

DEVELOPMENT OF THE FOSSIL-BEARING TENGGAR CAVE AS SUSTAINABLE EDUCATIONAL TOURISM IN TULUNGAGUNG.

Mochammad Ardi Setyawan^{1a*}, I Kadek Yudiana^{2b}, Mahfud^{3b}

¹Program Pendidikan Bahasa Inggris, Universitas 17 Agustus 1945 Banyuwangi, Jalan Adi Sucipto 26 Banyuwangi

²³Program Pendidikan Sejarah, Universitas 17 Agustus 1945 Banyuwangi, Jalan Adi Sucipto 26 Banyuwangi

^a ardiraffi8830@gmail.com

^b ikadekyudiana@untag-banyuwangi.ac.id

(*) Corresponding Author

ardiraffi8830@gmail.com

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ABSTRACT

Tenggar Fossil Cave in Tulungagung Regency is one of the significant geological sites with great potential to be developed as a sustainable geotourism destination. This study aims to identify the potential of the Tenggar Fossil Cave, examine the development challenges, and formulate sustainable management strategies that can empower local communities while preserving geoheritage values. The research method employed is a descriptive qualitative approach, with data collected through literature review, field observations, and in-depth interviews with community leaders, tourism actors, and relevant stakeholders. The results indicate that Tenggar Cave contains rich geological features, such as ancient marine fossils and sedimentary layers dating back millions of years, which can be utilized as educational media for natural history and geology. However, the development of this area still faces several challenges, including limited infrastructure, suboptimal community involvement in management, and low awareness of the importance of geoheritage conservation. Therefore, multi-stakeholder collaboration and the integration of educational, conservation, and local economic empowerment programs are necessary. Geology-based edutourism such as Tenggar Cave has the potential to serve as a medium for strengthening local identity, improving environmental literacy, and promoting sustainable economic development based on regional potential.

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Introduction

Tulungagung Regency is a region rich in natural resources and geological potential, including the presence of fossil sites with high scientific value. One of the most significant sites is the Tenggar Fossil Cave, which preserves a geological heritage of ancient marine fossil-bearing rock layers that reflect the geomorphological dynamics of the southern coast of Java. Despite its scientific importance, this cave remains relatively unknown and underutilized in terms of conservation, education, and tourism. In fact, the site holds great significance for supporting geological education as well as the preservation of natural and local cultural heritage. However, the lack of integrated management, limited academic publications, and insufficient community-based development have prevented the remarkable potential of Tenggar Fossil Cave from making a tangible contribution to regional development.

Research and development that specifically examine the potential of Tenggar Fossil Cave remain very limited. Most geotourism studies in Indonesia tend to focus on already popular areas such as national geoparks or major prehistoric sites (Irawan & Sari, 2020; Dewi et al., 2021; Pratama & Susilowati, 2022). Therefore, the development of geology-based educational tourism (edutourism) with a sustainability-oriented approach at the Tenggar Fossil Cave site offers a form of novelty through the integration of scientific conservation, local community empowerment, and environmental education based on local geological resources. This approach aligns with the vision of sustainable development, which balances ecological, economic, and educational dimensions (Budhiman, 2019; Widiatmaka, 2018; Adiwibowo, 2020). Focusing on such a local site also contributes to the decentralization of educational tourism and enriches the body of knowledge in Indonesian geotourism research.

The urgency of developing Tenggar Fossil Cave as a sustainable edutourism site lies in the threats of site degradation caused by both natural and anthropogenic factors, as well as the loss of opportunities for geological education at the local level. Edutourism serves as a strategic approach to optimizing natural potential through education-based and sustainable management (Susanti et al., 2016; Putra & Damayanti, 2019; Wibowo, 2021). Without adequate conservation and educational efforts, the ancient marine fossils within the cave are at risk of damage and extinction. Meanwhile, public education through scientific tourism such as this can enhance ecological awareness among younger generations while also providing an alternative economic source for local communities (Astuti & Sulistyani, 2020; Hakim, 2014; Priyanto, 2022). Therefore, a development approach that integrates educational, conservation, and participatory aspects is urgently needed.

More broadly, the development of Tenggar Fossil Cave could contribute to strengthening environment-based education and geodiversity awareness, which are increasingly promoted through the *Merdeka Belajar* curriculum and national conservation programs. According to Haris et al. (2020), introducing geosites to students can increase interest in science and foster environmental awareness from an early age. The site also has the potential to be included within a local or national geopark scheme, which would provide legal protection and support for sustainable development (Setiawan & Faridah, 2019; Yunus et al., 2021). In this context, this research is expected to make an important contribution to geotourism literacy, ancient marine fossil conservation, and the strengthening of environmental and character education in Indonesia.

