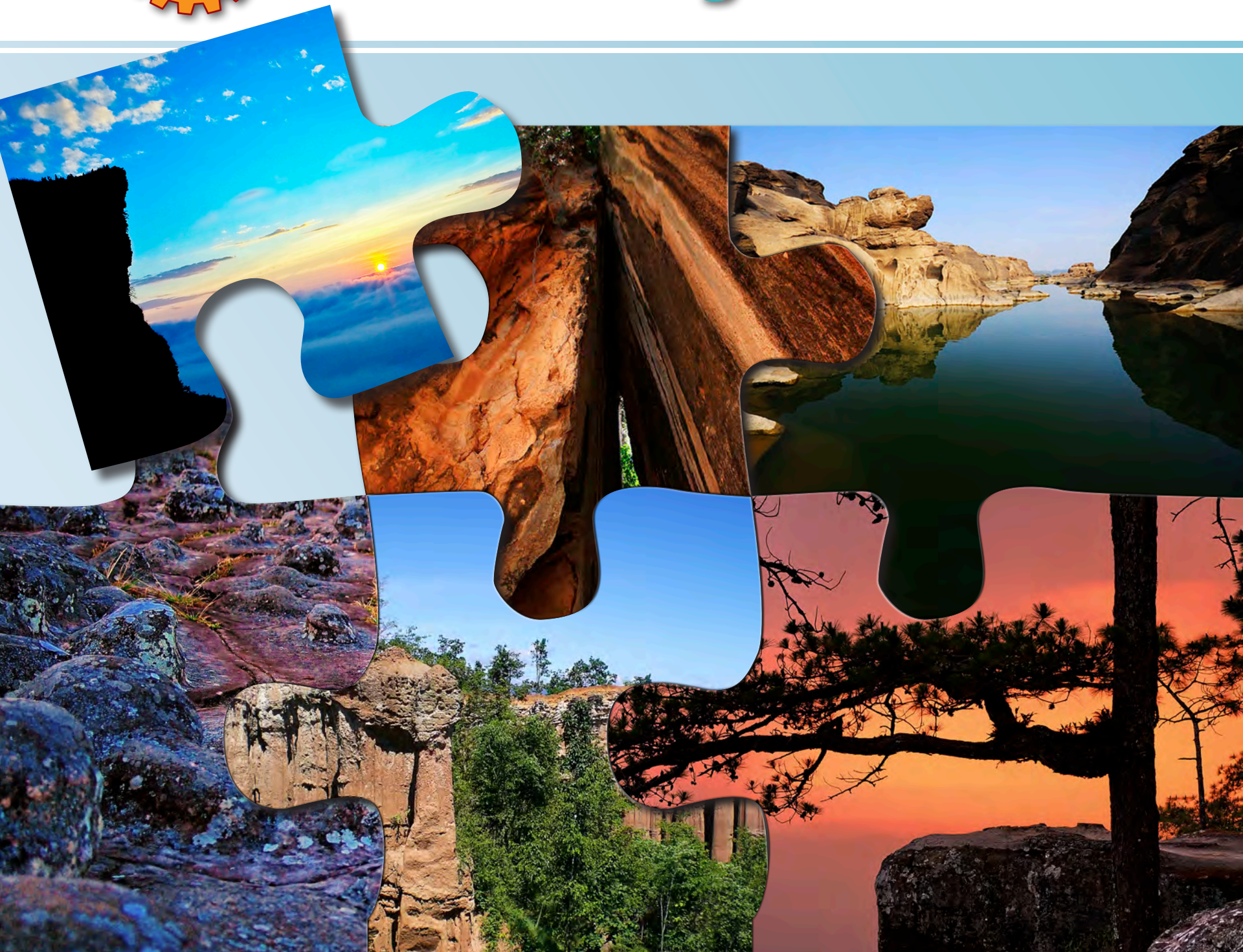




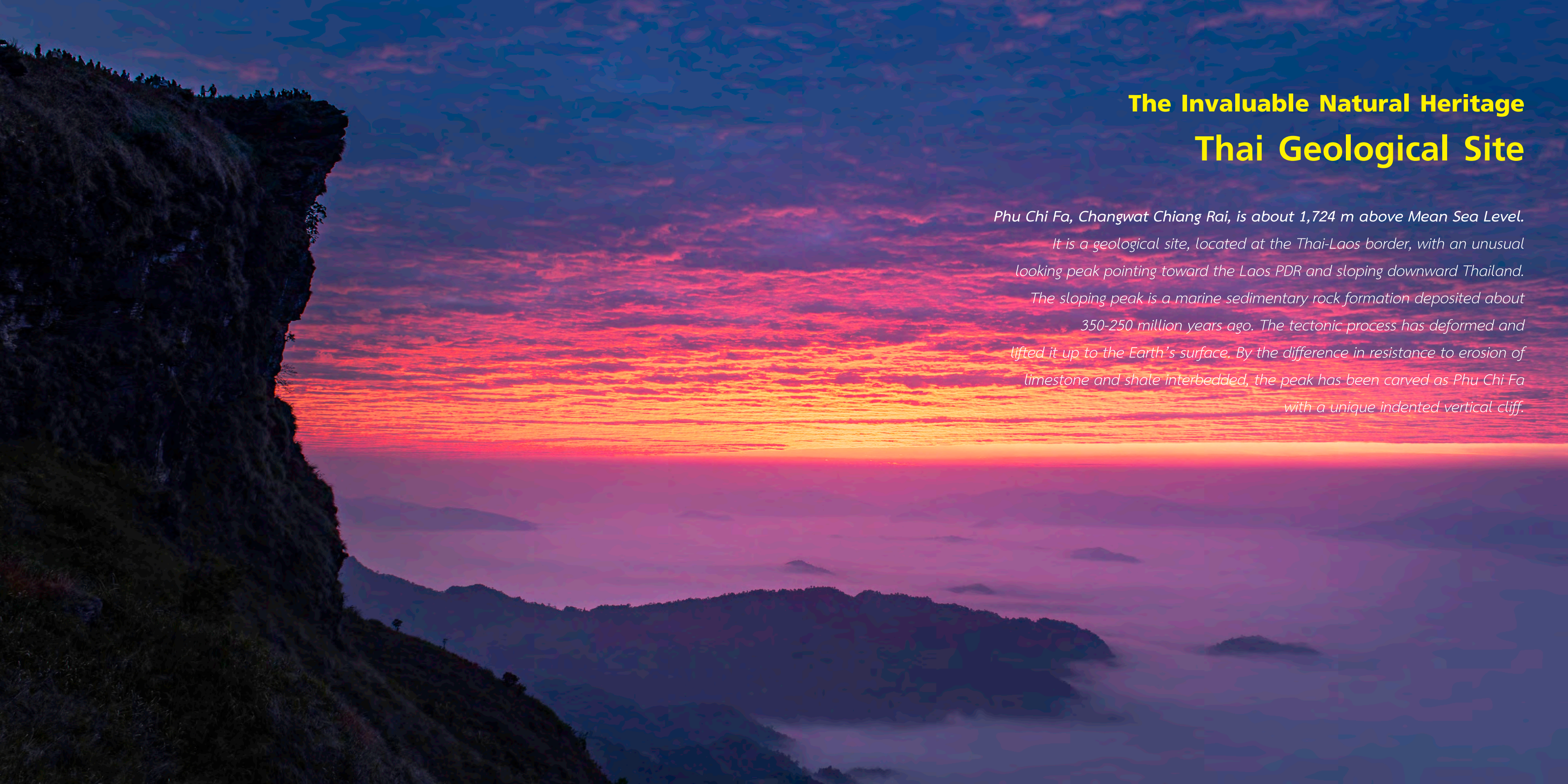
The Invaluable Natural Heritage

Thai Geological Site





• Phu Tok Noi, Amphoe Si Wilai, Changwat Bueng Kan.



The Invaluable Natural Heritage Thai Geological Site

Phu Chi Fa, Changwat Chiang Rai, is about 1,724 m above Mean Sea Level.

It is a geological site, located at the Thai-Laos border, with an unusual looking peak pointing toward the Laos PDR and sloping downward Thailand.

The sloping peak is a marine sedimentary rock formation deposited about 350-250 million years ago. The tectonic process has deformed and lifted it up to the Earth's surface. By the difference in resistance to erosion of limestone and shale interbedded, the peak has been carved as Phu Chi Fa with a unique indented vertical cliff.



Foreword

Geological sites are natural heritages that the Earth has given to all the world's members. Every geological site has its own worth, however, geological knowledge helps add to its value. Most of the geological sites in Thailand are located in National Parks or Forest Parks. Making the conservation not a major concern but instead the geological understanding of the people. Hence, geological knowledge dissemination is the primary task to be carried out.

The book "The Invaluable Natural Heritage: Thai Geological Site" was first issued in Thai. This English version has been published aiming to promote the geological sites conserved in Thailand and to encourage all the readers to visit any nearby geological site to perceive geological scenic beauty. The Department of Mineral Resources has realized the difficulties of the non-geologist readers in recognizing the geological terms and stories. Therefore every chapter is narrated using simple words, except some necessary technical terms. For every geological site, many pictures and graphic models are used to present its beauty and origin together with the descriptions of its geology and highlights. The twenty geological sites presented in this book are parts of many other sites explored and conserved in Thailand. The Department of Mineral Resources wishes to prepare and issue the following ones for all other sites and hopes that "The Invaluable Natural Heritage: Thai Geological Site" would help enthuse the readers to enjoy visiting geological sites. The Department of Mineral Resources believes that as one knows more about geological sites then one will love and help conserve it more, and also deeply believes that mankind has the highest potential in protecting the geological sites.

(Mr. Supot Jernsawatdipong)

Director-General

Department of Mineral Resources

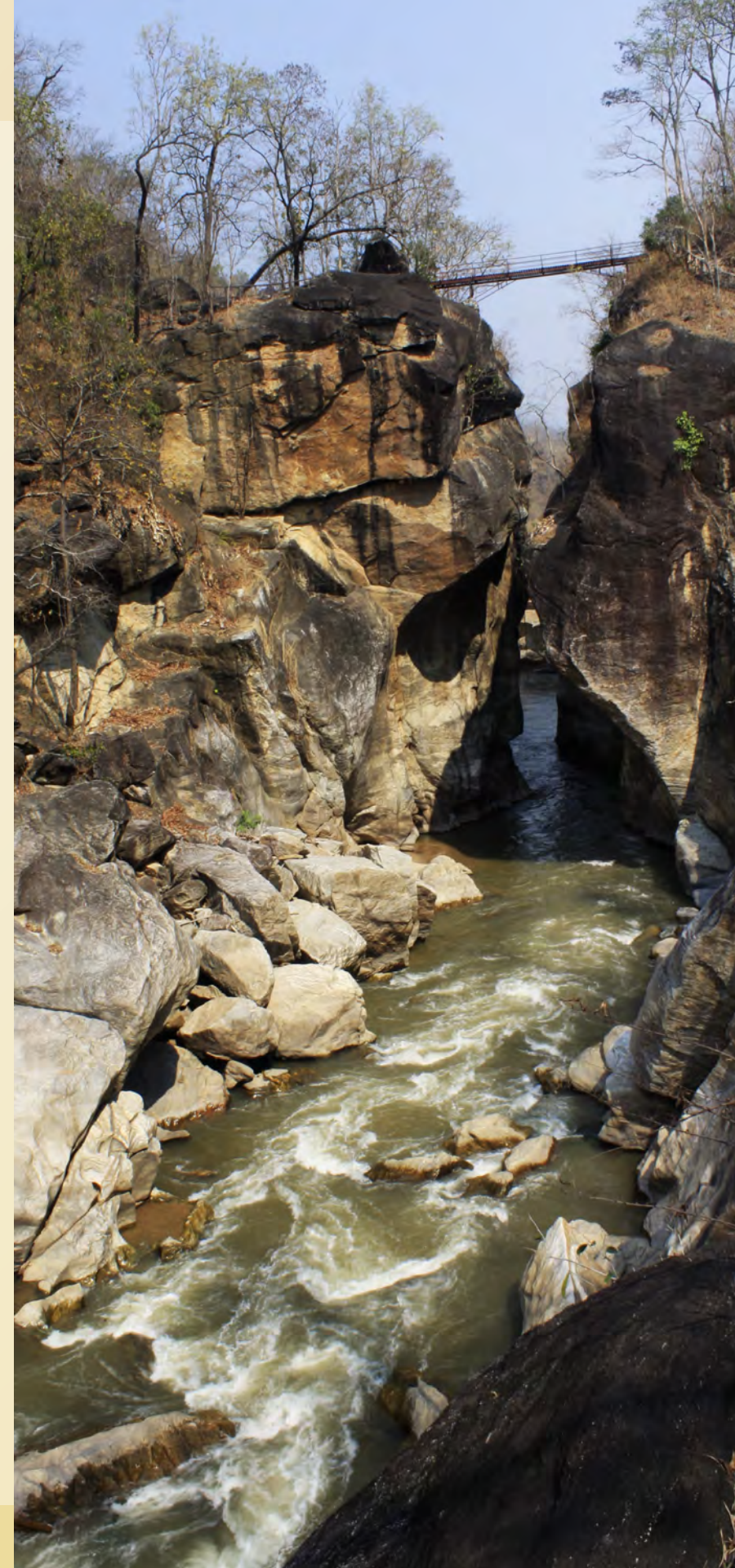
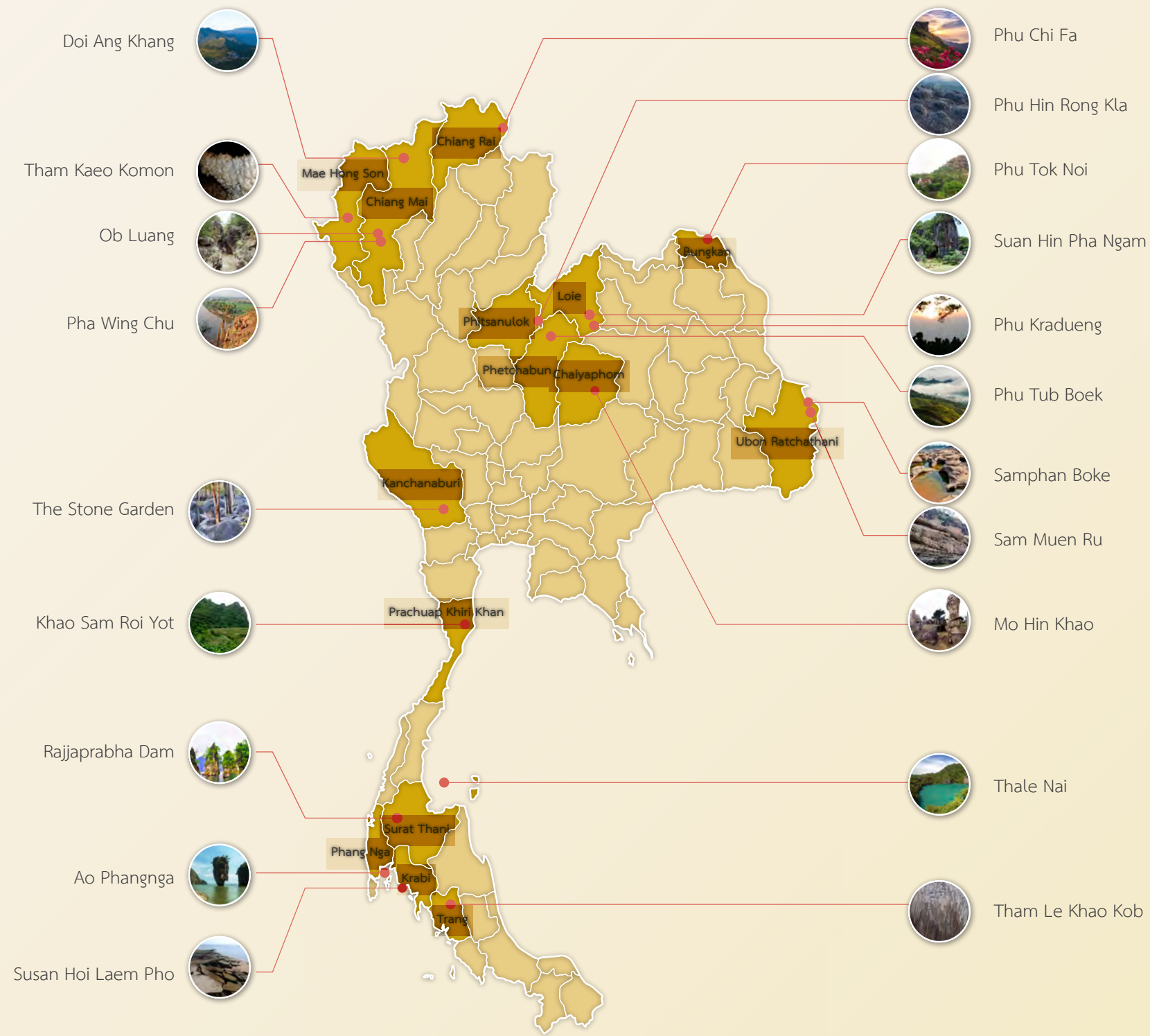


Table of Contents

008

The History of the Department of Mineral Resources

012

The Mission of the Department of Mineral Resources in Geological Conservation.

014

Geology of Thailand

040

Geological Sites in Thailand

044

The Invaluable Natural Heritage

Thai Geological Site

- Ob Luang

046

- Doi Ang Khang

054

- Phu Chi Fa

062

- Tham Kaeo Komon

070

- Phu Hin Rong Kla

078

- Pha Wing Chu

086

- Suan Hin Pha Ngam

094

- Phu Tub Boek

102

- Phu Kradueng

110

- Sam Phan Boke

118

- Sam Muen Ru

126

- Mo Hin Khao

134

- Phu Tok Noi

142

- The Stone Garden

150

- Khao Sam Roi Yot

158

- Thale Nai

166

- Ao Phangnga

174

- Rajjaprabha Dam

182

- Tham Le Khao Kob

190

- Susan Hoi Laem Pho

198

The Eternal Nature

206

Geological Conservation in Thailand

208

Bibliography

209

Production Teams



King Chulalongkorn the Great (King Rama V)

History

The Department of Mineral Resources

King Chulalongkorn the Great (King Rama V) established "The Royal Department of Mines and Geology" on 1 January 1891, under the Ministry of Agriculture to be responsible for the mining industry including the granting of tin mine concessions and royalty imposition, and academic affairs of mines and geology.



HRH Prince Ditsawarakuman, Prince Damrong Rajanubhab led The Royal Department of Mines and Geology as the Minister of the Interior for 13 years, during 1896-1909, and firmly founded mining and geological affairs of Thailand.



HRH Prince Ditsawarakuman, Prince Damrong Rajanubhab

1891-1897

The Royal Department of Mines and Geology

Ministry of Agriculture

The Royal Department of Mines and Geology was first led by HE Phya Bhaskarawongse (Bhorn Bunnag) the Minister of Agriculture acting Director General.

In the early phases, most of the department's responsibilities were in the field of mining management, i.e. granting of mine concessions and royalty impositions.

As mining was a very interesting investment, during 1891-1897, the Royal Department of Mines and Geology granted a plenty of tin, gold and gemstones mine concessions.



1897-1932

The Royal Department of Mines and Geology

Ministry of Interior

The Royal Department of Mines and Geology was divided into two parts; the mining management section, under the Ministry of Interior and the royalty imposition section, under the Department of Agriculture (The Ministry of Agriculture was demoted as a department under the Ministry of Treasure).

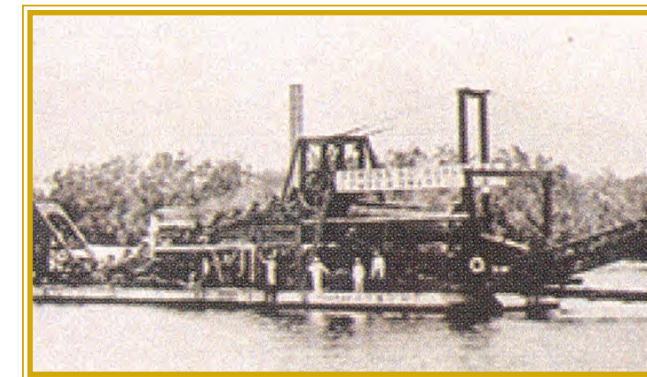
Mining

Three mining methods including ground sluicing, drifting and open pit were generally applied at that time.

The mining bill had been prepared for a decade, since the foundation, and the first Mining Act was promulgated in 1901.

In 1902, the first mine concession, No. 1/1 dated 1 August 1902, under the first Mining Act was issued for construction material in Amphoe Kaeng Khoi, Sara Buri Province.

In 1907, Edward Thomas Miles, an Australian tin mine owner, brought the first bucket ladder dredge to Thailand for tin mining operation in Tongkha Harbour, Phuket Province, causing the rise of tin production.



1934-1941

The Royal Department of Lands and Mines

Ministry of Agriculture

The Ministry of Agriculture was separated from the Ministry of Economics in 1934, and the Royal Department of Lands and Mines was put under the administration of this new established Ministry.

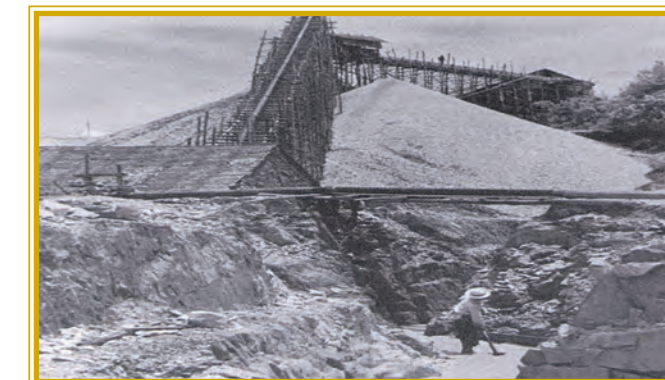
The Royal Department of Land and Mines was separated in 1941 as the Royal Department of Lands, under the Ministry of Interior and the Royal Department of Mines, under the Ministry of Economic Affairs.

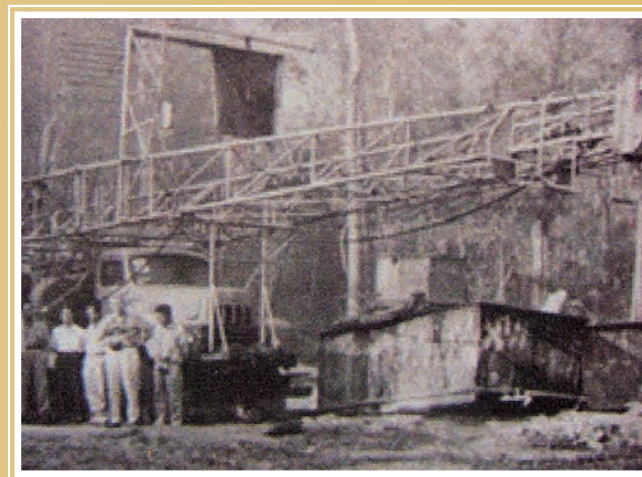
1942-1963

The Royal Department of Mines

Ministry of Industry

The Royal Department of Mines was transferred to the Ministry of Industry on 5 May 1942. The department was incorporated with Bureau of the Secretary, Concession Division, Mines Division and Geological Survey Division. Its responsibilities and scope of services was expanded to cover the geological survey and mineral and groundwater explorations for the development of mining and petroleum industries and groundwater resources. The petroleum exploration field at Amphoe Fang, Chiang Mai Province was initiated. Many lignite exploration projects were conducted throughout the country and two lignite reserves were discovered at Mae Mo Basin, Lampang Province and Bang Pudam Basin, Krabi Province. Moreover, a groundwater exploration program was launched to tackle the drought in the north-eastern part.





1963-1972

The Department of Mineral Resources

The Ministry of National Development

In 1963, the Ministry of National Development was established according to the nation's First Economic Development Plan. The Royal Department of Mines was then transferred to this new ministry and the name was changed to the Department of Mineral Resources on 20 May 1963.

The missions of the department have been fully extended to cover the management of other geological resources, e.g. energy, groundwater and basic geological issues of the country.

The department has been reorganized and some divisions were added to achieve the new missions as follow; The Office of the secretary, the Concession Division, the Mining Map Division (later changed to Survey Division), the Geological Survey Division, the Economic Geology Division, the Academic Division (later changed to Mines Division), the Metallurgy Division, the Geotechnology Division, the Groundwater Division and the Economics and publicity Division.



1972-2002

The Department of Mineral Resources

The Ministry of Industry

The Ministry of National Development was dissolved by the act amending ministry, sub-ministry and department B.E. 2515. Therefore, the Department of Mineral Resources was transferred back to the Ministry of Industry with the following authorities and functions;

- Geological survey and geological resources explorations.
- Constructing groundwater deep wells, granting and regulating groundwater businesses by the Groundwater Act B.E. 2520 and other concerned Acts.
- Granting prospecting licenses and mine concessions, and regulating mine businesses by the Mineral Act B.E. 2510 and other concerned Acts.
- Granting petroleum concessions and regulating petroleum businesses by the Petroleum Act B.E. 2514 and other concerned Acts.

2003-The Present

The Department of Mineral Resources

The Ministry of Natural Resources and Environment

The reorganization of the Department of Mineral Resources on 3 October 2002 following the bureaucratic system reform, under the act amending ministry, sub-ministry and department B.E. 2545, resulted in the move of the department to the newly established Ministry of Natural Resources and Environment, and the emerging of three new departments branching off of the Department of Mineral Resources, namely the Department of Groundwater Resources under the Ministry of Natural Resources and Environment, the Department of Primary Industries and Mines under the Ministry of Industry, and the Department of Mineral Fuels under the newly established Ministry of Energy.

Mission

Preserve, conserve, rehabilitate and manage geological issues and geological resources by conducting geological surveys, geological resources explorations and natural resources site evaluations; designating and regulating geological resources preserved and conserved areas for the sustainable development of geological resources, quality of life, economics and society.

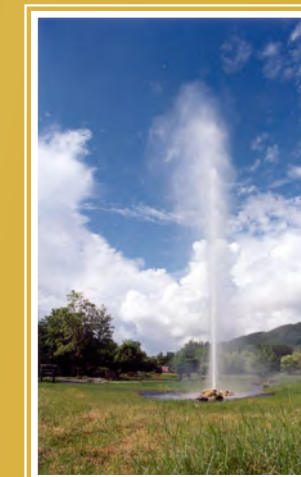
The Department of Mineral Resources has been reorganized several times since 2002 to harmonize with particular circumstances and its structure is as follow;

- The Office of the Secretary
- The Mineral Resources Analysis and Identification Division
- The Mineral Resources Conservation and Management Division
- The Mineral Resources Information Center
- The Mineral Resources Bureau
- The Geotechnology Bureau
- The Geological Survey Bureau
- The Environmental Geology Bureau
- The Fossil Protection Division
- The Office of Mineral Resources region 1 (Lampang Province)
- The Office of Mineral Resources region 2 (Khon Kaen Province)
- The Office of Mineral Resources region 3 (Pathum Thani Province)
- The Office of Mineral Resources region 4 (Surat Thani Province)
- The Sirindhorn Museum
- The Internal Audit
- Legal Affairs
- The Public Sector of Development



The Mission of the Department of Mineral Resources in Geological Conservation.

The Department of Mineral Resources has initiated the geosite conservation, the unique natural heritage which is geologically academic significant, since 2001. More than 850 geosites over the country have been surveyed, analyzed, researched and evaluated to arrange the geological conservation site inventory to propose to the Cabinet for an endorsement. The announced geosites would become geological learning sites and substantially conserved and protected.



Since 2010, the Department of Mineral Resources has academically promoted and supported the development of potential geotourism sites through people's participation under the concept of "Geopark Establishment" which would lead to the improvement of the quality of life and the economics of the local communities around the sites.



The progression of the mission in geological conservation of the Department of Mineral Resources.

2001-2004

Prepared and issued semi-academic documents "The Geo-Natural Heritage of Thailand" and "Geotourism Sites" for the public.

2006-2009

Prepared a preliminary inventory of 743 conservable geosites, with prominent academic, geology and tourism, and academically classified the sites into 7 categories.

2010-2011

Established the Geological Conservation Section under the Bureau of Geology to survey and prepared the detailed Geosite Inventory and study the possibility to join the UNESCO's Global Geoparks Network, starting with two pilot sites, i.e. Tarutao National Park and its vicinity and Loei Province.



2012

The Department of Mineral Resources has established the Geosite Conservation and the Management for the Sustainable Development Program to prepare a tangible proactive policy and guideline including geosite survey and research activities. The program aims to create a geological database and a geosite management guideline targeting geoparks. The program also promotes and supports local people's participation in management, learning sites and geotourism.

Geoparks establishments in many provinces throughout the country, e.g. Ubon Ratchathani, Khon Kaen, Satun, Chiang Mai, Chiang Rai and Suphan Buri have been carried out by the Department of Mineral Resources. The Pha Chun Sam Pan Boke National Park, Ubon Ratchathani Province is the first local geopark launched while Satun Province is being processed for the next local geopark.

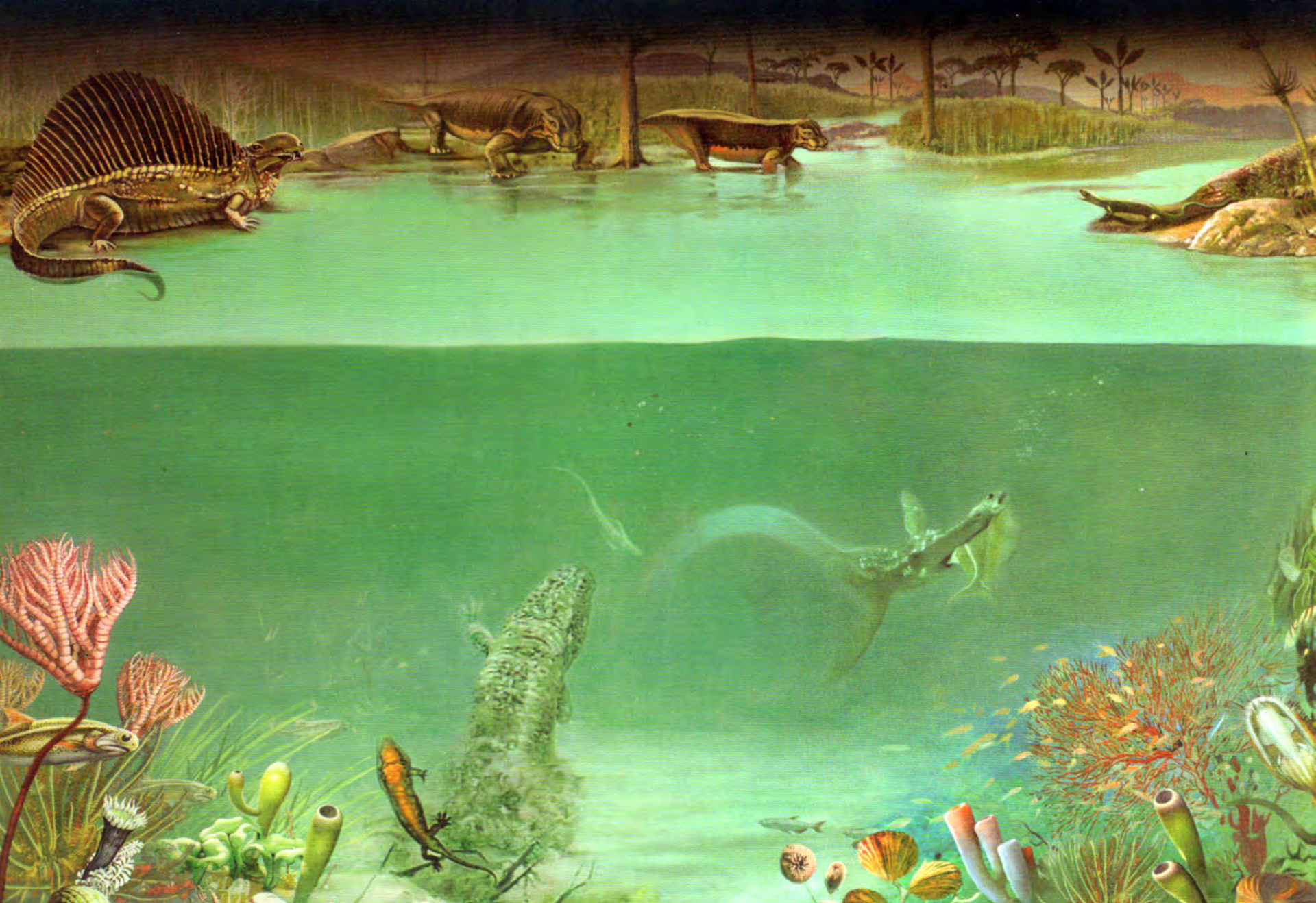
2013

Many Geosite Conservation Networks have been initiated in geosites all over the country, aiming mainly at education of the local people on the worth of their geosites and joining hands in geosite conservation and development. The first few pioneer sites are in Surat Thani, Satun and Suphan Buri Provinces.

Geology of Thailand

The Five Million Year Construction of the "Golden Peninsular"

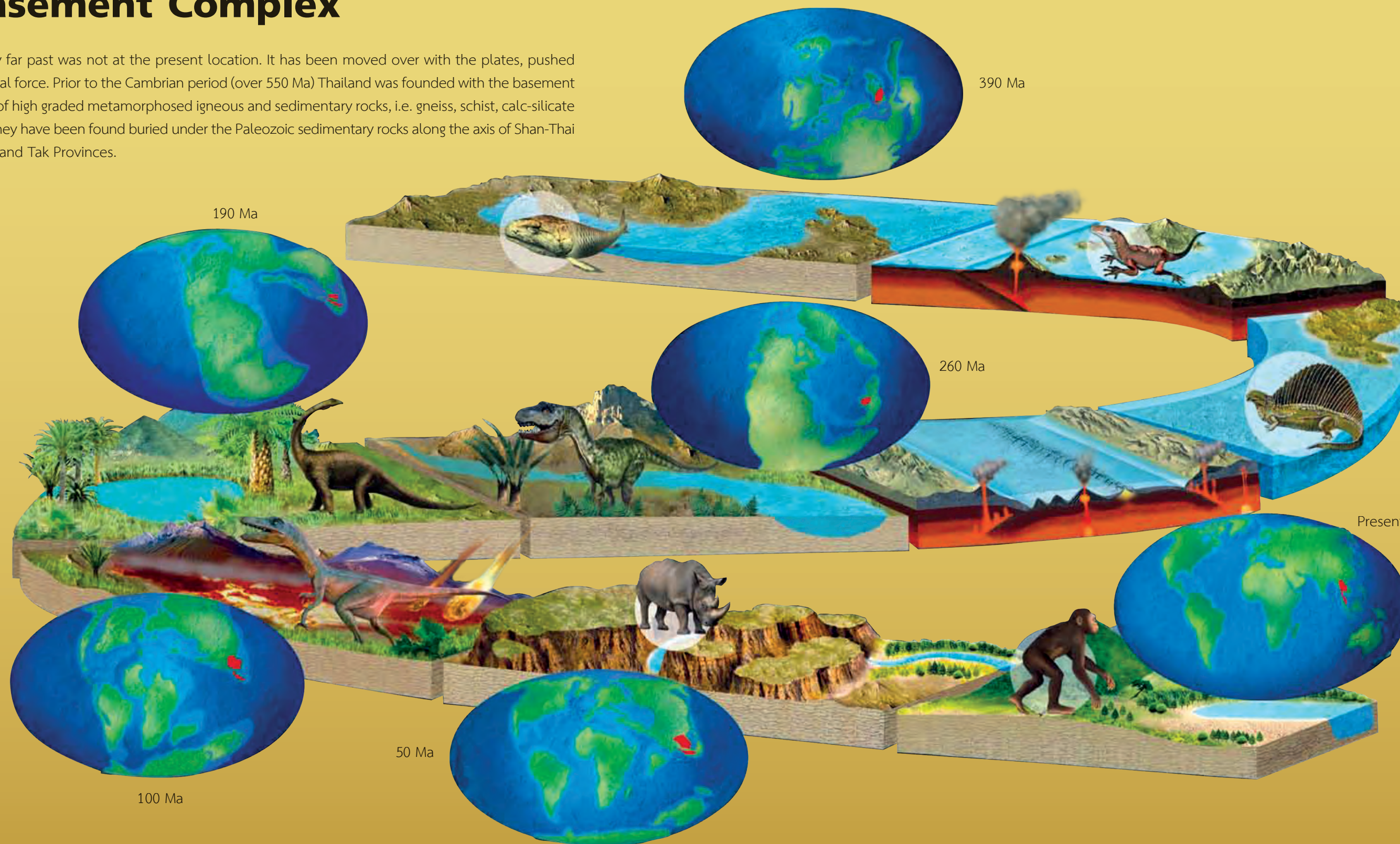
The geological history of Thailand has long been traced back beyond the Cambrian period or over 530 million years ago (Ma). Plenty pieces of geological evidence, e.g. geological stratigraphy and structures and fossils indicated that Thailand is placed over two tectonic plates; Shan-Thai to the west and Indochina to the east. The North-South suture zone between these two plates lies along Nan, Uttaradit, Sa Kaeo, Trat and Narathiwat Provinces.



| ERA | PERIOD & EPOCH | | EVOLUTION OF LIFE | GEOLOGY & LIFE |
|------------------------------|-------------------------|---|-------------------|--|
| CENOZOIC | QUATERNARY | HOLOCENE | | The period of the Modern Man |
| | | PLEISTOCENE | | The stone age, volcanic eruptions provided variety of gemstones. |
| | NEOGENE | 1.8 Ma PLIOCENE | | The depositions of lignite and the extensive diversity of large mammals. |
| | | 23 Ma MIOCENE | | Fully evolved flowered plants and the beginning of bears and dogs |
| | PALEOGENE | OLIGOCENE | | Opening of The Gulf of Thailand to develop sources of petroleum. Beginning of mice and monkeys. |
| 65 Ma EOCENE PALEOCENE | | Horses, hoofed animals and elephants begin. | | |
| MESOZOIC | CRETACEOUS | | | Deposition of rock salt and potash minerals in the Khorat basin. Intrusions of tin and wolfram bearing granites. Beginning of flowered plants and extensive diversity of non-marine Mollusca. Extinction of dinosaur at the end of this period. |
| | 145 Ma JURASSIC | | | Sea water regression, the beginning of birds and extensive diversity of ammonoids and dinosaurs. |
| | 200 Ma TRIASSIC | | | The union of the Shan-Thai plate and the Indochina plate, volcanic eruptions and granitic intrusions provide many mineral resources. The age of reptiles and the beginning of dinosaur. |
| PALEOZOIC | 251 Ma PERMIAN | | | Wide precipitation of limestone and gypsum (locally). The beginning of beetles, diversity of reptiles and extinction of trilobites. |
| | 299 Ma CARBONIFEROUS | | | The period of land plants; gigantic ferns and fertile forests. |
| | 359 Ma DEVONIAN | | | The period of fishes; the beginning of sharks, insects and amphibians. |
| | 416 Ma SILURIAN | | | Abundance of graptolites. |
| | 444 Ma ORDOVICIAN | | | Beginning of fish like animals without fins and jaws, presence of very big size trilobites and gigantic nautiloids, the shallow sea is plentiful of corals. |
| PRECAMBRIAN | 488 Ma CAMBRIAN | | | Beginning of hard shell animals, e.g. trilobite found at Tarutao Island, presence of crinoids and variety of mollusks. |
| | 542 Ma PROTEROZOIC | | | Presence of small organisms in the ocean. |
| | 2,500 Ma ARCHEAN | | | Presence of unicellular or single-celled organisms, e.g. bacteria and blue green algae. |
| | 4,600 Ma | | | |

The Basement Complex

Thailand in the very far past was not at the present location. It has been moved over with the plates, pushed by the Earth's internal force. Prior to the Cambrian period (over 550 Ma) Thailand was founded with the basement complex consisted of high graded metamorphosed igneous and sedimentary rocks, i.e. gneiss, schist, calc-silicate rocks and marble. They have been found buried under the Paleozoic sedimentary rocks along the axis of Shan-Thai Plate in Chiang Mai and Tak Provinces.

