

## THE IMPRESSIVE OF GEOLOGICAL EVIDENCE OF KUALA MUDA DISTRICT: A PROPOSAL FOR GEOTOURISM PRODUCTS IN KEDAH, MALAYSIA

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**Abstract:** This study provides primary evidence about the geological features in Kuala Muda district, indicating significant potential for development as a geotourism product. To collect primary data, we conducted survey and mapping activities to gather information about the current condition of 11 geosites, as well as the facilities already in place to facilitate seasonal tourism. In addition, a review of previous scientific research for each geosite is also carried out so that geosite speciality data can be summarized. The study's results have facilitated the creation of 17 tourism packages under the AncKed Sungai Batu Association, encompassing geology, geoarchaeology, biology, history, heritage, and culture tourism products in the Kuala Muda district. Offering tour packages enables the district to conduct knowledgeable tourism activities involving people from all walks of life and ages, with trained locals serving as tour guides. This ensures the preservation of geotourism at its optimal level.

**Keywords:** Kuala Muda district, survey, mapping, geosites, geology

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### INTRODUCTION

A geosite highlights the diversity and unique value of scientific, pedagogical, cultural, or tourism values, enabling its development into a successful tourism product. Generally, a geosite refers to a geological location or landform that reveals a unique aspect of geodiversity (Komoo, 2004; Reynard et al., 2007; Pralong, 2006; 2009; Reynard, 2009; Comănescu et al., 2011; Neches, 2016; Maghsoudi and Maryam, 2018), enabling the creation of geotourism with a specific focus on natural tourism elements like landscape and geology. According to Dowling and Newsome (2006: 2018); Hose (2008); Kubalíková (2013); Ólafsdóttir (2019) and Sadry (2021) geotourism is defined as one that maintains the local geographical features (environment, culture, aesthetics, heritage, and the well-being of its residents) in order to sustain this tourism.

The geological formation of Kuala Muda district (Figure 1), which forms the geological component of the Northwest Tectonostratigraphic Domain of Peninsular Malaysia, is the most complete sequence of Paleozoic-age clastic sedimentary rocks that comprise the geology of Jerai Mount. This region represents the lowest part of the sequence, which is the Cambrian age (Bradford, 1972). This domain has formed a series of gravel and carbonate sedimentary rocks in a variety of marine environments, ranging from the shallow sea to the deep sea. These rocks eventually became terrestrial due to granite body fractures in the early Triassic (Bradford, 1972). After that, a continuous denudation process involving weathering and erosion produced the panoramas and landscapes of the present terrain (Burton, 1967; Bradford, 1972).

As the area revealed unique geological evidence, academic studies began to be planned and conducted to enable field data to be observed. To achieve this goal, the National Geopark Committee was founded in 2015 (Ali et al., 2019) and began conducting research since 2016, which has been able to provide a complete set of primary data on geological, geoarchaeological, biological, and cultural specialities in this area. This research is in line with the establishment of the

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National Geopark Committee itself, which encourages efforts to develop national geoparks in each state so that it is eligible to become a UNESCO Global Geopark (UGGp) (Komoo and Said, 2019). The former director Center for Global Archaeological Research, Universiti Sains Malaysia, Penang conducted this academic research as the Chairman of the Jerai Geopark Promotion and Development Committee, under the transparent supervision of the Ministry of Natural Resources and Environmental Sustainability of Malaysia (Anynamous, 2018). To smooth the work of data observation in the field, cooperation with several parties, such as Sungai Petani Municipal Council, Yan District Council, Forestry Department of Peninsular Malaysia, Malaysian Geological Heritage Group, Universiti Kebangsaan Malaysia, Department of Wildlife and National Parks, Malaysia, and the Department of Irrigation and Drainage, was established.

The research focuses on characterizing and identifying geoheritage values or geoparks that have outstanding universal value (OUV) in geopark development. Consequently, survey activities recorded a total of 24 geosites (11 geosites in Kuala Muda district), encompassing various geological classifications such as 1) coastal landscape evolution, 2) Jerai Mount evolution geosite, 3) regional metamorphism geosite, 4) late magmatic phase and contact metamorphism geosite, and 5) quaternary geological evolution geosite mapped in this area. Such academic studies will undoubtedly benefit the area, transforming it into a lucrative sales product (Jenkins, 2003; Grayson and Martinec, 2004; Holt, 2004).

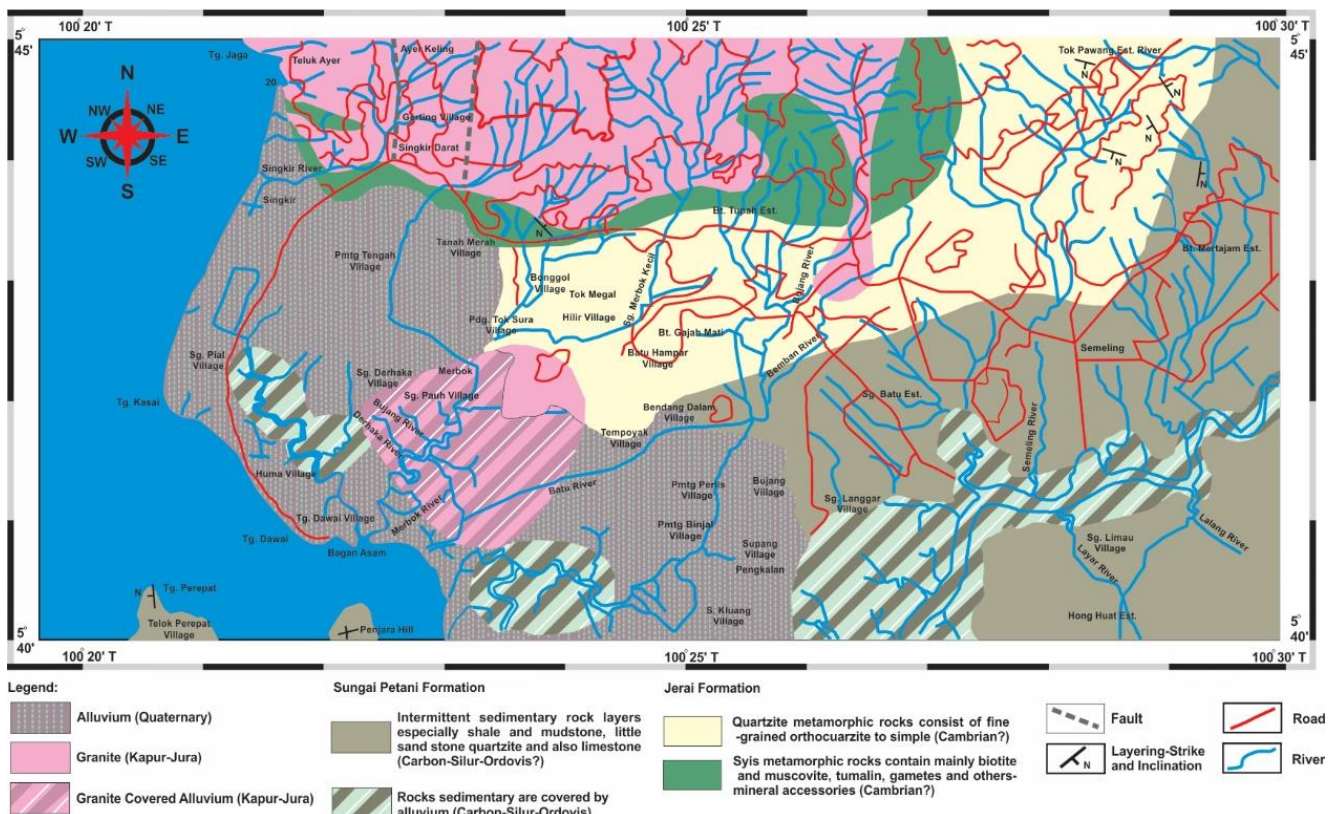


Figure 1. The geological formation of Kuala Muda district (Source: Director of National Mapping Malaysia, 1972)

