GeoJournal of Tourism and Geosites Year **XI**, vol. **22**, no. **2**, **2018**, p.**548-560**
ISSN **2065-0817**, E-ISSN **2065-1198** DOI **10.30892**/gtg.**22223-310**

GEODIVERSITY AND GEOCONSERVATION OF THE CHAIYAPHUM REGION IN THAILAND FOR SUSTAINABLE GEOTOURISM PLANNING

Vimoltip SINGTUEN
Department of Earth Sciences, Faculty of Science, Kasetsart University, 50 Phahon Yothin Rd., Khwaeng Lat Yao, Chatuchak, Bangkok10900 Thailand, e-mail: vimoltipst@gmail.com

Krit WON-IN*
Department of Earth Sciences, Faculty of Science, Kasetsart University, 50 Phahon Yothin Rd., Khwaeng Lat Yao, Chatuchak, Bangkok10900 Thailand, e-mail: kritwonin@yahoo.com

Citation: Singtuen, V., & Won-In, K. (2018). GEODIVERSITY AND GEOCONSERVATION OF THE CHAIYAPHUM REGION IN THAILAND FOR SUSTAINABLE GEOTOURISM PLANNING. GeoJournal of Tourism and Geosites. 22(2), 548–560. https://doi.org/10.30892/gtg.22223-310

Abstract: Chaiyaphum region in the westernmost edge of Khorat Plateau is the most famous natural land of northeastern Thailand. There are many spectacular landforms such as cliffs, pillar or pedestal rocks, and cascades. The selected geosites are located in Pa Hin Ngam, Sai Thong, Tat Ton and Phu Laen Kha National Parks and are covered by the Jurassic-Cretaceous (50-100 Ma) clastic sedimentary rocks of the Phra Wihan Formation, Khorat group. Based on geodiversity, scope and their values (scientific, tourism, natural, and aesthetic values) which are analyzed from field investigation data suggest this area is a highly valuable part for geotourism development. Promoting geotourism will help tourists understand the geological processes and realize the importance of the geomorphological heritage conservation. This research is the first step of geotourism announcement of the studied area, which is a powerful tool for sustainable economic and scientific development at both local and national scale.

Key words: Geodiversity, Geoconservation, Geotourism, Chaiyaphum, Thailand, Sustainable Development

* * * * * *

INTRODUCTION

The spectacular landforms, valuable Earth materials and rare geological phenomena can be tourism attractions all around the world. The values include scientific, aesthetic, economic, historical, cultural and functional values of the geoheritage. Geological concepts are developed from the potential geological attractions that focus on characteristic geological features (Gray, 2005; GSA, 2012; Nazaruddin, 2016). The

* Corresponding author

geotourism is referred to as a form of tourism, which focused primarily on the geology and landscape in the natural area (Gray, 2011; Newsome & Dowling, 2010; Hose, 1995, 2000). It is the new trend within the last two decades and promotes geological heritages and geoscientific knowledge to people (Demarest, 1997; Liebowitz, 1999; Hose, 2008, 2012; Reynard, 2008; Ruban et al., 2010; Henriques et al., 2011; Wimbledon & Smith-Meyer, 2012; Gray, 2013; Prosser, 2013; Reynard & Coratza, 2013; Ruban, 2015; Brilha, 2016; Neches, 2016; Mikhailenko et al., 2017; Sallam et al., 2017). In addition, it is the new form of tourism and research in Northeastern Africa, Western Asia, and Southeast Asia especially Thailand, which will help the economic and scientific development both at local and national scale (AbdelMaksoud et. al., 2018; Habibi & Ruban, 2017, 2018; Habibi et. al., 2017; Sallam et. al., 2017, 2018a, 2018b;). These relevant issues in Thailand were discussed, for instance, by Singtuen and Won-In (2017, 2018). Geotourism can be a threat to the geoheritage resources, due to its ability to increase visits to this area without sufficient protective regulations, could eventually mean a ruction of the geosite. However, an efficiently managed geotourism is a beginning process to sustainable development.

