GEOLOGICAL CONSERVATION IN TARUTAO ISLAND

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ABSTRACT

The Tarutao Island has long been known as one of the famous oldest Cambrian fossil age of Thailand. The area, located in the Malacca strait, belongs to the Tarutao National Marine Park is now a quite tourism area and was to be a natural heritage area of Asia by UNESCO during 1982s. Today the Island is one of the most famous tourism Islands in Thailand. It has grown to become a place that tourist visit year in year out. Tourists from all over the world come to this Island to experience the serenity and peace that these Islands have to offer. There are load of attractions in Tarutao such island, rapid, mountain, beach, wild animal as well as the beautiful topography i.e. limestone cliff. Fossil site at Ao Mo Lae is also fascinating and it is reported as the oldest trilobite site in Southeast Asia.

To conserve the geosites, Thailand has followed some Langkawi geopark’s practices such as specify geo-conservation areas, present their importance and develop and promote geotourism. The geosites in Tarutao are now defined into 4 areas depending the geological value and geomorphology, some sites need the urgent protection. Four protected area are introduced as 1) Ao Pante Malaka-Ao Son bio-diversity area is the fossiliferous diversity area of the oldest rock unit in Thailand together with rock and sedimentary structures diversity, fossil Diversity, landscape Diversity and at least 7 Geological Heritage Sites. 2) Ao Dan –Talo U Danç Geo-diversity area is remarkable such as stratigraphy and rock age which are perfectly continued succession. Rock and sedimentary structures diversity, fossil Diversity and at least 4 Geological Heritage Sites are recorded. 3) Tanyong Mara Landform area composes of various kinds of geological features i.e. beautiful karst topography, geodiversity, and at least 3 Geological Heritage Sites are observed. 4) Malaka Natural area shows the gorgeous karst topography Rock and sedimentary structures diversity, bio-diversity and at least 2 Geological Heritage Sites are found.

Some activities are set up in order to give the basic geological information to visitors as well as to make them realize that how important is the geological and natural value. Furthermore, considering geosite evaluation conducted by DMR, the potential for development of geotourism in Tarutao Islands is very good and is based on these key attributes; site management, Infrastructure, geotourism, action plan, promotion, communication, access and education and geotrial.

INTRODUCTION

The Tarutao Island has long been known as one of the famous oldest Cambrian fossil age of Thailand. The area, located in the Malacca strait, belongs to the Tarutao National Marine Park is now a quite tourism area and was to be a natural heritage area of Asia by UNESCO during 1982s. Since 1930s, the Tarutao Island was not an Island that one would have considered as a place to visit for a vacation. As at them, this Island functioned as a prison. The surrounding waters of this region is blessed with crocodiles and sharks; this made it appropriate and perfect to function as a prison as attempt to escape the island would be equivalent to one signing his own death warrant.

Today the Island is one of the most famous tourism Islands in Thailand. It has grown to become a place that tourist visit year in year out. Tourists from all over the world come to this Island to experience the serenity and peace that these Islands have to offer.
peace that these Islands have to offer. There are load of attractions in Tarutao such island, rapid, mountain, beach, wild animal as well as the beautiful topography i.e. coral limestone and cliff. Fossil site at Ao Mo Lae is also fascinating and it is reported as the oldest trilobite site in Southeast Asia.

Location

The Tarutao Island is located in the Malacca strait, about 50 km west of Satun Province Thailand (Fig.1). Tarutao Island having 26.5 km long and 11 km wide belongs to the Tarutao National Marine Park including its headquarters and two observation stations. Apart from the employees and their families of the park and a custom office on Tarutao Island, the other people are not allowed to live there. Accessibility of this area is only by boat and by cars along small track ways from Pante Malaka to Ao Son and Ao Talo Wao.

Physiography

Topography of Tarutao Island area is generally high mountainous, undulating and coastal landforms with the maximum elevation of 708 m above MSL. Semi-evergreen rain-forest blankets about 60 percent of the island, and pure mangrove swamps are found near the river mounts in the northern, eastern and southern parts of the island. General landform of the island consists of a rather smooth, but abruptly elevated coast on the western side of the island. The rocky cliffs are abruptly high up above the coast from a few metres to a few hundred metres. Rocky cliff on the northern and eastern sides of the island is common sea stacks, sea nocks and columns immediately offshore. Small limestone islands (less than one km long) along the eastern coast are well recognized. Smooth escarpments forming ridges of the sandstone ranges are in contrast with the rough surface topography of limestone cliff displayed in an aerial photograph. Persistent and low-lying escarpments are present along the eastern limbs of the eastern limbs of the anticlines.