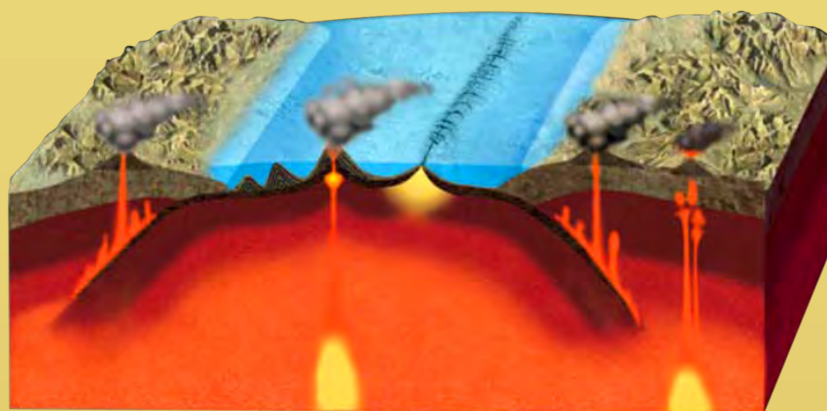


Various fossiliferous sedimentary rocks, e.g. sandstone, limestone and clays, deposited during the early Paleozoic period in shallow to deep marine environments, are mapped in the mountain ranges on the Shan-Thai Plate in the North, East and all the way along the western Thai border. The shallow marine sedimentary depositions, on the Indochina Plate, in the Central, Northeast and some part of the East of Thailand provide the main construction materials, e.g. limestone and marble, while the deep sea chert supplies the huge amount of filled material to the country.

During the end of the Permian period, the subduction of the oceanic crust, located in the middle, beneath the Shan-Thai and Indochina Plates, caused many gold and silver bearing volcanic belts, e.g. the Chiang Mai-Lampang-Sukhothai belt, the Loei-Phichit-Lop Buri belt and the Sa Kaeo-Trat-Narathiwat belt. There are two recently operating gold mines in Loei and Phichit Provinces.

• The evolution of the Earth since its 4.6 billion years origin, this planet has never been at rest. The red mark on the Earth planet represents the location of Thailand on each geological time, from 390 million years ago to the present "Golden Peninsular"

The Union of the Two Plates



•The driving force from the mid oceanic ridge pushed the heavier oceanic lithospheric plates to subduct beneath the Shan-Thai and Indochina Plates, causing the violent explosions of the volcanoes in the volcanic belts lying along the subduction zones.

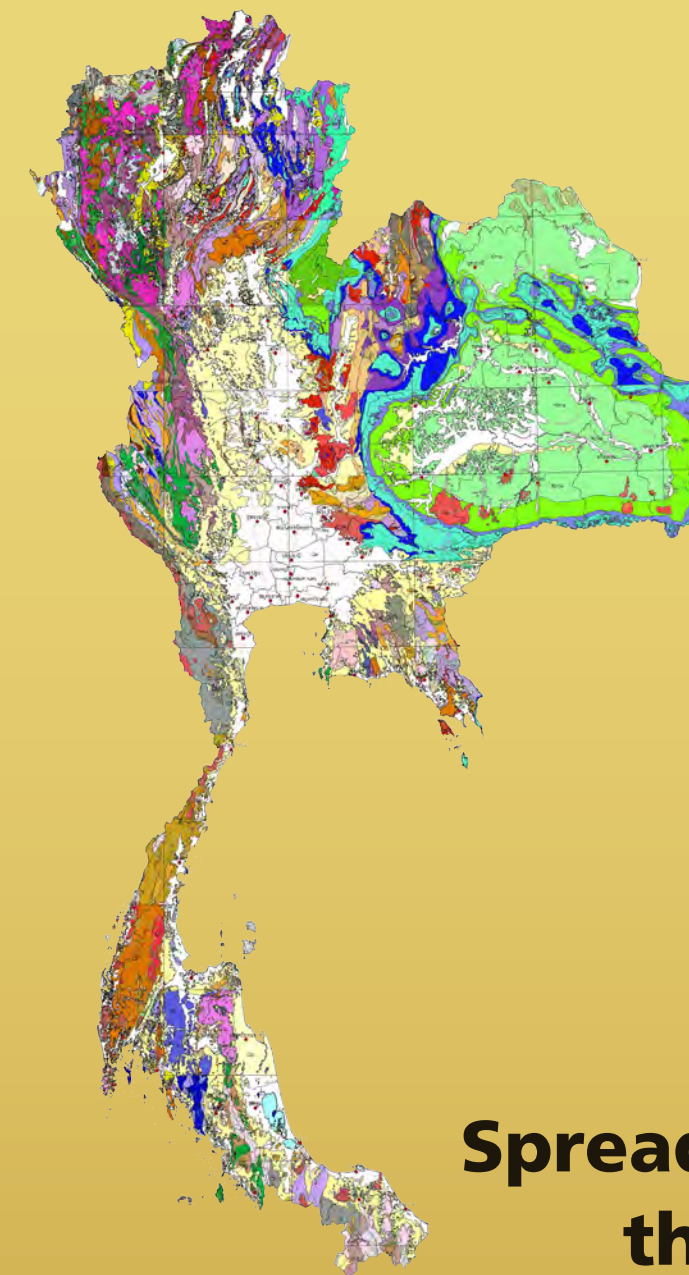
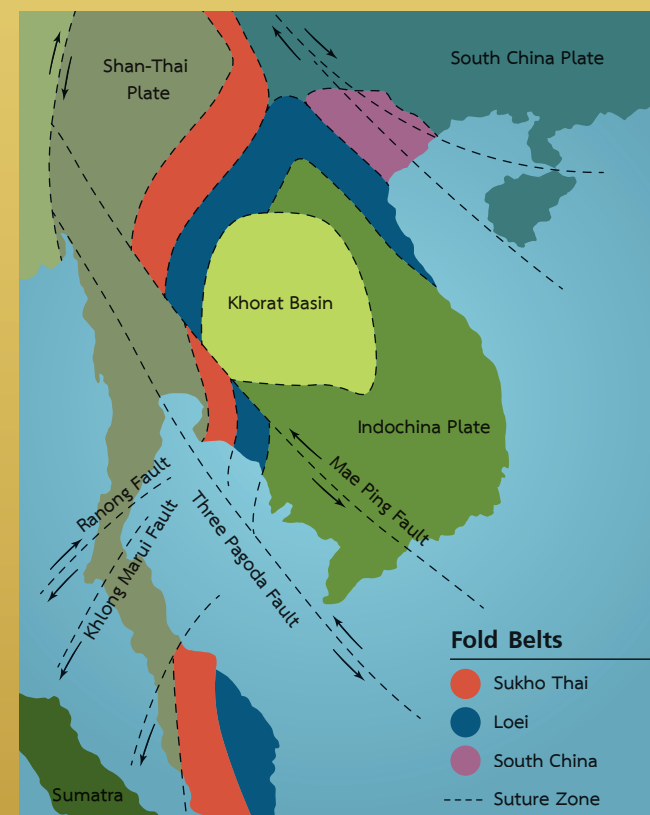
The Shan-Thai and Indochina Plates continuously moved toward each other and the colliding began in the Early Triassic or about 220 Ma. The processes of collision and subduction proceeded until the end of the Triassic period. There were many volcanic eruptions, in the meantime, and some granitic intrusions which lifted the Earth's crust up and formed mountain ranges. Some pieces of deep seated evidence, i.e. chromite, nickel, magnesite and talc are found along this suture zone. During the Triassic period, two major igneous intrusions built two prominent North-South trending metalliferous granitic mountain ranges, i.e. the Eastern and Central belts. These belts are presently sources of gold, tin and wolframs. Furthermore, these belts also provide fluorite, feldspars, kaolinite, dimension stones and construction material.

The processes of sedimentation

After the collision and coalition of these plates, the Paleo-Tethys was regressed and only a shallow sea was left behind. Triassic-Jurassic conglomerate, sandstone, shale and limestone are found on the Shan-Thai Plate, unconformably covered with Jurassic-Cretaceous non-marine red bedded sandstones. The third granitic belt of Thailand is a tin and wolframites bearing belt which lies over the Thai-Burma border. This western belt was formed as the Shan-Thai Plate was collided by the West Burma Plate in the Cretaceous period.

The Indochina Plate, for almost the whole range of the Mesozoic era, formed as a continental depositional basin with an erratic tropical climate which sometime arid as a desert. The basin was later inundated with saturated sea water and a gigantic evaporite including rock salt and potash minerals was found deposited.

The Mesozoic era was the only fertile evolutionary time for the diversity of dinosaurs; however, all were extinct at the end of the Cretaceous period. Their footprints and fossils have been left buried within the sediments of sandstone and shale of the Khorat Group. There are at least eight new dinosaur species found in Thailand and the most famous one is the "Phuwiangosaurus sirindhornae" sauropod, which was named in honor Her Royal Highness Princess Maha Chakri Sirindhorn.



The Crustal Harmonization

The Cenozoic era, or the Age of Mammals began 65 million years ago. During this era, the Indian Plate moved northward and hit the Eurasian Plate pushing Thailand to rotate clockwise. Thailand on the Indochina part was lifted up and formed the Khorat Plateau, while the mountain ranges in the north have been deformed and plenty of big and small hills throughout Thailand have been built. Meanwhile, northeast-southwest strike-slip faults, e.g. Utaradit -Nan Fault, Ranong Fault and Khlong Mariu Fault; and northwest-southeast strike-slip faults, e.g. Ping River Fault, Three Pagoda Fault and Sri Sawat Fault have been developed.

Plenty of north-south trending normal faults have been developed on the Shan-Thai side of Thailand. Later, small basins have been abundantly developed parallel to these normal faults, all the way from the north down to the south, and the Gulf of Thailand has been opened. The Thai's mineral fuels including lignite and petroleum, both on land and offshore, deposited in most of these basins.

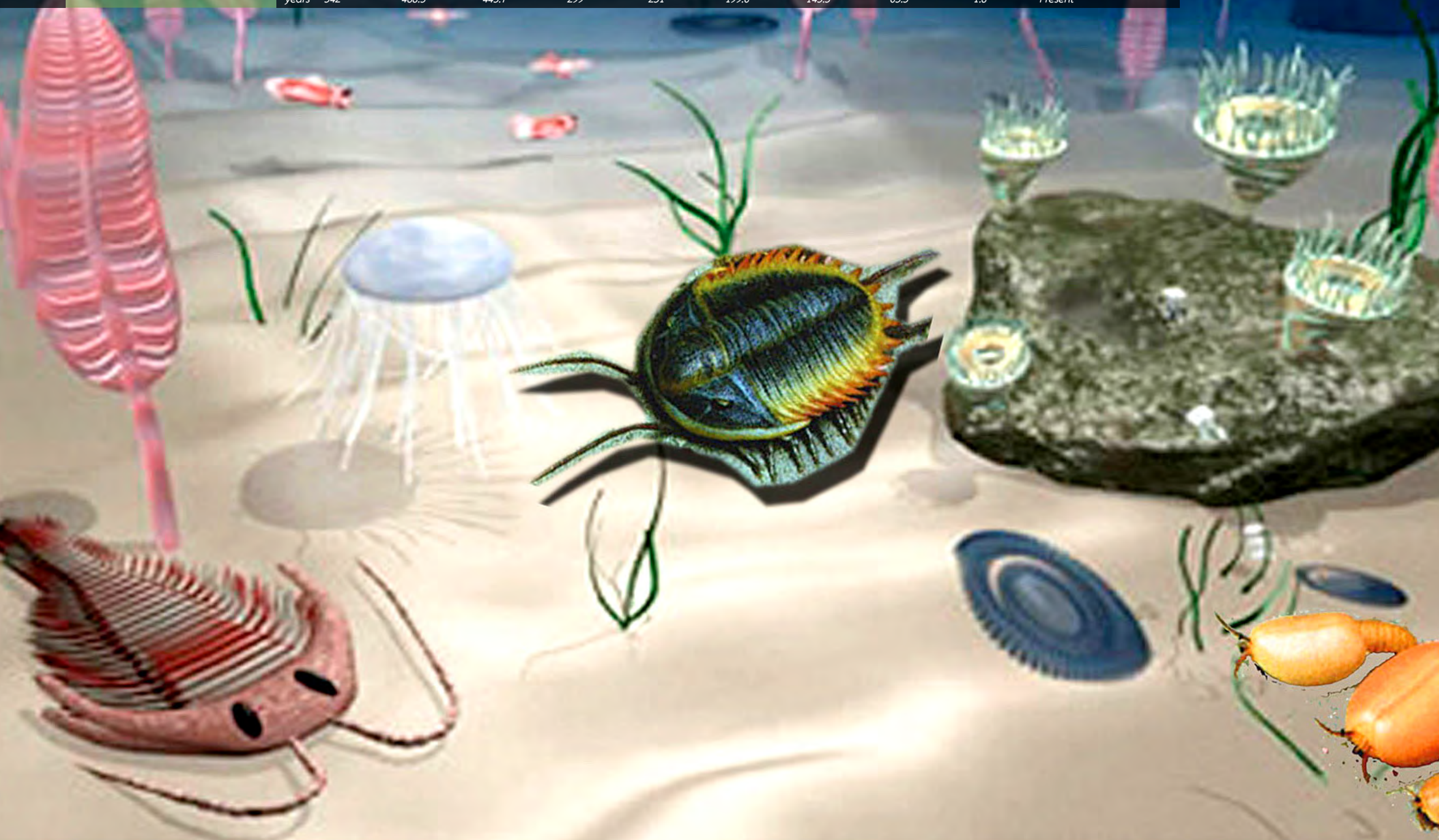
There were some volcanic eruptions in many portions, e.g. the Petchabun range in the north, southern rim of the Khorat Plateau and in the eastern and western parts of the country. These volcanic rocks contain a lot of plant nutrients and some are gemstone bearing basalts.

Spreading Prosperity throughout the "Golden Peninsular"

All the geological processes, both constructive and destructive, are for the Earth's equilibrium. The mountain building process and the uplifting of a plateau are constructive, while erosional processes by the water, the wind, the sun or natural chemicals are destructive; however, all the processes have helped create mountain ranges and hills which provide streams, sediments and fertility to the floodplains. The natural sediment sorting by the differential energy of the streams built up gravel, sand and clay deposits in all of the 25 watersheds of Thailand. The attacking storms on both sides of the Thai Peninsular have carved the geological morphology and topography to be islands, cliffs, sea shores and mangrove forests. These long proceeded geological processes have brought all the wealth and fertility to the "Golden Peninsular"

Cambrian Period (542.0-488.3 Ma)

The beginning of lives – The Thai marine creatures

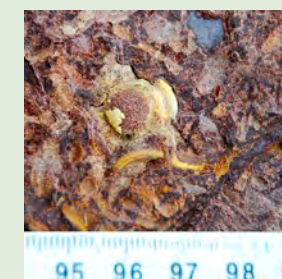


Tracing back beyond the Cambrian period, the origins of the western part of Thailand or the Shan-Thai Plate and the eastern part or the Indochina Plate were parts of the southern hemisphere gigantic continental plate called “Gondwana”. At that time the unicellular or single-celled organism, e.g. bacteria and blue green algae had already existed.

In the Cambrian period or around 542 million years ago (Ma), the Shan-Thai and Indochina Plates were on the western part of Gondwana. At that time, this part of Gondwana was a very fertile shallow sea where variety of organisms lived along the coast lines further to offshore bars, including hard shelled invertebrates, such as trilobites, brachiopods, nautiloids, corals, sea shells and other animals without hard shell, e.g. worms and jellyfishes. In this shallow sea, an age-long sedimentation of sea sands was continuously occurred causing very thick grey, white and red beds of sandstones, found similarly from Amphoe Fang, Chiang Mai Province to Ko Tarutao, Satun Province.

This Cambrian red sandstone has been mapped as Tarutao Group which is the oldest group of sedimentary rocks of Thailand. The trilobite and brachiopod fossils found at Ao Molae, Ko Tarutao are about 500 million years old and are the oldest fossils of Thailand.

Fossil Evidence



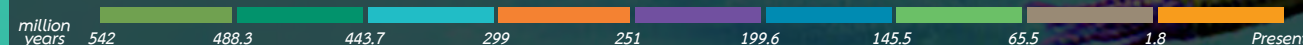
- **Trilobites** are jointed appendage animals, Arthropoda Phylum, Trilobita Class, found at Ko Tarutao, Satun Province. Trilobite means “three lobes” which referred to its head, body and tail. The first appearance of trilobites was in the Early Cambrian. They flourished throughout the early Paleozoic era before beginning a drawn-out decline to extinction. All trilobite orders except Proetida died out during the Devonian. Trilobites finally disappeared in the mass extinction at the end of the Permian, about 250 Ma.

- **Brachiopods** are marine invertebrates lived on shallow sea floor, often known as “lamp shells”. Brachiopods have hard “valves” similar to bivalve molluscs, but are not actually closely linked. Brachiopod fossils were first found in the early Cambrian period and were abundant through the Paleozoic era. Brachiopods went into decline after the Permian–Triassic extinction and, from the Mesozoic era, their abundance and diversity declined more rapidly. Recently, bivalve species have increased and are more diverse than brachiopods.



Ordovician Period (488.3-443.7 Ma)

Thailand on the continental shelf - The flourishing marine lives



During Ordovician period or 488.3-443.7 million years ago (Ma) the Shan-Thai and Indochina Plates were still attached to the western part of the Gondwana, as in the Cambrian period. From the Cambrian shallow sea and shore, the rise of sea level and temperature in Ordovician slowly changed the entire ancient Thailand to be a continental shelf. Gradually, the deposited sediments were finer, from sand to silt and clay and finally carbonate, causing siltstone interbedded with thin layers of shale, and became thick to very thick bedded dark grey argillaceous limestone and limestone. This succession of marine sedimentary rocks has been mapped as Thung Song Group which is found similarly all over Thailand. The Thung Song Group in the north and west of Thailand has been metamorphosed to be marble and calc-silicate rock.

The Ordovician lives were very diverse; both benthic organisms such as coral, shell, sponge, trilobite and crinoids; and pelagic organisms such as graptolite, conodont and nautiloids.

Subsequently, various fossils have been found in Thung Song limestone and shale, especially, the red to greyish-red stromatolite formation which formed by alternating layers of thin films of carbonate or silicate sediment and fossilized algal mats.

Fossil Evidence



- **Stromatolites found in Satun Province.** Stromatolites are accretionary structures formed in shallow water by blue-green algae (cyanobacteria) or other bacteria and unicellular algae as well. The biofilms of microorganisms, especially bacteria, trapped fine sedimentary grains such as clay and cemented them with calcium carbonate precipitation by the blue-green algae or others in shallow sea water, mostly at the low tide line. By repeated colonization, stromatolites are formed as alternating light and dark layers with different morphologies, e.g., flat, hummocky, or dome-shaped.

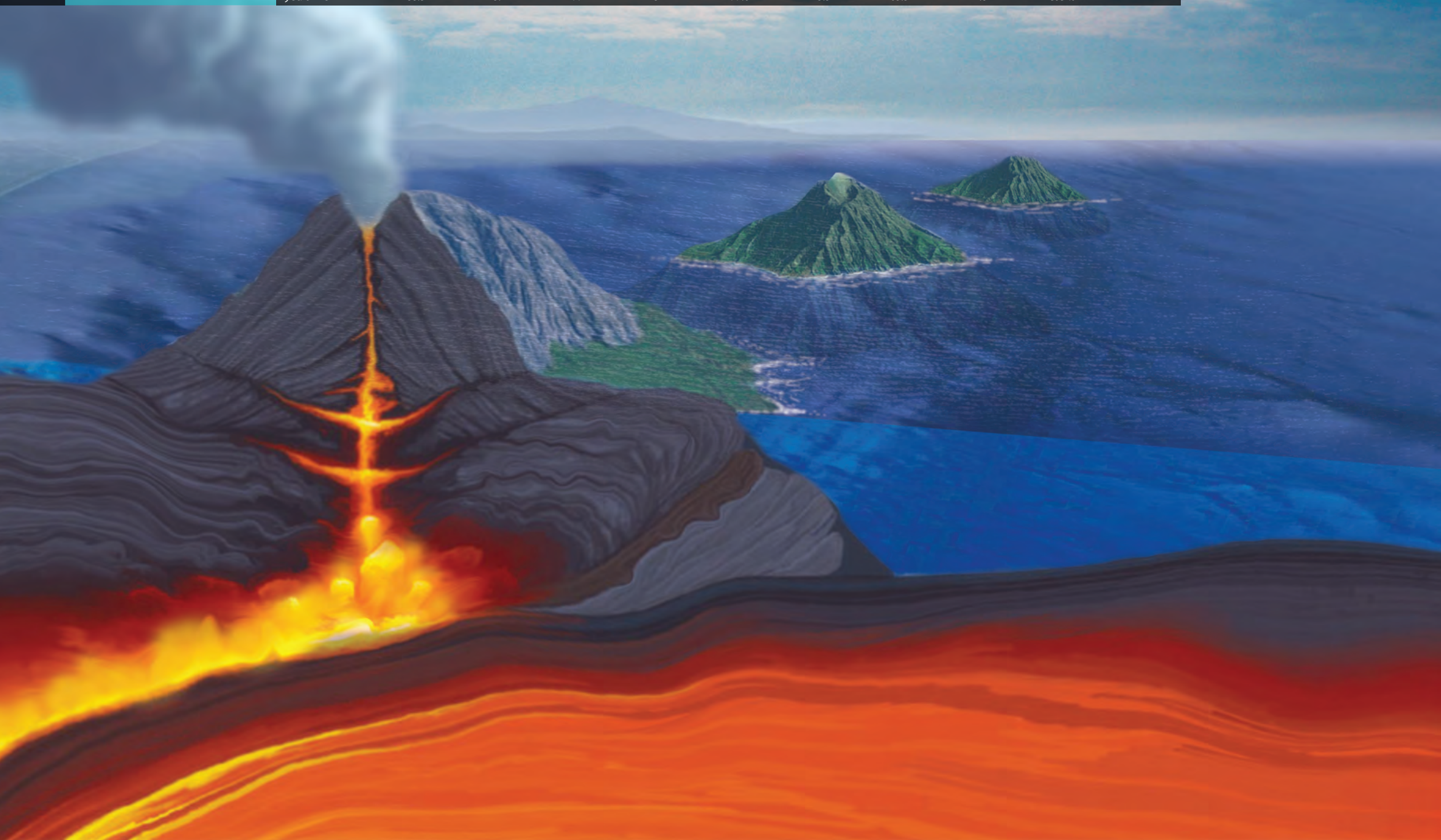
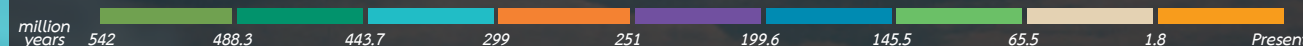


- **Nautiloids found at Satun Province.** Nautiloids are group of invertebrates called "Cephalopod", Cephalopoda Class, which include ammonoids, belemnoids and the recent colliods. The first appearance of nautiloids was in the Cambrian period and flourished between the Ordovician and Devonian. The decline of nautiloids and evolution of ammonites occurred inversely during Carboniferous to Permian. Only some nautiloids have developed to be the recent nautilus.

Silurian-Devonian-Carboniferous Period

(443.7-299 Ma)

The Long Journey Has Begun: Drifting from the "Gondwana"



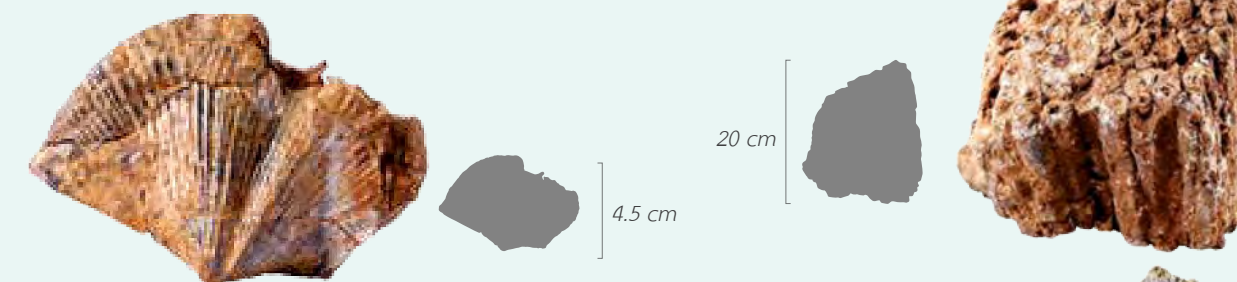
Tracing back in time to the Silurian - Devonian, which is about 443 – 360 million years ago (Ma), the two original pieces of land, the “Shan-Thai and Indochina Plates ”, separated from the ancient Gondwana in the Southern Hemisphere and drifted to the North toward the equator. The Indochina Plate moved faster causing a subduction of the Paleo Tethys, located between the Gondwana and the Equator, beneath both plates resulting island arcs and trenches. The topography of the ancient Thailand was similar to the recent volcanic terrains where depositions of coarse sand, clay, silica and deep carbonate sediments along the continental shelf and slope are supplied by volcanic eruptions. Various related geological evidence can be found in Loei, Chiang Mai, Kanckanaburi and Yala Provinces, especially in the sedimentary rocks of the Thong Pha Phum Group and Na Mo Formation.

The flourish of both benthic and pelagic organisms of these periods, e.g. coral, graptolite, tentaculite and radiolarian, indicate the sedimentation in a rather deep turbid marine environment with a slightly cool climate.

The Carboniferous covers the period between 359 - 299 Ma. During these times, the subduction of the oceanic plate continued until the Late Carboniferous time. Thailand was slowly lifted up, and hence the generally setting became a shallow sea and coastal plains with some volcanic extrusions, moreover, many small and fertile marshes developed on elevated plains above sea level. The sedimentations of sand, silt, clay, silicate substances, peat and volcanoclastic sediments from the coastal plain to the continental shelf, and some formations of coral reefs were encountered, throughout this period. The Carboniferous evidence can be seen in Loei Province and from Chiang Mai to Kanchanaburi and all the way down to Yala Provinces. The important Carboniferous rock units of Thailand are the Mae Tha Group and Wang Saphung Formation containing fossil evidence including algae, coral, foraminifera and brachiopods.

Fossil Evidence

- *Lublinophyllumthailandicum* found in Loei Province. These multicellular invertebrates, similar to sponges, lived and flourished in shallow reefs and marine floor during the Early Carboniferous.



- **Brachiopods**, found in Loei, Kanchanaburi, Nakhon Si Thammarat and Satun Provinces. These primeval marine invertebrates characterized by two bilaterally symmetrical valves. Brachiopods were usually attached to a solid substrate with a muscular structure called a pedicle. Brachiopods were abundant during Paleozoic Era. Most went extinct at the end of the Permian.

- **Stromatoporoid** found in Loei Province. These invertebrate and most primitive of multicellular animals were abundant between the Devonian - Carboniferous periods.



During the Permian period or 299-251 million years ago (Ma), the two continental plates of Thailand, which were separated by an oceanic plate, reached the equator, ready to move toward each other. Because they were moving toward the equator, the climate of ancient Thailand got warmer and various marine lives were abundant along the primeval shallow sea and coastal plain.

In the early Permian, The basement of the western Shan-Thai Plate was subsided as a depositional basin which coincided with the western provinces of Thailand, i.e. Mae Hong Son, Petchaburi and Song Khla. The deposition of a turbidite sequence in the basin, including shale, pebbly sand and greywacke, was added with some sediment from the South Pole's glaciers. This turbidite sequence has been mapped as the Kaeng Krachan Group.

During the Middle to Late Permian, the sea water transgression covered all over the two plates. Under such topographic and climatic conditions, fine grained sediments and carbonate were widely deposited along the continental shelf and slope. This marine sedimentary rock sequence has been mapped as the Ratburi Group and Saraburi Group.

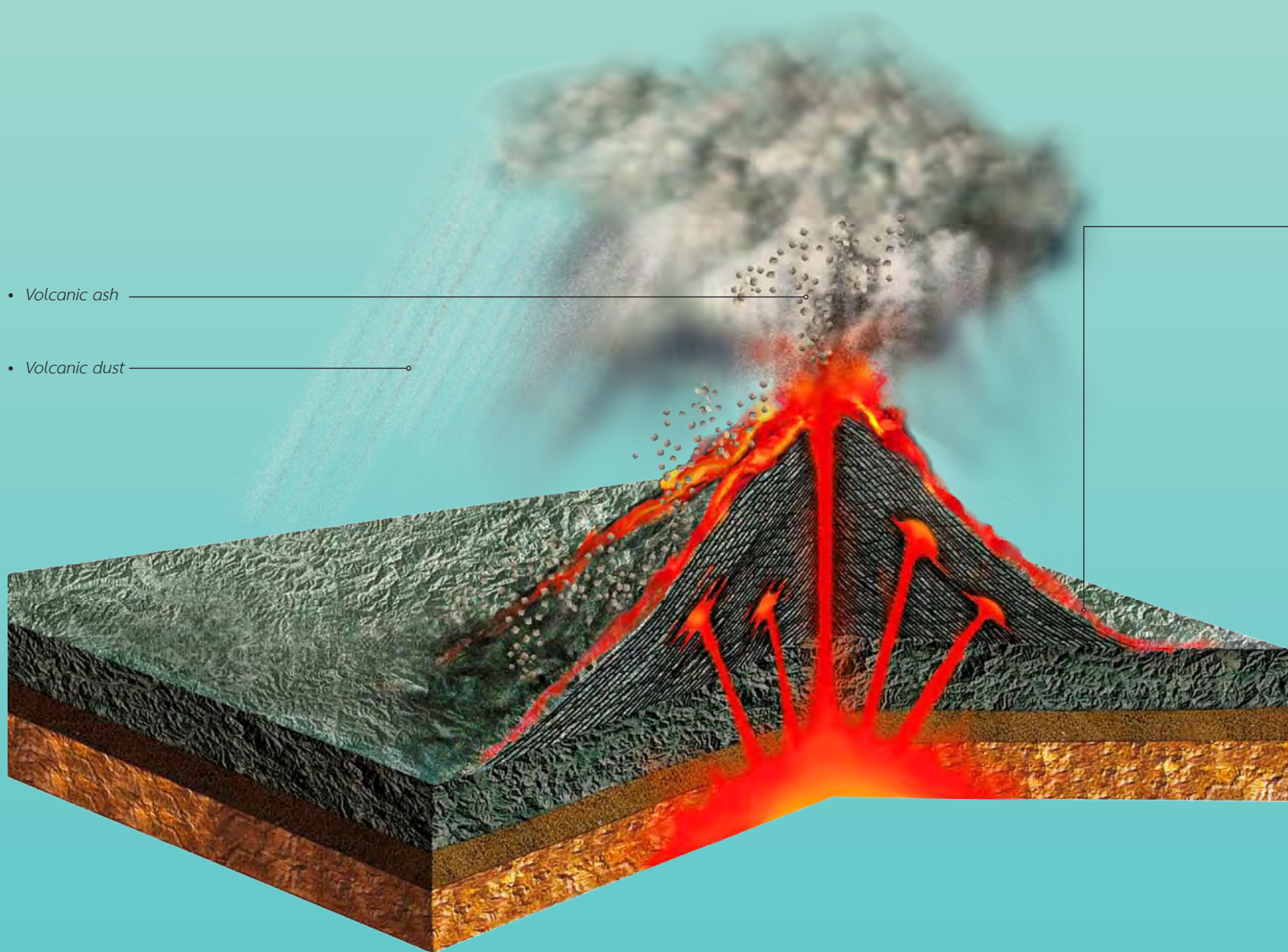
All of the Permian lives were marine organisms, both pelagic and benthic, with highly diversity including fusulinid, brachiopod, bryozoa, coral, foraminifera, worm, bivalve, gastropod and ammonite.

Fossil Evidence



- **Coral found in Loei Province.** Coral lives in a shallow sea where sunlight can be reached with a warm climate, therefore, coral fossils are usually found in limestone, especially of the Permian Age.
- **Fusulinid found in Petchabun Province.** Fusulinids are unicellular organisms with the shape of a grain of rice of approximately 0.5 - 1 cm long. Fusulinid began to appear in the Late Carboniferous and became extinct at the end of the Permian. Because of that, it is very useful to use fusulinids as an index fossil for the rock unit formed during 299 - 251 Ma.
- **Ammonoids found at Khao Chonto, Petchabun Province.** Ammonoids are in the same class with the recent sea squids, characterized by thick external shell characterized by ornaments and suturing. Most ammonoids float near to the sea surface.
- **Alatoconcha found at Khao Thong, Saraburi Province.** Alatoconcha is a shallow marine animal of Alatoconchidae that had adapted to its habitat in the warm sea area in Thailand. The fossils were found in the rock of Saraburi Group in a number of provinces including Saraburi, Lopburi, Nakhon Ratchasima, Nakorn Sawan. It was also found in rocks of Ratchaburi Group in Chumphon Province.





• Volcanic bomb found in Lampang Province.

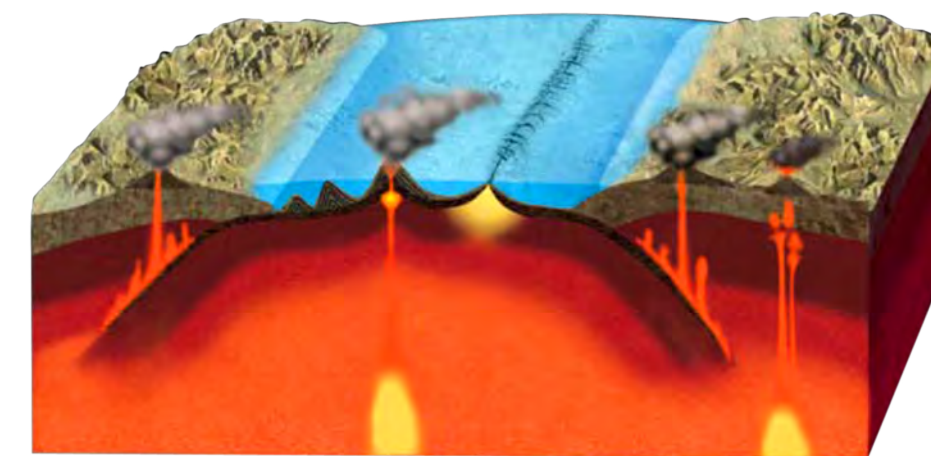


• Agglomerate found in Hew Suwat Waterfall Area clearly showing the alignment of rhyolite.

During the end of Permian and the beginning of Triassic, about 250 million years ago (Ma), a series of oceanic ridges began to rise along the area between the Shan-Thai and Indochina Plates. The event had caused the subduction of the oceanic lithospheric plate beneath those two continental plates, which in turn rapidly moved toward each other along with violent volcanic eruptions along those two subduction zones causing earthquakes, land subsidence, and lifting in Thailand. This global tectonic event caused the major extinction of many plants and animals, especially the marine life, e.g. trilobite and some species of nautiloid and brachiopod.

The evidence of these two volcanic belts is recently obvious, the first belt located along the area ranging from Chiang Rai, Lanpang and Sukho Thai Provinces down to Narathiwat Province, while the second one is in the area ranging from Loei Province down to the southwestern rim of the Khorat Plateau. The belts are generally composed of flow layers of agglomerate, tuff, rhyolite, andesite and basalt; and some parts of them have been intruded by igneous rocks.

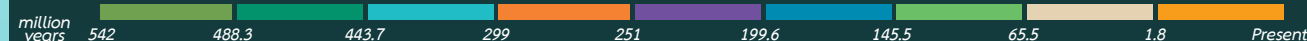
The volcanic eruptions spilled out pyroclastic sediments of various types into the atmosphere which resulted in the fine volcanic dust being blown by the wind for great distances and depositing to become tuffaceous rocks. Hot volcanic ashes, along with gases and water vapours, spewed out from volcanic vents and fell down on the slope of the volcanoes and flowed along the slope, cooled down and turned to ash-flow tuff or ignimbrite. Large pieces of pyroclastic materials such as volcanic bombs or lapilli always deposited near to the volcanoes to form agglomerate.



• The heat released from the Earth's inner layers is a driving force that has broken the mid oceanic ridge and pushed the heavier oceanic lithospheric plates to subduct to the west beneath the Shan-Thai Plate and to the east beneath the Indochina Plate, causing the violent explosions of the volcanoes in the volcanic belts lying along the subduction zones.

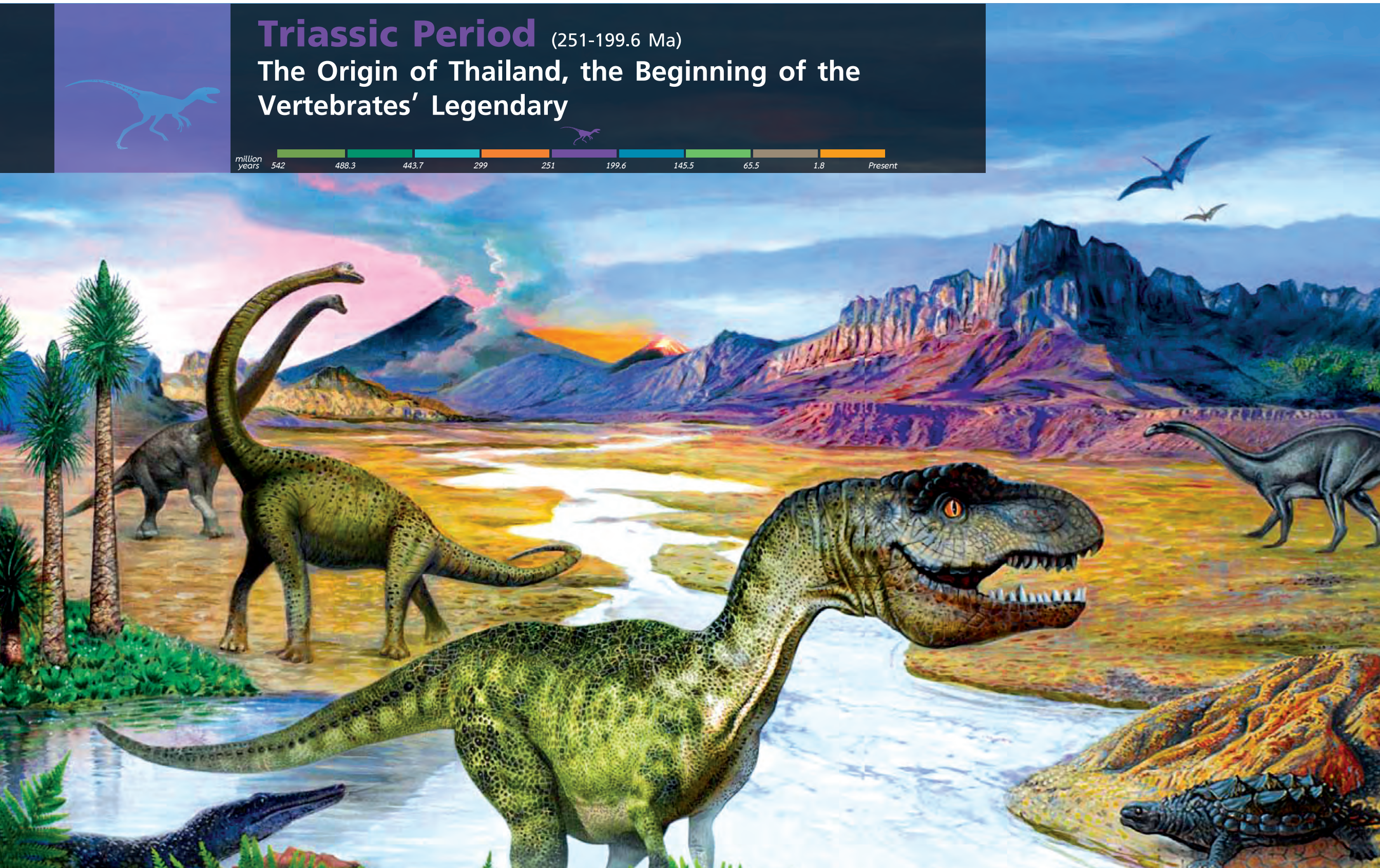
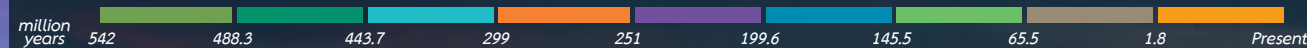
Permian-Triassic Period (250 Ma)

Furious Earth, Earthquake, Thundering Volcanic Eruption



Triassic Period (251-199.6 Ma)

The Origin of Thailand, the Beginning of the Vertebrates' Legendary



During the Early Triassic period or around 251-220 million years ago (Ma), the subduction of the oceanic plates continued to occur and created many trenches in Thailand. The major trenches are the Phrae-Nan-Lampang-Utaradit Trench, Kanchanaburi Trench and Songkhla-Yala-Narathiwat Trench. The depositions of marine sediments from coastal plains to these trenches created very thick sequences of sedimentary rocks, mapped as the Lampang Group, including shale, clay stone and sandstones which deposited in turbid water interbedded with limestone. New species of marine lives and those survived from the Permian extinction, mainly benthic organisms, e.g. ammonite, bivalve, coral, algae and sponge fossils have been found in the sedimentary rocks of the Lampang Group.

