

## Research on geological value and tourism potential of Ba The mountain, Thoai Son, An Giang

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**Abstract:** *The research area exposes geological granitic formations and Holocene sediments. The landforms these formations have left behind include mountains, stacking stones, fairy footprints, granitoid intrusions of the Deo Ca complex, and mineral compositions such as plagioclase, K-feldspar, quartz, biotite, and hornblende. The Ba The granites were formed in the subduction of the West Pacific Plate under the Indochina block in the Cretaceous period (92 Ma). The diversity of terrain and geology with unique landscapes and interesting geological heritages with scientific and aesthetic values associated with mysterious legends and myths not only attracts tourists to visit natural landscapes and spiritual tourism, but these geological values also have the potential to serve the education of earth science. Additionally, the research area is closely linked to the Oc Eo-Ba The culture, which is widely recognized for its rich, diverse cultural resources and strong national identity. Simultaneously, the Oc Eo-Ba The culture has a close relationship with tourism activities in the Mekong Delta. The geological value and culture are inseparable, interactive, and intertwined, serving as a source of natural and human resources and providing an environment for the development of various tourism types in the Mekong Delta.*

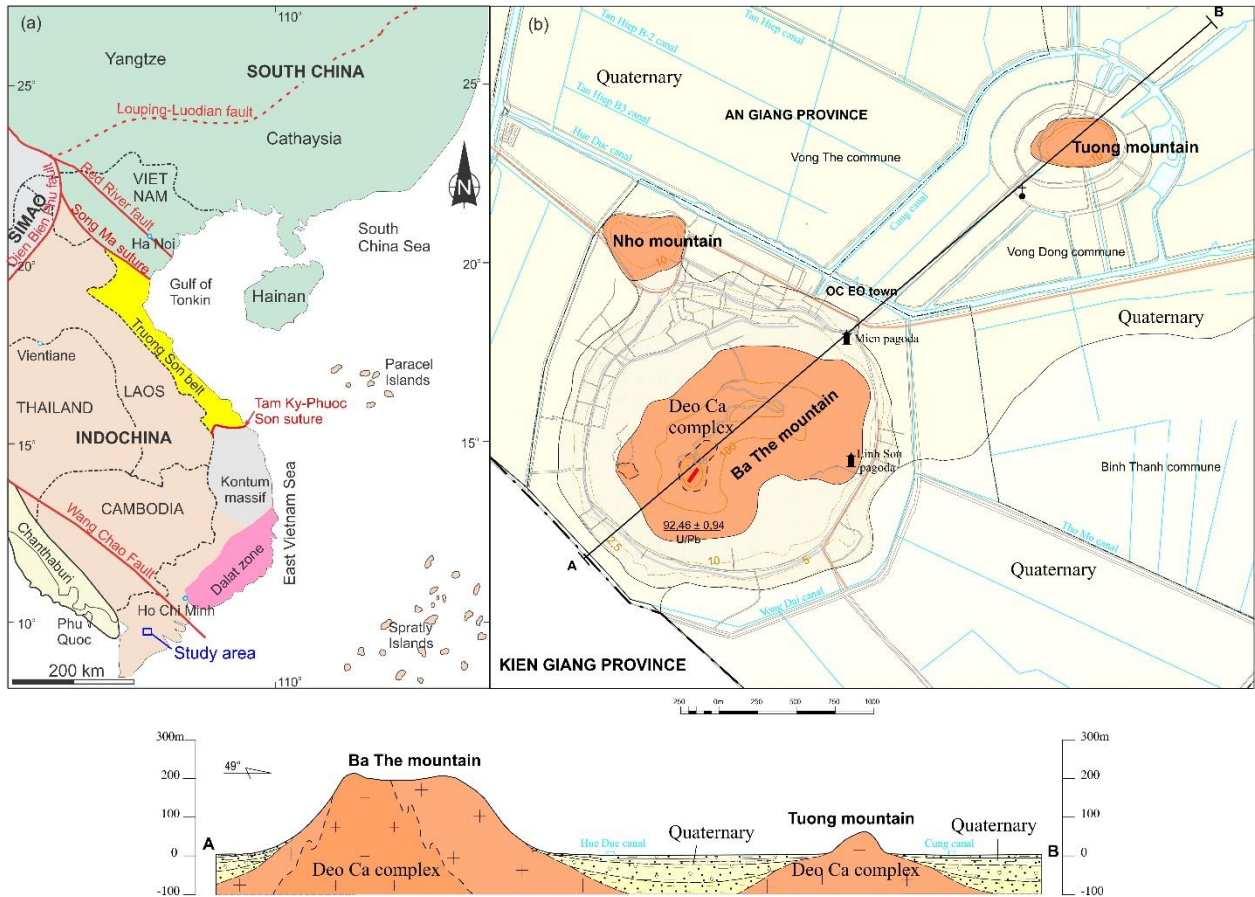
**Key words:** *Geological value; tourism; Ba The mountain; Mekong Delta*