PREVIOUS WORKS

Geological aspects of the Tarutao Island had been studied and reported by many workers. The Cambrian fossils were firstly discovered from low easterly dipping sandstone at the Tarutao Island, whence some Upper Cambrian trilobites and brachiopods were described by Kobayashi (1957). An addition list of Cambrian fossils was given by Buravas (1961). The sandstone sequence at the Tarutao Island was defined, from previous record as the Tarutao Group in later year (Javanaphet, 1969), and hence know as the only fossiliferous Upper Cambrian rocks in Thailand. The first reconnaissance geological map of the Tarutao Island and a possible northward extension of the Cambro-Ordovician rocks from this area to the mainland in the north were given by Bunopas (1974a).

Taraoka et al. (1982) carried out the studies of the Lower Paleozoic Formations of the Tarutao Island. They divided the Tarutao Formation into 4 members and the Thung Song Formation into 5 members. Additional information of rock units, stratigraphy, fossil assemblages and depositional environments were continuous studied by Wongwanich et al. (1983), Akerman (1986), Mason (1986) and Wongwanich (1990).

The systematic mapping on the scale of 1: 250,000 in the Transect area (Thai side) started by Tansuwan et al. (1985). They published a regional geological map of the Changwat Satun sheet (NB47-7) at scale 1:250,000. The systematic geological mapping on the scale of 1: 50,000 in Ko Tarutao (4922 II) sheet was done by Tansathien et al. (1999). In 2013 the Malaysia -Thailand Border Joint Geological Survey Project (MT-JGS) revised the new geological map of the Langkawi -Tarutao transect area at scale 1:100,000.

Geoconservation sites, geotourism sites and prospect area for conservation Island were made by Geoconservation section, Department of Mineral Resources, Thailand since 2010-2011. Later year, year 2013, the Malaysia -Thailand Border Joint Geological Survey Project (MT-JGS) reported the geological
conservation and geological tourism in Langkawi – Tarutao islands. Most attractive geological sites were listed and were evaluated for geopark preparation.

**GEOLOGY**

The Tarutao Island is a part of the 3,600-4,000 m thick continuous sequence of marine Paleozoic succession (Late Cambrian to Late Permian) distributed as a cratonic area of the Sibumasu terrane (Bunopas, 1981). The main structure of the rock sequence is situated in the N-S direction parallel to the older rocks located in the central region of Malay Peninsula. Paleozoic succession is mainly composed of shallow to deep continental shelf carbonate and clastic sedimentary rocks with locally low-graded metamorphic rocks. In the central and western parts of this craton, the Paleozoic succession is intruded by N-S trending of two belts of granitic rocks; Triassic Central belt and Cretaceous Western belt. Deformed structure and contact metamorphism and mineralization are also recognized. In the Island, rock units consist of two contrasting Lower Paleozoic stratigraphic units and three Quaternary sediment units (see Fig. 1 and Fig.2).

**The Tarutao Group**

The unit is the oldest sedimentary rocks of the Tarutao Island based on the stratigraphic correlation and fossils. Distribution of the succession is located in the mountainous terrains, coast embayments and rock cliffs in the western, central and southern parts of Tarutao Island. The group, exceed 1,400 m thick, can be separated based on lithostratigraphy and faunal assemblages into 4 units, namely, Ao Makham Formation (EO.mk), Ao Tami Formation (EO.tm), Ao Mo Lae Formation (EO.ml) and Talo Wao Formation (O.tw). General characteristic of this succession consists of well-bedded, brown to reddish brown sandstones and minor interbedded shales. There are a lot of fossils such as trilobites (*Parakoldinioidea thaiensis* and *Eosaukia buravasi*) and brachiopods which indicate Late Cambrian- Early Ordovician age.

