pidie Regency (3 locations). The three locations in the Aceh Besar Regency area are in the Jantho Nature Park and are the upstream part of Krueng Aceh. Two locations in Aceh Jaya are also related to the existence of the Lambeuso River, which empties into the West Coast of Aceh. This location is also on the back of the Bukit Barisan. Three locations in the Pidie Regency area are also related to the presence of a river, namely Krueng Sekuleh, which is upstream of Krueng Teunom and empties into the West Coast of Aceh.

b. Cluster II

There are three groups of locations for the alleged existence of caves in this cluster.
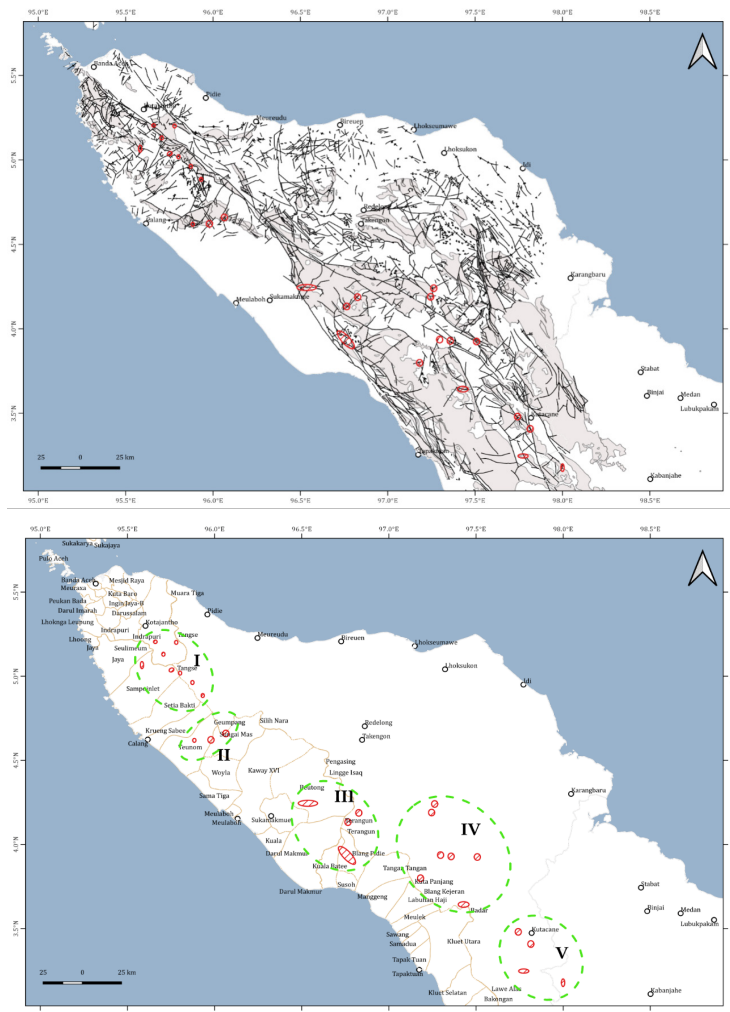

Figure 4. Locations where caves and inlets are assumed
(Source: Setiawan and Nasution, 2023)

All three are still in the same border area between Aceh Jaya and Aceh Barat. These three locations are around the Teunom River.

c. Cluster III

In this group, four locations have the potential for the existence of a cave. The two locations are in the border area between Naganraya Regency and Gayolues Regency. Two potential locations in the Naganraya region are in the eastern region in the Bukit Barisan Mountains. They are related to the upstream existence of two rivers that empty into the West Coast of Aceh: the Seunagan and Seumayam rivers. The other two locations are close to the existence of Krueng Tripa, which originates in the Blangkejeren area.

d. Cluster IV

This group found seven locations that have the potential for the existence of a cave. This location is entirely in the administrative area of Gayo Lues Regency. This group of alleged locations is the upstream part of three long rivers. In the upper reaches of the Jambuaye River, two locations have the potential for cave existence. This river leads to the north and empties into the East Coast of Aceh. One other location is in the west, the upstream part of the Krueng Kluet River, which empties into the West Coast of Aceh. One location in the south is upstream of the Jambupapeun River, one of the Krueng Kluet tributaries. Three locations with potential caves discover close to Blangkejeren City.

e. Cluster V

The last group has the potential for the existence of a cave in the Southeast Aceh Regency. The alleged location is around the Semayamcut River, which passes through Kutacane and originates in Blangkejeren, Gayolues.

In the five identified clusters (see Figure 5), several phenomena are pretty exciting and have the potential for study. The existing clusters of estimation locations are on the Bukit Barisan Mountains ridge at an altitude of between 500-3,000 mdpal. These locations are also in the rivers' upstream part that drains into Aceh's West Coast. There are only two locations related to the existence of a river that empties into the north, namely Krueng Aceh (cluster I) and the Jambuaye River, which empties into the East Coast of Aceh (Cluster IV).