### 1. Introduction

Vietnam possesses abundant natural resources, including tourism resources and geological heritage. Many natural heritages with outstanding geological and geomorphological values have been recognized by UNESCO as world heritage sites. Typically, the Trang An scenic complex is the first and only mixed heritage in Vietnam as well as Southeast Asia, among 38 mixed heritages recognized by UNESCO worldwide. Researchers have also studied sites like Ke Ga Cape and Phu Quy Island [1, 2]. In terms of geology and geomorphology, the Trang An scenic spots are known for their karst landscapes, which include karst cones and towers, sinkholes, basins, waterlines, flooded caves, underground rivers, and caves containing sediments, demonstrating the final stage of karst evolution in a humid tropical environment. In addition, two other world natural heritages, Phong Nha-Ke Bang National Park and Ha Long Bay, also have international geological and geomorphological significance. Ha Long Bay Heritage, with its unique karst topography, closely linked to the history of climate and tectonic movements of the Earth's crust. Ha Long Bay Heritage is a karst landscape that has been formed over millions of years. The karst towers here feature unique pyramidal and tower shapes that have been eroded, creating a unique landscape [3]. Phong Nha-Ke Bang National Park, with its limestone mountain system over 400 Ma, is the result of a long-term tectonic process. It forms a special system of caves and underground rivers with more than 300 large and small caves and a noteworthy geographical location [4]. This resource is of immense value in the conservation and socio-economic development of the region. Currently, Vietnam has three geoparks recognized by UNESCO as Global Geoparks, including the Dong Van Karst Plateau (Ha Giang), Non Nuoc Cao Bang, and Dak Nong Geoparks [5-8]. Ly Son-Sa Huynh Geopark has also submitted a dossier to UNESCO, and the two provinces of Lang Son and Phu Yen are preparing a project to establish a geopark to submit to UNESCO for recognition.

The Ba The mountain is located in Thoai Son district, An Giang province, in the Mekong Delta (Fig. 1a,b). It is one of three mountains in the area: Ba The mountain, Tuong mountain, and Nho mountain (Figs. 2, 3, and 4). It is a well-known location with numerous important national relics and places of worship, as well as the potential to grow ecotourism, spiritual tourism, and cultural-historical tourism. In addition, local people also develop orchards, handicrafts, and accommodation services to serve tourists. Thoai Son district has nine communal houses, six temples, and nationally ranked relics, such as the Thoai Ngoc Hau communal house and Thoai Son stele (Nui Sap town), Linh Son Pagoda with the four-armed Buddha statue

(Trung Son hamlet, Oc Eo town), and Oc Eo relic site [9]. The study area also has more diverse geological and topographical features than other regions in the Southwest, associated with many national-level cultural and historical relics, famous cultural and religious festivals, and mysterious legends. These national relics are located on Holocene and granitoid geological formations. However, the geological significance of the Ba The mountain area has not been specifically studied and evaluated. The analysis and evaluation of geological and topographical values in this area will contribute significantly to the development of tourism, especially geotourism, attracting more tourists to Thoai Son district at the same time, serving the conservation of geological resources.



**Fig. 1.** (a) Geological map of Indochina and (b) Geological map of Ba The mountain area, Thoai Son, An Giang



**Fig. 2.** Flycam image of Ba The mountain area, Thoai Son, An Giang and surrounding areas



**Fig. 3.** Flycam image of Tuong mountain area, Thoai Son, An Giang



**Fig. 4.** Image of Nui Nho mountain viewed from Ba The Mountain, Thoai Son, An Giang

## **2. Database and research methods**

### **2.1. Database**

This includes gathering, sorting, and putting together documents that are related to the Ba The mountain cluster area. These may comprise geological research projects as well as geological and mineral mapping projects of different sizes and stages so that the research area can be understood better. The documents used for this study include (1) Report, "Measuring and mapping geology and searching for minerals in the Southern Delta sheet group at a scale of 1:200.000," edited by [DGMVN \(1995\)](#); (2) Report "Measuring and mapping geology and searching for minerals in the Ha Tien - Phu Quoc sheet group at a scale of 1/50,000" edited by [DGMVN \(1997\)](#) and (3) Report "Planning for tourism development in An Giang until 2020, with a vision to 2030" by the Department of Culture, Sports and Tourism of An Giang province (2012).