### Geological Setting

Jerai Geopark covers Kuala Muda and Yan districts, covering an area of up to 816 km<sup>2</sup> (Figure 2). The area encompasses both terrestrial and archipelago environments, where field observations recorded 24 geotrail findings. Field observations have classified the boundaries of Jerai Geopark as Sungai Limau (Yan) in the north, Persekutuan Road Fi and F257 (Kuala Muda-Yan) in the east, Muda River (Kuala Muda) in the south, and the sea border covering Sayak Island (Kuala Muda), Bidan Island (Yan), Songsong Island (Yan), Telor Island (Yan), and Bunting Island (Yan) in the west (Komoo and Said, 2019). The area around Kuala Muda-Yan district shows how Jerai's Mount geology and landscape have changed over time. The main things that were used to choose the borders of the Jerai Geopark were geoarchaeological sites, the biology of the Merbok River, and the beautiful islands off the coast of Kuala Muda and Yan (Komoo and Said, 2019). On July 5–7, 2017, the validity of the facts led to its designation as a national geopark.

Based on the geological map in Figure 2, it is clear that the Jerai Geopark area has a rock structure that forms the geology of Mount Jerai, apart from the low undulating hills at its feet and the beautiful island landscape to the west. This area also records the existence of the Jerai and Mahang Formation (Table 1), which formed from the Late Cambrian period to the Middle Ordovision for the Jerai Formation and from the Central Ordovision to Central Devon for the Mahang Formation, thereby explaining the geological features of Jerai Geopark in Kuala Muda and Yan districts.

### LITERATURE REVIEW

Globally, there has been a sustained focus on studies related to geological specialties and the development of heritage tourism packages. Sasso di Castalda, located 20 km south of Potenza in the Southern Apennines thrust-belt, is one of the

geological tourism locations actively developing its tourism products. According to Palladino et al. (2013), this area boasts distinctive outcrops of Mesozoic rocks (Bertinelli et al., 2005). These outcrops are so spectacular that stakeholders have created seven stops to allow tourists to witness the unique Mesozoic stratigraphy of the Deep Sea Lagonegro from the Triassic to Cretaceous age (Bentivenga et al., 2017). Bentivenga et al. (2017) classified and focused the first stop on 1) the geology of the Craco village area, 2) the Aliani Badlands, 3) the Alianello Anticline, 4) Il Monte, 5) the Monte Volturino structure, 6) the Monte Lama-Serra di Calvello structure, and 6) structures at Sasso di Castalda. The focus of all excursion programs is on the unique geological processes that occur in this area, making it unique in the history of Earth's formation.

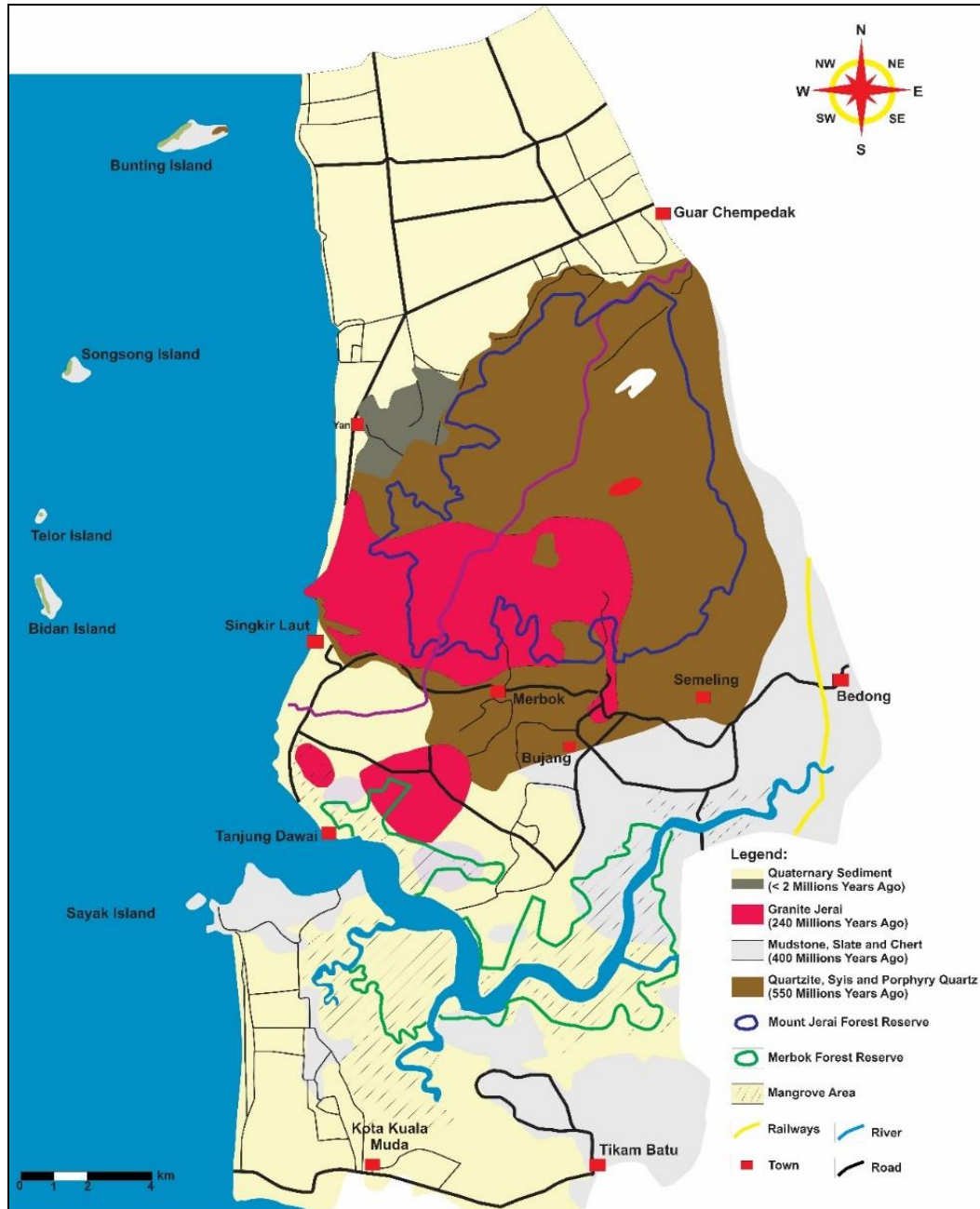


Figure 2. The Kuala Muda-Yan district area revealing the uniqueness of the geological formation that allows it to be recognized as Jerai Geopark (Source: authors based on data from Komoo and Said, 2019)

According to Palladino et al. (2013), the story was made so that people could (1) see the thick layer of sediment that fills the Lagonegro Basin in deeply cut natural sections that show off the lithology, stratigraphic contacts, and geometry of the sedimentary bodies; (2) look at 3D-fold geometry at different sizes; and (3) see well-exposed postorogenic faults that cut through the earlier structures that were stretching. Even to maximize the tour experience, the packages offered also involve geologists as tour guides. Additionally, Prykhodchenko and Tykhonenko (2017) discussed the geological features around the Mokra Sura river (Archean Rocks) to facilitate the creation of tour packages. The area's tour packages concentrate on two main attractions: 1) the outcrop of plagiogranites from the Sura Mesoproterozoic complex (Surianochka open-pit) and 2) the Novomykolaivka granite quarry. In fact, Prykhodchenko and Tykhonenko (2017) suggested incorporating photography and video recording activities into future tourism activities in this area to enhance tourist satisfaction.