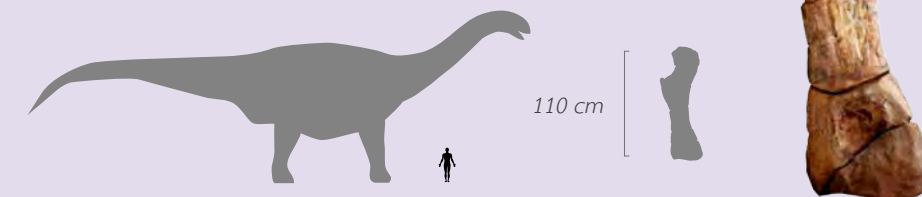
During Late Triassic or around 230-200 Ma, the subduction of the oceanic plates continued to occur until the Shan-Thai Plate joined with the Indochina Plate to become one piece of landmass of Thailand. The violence of the event had resulted in the uplifting of the area along the suture zone and the widely granitic intrusions, which raised the entire Thailand up over sea level, and the formation of many vast flat plains, e.g. the whole northeast part and in Loei, Pitsanulok, Phayao and Nan Provinces. Later, the formation of the Lower Khorat Group began by sedimentary depositions of gravels, sands, and silt on lowlands. Volcanic eruptions in the northern part of Thailand still occasionally occurred. The Triassic period is the time when the vertebrate animals such as dinosaurs, fresh - water crocodiles, reptiles, turtles, as well as a number of seed plants, began to rise.

Fossils Evidence

- **Bones and teeth of Phytosaur**, found in Loei Province. Phytosaur, the ancient animal similar to the ancient crocodile lived through the Late Triassic. Only fossils of the jaws and teeth were found.





- ***Isanosaurus attavipachi***, found in Chaiyaphum Province. The oldest plant-eating dinosaur, with an average length of 13 - 15 meters, lived during the Late Triassic. Its neck, tail and back bone fossils were found in the rock of the Nam Phong Formation.



During the Jurassic period or around 199.6-145.5 million years ago (Ma), the Shan-Thai and Indochina Plates were completely connected. Under the alternative humid and arid climates, the degradation process started by lowering the bedrocks and transported sand, silt and clay to the lowlands. The deposited sediments were later formed as parts of the Khorat Group. Almost the entire areas of Thailand were alluvial plains and marshlands, except the ranges lying along the suture zone and the recent Chiang Mai-Tanaosi mountain range.

According to the sedimentation pattern of the sedimentary rocks indicates that sediments found during Middle to Late Jurassic times deposited in the environment of meandering streams with strong and turbulent running water resulting in the sedimentation along both sides of the river plain and marshes. The sedimentation continued until about the end of the Jurassic period and the beginning of Cretaceous period, when the sedimentation changed to the braided stream environment. Such fertile ecosystems had resulted in the flourishing of plants and vertebrate animals like dinosaurs, fresh water crocodiles, reptiles, turtles, including the *Lepidotes* fish.


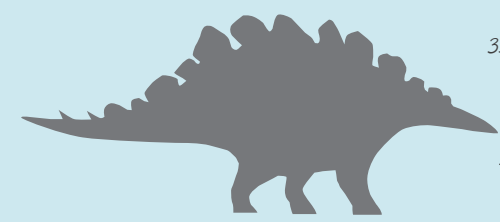

Fossils Evidence

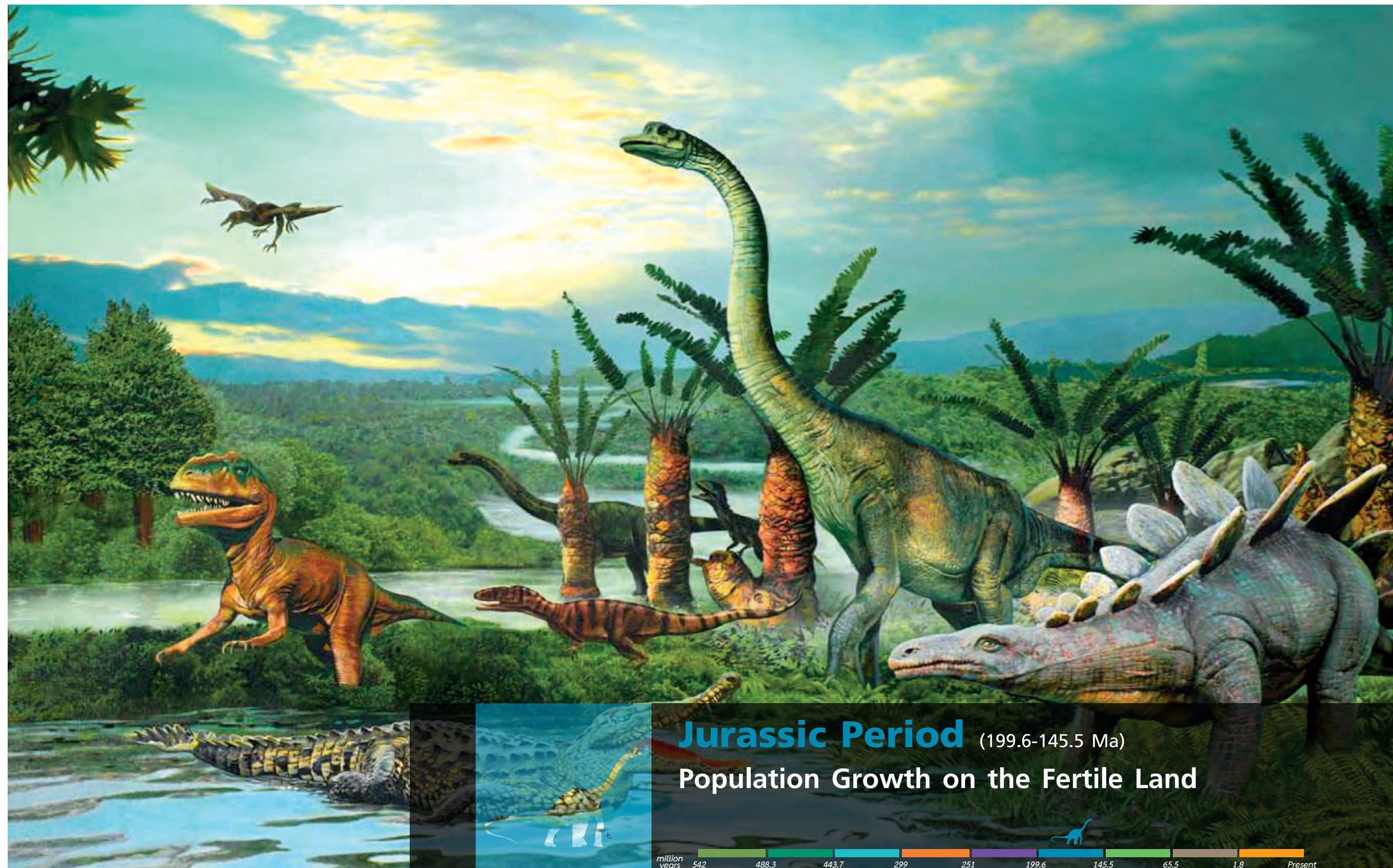
30 cm

- Nam Chan Fishes: *Lepidotes buddhabutrensis***, found in Kalasin Province. The Nam Chan fishes used to live during Late Jurassic time to Early Cretaceous. These herbivorous fishes, 30-60 cm long, with hard rhombus shaped scales had died out 65 Ma.

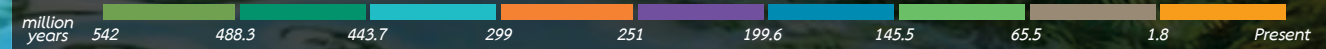
- Stegosaurid dinosaur**, found in Kalasin Province. Jurassic plant-eating Stegosaurid, a 15 meter long dinosaur, was firstly found in the rock of the Phu Kraueng Formation. The fossils found include the spine bone with the part that used to be connected to the back plate.

35 cm

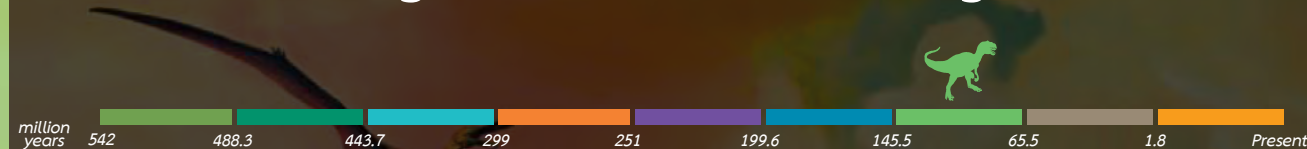


Jurassic Period (199.6-145.5 Ma)
 Population Growth on the Fertile Land



Cretaceous Period (145.5-65.5 Ma)

The Golden Age of Dinosaur, Heading toward the End

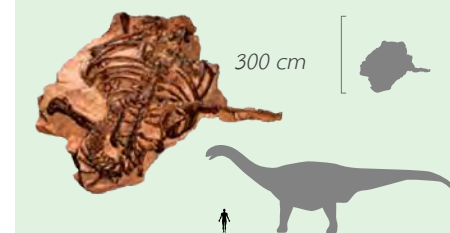


During the Cretaceous period or around 145.5-65.5 million years ago (Ma), sedimentation of sand, silt and clay still played an important role in alluvial plains in the northeastern, northern and southern parts of Thailand. The climate was getting warmer and more arid until the end of the period or about 93 Ma when the environment changed to salt-lake by a transgression on sea water. Due to the hot and arid weather, vast amount of water in the lake evaporated leaving behind evaporites that later became thick beds of rocksalt and potash minerals in the north-eastern part of Thailand. This evaporite formation has been mapped as Maha Sarakham Formation. In the Late Cretaceous, the northeastern part and the eastern of the northern part of Thailand were deserts where the thick beds of fine grained sand were deposited as the topmost formation of the Khorat Group. The top of this formation indicates the end of sedimentations at the end of Cretaceous.

Most of the dinosaur fossils were found in the northeast and some found in the north, south and west of Thailand. The abundance of dinosaur bones, fangs, teeth and footprints of various species found in red beds of the Khorat Group confirms the flourishing age of dinosaurs in Thailand during the Cretaceous period.

At the end of the Cretaceous period, the great extinction of dinosaur emerged worldwide, including Thailand. Some scientists believe that the event occurred as a result of extensive mega volcanic explosions. Some believe that the Earth was hit by large meteorites that caused tremendous amount of terrestrial dust to float into the sky and blocked the sunlight from reaching the ground surface for a very long period of time. This might have resulted in death of many plants and animals, especially the big ones like dinosaurs that ended up in extinction. Recent findings confirm the meteor hypothesis through the finding of iridium element, which is normally abundant in the meteorite, accumulated in an anomalous amount in thin layers of sedimentary rocks occurred during the boundary between Cretaceous and Paleogene times worldwide.

Fossils Evidence

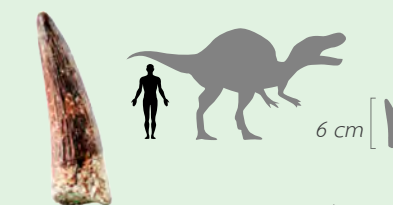


- **Bone fossils and teeth of the plant-eating dinosaur (sauropod) “*Phuwiangosaurus sirindhornae*”**, found in Kalasin and Khon Kaen Provinces. *Phuwiangosaurus sirindhornae*, a 15 - 20 meter long plant-eating dinosaur lived in the Early Cretaceous. The fossils of this long-neck sauropod were found in the rock of the Sao Khua Formation. The name “Sirindhornae” was given to highly honour Her Royal Highness Princess Maha Chakri Sirindhorn, who is interested in paleontology.



- **Tortoise shell “*Isanemys srisuki*”**, found in Nong Bua Lamphu Province. The fossil found was an almost complete shell of an ancient fresh-water tortoise that lived during the Early Cretaceous.

- **Teeth of fish-eating dinosaur “*Siamosaurus suteethorni*”**, found in Khon Kaen Province. The fossils found were sharp ended teeth of the seven meter long fish-eating dinosaur with three finger claws. This long and narrow jaw Spinosauridae dinosaur lived during the Early Cretaceous.



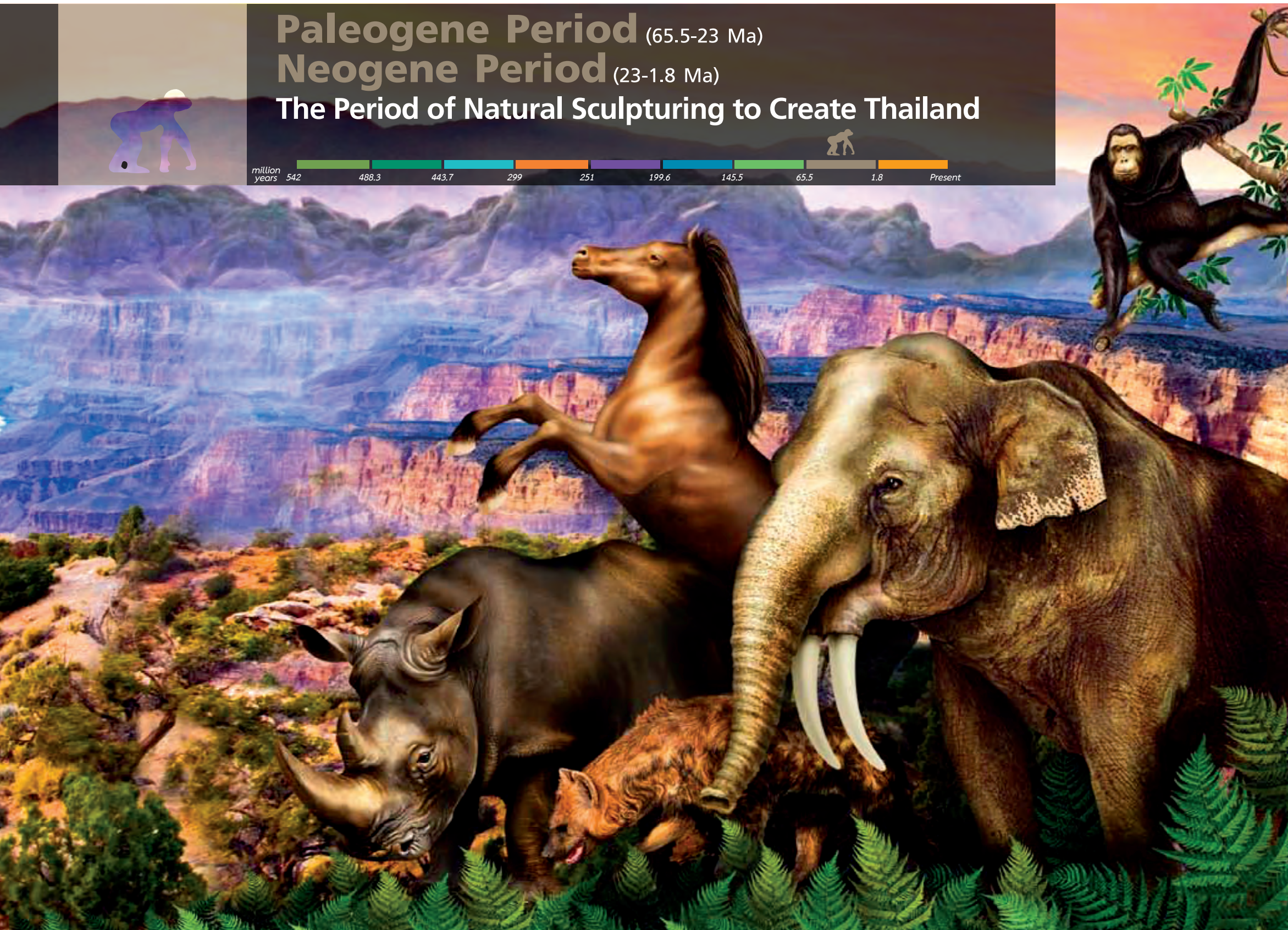
- **Fossil of *Psittacosaurus sattayaraki***, found in Chaiyaphum Province. This small plant-eating dinosaur with its mouth similar to a parrot’s beak, and quick movement, lived during the Early Cretaceous. The body is approximately 1.5 m long. Fossils found include molar teeth and the upper and lower teeth.



Paleogene Period (65.5-23 Ma)

Neogene Period (23-1.8 Ma)

The Period of Natural Sculpturing to Create Thailand



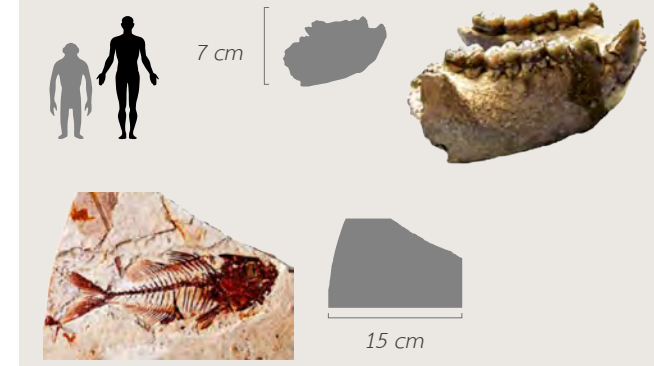
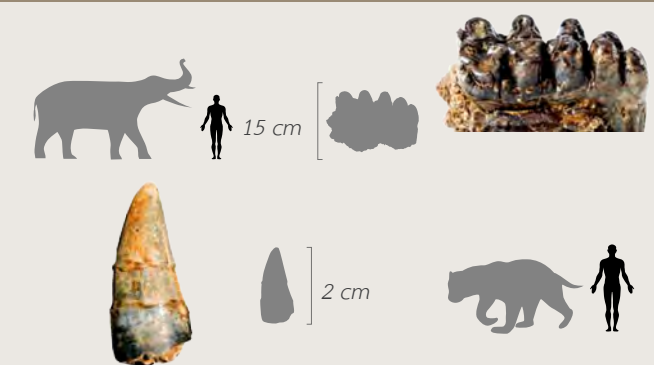
During the Early Paleogene or about 55 million years ago (Ma), the Indian continental plate moved from the south and collided with Eurasian continental plate resulting in the uplift of the Everest and the Tibet Plateau. The collision consequentially uplifted the northern, western and southern parts of Thailand and formed mountain ranges with intermountain plains. The Khorat plain was lifted up as a plateau, as well as creations of faults, fractures and joints in all the rock units in Thailand. At the end of the Paleogene period the subsidence of the Central Plain and the opening of the Gulf of Thailand occurred by the Oligocene extension.

From the Neogene period, about 23 Ma, to present, the major rivers played a key role on erosion, transportation and deposition of sediments. All the highlands have been sculpted and most of the sediments were washed down to accumulate along the flat plains and shallow water lakes. This period was truly the beginning of the time nature began to carve Thailand to become how it is today.

Neogene was the golden age of the mammals and reptiles in the northeast. The Khorat ape, which is one of the closest ancestors of orangutans, was found along with other fossils, e.g. elephant, rhinos, horse, large tortoise and crocodile. In the north and the east of Thailand, more than 20 mammals have been found in the lignite mines, e.g. “Chiang Muan Ape” the ancestor of apes, mastodon, flying lemur, deer, pig and mouse. Moreover, tortoise, fish, crocodile, snake and plenty of fresh water gastropods and bivalves were found in lignite seams. In Petchabun Province, at least nine species of fresh water fish fossils have been found, six of them were new species.

Fossils Evidence

- Tetralophodon elephant teeth, found in Nakhon Ratchasima Province. Tetralophodon elephant was the primitive types of mammals with the same size as recent elephant. The Neogene fossil found is a jaw with teeth.
- Fossil of *Maemohcyon potisatifi* found in Mae Mo District, Lampang Province. A new meat-eating, large sized, of the Amphicyonidae Trouessart Family with a combined dog-bear characteristics. The fossils found included 4 molar teeth.

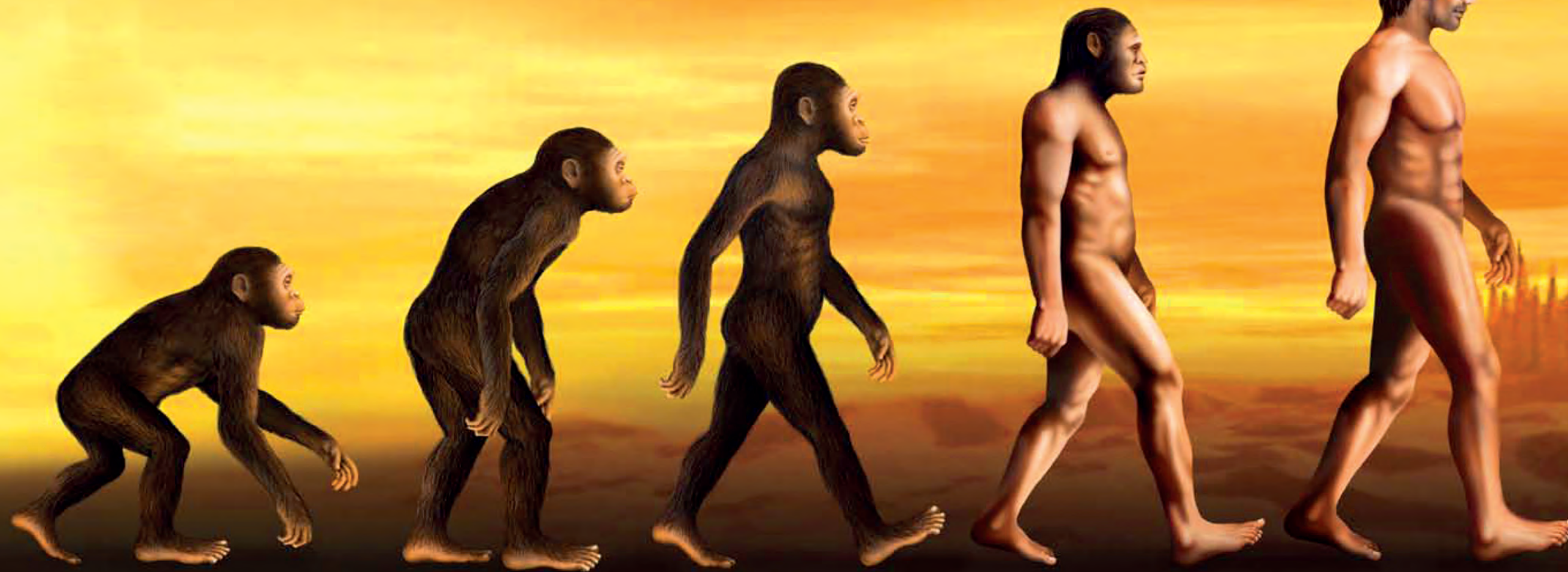


- Fossil of *Khoratpithecus piriyai*, found in Chaloem Phra Kiat District, Nakhon Ratchasima Province. This Khorat ape has a special characteristic, which is its large size, the same size as the present orangutan. The found fossil confirms the existence of the orangutan’s ancestors in Thailand.
- *Parambassis paleosiamensis* fish bone, found in Phetchabun Province. The new found fresh water fish bones of the Miocene epoch belong to *Parambassis* group, *Ambassis* family, with 7.5 cm length from head to tail.



Quaternary Period (1.8 Ma – Present)

Ready to be the World Heritage



According to the geological time scale, the Quaternary is the last period that covers the time from 1.5 million years ago to the present, including alternating glacial and interglacial periods. The weathering and erosion continued to work on rocks located within Thailand from the previous period. Wind and running water were still the main erosional agents. The erosion occurred deep into the rock forming steep valleys and washing all sediments, rock fragments, gravels, sand and mud to deposit along the bottom of the valleys, hill slopes, streams, plains and deltas.

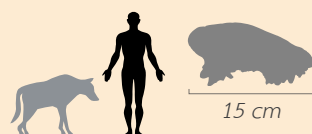
The creatures found during this period comprised the mammals that continued live through the present, monocotyledon and dicotyledon plants. Moreover, some expected extinct mammals found are Hyena Crocutas, ancient Rhinoceridas and giant pandas and additional molluscs deposited during the last transgression of sea water, about 6,000 years ago.

At the same time, running water cut through the rock beds to create various types of landforms which varied with bedrock types, e.g. karst topography in limestone terrains, high peaks in hard rock, small hills in lower resistant rocks, and also created cliffs, waterfalls, valleys and sea shores. The weathering and erosion processes gradually changed the highland or plateau to a number of smaller highlands called mesa and butte. These processes also carved a cuesta from a hill with gently mono incline rock beds. The natural sculptor creates beautiful and attractive landforms which become geological conservation sites throughout Thailand.

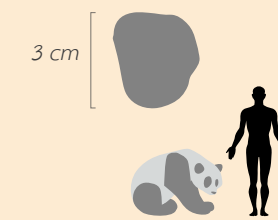
Fossils Evidence



- **Molar teeth of a Hyena Crocuta crocuta** found in Nakorn Ratchasima Province. According to the skull and teeth found, it is estimated that it had a body of 1.0 - 1.6 meters long. Hyenas live in the open and dry area. This can clearly imply the Pleistocene's weather during the Early Quaternary.



- **Rhinoceridas' bone**, found in Kalasin Province. Rhinoceridas, an ancient large hoofed animal, had a characteristic similar to the present rhinos. It lived in the Early Pleistocene of the Quaternary period.



- **Grinder teeth of the giant panda "Ailuropoda melanoleuca baconi"**, found in Chaiyaphum Province. The giant panda, Ailuropoda melanoleuca baconi, is the meat-eating mammal lived in the temperate to cold areas. The finding of the bones of giant panda in Chaiyaphum Province informs us that the area used to have cold weather during the Quaternary.

Geological Sites in Thailand



The geological sites in Thailand are both natural tourism sites and geological conservation sites. They are all related to "geology" which is the scientific study of the substances composing the earth, the processes affecting these substances and their results and including ever-existing living things on earth. Some natural tourism sites are very well-known and are also geologically prominent. They may contain the history or the evolutionary evidence of Thailand that can be academically referred.

Recently, over 830 geological sites from all over the country have been explored and inventoried by the Department of Mineral Resources.

Using geological knowledge to explain the story of any geological site serves not only to publicize the knowledge in order to raise the academic interesting of the site, but also to increase public awareness of the invaluable geological heritage conservation.

Any geological site in Thailand may be created by a combination of many geological processes; however, they could be classified base on the related basis and the prominent of the sites into 3 categories.

- The geological sites related to surface geological processes.
- The geological sites with prominent rocks and fossils.
- The geological sites related to geological structures.

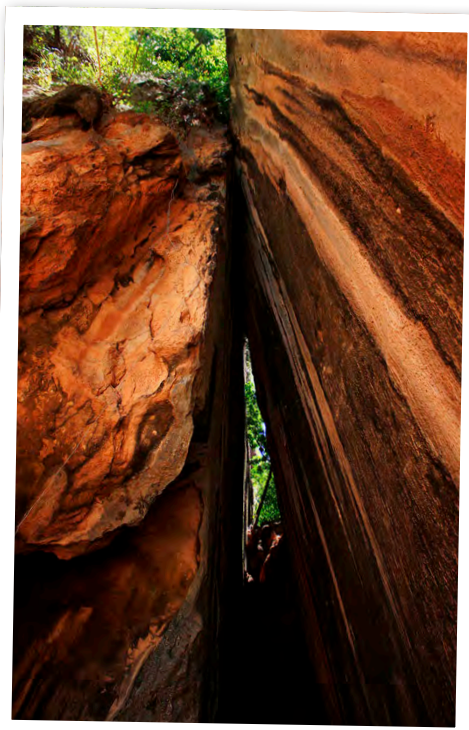


• **The geological sites related to surface geological processes usually involve any geological change on the Earth's surface.**

1. **Degradation** is the naturally changing, lower the level, of the Earth's crust, where the surface geological processes may create beautiful, unusual looking geological sites in various areas:-
 - Weathering, chemically and physically, and erosion are the processes that change the shape of any area by some media, e.g. the water, the wind, the wave, the sun, the animal and plant.
 - Weathering and erosion by sea water, sea wave, tidal wave and wind usually found at the pointed cliffs.
 - Erosion by stream, water is the main medium of erosion of bedrocks.
2. **Aggradation** is the raise of the ground level by the deposition of sediments transported by various media, e.g. stream, wind and sea wave, which may create prominent geological sites. The aggradation may be caused by different methods:-
 - The deposition of sand by sea water creates various coastal landforms, e.g. sea shore, tombolo, split, beach dune, longshore bar, etc.
 - The deposition of sediments by streams creates different landforms, e.g. alluvial fan, sand bar, delta, etc.
 - The deposition of sediments by wind, e.g. sand dune and loess.



• The geological sites with prominent rocks and fossils.



Most of the geological sites with prominent rocks are geological reference sites located in beautiful natural landforms which are very attractive to tourists by the uniqueness of the rocks. There are many types of such geological sites, as follow:-

- Karst topography in limestone terrains, e.g. tower karst, haystack hills and caves which can be seen at Khao Sam Roi Yod, Prachuap Khiri Khan Province.
- Caves and their depositional and erosional features can be found in all parts of the country, e.g. Chiang Dao Cave, Chiang Mai Province and Kaeo Komol Cave, Mae Hong Son Province.
- Eroded igneous rocks which present strength fascinating landforms, e.g. Hin Ta and Hin Yai on Ko Samui, Surat Thani Province.
- Additionally, geological sites developed from abandon mines, e.g. Khao Chi Chan where a gigantic golden drawing of the Lord Buddha was engraved on the steep limestone cliff.

Fossil sites are one of the geological sites where fossils or trace fossils are preserved within the rocks. A fossil is formed by a fossilization of the whole or only some parts of any ancient-creature or its habitat or trace, within a sedimentary unit. The fossiliferous geological sites are importance geological references of the age, diversity and evolution of ancient creatures.



• The geological sites related to geological structures.

Almost all of the geological sites related to geological structures are rare, beautiful and attractive. The sites are found from geological structures, positions of the rock units and internal structures which formed simultaneous with or after the depositions, for example:-

- The syn-deposit geological structures, e.g. beddings, cross beddings and ripple marks are able to define the depositional environment.
- The post-deposit geological structures, e.g. folds, faults, fractures, etc. are created by deformations which are caused by external forces.
- The extrusions of magma, gases and volcanic ash from under the crust would form volcanos, which are obvious topographic features. Volcanic bombs, volcanic glasses and columnar joints are typical volcanic features, generally found around the craters.
- Hot springs caused by leakages of underground hot water to the Earth's surface. When surface water is infiltrated and heated up by geothermal energy, its temperature and pressure would be gradually raised up until it is squeezed out, through fractures, as a hot spring.



**The Invaluable
Natural Heritage**
Thai Geological Site

01

Ob Luang

The only place in Thailand to admire the sounds of vigorously flowing rivers through a gigantic gorge harmonizing with singing bird songs is "Ob Luang. While crossing the bridge over the gorge, the scenes of Mae Cham River below and surrounded panoramas would amaze every visitor. Reaching on the other side of the gorge cliff, a prehistoric site of about 3,500-2,500 years B.C. is another interesting site to observe.

Location:

Ob Luang is about 105 km south of Chiang Mai City, it is located in Ob Luang National Park, Amphoe Mae Chaem, Changwat Chiang Mai. From Chiang Mai city, using highway number 108 to the south for about 87 km to Amphoe Hot and turn right to road number 1088. Travelling about 16 km or about 20 minutes from Amphoe Hot to the west, Ob Luang is sitting on the right hand side of the road, though the entrance of the National Park is 1 km further. There are many other geosites on both sides of this road which runs beside Mae Chaem River. Those geosites, e.g. Mae Bua Kam waterfall, Mae Chon waterfall and Theppanom hot spring are less than 15 km away from Ob Luang.



Geology:



• The partial melting in the Ob Luang migmatites.

Ob Luang is a big gorge situated on a high grade metamorphic terrain. At about 220 million years ago, the 600 million years old parent rocks were strongly metamorphosed with partially melt and recrystallized. This area was metamorphosed again around 55-30 million years ago and turned the rocks to be “Migmatite” with bands of different color crystals (foliation). Migmatites are comprised of many different rocks, e.g. foliated porphyritic granite, pale colored granite, biotite gneiss, quartzo-feldspartic gneiss, schist and marble. Quartz, aplite and pegmatite veins with rotated crystals are typically found cutting through these rocks.

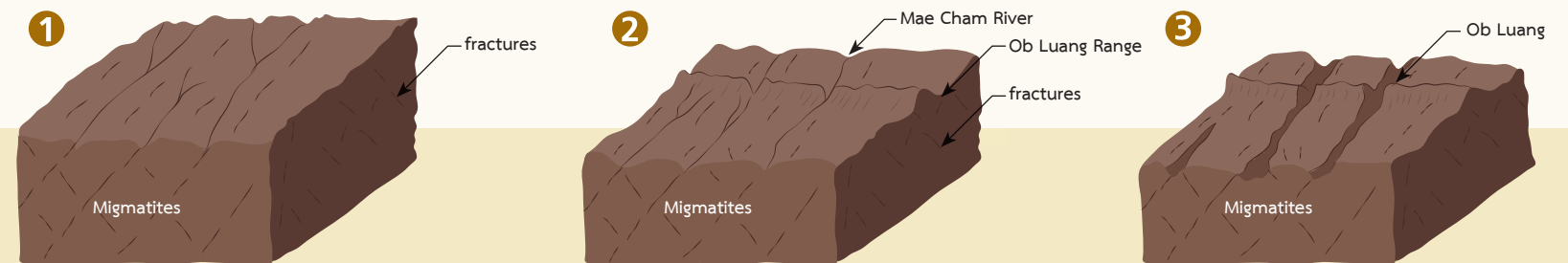


• Ob Luang looking from the east.

Ob Luang was uplifted, 55-30 million years ago, from the depth of over 10 Km to the Earth’s surface and formed the highest mountain range in Thailand. The crustal uplifting caused fractures which were weak zones and ease to erosion. Fractures in this area has been expanded, 1.6 million years ago, and gradually eroded by Mae Chaem River. Since this terrain has been continuously uplifted, Mae Chaem River is also still carving down and hence the big gorge of Ob Luang becomes deeper.



The Origin of Ob Luang



1 The uplifting caused fractures within the rocks and began the development of streams.

2 Weathering and erosional processes have carved the topography and created the Ob Luang Range.

3 The vertical erosion has gradually created the Ob Luang gorge.



• The looking up stream scenic of the Mae Chaem River.



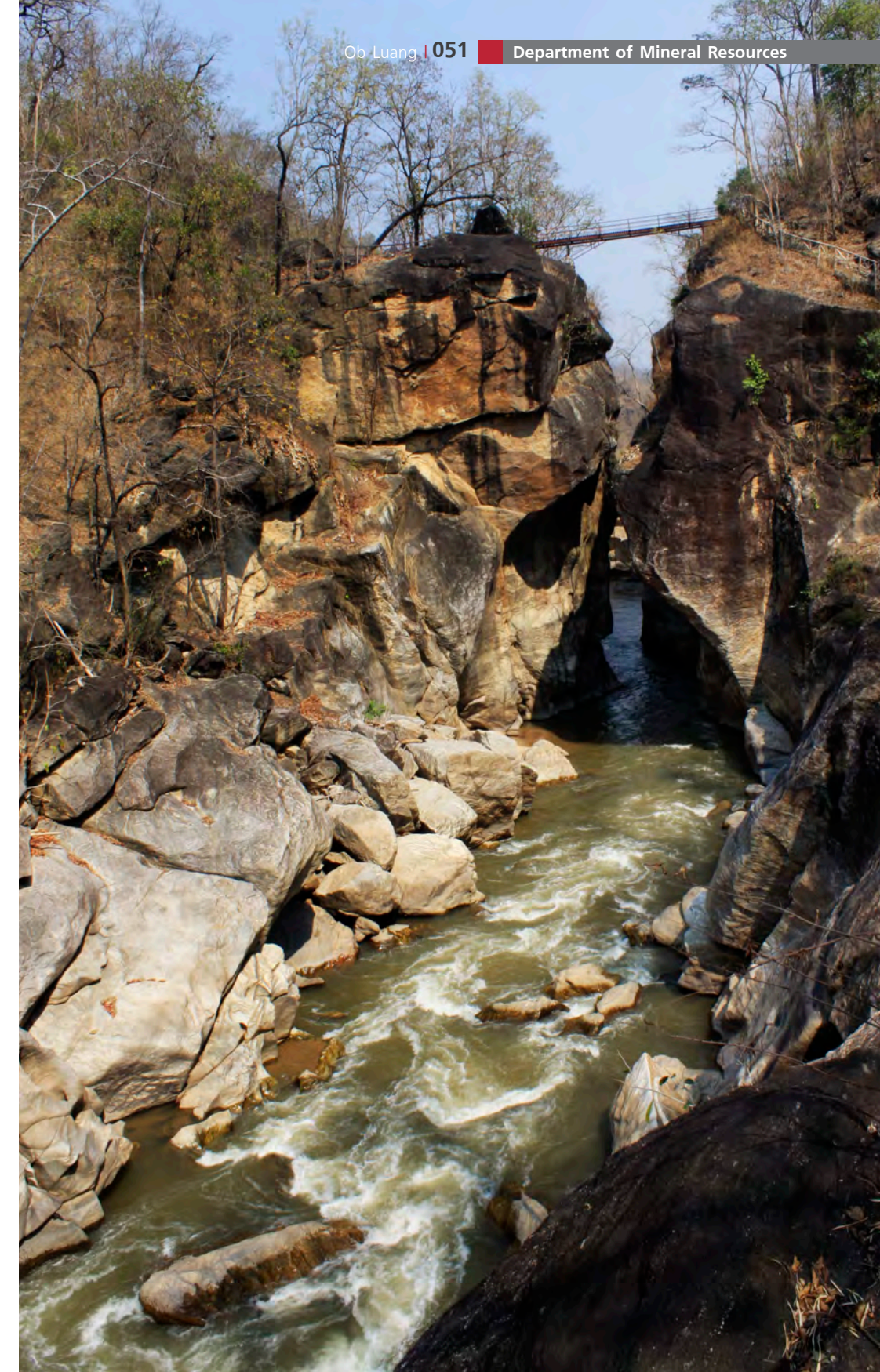
• The Ob Luang foliated gneiss.