**The Thung Song Group**

The Thung Song Group, exceed 750 m in thickness, is conformably underlain by the Talo Wao Formation of the Tarutao Group. Distribution of the group is situated in the karst topography terrains, coasts, rock cliffs, sea stacks and small islands in the northern, eastern and southeastern parts of Tarutao Island. Thin- to medium-bedded, argillaceous limestones, laminated limestones with intercalations of fine argillaceous bands and medium- to very thick -bedded dolomites, spartic limestones with stylolitic texture and thin-bedded calcareous shales are typical rocks of this group.

At least three distinct lithostratigraphic units have been recognized as the Pante Malaka Formation (O.pm), the Lae Tong Formation (O.lt), and the Rung Nok Formation (O.n). Gastropods, nautiloids, polyplacophorans, monoplacophorans, trilobites, brachiopods bivalves, echinoderm fragments are observed in this group which indicate Early to Middle Ordovician age.

**Surficial Deposits** (Quaternary deposits)

Quaternary sediments are unconsolidated covering the area near the coast of these islands. Sediments originated by stream and long shore current can be divided as three units. The Talo U Dang formation (Q.ud), colluvial and alluvial sediments, were transported by rivers and streams. They cover low-lying lands from seashore up to the base of terraces. The sediments comprise gravel, sand, clay and mud. The Ao Chak formation (Q.ac), beach sediments, were deposited along seashore, consisting of sand, quartz sand, gravel, pebble, shell fragments and corals. Grey and muddy sediments in the Ao Son formation (Q.as) mangrove forests are composed of mud and silt with thickness of 3-7 metres.
Structural Geology

On Tarutao Island and the adjacent area, strata are openly folded into a series of northwesterly plunging asymmetric anticlines and synclines with easterly dipping axial planes. The easterly dipping angle strata are much less tilted than the westerly dipping angle strata, and were formed as resistant escarpments extending for a considerable distance. High angle normal and reversed faults are slightly paralleled to the fold axes. Smaller scale transverse faults offset these major fold axes in places. The rocks are only slightly deformed but the fold cleavages are weakly developed in medium scale in the less competent beds leading to the occurrence of the undulated beds, especially in limestone sequences east of the island.

GEOCONSERVATION

In 2001, the first geological conservation activity carried on by DMR was started. Previous geological exploration data was integrated to produce a publication, “Geological Natural Heritages of Thailand” and in 2004 the publication “Geotourism Sites” was followed. In 2009, DMR commenced a geoconservation program by defining geoconservation policy and management scheme in order to specify the boundaries of geoconservation site/geosite, establishment of geoconservation and coordination networks, knowledge management as well as introduce geopark as a new dimension of geoconservation through sustainable development and coordination among all stakeholders.

Consequently, in early 2010, a pilot project on selecting an area for geoconservation at Tarutao Islands and other areas of Satun province was launched. The project objectives are to compile geosite information, evaluate geosite development potential and propose the suggestion for conserving geosites according to their significance. Geoconservation areas were screened by the evaluation criteria including geosites, ecological sites, archaeological sites and cultural and traditional sites. So far, the Tarutao Islands and inland areas of Satun province are designated as the geoconservation areas and be in the process of Satun Geopark establishment.

In fact, Tarutao Island is belonging to the national park, so all geosites in the area are automatically protected under the National park Act 1961 and due to the significant fossil site found in Tarutao Islands, therefore, DMR has introduced the legislation as an additional instrument for proper protection and conservation of the significant geosites, that is Fossil Protection Act 2008.

PROTECTED GEOSITES

Many geological sites in the Tarutao National Park area, Satun Province, Thailand, have been selected for investigation. Of these, the 20 sites from 4 kinds of geological features (structural geological sites, geomorphological sites, stratigraphic section sites and fossil sites) have been collected (Table 1). The geosites in Tarutao are now defined into 4 areas depending the geological value and geomorphology (Fig. 3), some sites need the urgent protection. The followings are details of each area;

1. Ao Pante Malaka-Ao Son bio-diversity area

The protected Geosites is the fossiliferous diversity area of the oldest rock unit in Thailand known as Tarutao Group. The area is covered along the coast of sandstones from Ao Pante Malaka- Ao Chak-Ao Moe Lae – Laem Hin Ngłam – Ao Son, in the western part of Tarutao. The protected area consists of two subunits of the middle to upper Tarutao Group and one unit of the lower part of the Thung Song Group. Type section of the Tarutao Group in Thailand was also measured in this area (Fig. 4a-e.).
a) Fossil Diversity

Many fossils have been reported especially at Ao Mo Lae, Ao Son, Ao Chak and Ao Pante Malaka in the West of Tarutao Island. The fossils can specify rock age and paleo-environment, and detail studies find that 15 species are identified with various ages and sources. These indicate the high level of paleo-biodiversity in this area (Fig.5a-f). The conclusions are as follows;

Numerous trilobites and brachiopod are present west of Tarutao Island. The best known trilobites are Pagodia thaiensis, “Eosaukia” buravasi, and Coreanocephalus phanulatus. Brachiopod is Apheorthis (?) sp.