Table 1. Classification of Jerai and Mahang Formations in Jerai Geopark  
(Source: authors based on data from Burton, 1967; Bradford, 1972; Jones, 1973)

Formation	Characteristics
Jerai	<ul style="list-style-type: none"> <li>Sequences of sedimentary and metasedimentary rocks exposed on Mount Jerai at altitudes above 80 m above sea level;</li> <li>Is a gravel sedimentary rock that has been regionally metamorphosed and metamorphosed again by contact during granite body crushing;</li> <li>It forms the Lower group and the Upper group of the Jerai Formation;</li> <li>The lower member is formed by the Argilite Facies which consists of quartz-mica shale, phylit and in some places garnetized amphibolite rocks and 900 m thick;</li> <li>The Upper group is represented by a 500 m thick Arenite Facies represented by quartz arenite with spherical grit present in a finite distribution</li> </ul>
Mahang	<ul style="list-style-type: none"> <li>This formation is represented by exposed rocks in the eastern part of Mount Jerai at an altitude not exceeding 80 m above sea level;</li> <li>Consists of three facies namely Argilitic Facies, Arenitic Facies and Calcium Facies;</li> <li>Arenite facies are characterized by a sequence of red shale and chert especially south of Mount Jerai;</li> <li>Arenite fissures consist of relatively sparsely dispersed sandstone and orthoquartzite;</li> <li>The calcareous facies are represented by a single outcrop of limestone on Bidan Island located about eight kilometers west of the foot of Mount Jerai</li> </ul>

Researchers in the Batuecas-Sierra de Francia-Candelario region (Martinez-Grana et al., 2019), Spain, have documented scientific data about the area's distinctiveness. The study's findings revealed that this area has 100 geosites scattered in the provinces of Salamanca, Paservila, and C. Paserceres (Spain). Using geomatics tools for field data observation, the organization organized digital information from various thematic layers and integrated it with pictures, diagrams, and descriptive cards to create educational resources. The Google Earth platform processes the data for 3D virtual flights (Martinez-Grana et al., 2019), providing access in various formats (mpeg, avi, wma). This ensures the sustainability of the tourism development program. LeBlanc (2022) discusses the itinerary of geological tourism in Qatar, which involves a three-day excursion program. The first day of the tour program focused on visits to 17 tourist sites, five on the second day, and six geological tourism sites on the third day. The test is based on evidence from outcrops in the Lower Eocene Rus Formation, Middle Eocene Damman Formation, Lower Miocene Dam Formation, Mio-Pliocene Hofuf Formation, and Pleistocene and Holocene deposits. The field trip's aim is to help the participants recognize the various formations and their members, as well as the most obvious features (faults, folds, dissolution, mineralization, fossils, etc.).

In addition, the Talib et al. (2022) study made it possible to identify eight geoarchaeological sites that show how prehistoric humans interacted with the geological landscape, as well as 27 geosites that illustrate four significant geological and historical tectonic evolutions and unique geomorphic features in the Lenggong Valley. The distinctive and conserved customs of life, art, and culture now have greater value thanks to the geosites. Furthermore, 22 geosites encompassing land and island areas were discovered in the Mersing district of Johor, Malaysia, according to a study conducted by Said et al. in (2021). Within the protected region, noteworthy plants and fauna have also been identified by researchers. This geopark has potential to become a prosperous geotourism destination because of its distinctive and still-preserved customs of life, art, and culture.

Particularly in Malaysia, researchers have carried out numerous studies that not only concentrate on geological features (Rapidah et al., 2018), but also uncover evidence of geoarchaeological sites (Abd Halim et al., 2022a, b: 2023; Ali et al., 2023), biology (Ali et al., 2021a), history (Ali et al., 2021b), and culture (Hasan et al., 2018), all of which contribute to the creation of tourism itineraries. Researchers are currently required to carry out field research and gather primary data on the unique characteristics of the region, enabling the provision of heritage tourism packages to visitors. In particular, this will guarantee the effective and sustainable implementation of knowledge tourism activities.

### Aims of the Study

This study aims to infer data related to privileges, availability of basic facilities, and development of special geotourism packages in Kuala Muda district. In addition, the study aims to offer a total of 15 tour packages that combine geological, geoarchaeological, biological, historical, and cultural tourism locations. Several global geopark tourism locations in Malaysia, particularly Lenggong Valley (Rapidah et al., 2018) and Langkawi (Komoo et al., 2018), have implemented such tourism packages and successfully attracted tourists.

### METHODOLOGY

The Jerai Geopark survey and mapping study conducted research on the thesis, journals, articles, scientific studies, newspapers, and online websites to identify suitable areas for field survey activities. Additional references were also made at Hamzah Sendut Library, Universiti Sains Malaysia, Penang, the Centre for Global Archaeological Research Library, Universiti Sains Malaysia, Penang, and the Sungai Batu Archaeological Site Library, Bujang Valley, Kedah, to maximize data findings before survey and mapping activities were carried out.

The district of Kuala Muda conducts a survey and mapping process to determine the geosite location for a potential geological tourism product. This survey activity entails investigating the Jerai Geopark map, which includes geosite and geotrail features (a), the Sungai Petani Municipal Council's existing tourist site location map (b), the Sungai Petani district road network map (c), and the river network system (d). The goal is to gather information about the area's location and basic facilities, thereby promoting it as a district tourism product. The study on the Jerai Geopark map

(Figure 3) enables the study, identification, and recording of basic information about the geopark's location and the seven geotrains, particularly those that are close to each other and can be traced through roads and rivers. Based on the information, it is possible to determine the parameters of the geosite survey only in the vicinity of the district.