■ **The highlight:** -----

The words “Ob Luang” are local words which mean a big gorge (Ob means gorge and Luang is big). The most prominent point of this geosite is the steep narrow gorge, running through by Mae Chaem River. This river has already carved about 32 m deep into the foliated migmatite gorge which is about 300 m wide. The flanks of Ob Luang are not vertically parallel; the narrow most point is only 2 m. These occurred due to the vertical weak zone fractures, the differential resistance of the migmatite and the powerful river.



• Various textures of the Ob Luang bedrocks are pieces of evidence of the long evolutions of the Earth's crust.



• The foliated migmatite gorge is 32 m deep with the narrow most point of only 2 m



Ob Luang allows Mae Chaem River to pass through for joining Ping River, one of Thailand's main streams, to provide water and fertility to the Chiang Mai Basin and to the central part of the country. The strange looking natural carved massive wall and its internal structures caused by different rocks and the metamorphisms make Ob Luang the most famous geosite for recreation and especially for geological study and references of the evolution of the earth. Ob Luang is an extraordinary site not only for us, but also for the prehistoric human race that lived and lay buried peacefully in this area 5,500-4,500 years ago.

Mae Chaem River has taken over a million years to create Ob Luang.
Let's save this unique gorge.



• The charming scenery of the Mae Chaem River in Ob Luang, a significant geotourism site of Chiang Mai.



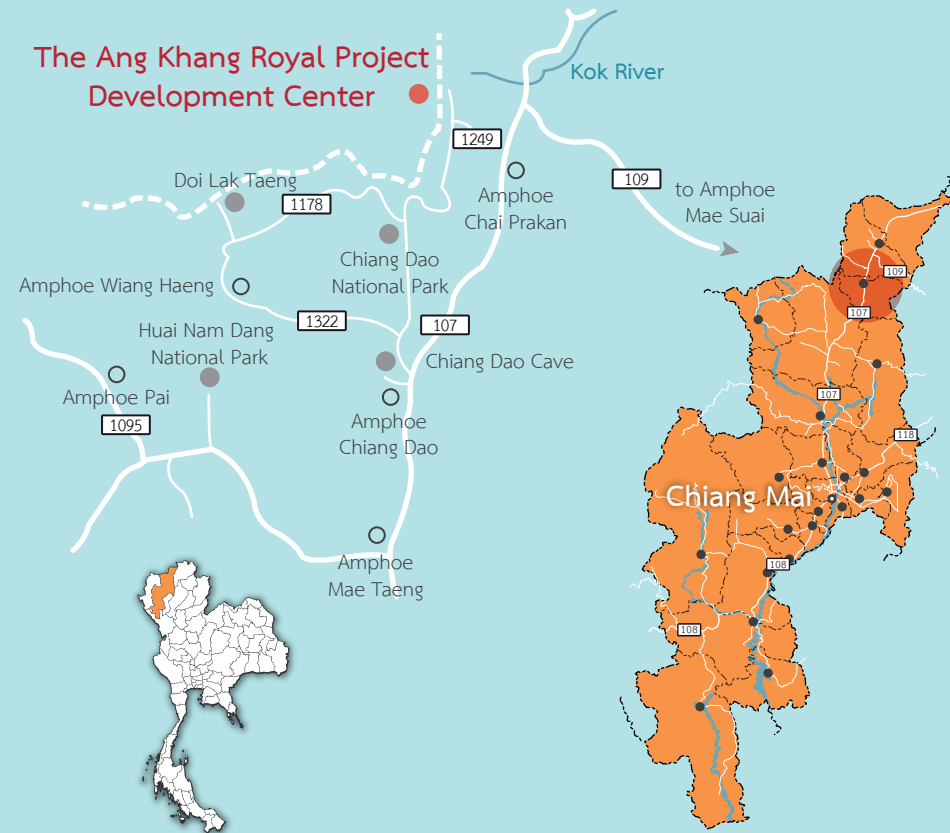
02

Doi Ang Khang

Appreciating the sunrise from a series of foggy mountain ranges and hills in the dawn, joining the simple local hill tribe's folk on a flowering landscape in the day and admiring the serene sunset in the dusk are all things one can do at Doi Ang Khang.

Location:

Doi Ang Khang is in the Doi Pha Hom Pok National Park, located in Amphoe Fang, Changwat Chiang Mai. There are two routes to travel to Doi Ang Khang. Starting from Chiang Mai city, traveling to the north using highway number 107 and then chose any route. Route A.) turn left at Km. 79, Amphoe Chiang Dao, to use road number 1178 to Bann Arhunothai - Ang Khang junction which is quite narrow but not hilly or using Route B.) by going further to Km. 137, Amphoe Chai Prakan, and turn left to road number 1249 which is rather wide but hilly and crooked. Using route A visitors can enjoy the beautiful landscapes and wild flowers on both sides of the road while route B is only for adventurers.



Geology:

Doi Ang Khang is seated on a series of sinkholes occurred in the north-south contact zone between two sedimentary rock units which are dipping to the west. The lower unit is found in the east and north of Doi Ang Khang. It composes of marine sediments of “Mae Tha Group”, e.g. sandstone, siltstone, shale and chert of Carboniferous Period (350-295 million years old). Doi Ang Khang is sitting on top of the upper unit of “Ngao Group” which includes massive limestone and volcanoclastic sediments, deposited in the Permian sea around 295-250 million years ago (Ma).



• The lapias at the Ang Khang Royal Project Development Center.

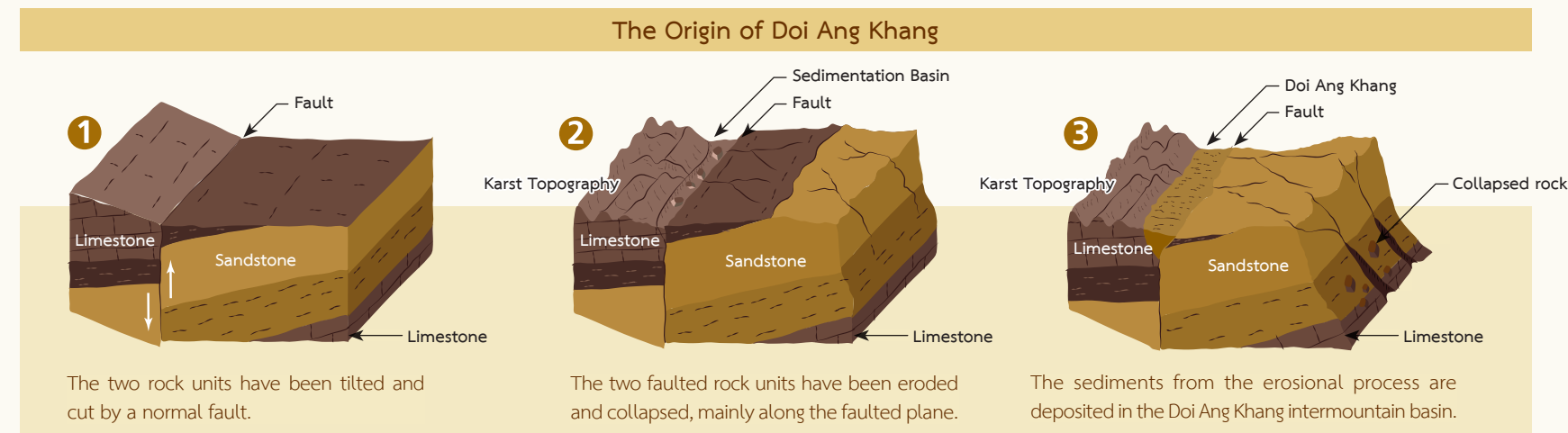


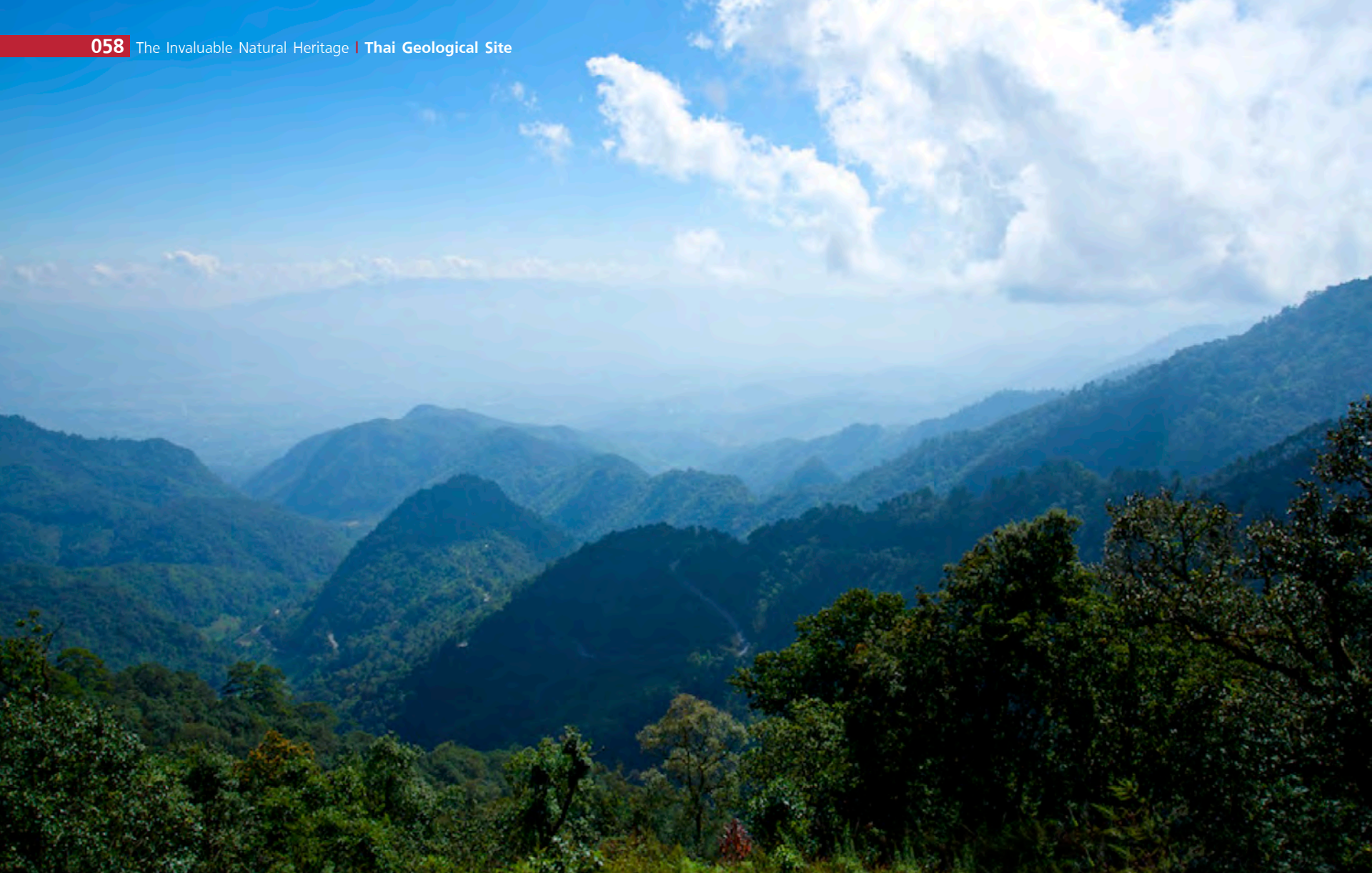
• The outcrops of dolomitic limestone, sandstone and chert at Doi Ang Khang



• The Doi Ang Khang intermountain basin.

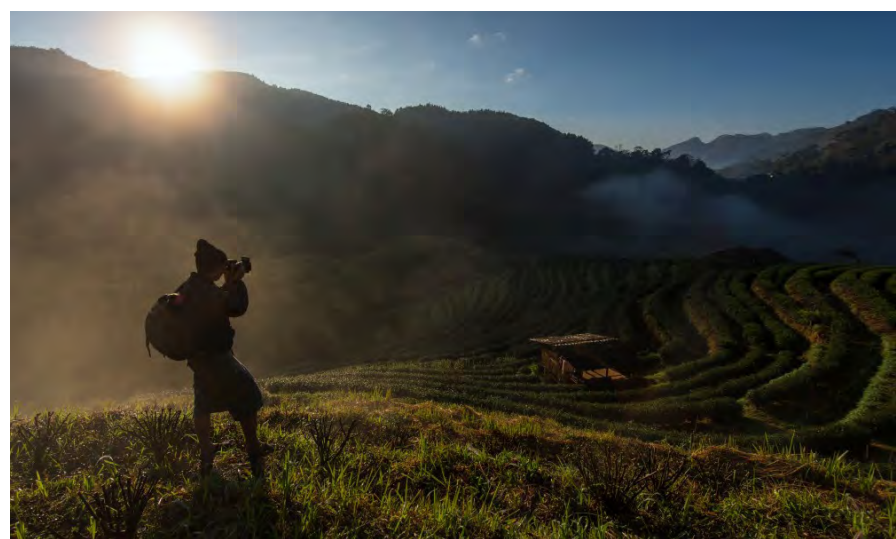
These sediments were uplifted to the Earth’s surface 220 Ma. The collision of Indian and Eurasian Plates, 55-30 Ma, caused the subsidization of the Fang Basin to the east and deformation of the rocky mountain range to the west. By the erosional process, especially along the fault and fracture zones, the dissoluble Permian limestone formed as a karst topographic terrain including uneven hills and sinkholes, while the Carboniferous rock unit formed as a mountain range with a series of high peaks including Doi Pha Hom Pok the second highest summit in Thailand.





■ The highlight:

“Doi Ang Khang” means the hill with a pan like valley, where the three words mean hill-basin-pan respectively. The elevation of about 1,400 m above Mean Sea Level keeps Doi Ang Khang cool for the whole year. The term “Thai Switzerland” assures the beauty and charm of Doi Ang Khang where all tourists dream to visit. Visitors can spend every minute admiring the nature and culture. In the dawn, one can admire the rising sun from the foggy mountain ranges with a dewy foreground or frosty foreground in winter. During the day, enjoy travelling along the Doi Ang Khang – Bann Luang – Arhunothai route where everyone can be excited with distinct spectacular landscapes, limestone cliffs



• The beautiful landforms of the Doi Ang Khang Valley, next to the Thai-Myanmar border.



• The cold and calm sea of mist in a mellow morning at Doi Ang Khang.



• The beautiful landscape and winter flowers of the Ang Khang Royal Project Development Center.

in a karst topographic terrain to the west and sandstone mountain ranges to the east. Visiting the Ang Khang Royal Project Development Center where different tribe people from 9 villages grow different kind of crops like organic vegetables, temperate fruits, ornamental flowers, organic tea and herbs and have been trained about handicraft work and being local guides. In the dusk, the sunset slowly vanishes from the sky and can be admired from the Kiew Lom View Point.

Where else could you find such a beautiful hill tribe's folk on a flowered landscape over fascinating geological features on Earth?



• The fascinated dense forest of Doi Ang Khang caused by the fertile "Terra Rossa" or red soils which are weathering products of the underline limestone.



Phu Chi Fa

The Earth has prepared bedrocks for millions of years then lifted them up and paved the top with grassland, decorated with pink and white orchid trees. That is there for everyone to walk up to and appreciate the sunrise and sunset with a foreground of the sea of mist on Phu Chi Fa.

03

Location:

Phu Chi Fa is a high peak, about 1,724 meters above mean sea level, located in the Phu Chi Fa Forest Park on the Doi Pha Mon Range, Amphoe Wiang Kaen, Changwat Chiang Rai, next to the Thai-Laos border. Phu Chi Fa is about 144 km. from Chiang Rai Province. From the city going east to Amphoe Thoeng using highway No. 1020 and continue with highway No. 1021 for 6 km. then turn left at Km. 94 to road No. 1155 which is quite narrow and crooked. At Km. 25 of road No. 1155 turn right to use road No. 1093 about 11 km. to the Thai-Laos border and then turn left to the steep and crooked road to Phu Chi Fa.



Geology:

During the Carboniferous-Permian period or about 350-250 million years ago (Ma), Phu Chi Fa was a small portion in a depositional basin where alternated marine sedimentations of limestone and clay took place. This succession of sediments has been uplifted about 55-30 Ma, in the Paleogene period, and formed a formation of thin layers of black to dark grey limestone and marble which looks like a little wrinkled pages of a book. Very thin layers of phyletic shale, about 2-3 mm, are found interbedded. The rock formation with generally fractures and slightly deformed is dipping about 30-40 degrees toward southwest.

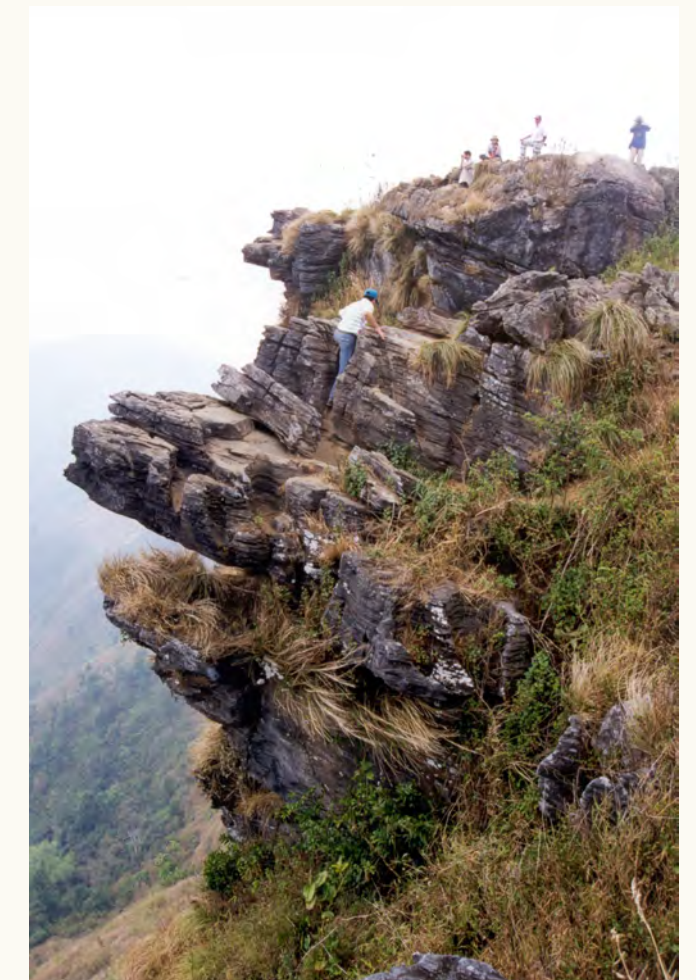


• The Phu Chi Fa peak capped with a succession of marine sedimentary rocks.



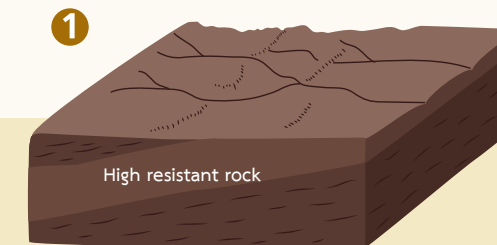
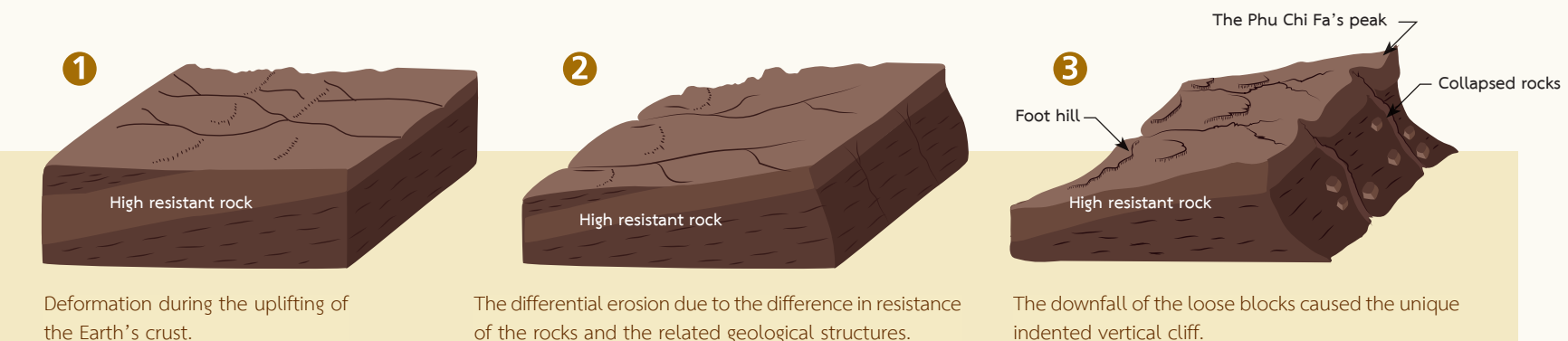
• The limestone beds, cropped out on the Phu Chi Fa's peak, have been deformed by the uplifting of the Earth's crust.

After the end of the Paleogene tectonic, the balancing surface geological process was taking place. Water was the main erosional medium which gradually carved the mountain range and the different resistant of the sedimentary beds restrained the degree of the erosion. Shale is normally less resistant and hence easily eroded while marble and limestone are more resistant and left capped the Phu Chi Fa peak. Gravitational force has helped pulled the loose blocks of eroded rocks downward forming a vertical cliff on the northeastern side with a height of over a hundred meters. Looking north, Phu Chi Fa formed as a right triangle cliff with an inclined ridge which is parallel to the bedding plane of the sedimentary rock formation beneath.



• The well-known indented cliff of Phu Chi Fa created by a dipping formation of limestone with shale interbedded.

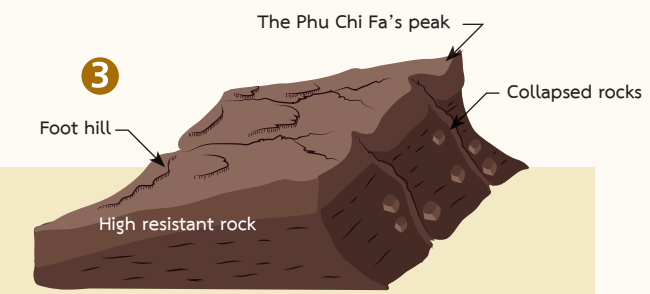
The Origin of Phu Chi Fa



1 Deformation during the uplifting of the Earth's crust.



2 The differential erosion due to the difference in resistance of the rocks and the related geological structures.



3 The downfall of the loose blocks caused the unique indented vertical cliff.



• The Phu Chi Fa's peak viewing from its ridge.



• The all-season splendors of Phu Chi Fa are the all-season creations of the nature.

■ **The highlight:** -----

Phu Chee Fa or “the Sky Pointing Mount” is a high peak where the sunny panoramic scenes can be viewed daily. The atmosphere of both sunrise and sunset with a foreground of hazed mountain ranges and the reflection of the sunlight from the distant flowing Mae Khong River in Laos can be perceived from the peak. Looking from the peak, especially in the winter with cold fresh air, the valleys around the Phu Chi Fa are shrouded in endless mist.



• *The Phu Chi Fa's beautiful dawn in the serene sea of mist.*

The vertical cliff of Phu Chi Fa is comparable to a vertical geological timescale. The lower beds represent the older geological records and different rock types represent different geneses. Not only the present environment around Phu Chi Fa that is enjoyable but the paleo-environment of the bedrocks beneath Phu Chi Fa is also very spectacular. The geological history of Phu Chi Fa has been recorded in every piece of rock and scenery. They tell us all about the origin and the sequence of events they experienced through time.

Save the present environment
to conserve the
preserved paleo-environment.



04

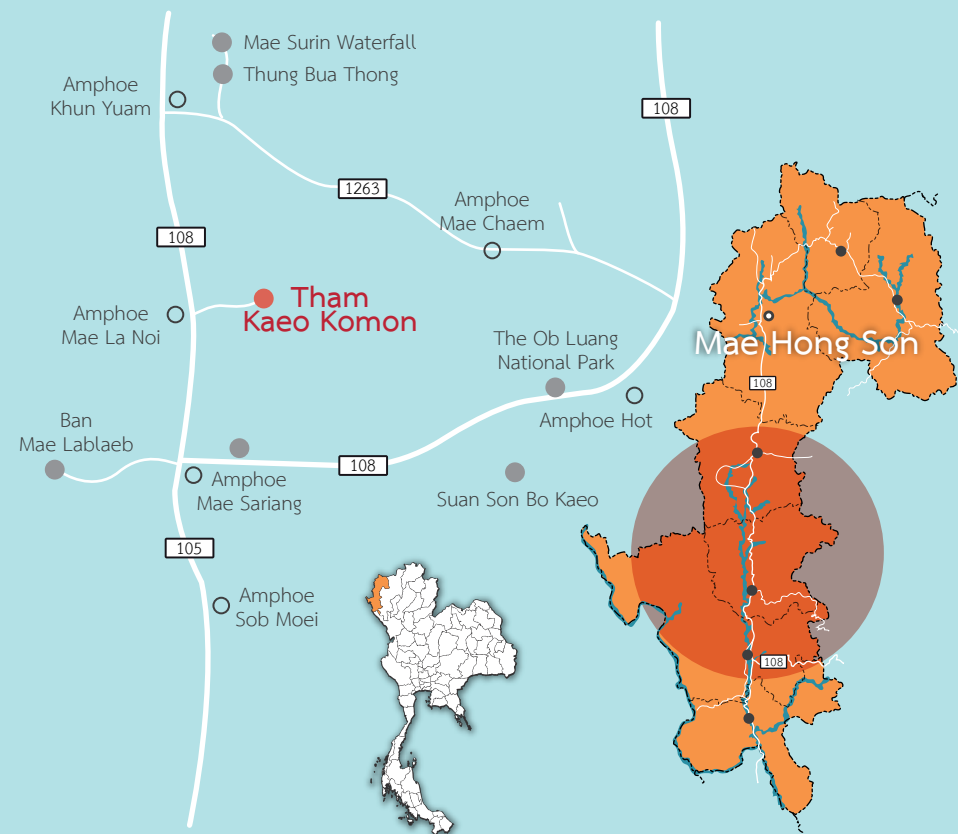
Tham Kaeo Komon

Tham Kaeo Komon is the only calcite crystal cave in Thailand and is one of the three in the world. The five cave halls are absolutely exquisite with various appearances of calcite crystals which corresponding to their royal names given by Her Majesty Queen Sirikit.



Location:

Tham Kaeo Komon is located in an abandon fluorite mine, in the Kaeo Komon Forest Park, on the Doi Tham Hill, Amphoe Mae La Noi, Changwat Mae Hong Son. Amphoe Mae La Noi is on the highway No. 108 which connects Mae Hong Son Province to Chiang Mai Province. Amphoe Mae La Noi can be reached by travelling south 134 km from Mae Hong Son or doing west 225 km from Chiang Mai. The Kaeo Komon Forest Park is 5 km. further east from the Mae La Noi Hospital. There are lots of natural sites to be visited along the highway No. 108 including waterfalls, hot springs, forest parks, geosites, caves, etc.

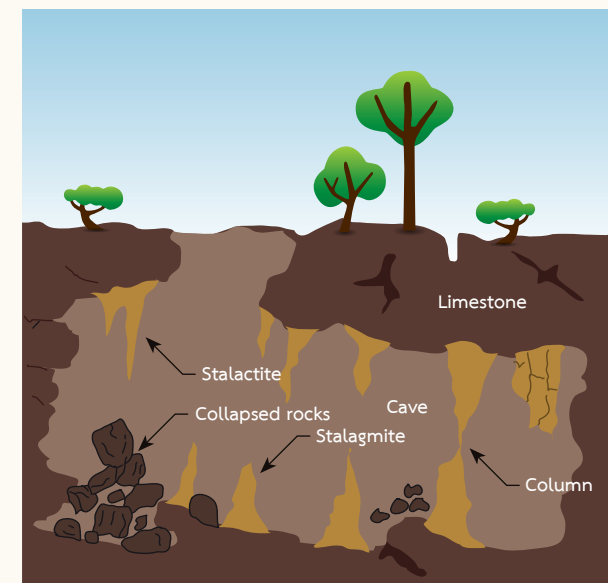


Geology:

The limestone and clay deposited in the Ordovician sea, about 440 million years ago (Ma), have been mapped as the Thung Song Group which is found similarly all over Thailand. The Thung Song Group in the north and west of Thailand has been metamorphosed, about 30 Ma and systems of joints were developed. The movements of the slightly acidic groundwater along the joint structures have created underground drainage systems. The uplifting of the Earth's crust or the lowering of the groundwater level caused the upper parts of these subsurface drainages to become exposed to the atmosphere.



• The exquisite cluster of flake and needle shaped snowy calcite crystals



• The section of a cave presenting its make-ups and structures



• Bouquets of reddish white rhombus calcite crystals, found in the cave hall.

Under the Earth's atmospheric condition, naturally, rain water has is slightly acidic caused by carbon dioxide in the air and by some organic acids in the soils. While seeping through the joint systems, calcium carbonate is dissolved by this surface water. In the cave, where the calcium bearing water touches the air, it evaporates and

loses carbon dioxide, and then calcium carbonate is left behind. This process grows stalactites and stalagmites, from the ceiling and the floor of the cave respectively. In a special closed condition where geothermal vapor is associated, the calcite crystals are formed larger with variety of shapes as found in Tham Kaeo Komon.



• The origin of Tham Kaeo Komon was influenced mainly by groundwater (blue areas).

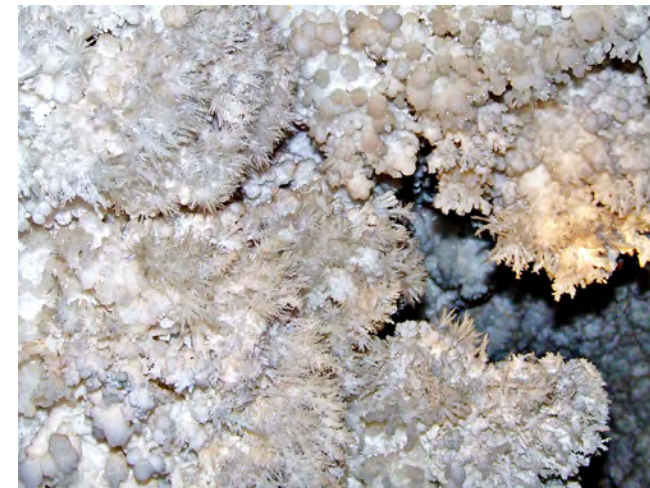
1. The limestone cavity is filled with saturated calcium carbonate solution.
2. While the level of the solution is lower, calcite crystals are formed.
3. The cavity is refilled in the next wet season.
4. The growth of the crystals and deposition of carbonate sediments on the floor.
5. While the level of the solution is lower, calcite crystals are increased.
6. The carbonate sediments on the floor are dissolved when the solution is dilute. The steps of the process are repeated several times.
7. These processes take place for several thousands of years.



• Clusters of ice flaked calcite crystals in Tham Kaeo Komon.

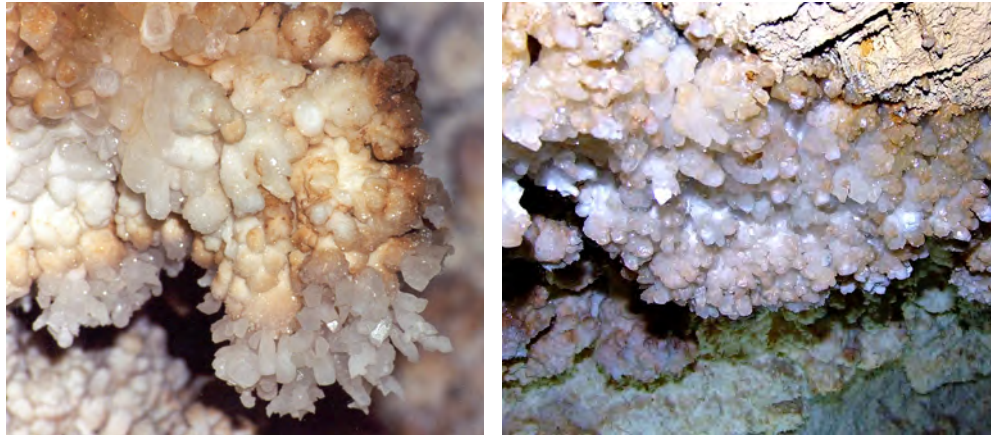
■ The highlight:

Tham Kaeo Komon is the only calcite crystal cave in Thailand and is one of the three in the world; the other two are in China and Australia. Tham Kaeo Komon, once called the “Mae La Noi Calcite Crystal Cave” and “Frozen Cave”, was discovered unexpectedly by a mining engineer of the Provincial Office of the Department of Mineral Resources in 1996, while operating an underground mining along a fluorite vein. The crystal cave was conserved and later developed as a geotourism site by the Department of Mineral resources and finally transferred to the Mae Hong Son Province in 2000.



• The stalactites, stalagmites and columns found in Tham Kaeo Komon.





• The most fascinated clusters of various shaped calcite crystals decorating the inner most hall named “Phroed Phraeo Manee Bubha” or the “Shining Crystal Flowers”.

Tham Kaeo Komon or the “Beloved Crystal Cave” has been named by Her Majesty Queen Sirikit after her visit in 2001. In that occasion, the five crystal cave halls have been also named in accordance with their physical characteristics as follow.

- **Hall 1** “Phra Thai Tham” or the “Beloved Crystal stream”, named by its flowing feature.
- **Hall 2** “Wiman Make” or the “Crystal Cloud Palace”, named by its cloudy appearance.
- **Hall 3** “Chake Himmabhan” or the “Crystal Himmabhan Forest”, named by its appearance of the Himmabhan Forest in a Thai literature.
- **Hall 4** “Man Pha Kaeo” or the “Crystal Curtain”, named by its appearance of a curtain of crystal flakes and needles.
- **Hall 5** “Phroed Phraeo Manee Bubha” or the “Shining Crystal Flowers”, the inner most hall, the most impressive hall of fascinated crystals.

Tham Kaeo Komon the “Beloved Crystal Cave” of Her Majesty Queen Sirikit and everyone.





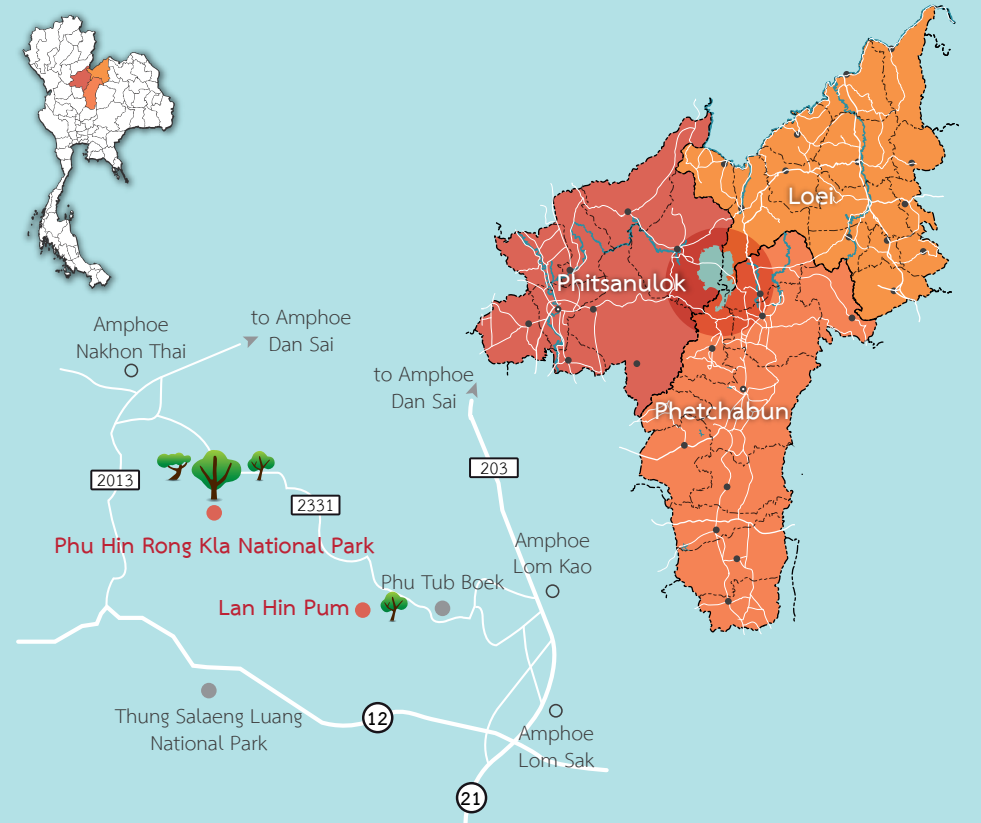
05

Phu Hin Rong Kla

Three special features are packed in one national park in Changwat Phitsanulok. The beauties of the nature, the mysteries of the geological sites and the memories of the past political evidence are waiting for visitors to experience at the Phu Hin Rong Kla National Park.

Location:

Phu Hin Rong Kla is located about 1,617 meters above MSL in the Phu Hin Rong Kla National Park, Amphoe Nakhon Thai, Changwat Phitsanulok. Travelling from the Phitsanulok city, visitors can use highway No. 12 (Phitsanulok-Lomsak) for 68 km to Ban Yaeng and turn left to road No. 2013 for about 29 km to Amphoe Nakhon Thai and then turn right to road No. 2331 for 28 km to the Phu Hin Rong Kla National Park. As the area is located on fractured sedimentary rock units covered with water source forests, visitors could visit almost ten waterfalls while travelling to this national park. After visiting Phu Hin Rong Kla visitors can go further to Phu Tub Boek, a nearby geosite, using road No. 2331.



Geology:



• The rounded rocky knobs on Lan Hin Pum.

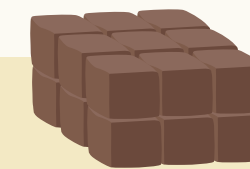
There are many geological sites included in the Phu Hin Rong Kla National Park, e. g. Lan Hin Taek, Lan Hin Pum, Mon Hin Son and Pha Chu Thong. All of these geosites are located on the Phu Phan Formation of the Khorat Group which composes mainly of thick beds of clean white quartz sands. Conglomeratic sandstones and conglomerates with gravels of quartz, chert and rock fragments are also found interbedded. Most of the sedimentary beds preserved prominent cross beddings indicating southwest direction of the strong paleo-currents which moved fine grained sediments away and left only coarse grained sediments to deposit about 110 million years ago.

The sedimentary succession of the Khorat Group has been lifted up as a plateau since the beginning of the Cenozoic era. The tectonic processes have deformed the rock formations and some hard units have also been fractured and faulted. Later, the surficial geological processes, weathering and erosion, with the geological constraints, i.e. the rock textures and internal geological structures, have gradually created the present landforms of the Phu Hin Rong Kla National Park with spectacular geological features.



• Lan Hin Pum has been carved by natural processes.

The Origin of Lan Hin Pum



A rock formation is systematically fractured.