### **2.2. Research method**

#### **a. Method of collecting and analyzing documents**

The information includes (1) natural characteristics, natural resources, and socio-economics in the area; (2) information on tourist spots/areas, including the number of visitors per year and month; (3) the current status of infrastructure and services in the area; and (4) types of tourism activities and main tourism products, such as sightseeing, religion, belief, research, relaxation, and entertainment.

#### **b. Method of inventory, assessment of geological and topographical values and quantitative analysis. Includes 3 stages**

(1) Inventory: The main purpose of this phase is to determine the quantity and format of geological areas; a survey was conducted on the Ba The mountain area underwent direct observation, recording, UAV photography, and a detailed description of the observed elements, including their morphology and the geomorphological processes that have occurred or are currently occurring. Evaluation: Evaluate the inventoried geological areas based on the following criteria: (i) scientific value (rarity of the area; observation conditions-viewpoints; illustrative ability; diversity of geological features/processes); (ii) additional value (aesthetic value; development and use; access to geological information; use of laws for protection; cultural/historical value); and (iii) site value (trails; major roads; support services; accessibility). Quantitative analysis of granitoid geological formations to find out how much granitoid rock there was: (1)

thin-section petrography; (2) XRF major elements and trace elements (ICP-MS); and (3) U-Pb zircon isotopic age for Ba The mountain. The mountain granitoid was analyzed using the LA-ICP-MS method.

### 3. Research results and discussion

#### 3.1. Geomorphological value

##### 3.1.1. Scientific value

The Ba The area, located in the centre of a large fluvial plain with five hills and mountains, has gathered many species of terrestrial flora and fauna. This is also a stable place for people to live, especially in the foothills, and on the highlands is where temples, shrines, etc. are built. The mountainous region is the origin and development of biodiversity, culture, and beliefs, and it attracts tourists who come to see, admire, and enjoy the scenery.

In terms of morphology, there are two main types of terrain: mountainous (including hills, low mountains, and mid-mountains) and plains (fluvial plains, including sandbanks, basins, and slightly inclined forms; coastal plains, including deluvial and ancient fluvial types).

In terms of origin, there are two types: denudation terrain (including flat surfaces and marine terraces of abrasive origin) and accumulation plains (including four main types of origin: river, river-sea, sea, and swamp).

The topography of the Ba The area has unique landscapes, from which people have built legends and anecdotes to determine the place name. The legend of Ba The mountain has a fairy and three wives competing to build mountains; the three wives built high mountains, which are the 3 peaks of the Ba The mountain. The fairy built low mountains, which are the Nho mountains.

Depending on the area and lithological composition of the mountain massif, during the process of uplift and erosion, it is possible to create flat surfaces of different sizes and ages. If the scale of the mountain massif is small, there will be a small flat surface, just a flat top and gentle slopes, such as Tuong mountain and Nho mountain (Figs. 3 and 4), while the flat surface of the Ba The mountain has a large area of several hundred to thousands of square meters.

The majority of historical and cultural relics, pagodas, temples, and other structures are built on high hill terrain with a solid geological foundation (Figs. 5, 6 and 7). The hillside is primarily populated by Kinh and Khmer ethnic groups. Furthermore, low terrain promotes cultural and historical biodiversity. Low-lying areas that are constantly flooded also promote biodiversity, provide green, cool landscapes, and attract ecotourists.



**Fig. 5.** Buddha statue built on granite foundation as a place of worship for people



**Fig. 6.** Granite blocks stacked on top of each other create a place of worship for local people



**Fig. 7.** Granite rocks stacked on top of each other create the cave "White Tiger General" guarding and protecting Ba The mountain, Thoai Son, An Giang

### 3.1.2. Aesthetic value

The road to the top of the Ba The mountain, 221 m high, about 2 km long, and flanked by pristine forests and tall trees, gives a cool and airy feeling. This is an ideal place for mountain climbing combined with spirituality. At the foot of the Ba The mountain in the southwest, there is also a reservoir created after exploiting landfill materials and split rocks surrounding the lake with a concrete embankment, creating a beautiful, cool, and green landscape that attracts tourists, especially young people.

### 3.1.3. Historical and cultural values

It is not only a location of exceptional natural beauty, but also a repository of a wide range of historical and cultural significance, due to its exceptional height in comparison to the surrounding terrain.

Along with other spiritual buildings, pagodas are religious symbols that show spiritual life and community faith (Fig. 8).

The Oc Eo culture, which typifies the richness and diversity of history, is preserved and developed in the mountainous area (Fig. 9). Inheritance and preservation help to sustain and develop the Oc Eo culture, providing opportunities for current and future generations to better understand their history (Fig. 10).

Furthermore, high mountains have a significant impact on security and defence.