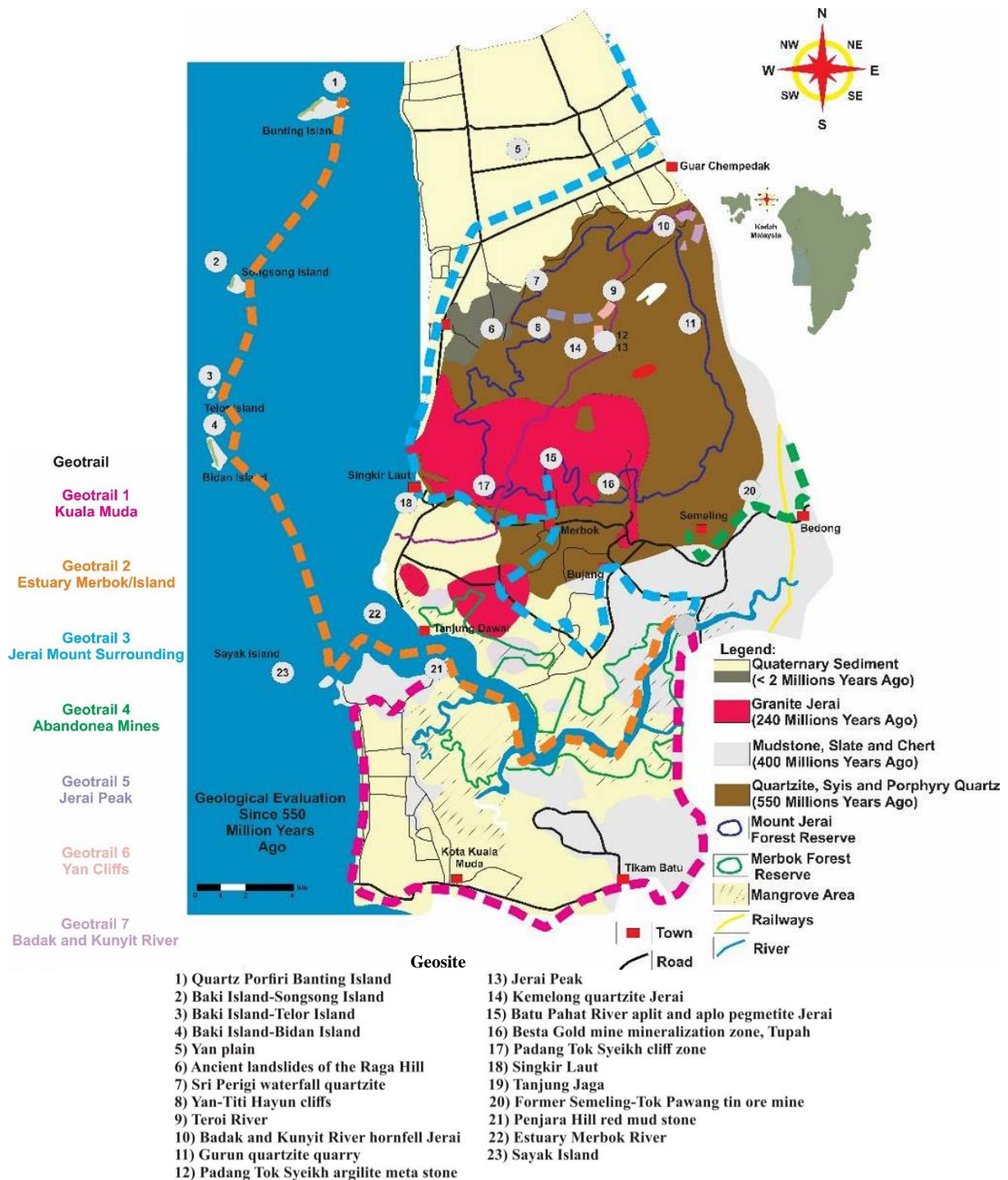


Figure 3. Analysis of the Kuala Muda-Yan Geopark Jerai map which provides basic data on geosite, geotrail and other tourist sites in this district (Source: authors based on data from Ali et al., 2019)

The Sungai Petani Municipal Council, Kedah (MPSPK) also conducted a study on the existing tourism map (Figure 4) to bolster the data from the Jerai Geopark map. The tourism map study reveals that the well-developed road network system enables easy access to all the mapped geotaps, and the river route has established a water taxi service in Sungai Merbok, leading to the development of geosites in Kuala Muda-Yan district (Figure 5).

The map of the river drainage system (Figure 6) clearly demonstrates that the Kuala Muda district boasts two main tributaries, the Muda and Merbok Rivers, capable of irrigating water into tributaries such as the Bujang, Terus, Simpor, and Batu River. These tributaries are in close proximity to several geosites in the area. Therefore, it is not unexpected that the district of Kuala Muda not only boasts a geosite but also reveals a geoarchaeological, biological, heritage, history site, and so on, where the river served as the primary communication and trade route in the past.



Figure 4. Tourism map in Kuala Muda-Yan district (Source: authors based on data from Ali et al., 2019)

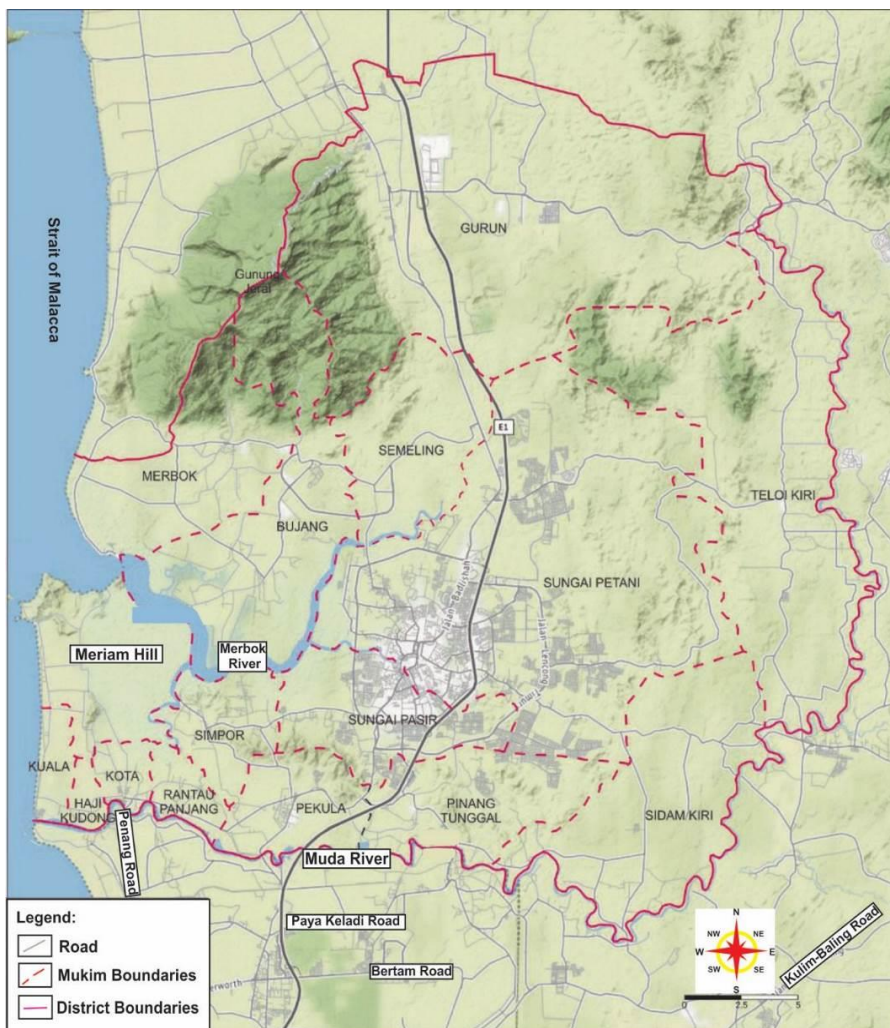


Figure 5. Existing road network system in Kuala Muda district (Source: authors based on data from Stamen, 2020)