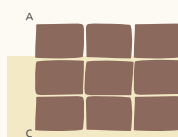


Weathering and erosion remove the outer parts of the fractured rock formation.

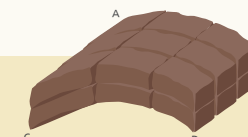


Rounded rocky knobs are the remains of the eroded fractured rock formation, when time has passed.

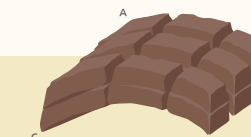
The Origin of Lan Hin Taek



A rock formation prior to the deformation.



The deformation of the rock causes two sets of fractures which are parallel and perpendicular to the folding axis.



The fractures have been enlarged by weathering and erosion, and Lan Hin Taek is formed.



• A set of parallel fractures, with a length of over ten meters each.



• Lots of naturally beautiful rocky knobs (Hin Pum) which are beyond the human's creation capability.

■ The Highlight:

The obvious unusual looking geological features of Phu Hin Rong Kla have baffled most of the visitors and motivated them to find the explanations. The brief stories of these mysterious geological sites are as follow.

- Lan Hin Taek or the “Fractured Rock Terrace” is just as it is called. These fractures caused by the tectonic movement of the Earth’s crust during the Early Cenozoic era. Weathering and erosion are the main processes which have expanded the long straight fractures on Lan Hin Taek. Their widths are varied from a few centimeters to two meters, with the maximum depth of about twenty meters.



• Thick fractured sandstone beds formed as a vertical cliff at the Phu Hih Rong Kla National Park.



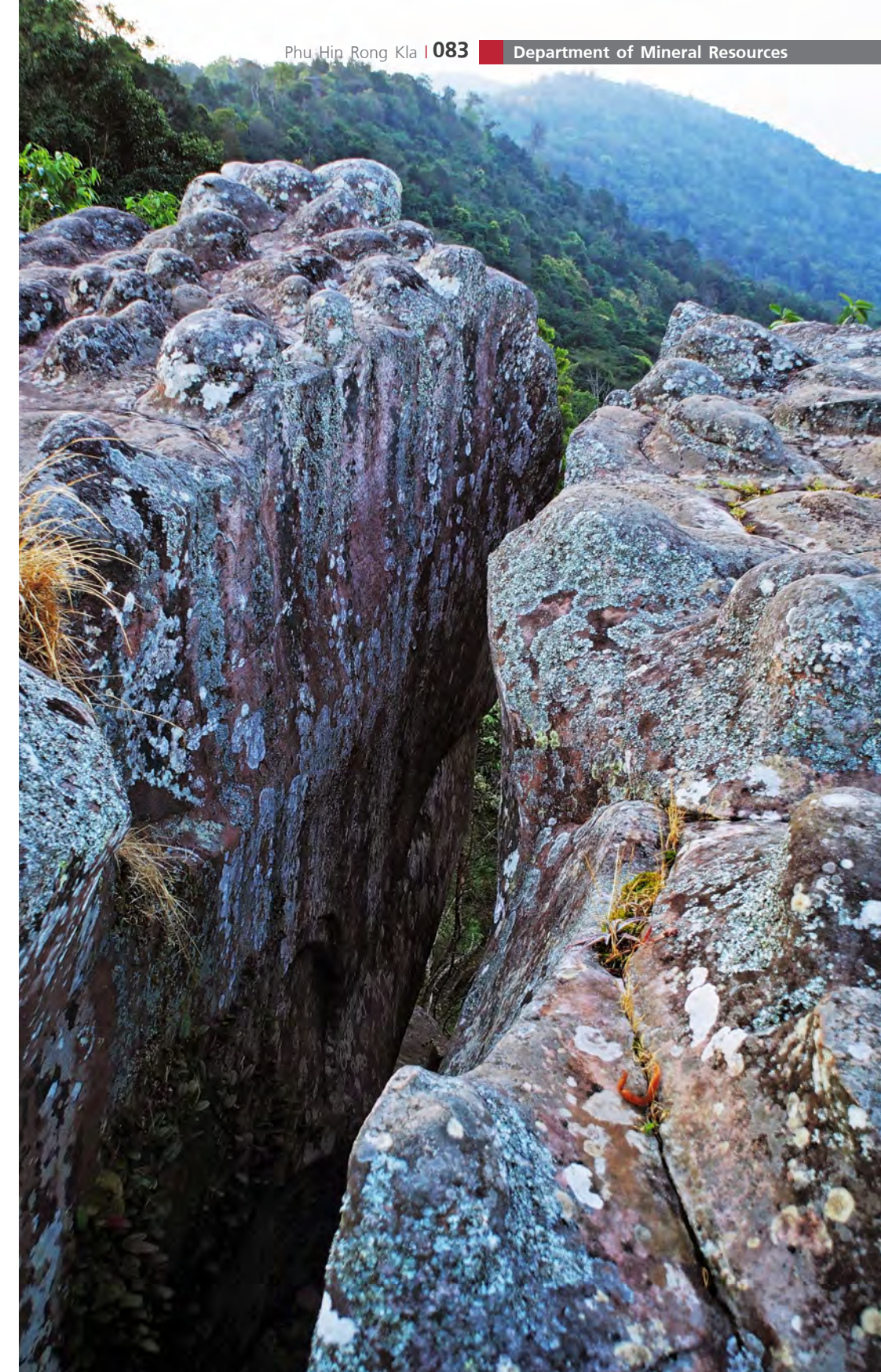
• Prominent cross beddings in sandstones of the Phu Pan Formation.



• A stack of pillows (Mon Hin Son) on the way to Lan Hin Pum.

- Lan Hin Pum or the “Knobby Rock Terrace” appears as its name. There are two main sets of fractures occurred in the same time as Lan Hin Taek. Later, the fractures have been enlarged and knobby rocks are remnants of the surficial geological processes.

• Mon Hin Son or the “Stacks of Pillows” have the appearances of the homogeneous fine grained sedimentary rocks which have been physically weathered by the sun. Changes of the temperature during the day and the night lead to daily expansions and shrinkage of the rocks. These repeated processes cause polygonal cracks in the rocks and the erosion helps create the stacks of pillows.



• A set of rounded rocky knobs lays parallel on top of a deep fracture, on Lan Hin Taek of the Phu Hin Rong Kla National Park.



- Pha Chu Thong or the “Flag Cliff” is the cliff where the former members of the Communist Party of Thailand assembled to celebrate and waved their flag after every triumph. As Pha Chu Thong is a west-facing cliff, it is another best place for admiring the sunset and the twilight.

Visit Phu Hin Rong Kla to observe the political-historical evidence superposed onto wonderful geological-historical evidence.

• One of many Mon Hin Son sites in the Phu Hin Rong Kla National Park.



• The top of a thick sandstone bed has been developed as a set of Hin Pum (Rocky knobs).

06

Pha Wing Chu

Viewing from the top of Pha Wing Chu, the superb panorama of the Chiang Mai intermountain basin seems to move further annually, Pha Wing Chu is actually eroded backward by the powerful Ping River. However, Pha Sing Liao, its neighbor, guarantees that Chiang Mai will always present such wonderful landscape geosite to every visitor.

Location:

Pha Wing Chu is located on the left bank of the Ping River in Amphoe Hot, Changwat Chiang Mai. Using highway No. 108, going south to Amphoe Hot and go further south using road No. 1012 for about 12 km and then turn left to road No. 4011 for about 3 km and then turn left again to Pha Wing Chu. Alternatively, from Amphoe Hot visitors can use road No. 1103 (Hot-Doi Tao) for 18 km and then turn right to road No. 4011 about 3 km and then turn right again to Pha Wing Chu. Pha Sing Liao is the nearby geosite located in Ban Tan which can be approached using the Hot-Doi Tao road about 14 km from Amphoe Hot then turn left and follows the signs. Pha Sing Liao is about 3 km further from Ban Tan Village.



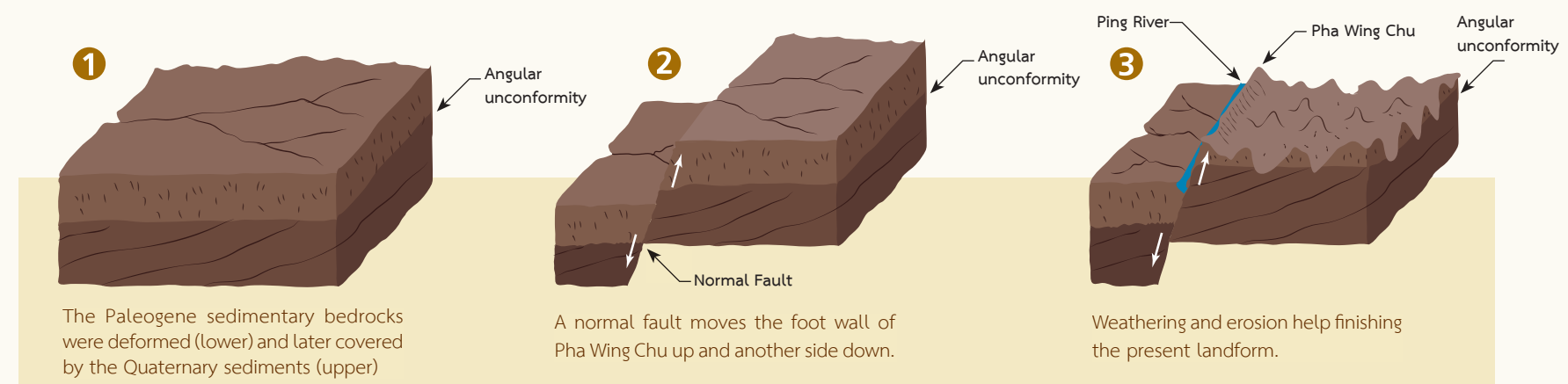
Geology:

Pha Wing Chu and Pha Sing Liao are amazing creations of weathering and erosional processes. They have been formed in faulted rock formations including interbedded semi-consolidated siltstones, sandstones and conglomerates overlaid with recent sediments. The lower rock formation was deposited in Miocene and partially eroded after being uplifted and slightly deformed. Later, it was unconformably covered with the Early Quaternary sedimentary unit. Both units were faulted about 1.6 million years ago and then the natural carving processes have begun.



• This cliff is made up with layers of semi-consolidated sediments.

The Origin of Pha Wing Chu



Pha Wing Chu is located at the edge of the footwall of a normal fault which the Ping River runs along. Pha Sing Liao is also located at the edge of a fault located about 9 km further east. Both Pha Wing Chu and Pha Sing Liao are appearing as strange looking landforms where series of beautiful beds of sediments are uncovered. Some parts of the cliff have been vertically cut by strong erosion and formed as spines capped with harder rocks of the upper unit. Hence, the edges are gradually eroded backward.



• The viewpoint of Pha Wing Chu.



• The beautiful and calm Ping River, viewing from Pha Wing Chu.



• The geological unconformity at Pha Wing Chu.



• The capped and uncapped (once were capped) spines of Pha Wing Chu.

■ The Highlight: -----

The weathered and eroded landforms comprise a lot of vertical cut gullies which open the beautiful series of buried sedimentary layers. The remains have been developed as unstable tapered spines with and without hard rocks capped. These unusual looking landforms typically developed at the edge of faulted rock units like the Pha Wing Chu and Pha Sing Liao geosites. The highlights of Pha Wing Chu are its prominent 25 meter high eroded cliffs laying 250 meters along the Ping River. The opposite side of the Ping River also has a panoramic view of very peaceful rice fields with the background of the Chiang Mai intermountain basin. As it is sitting at the edge of a fault which is gradually destroyed by the Ping River, the details of this geosite are rather difficult to explore and visitors must be carefully guided.



• The wonderful remnants at Pha Sing Liao preserving an evidence from millions of years.



• The eroded landscape of Pha Sing Liao with a hilly background.

Another beautiful badland, Pha Sing Liao, is located on the same geological units and has been developed with the same geological processes. Since Pha Sing Liao is located at a foothill in Ban Tan where it is not disturbed by the Ping River, the spines found at Pha Sing Liao are higher than those located at Pha Wing Chu. Additionally, visitors can observe more details of the geological site and can explore through the landscape safely.

The Chiang Mai's wonderful landscape geosites, Pha Wing Chu and Pha Sing Liao, have been daily destroyed naturally; please do not help the nature to do so.



• The Quaternary sediments lay on top of the underneath Miocene beds.



Suan Hin Pha Ngam

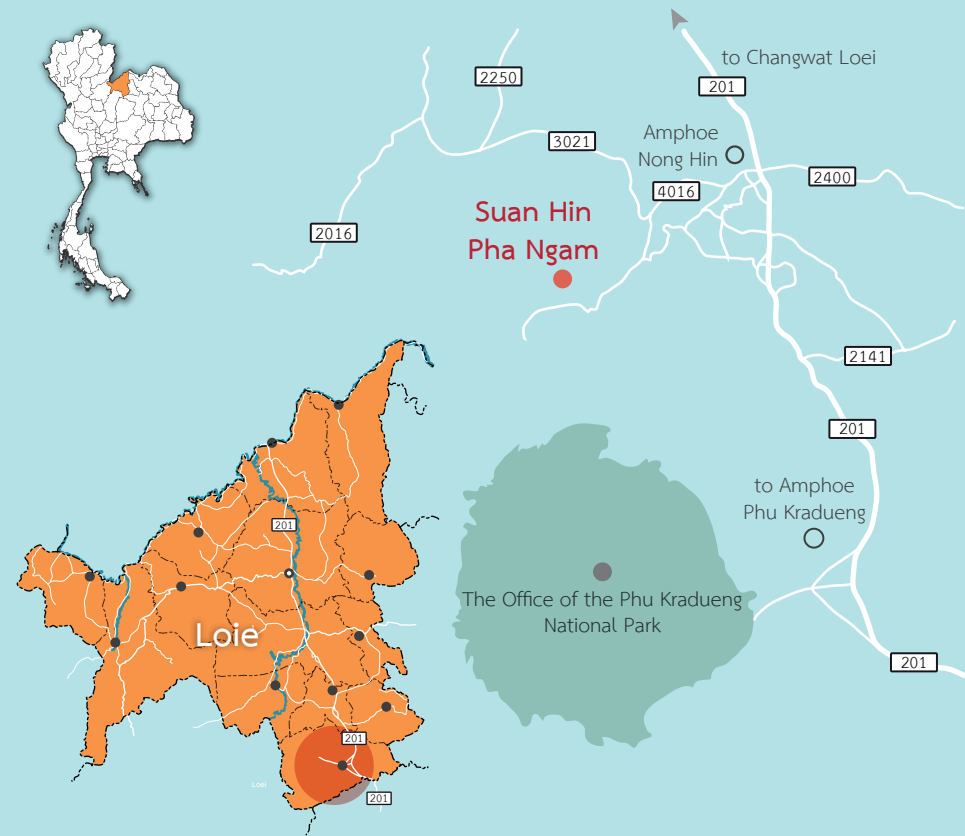
Many amazing sceneries are located in the maze concealed behind the Permian limestone terrain of Suan Hin Pha Ngam, also known as "Thai Kunming". "Pa Prong" the prehistoric cycad bush in "The Planetarium" makes Suan Pha Hin Ngam even more primeval.

07

FREE PARKING

Location:

Suan Hin Pha Ngam is located in a limestone terrain, covering about 15 square kilometers, in Amphoe Nong Hin, about 62 km south of Changwat Loei. Visitors can travel south from the Loei Province using highway No. 201 to Amphoe Nong Hin then turn right to use road No. 4016 for about 18 km to Ban Pha Ngam and then turn right again for the last 500 meters to the Suan Hin Pha Ngam Tourist Service Center. There are many limestone geological sites located nearby, as the area is underlain with limestone, e.g. Phiang Din waterfall, Phu Pa Poa viewpoint and many beautiful caves. The Phu Kradueng National Park is another famous geological site located about 30 km south of Suan Hin Pha Ngam.



Geology:

In the Permian period or about 295-250 Ma Suan Hin Pha Ngam originated by calcium carbonate precipitations in a warm shallow sea on a continental shelf. The major geological evidence is the formation of thin layers of grey to dark grey limestones with fossils of corals, fusulinids, crinoids and gastropods. This depositional basin was lifted up to the Earth's surface by the Permo-Triassic tectonic about 220 Ma and became a non-marine basin which various continental sediments have been deposited. At the beginning of the Cenozoic era a remarkable tectonic shift lifted up the Khorat Plateau which also pushed the ancient Suan Hin Pha Ngam up as a mountain range and then the surficial geological processes have activated.



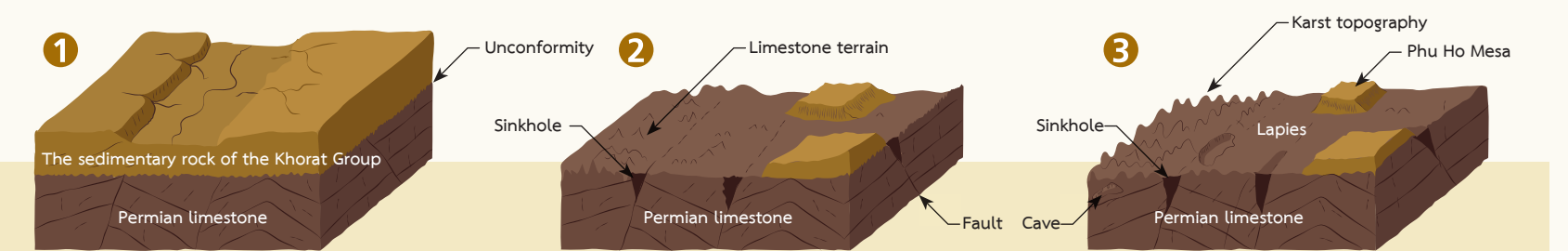
• Fossils of crinoid stems and fragments in a Permian limestone outcrop.



• The limestone hill at the entrance of Suan Hin Pha Ngam.

The result of these geological processes are the deformation of the rocks, the removals of the upper rock units and the present landforms which have been carved and controlled by the geological structures and the physical properties of the rocks themselves. The spectacular karst topography or a soluble landscape of Suan Hin Pha Ngam is a wonderful configuration of sinkholes, caves, lapies and stone forests in combination with Permian marine fossils and the nearby Phiang Din waterfall.

The Origin of Suan Hin Pha Ngam



The Permian limestone was covered with the sedimentary rocks of the Khorat Group before the whole mass was lifted up.

Next, most of the upper rock units have been removed by weathering and erosional process, and left behind the wonderful limestone terrain.

The karst topography with various limestone features have been developed later.



• The 'Planetarium' viewpoint surrounded with natural limestone barriers which look like "Kunming" of the People Republic of China.

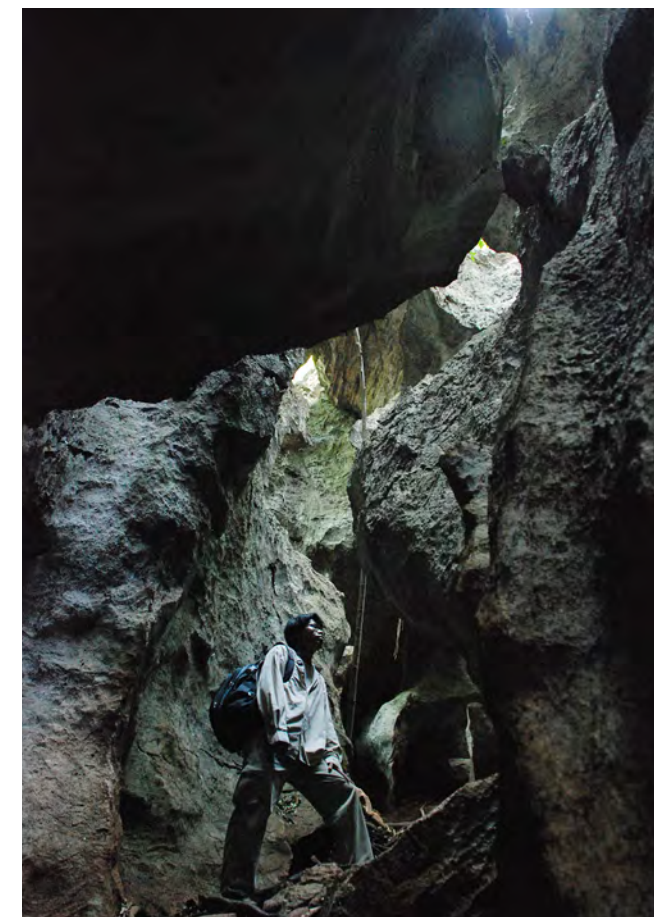
■ **The Highlight:**

To explore the various highlights spread around Suan Hin Pha Ngam thoroughly, the two kilometer travelling path and local professional guides have been prepared for all visitors. The three major tourist attractions are the Maze, the Maze Gateway and the Planetarium.

“The Maze” is a large sinkhole surrounded with complicated assemblages of collapsed limestones with various sizes and shapes where visitors can enjoy the various strange looking scenes. Some parts of the limestone assemblages can be unexpectedly passed through like walking in a maze.



• The attractive view of the natural creative surroundings of Suan Hin Pha Ngam.



• “The Maze Gateway” - The rough mazy way which leads to the top of limestone hills is one of the highlights of this geosite.





• The Phiang Din Waterfall is coated with re-precipitated calcium carbonate dissolved from the limestone bedrocks which the stream has run across.

“The Maze Gateway” is the beginning of the mazy path along strange looking cavities and nooks leads up the limestone hills. The fossils of marine gastropods are found preserved in the large Permian limestone outcrops beside this mazy path.

“The Planetarium”, the last target of this journey, is a high viewpoint surrounded with natural limestone barriers which look like “Kunming” of the People Republic of China. The most amazing evidence making the Planetarium more primeval is the “Cycad Bush” or “Pa Prong” (in Thai), as cycad is a palm like plant which has presented on Earth since the Early Permian.

Let's explore the Permian marine fossils “gastropods and crinoid stems” and experience the living fossil “Pa Prong” in the maze of Suan Hin Pha Ngam.





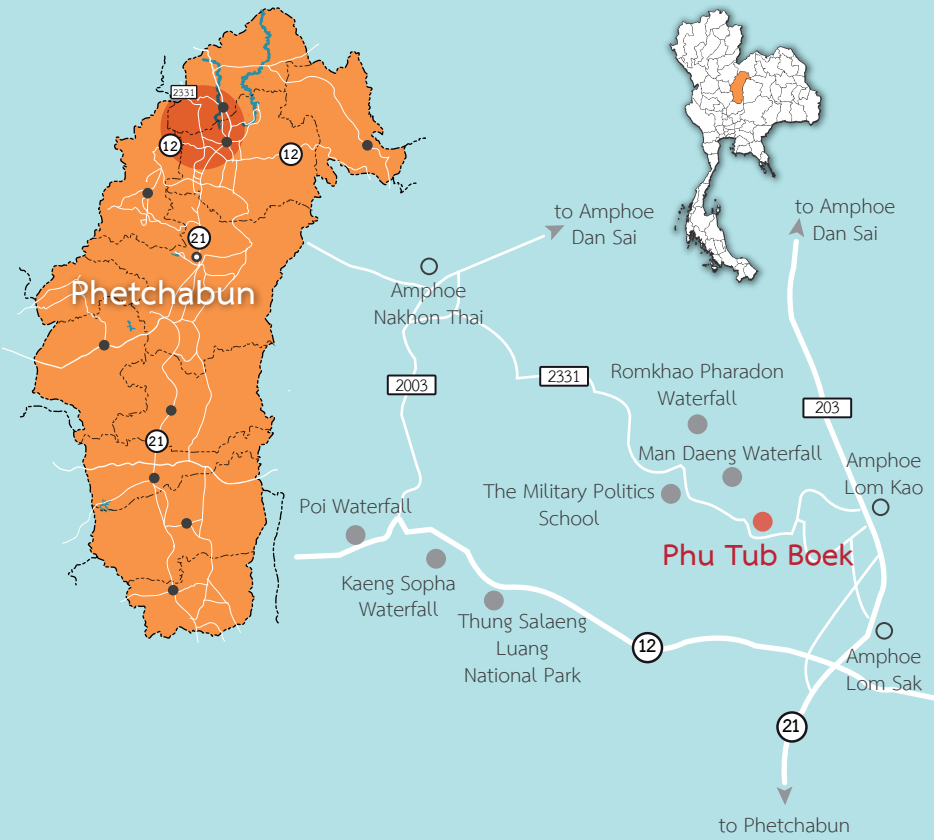
Phu Tub Boek

One can see simultaneously 360 degree surrounded with mountain ranges, seas of mist, fresh air, cabbage crops, local hill tribe folks and especially the geological history preserved beneath one's feet on the unforgettable summit of Phu Tub Boek.

08

Location:

Phu Tub Boek is the summit of a mountain range located, at the border between Phitsanulok and Phetchabun Provinces, in Amphoe Lom Kao, about 76 km. north of Changwat Phetchabun. Visitors can use highway No. 21 travelling about 40 km. from the Phetchabun Province to the north then turn left to highway No. 12 at the intersection. At the fourth kilometer from the intersection turn right to road No. 2372 for 13 km. and turn left to road No. 2331 to Phu Tub Boek. The first 9 km. of this road is quite easy to drive but the last 10 km. is rather hilly and crooked, although very beautiful though.



Geology:



• Thick white sandstone beds on the summit of Phu Tub Boek.

The union of the Shan-Thai Plate and the Indochina Plate about 220 million years ago (Ma) has lifted this part of the Earth up to the surface and formed as a continental basin under the influence of a paleo fluvial system. Hundreds of different sedimentary beds have been deposited simultaneously with the preservations of the remains of the fertile ancient creatures, e.g. dinosaurs, turtles, crocodiles and lepidotes fish. The Early Cenozoic tectonic, about 55 Ma, has lifted this basin up and formed the Khorat Plateau. Phu Tub Boek is a part of the results of this tectonic which has been further lifted up as a mountain range at the end of the Paleogene period. Later, the Phetchabun basin has been subsided by the Oligocene extension.

The fractured sedimentary sequence of Phu Tub Boek which is slightly dipped eastward has been gently eroded along the dip slope side while the collapse of the escarpment created the famous cliff of Phu Tub Boek. The cross section of Phu Tub Boek presents three prominent distinct formations as follow:-

- The lowest sloped formation contains purplish red siltstone and mudstone interbedded with reddish brown and greenish grey sandstones of the Phu Krađueng formation.
- The middle formation which is the vertical cliff of the Phu Tub Boek summit, about 1,768 m above MSL, comprises white and pink quartz sandstones and conglomerates of the Phra Wiharn formation.
- The top most formation of Phu Tub Boek includes sandstones interbedded with siltstones and mudstones of the Sao Khua formation.

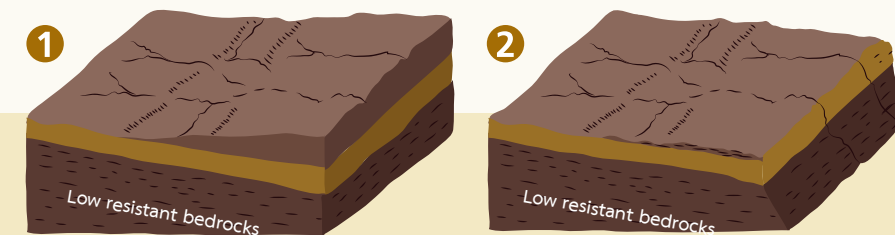


• The monoclinical formations of Phu Tub Boek.

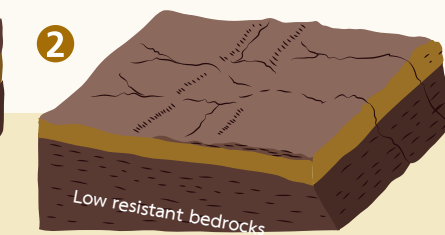


• The undulated dip slope of Phu Tub Boek.

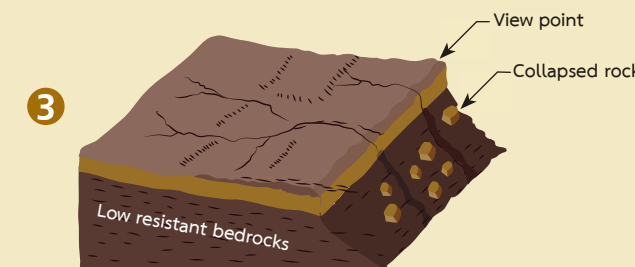
The Origin of Phu Tub Boek



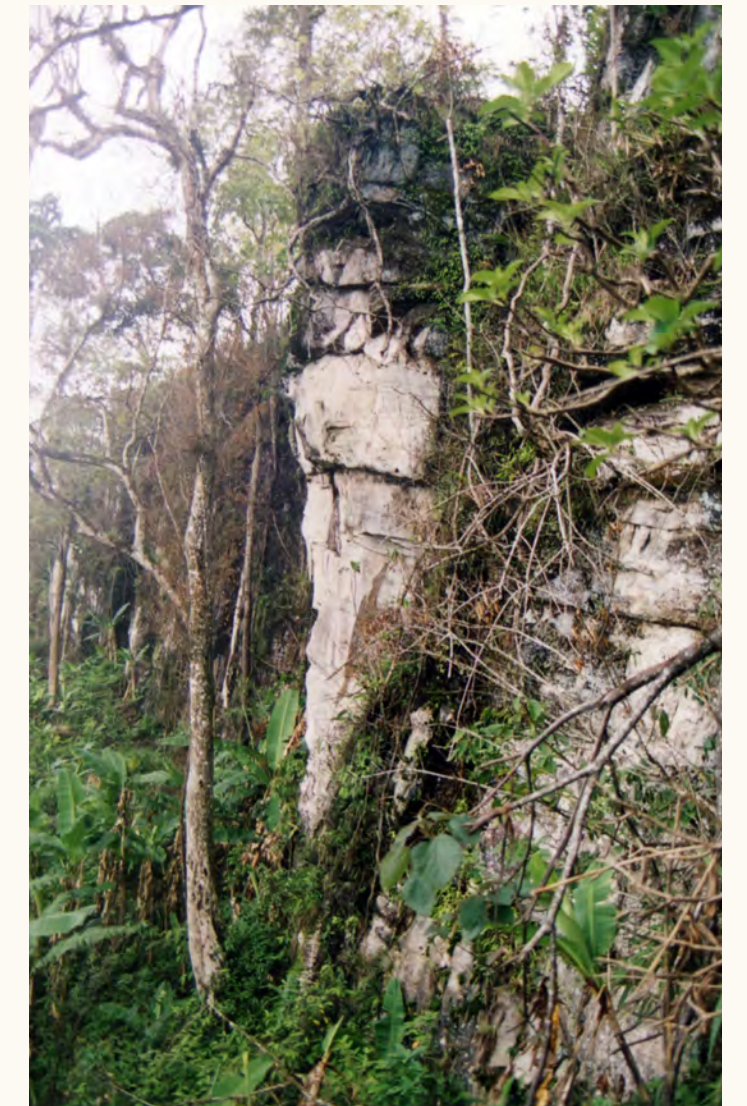
Sedimentary rock formations are deformed by the movement of the Earth's crust.



Geological structures and different resistances constrain the erosion of the deformed rock formations.



The erosion and collapse of the fractured rocks create the famous Phu Tub Boek.



• The quartz sandstone base of Phu Tub Boek.



• Fascinating views of Phu Tub Boek from different corners.

■ The Highlight:

Looking from a distance, Phu Tub Boek is just like a very thick book which every page is a sedimentary bed and each chapter represents a rock formation. However, this book presents only three middle chapters of the whole book of the Khorat Group. From the highest peak of Phu Tub Boek visitors can view Amphoe Lom Sak and Amphoe Lom Kao located in a distant valley beyond the sea of mist and a north-south trending limestone range located along the road leading to this geosite. In every winter, groups of tourists visit Phu Tub Boek to admire the sunrise from the boundless sea of mist in the dawn before enjoying a hot set of breakfast in the cold morning.



• Cabbage crops on the back of Phu Tub Boek.

During the day visitors can experience the local hill tribe's folklore and enjoy the cabbage crops spread across the Sao Khua sedimentary formation covering the back of Phu Tub Boek. The preserved geological evidence is also, everywhere from the foothill to the top, waiting for observations. After the whole day of exploring around in a cold atmosphere, everyone can watch the clear starry sky before bedding down in a warm place, available in the tenting ground on Phu Tub Boek, to relax and prepare oneself to welcome the next sunrise.

The three chapters in the Phu Tub Boek gigantic geological book are waiting for everyone to visit and observe. Please open this book gently.



• The tenting ground where everyone can relax and prepare oneself to welcome the next sunrise.

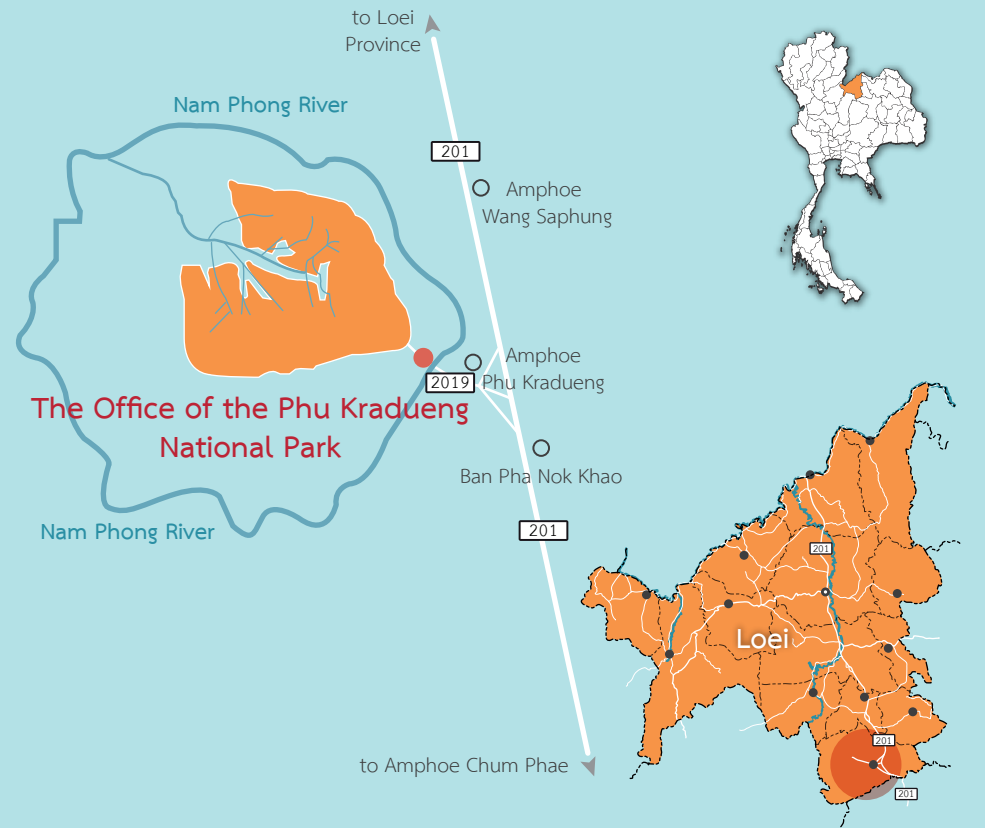
09

Phu Kradueng

Looking from the space, focusing on to the south of the Loei Province, the most prominent feature on Earth would be the wedding cake like mesa with a heart shaped topping of Phu Kradueng. The bottom rock unit of the Phu Kradueng Mesa is the stratigraphic type section of the Phu Kradueng Formation which belongs to the Khorat Group.

Location:

Phu Kradueng, one of the top ten famous tourism sites of Thailand, is located in the Phu Kradueng National Park, Amphoe Phu Kradueng, Changwat Loei. It is located in the south most part of Changwat Loei at the junction of Loei, Phetchabun and Khon Kaen Provinces. Although the Phu Kradueng National Park is rather far (82 km) from the Loei Province, it is very conveniently reached. Just travel using highway No. 201 for 75 km to Amphoe Phu Kradueng and then turn right to use road No. 2019 for 7 km and you will be there. Suan Hin Pha Ngam or the Thai Kunming, another famous geological site, is located about 30 km north of the Phu Kradueng National Park.



Geology:

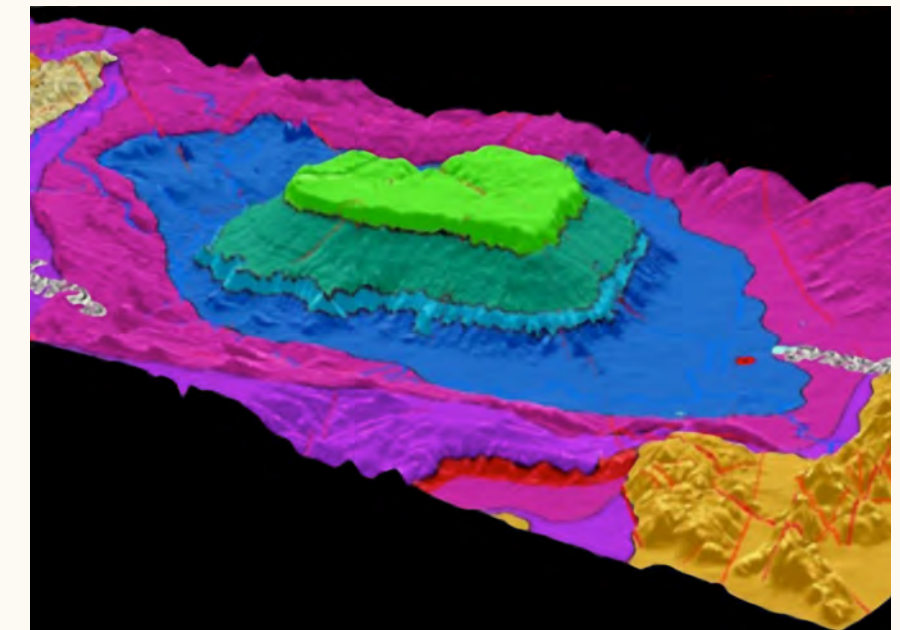
Phu Kradueng is a mesa, a small plateau with a flat top surrounded with steep sides. The area of its flat top is about 60 square kilometers with the highest point of about 1,316 meters above MSL. This mesa has been built up with four sedimentary formations of the Khorat Group, including Phu Kradueng, Phra Wiharn, Sao Khua and the top most Phu Phan Formation. The four formations, deposited about 150-110 Ma in a fluvial environment, consist mainly of sandstones, siltstones and shale which varies in colors and patterns of succession by the changes of local depositional conditions. All the formations slightly dip around 5-10 degrees, northwestward which constrained the direction and the pattern of the drainage system on the top of the Phu Kradueng Mesa.



• The mesa landform of Phu Kradueng.

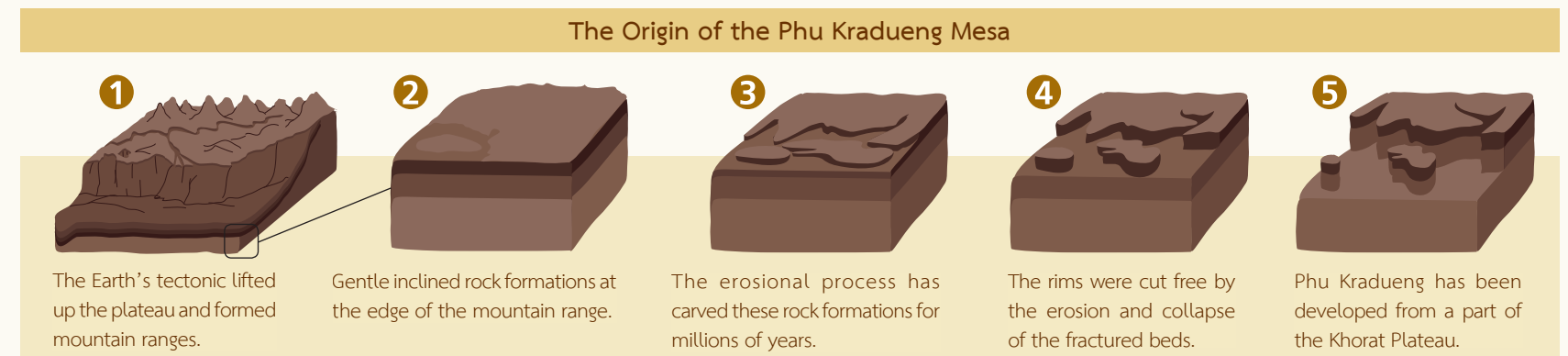


• The beautiful cliff and waterfall on the top of Phu Kradueng.