Method

This study employs a descriptive qualitative approach to provide an in-depth depiction of phenomena occurring at the Kawitan Site as a religious educational tourism destination. Data were collected through in-depth interviews with site custodians, Perhutani officers, local community members, and visitors, as well as direct observation at the research location. The instruments used included semi-structured interview guidelines and field notes, which allowed flexibility in exploring information.

The informants in this study included the Village Head, managers of the Tenggar Fossil Cave Site, members of the Tourism Awareness Group, local community members, and visitors to the Tenggar Fossil Cave. The data analysis process was conducted using thematic analysis techniques, in which the collected data were grouped into themes that emerged naturally from interview transcripts and observation results (Heriyanto, 2018).

To ensure data validity, triangulation was applied by comparing information from various sources and different data collection techniques (Nurfajriani et al., 2024). In addition, this study also employed SWOT analysis through the

formulation of internal and external factor analysis (IFAS and EFAS) to identify strengths, weaknesses, opportunities, and threats (I. G. N. A. B. Putra, 2019) at the Kawitan Site. The IFAS and EFAS matrices were used to assess factors influencing the potential of the Kawitan Site as a religious educational tourism destination, not with the objective of directly developing educational tourism, but rather focusing on mapping potential and identifying supporting and inhibiting factors for its development.

Result and Discussion

Overview of the Tenggar Fossil Cave

The geosite is located in Tenggarejo Village, Tanggunggunung District, Tulungagung Regency. It possesses outstanding geological components, namely limestone rocks that have undergone diagenesis and are part of the Campurdarat Formation, which dates back to the Early Miocene. Tenggar Cave is characterized by an active underground river system, with endokarst features such as stalactites and stalagmites well developed (Putri et al., 2020; Raharja et al., 2019). This cave is not merely a natural landform, but also a geological archive that records traces of past life and geological processes that have shaped the region over millions of years (Kusumayudha et al., 2020). The geosite potential of the Tenggar Fossil Cave lies in its unique morphology, endokarst features, and fossil content, making it a distinctive attraction for the development of geo-ecological tourism (Kusumayudha et al., 2020). Furthermore, the existence of this cave has the potential to enhance the local community's economy.

The Tenggar Fossil Cave has high scientific value because various types of well-preserved fossils have been discovered within it (Winarno et al., 2019). These fossils provide important information about the types of organisms that once lived in this region, past environmental conditions, and climate changes that have occurred over millions of years (Abdullah et al., 2023). The uniqueness of the Tenggar Fossil Cave lies in the combination of beautiful karst formations and rare fossils of high scientific value, making it a unique and important geological site that must be preserved (Ansori et al., 2021). To maintain the sustainability of the Tenggar Fossil Cave, conservation efforts involving multiple stakeholders are required, including local government, local communities, academics, and environmental organizations. These conservation efforts include cave mapping and inventory activities, controlling visitor access, preventing littering and vandalism, and providing education and outreach to the public regarding the importance of preserving the cave and the fossils within it.

The Tenggar Fossil Cave has significant potential as a geosite due to the combination of its geological, paleontological, and ecological values. Geologically, the cave demonstrates complex karst formation processes, with stalactites, stalagmites, flowstone, and pillars decorating its interior. These formations were created by the deposition of calcium carbonate from solution over thousands of years, forming a spectacular subterranean landscape. The presence of fossils within the cave provides direct evidence of past life, including types of fauna that once inhabited the region (Kusumayudha et al., 2021). Petrographic analysis of rocks surrounding the Tenggar Fossil Cave can provide insights into the ancient depositional environment and the tectonic history of the region (Syahputra et al., 2018).

Based on previous research conducted at the Tenggar Fossil Cave, several important fossils have been identified, including:

1. Planktonic foraminifera, such as *Globorotalia menardi* (d'Orbigny), *Sphaerodinella subdehiscenes* (Parker and Jones), *Globorotalia praemenardii* (Cushman and Stainforth), *Globorotalia fohsi* (Cushman and Ellisor), and *Orbulina suturalis* Brönnimann;
2. Benthic foraminifera, such as *Pyrgo depressa* (d'Orbigny), *Planodiscorbis rarescens* (Brady), *Quinqueloculina bicornis* (Walker and Jacob), *Pyrgo denticulata* (Brady), and *Quinqueloculina seminulum* (Linnaeus), found in carbonate rocks and slightly sandy limestone (packstone-grainstone);
3. Vertebrate fossils, including buffalo skulls and possible human remains.