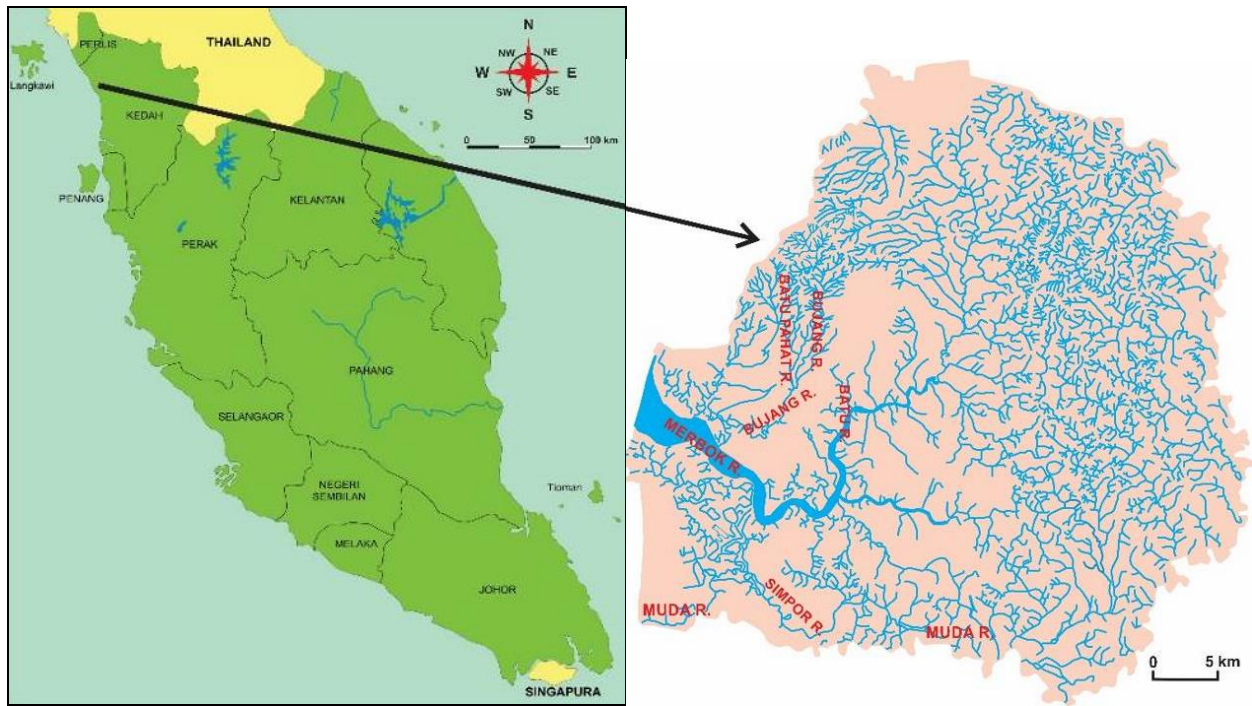


Figure 6. Map of the river drainage system of Kuala Muda-Yan district showing the location of the geosites, close to the river drainage (Source: authors)

The study used the Jerai Geopark map (which includes geosite and geotrail) (Figure 7), the existing tourist site location map by the Sungai Petani Municipal Council, the Sungai Petani district road network map, and the river network system to find out more about the geosite's unique features and how to make it a sustainable district geological tourism product. This was done through a field study that included surveying and mapping in the Kuala Muda district. Good tourist infrastructure has made it possible to offer tour packages effectively. As demonstrated in the Iskandar Malaysia (WIM) region, the outcome will empower the tourism sector in a more sustainable direction (Said et al., 2022).

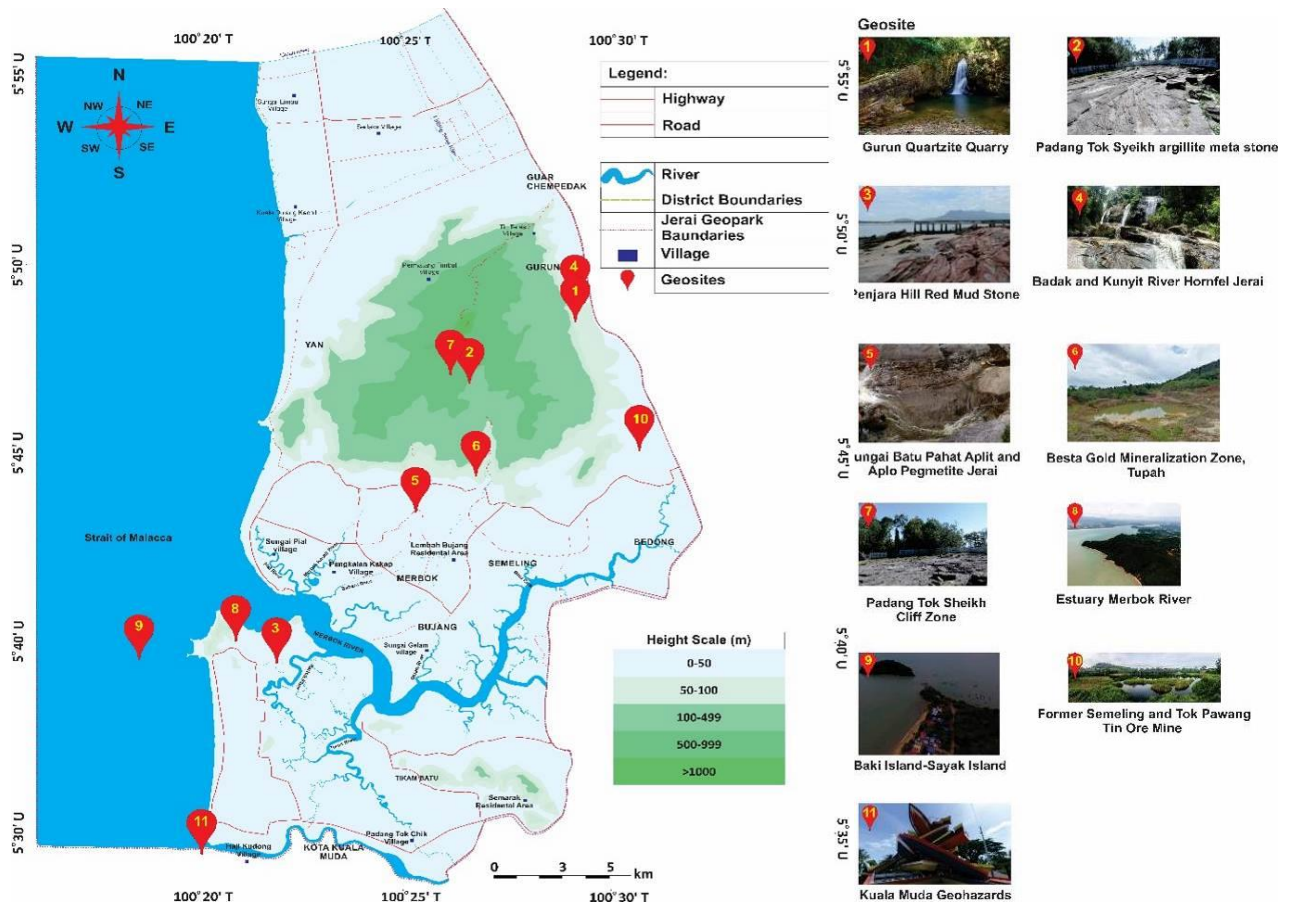


Figure 7. Geosites location mapped in Kuala Muda district (Source: authors)

**RESULT AND DISCUSSION**

**1. Geotouristic Itinerary**

The survey (Figure 8) classifies the geosite into two main categories: (i) easily accessible and (ii) difficult to access based on road network system in Kuala Muda district. The creation of each geotrail necessitates daily visits to the site, accessible by car, motorcycle, and water vehicles like water taxis. Some geosite require walking activities to visit in order to fully experience the area. In fact, the survey activity revealed that the installation of an info panel pertaining to each geosites facilitated the process of providing tourists with basic information about tourist destinations. This means that the basic information for each geosite has been obtained in the field.



Figure 8. Kuala Muda-Yan District has installed general information panels about Jerai Geopark (a) and special information panels for each geosite (b, c, d) (Source: authors)



The mapped locations of 11 geosites within the Kuala Muda district represent various categories such as coastal landscape evolution, Jerai Mount, regional metamorphism, late magmatic phase, contact metamorphism, and quadrant geological evolution. The survey and mapping process revealed the value of global excellence in the 11 geosites, which the data that can use in the dossier process to recognize as a national geopark and later designate as a UNESCO Global Geopark (UGGp) as a Langkawi (Anynamous, 2018) and Kinabalu (Dousin et al., 2024) UNESCO Global Geopark). This is due to the fact that the Jerai Geopark area, home to rocks from the Cambrian-aged Jerai Formation, possesses significant scientific value worthy of global recognition (Table 2). Therefore, the academic research of Saidin et al., (2019) in the district of Kuala Muda district has so far successfully provided a knowledgeable tourism product in the category of geotourism for this district. Although there are geosites that require tourists to walk, the geotrail created is not too difficult or challenging. The recreational sites of Kunyit and Badak River waterfalls are accessible due to their sloping and safe routes. Four-wheel drives can access the geotrail of the former Semeling and Tok Pawang tin mines.