In the western part of Laem Hin Ngam, The oldest trilobites include Hoytaspis?thanisi, and Prosaukia ? aff. Nema were found. Shergold et al. (1988) studied the trilobites of the Tarutao Group from Tarutao Island and concluded that they are Late Cambrian to the boundary between Cambrian and Ordovician. The trilobites fossils were found in Talo Topo Bay (Ao Mo Lae) consisting of Lichengia? tarutoaensis Kobayashi (=Saukiella tarutoaensis), Lophosaukia cf. jiangnanensis, Micagnostost (Micagnostost) sp. indet., Quadratichephalus planulatus Kobayashi (= Coreanocephalus planulatus), Leiostegiid gen. et sp. indet., Shumardiid gen. et sp. indet., Szechuanella ? cf. damujingensis, Thailandium solum, Tsinania (Tsinania) cf. nomas. Bunopas et al. (1980) reported trilobite and brachiopod Thailandium solum, Eosaukia buravasi, Pogodia thaiensis, Agnostid, Arpheorthis sp. and Orthid group in the Ao Son area.

Teraoka et al. (1982) reported the discovery of conodonts in the lenticular interbeds of limestone in the upper part of the Tarutao Group. They are Chosonodina herfurthi, Poltodus deltifer and Scolopodus rex Chosonodina designate to upper Tremadocian age.

b) Landscape Diversity

Rock cliff of well-bedded sandstones with low angle dipping is commonly observed in the western part of Tarutao Island especially along the coast line close to mountain or steep cliff. The section is sandstone of Tarutao Group formed by wave action, tidal currents and southwest monsoon leaving the remains as rock cliff at Ao Son, Laem Hin Ngam and Ao Chak. Karst topography is found in the north and can be grouped to the Thung Song Group i.e. the area of Malaka creek (Fig.6).

c) Geological Heritage Sites

At least 7 Geological Heritage Sites were record in the Ao Pante Malaka-Ao Son bio-diversity area. They consists of Ao Pante Malaka, Ao Son gravel and sand beaches, Tobu Scrap, Ancient turtle at Laem Chorakhe, Ao Hin Chiang-Lan Hin Pum, The rock sequence of Ao Sarapee and Trilobites of Tarutao Island.

2. Ao Dan –Talo U Dang Geo-diversity area

Geodiversity in this area is remarkable such as stratigraphy and rock age which are perfectly continued. This can indicate the evolution of area which composes of Tarutao Group and complete Thung Song Group. The area is covered along the coast of sandstones and limestones from Ao Dan- Ao Talo U Dang – Panan Island- Lae Tong Island, in the southern part of the Tarutao Island.

The geo-diversity area consists of three subunits of the lower to upper Tarutao Group and three units of the lower-upper part of the Thung Song Group. Type section of the Thung Song Group in Thailand was also measured in this area (Fig.7)
a) Fossil Diversity

Ao Dan–Talo U Dang geo-diversity area is a rich place of fossils. Many importance fossils have been reported at Ao Talo U Dang, Pa Nan Island and Lae Tong Island. The details studies were conducted and can identify many fossil species. These fossils indicate the high level of paleo-biodiversity in the area. The conclusions are as follows;