In addition, based on interviews conducted, numerous fossilized seeds and fruits were also found within the cave.

Potential of the Tenggar Fossil Cave

a. Scientific Potential

The Tenggar Fossil Cave geosite in Tulungagung Regency represents one of the important geological assets in the southern coastal region of East Java. The cave preserves layers of ancient marine sedimentary rocks containing various types of fossils, such as mollusks, corals, and foraminifera, which serve as evidence of past tropical shallow marine life. These fossils are well preserved within limestone and calcareous sandstone, providing a clear depiction of tropical marine ecosystems during the Miocene period (Hall & Nichols, 2002; Setyawan et al., 2020). The presence of in situ fossils gives the site high scientific value and functions as a geo-historical record of marine environmental development over millions of years.

b. Geological Potential

From a geological perspective, the Tenggar Fossil Cave displays reef limestone formations and quartz sandstone that were formed as a result of active tectonic uplift caused by the interaction between the Indo-Australian Plate and the Eurasian Plate in the southern Java zone. This process led to the exposure of shallow marine layers onto the land surface, which can now be directly studied (van Bemmelen, 1970; Suroño & Gafoer, 1992). The stratigraphy of the cave contains important information regarding the geodynamic history of southern Java, including cycles of sedimentation, uplift, and erosion, making this geosite highly suitable for field-based geological learning.

Field observations indicate that the Tenggar Fossil Cave possesses unique and intriguing geological characteristics. The rock formations surrounding the cave are dominated by limestone formed during the Miocene period, approximately 23 to 5 million years ago. This limestone has a coarse and porous texture, making it susceptible to dissolution by acidic water. The dissolution process has created various karst features within the cave, such as stalactites, stalagmites, pillars, and flowstone. The presence of fossils in the Tenggar Fossil Cave indicates that this region was once an environment rich in life.

The fossils found in the cave include mollusks, foraminifera, and small vertebrates. These fossils provide important information about past environmental conditions, such as water temperature, salinity, and sea depth. Further analysis of these fossils can offer a clearer understanding of the evolutionary history of life in the Tulungagung region and its surroundings. The Tenggar Fossil Cave holds great potential as a natural laboratory for studying geological processes in karst environments.

Moreover, the cave can serve as a site for training and education for students and researchers interested in geology, paleontology, and archaeology. Sustainable utilization of the geological potential of the Tenggar Fossil Cave is expected to contribute to the development of science, tourism, and the local economy (Putra et al., 2023). The development of tourism-related products is also necessary to strengthen the growth of this sector (Bian et al., 2022).

c. Paleontological Potential

The Tenggar Fossil Cave possesses significant paleontological potential, making it a valuable source of information about ancient life in the region. The fossils discovered in the cave include various organisms, ranging from marine invertebrates such as mollusks and foraminifera to terrestrial vertebrates such as small mammals and reptiles (Saul et al., 2022). The existence of these fossils provides concrete evidence of past biodiversity in the Tulungagung region and offers insights into environmental and climatic changes that occurred over millions of years.

Analysis of these fossils can reveal important information about the age, morphology, and phylogeny of ancient organisms, as well as help reconstruct the ecosystems and environments in which they lived. In addition, paleontological studies can provide insights into evolutionary processes and organismal adaptation to environmental changes. The paleontological potential of the Tenggar Fossil Cave is not limited to scientific value alone, but also has high educational and conservation value.

By developing the cave as a center for paleontological research and education, public awareness of the importance of preserving natural and historical heritage can be enhanced. To optimize this potential, sustainable conservation and management efforts are required, including the protection of fossil sites, development of research infrastructure, and capacity building in the field of paleontology.

d. Natural Tourism and Geotourism Potential

The potential for natural tourism and geotourism at this site is substantial. The uniqueness of the cave's morphology, the presence of naturally embedded fossils, and the exotic and tranquil atmosphere make the area attractive to nature enthusiasts and students. The development of conservation-based geotourism at this site will strengthen the educational and sustainable tourism sector (Dowling & Newsome, 2010; Harahap et al., 2021). Through an interpretative approach and local community involvement, the cave can serve as a model geotourism destination that integrates educational, economic, and ecological values.

The Tenggar Fossil Cave offers a unique and attractive tourism experience, combining the natural beauty of the cave with its historical and scientific significance. The presence of stalactites, stalagmites, and other karst formations creates a spectacular underground landscape that appeals to visitors who enjoy adventure and natural scenery. In addition, the fossils found within the cave provide an educational and informative tourism experience.