Geosite is any site with the feature or landform that contains significant geodiversity and indicates these high geodiversity values (Wimbledon, 1996; Komoo, 2004). In 2011, ProGEO defined geosite as an area shows geological features with scientific values and make people understand the geologic processes and the evolution of the Earth. In addition, geomorphosites is defined as any site, which particularly applies to highlights the distinctiveness of scientific and additional values especially geomorphological interest (Panizza 2001; Reynard et al., 2007). According to many kinds of research (Ruban, 2005, 2010; Ruban & Kuo, 2010; Neches, 2016), geosite were identified into 21 types as cosmogenic, economic, engineering, geochemical, geocryological, geohistorical, geomorphological, geothermal, hydrological and hydrogeological, igneous, metamorphic, mineralogical, neotectonical, paleogeographical, paleontological, pedological, radiogeological, sedimentary, seismical, stratigraphical and structural types. The Chaiyaphum Province means “The Land of Victory” and is the gateway to northeastern Thailand. The Chaiyaphim region was a small town of the Khmer Empire in the 12th century and was settled between Angkor and Prasat Singh by Laotians in 1817. This region is located in the Phetchabun Mountain Range, which was originally paleo-Tethys between Shan-Thai and Indochina Terranes and closed in Permo-Triassic Period (Kamvong et al., 2006; Boonsoong et al., 2011). Because this area is a part of the suture zone, many structures are presented such as faults and folds. It is mostly covered by Triassic-Tertiary sedimentary rocks of the Khorat Group and Permian Limestone, with a small amount of Permo-Triassic Volcanic Rocks (Figure1). However, all of the geosites are located in the Phra Wihan Formation, which is a sedimentary rock formation of the Khorat Group. These geosites show the uniqueness and rarity of geological features in this region and have high scientific values. The geosites in the Chaiyaphum region are divided into three groups such as cliffs, pillars, and cascades that are distributed in 4 National Parks; (1) Pa Hin Ngam, (2) Sai Thong, (3) Tat Ton, and (4) Phu Laen Kha.

The Phra Wihan Formation comprises fine-coarse grained pale yellow sandstone, siltstone, mudstone, and conglomerate. They show well-sorted and rounded grain. Most of the detrital grains in sandstone are quartz. Thick sandstone beds occurred as high cliffs were deposited in braided stream environment, whereas thinner sandstone beds were deposited in meandering rivers (Meesook, 2000). Intercalations of siltstone and mudstone are found mainly in the latter sandstone beds which show little resistance to weathering and reduced them to small hills. Palynomorphs include *Cyathidites sp., Classopollis sp., Ballosporites hians, Lycopodiacidites sp., Calamospora sp.,*

Monosuleites sp.,? Ballosporites sp., Cyclotriletes subgranulatus MADL, Minutosaccus sp., Chasmatosporites sp., and *cf. Anulatizonites* indicating a Late Triassic to Early Jurassic age (Hahn, 1982). There are many fault segments of the Phetchabun Fault Line and the rocks have different weathering rate, so the sedimentary rocks in the Chaiyaphum region show many outstanding geologic features for tourist attraction especially "Mo Hin Khao". This research groups the potential geosites to each national park and describes them so that the national park can be promoted for ecotourism. There is a strategy to interpolate the scientific and geological data to each site and to assess the national park in the value of geoheritage resources. This research for broader publication will help tourists understand the geological features and realize the importance of conservation.