Table 2. List of geosites at Kuala Muda distict (Source: authors)

no.	NAME OF GEOSITE	COORDINATE	ACCESSIBILITY	RELATED ACTIVIES
1	Gurun Quartzite Quarry	5.797492° N and 100.473156° E	Four wheel drives	Visiting for tourism, research, and educational purposes
2	Padang Tok Syeikh argillite meta stone	05°47'43" N and 100°26'18" E	Motorbike and four wheel drives	Visiting for tourism, research, and educational purposes
3	Penjara Hill Red Mud Stone	5.669439° N and 100.369838 E	All means of transportation and walking	Visiting for tourism, research, and educational purposes
4	Badak and Kunyit River Hornfel Jerai	5.822474 N and 100.461217 E 5.815375 N and 100.464630 E	All means of transportation and Walking	Variety of leisure activities including visiting and camping
5	Sungai Batu Pahat Aplit and Aplo Pegmetite Jerai	05°44'288" N and 100°24'908" E	All means of transportation	Variety of leisure activities including visiting and camping
6	Besta Gold Mine Mineralization Zone, Tupah	5.735229 N and 100.386113 E	All means of transportation	Visiting for tourism, research, and educational purposes
7	Padang Tok Syeikh Cliff Zone	5.790625 N and 100.435422 E	All means of transportation and walking	Visiting for tourism, research, and educational purposes
8	Estuary Merbok River	5.681932 N and 100.467846 E	Boat and river taxi	Variety of leisure activities including visiting, camping, guided and fishing
9	Baki Island- Sayak Island	5.662541 N and 100.330664 E	Boat and river taxi	Variety of leisure activities including visiting, camping, guided, fishing, swimming
10	Former Semeling and Tok Pawang Tin Ore Mine	5.711539 N and 100.474032 E	Four wheel drives	Visiting for tourism, research, and educational purposes
11	Kuala Muda Geohazards	05°35'10.71" N and 100°20'23.55" E	All means of transportation	Visiting for tourism, research, and educational purposes

## 2. Evolution of Coastal Landscapes Geosite

The Tsumani disaster on 2004 (Rossetto et al., 2007; Ramalanjaona, 2011; Moon et al., 2022), struck by a volcanic eruption in the Indian Ocean with a magnitude of 9.0 on the Richter scale, has caused waves with a height of more than 10 meters. The wave has affected 13 countries, especially in Indonesia, Thailand, Myanmar, Bangladesh, India, Somalia, Sri Lanka, Tanzania, Kenya, Yemen, Maldives, Seychelles, and Malaysia (Asmawi and Ibrahim, 2013).

In Malaysia, the states affected by the tsunami disaster are Penang, Kedah, Perak, and Selangor. The tsunami disaster also affected 13 villages in Kuala Muda, Kuala Triang, and Langkawi Island in the state of Kedah (Krishnaswamy et al., 2012; Zahari et al., 2013), leading to a change in the local landscape. In the Kuala Muda area, we built a museum and tsunami memorial (Figure 9) to commemorate the incident, which now serves as a geosite for cultural tourism.



Figure 9. The Kuala Muda Tsunami gallery (a), exhibition space (b) and memorial (c) as a cultural geosites at Kuala Muda district (Source: authors based on data from Mohd Nor et al., 2019)

## 3. The evolution of Mount Jerai Geosite

Jerai's Mount evolution lists three geosites: the former Gurun quarry, Padang Tok Syeikh quartzite, and Penjara Hill

Red Mudstone. The fracture of granite into the rock sequence of the Jerai Formation has metamorphosed the rock structures of the former Gurun quarry into hornfels. This Gurun Quarry clearly reveals the structure of quartzite, granulite, and grit interspersed with argillite facies. Padang Tok Syekh quartzite represents the lower (oldest) part of the Jerai Formation, revealing thin layers of fine-grained quartzite as well as trace fossils that represent deeper marine life.

*Dictyodora* sp., one of the most notable fossils found in this area, is associated with the Machinchang Formation in Langkawi. The Penjara Hill Red mudstone reveals the geological features, which are 480 million years old and the only clastic rock of the Mahang Formation to date (Ali et al., 2019). The deep sea environment has deposited these massive red mud rocks, as evidenced by the discovery of graptolite fossils found there. The high content of iron oxide in the mudstone, which contributes to its red color, further explains the site's uniqueness. The tourism sector of Kuala Muda district has selected the area as a geosite due to its high scientific value for educational and research purposes (Figure 10).

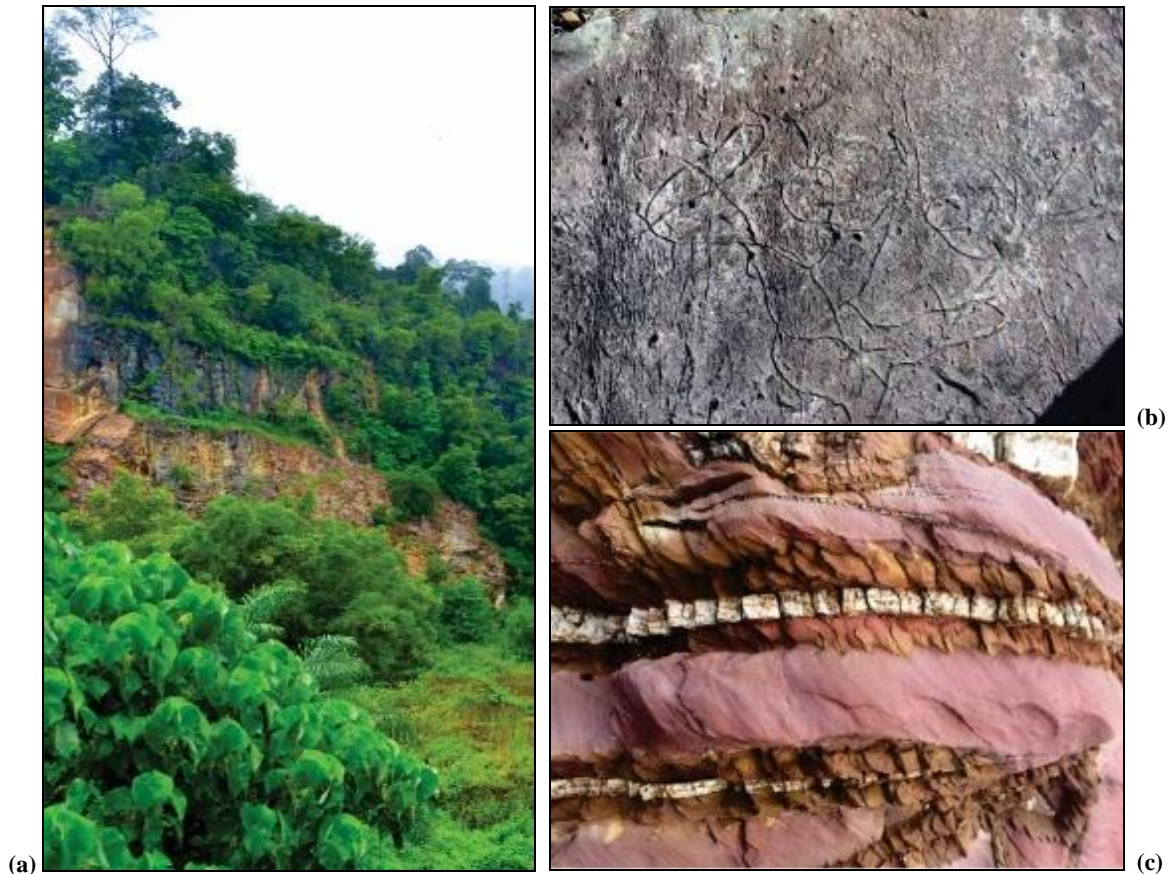


Figure 10. Gurun quarry (a) Padang Tok Syekh quartzite with fossil traces (b) and Penjara Hill red mudstone which highlights the geological uniqueness of the area which is used as a tourism product of Kuala Muda (Source: authors based on data from Ali et al., 2019)