• The heart shaped topping of the wedding cake like Phu Kradueng Mesa.

The Khorat Basin developed during the Mesozoic era, after the collision of the Shan-Thai and Indochina Plates. At the beginning of the Cenozoic era the basin has been lifted up as a highland with ranges of mountains in the west and the north. These ranges have been continuously eroded for millions of years and later the edges the ranges were cut off as mesas. Some small mesas have been completely eroded or only some remains are left. Most of the mesas on the Khorat Plateau are water source forests and have been designated as National Parks including the famous Phu Kradueng National Park.





• The fractured thick sandstone beds in Phu Kradung have been cut backward by a waterfall.

■ The Highlight:

The bird's-eye view of Phu Kradueng appears as a romantic landform of a wedding cake like mesa with a heart shaped topping. Many waterfalls and famous cliffs spread all over the forests on this large flat top, e.g. the Wang Kwang Waterfall, the Penpobmai Waterfall and the Ratana Waterfall; the Makduk Cliff, the Pha Daeng Cliff, the Pha Song Lok Cliff, etc. The two special symbols of Phu Kradueng are the Nok An Cliff and the Lom Sak Cliff where visitors can admire the beautiful sunrise and sunset respectively. In the cold dark night every couple can fantastically watch the countless stars accompanied by the wildlife sounds from the nearby woods.



• Some wonderful famous sites on the top of the Phu Kradueng Mesa.



• Thick white sandstone beds with prominent cross beddings.



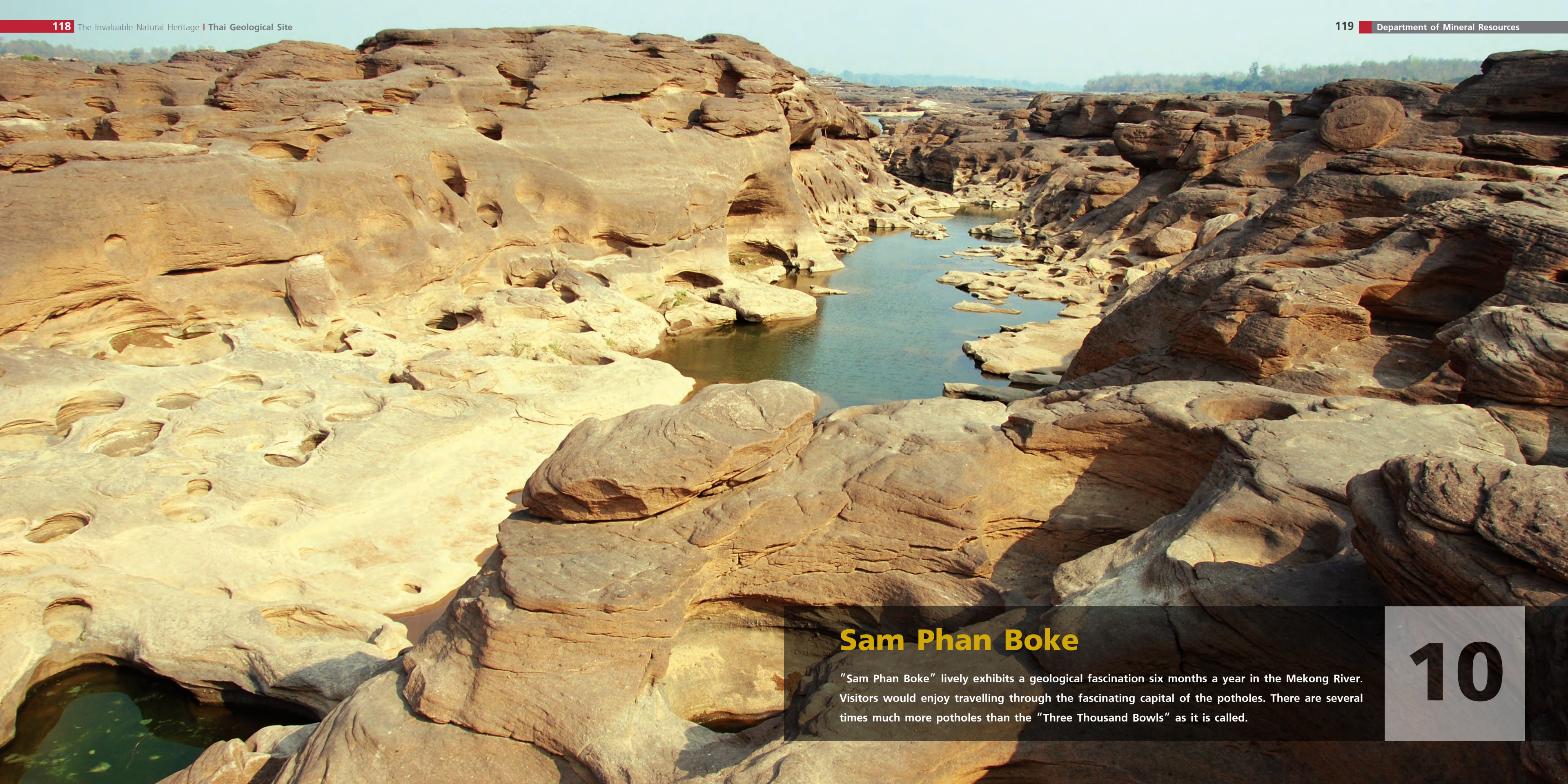
• Phu Kradueng in the twilight.

The round trip along the steep and rugged rocky track which leads to the heart shaped top of Phu Kradueng is the task that visitors manage to overcome, especially between couples to take care of each other to prove their true love. However, the most significant state of Phu Kradueng is not the site for wonderful journeys, but it is the stratigraphic type section of the Jurassic Phu Kradueng Formation of the Khorat Group which is a very important national geological reference.

Let's visit and save the true love proving Phu Kradueng Mesa, the only wedding cake like mesa on Earth.



• Pha Lom Sak the Phu Kradueng's symbol where the sunset is admired.



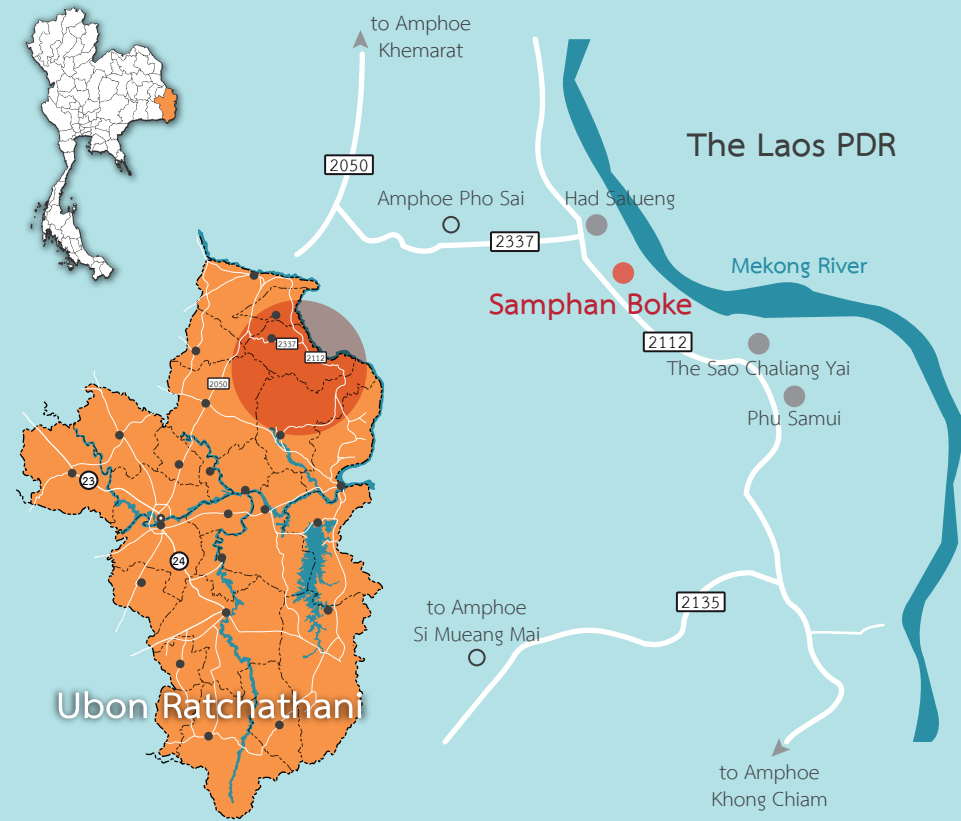
Sam Phan Boke

"Sam Phan Boke" lively exhibits a geological fascination six months a year in the Mekong River. Visitors would enjoy travelling through the fascinating capital of the potholes. There are several times much more potholes than the "Three Thousand Bowls" as it is called.

10

Location:

Sam Phan Boke is located in the Mekong River at Amphoe Pho Sai, Changwat Ubon Ratchathani. The Sam Phan Boke geological site is about 118 km northeast of the province, reaching by using highway No. 2050 to Amphoe Pho Sai for about 80 km and turn right to road No. 2337 for around 30 km to Ban Song Khon. From Ban Song Khon, there are 2 alternatives to approach Sam Phan Boke. Visitors can turn right to road No. 2112 for about 8 km or travel further by boat at Had Salueng along the Mekong River to the geosite.



Geology:

Sam Phan Boke and its vicinity are parts of the Phu Phan sedimentary rock formation of the Khorat Group. The rock formation comprises thick beds of white and pale grey sandstones and conglomeratic sandstones deposited in a fluvial system about 110 million years ago. The rocky banks of the Mekong River in this area have a generally uniform height, due to the very gentle inclination of the Phu Phan Formation. Cross beddings indicating the directions of the paleo-channels are always found on the sections of sandstone beds, while various sizes of potholes abundantly spread across the bottom of the Mekong River.



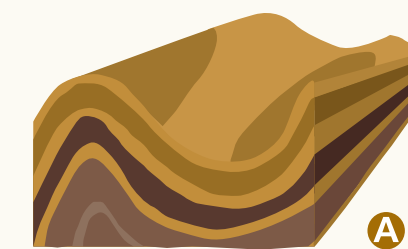
• A ten meter wide waterlogged pothole at Sam Phan Boke.

Mekong River at Sam Phan Boke has developed along the weak zones and low resistant beds of the folded sequence of Phu Phan formation. The crooked flow of the Mekong River, due to the obstruction of high resistant beds, caused turbulent flow and whirlpools which have created millions of potholes at Sam Phan Boke. Furthermore, the power of the Mekong River has also carved a spectacular natural bridge from a high resistant bed.

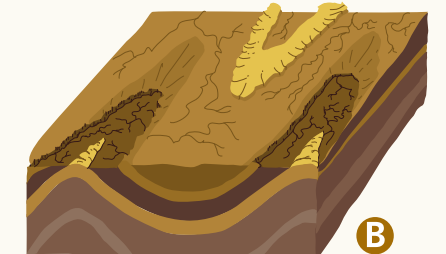
Potholes are holes in the rock beds with a pot shaped which caused by abrasions of gravels and sand grains powered by the flow of Mekong River during flooding period of the year. Potholes developed from small shallow scars on the bottom of the river which have been annually enlarged by the whirlpool motion of the coarse grained sediments trapped inside. At a particular depth the vertical abrasion is terminated while the horizontal one is very operative, the pot shaped is then developed. Potholes are randomly developed, therefore many superpositions of potholes are generally found in various styles.



• The Phu Phan sandstone formation with prominent cross beddings, looking from the Mekong River.

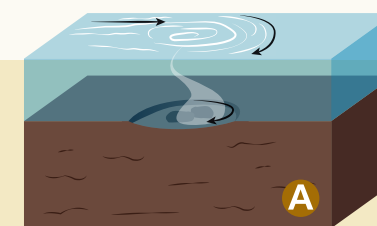


Horizontal beds are folded by compression due to the Earth's tectonic.

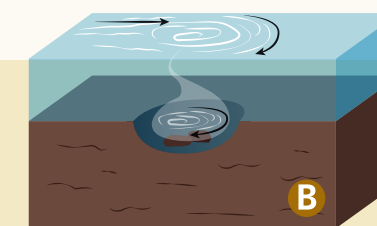


Weathering and erosional processes remove low resistant beds, only high resistant ones are left behind.

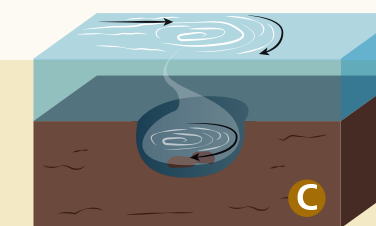
The Development of a Pothole



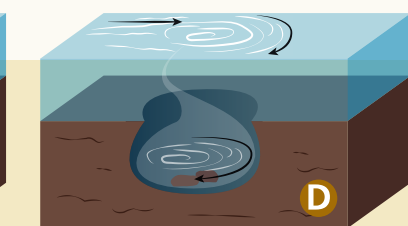
The bottom of the Mekong River is scraped by moving gravels.



The whirlpool motion of gravels and sand grains causing downward abrasions on the scraped bedrock.



The repeated abrasions enlarge the size of the hole.



At a particular depth, the horizontal abrasions are more effective and the hole is shaped as a pot.



• The spectacular natural bridge of Sam Phan Boke.



• The beautiful rocky bank of the Mekong River.

■ The Highlight:

Tourists are only welcome to Sam Phan Boke during the dry season, around December to May, for the fantastic natural sculpture open gallery. The rest of the year is the time for the Mekong River to generate new potholes and prepare new arrangements of the existing potholes for the coming dry season exhibition. “Sam Phan Boke” means three thousand bowls, however, it is only a name, as there are countless number of potholes in Sam Phan Boke. Additionally, combinations of neighboring potholes by the simultaneously enlargement of everyone are commonly found. This brings about plenty of arrangements which visitors can endlessly imagine, e.g. the Mickey Mouse, the Universe, a jar, number 8, etc. Moreover, the fantastic natural bridge is also a very famous selfie location for youngsters.



• Thousands of potholes are always appearing in every corner of Sam Phan Boke.



• *Superpositions of potholes in various styles.*

The exhibition of Sam Phan Boke leads the visitors to the boundless imaginations comparable to what they have ever encountered in their lives. Moreover, the substantial records within the Phu Phan Formation would lead visitors back to the far past when these sedimentary units have been formed, uplifted, fractured and carved. Recently, the carving process has not yet over, it continuously proceeds to create more wonderful geosites for us, so let's save Sam Phan Boke for everyone.

Any activities disturbing the life cycle of the Mekong River may terminate the live geological exhibition of Sam Phan Boke eternally.

11

Sam Muen Ru

"Sam Muen Ru" or the "Thirty Thousand Hollows" is named to harmonize with the neighboring "Three Thousand Bowls" or the "Sam Phan Boke" geosite. However, "Sam Muen Ru" exhibits several times more than thirty thousand hollows, six months a year on the right banks of the Mekong River.

Location:

“Sam Muen Ru”, the right bank of the Mekong River with hollowed sedimentary beds is located in the Pha Taem National Park at Ban Pha Chan, Amphoe Pho Sai, Changwat Ubon Ratchathani. The Sam Muen Ru geosite is about 133 km north-east of the province, reaching by highway No. 2050 to Ban Huai Bang, Amphoe Pho Sai for about 80 km and turn right to road No. 2337 for around 30 km to Ban Song Khon. From the intersection with road No. 2112 turn right for about 18 km and then turn left for about 5 km to the wharf of Ban Pha Chan to enjoy the Sam Muen Ru boat touring.



Geology:



• Hollowed silicified sandstone beds.

The Sam Muen Ru and the nearby geosites, like Pha Chan and Sam Phan Boke are parts of the Phu Phan Formation which belong to the Khorat Group. The rock formation composes mainly of thick beds of white and pale grey sandstones and conglomeratic sandstones deposited in a fluvial system under a warm humid climate about 110 million years ago. Cross beddings indicating the directions of the paleo-channels are always found on the sections of the nearly horizontal beds of the Phu Phan Formation. Most parts of the right rocky bank of the Mekong River at the Sam Muen Ru geosite have a very special “Honey Comb-like” feature which appears on the surfaces of the banks only on the parts which annually immersed in the Mekong River during the wet season.



• Abraded hollowed silicified sandstone beds.

The “Honey Comb-like” feature caused when the matrix of conglomeratic sandstone beds was silicified with siliceous solution and became hardened. Later, annually immersed under strong current of the Mekong River for about half a year, most of gravels embedded in the sandstones have been removed and millions of hollows are left on the surfaces of the rocky banks. The Honey Comb-like sections present not only the hollows but also the remains internal structures of the sedimentary beds, i.e. bedding planes, laminations, cross beddings and even the shapes and sizes of the removed gravels.



• Hundreds of meters of sandstone beds with the Honey Comb like feature at the Sam Muen Ru geosite.





• The silicification has preserved bedding planes, laminations, cross beddings and hollows of the removed gravels.



• The sizes of the hollows imply the sizes of the removed gravels.

■ The Highlight: -----

The “Thirty Thousand Hollows” or “Sam Muen Ru” geosite was called as “Pha Ru or the Hollowed Cliff” and “Pha Wua Toke or the Dropped Cow Cliff” as there was a cow dropped accidentally into the river while grazing beside the cliff. Later, it is called “Sam Muen Ru” in order to harmonize with the neighboring famous geosite “Sam Phan Boke or the Three Thousand Bowls”.



• The beauty and spectacles of the nature.



• The closed up picture shows some gravels going to be removed.



• The unique 3 dimensional Honey Comb like feature of the Sammuen Ru geological site.



• The Sam Muen Ru touring boats at Ban Pha Chan.

Hundreds of meters of the hollowed rocky banks of the Mekong River naturally display their amazing attractions to all visitors six months a year. The countless number of the Sam Muen Ru's pictures has been taken due mainly to its beauty and spectacles. Beside these, Sam Muen Ru has preserved a millions of years of geological history since the deposition of the first sedimentary bed forming the Phu Phan Formation. The historical evidence of the tectonic and relevant geological processes including their remains has been recorded inside and on the surfaces of the sedimentary layers laying along the right bank of the Mekong River waiting for discoveries.

Knowing about the origin of Sam Muen Ru, its next picture may be taken with an extraordinary focusing



• The geological learning site at the wharf of Ban Pha Chan presents beds of sandstones deposited in different environments.



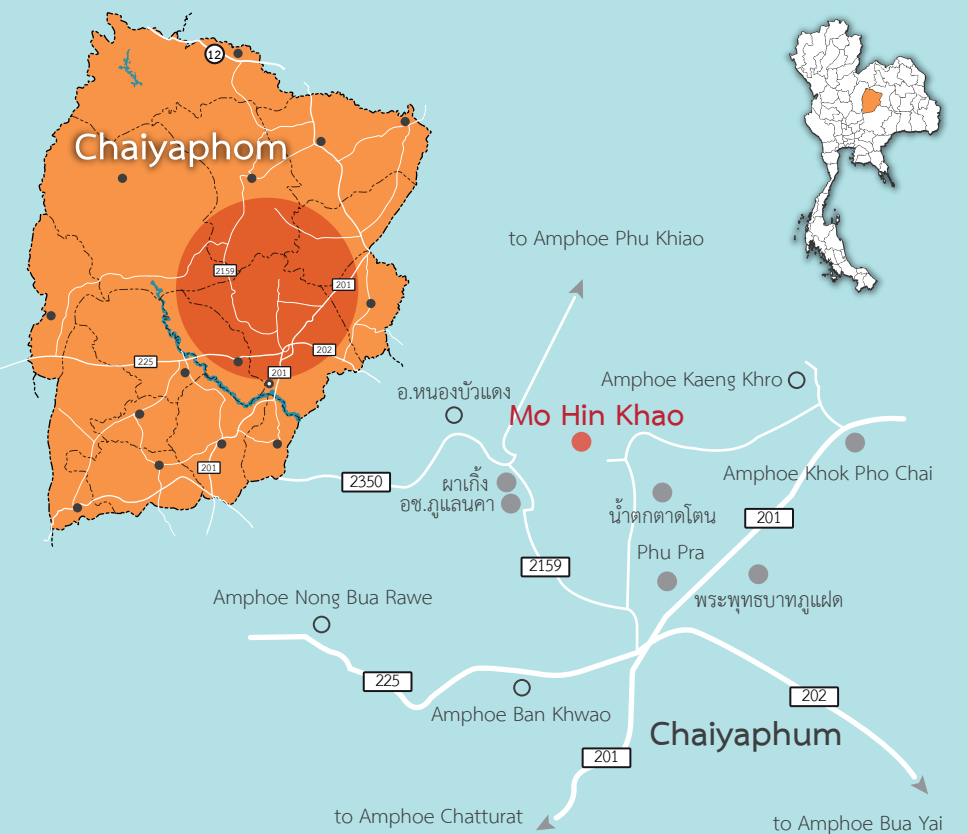
12

Mo Hin Khao

Mo Hin Khao or the "Hill of White Rocks" is a cluster of upright protruding massive white rocks that looks alien-made. Mo Hin Khao, also called Stonehenge of Thailand, is abundantly surrounded with various sizes of standing rocks which look similar to collections of different creatures and many other imaginings.

Location:

Mo Hin Khao, one of the Seven Wonders of Thailand, is a part of the Phu Laen Kha National Park, located in Amphoe Mueang, Changwat Chaiyaphum. Travelling to this geosite, visitors can use highway No. 2051 (Chaiyaphum-Tat Ton) about 18 km from the province and turn left to the Tat Ton- Tha Hin Ngom road for 12 km. From this point, turn left to the Chaeng Charoen-Sok Chuak dirt road for another 6.5 km to Ban Wang Khan and Mo Hin Khao is around 3.5 Km further.



Geology:



• Pha Hua Nak is a wonderful sunset admiring viewpoint.

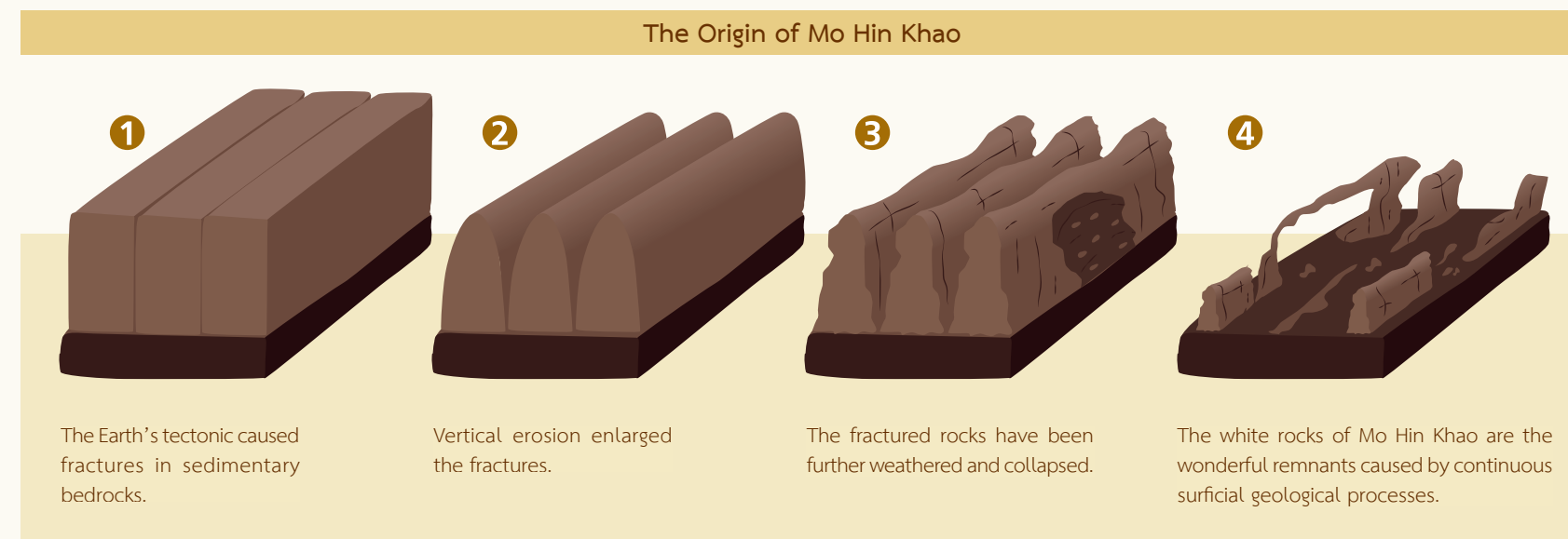
Mo Hin Khao and its vicinity are laid buried with 2 formations of sedimentary rocks of the Khorat Group, deposited about 160-140 million years ago (Ma). The lower formation found at the foothill is the Phu Kraeng Formation including mudstone, siltstone and sandstone deposited in a tropical climate. The standing white rocks belong to the Phra Wihan Formation composed mainly of white quartz sandstones and conglomeratic sandstones with prominent cross beddings indicating the westward paleo-currents.

The two sedimentary formations have been oriented in the northeast-southwest trending with a very gentle inclination toward southeast. They are generally fractured due to the Early Cenozoic tectonic which lifted the Khorat Plateau up around 55-30 Ma.

Mo Hin Khao has been originally created by the vertical erosional process along these fracture zones which separated the Phra Wihan Formation as rows of hills. Later all the hills have been further weathered and collapse over a million years and clusters of white rocks are left standing at the Mo Hin Khao hillside.



• A white protruding sandstone of Mo Hin Khao with many preserved geological information.





• A wonderful strange looking cluster of white rocks on Mo Hin Khao has been telling us many old stories.



• The turbaned oldster.

■ The Highlight: -----

The highlight of Mo Hin Khao or the “Hill of White Rocks” is the well-known cluster of 5 massive standing white rocks. Their average height is around 12 meters with different perimeters. The largest protruding white rock needs twenty persons to be able to encircle it within their arms. The cross-beddings found on the white standing rocks are the wonderful natural inventions enhancing the attractions of Mo Hin Khao. Moreover, there are many white standing rock parks spread around the Mo Hin Khao hillside which look similar to collections of elephants, mushrooms, boats, turtles, pagodas, etc.



• The appearances of a white standing rock park lead to various imaginings.



Additionally, admiring the sunset and the sparkle of light from Amphoe Nong Bua Daeng from Mo Hin Khao in the twilight prior to experience Mo Hin Khao in the moonlight are special suggested programs for all visitors. A tenting ground service is also available for all visitors to relax after enjoy looking for shooting stars in the starry sky of Mo Hin Khao. Mo Hin Khao is an extraordinary geosite which provides visitors not only geological information but also opportunities for recreational and astronomical activities.

Mo Hin Khao:
the astronomic recreational geosite.



• The cluster of five standing white rocks - the unique symbol of Mo Hin Khao.



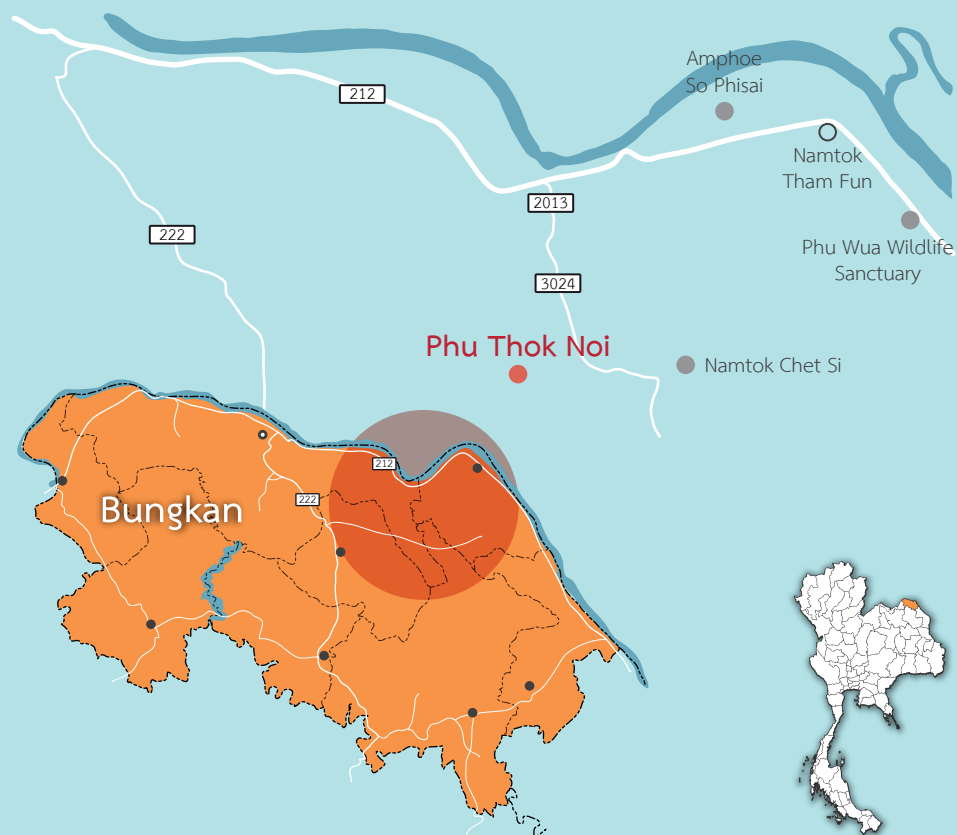
Phu Tok Noi

Phu Tok Noi was initially created as the red cap of the vast Khorat Plateau. It has later eroded and finally cut-off by the Mekong River. The isolated Phu Tok Noi monadnock has never been lonesome as the multi-level wooden walkway has held it in a warm embrace.

13

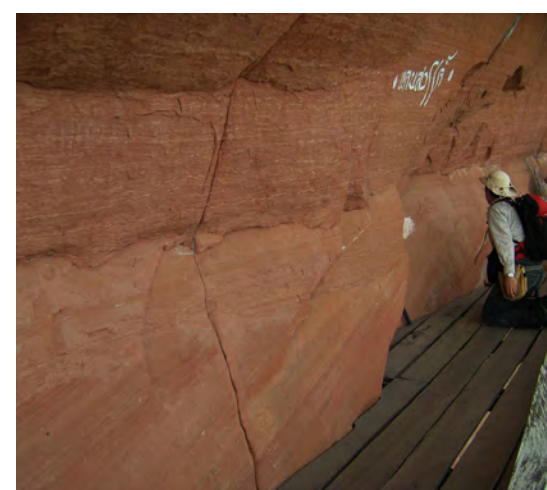
Location:

Phu Tok Noi is an isolated small hill located in the monastic land of Wat Chetiya Khiri Wiharn, Amphoe Si Wilai, Changwat Bueng Kan. From the province, there are two routes approaching Phu Tok Noi. Route 1 using highway No. 212 (Bueng Kan-Nakhon Phanom) to Ban Chai Phorn then turn right to the Chai Phorn-Ban Tong road and go further with a local paved road to Wat Chetiya Khiri Wiharn. Or route 2 using highway No. 222 (Bueng Kan-Si Wilai) to Amphoe Si Wilai then go further using a small local paved road which passes through some villages to Phu Tok Noi.



Geology:

Phu Tok Noi is a monadnock located at the southeast end of the NW-SE trending Phu Sing-Phu Tok Yai range. It is a 140 meters high mesa with an equal width and length of about a half km bounded with steep sides. Some parts of the surrounded cliffs have been horizontally carved deep inside the softer sandstone beds which caused unevenly surfaced cliffs. The Phu Tok Noi monadnock is the type section of the Phu Tok Noi Formation of the Khorat Group. This sedimentary rock formation typically composes of intercalations of alluvial sediments and loess which is an accumulation of wind-blown aeolian sediments. Hence, the prominent textures of the Phu Tok Noi Formation are very fine grained, partly calcareous, reddish colors sandstones with ripple marks; and fine to coarse grained sandstones with multi-direction cross beddings. Some weathered sandstone beds present a polygonal-crack feature which similar to a stack of pillows.



• The typical sandstones found at Phu Tok Noi.

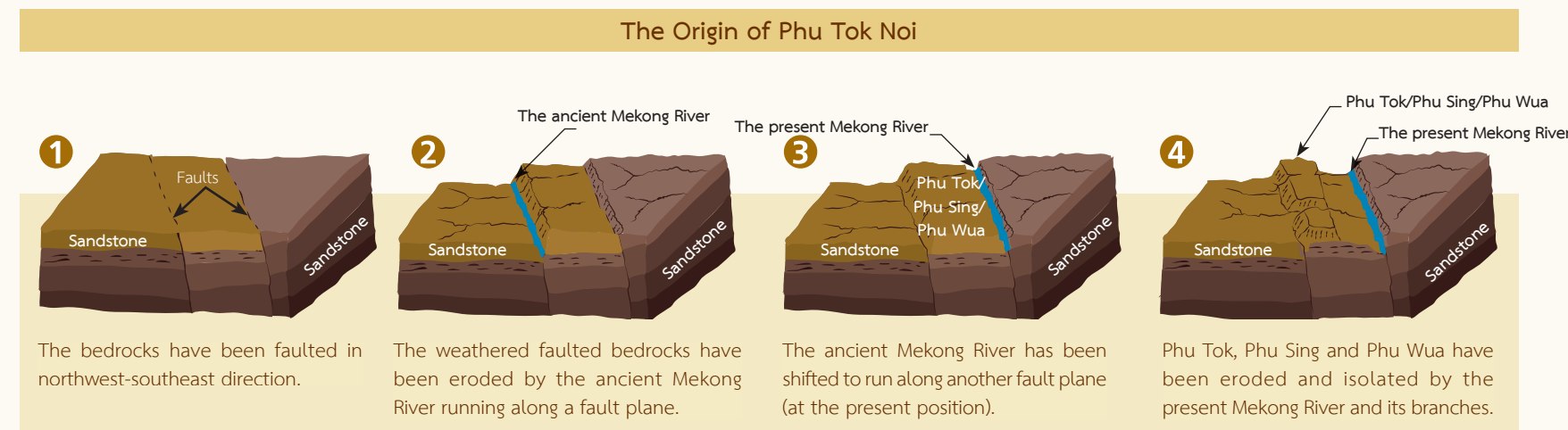


• Wat Chetiya Khiri Wiharn is located on the monastic ground of Phu Tok Noi.



• The soft fine-grained sandstone wall of the fifth level walkway of Phu Tok Noi.

The interbedded sedimentary sequence of the Phu Tok Noi Formation has been deposited in a semi-arid climate about 75 million years ago (Ma). It has been together lifted up with the Khorat Plateau by the Early Cenozoic tectonic around 55-30 Ma. The influences of the Mekong River and its branches have carved the red cap of the Khorat Plateau for hundreds of thousands of years and the Phu Wua-Phu Sing-Phu Tok range is left lying parallel to the flow of these powerful rivers.





• The intercalation of high and low resistant sandstone beds on the fifth level walkway of Phu Tok Noi.

■ **The Highlight:**

The most prominent feature of this monadnock is its uneven surfaced cliffs which caused by differential erosions of the intercalated beds. There are 7 low resistant beds at different heights where the cliffs have been horizontally carved about 3-7 meters inside the beds. A multi-level wooden walkway, known as the “Hell-Heaven Bridge”, has been constructed around this small hill along these 7 beds. This walkway is the main path to the top of Phu Tok Noi or “heaven”. Amazingly, it has been built since 1969 by the monks and villagers using local engineering wisdom.

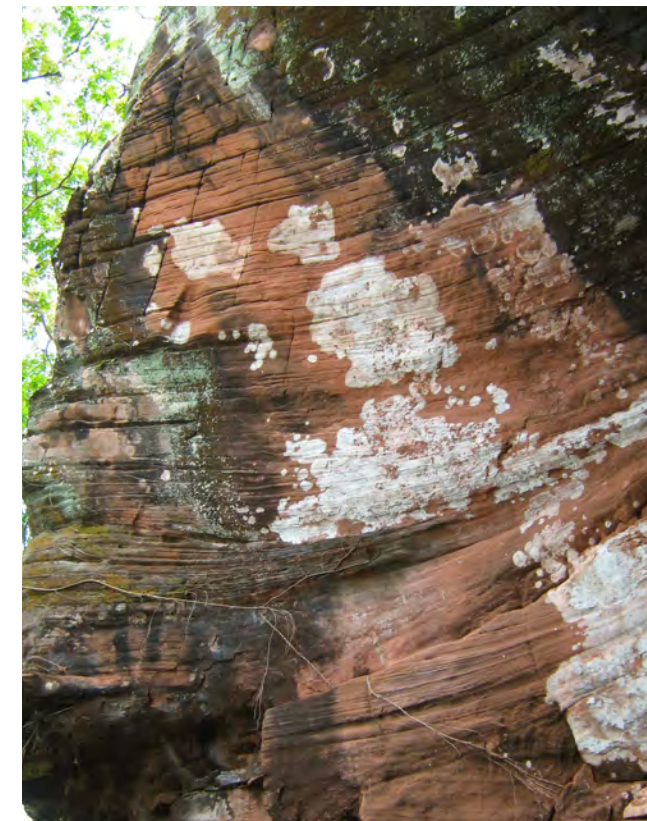
Walking up to the top of Phu Tok Noi is just like coming back from the Late Cretaceous period to the present time as the sequence of the sedimentary beds is younger upward. Visitors can explore the type section of the Phu Tok Noi Formation which tells us about its sedimentation, tectonic, weathering and erosional histories through the geological structures and the preserved geological features.



• Fine ripple marks preserved in the fine-grained sandstone of Phu Tok Noi.



• A pillow-like feature on the weathering surface of a sandstone bed.



• Large cross beddings on the wall of the forth level walkway of Phu Tok Noi.



• The wooden walkway hanging on the vertical cliff is the main path to the top of Phu Tok Noi.



• The Buddha's relics have been placed on this isolated Sao Chaliang.

On the walkway at high levels, fantastic bird's eye panoramas around Phu Tok Noi would delight all visitors, especially the photographers. On the fifth level, there is a small monastic pavilion and many small houses for the monks enclosed with small caves and beautiful cliffs. Significantly, visitors would have chances to pray to the Buddha's relics which have been placed in "Wiharn Phra Phut" or the "Temple of the Lord Buddha". This temple is located on an isolated sandstone column with prominent cross beddings or "Sao Chaliang" (in Thai) which is connected to Phu Tok Noi with a wooden bridge.

Walking consciously up to the top of Phu Tok Noi is going to the heaven.



• A fascinating panorama of the surrounded landform of Phu Tok Noi viewed from the Hell - Heaven Bridge.

The Stone Garden

The stone garden was initially created by nature almost 300 million years ago. This beloved garden has been beautifully finished by the faithfulness of Thai people as the garden of remembrance of Her Royal Highness Srinagarindra the Princess Mother with variety of trees, flowers and wildlife in a delightful atmosphere.