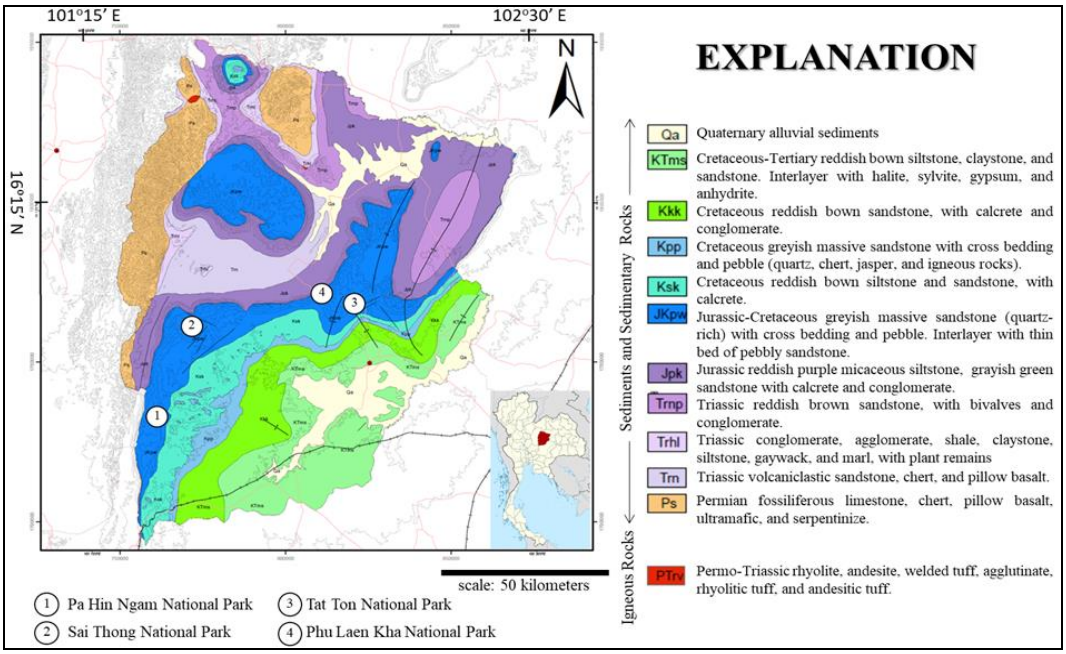

Figure 1. Location and Geologic map of study area
in Chaiyaphum Province, Thailand (modified from DMR, 2007)

MATERIALS AND METHODOLOGY

The topographic map of the study area scale 1:50000, geologic map of Chaiyaphum Province, Thailand scale 1:1000,000 and many kinds of literature are studied by the methodology, which comprises the inventory, characterization, classification and assessment respectively. First, geosites were identified, inventoried and mapped in the field. The characterization of geosites was carried out by observations and description of the landform groups occurrence. The assessment comprises qualitative and quantitative methods. The qualitative method is the basic assessment, which determines geosite in term of the values and levels of significance. On the other hand, the quantitative method uses valuing assessment of the studied geoites. Geosites where than described in terms of attractiveness and spatial distribution within each national park. Classification details are comprising the geodiversity, scope and scale of the sites were presented. In addition, SWOT analysis was performed in order to identify strengths, weaknesses, opportunities, and threats of potential geosites for geoconservation and geotourism development in the Chaiyaphum Region.

INVENTORY

Based on the previous famous attraction in Chaiyaphum Province, researchers were identified and mapped the geological sites in the study area. Although this area is popular and easy to reach, the geoscientific knowledges have never been demonstrated in any scientific description to educate people. Accordingly, with the theory of Đurović and Đurović (2010) and Pralong (2005), criteria such as their occurrence, rarity, integrity, and representativeness of geological features must be taking into consideration for the geosites identification process. In this study case, the criteria used for geosites identification was the occurrence, identity, rarity and outstanding. These criteria can be divided geosites in Chaiyaphum Province into cliffs, pillar or pedestal rock, and cascade. Thailand consists of many kinds of rock and structural geology and Chaiyaphum is the typically geosite of the clastic sedimentary rocks. The studied geosites are located in Pa Hin Ngam, Sai Thong, Tat Ton and Phu Laen Kha National Parks. The study area has the unique sandstone cliff, which formed by tectonic setting at the western edge of the Khorat Plateau and linked with the central plain of Thailand. The sedimentary rocks also formed the spectacular cascade, which is flat, wide and parallel with their sedimentary layer. Moreover, there is the Mo Hin Khao, which is the only one geosite of pillar rocks of Thailand.

CHARACTERIZATION

The geosite of the Chaiyaphum Region, which is located in the westernmost edge of Khorat Plateau, consists of the cliff, pillars and cascade. These geosites in Chaiyaphum Province were classified as geomorphological, sedimentary, stratigraphical and structural types based on their origin and characteristics of sites (Ruban, 2005, 2010; Ruban & Kuo, 2010; Neches, 2016). Meanwhile, the national park has many other attractions such as Siam Tulip Fields and Viewpoints (Table 1).