**Fig. 8.** Linh Son Co Tu Pagoda, Ba The Mountain, An Giang



**Fig. 9.** Granite blocks stacked for construction at the Oc Eo cultural reserve



**Fig. 10.** Oc Eo Cultural Exhibition House, Ba The Mountain, An Giang

#### 3.1.4. Economic value

Forestry development-planting trees and afforestation-not only helps protect land but also creates a stable source of income for local communities, preserves biodiversity, and maintains ecological balance.

Facilitate conservation and development of flora, fauna, and ecosystems.

Urban development on high terrain, which includes residential areas and traffic routes, creates connections that facilitate trade and economic development.

#### 3.1.5. The importance of topographical values

Terrain diversity contributes significantly to cultural diversity, rich history, and religion. It also attracts the attention of scientific researchers in geomorphology, ecology, biology, archaeology, culture, history, and other fields, making it more appealing to ecotourists, geotourists, and spiritual and religious visitors.

### 3.2. Geological value

#### 3.2.1 Scientific value

In An Giang province, there are nine sedimentary and volcanic stratigraphic units and four plutonic magmatic complexes. In the early Cretaceous, the granitoid comes from the Dinh Quan complex. The granites come from the Deo Ca and Ankoet complexes in the late Cretaceous. And the mafic dyke comes from the Cu Mong complex in the Paleogene.

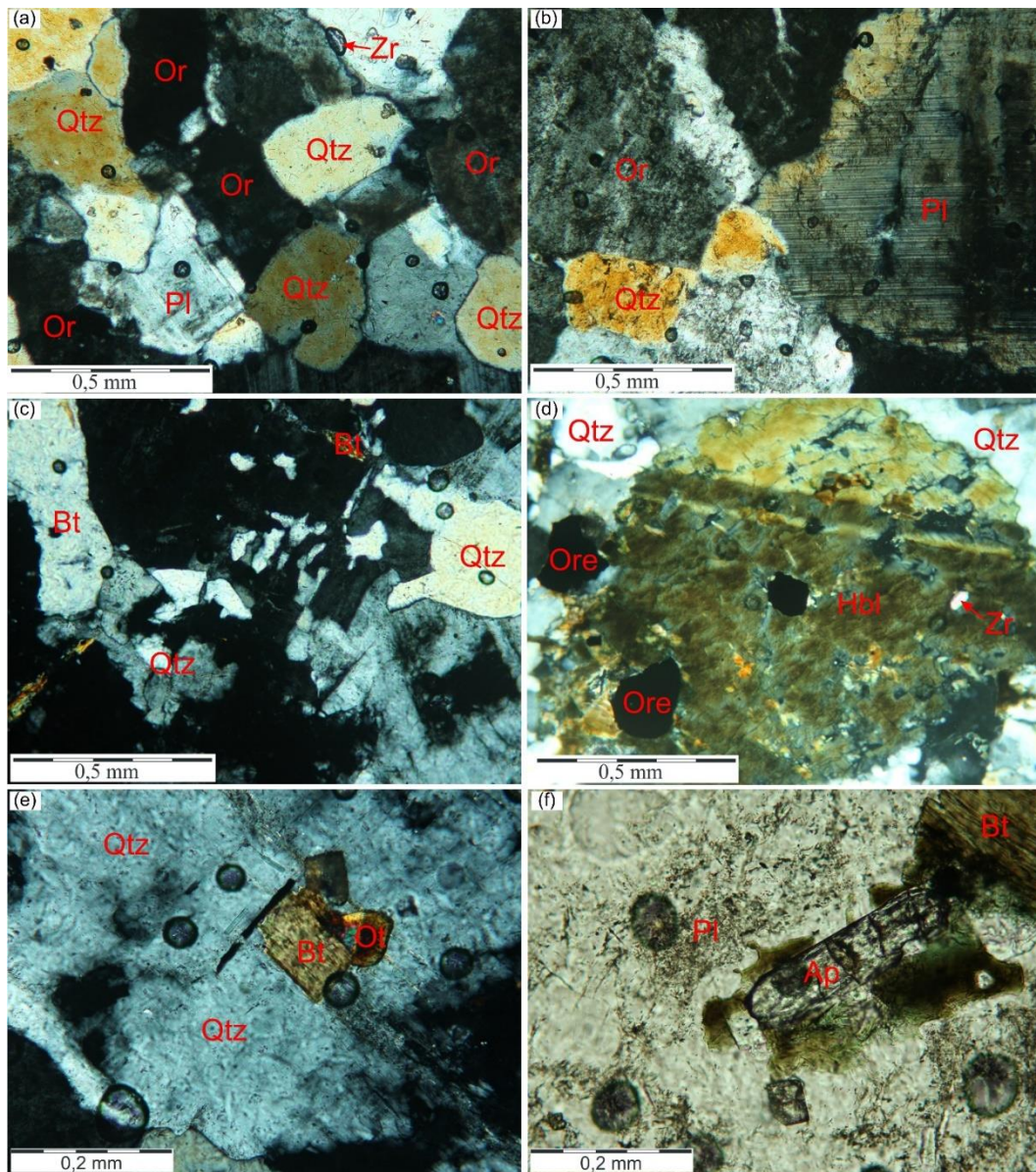
The Ba The mountain group is the Deo Ca complex, and the granite composition is homogeneous, solid, and extremely durable when exposed to the ground and affected by the weathering process (Fig. 11). Therefore, granite often creates higher mountains than other rocks.