Visitors can learn about the history of life on Earth and understand the geological processes that shaped the cave and its environment. The development of the Tenggar Fossil Cave as a tourism destination must be carried out carefully and sustainably, with due consideration for conservation and environmental preservation.

e. Educational Potential

In the field of education, the Tenggar Fossil Cave has the potential to function as an open natural laboratory for students, university learners, and researchers. Exposed rock structures and fossils provide irreplaceable opportunities for empirical learning. The study of geology, paleontology, and environmental science can be conducted directly, contextually, and meaningfully (Sulastriono et al., 2018; Leman et al., 2007). Furthermore, this geosite can also be used for conservation training and capacity building for teachers in nature-based learning approaches.

f. Humanistic and Reflective Values

The humanistic and reflective values of this geosite are equally significant. The silent cave that preserves traces of ancient life serves as a space for reflection on the relationship between humans, the Earth, and time. Experiencing the cave while observing fossils that are millions of years old can foster deep ecological and spiritual awareness (Nita et al., 2021; Hikmatullah et al., 2019). Through cultural and ecological interpretative approaches, this site can become a venue for character education and the preservation of local wisdom values.

g. Geopark Development Potential

Strategically, the Tenggar Fossil Cave has considerable potential to serve as a supporting site for the Tulungagung Geopark. The presence of marine fossils, unique rock formations, and comprehensive geological narratives can strengthen the diversity of geosites required for geopark development. The role of this geosite as a supporting site will contribute to the expansion of networks of educational, conservation, and sustainable tourism sites within the geopark area (Ruban, 2010; Kusumah & Haris, 2020). By strengthening geodiversity narratives and integrating community-based management, the Tenggar Fossil Cave can support the positioning and development of the Tulungagung Geopark.

Challenges in Developing Educational Tourism at the Tenggar Fossil Cave

Based on field observations, one of the main challenges in developing educational tourism at the Tenggar Fossil Cave is the inadequacy of infrastructure conditions. Access roads to the site remain narrow and partially unpaved, making it difficult for visitors, particularly educational groups such as students and university learners, to reach the location. Basic facilities such as information boards, safe trekking paths, public toilets, and geological information centers are also not yet available in a representative manner. This situation contradicts the principles of educational tourism, which require comfort and safety for visitors during field-based learning activities.

These observations are consistent with the statement of Mr. Adi (Head of the Tourism Awareness Group), who emphasized that developing the Tenggar Fossil Cave as sustainable educational tourism is indeed appropriate, but many aspects still require attention, including site development and maintenance, supporting facilities and infrastructure, and inadequate access to the location. Furthermore, an equally important issue is how to ensure the sustainability of the site as an educational tourism destination without damaging the fossils and the natural integrity of the Tenggar Fossil Cave.

The development of educational tourism areas requires active collaboration among local government, academics, local communities, and tourism industry stakeholders. However, to date, such synergy remains partial and has not been institutionalized. The government has not yet positioned this site as a priority geotourism destination, while academic institutions remain limited in conducting research and providing assistance. According to Pramudji (2006), the success of educational tourism is strongly influenced by the participation of multiple stakeholders who complement each other in managing tourism areas.

Based on interviews with the village head and members of the Tourism Awareness Group, it was revealed that tourism management at the Tenggar Fossil Cave has so far been carried out independently, without collaboration with relevant parties such as the tourism office, local government, or private sector. Meanwhile, because the location of the Tenggar Fossil Cave is within the Perhutani area, some facilities and infrastructure have been supported by Perhutani, but these remain very limited. Currently, visits to the Tenggar Fossil Cave are still largely restricted to scientific activities such as research.

Another significant challenge is the low level of public literacy or knowledge regarding the Tenggar Fossil Cave. Educational tourism based on geoheritage, such as the Tenggar Fossil Cave, requires public understanding of the importance of geodiversity conservation. Unfortunately, geological literacy among local communities and visitors remains relatively low. Many residents do not yet understand the significance of marine fossils embedded in the cave walls, making them vulnerable to destructive actions, whether intentional or unintentional. In this context, conservation education becomes an urgent necessity to ensure that the educational value of the site is preserved (Reynard, 2009; Hose, 2012).