In the upper part of the Tarutao Group Shergold et al. (1988) reported that the youngest Cambrian fossils were found at Ao Talo U Dang as identified by the trilobite *Parakoldinioidia thaiensis, (= Pagodia thaiensis)*, which dates closely to the Cambro- Ordovician boundary. The other trilobite includes “Eosaukia” buravosi. Teraoka et al. (1982) reported the discovery of conodonts in the lenticular interbeds of limestone in the upper part of the unit. They are *Chosonodina herfurthi, Poltodus deltifer* and *Scolopodus rex*. Chosonodina designates to upper Tremadocian age. Wongwanich (1990) reported fossils including nautiloids, gastropods, and the polyplacophoran *Chelodes*. Trilobite, bivalve, calcareous algae and echinoderm debris are observed in thin sections. Orthoconic nautiloids and *Chelodes* are also found. Stait and Burrett (1984a) identified many polyplacophoran valves from the formation as *Chelodes whitehousei* which is indicative of the lower Ordovician. The valves occur with Euchasma and the conodont fauna including *Scolopodus quadraplicatus* and *Acontiodus latus*, suggesting the Late Tremadoc age for this assemblage. Stait and Burrett (1984b) also identified the orthoconic nautiloids within the lowest formation of the Thung Song Group on Tarutao Island as *Endoceratidae gen.et sp. indet*, indicating a Late Ibxian age (Late Tremadoc).

Teraoka et al. (1982) identified several conodonts from the upper part of this Formation. The conodonts include *Drepanodus basiovalis, Drepanodus forceps, Paroistodus parallelus, Baltoniodus oepiki* and *Prioniodus evae communis*, suggesting a Middle Arenig age. Stait and Burrett (1984) identified the nautiloids from the upper member of the Lae Tong Formation as *Hardmanoceras chrysanthemum* associated with the conodont *Prioniodus evae* zone of probable Middle Arenig age and correlated with the same fauna in the Middle Arenig Emanuel Formation of Western Australia and in the probably Middle Arenig of North China.

b) Landscape Diversity

Rock cliff in the western part of Tarutao Island has a beautiful morphology by weathering and erosion processes. The steep cliffs look like a painting of the ancient town. Cliffs are composed of yellowish brown, well-bedded sandstone with low angle dipping rocks that look like a castle in the ancient city of Cambodia (Fig. 8). Beautiful karst topography is always found along the coast from Talo U Dang to Rung Nok Island, southern part of the Tarutao Island.

c) Geological Heritage Sites

At least 4 Geological Heritage Sites were record in the Ao Dan–Talo U Dang. They comprise Music of Ao Dan gravel beach, Talo-Udang Laagoon, Ancient town at Ka Lok cliff and the stratigraphic sequence of Ao Talo Udanğ.

3. Tanyong Mara Landform area

This protected area compose of various kinds of geological features i.e. beautiful karst topography, geodiversity and stratigraphy which are continuous sequence. These sequences can indicate the evolution of the area where some part of Thung Song Group is exposed. The area is covered along the coast of limestone landforms from Laem Tayong Mara to Rusi Cave, in the northern part of the Tarutao Island.
a) Landscape Diversity

Karst topography of this rock cliff landscape is quite similar to Kilim geoforest park of Malaysia. The topography is largely shaped by the dissolving action of water on limestone of the Thung Song Group, and is also developed by fracture and fault in limestone as shown in the pictures below (Fig. 9).

b) Geological Heritage Sites

At least 3 Geological Heritage Sites were record in the Tanyong Mara Landform area. They consist of Laem Tonyong Mara Natural Bridge, Papiyong Scarp and Tham Tai (inactive cave) at Ao Rusi.

4. Malaka Natural area

This protected area shows the gorgeous karst topography where some part of the Thung Song Group is exposed. The area is located along the mouth of Malaka canal to Crocodile cave, in the northern part of Tarutao Island. Beautiful mangrove forest along the canal is also well present.

a) Geological Heritage Sites

At least 2 Geological Heritage Sites were record in the Malaka Natural area. They consist of Crocodile cave and stratigraphic sequence at the entrance of Chorakhe cave.

DEVELOPMENT OF THE GEOLOGICAL TOURISM

Some activities are set up in order to give the basic geological information to visitors as well as to make them realize that how important is the geological and natural value. Furthermore, considering geosite evaluation conducted by DMR, the potential for development of geotourism in Tarutao Islands is very good and is based on these key attributes;

Key attributes

1. Site management

Good dissemination of geosites throughout the area especially along the coast line. The geology and the beautiful landscape of these sites are adorable and most of them being open to the public.

DMR is the main organization for geosite management with strong links to Tarutao National Park and geoconservation networks in Satun province.