14

Location:

The Garden of Her Royal Highness Srinagarindra the Princess Mother is commonly known as the “Stone Garden”. This garden is located in the Kanchanaburi College of Agriculture And Technology, Amphoe Mueang, Changwat Kanchanaburi. The shortest way to the Stone Garden from the City Pillar of the Kanchanaburi Province is to cross the Somdet Phrayannasangwon Bridge or use the Khwae Noi-Khwae Yai ferry crossing service and go further for 9 km using Road No 3228 (Song Khwae Road). Visitors can stop by at the World War II historical site “Chong Kai War Cemetery”, the Common Wealth War Graves, which is located about 2 km from the ferry landing.



Geology:



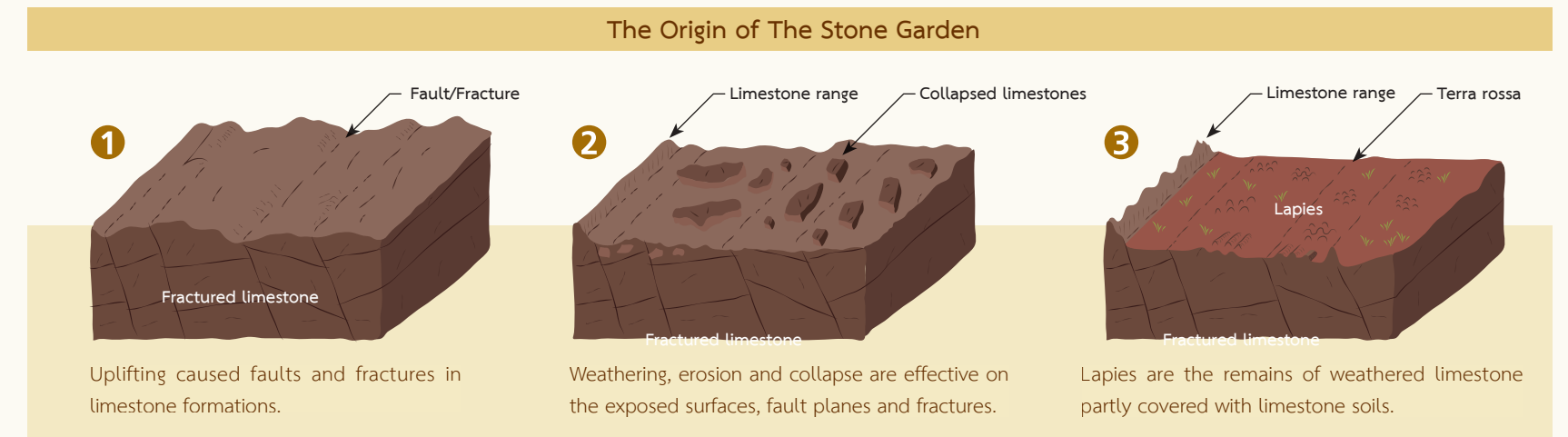
• The lapies in the delightful Stone Garden of remembrance.

In the Permian period or about 295-250 million years ago (Ma) the western part of Thailand was located under the sea in a warm climate region. The Permian sea water with high concentrations of dissolved calcium carbonate was a very fertile habitat for various marine creatures. From this sea water a group of massive limestone formations has been deposited and preserved various Permian marine fossils, e.g. fusulinids, corals and crinoids. The Permo-Triassic tectonic has lifted these limestone formations up over the sea level about 220 Ma causing many fractures and faults. Later, the movements of the Sai Yok Fault, which the the Khwae Noi River runs along, and erosions caused many caves and sinkholes.

In tropical countries chemical weathering and erosion causing typical karst landforms in limestone terrains, including many unusual geological features, e.g. caves, sinkholes, lapies, etc. The Stone Garden is a part of lapies which are remnants of the underlain weathered and eroded limestone beds. Most of the exposed limestones have been naturally carved as groups of round shaped outcrops spread over a terrain of red soil or “Terra Rossa” which is the weathering product of limestone containing iron oxides (rust). Lots of fusulinid, coral and crinoid fossils have been obviously found on many limestone outcrops.

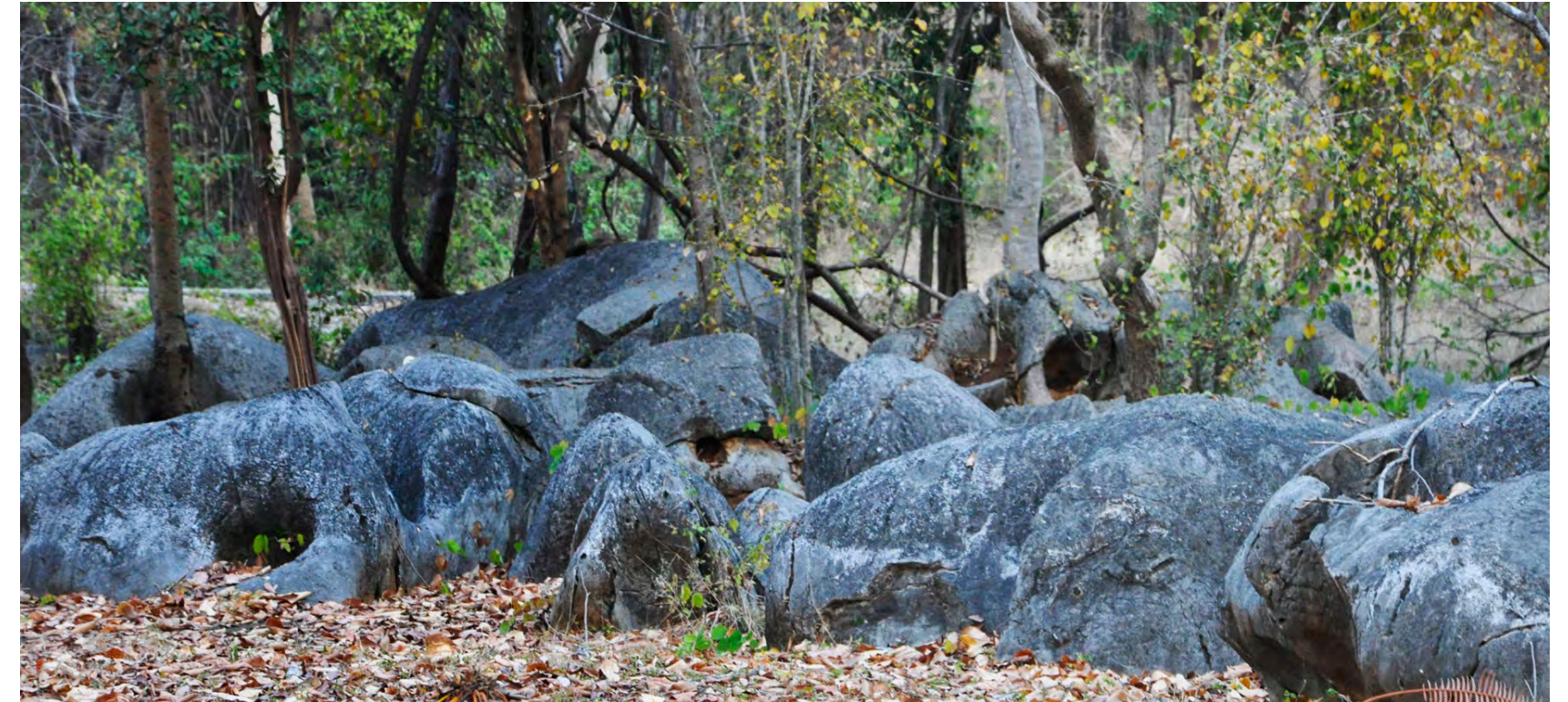


• The round limestone outcrop in the lapies looks like the back of an elephant or a whale.





• The statue of Her Royal Highness Srinakardindra Princess Mother is the symbol of this Stone Garden.



• A relaxing herd of elephants or walruses or other imaginings.



■ The Highlight:

The beautiful unusual landscape decorated with many different forms of weathered limestone outcrops of the Stone Garden is open to the imaginations of the visitors. Lions, whales, rhinoceros or even dinosaurs have been the foremost imaginary animals by most of the tourists. Some natural abstract carving limestone outcrops will make a ringing sound when hit by a piece of wood. Additionally, inside the rocks themselves plenty of Permian marine fossils have been permanently preserved to guaranty that they have been made under the sea hundreds of millions of years ago.



• A decorative white marble in the green park.



• The rough and spikey erosion surface of a limestone outcrop is caused by rain.



• An undisturbed limestone hill beside the Stone Garden of remembrance.



• This natural abstract carving will make a ringing sound when hit by a piece of wood.



• Lots of marine fossils are obvious on this limestone outcrop.

The Stone Garden is the garden of remembrance of Her Royal Highness Srinagarindra the Princess Mother. Her beloved statue is the symbol of this beautiful garden which has been decorated with the integrated philosophies of geology, forestry and a wildlife sanctuary. It is not generally known that this shady garden, which is covered with a variety of local specie trees and colorful flowers and cheerful with different kinds of beautiful birds, has concealed herds of wildlife, e.g. barking deer, serow, Burmese hares, pheasant, etc.

A fantastic geosite and a wildlife sanctuary with colorful flowers have been packed by the faithfulness of all Thais as the Stone Garden of remembrance.



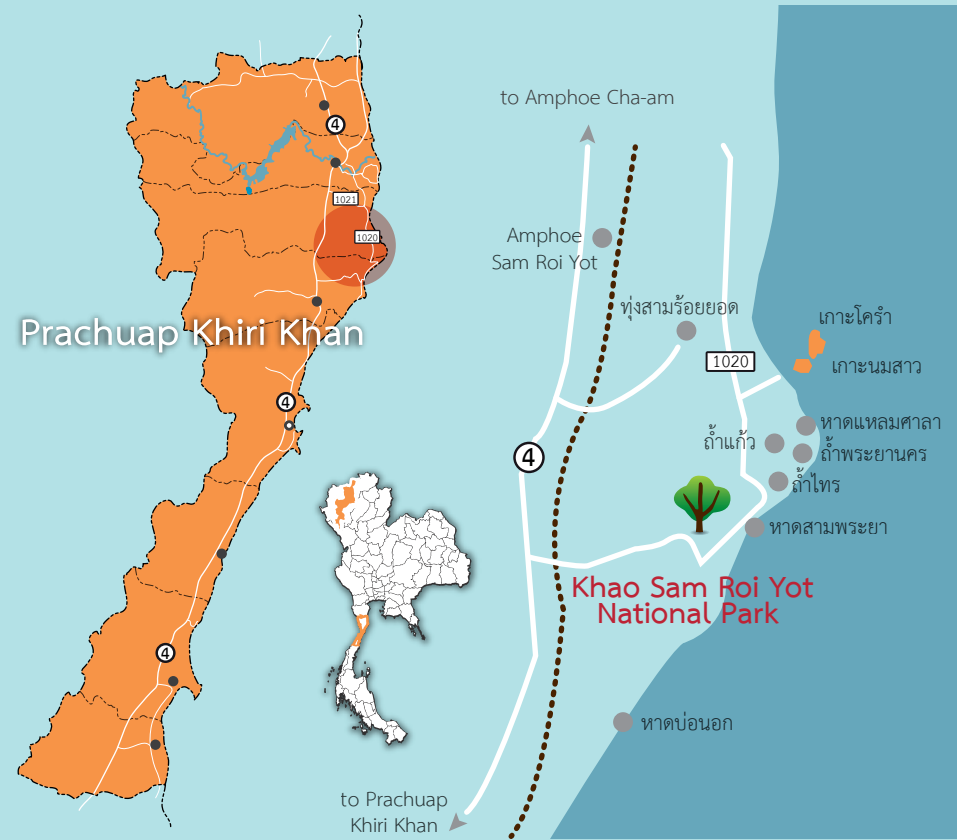
Khao Sam Roi Yot

Khao Sam Roi Yot is an eco-geological site surrounded with spectacular limestone ranges with plenty of beautiful caves. It is the first coastal National Park of Thailand which is bounded in the east with a huge fresh water marsh and mangrove forests. Khao Sam Roi Yot is truly a heaven on earth for mankind, birds and all other creatures.

15

Location:

Khao Sam Roi Yot has been designated in 1966 as the first coastal National Park of Thailand covering an area of about 99 sq km in Amphoe Kui Buri and Amphoe Pran Buri of Changwat Prachuap Khiri Khan. The office of the National Park is located about 14 km. east of the Km 286-287 of highway No. 4. There are 2 simple alternatives to reach the National Park. First route, from the Pran Buri Intersection using the Paknam-Pran Buri road to the east for 4 km then turns right to go for 31 km to the National Park. Second route, turn to the road No. 1026 at Km. 286.5 of highway No.4 (about 6 km north of Amphoe Kui Buri) to travel for 14 km to Khao Sam Roi Yot.



The Ratburi limestone has been lifted up above sea level, together with the western part of the Thai Peninsular, about 220 Ma due to the Permo-Triassic tectonic. This region has been lifted up as mountain ranges, including limestone islands in the vicinity, with generic fractures and faults around 55-30 Ma. The subsequent weathering and erosion caused by meteoric waters, running water and groundwater have cooperatively carved all the special karst landscapes including caves, sinkholes, uneven cliffs and valleys. Since the Middle Pleistocene epoch, the depositions of sand bars along the sea shore have blocked off the influences of sea water, therefore the environment has been gradually changed to be brackish and freshwater wetland respectively.



• The karst topographic symbol of Khao Sam Roi Yot.

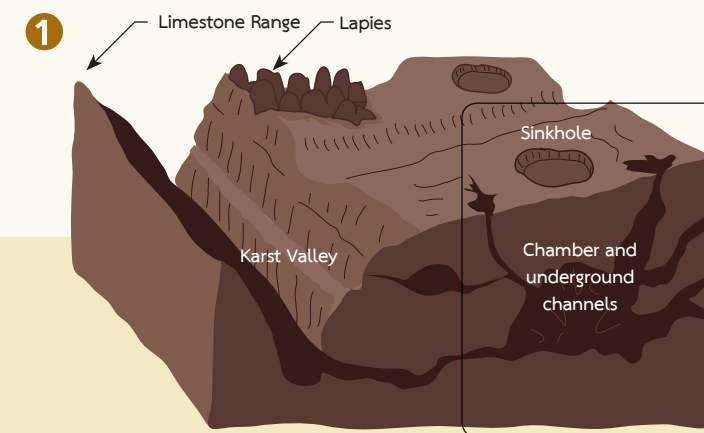
Geology:



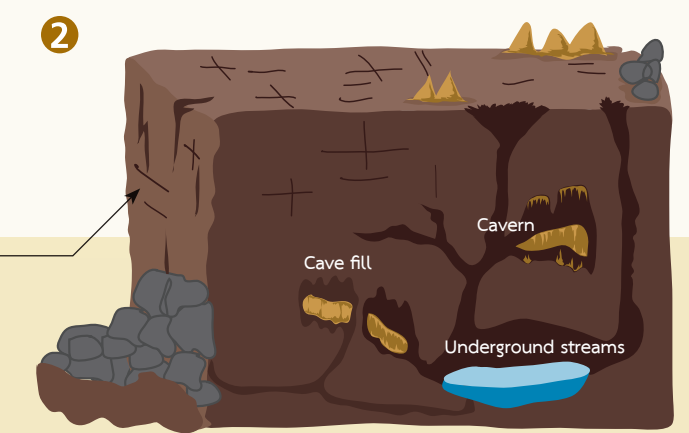
• A typical eroded massive limestone bed of Khao Sam Roi Yot.

The Khao Sam Roi Yot National Park is located on the north-south trending Permian limestone of the Ratburi Group deposited 295-250 million years ago (Ma). The Ratburi Group composes mainly of white to grey massive limestone formations. Plentiful marine fossils of algae and foraminifera have been found preserving in several formations. The lowland areas in the National Park are covered with Quaternary sediments which have been deposited since the Lower Pleistocene epoch (about 1.6 Ma). Three main groups of sediments are found deposited around the limestone range, including black clays with remains of aquatic plants in the marsh, grey clays on the flood plain and sands and gravels on the beach respectively.

The Origin of Karst Topographic Landform of Khao Sam Roi Yot.



Limestone beds have been fractured and faulted by the Earth's tectonic. Later caves, sinkholes and karst valleys have been carved within the karst topographic landform by weathering and erosion.



Weathering and erosion are the main processes which cause collapse of fractured rocks, deposition of cave sediments and development of caves, sinkholes and underground channels.



• A beautiful scenery viewed from the Khao Daeng Viewpoint.

■ **The Highlight:**

Khao Sam Roi Yot or the “300 Peak Mountain” has been named by its natural “karst” topography of an eroded limestone terrain. It is composing of uneven hay stacks like hills, e.g. Khao Chalome Fang, Khao Krajome, Khao Yai and Khao Daeng with a great viewpoint. In the nearby sea, the extended limestone ranges have been formed as beautiful islands, e.g. Ko Sattakut, Ko Nom Sao, Ko Rawing, Ko Rawang and Ko Khi Nok.

The Sam Roi Yot marsh is a freshwater wetland covering one-third of the park with a specific environment which provide a rich habitat for great aquatic plants and approximately 300 recorded species of birds. Visitors could experience the wonderful nature in the Bueng Bua Natural Study Center. Additionally, the park is a popular spot for bird watchers as it is located on the East Asian/Australian Flyway.



• The highlights of the Khao Sam Roi Yot National Park are the special geological features of karst landform and the “Khuha Kharuhath Pavilion” the symbol of the province.



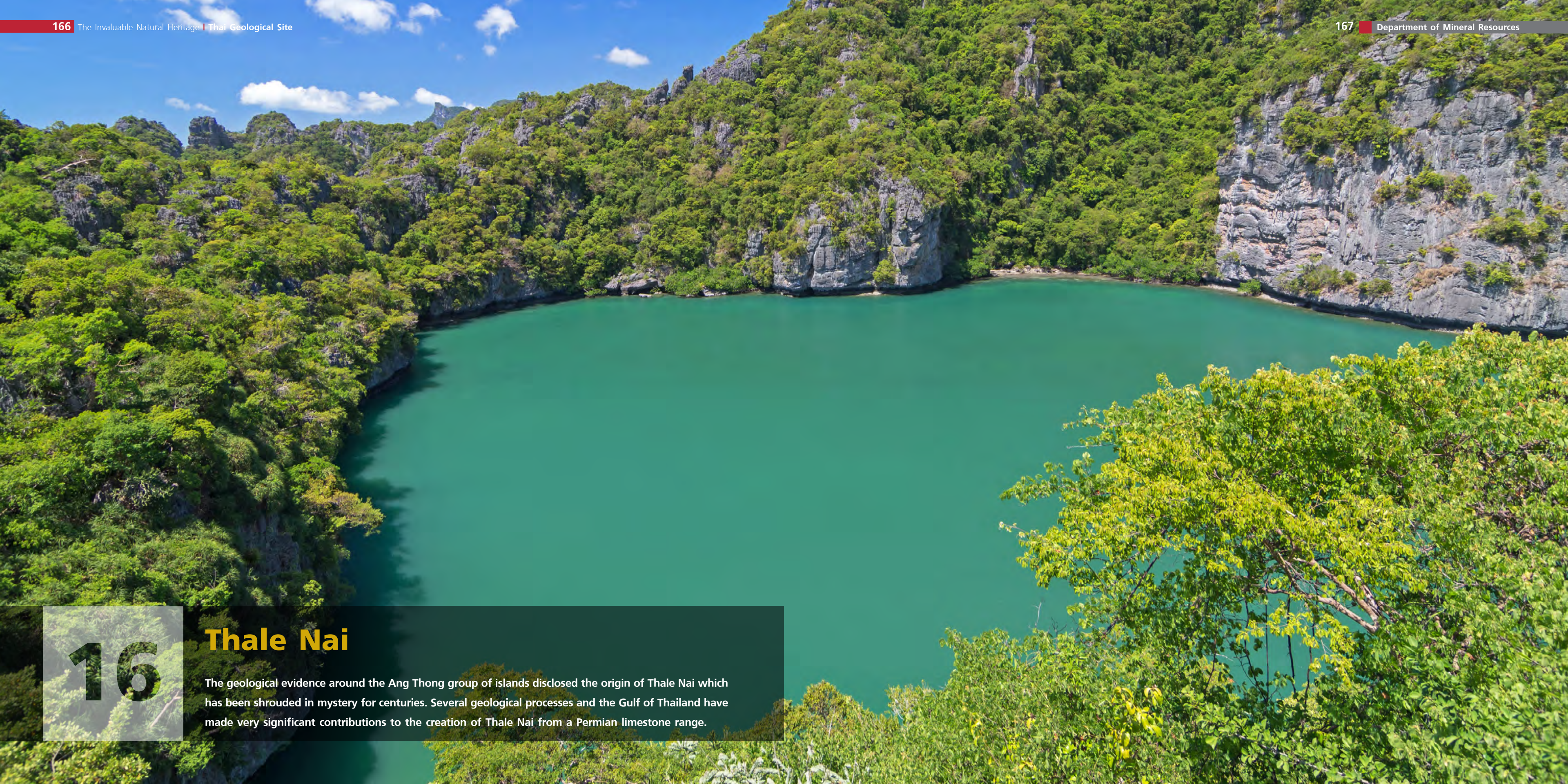
• The wonderful landscape of the Khao Daeng Hill and the lively atmosphere of the Khao Daeng Canal.

Beside these, the Coastal National Park offers the visitors a tremendous variety of attractions of soluble limestone bedrocks which have been carved as caves, e.g. Tham Kaeo, Tham Phrai and Tham Phraya Nakhon. Inside Tham Phraya Nakhon is the “Phra Thenang Khuha Kharuhat”, a magnificent Thai style pavilion constructed for King Chulalongkorn the Great when he was visiting Tham Phraya Nakhon in 1890. “Phra Thenang Khuha Kharuhat” has then become the official symbol of Prachuap Khiri Khan Province.

Explore Khao Sam Roi Yot National Park to experience its great recreational, educational, geological and ecological significances.



• The Sam Roi Yot Marsh - the wonderful conserved natural heritage.

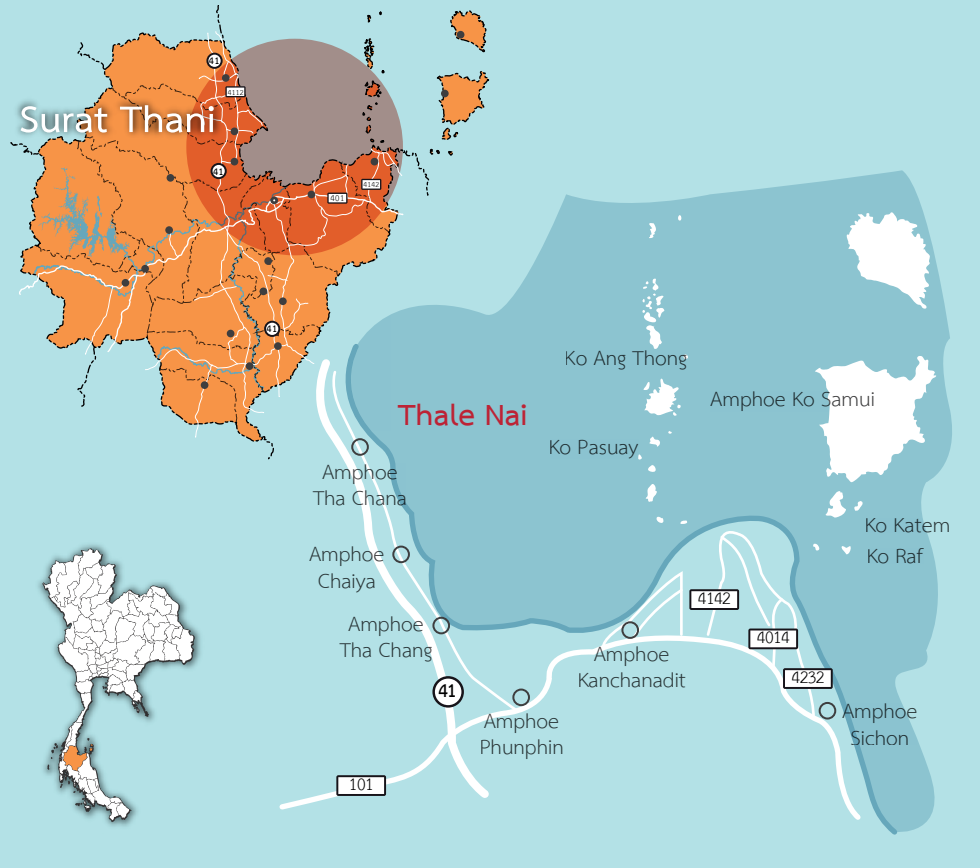
**16**

Thale Nai

The geological evidence around the Ang Thong group of islands disclosed the origin of Thale Nai which has been shrouded in mystery for centuries. Several geological processes and the Gulf of Thailand have made very significant contributions to the creation of Thale Nai from a Permian limestone range.

Location:

Thale Nai is a part of “Ko Maeko” island which is one of a group of 42 islands named “Ang Thong” located in the Mu Ko Ang Thong National Park, Amphoe Ko Samui, Changwat Sarat Thani. Travelling to Thale Nai, visitors have to go by a ferry from Ko Samui to the office of the National Park which is located on Ko Wua Talab about 28 km. west of Ko Samui. From the office on Ko Wua Talab go further by boat to Ko Maeko for about 15 minutes and take a trip for 400 m. on foot to Thale Nai.



Geology:



• The eroded massive limestone bounding Thale Nai.

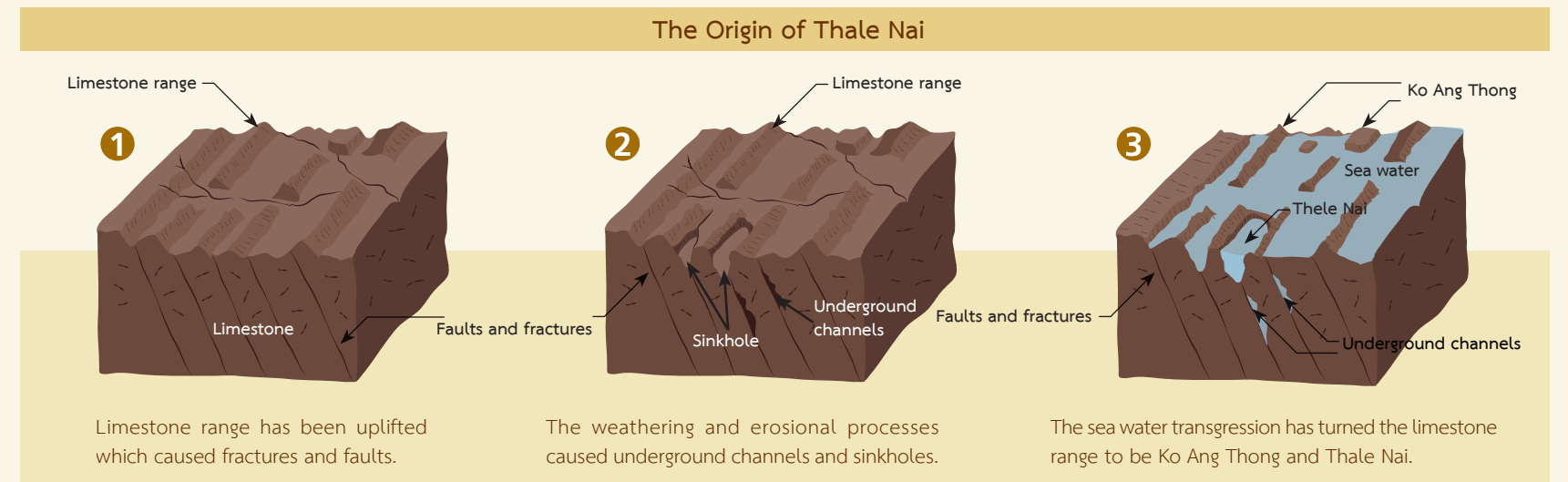
All the islands in the Mu Ko Ang Thong National Park have been formed from the Permian limestone of the Ratburi Group, deposited about 280-260 million years ago. The Ratburi Group comprises mainly of grey massive limestone and dolomitic limestone with some minor thin limestone beds in the lower formations. Very thin chert beds and nodules are also found intercalated. Over 200 million years after the deposition, the Ratburi limestones have been lifted up by the Cenozoic tectonic which caused generic fractures and faults.

The tropical atmosphere has gradually weathered and eroded the Ratburi Group and formed karst topography with uneven hills and karst valleys. As limestones are soluble rocks, many underground channels have been developed especially along fracture and fault zones. The enlargements of the shallow underground channels caused collapsing of their thin ceilings and then sinkholes have been commonly formed.

The last sea water transgression, occurred around 6,000 years ago, turning this karst topographic land-form into a group of islands. All the sinkholes, linked by the underground channels network, have been inundated by sea water and the largest one with quite a perfect ring-shaped is called “Thale Nai”.



• Thale Nai is encircled with eroded massive limestone hills.





• The fantastic shade of green reflected from the dense wood and the Thale Nai's emerald pool.

■ The Highlight:

The inner sea “Thale Nai” is one of Thai’s natural wonders. Beside its natural beauty, Thale Nai has a special unusual looking landform of circular lying uneven limestone hills which is filled with sea water. To appreciate these wonders, visitors have to walk up a limestone hill along an adventure track to the Thale Nai viewpoint. Most of the limestone outcrops feature prominent spiky surfaces which are caused by rain erosion. Many coral fossils are also found in limestone outcrops on the way to this viewpoint. From one side of the viewpoint, the beauty of islands and islets spreading over the blue sea would amaze everyone. On the other side, the beauty of Thale Nai’s shade of green reflected from the evergreen wood over the emerald inner sea would fascinate all visitors.



• The scenic panorama with plenty of surrounding islets from the Thale Nai viewpoint.



The origin of Thale Nai has been shrouded in mystery for centuries. Most people thought that it was a volcanic crater by its round shaped. However, many pieces of geological evidence around the Ang Thong group of islands have disclosed the wonderful history of the Thale Nai's formation which is quite complicated. This National Park has taken millions of years to create; however, it could be shortly destroyed. Changes of the environment, either naturally or by human, could eternally damage this sanctuary where varieties of birds, fishes, mammals and amphibians have been peacefully settled.

Save the wood and the water
to save the wonderful Thale Nai's shade of green.

• *The unique emerald pool of Thale Nai holds a fascination for all tourists.*



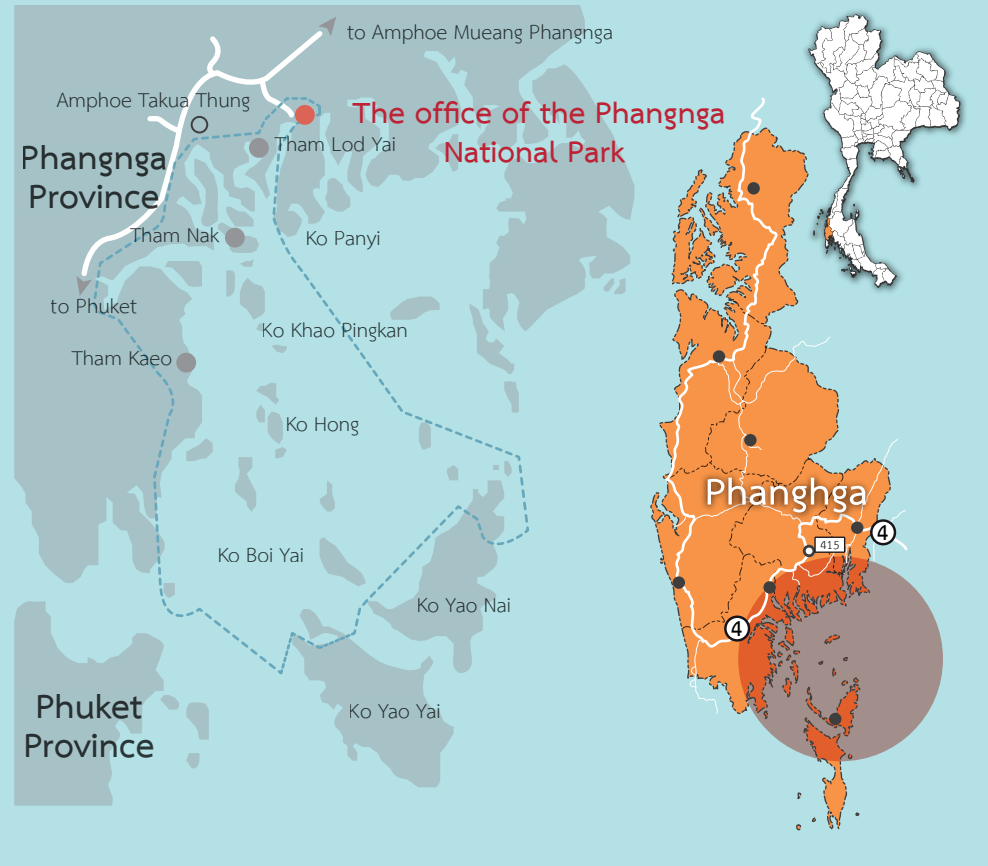
Ao Phangnga

Enjoy the very impressive collection of Thailand's famous islands and experience the geological marvels in a marine geosite of the Ao Phangnga National Park. Moreover, tourists can admire the Panyi exclusive way of life, enjoy diving, feeding marine fishes, kayaking around the "James Bond Island", and exploring wildlife in the largest mangrove forest of Thailand.

17

Location:

Ao Phangnga or the “Phangnga Bay” is a part of the Ao Phangnga National Park which covers the Andaman Sea in Phangnga and Phuket Provinces. There are over 42 large and small islands in the bay, such as Ko Yao Yai, Ko Panyi, Ko Khao Pingkan, Ko Hong, Ko Boi Yai, etc. From Phangnga Province, visitors can go to the office of the Ao Phangnga National Park using highway No. 4 about 8 km. and turn left to road No. 4144 of about 2.5 km. There are many Phangnga Bay tourist boat services offering at the office. Travelling by ferries from Phuket Province is a tourist favorite alternative.



Geology:



• The typical wave-cut notch and stalactites on the massive limestone cliffs in Ao Phangnga.

The Ao Phangnga National Park is underlain mainly with Permian carbonate rocks of the Ratburi Group which deposited about 295-250 million years ago (Ma). It composes mainly of massive and thick beds of limestone and dolomitic limestone which has been lifted up to the Earth’s surface around 220 Ma. The Cenozoic tectonic due to the collision of the Indian Plate and the Eurasian Plate caused many northeast-southwest strike-slip faults including Khlong Marui Fault which run from the mainland through the Phangnga Bay. There are plenty of cavities, caves, stacks and cliffs in this bay which caused by the movements of the Khlong Marui Fault and its branches which run parallel and perpendicular to the main one.

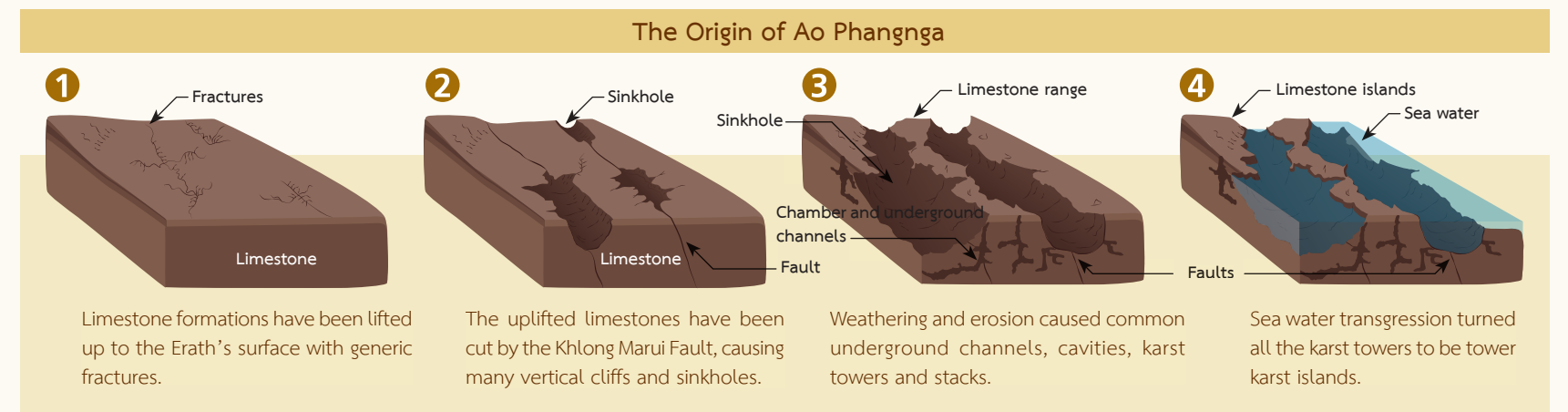


• Ko Khao Pingkan is one of the symbols of the Ao Phangnga National Park.



• The faulted limestone blocks are standing “Pingkan” or against each other at the pier.

The evidence of these faults and fractures are presented as vertical cliffs in most of the islands, especially at Khao Pingkan and Khao Tapu. At the end of the last Ice Age or about 10,000-6,000 years ago, the sea water transgression has turned all the limestone hills in this area to be islands and islets. Khao Pingkan was also turned to be an island with a cape called Khao Tapu. Later the cape was cut off by wave erosions and formed as a nail head shaped seastack.





• An impressive panorama of the unique Phangnga Bay.

■ The Highlight:



• Tourists enjoy kayaking in Ao Phangnga.

The beautiful scenery of Ao Phangnga together with the unique way of life of Ko Panyi's community and the fantastic legend of Ko Khao Pingkan and Ko Tapu have been completely merged as one as the symbol of the Phangnga Bay. The word "Pingkan" means leaning against each other which referred to the two limestone blocks which have been torn apart by the Khlong Marui Fault and finally the top of the two blocks are leaning against each other at Ko Khao Pingkan.