Table1. Information delivery and interpretive strategies used in geotourism (modified from D. Newsome et al., 2012)

Strategy	Pa Hin Ngam	Sai Thong	Tat Ton	Phu Laen Kha
Geosite	Lan Hin Ngam, Sut Phaen Din Cliff, Thep Phana Cascade	Sai Thong Cascade, Hum Hod Cliff	Tat Ton Cascade, Tat Fah Cascade, Pha Lang Cascade	Mo Hin Khao, Pa Hin Ngam Chan-Daeng, Pratu Khlong, Pha Hua Nak Cliff, Pha Phae Cliff
Geotails	Thung Dok Krachiao-Nature Trail	Sai Thong Cascade- Trail	Nature Trails	Nature Trails
Geological garden	Dok Kra Jiao Field	Thung Bua Sawan- Field		Pa Hin Ngam, Thung Khlong-Chang flower Field
Visitor centers	National Park			

The Pa Hin Ngam National Park consists of the great unusual rocks such as nail, large snake and castle, which are identity and rarity geosite in Thailand. These sites are developed by the geological phenomena, which is a weathering process with different erosion ratio of sedimentary rock layers (Figure 2a). The Dok Krachiao or Siam Tulips (a type of wildflower related to ginger) sprout cheery pink and white blooms all over the area (Figure 2b) during the early rainy season in July. Also, orchids emerge from the fracture of the rocks, alongside numerous wildflowers in the winter. The Sut Phaendin is a steep sandstone cliff and connects Mountain range of northeast Regions with the

central plain of Thailand (Figure 2c). Curved faces or slickrock slopes on Sut Phaen Din Cliff are mainly the results of grain-by-grain weathering and erosion, and of the peeling of thin weathered rinds like the curved faces on cliffs in Monolith Valley, southern Sydney Basin, Australia (Young et al., 2009). The tourists can enjoy the surrounding area with the rocks and the panoramic views from the highest viewpoint. In addition, there is Namtok Thep Pratha, which is a medium-sized cascade and it is the most beautiful in the rainy season (Figure 2d). Ahnert (1998) divided waterfall into 3 types; 1) the Niagara type of waterfall 2) Cascade waterfall and 3) Hanging valley waterfall. Namtok Thep Pratha has the character like the cascade type that he also described it is the waterfall over several, usually small, step rather than other waterfalls.

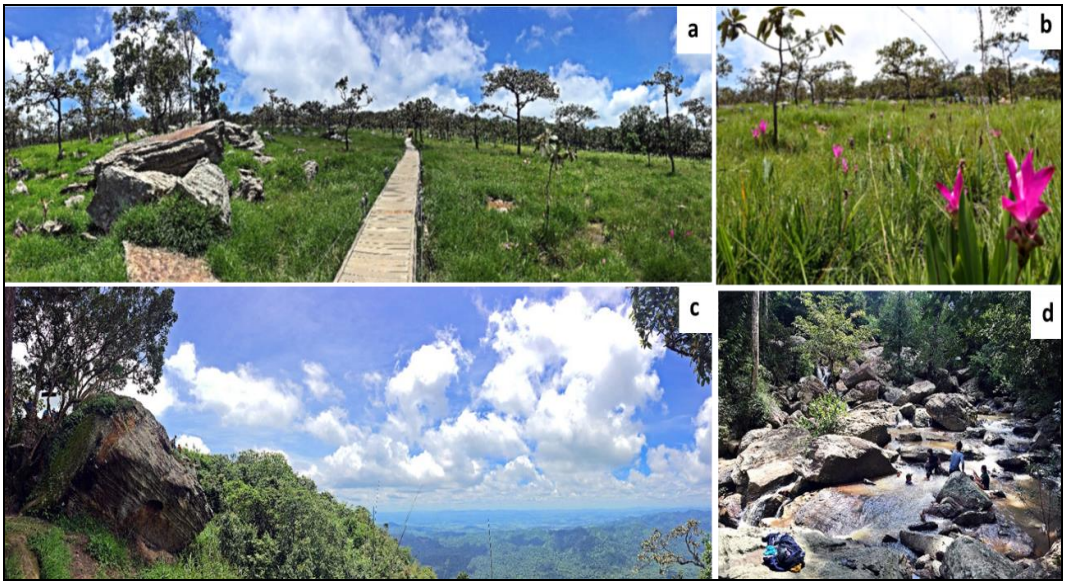

Figure 2. The geodiversity of the Pa Hin Ngam National Park; a) Lan Hin Ngam, b) Thung Dok Krachiao Nature Trail, c) Sut Phaen Din Cliff, and d) Thep Phana Cascade