2. Infrastructure

A convenient transport network e.g. buses, boats serves in the islands, as well as airports at Trang and Had Yai. A comfortable tourist infrastructure exists with standard capacity such as weekend houses and restaurant run by the national park.

3. Geotourism

Tourist information centres both inland at Satun province and at Tarutao Island. Growing link with neighboring area that is Langawi Geopark of Malaysia with related designations.

High potential to promote activities under geotourism theme e.g. geotrail, kayaking, snorkeling and rock climbing High potential of educational activity arranged by national park staff skilled in marine biology and basic geology informed by DMR.
Action Plan
To develop geotourism in Tarutao Islands, DMR has encouraged Satun geopark committee to publish management plan of Satun geopark including the action plan. The followings are proposed action plan;

1. Promotion
Work with geoconservation networks and other partners to organized an annual workshop/ training and awareness event for tourism sector
Update and manage website and Geopark Thailand face book.
Review Tarutao’s history where appropriate.

2. Communication, Access and Education
Create an education and interpretation strategy to ensure that interpretative provision is suitably targeted i.e. geological/technical groups, school/collage groups and general visitors.
Encourage the development of geo-boat trips to visit inaccessible sites from the sea.
Develop geological exhibition both at Satun province and Tarutao visitor centre.
Promote geotourism packages for tourism sector.
Offer field study trips to geological sites to local schools/collages and community groups.

3. Geotrail/Geotourism
Develop themed geopark events and tours for adventure groups
Develop the geotrails incorporating a general leaflet, individual geosite leaflet and on-site interpretative signs.
Develop ‘Gateway Geopark Visitor Centre’ in Tarutao Island.

CONCLUSION
Although the development of geo-tourism in Tarutao Islands is now in the beginning process and not very much touchable, some activities are set up in order to give the basic geological information to visitors as well as to make them realize that how important is the geological and natural value.
Furthermore, considering geosite evaluation conducted by DMR, the potential for development of geotourism in Tarutao Islands is very good and is based on these key attributes; site management, infrastructure, geotourism, action plan, promotion, communication, access and education and geotrial.