The development of tourism areas without long-term conservation-based planning can instead lead to negative impacts such as site degradation, environmental exploitation, and uncontrolled commercialization. To date, there is no official planning document (master plan) that regulates governance, zoning, promotional strategies, and educational approaches at the Tenggar Fossil Cave site. Meanwhile, UNESCO Global Geoparks emphasize the importance of management based on strategic planning documents to ensure that geological heritage can be utilized sustainably (UNESCO, 2016). This is in line with the statement of Mr. Arief (Head of the Tourism Awareness Group), who stated that there is no clear development plan from stakeholders, either from local government or Perhutani. So far, local residents under the Tourism Awareness Group have acted independently, meaning that development has been limited to the community's capacity. Therefore, future development requires a clear long-term master plan so that it not only impacts local communities but also contributes to regional government revenue. This is highly feasible considering the exceptional and unique potential of the Tenggar Fossil Cave in East Java.

Ideally, educational tourism should generate positive economic impacts for local communities. However, in reality, communities around the Tenggar Cave have not been actively involved as tourism actors, whether as local guides, service providers, or managers of tourism-based micro, small, and medium enterprises (MSMEs). Without inclusive community participation, the benefits of educational tourism will be enjoyed primarily by external parties, while local communities remain spectators in their own region (Fayos-Solà et al., 2014). Therefore, strengthening capacity and empowering the local economy become both a challenge and an opportunity.

CONCLUSION

Conclusions

The Tenggar Fossil Cave is not merely a silent space filled with rocks and ancient layers of soil. It is a silent witness to thousands to millions of years of Earth's history, preserved in ancient marine fossils that record environmental, geological, and biological changes over time. Its scientific potential is immense, not only for researchers in geology and paleontology but also as an open learning space for younger generations to understand the geological heritage of the Indonesian archipelago, which is often overlooked. More than a physical site, this geosite carries an existential message: that humans are part of the Earth's long history, which must be preserved and meaningfully understood.

The Tenggar Cave also reflects a paradox of development: extraordinary natural wealth has not been matched by adequate attention and protection from society and government. Challenges such as inadequate supporting infrastructure, limited access to information, and minimal involvement of local communities in management indicate that current development approaches have not fully aligned with educational, ecological, and humanistic values. This situation risks allowing the site to be eroded by time and neglect, even though it has the potential to become a center of learning, a scientific tourism destination, and a driver of culture- and environment-based economic development.

Within the framework of sustainable development, the Tenggar Fossil Cave offers strategic opportunities to integrate scientific knowledge, tourism, and the preservation of local cultural heritage. Educational tourism is not merely about attracting visitors, but about creating a space for dialogue between humans and nature, between knowledge and empathy. Efforts to develop this site must involve multiple stakeholders—academics, communities, local government, and tourism actors—within an equitable collaborative framework. Data-driven planning, public education on the significance of geosites, and community empowerment strategies that position local residents as subjects rather than objects of development are essential.

If managed with a sustainability-oriented vision, the Tenggar Fossil Cave can evolve into a natural laboratory, a contemplative space, and a new economic resource rooted in local wisdom. This represents a critical momentum for Tulungagung not only to preserve the past embedded in rock formations but also to build a future grounded in knowledge, conservation, and humanity.

Recommendations

The recommendations derived from this study are as follows:

1. Local governments, in collaboration with higher education institutions and independent researchers, should conduct a comprehensive inventory of geological and fossil resources in the Tenggar Cave. Such scientific studies will serve as a foundation for designing data-driven educational tourism programs while preventing exploitation and misuse of the site by irresponsible parties.
2. Facilities and infrastructure such as interpretive trails, educational signage, resting areas, and access roads to the site should be developed while maintaining the sustainability of the surrounding ecosystem. The application of low-impact development principles is crucial to ensure that visitor comfort does not compromise environmental conservation.
3. The development of the Tenggar Cave should position local communities as key partners, not merely as site guardians but also as tour guides, local entrepreneurs, and transmitters of cultural values. Continuous education and training in conservation, tourism services, and geological interpretation should be provided to enhance community capacity.
4. The Tenggar Cave can serve as a field laboratory for students, particularly in geography, history, and environmental studies. Schools in Tulungagung are encouraged to incorporate site visits into contextual learning activities so that the values of geological heritage can be instilled from an early age.
5. Synergy among local government, academics, conservation communities, the private sector, and tourism stakeholders is needed to formulate a master plan for educational tourism at the Tenggar Cave. This collaboration must be grounded in principles of ecological justice, economic sustainability, and the preservation of local cultural values to ensure that development is not merely temporary or exploitative.
6. In the digital era, it is important to promote and disseminate knowledge about the values of the Tenggar Fossil Cave through social media, documentary videos, and educational digital platforms. This approach can enhance public awareness, particularly among younger generations, regarding the importance of protecting and appreciating geological sites as a shared heritage of humanity.

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