Granite contains a mineral assemblage of plagioclase, quartz, K-feldspar, and biotite, which are typical mineral assemblages of granite (Fig. 12). It has geochemical characteristics of I-type granite and is formed from the mantle (Fig. 13a-d).

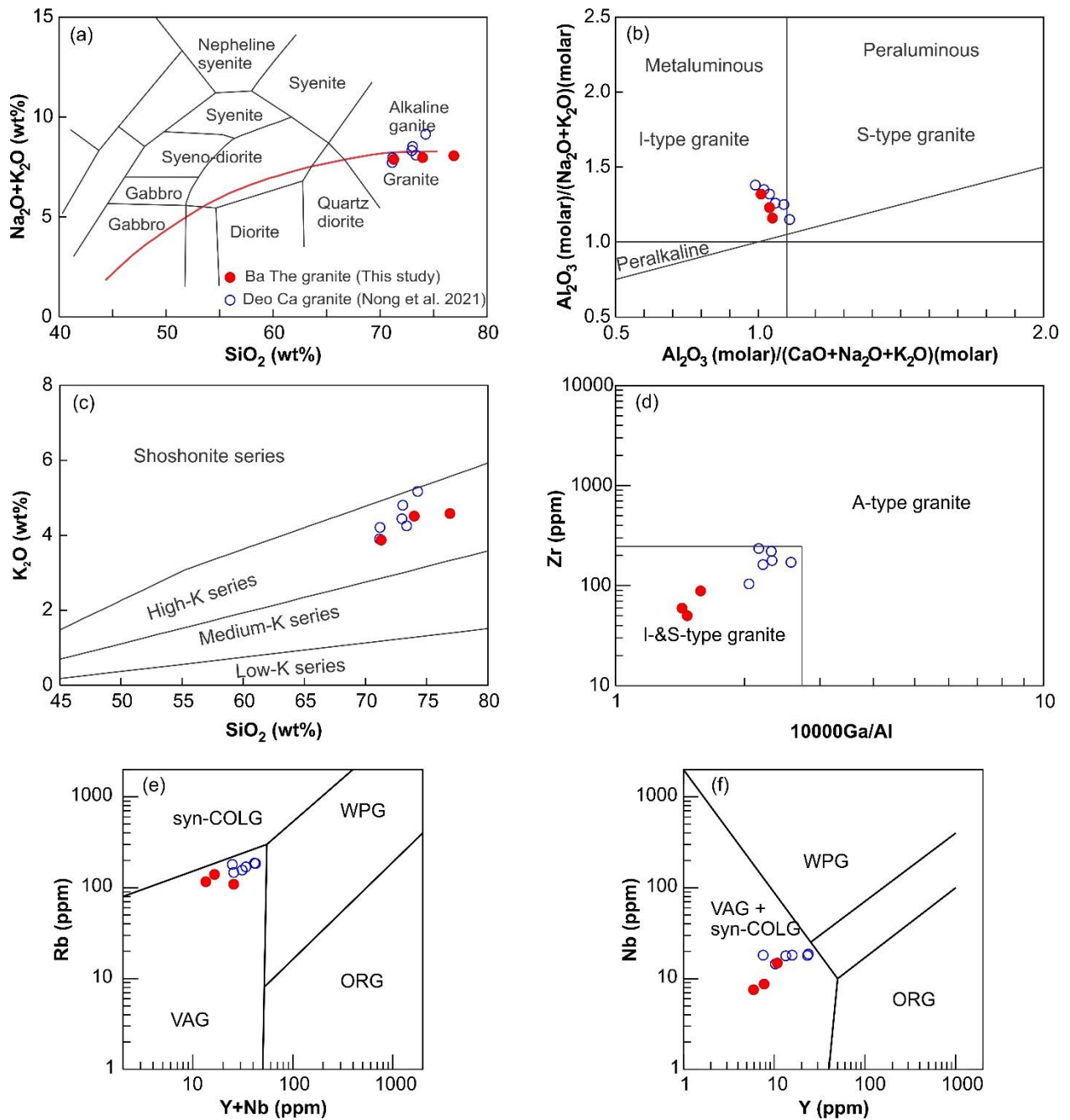
The LA-ICP-MS method determined the formation age of Ba The granite at 92 Ma (Fig. 14), which corresponds to the Early Cretaceous period. In terms of mineralogy, petrography, and origin, Andean granite formations resemble magmatic arc granite formations. These formations occurred when the oceanic crust was pushed beneath the Indochina continent during the Jurassic and Cretaceous periods (Figs. 13e,f and 15).