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<table>
<thead>
<tr>
<th>No.</th>
<th>GEOLOGICAL SITES</th>
<th>SIGNIFICANT</th>
<th>GEODIVERSITY</th>
<th>Protection Status</th>
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<tbody>
<tr>
<td>1</td>
<td>Ao Pante Melaka (TT 7)</td>
<td>The oldest rocks in Thailand are well exposed.</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>2</td>
<td>Laem Tonyongmara Natural bridge (TT 16)</td>
<td>A beautiful scenic morphology represented by cape and sea knock.</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>3</td>
<td>Ao Son gravel and sand beaches (TT 1)</td>
<td>The site is characterized by 4 km long white sand and gravel beaches.</td>
<td></td>
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<tr>
<td>4</td>
<td>Ao Makam gravel and sand beach (TT 9)</td>
<td>It is characterized by 2 km long white sand and gravel beaches.</td>
<td></td>
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<tr>
<td>5</td>
<td>Music of Ao Dan gravel beach (TT 10)</td>
<td>It is represented by the 1 km long gravel beach during deposition having music and transportation.</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Talo-Udang Lagoon (TT 12)</td>
<td>It is represented by the lagoon deposits close to the sand barrier.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ao Talo Wao (TT 2)</td>
<td>It is characterized by the karst topography of the Ordovician limestone with faults and fractures.</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Papiyong Scarp (TT 3)</td>
<td>It is characterized by the karst topography</td>
<td></td>
<td></td>
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<tr>
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<td>Site Name</td>
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<td>9</td>
<td>Crocodile cave (TT 6)</td>
<td>It is characterized by the karst topography and a cave in the Ordovician limestone with beautiful stalagmites and stalactites.</td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
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<td>Tobu Scrap (TT 8)</td>
<td>It is characterized by the karst topography and fault scarp in the Ordovician limestone with beautiful scenery.</td>
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<td>11</td>
<td>Ko Plawarn (Islands of Whales) (TT 14)</td>
<td>The islands are caused by weathering and erosion processes. Stunning natural sculptures look like a whale that pops up from the sea.</td>
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<td>12</td>
<td>Tham Tai (inactive cave) at Ao Rusi (TT 15)</td>
<td>A small cave with stalactites on the ceiling. Nearby, there is a beach surrounded by limestone cliffs.</td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
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</tr>
<tr>
<td>13</td>
<td>Ancient turtle at Laem Chorakhe (TT 17)</td>
<td>This site has a beautiful morphology shaped like “green turtle”. This stunning natural sculpture is caused by the processes of weathering and erosion.</td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
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<tr>
<td>14</td>
<td>Sea arch at Ko Khai (TT 18)</td>
<td>This site has a beautiful morphology by weathering and erosion processes. The sea arch shape looks like wedding arch.</td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
</tr>
<tr>
<td>15</td>
<td>Ancient town at Ka Lok cliff (TT 19)</td>
<td>This site has a beautiful morphology by weathering and erosion processes. The steep cliffs look like a beautiful painting of the ancient town.</td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
<td><img src="%E2%9C%94%EF%B8%8F" alt="✔️" /></td>
</tr>
<tr>
<td>16</td>
<td><strong>Ao Hin Chiang-Lan Hin Purn (TT 4)</strong></td>
<td>This site is a bay located east of Ko Tarutao and presents the type section of the Tarutao Group.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>17</td>
<td><strong>The stratigraphic sequence at the entrance of Chorakhe cave (TT 5)</strong></td>
<td>This site is located east of Ko Tarutao where the type section of the Malaka Formation of the Ordovician Thung Song Group is indicated. These limestones have been eroded until there are a lot of amazing looks such as a craggy rock, cavity, caves etc.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>18</td>
<td><strong>The stratigraphic sequence of Ao Talo Udang (TT 13)</strong></td>
<td>This site has a good section for study the rock sequence of the Thung Song Group. Beautiful cliffs can be observed from this area caused by folding and erosion processes.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>19</td>
<td><strong>The rock sequence of Ao Sarapee (TT 21)</strong></td>
<td>This site is in the northwestern part of Ko Tarutao consisting of the type section of the La Nga Formation, Thung Song Group (Ordovician). A beautiful dark grey, thick-bedded limestone is exposed with eastward dipping. There are rough surfaces of a sharp edge.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>20</td>
<td><strong>The site along the road from Pante Malaka to Ao Talo Wao, at the crossroad to Ao Son. (TT 20)</strong></td>
<td>Oldest trilobite fossils and rock sequences in Thailand are present. The trilobite was identified as the new species of the world i.e. Easaukia buravasi.</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Figure 1: Location and Geological map of Tarutao Island, Thailand (after MT-JGS, 2013)
Figure 9: Composite section of rock units, lithology and faunal assemblages in Transect area of Thailand

Total thickness about 2,300 m

TARUTAO GROUP

Talo Wao Formation (Otw): well laminated, fine-grained sandstones to siltstones rhythmically alternated with mudstones having beds less than 15 cm thick. Cross-bedding, load cast, ball and pillow and slump structures are common. Calcareous sandstone with limestone lenses is recorded in the upper part of the sequence.

Ao Mo Lae Formation (EOml): lower part: brown and brownish red, laminated, medium- to thick-bedded arkosic sandstones and minor quartzitic sandstones with tabular cross-bedding, and green and brown siltstones.

Upper part: purplish red to brown, medium- to very thick-bedded sandstones. Green, brown, purplish red, thin-bedded, mudstones to very fine-grained sandstones is sometime intercalated. Volcano-clastic sedimentary rocks are also recorded.

Fossil assemblages: Gastropods, nautiloids, polyplacophorans, monoplacophorans, trilobites, brachiopods bivalves, echinoderm fragments

THUNG SONG GROUP

Rung Nok Formation (On): The lower part of unit is dark grey to grey, thin- to thick-bedded limestones and digitate or colony stromatolitic limestones. The upper part consists of grey, medium- to very thick-bedded, limestones with occasional stylolites and massive dolomites. Oolitic limestone rich in crinoid stems is found in the lower part of the sequence.

Lae Tong Formation (Olt): interbeds of dark grey to pink, very thin- to thin-bedded argillaceous limestones having occasional ripple cross-lamination, and greenish grey, black and red shales. Hummocky cross-bedding is generally found.

Pante Malaka Formation (Opm): grey to dark grey, thin- to thick-bedded limestones intercalated with black, greenish grey to red shales, grey nodules limestones and dolomites. Lenses of digitate stromatolites are recorded in some places. Wavy bedding, ripple cross-lamination, convolute lamination and stylolitic texture are usually found.