#### 4. Late Magmatic Phase and Metamorphism Geosites

Three geosites were selected to represent the late magmatic phase and metamorphism of Kuala Muda tourism products, namely Hornfels Jerai Badak and Kunyit River, Aplit and Aplo Pegmatit Jerai Sungai Batu Pahat, and Besta Gold Mine Mineralization Zone, Tupah. The hornfels of the Badak and Kunyit Rivers are formed as a result of the heat carried by the magma having erupted into empty cavities, causing the surrounding wall rocks to turn into tactile metamorphisms. Wave ripples, which indicate sediment formation in the Jerai Formation, have occurred in the shallow marine environment. Trace fossil finds were also recorded in this area, which showed the high potential of this area to be developed as a geosite. In addition, the pegmatite of Jerai Sungai Batu Pahat has revealed three sets of dykes and pegmatite veins on the granite rock slate outcrop. The geosite also recorded the discovery of very large pegmatite minerals in this area, such as feldspar, tourmaline, and muscovite. The Besta Gold mine site in Tupah, on the other hand, revealed the occurrence of a mineralization process due to the ingress of magma during the granite fracture that occurred in this area. While conducting survey activities, the area also recorded the discovery of two exotic iron ores such as muscovite, garnets, and coarse-sized tourmaline with perfect crystal shapes (Ali et al., 2019).

The validity of the facts supports the use of the area (Figure 11) as a geosite in the Kuala Muda district.

#### 5. Landscape Evolution Geosite

The geosite classifications in the Kuala Muda district include the Padang Tok Syekh Cliff Zone, the Estuary Merbok River, Baki Island-Sayak Island, and the former Semeling and Tok Pawang Tin Mines (Figure 12).

On top of Jerai Mount, there is also a Padang Tok Syekh Cliff Zone, located a top Jerai Mount, is the result of fault displacement between hard rock (metquartzite) and soft rock (meta-argillite).



Figure 11. The geosites of Badak and Kunyit River (a), pegmetite Jerai Sungai Batu Pahat (b), and the Besta Gold Mine Mineralization Zone, Tupah (c) reveal the characteristics of late magmatic phase and contact metamorphism in Kuala Muda district (Source: authors based on data from Ali et al., 2019)



Figure 12. Padang Tok Syekh Cliff Zone (a), Estuary Merbok River (b), the former Semeling and Tok Pawang Tin Mines (c), and Baki and Sayak Island (d) are the geosites of Kuala Muda district for the landscape evolution category geosites (Source: authors based on data from Ali et al., 2019)

This displacement leads to soft rock erosion, leaving the hard rock in the foot block as Estuary Merbok River is a geosite with a beautiful view, particularly at the mouth of the Merbok River, a tidal estuary that used to be a large bay. Because it serves as an estuary, it is able to accommodate the diversity of mangrove swamp species that thrive in this area. In fact, the Merbok River estuary also serves as a route and gateway for merchant ships to the ancient port of ancient Kedah Kingdom, further emphasizing the significance of this geosite.

Sea erosion on the 450 million-year-old Fomasi Mahang rocks formed the remaining Baki-Sayak Island geosite. Due to its remnant evidence of marine geological processes directly related to Holocene sea level changes, it holds high scientific value (Burton, 1967; Bradford, 1972; Ali et al., 2019; Ali, 2022). The geosite of the former Semeling and Tok Pawang tin mines is an area of active mining sites from 1946 to 1964.

This area's main mining products are garnet, molybdenite, struverite, ilmenorute, and minerals like columbite-tantalite and cassiterite, which come from eroded pegmatite and are found in alluvial sediments. These minerals show the variety of minerals that have built up in an area. Due to the academic value of the geosite, which has an impact on the world, the geology-based tourism sector empowerment program is intensifying in the Kuala Muda district area. To meet these needs, the Minister of Energy and Natural Resources, Dato Dr. Shamsul Anuar Nasarah, has allocated a total of RM 0.5 million to upgrade the Jerai Geopark Gallery at the Wan Mat Saman Gallery and another RM 0.5 million to upgrade the Forestry Museum at Gunung Jerai (Anynamous, 2020) to strengthen the geopark tourism sector.

Pakej Package	HARGA PAKEJ / Package Price	
	Dewasa / Adult	Pelajar / Student
Pakej 1 Package	RM20 /	RM10
Pakej 2 Package	RM100 /	RM50
Pakej 3 Package	RM130 /	RM80
Pakej 4 Package	RM90 /	RM60
Pakej 5 Package	RM160 /	RM95
Pakej 6 Package	RM90 /	RM60
Pakej 7 Package	RM160 /	RM95
Pakej 8 Package	RM110 /	RM70
Pakej 9 Package	RM190 /	RM110
Pakej 10 Package	RM80 /	RM55
Pakej 11 Package	RM150 /	RM90
Pakej 12 Package	RM180 /	RM105
Pakej 13 Package	RM350 /	RM310
Pakej 14 Package	RM130 /	RM80
Pakej 15 Package	RM210 /	RM120
Pakej 16 Package	RM170 /	RM100
Pakej 17 Package	RM50 /	RM40

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**Pakej Arkeo Pelancongan**  
**Archaeotourism Package**

Persatuan Ancked Sungai Batu

Figure 13. The AncKed Sungai Batu Association has created a brochure list of tour packages that emphasize visits to geological sites (Source: AncKed Sungai Batu Association, 2024)

## 6. Tourism Packages

As the geological evidence of Kuala Muda district reveals its specialty, the AncKed Sungai Batu Association has offered 15 tour packages that combine geological, geoarchaeological, biological, historical, and cultural tourism sites (Figure 13). Of the total of 17 tour packages, six focused on visiting geological tourism sites in Kuala Muda District (Table 3). This enables tourists to learn about the history of Kuala Muda Earth's formation during their visit.

Through the provided tour guide services, the created tour packages enable tourists to gain comprehensive information about the areas they visit. This implies that a guided tour package only includes a visit to the selected travel site, as specified in the package. The description of the study data for each site is discussed comprehensively to reveal the uniqueness of the Kuala Muda district since 550 million years ago until now. In addition to guided tours to selected tourist sites, the complete package includes demonstrations and hands-on activities, particularly at SBAC. Among the activities created are iron smelting demonstrations, hands-on excavations, and ancient brick making (Figure 14), which are able to provide a clearer picture and understanding of tourism based on the participating activities carried out.