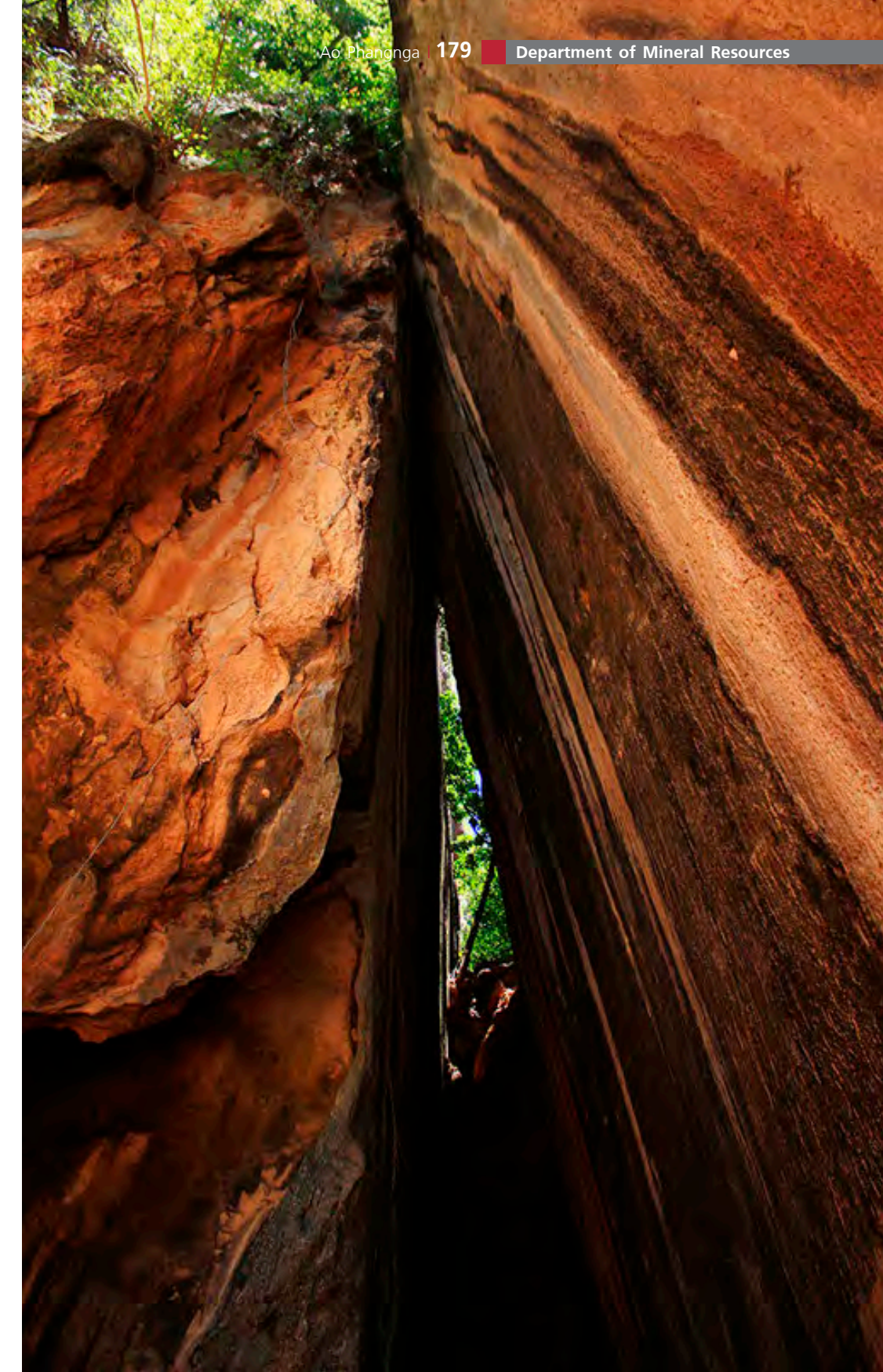
In the vicinity, the seastack of Ko Tapu has been cut off and carved by the sea waves as a nail head or a crab's eye shape. The sea level in the Phangnga Bay was about 4 meters higher than the present level around 6,000 years ago. The sea level later, around 2,500 year ago, decreased about 1.5 meters before dropping to the present level. These have been evident by the three wave-cut notches on the Ko Tapu seastack at the 4 and 2.5 meters levels above the sea and the



• Tham Lod - the well-known sea cave of the Phangnga Bay.

narrowest notch at the present sea level. A further proof of the decreasing of sea levels is the ancient shells of marine mollusks attached to these notches. Ko Tapu is also called "James Bond Island" as it has served as the scenery of the James Bond classic, "Man with a Golden Gun" and more recently, "The Beach".

The Phangnga Bay is underlain by a karst landform where most of the karst features, e.g. karst valleys, sinkholes and underground channels have been inundated. The only obvious karst feature remains are tower karst islands, caves and sea caves. Tham Lod is one of well-known sea caves where tourists can view many stalactites on the 1-5 meters high ceiling while kayaking through.



• Khao Pingkan - the leaning against each other of two fault plains of the Khlong Marui Fault with prominent slickensides.



• The Panyi commune lives peacefully by its own exclusive way of life.

Besides experiencing this marine geosite, tourists can enjoy kayaking, diving, feeding fish and exploring the wildlife in the largest mangrove forest of Thailand with various species of mangroves depending on elevations and relative tidal ranges.

Ao Phangnga - The real multi-aspect marine tourist complex of Thailand.



• Ko Tapu - the most well-known nail head shaped seastack is the logo of Ao Phangnga.

18

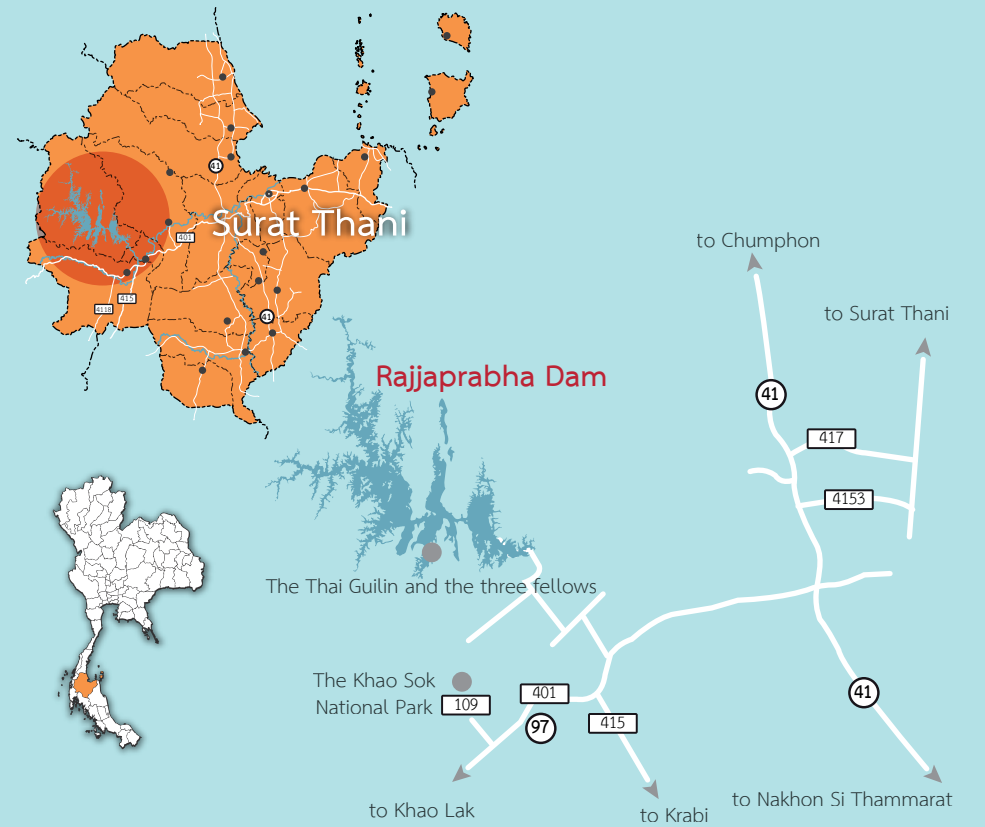
Rajjaprabha Dam

Khao Sam Kloe or the "Three Fellows" is one of the highlights of the Rajjaprabha Dam that have impressed all the tourists. Rajjaprabha Dam is the only reservoir in Thailand which is surrounded with spectacular tower karsts, vertical cliffs, waterfalls and caves, and is also known as "Thai Guilin".



Location:

The Rajjaprabha Dam, formerly called “Chiao Lan Dam”, is the only Thailand’s karst reservoir located in the Khao Sok National Park, Ban Chiao Lan, Amphoe Ban Ta Khun, Changwat Surat Thani. The entrance of the Rajjaprabha Dam, with a big guide post, is located between Km. 57-58 of highway No. 401 (about 40 km from Ban Ta Khun). The Rajjaprabha Dam, the viewpoint and the tourist service center are about 12 km further. The Rajjaprabha Dam is a part of the Khao Sok National Park which its office is located at Km. 109 of the same highway.



Geology:



• The Rajjaprabha reservoir with the background of limestone hills.

Rajjaprabha Dam is composed of 2 rock units. The lower unit, found at the hills beside the dam, has been mapped as the Kaeng Krachan Group. This unit comprises mudstones, pebbly mudstones, pebbly sandstones and quartz sandstones deposited in a continental shelf in Early Permian or about 295-280 million years ago (Ma). The upper unit, found in the reservoir, has been mapped as Ratburi Group. The upper unit composes mainly of thick bed and massive limestone and dolomitic limestone slightly interbedded with shale, deposited in a shallow sea in Middle Permian or about 280-260 Ma. Many marine fossils have been found in limestone, e.g. fusulinids, crinoids, corals, gastropods, brachiopods and bryozoas.

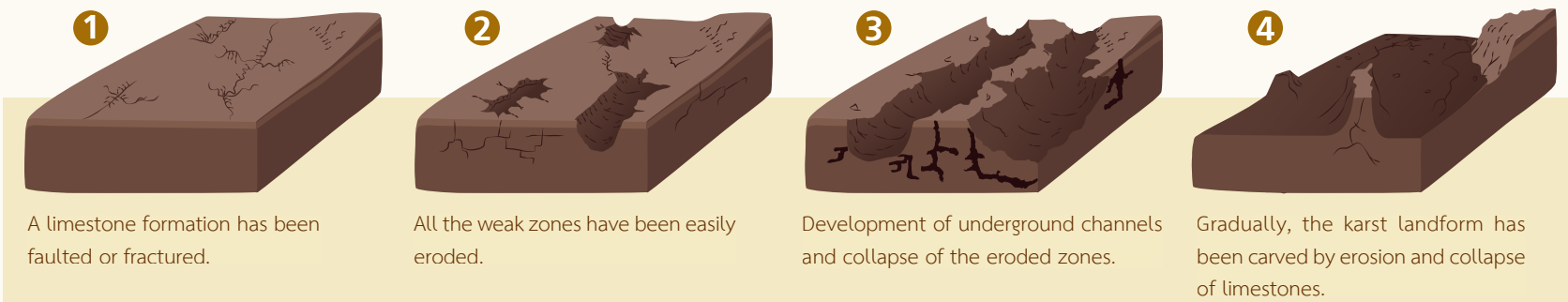
The two rock units have been deformed and lifted up to the Earth’s surface about 220 Ma causing common fractures and foldings. The Cenozoic northeast-southwest and north-south trending faults triggered many branch faults and fractures parallel and perpendicular to the main ones which formed many beautiful vertical cliffs. The influence of the tropical climate has gradually eroded and sculpted the faulted and fractured limestone hills forming a beautiful unusual looking karst topographic landform including tower karsts, karst valleys, sinkholes, caves and underground channels networks.

This area has been flooded by the Khlong Saeng stream after the construction of the Rajjaprabha Dam and the only leftover karst features are tower karst islets with some beautiful cliffs and caves. However, many caves have been permanently flooded.



• A boat trip around the Rajjaprabha reservoir among the 162 tower karst islets.

The Origin of the Karst Landform in the Rajjaprabha Dam





• The beautiful “Khao Sam Kloe” or the Three Fellows.

■ The Highlight:



• A fault cut vertical limestone cliff.

Chiao Lan Dam is a multipurpose dam providing agricultural irrigation and hydro-electricity generation services. It has been later officially named by His Majesty the King as “Rajjaprabha Dam” which means “the Light of the Kingdom”. Rajjaprabha Dam has become a geological tourism site by the well arrangement of its attractive geological features and scenes. It is also known as “Thai Guilin”. The beautiful 162 tower karst islets and the 70 meters deep reservoir are the main features that generate countless wonderful panoramas obtaining in different viewpoints, times and seasons. Most of these islets are found clustering in the narrowest part of the reservoir called “Chong Kaeb Khao Ka Loh”. The foremost highlights of the Rajjaprabha Dam’s reservoir are the “Three Fellows” which are three tower karst islets standing close to each other like the three fellows having conversations.



• The geological and biological beauties of the Rajjaprabha reservoir.



• A vertical limestone cliff is an evidence of a fault.

There are many other highlights in this geological site, e.g. exploring the coral cave and the Tham Nam Thalu cave, kayaking or canoeing around the three fellows and visiting aquatic farms. Moreover, visitors can enjoy many caves and waterfalls in the Khao Sok National Park or join a bush walking to experience *Rafflesia kerri Meijer* (“Bua Phut” in Thai) the gigantic land lotus (70-80 cm in diameter). The Thai Guilin provides not only geological fascination to the visitors, it also serves as a geological information site, a wildlife sanctuary and a recreation site.

The Rajjaprabha reservoir serves the tourist an exciting channel to closely experience the fantastic remains of the karst landform.



• The Thai Guilin and The Three Fellows of the Rajjaprabha Dam are covered with conserved evergreen forests.



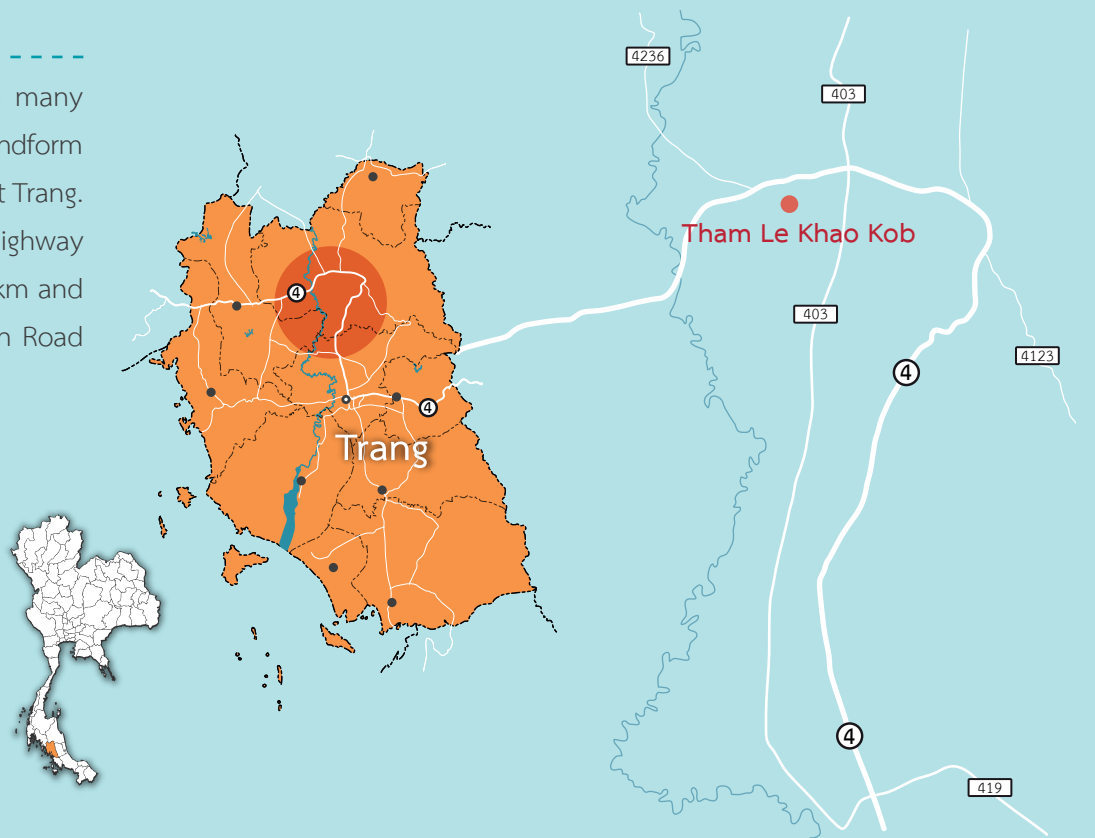
Tham Le Khao Kob

Tham Le Khao Kob is an Unseen Thailand and is one of the tourist favorite targets in southern Thailand. Explore Tham Le Khao Kob by boat to experience the wonderful speleothems like stalactites, stalagmites, columns or pillars and especially their baby phases "soda straws".

19

Location:

Tham Le Khao Kob is a big cave with many entrances located in a karst topographic landform at Khao Kob, Amphoe Huai Yot, Changwat Trang. Travelling from Trang Province using highway No. 4 (Trang-Huai Yot-Wang Wiset) for 7 km and then turn left to the Khao Kob-Hua Wan Road only 700 meters to Tham Le Khao Kob.



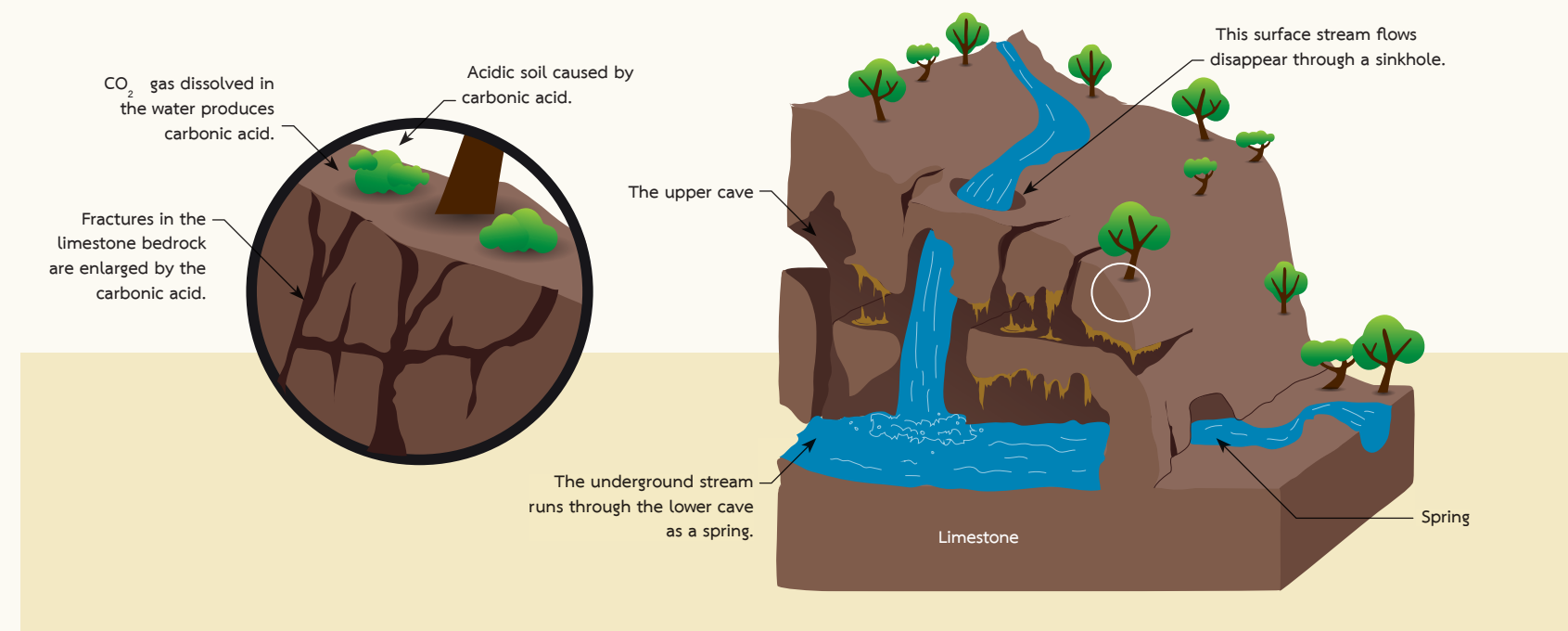
Geology:



• Some soda straws are over one meter long.

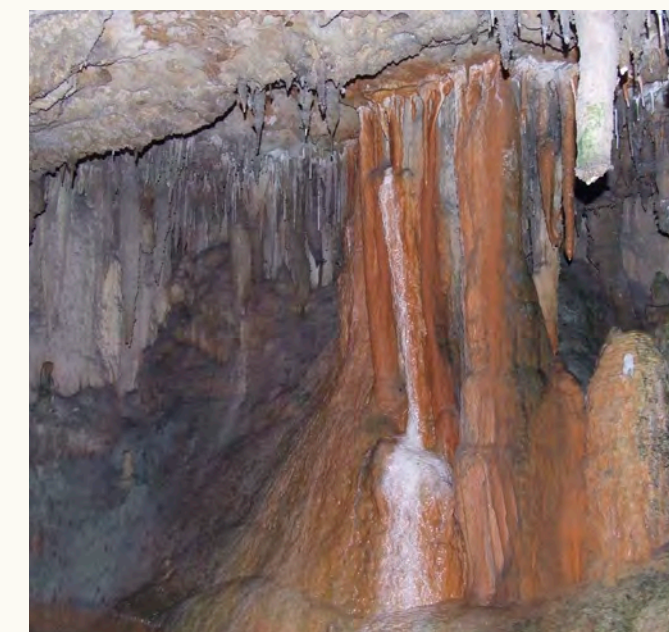
Khaokob is a hill which composes mainly of grey to dark grey fine grain limestone, dolomitic limestone and dolomite of Ratburi Group deposited in a shallow sea in Permian period or about 295-250 million years ago (Ma). The Ratburi Group has been deformed and lifted up to the Earth's surface by the collision of the two main tectonic plates composing the Thai Peninsular about 220 Ma. Most of the rocks have formed as thick beds oriented in a northeast-southwest striking and dip toward southeast. Khaokob has been cut through by many faults, shown by layers of brecciated limestones with carbonaceous cementing materials on the fault planes. Moreover, it is partly recrystallized due to local metamorphisms.

The Origin of Tham Le Khao Kob.

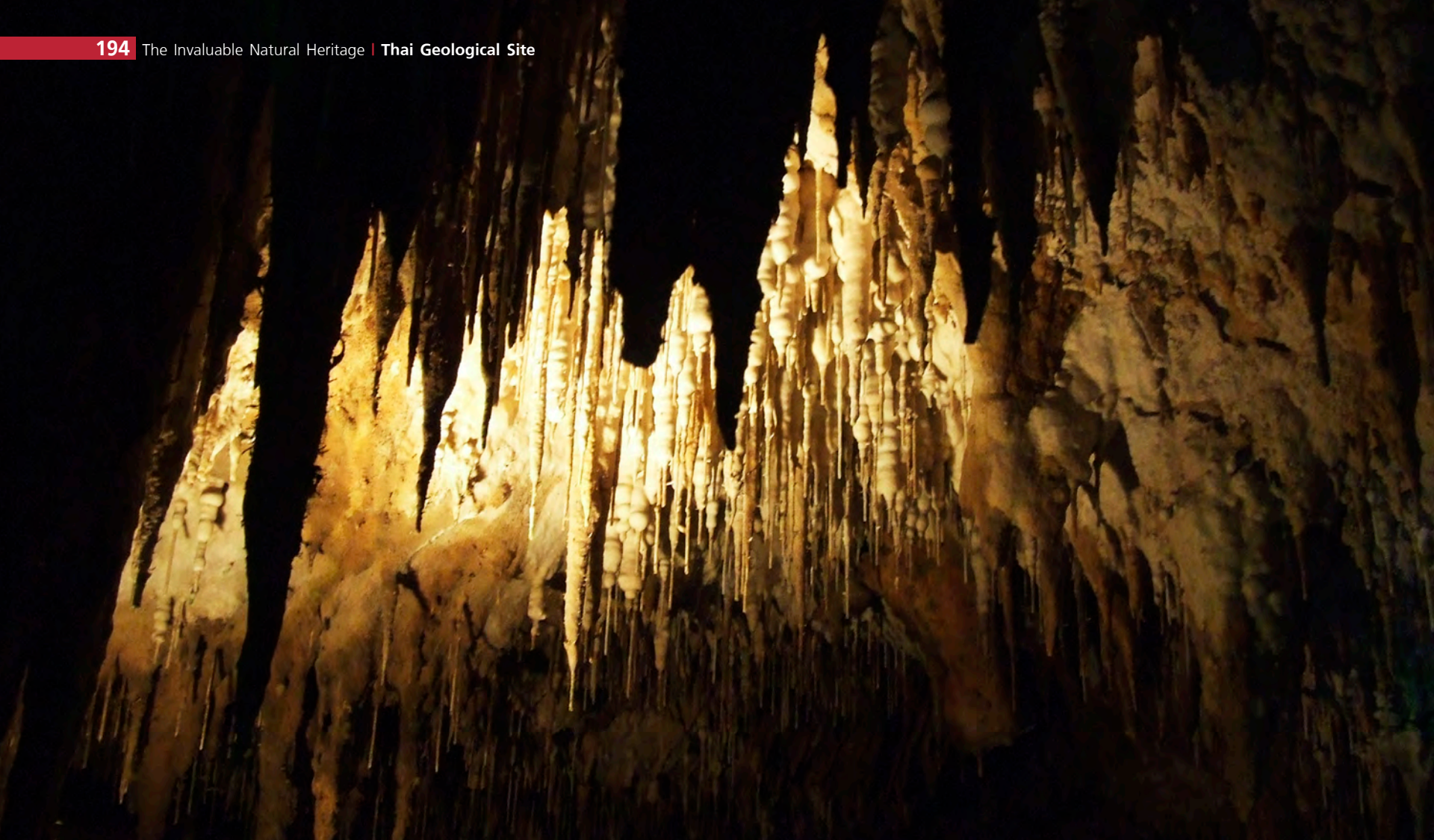


The faulted and fractured limestones have been progressively weathered and eroded after exposed to the atmosphere. Moreover, networks of underground channels have been also developed and enlarged by the flows of groundwater along the fracture zones. Khaokob has been formed as a karst topographic terrain with 6 remains of tower karsts and generic sinkholes and caves. Later, the Earth's tectonic has lifted up this karst terrain together with the underground channels network which partly turned to be caves with connections to the surface stream system. Then the enlargements of the caves have been terminated. Instead, all the wonderful speleothems have been created in various forms.

Especially, the spectacular clusters of hollow soda straws or the groups of "baby stalactites" which are going to merge and form stalactites. Some soda straws are over one meter long. The calcium carbonate solution dropping from a stalactite which is joined to the cave ceiling supplies material to create a stalagmite which is fixed to the cave floor. The progressively growth of both speleothems, until they meet each other, would form a column.



• Stalactites, stalagmites and a column are coated with rust stain dissolved from limestones.



• A cluster of baby stalactites (soda straws) is one of the highlights of Tham Le Khao Kob.

■ The Highlight:



Tham Le Khao Kob means a sea cave which is located at the Khao Kob Hill. They are called “Tham Le” because they are comparable to sea caves by branches of streams which are running through the network of caves and joining the surface stream system running outside. There are many fantastic caves with different shapes and sizes which have been named by their special appearances, e.g. Tham Mung Khon (Dragon’s Cave), Tham Khon Tan (Gandharva’s Cave), Tham Chao Sao (Bride’s Cave), Tham Phetch (Diamond Cave), Tham Phloi (Gems Cave), etc. All the caves could be accessed by boat through many entrances which connected to beautiful canals running around the Khao Kob Hill.



• The progressive formation of speleothems in the caves.

Tham Mung Khon or Tham Lod is one of the highlights of Tham Le Khao Kob because its ceiling is only 1-2 meter above the water surface. Visitors have to lean backwards on the boat while travelling through this 350 meters long cave which is comparable to passing through a dragon’s long belly. Beside the beauty of this wonderland appearing geological site, visitors can also enjoy an in the cave on the boat bat watching.





• Many slim columns have been created by the joining of stalactite-stalagmite pairs.



• The remains of eroded limestone in the cave - An evidence of the underground channel.

The wonderful highlights plus the geological knowledge about the origin of karst topographic landform, caves and speleothems would increase the value of Tham Le Khao Kob. Especially, the baby stalactites or the hallow soda straws which are very uncommon and make Tham Le Khao Kob an unseen Thailand.

Experience Tham Le Khao Kob the wonderful on-land sea cave and make this unseen Thailand to be seen everlastingly.



• The uncommon soda straws of Tham Le Khao Kob always amaze the visitors.

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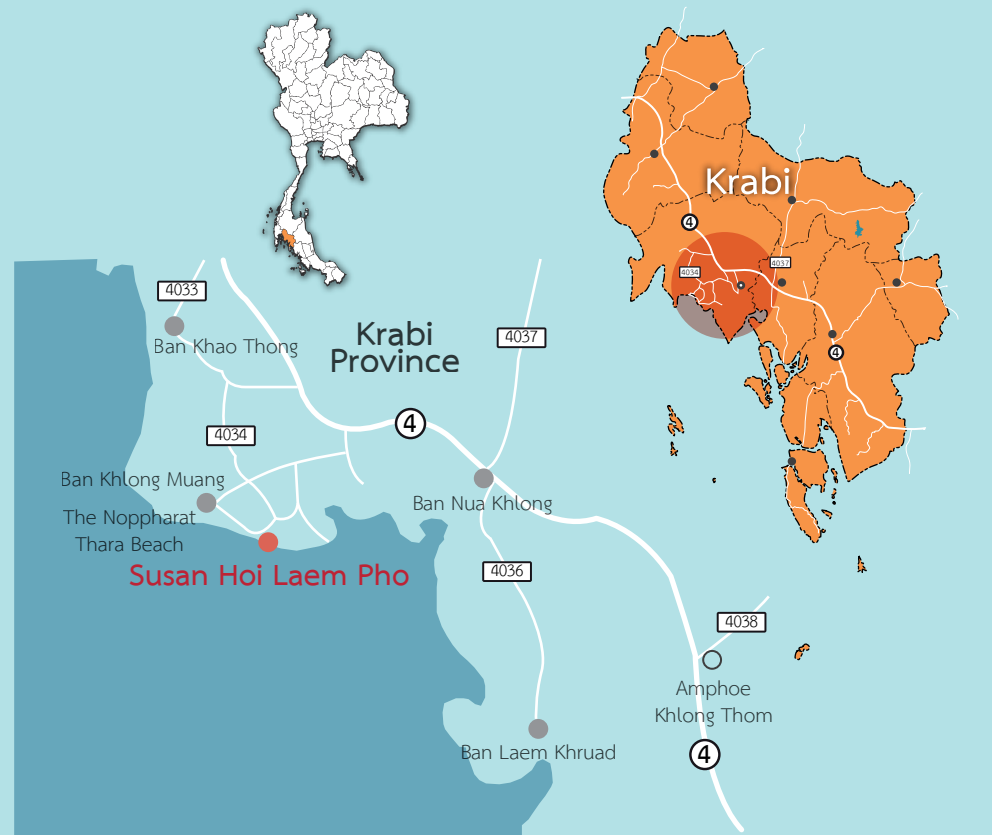
Susan Hoi Laem Pho

The first amazing place to visit in Krabi is the Cape of Laem Pho where millions of fresh water gastropods have been submerged twice day-to-day by tidewater. These molluscs have been preserved by cementing with calcareous material since the Eocene-Oligocene epochs. They are now appearing as thousands of concrete slabs paving the seashore of Susan Hoi Laem Pho.



■ **Location:**

Susan Hoi Laem Pho is located on the beach in the Hat Noppharat Thara - Mu Ko Phi Phi National Park, Amphoe Mueang Krabi, Changwat Krabi. There are many routes with good tourist signs to approach Susan Hoi Laem Pho because it is located close to the famous tourism sites of Krabi Province, e.g. Hat Noppharat Thara Beach and Ao Phra Nang Bay where visitors can travel by a ferry to Mu Ko Phi Phi and others. The best way to access Susan Hoi Laem Pho from the province is to use Road No. 4204 (Krabi-Hat Noppharat Thara- Lae Pho) for about 20 km.



■ **Geology:**



• The 40-20 million years old gastropods have been cemented with calcium carbonate.

Susan Hoi Laem Pho is underlain by a sedimentary rock formation consist of semi-consolidated, reddish-brown to grey sandstone, siltstone, claystone, limestone interbedded with layers of gastropod fossils and lignite seams. This sequence of sediments deposited in a large swamp during Eocene-Oligocene epochs or about 40-20 million years ago and has been mapped as Krabi Group. The broken fossiliferous beds, from a distance, appear as thousands of concrete slabs paving the seashore of the Laem Pho Cape. Inspected closely these beds are compacted fresh water gastropods of the Viviparidae family which have been cemented with calcareous material. These fresh water limestone beds are generally about 0.5 to 1 meter thick.

The succession of the sedimentary beds and the animal and plant remains indicated that the Krabi Group has been deposited in a large swamp surrounded with a floodplain and a tropical forest. The environment of the depositional basin suited gastropods, bivalves and many other vertebrates. An abrupt change of the paleo-environment restrained the flourish of the living creatures in the swamp, mainly Viviparidae. Their remains have been preserved by the covered sediments, e.g. sand, silt and clay, and the calcareous cement. These events occurred repeatedly which evidence by the interbedded of shelly limestone and claystone beds and lignite seams.

The Earth's tectonic has tilted and lifted this depositional basin up to the surface around 1.6 million years ago. The last sea water transgression has flooded about 4 meters above this sedimentary sequence, about 6,000 years ago. Later the sea level has declined to the present level and this Susan Hoi or Shell Cemetery has been exposed at the Laem Pho Cape.



• The broken gastropod slabs at the Laem Pho Cape.



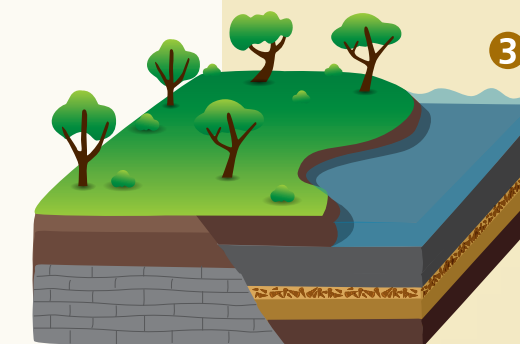
• The elongated and stubby shaped gastropods.



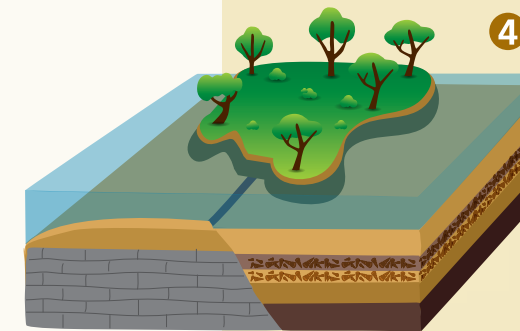
1 Ban Laem Pho 40 million years ago was a large fertile swamp surrounded with a large flood plain and a tropical forest.



2 The abrupt changes of the paleo-environment terminated the flourish of the gastropods. Their remains have been preserved by the deposited sediments which completely filled up the basin.



3 The sequence of semi-consolidated swampy sediments has been covered with younger fluvial sediments.



4 This depositional basin has been tilted and lifted up to the Earth's surface during the last Ice Age and flooded with sea water at the end of the age. Later the sea level has declined to the present level and this Susan Hoi has been exposed at the Laem Pho Cape.



• *Compacted gastropods of the Viviparidae family.*

■ The Highlight:



• *The classic view of Susan Hoi Laem Pho.*

During the ebb tide visitors can enjoy the beauty of the sand beach, and sea waves with gentle sea breeze along the two kilometers shoreline of Laem Pho. However, enjoying the beauty of the sea is the second intention for every tourist, because there is a more impressive target. That is Susan Hoi Laem Pho where millions of fresh water gastropods have been naturally compacted and paved the seashore. They are broken concrete slabs placed leaning gently toward the sea at the first glance but looking closely these beds are compacted fresh water gastropods of Viviparidae family.



• *Sea waves have continuously eroded the underlying claystone and the shelly limestone beds.*





Susan Hoi Laem Pho once called “75 Million Years Old Susan Hoi”. Later the micro fossils found in claystone beds revealed that the Krabi Group deposited about 40-20 million years ago. There are three Susan Hoi sites crop out as rocky beaches consisting mainly of gastropod fossils ranging in size from 1-5 cm Site 1 is about 300 meters west of the Laem Pho Visitor Centre. The fossil beds consist mainly of stubby-shaped gastropods ranging in size from 1-2 cm Site 2, located at the Visitor Centre, is the largest shell cemetery is composed of millions of gastropod fossils compacted as thousands of concrete slabs. Site 3 is about 1 km northeast of the center. The fossil beds at this site consist of stubby and elongated shaped gastropods and bivalves.

These sedimentary beds have been fractured by the Earth’s tectonic and are easily eroded by wave resulting in the collapse of the gastropod beds which underlain by lignite and claystone beds. Susan Hoi Laem Pho has been conserved as one of the best sites in Thailand for paleo-environmental studies. Unfortunately, by its setting, it is continuously eroded by sea waves.

Visit Krabi to appreciate beautiful islands, sand beaches and millions of fresh water gastropods on the seashore.





The Eternal Nature

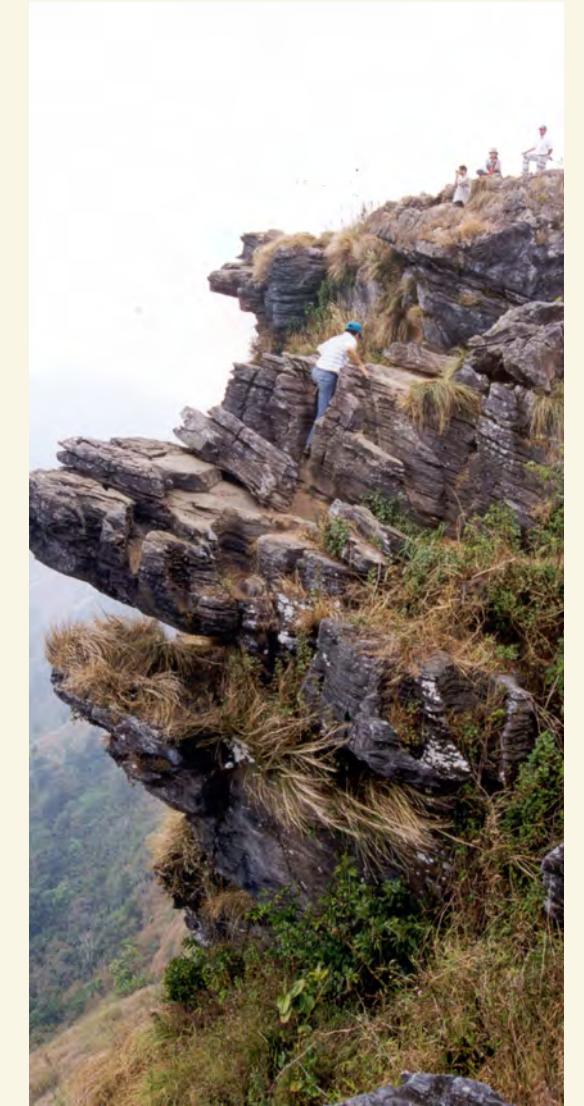
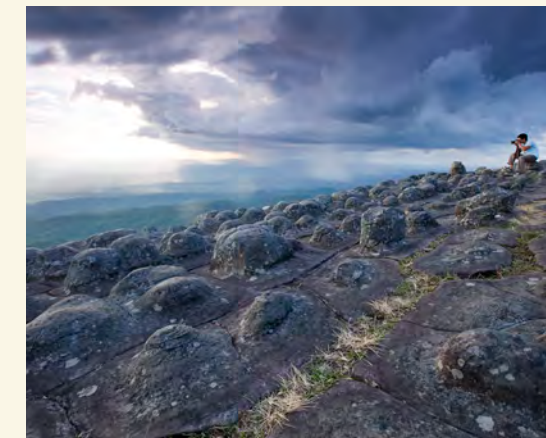
Geological Conservation in Thailand

The nature has taken millions of years to create the fertile lands and seas from a barren hot planet. The pieces of the Earth's surface have been moving through time along with the tectonic plates to create a world with wonderful environment for all creatures. The nature not only gives us the four requi-

sites, i.e. food, clothing, shelter and drug but also the mental nutrients through our five senses.

The geological sites are one of mental nutrients that the Earth gives to everyone. The twenty geological sites appearing in this book are examples of the conserved sites in

Thailand. They all have their own unique attraction. Most of them are located in the National Parks or Forest Parks which are surrounded with rich forests and wildlife. The link between the three partners, geological sites, forests and wildlife, is naturally very strong. However, whenever one of the three



partners is damaged, the other two are indirectly affected. On the other hand, whenever one of the three partners is conserved, the other two are as well.

When visiting a geological site, one will sense the natural mental nutrients via the atmosphere, the astonishing geological

features and the biodiversity of the recent and the ancient lives. A geological site is, therefore, comparable to a mental apple, so "visiting a geological site today keeps the doctor away".

Geological sites are the natural heritages that the Earth gives to everyone. Therefore,

it is everyone's task to protect our mental nutrients which cannot be created by human beings. The Department of Mineral Resources strongly believes that "Mankind has the highest potential in protecting nature". So, let's visit and conserve the nearby geological sites for the Eternal Nature and everyone.

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