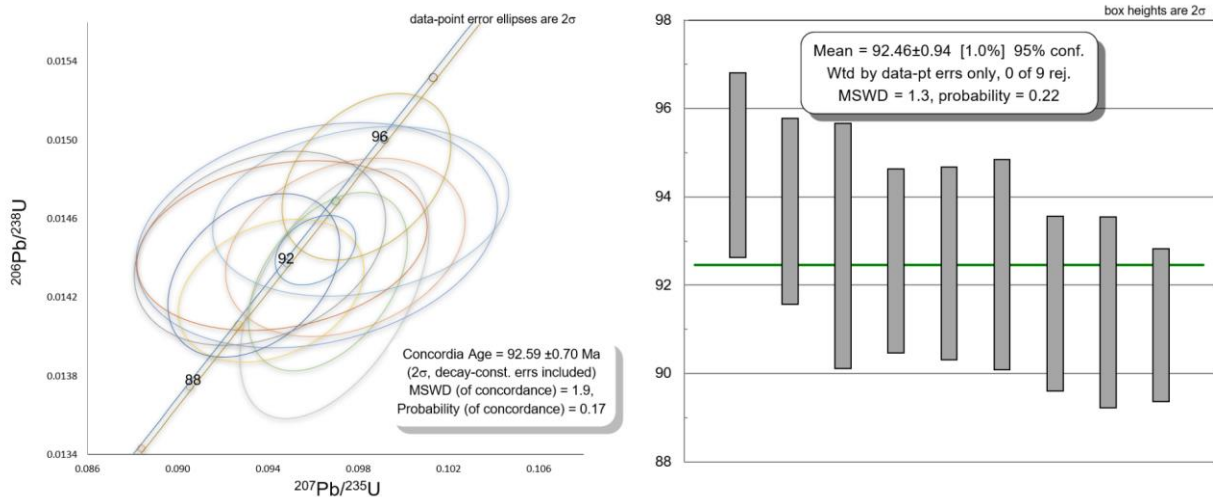
**Fig. 11.** Petrographic-mineral composition of granite from Ba The mountain as seen with the naked eye



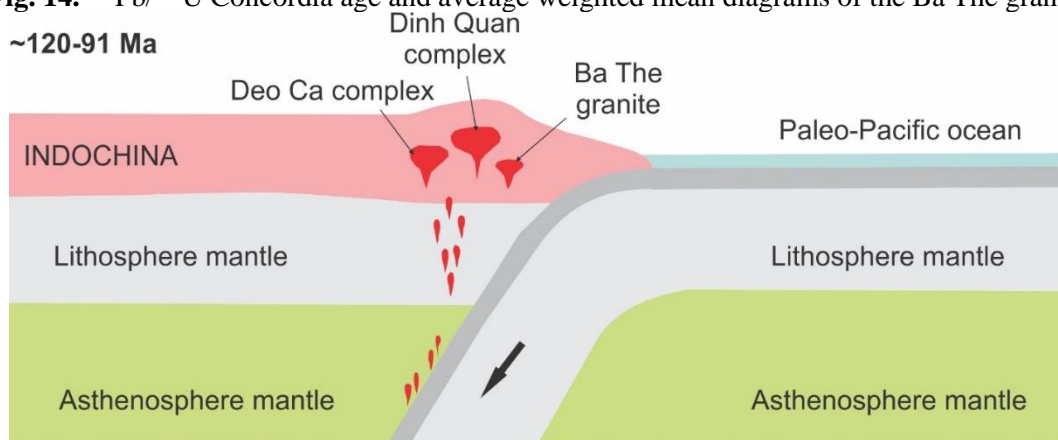
**Fig. 12.** Cross-polarized light photomicrographs of Ba The granites in southern Dalat Zone. Abbreviations of mineral names: Pl: plagioclase, Or: Orthoclase, Qtz: quartz, Hbl: Hornblende, Bt: biotite, Ap: apatite, Zr: zircon, and Ot: Orthite



**Fig. 13.** (a) Ba The magmatic classification diagram [12]; Ba The index scheme [13]; (c)  $\text{K}_2\text{O}$  versus  $\text{SiO}_2$  diagram [14]; (d) Zr versus  $10000 \times \text{Ga/Al}$  diagram [15] and (e,f) Geotectonic classification diagrams [16]. The geochemical data from Nong (2021) and this study



**Fig. 14.**  $^{206}\text{Pb}/^{238}\text{U}$  Concordia age and average weighted mean diagrams of the Ba The granite  
~120-91 Ma



**Fig. 15.** Tectonic setting model of granite formation in the Ba The mountain

### 3.2.2. Aesthetic value

Only plutonic rocks, due to their physical-chemical properties and natural weathering and erosion conditions, can produce unique shapes and patterns that increase aesthetic value, pique curiosity, and attract tourists. Furthermore, they inspire people's vivid imaginations to create exciting legends and myths.