In the article "Loyang Mendali Prehistoric Residential Sites in Inland Aceh: Initial Assumptions on the Results of Research on Caves in Central Aceh District, Nanggroe Aceh Darussalam Province" written by Setiawan (2009, p. 238), there were four possible migration routes in into Loyang Mendale. One possibility is a river path that empties into the East Coast of Aceh, namely the Peusangan River, and a river route east and south of Lake Lut Tawar. The rivers are the Wih Delung River and the Jambuaye River, which are branches of the river from Krueng Pasai. Therefore, cluster IV, which is upstream of the Jambuaye River, is exciting to study.

Related to the above, Cluster IV and Cluster V can be of more concern considering that both cluster in the same Semayamcut River flow path that connects it with the southern region. One of the results of research conducted in Loyang Mendale and sites in the Gayo highlands shows a cultural link between Gayo, Karo, and Pakpak (Wiradnyana and Setiawan, 2011). These two clusters provide an overview of the existence of archaeological sites that can provide additional data about the results of this relationship.

Regarding the scope of research on the Western Coast of Aceh, the results of the estimated locations that have the potential to be the following research are Cluster III, located in the mountainous border region between Aceh Barat, Nagan Raya, and Gayo Lues. At that location, four locations have the possibility of
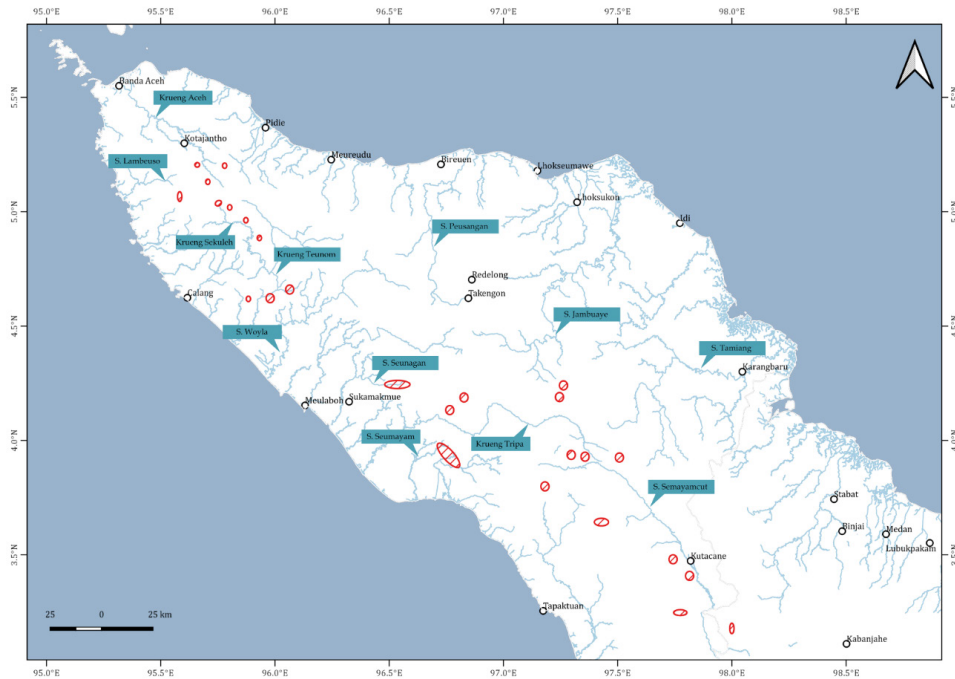
Figure 5. The location of the alleged existence of a cave and its relation to the presence of a river
(Source: Setiawan and Nasution, 2023)

the existence of a cave. Therefore, this location needs attention and may become the main focus of efforts to uncover prehistoric life in the area.

Potential residential locations around Tangse, Pidie Regency, and included in the estimation location of cluster I may be one of the initial stepping stones to finding out the potential of past life in the northern part of the Bukit Barisan mountain area. The discovery of sites provides an overview of past settlements in the northern region of Sumatra.

4. Conclusion

The existence estimation of the cave on the Western Coast of Aceh has found as many as 26 locations. These locations still require field testing and more detailed estimation methods by utilizing high-resolution image data and other supporting data. For testing the result, we can provide research on karst areas in the West Aceh, Nagan Raya, and Gayolues regions. In addition, other research projections can also determine the potential presence of archaeological sites in the areas of Blangkejeren, Gayolues, and Kutacane,

Southeast Aceh. Further reveals a relation between Gayo, Karo, and Pakpak as a follow-up to the results of research in the Gayo Highlands which has revealed.

Author Declaration

Both authors declare a proportional scientific contribution to the manuscript. All authors declare no conflict of interest and no competing issue related to the publication of this paper.

Acknowledgement

References

Ahmad, Mufti Latif, Suratman Worosuprodjo, and Eko Haryono (2005) Geomorfologi Karst Mayor Antara Telaga Sanglen Dan Kamal, Kabupaten Gunungkidul, DIY. Gunung Sewu Indonesian Cave and Karst Journal 1(1):31–39.

Anon (2013) "Caves-ID: Let's Map the Distribution of Karst in Indonesia." Retrieved (www.peta.caves.or.id).