Figure 14. The full package activities include a site visit (a), an iron smelting demonstration (b), hands-on ancient brick making, (c), and excavation (d) (Source: Sungai Batu Archaeological Complex, 2024)

Table 3. Tour packages managed by the AncKed Sungai Batu Association (Source: authors)

Packages	Locations	Classification
1	Sungai Batu Archaeological Complex [SBAC] (geoarchaeology)	Tour package
2	SBAC (geoarchaeology)	Full package
3	SBAC + Gallery Archaeology Guar Kepah (geoarchaeology)	Tour package
4	SBAC + Bujang Valley Archaeological Museum + Bukit Batu Pahat Archaeological Complex (geoarchaeology) + Pegmetite Jerai (geology)	Tour package
5	SBAC + Bujang Valley Archaeological Museum + Bukit Batu Pahat Archaeological Complex (geoarchaeology) + Pegmetite Jerai (geology)	Full package
6	SBAC + Pengkalan Bujang Archaeological Complex (geoarchaeology)	Tour package
7	SBAC + Pengkalan Bujang Archaeological Complex (geoarchaeology)	Full package
8	SBAC + Bujang Valley Archaeological Museum + Bukit Batu Pahat Archaeological Complex (geoarchaeology) + Pegmetite Jerai (geology) + Pengkalan Bujang Archaeological Complex (geoarchaeology)	Tour package
9	SBAC + Jeniang Archaeological Site (geoarchaeology)	Full package
10	SBAC (geoarchaeology) + Kedah Tua Interpretation Center	Tour package
11	SBAC (geoarchaeology) + Kedah Tua Interpretation Center	Full package
12	SBAC (geoarchaeology) + Kedah Tua Interpretation Center + Singkir Laut (geology) + Tanjung Dawai (culture) + Pillbox Sungai Muda (history)	Full package
13	SBAC (geoarchaeology) + Padang Tok Syeikh + Jerai Peak (geology)	Full package
14	SBAC (geoarchaeology) + Kedah Tua Interpretation Center + Pengkalan Kakap Mosque (history)	Full package
15	SBAC + Kuala Muda Fort (geoarchaeology) + Whisper Market + Tsunami Gallery (culture) + Merdeka Beach (geology, geoarchaeology)	Full package
16	SBAC + Pengkalan Bujang Archaeological Complex + Bujang Valley Archaeological Museum	Full package
17	Living culture gallery at SBAC (iron smelting demonstration, hands-on excavation and ancient brick making)	Living culture gallery package

## DISCUSSION

Research from the past has demonstrated that the Kuala Muda district boasts unique geological, biological, geoarchaeological, cultural, historical, and other tourism sites that can serve as a profitable tourism product. The survey also revealed that every geosites remains intact, equipped with an information panel that provides essential details about the tourist destination. Additionally, the presence of roads facilitates easy access, and the tourist location boasts a variety of basic amenities like restaurants, restrooms, mosques, surau, pharmacies, and clinics.

The completion of this development aligns with the global availability of tourism facilities, as it will significantly enhance the tourism industry (Rojas and Huete-Alcoer, 2021; Pengemanan et al., 2022).

Generally, tourism development serves as a "super capital," capable of bringing about change and demonstrating mutual dependence with the country, state, district, or local area (Ibrahim et al., 2013). This is because in tourism development, the availability of tourist attractions such as tourist places that have good network and coverage characteristics, such as the availability of transportation service networks (Tajidin and Abd Rahman, 2021), accommodation (Roosli and Jusoh, 2017), culinary (Mapjabil et al., 2020), and so on, in addition to the availability of internet coverage and telephone lines, especially in the area of biological tourism sites, allows a tourist area to grow. The diversity of tourism site offerings, such as geoarchaeology, geology, and biology of mangroves and Jerai mountain forests, which are accessible through transportation logistics and route tracks, is an attractive feature to expand tourist destinations.

Moreover, organized tourism marketing has the potential to enhance the tourism industry. Various parties initiated and executed the tourism marketing work. They all aim to enhance the existing tourist sites in the district. Well-organized, sophisticated, and up-to-date marketing methods can provide or highlight the unique identity and uniqueness of an area, making it a desirable destination (Svajdova et al., 2019; Marios, 2021). This is because well-targeted tourism promotion helps the local economy grow and increases awareness of a destination's appeal (Vitalisova et al., 2017).

This is due to the fact that marketing places in a quality, planned, and structured manner can specifically target tourist destinations (Azhar et al., 2019), while also actively contributing to regional and rural development (Maheshwari et al., 2011). Particularly in the Kuala Muda district, the identification of the geological formation's peculiarities led to the serious creation of tour packages. Travel agencies, professionals, press conferences, documentaries, tourism festivals and events, and the internet all played a regular role in planning and executing the effective promotional channels for tourism.

The tourism promotion movement effectively disseminated information about tourist destinations in the Kuala Muda district, paving the way for increased visits. In fact, the AncKed Sungai Batu Association has played a significant role in preserving tourism in the district by providing a dynamic and focused archeotourism package that caters to the geological, geoarchaeological, historical, and cultural tourism locations within the district. The creation of archeotourism activities has provided tourists, the local community, and the current generation (students, universities, and researchers) with opportunities to learn about the Earth's formation history and its relationship to the development of early civilizations, particularly in Kedah, Malaysia. This undoubtedly fosters a strong sense of identity and cultivates a love for the homeland, thereby fostering a more dynamic next generation.

Two-way communication during tourism activities shall be ensured in order to guarantee the achievement of this goal. This enables tourists to effectively receive and comprehend information, thereby enhancing their overall tourism satisfaction. The AncKed Sungai Batu Association offers a more academic tour package that leverages the primary information from the study's results, with the researchers themselves serving as the tour guides. This is because, having been extensively trained in a particular tourist destination, a licensed tour guide will surely offer value and bring visitor's an entertaining experience (Tetik, 2016; Mustafa et al., 2021; Abdul Satar et al., 2022).

As in other parts of the world, such as Ciletuh-Palabuhanratu (Yani et al., 2021), Danxia Shan National Natural Reserve, and Geo-Park (Xu et al., 2012), accredited tour guide services are an added value to the advancement of tourist locations. Even if digital technology is applied to the geosite, as discussed by Pica et al. (2017) and Fassoulas et al. (2022), it is also the best measure to empower this geological tourism sector. Only geoarchaeological sites in Kuala Muda district have access to digital technology (Abd Halim et al., 2024), necessitating its extension to all geological, biological, historical, cultural, and other tourism sites within the district. Therefore, the continuous academic studies that facilitate the collection of primary data have paved the way for the provision of tour packages in Kuala Muda district. Furthermore, the AncKed Sungai Batu Association, which offers 15 geology, geoarchaeology, biology, history, and culture tour packages with an accredited geoguide, has boosted the development of the Kuala Muda district's tourism industry. A sustainable stakeholder approach (Pásková and Zelenka, 2018) is expected to preserve this geotourism so that it can become part of the UNESCO Global Geopark community in the future.

## CONCLUSION

Systematic academic research since 2017 has succeeded in realizing the idea of Jerai Geopark which has become one of the iconic tourism products in Kuala Muda District. Starting from 550 million years ago with a series of sedimentation, metamorphism, fission and denudation that resulted in the formation of the beautiful panorama of Kuala Muda newday. As a result, a total of 11 geosites with geological features such as i) coastal landscape Evolution, ii) Mount Jerai Evolution, iii) late magmatic phase and metamorphism and iv) landscape evolution have been mapped and elevated into geotourism products created through seven geotrail tours in the district.

To maintain this tourism then products that reveal this geological-cultural interest must be preserved. The conservation process should begin with continuous academic studies by researchers to record as much data as possible related to geosites so that appropriate control measures can be proposed and nominated as a UNESCO World Heritage Site. This is because existing research has proven that Kuala Muda is the only area in the world that is able to reveal three important evidences related to the uniqueness of geology, geoarchaeology and biology in the same area.

The Kuala Muda district has leveraged this privilege to promote the location as a tourism product, leading to the creation of 15 iconic tourism packages. All of this is done with the sole purpose of ensuring that the current generation gets useful benefits as a result of knowledgeable tourism experiences in the Kuala Muda district.

### Limitations and suggestions for future studies

The mapping of iconic tourism products in the Kuala Muda district served as the foundation for this study. The mapping records geological, geoarchaeological, and biological tourism products and byproducts, including historical, religious, agro, eco and recreational, cultural, health, education, sports, and gastronomy tourism sites. However, this study solely provides scientific proof of geological tourism spots, enabling their development as distinctive tourist destinations in the Kuala Muda district. Therefore, we suggest that future research should incorporate surveys that directly benefit all tourism locations in the Kuala Muda district, enabling their development as sustainable tourism destinations.

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