#### *Special shapes of granite*

Tuong mountain in Oc Eo town, Thoai Son district, gets its name from the shape of the granite block on top, which has been peeled off and rounded to resemble an elephant head (Fig 16). The lonely stone pillar is constructed from two granite blocks. Where they meet, climbing plants grow around it, and the shape resembles a toad lying on the grass.

The unique shape is linked to myths and legends. The "fairy footprint" on Son Tien Pagoda, which is about a foot long and was left by pegmatitic nests wearing away in granite (Fig. 17), has also been preserved and is thought to be a fairy's footprint. The large stone knife on the top of Ong Ta, Ba The Mountain is a large piece of granite shaped like a large knife that was broken off from a large rock block during a stormy night with thunder and lightning (Fig. 18).

#### *Create a cave*

The granite blocks pile up to form caves, such as Chon Thien Cave on Ba The Mountain, which is said to have been used by a local nun to practice healing and as a safe haven during the war (Fig. 19). The small cave on top of Tuong mountain is the result of weathering, peeling off the round crust, and rolling and piling up rocks (Fig. 20 and 21).

#### *Rolling stone*

The size and shape of rolling stones used as ornamental stones in temple yards, gardens, parks, road construction, paving stones, and so on meet the requirements of natural materials on-site while also having aesthetics that complement the natural landscape.

On the concrete road to the top of Ba The mountain, there is a rolling granite block measuring 2.5x5x3m. This block of rock rolled and came to a stop on the road, despite the fact that it was on the slope surface with a slope of 5-100. Locals consider this to be a sacred site (Fig. 22).



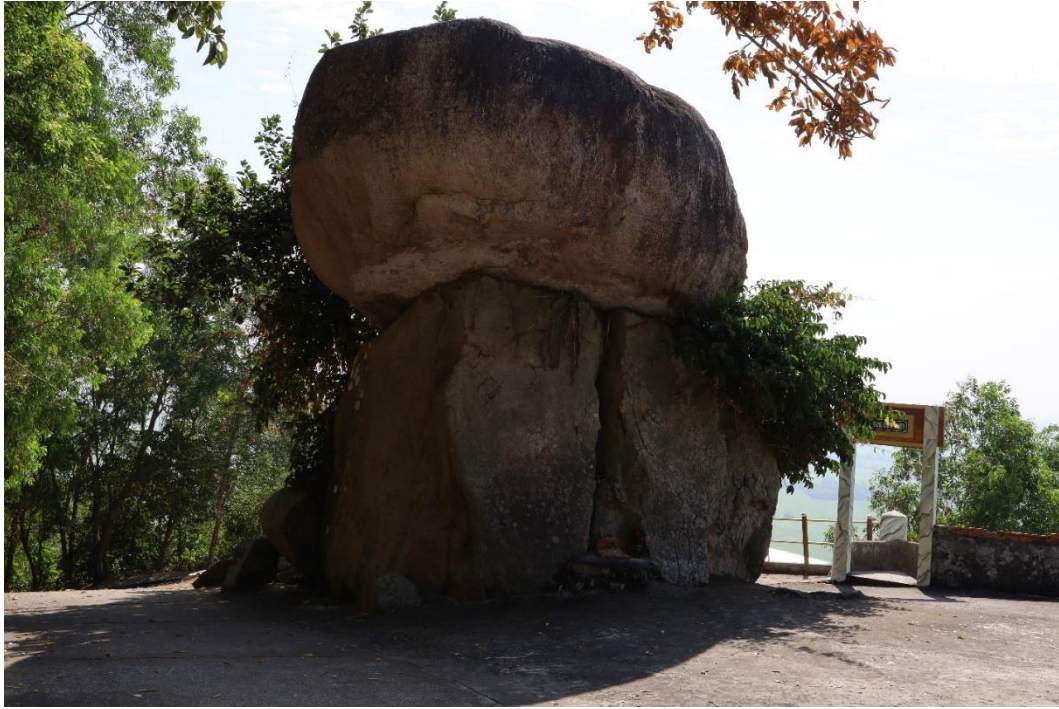
**Fig. 16.** The rocks piled on top of Tuong Mountain resemble an elephant's head