Asikin, S. (1978) Dasar-Dasar Geologi Struktur. Bandung: Department of Geological Engineering ITB.

Conolly, J. and M. Lake (2006) Geographical Information Systems in Archeology. Cambridge: Cambridge University Press.

Ford, D., and Paul Williams (2013) Karst Geomorphology and Hydrology. Revision E. London: John Wiley & Sons, Ltd.

Drawhorn, G.M. (2000) "Indonesian-International Sumatran Cave Research and Exploration Expedition." Retrieved (www.csus.edu/indiv/d/drawhorng/).

Gillieson, D. (1996) Caves: Processes, Development and Management. Oxford: Blackwell Publishing.

Kuswanto, Gregory Dwi (2016) Pemodelan Pendugaan Situs Gua Arkeologis Di Kawasan Karst Gunungsewu Berbasis Citra Penginderaan Jauh Dan Sistem Informasi Geografis. Master Thesis. Gadjah Mada University.

Putri, Carolina Ajeng Sukmawati and Taufik Hery Purwanto (2015) "Interpretation of Geological Structure and Lithology by Landsat 8 and SRTM Imagery in Rembang District and its Surrounding." Jurnal Bumi Indonesia 4(4).

Raja, Martua P., Irwan Muksin, and Ganjar Labaik (2014) Eksplorasi Umum Endapan Kuarsit Di Kabupaten Gayo Lues, Provinsi Nanggroe Aceh Darussalam.

Samodra, Hanang (2005) *Peristilahan Kars Dan Gua*. Bandung: IAGI Karst Commission.

Sayekti, Bayu and Martua Raja (2011) Inventarisasi Mineral Non Logam Di Kabupaten Aceh Jaya Dan Kabupaten Aceh Barat, Provinsi Nanggroe Aceh Darussalam in Prosiding Hasil Kegiatan Pusat Sumber Daya Geologi Tahun 2011

Setiawan, Taufiqurrahman (2009) Loyang Mendale Situs Hunian Prasejarah Di Pedalaman Aceh: Asumsi Awal Terhadap Hasil Penelitian Gua-Gua Di Kabupaten Aceh Tengah, Provinsi Nanggroe Aceh Darussalam. Sangkhakala. 12(24):229–39.

Setiawan, Taufiqurrahman (2013) Permukiman Gua di Kabupaten Bener Meriah (Sebuah Analisis Pendahuluan). Sangkhakala 16(I):60–77.

Setiawan, Taufiqurrahman (2020) Potensi Hunian Gua Dan Ceruk Di Kabupaten Aceh Besar. Berkala Arkeologi 40(1):23–44.

Setiawan, Taufiqurrahman, Aswan Aswan, Nenggih Susilowati, Andi Irfan Syam, Anton Ferdianto, Anggun Ibowo Saputra, Dwi Wahyudi, Deni Adreian, Muhammad Bahrum, Primawan Primawan, and Sopingi Silalahi (2021) Rekaman Tsunami Di Pesisir Barat Aceh: Sebuah Laporan Awal dan Prospek Penelitiannya. Prosiding Balai Arkeologi Jawa Barat 4(1 SE-):27–37.

Setiawan, Taufiqurrahman, Anton Ferdianto, Nenggih Susilowati, Aswan Aswan, Andi Irfan Syam, Anggun Ibowo Saputra, Dwi Wahyudi, Deni Adreian, Muhammad Bahrum, Primawan Primawan, and Sopingi Silalahi (2020) "Gua Mabitce: Data Baru Situs Hoabinh Di Sumatra Bagian Utara." Amerta 38(2):115–28.

Sharer, R. J., and Wendy Ashmore (2003) Archeology Discovering Our Past. 3rd Edition. New York: The McGraw-Hill Companies, Inc.

Sweeting, M.M. (1968) "The Solution of Limestone." in Research Methods

in Geomorphology 1st Guelph Symposium on Geomorphology. London.

PA Leuser UKM. (2004) "Term of Reference (TOR)/KerangkaSeminar Nasional Kawasan Karst 2004" Retrieved (http://groups.yahoo.com/group/subterra-id/message/337).

Verhagen, P. (2007) Case Studies in Archaeological Predictive Modeling. Edited by LU Press. Leiden.

Wiradnyana, Ketut and Taufiqurrahman Setiawan (2011) Gayo Merangkai Identitas. Jakarta: Indonesia Torch Foundation.

Yuwono, J. Susetyo Edy (2004) Arkeologi Karstik Dan Metode Penelusuran Potensi Kawasan: Introduksi Tentang Model Penerapannya Di Gunung Sewu.

Yuwono, J. Susetyo Edy (2005) Mozaik Purba Gunung Sewu: Hipotesis Hasil Eksplorasi Gua-Gua Arkeologis Di Kecamatan Tanjungsari-Gunungkidul. Gunung Sewu Indonesian Cave and Karst Journal. 1(1 (April 2005)):40–51.
Symposium on Geomorphology.
London.

Wiradnyana, K. and Setiawan, T (2011) *Gayo Merangkai Identitas*. Jakarta: Yayasan Obor Indonesia.