Fossil assemblages: Gastropods, nautiloids, polyplacophorans, monoplacophorans, trilobites, brachiopods bivalves, echinoderm fragments

CAMBRIAN

Ao Mo Lae Formation (EOml):
- Lower part: brown and brownish red, laminated, medium- to thick-bedded, arkosic sandstones and minor quartzitic sandstones with tabular cross-bedding, and green and brown siltstones.
- Upper part: purplish red to brown, medium- to very thick-bedded sandstones. Green, brown, purplish red, thin-bedded, mudstones to very fine-grained sandstones is sometime intercalated. Volcano-clastic sedimentary rocks are also recorded.

Ao Tami Formation (EOtm): white, pink and reddish brown, well-bedded, medium- to thick-bedded, tabular cross bedded quartzitic sandstones, with partly pebbly sandstones and conglomerates.

Ao Makham Formation (EOmk): dark brown to cream, medium-very thick beds of siltstones and minor sandstones


Brachiopod Apheorthis (?) sp.

Total thickness about 2,300 m

Figure 2: Composite section of rock units, lithology and faunal assemblages in the Tarutao Island (after MT-JGS, 2013)
Figure 3: The location of four protected geosites and geoheritagesites in Tarutao Island, Thailand

1. Ao Pante Malaka - Ao Son bio-diversity area
2. Ao Dan – Talo Udang geo-diversity area
3. Tanyong Mara landform area
4. Malaka natural area
5. Tanyong Mara landform area
6. Ao Dan - Talo Udang geo-diversity area
7. Ao Son gravel and sand beaches
8. Ao Makam gravel and sand beach
9. Ao Talo Wow
10. Sea arch at Ko Khai
11. Sea arch at Ko Khai
12. Talo-udang Lagoon
13. The stratigraphic sequence of Ao Dan gravel and sand beach
14. The stratigraphic sequence of Ao Talo Udang
15. Tham Tai at Ao Rueoi
16. Laem Tom Ingamara Natural bridge
17. The rock sequence of Ao Sarapee
18. The stratigraphic sequence of the entrance of Chorakhe cave
19. The stratigraphic sequence of the entrance of Chorakhe cave
20. The stratigraphic sequence of the entrance of Chorakhe cave
21. The rock sequence of Ao Sarapee
22. The rock sequence of Ao Sarapee
Figure 4a: Exposure of 10 m thick, well-bedded red sandstones in Ao Son area, Tarutao Island.

Figure 4b: Well-bedded, medium-bedded sandstones in Ao Moe Lae area, Tarutao Island.

Figure 4c: Thin-bedded sandstones and mudstones with slump structure and ball and pillow in Ao Pante Malaka, Tarutao Island.

Figure 4d: Closed-up views of ball and pillow structures at Ao Pante Malaka, Tarutao Island.

Figure 4e: Good exposure of the laminated limestones, lower part of the Thung Song Group at Malaka creek, northwestern part of the Tarutao Island.
Figure 5a: Closed-up view of fossil assemblages in sandstones of the Tarutao Group. Most of them are rather incomplete consisting of broken pieces, Ao Mo Lae, Tarutao Island.

Figure 5b: Closed-up view of giant spines of trilobites in the Tarutao Group at Ao Mo Lae, Tarutao Island.

Figure 5c: Closed-up view of several types of trilobite in the Tarutao Group. The trilobites have been identified as *Thalassemium solum* Kobayashi, *Eosaukia buravasi* Kobayashi and *Coreano cephalus planulatum*.

Figure 5d: Closed-up view of perfect bodies of brachiopod in the Tarutao Group at Ao Mo Lae, Tarutao Island.

Figure 5e: Closed-up view of *Eosaukia buravasi*, Tarutao Island.

Figure 5f: Closed-up view of brachiopods in the Tarutao Group, Tarutao Island.
Figure 6: Sandstones and Limestones Landscape of the western part of the Tarutao Island
Figure 7: Exposures of the complete sequence of the Thung song Group along the coast of Ao Talo Udang, Tarutao Island

Figure 8: Ancient town at Ka Lok cliff, Ao Tami, Tarutao Island
Figure 9: General views of the Ordovician limestone at Laem Tanyong Mara, Tarutao Island.