**Fig. 17.** “Fairy footprints” in granite at Son Tien Tu pagoda, Ba The mountain top, Thoai Son, An Giang



**Fig. 18.** "Stone knife" made from naturally cracked granite in Ong Ta, Ba The mountain.



**Fig. 19.** Granite blocks stacked on top of each other to form Chon Thien cave, Ba The mountain



**Fig. 20.** a haven in granite due to weathering



**Fig. 21.** Victory Monument of Ba The Special Forces



**Fig. 22.** Ba The Mountain. Rolling granite blocks on the slope surface on the way up the mountain

### 3.2.3. Educational value

Education is essential for managing and conserving geological heritage. Education is carried out by the management team, tour guides, and local communities.

The content of geological heritage conservation education must be closely tied to regional culture. Leaflets, signs, websites, media, seminars, and exhibitions are all examples of educational aids.

#### 3.2.4. Economic value

A solid foundation structure facilitates and lowers construction costs.

Create a source of local common building materials. However, exploitation should be limited to preserve cultural beliefs.

Encourage the growth of traditional industries related to local specialties in order to combine diverse tourism destinations.

Create jobs for local residents. At the same time, tourism revenue contributes to the local budget, which helps to fund development and improves the community's quality of life.

#### *The importance of geological value*

Each landscape, a natural geological product associated with myths and legends, represents a natural legacy of long-term geological activity.

Preserving and promoting geological heritages to support socioeconomic development, serving scientific research subjects, and Earth Science students, and attracting tourists who enjoy nature and geological heritage.

#### *Limitations and difficulties of geotourism in Ba The area, An Giang in particular and our country in general*

Geotourism sites have not been thoroughly investigated and assessed for geological potential. This has resulted in a scarcity of detailed and accurate information, impeding the development of geotourism strategies and plans. Many geotourism sites focus solely on sightseeing and sightseeing, rather than exploring and creating unique experiences for visitors. Diversity in exploration and experience activities must be developed. Environmental and geotourism product protection has not received adequate attention, resulting in littering, destruction of cultural relics, and a lack of interest from the community and managers. Strategies are required to raise awareness and take action to protect the environment and geotourism products. Limited human resources, particularly local human resources, are experiencing difficulties. Infrastructure and transportation, particularly in rural areas, are also experiencing material constraints, limiting their ability to attract tourists.

The invasion of spiritual tourism impedes geotourism, particularly among Western tourists (who are Catholic).

There is a limited understanding of geology and the ability to communicate this knowledge to tourists. Developing in-depth geological knowledge will contribute to a better and more enjoyable geotourism experience.

A mechanism for dealing with violations in the tourism sector is required to ensure compliance and maintain the quality of geotourism products. The system for handling violations must be adaptable and integrated at all levels, from local to national. These obstacles necessitate the collaboration of tourism industry professionals, local communities, tourism businesses, and local authorities in order to establish a sustainable and evolving geotourism environment.

#### *To bring about sustainable development of geotourism value in the Ba The area, the following solutions need to be implemented in the coming time*

It is critical to create a set of legal documents and policies specifically for the geotourism industry. These documents must include regulations for environmental protection, geotourism management, and the protection of local communities' rights.

Investigate, evaluate, and delineate geological heritage, laying the foundation for detailed planning.

Geoheritage planning for geotourism, with a focus on conservation, rational exploitation, and sustainable geotourism development, is critical. These plans must be carefully coordinated with environmental management and resource conservation plans. Geotourism guide training and certification is an important step in ensuring that tourists receive quality guidance and experiences. Training programs should place a strong emphasis on geoheritage knowledge, environmental management, and effective tourist communication skills.

Communication and promotion strategies must be optimized to enhance the tourist destination's image and value. Combining traditional media and digital technology is critical for reaching a large audience and increasing community awareness.

It is critical to establish a flexible and effective management mechanism by delegating responsibility for tourism areas to local units. This ensures local management and flexible responses to each area's specific challenges.

Building short-term and long-term geotourism routes improves the visitor experience, stimulates demand, and generates new economic opportunities in local communities.

#### 4. Conclusion

The diversity of terrain and geology, with unique landscapes and interesting geological features associated with mysterious legends and myths, appeals not only to nature and belief enthusiasts, but also to scientific researchers. As a result, the Ba The area has enormous geotourism development potential based on the discovery of unique features, the preservation and conservation of unique and interesting existing terrain, and geomorphology-geology heritages. The diversity of terrain and geology also contributes significantly to the richness of culture and history, with a unique culture of a multi-ethnic and multi-religious land with mysterious spirituality and biodiversity of the mountainous region in the middle of the river basin.

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