The Sai Thong Cascade is the highlight of the Sai Thong National Park, which is located approximately 1 kilometer from the park office (Figure 3a). This is the spectacular cascade in this region, which is very wide and parallel to their bedding. In this case, the rocks are divided by layer of sedimentary rocks and almost vertical tectonic joints that provide the weathering and erosion on surfaces and create the step-like form of the cascade (Ahnert, 1998). The stream of cascades flows down that has the height of about 100 meters. There is a large field of Dok Krachiao the same as the Pa Hin Ngam National Park. The tourists can access this field by hiking only and can camp overnight. In addition, the tourist can see a panoramic view from the Pha Ham Hod cliff, which is a projecting plate like the Eagle rock in the Royal National Park of Sydney (Young et al., 2009) (Figure 3b). This is one of cliff fascinating of Thailand.

In the case of the Pha Ham Hod Cliff, where the undercut section of sandstone takes the form of a block or plate projecting from the cliff, rather than a column, its stability can be more appropriately analyzed by considering it to be analogous to a simple cantilever. Tensional stress at the junction of the projecting plate and the cliff will again be determined by the density of the sandstone and the dimensions of the plate (Figure 4). The

stress arises from the load $P = 2clp$. The density is p, which acts along a moment arm of length $l/2$ of a cantilever of thickness $2c$ (Robinson, 1970). Following the method of Timoshenko and Goodyer, Robinson (1970) derived the tensile stress acting along the junction of the plate and the cliff and then rearranged the equation to give a ratio of the plate dimensions at the critical level at which failure occurs: where σ is the tensile strength. Assuming a density of 2.3 g/cm^3, a tensile strength of 2MPa and letting $2c$ = 40 m, Robinson computed a critical length of 34 m for projecting plate in the Navajo Sandstone.

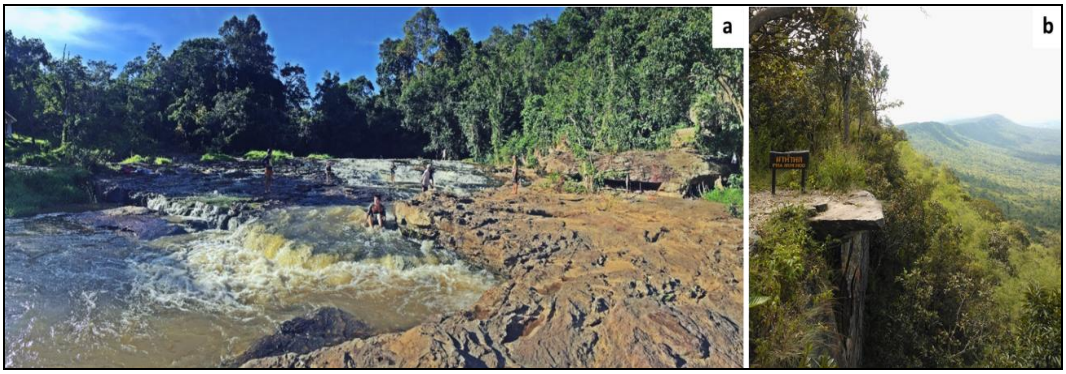

Figure 3. The geodiversity of the Sai Thong National Park; a) Sai Thong Cascade and b) Hum Hod Cliff

$$l / c = (2\sigma / 3pc)^{1/2} \qquad (1)$$

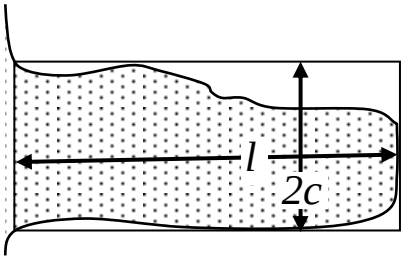

Figure 4. The parameters used in Equation (1), representing a projecting plate as a cantilever (modified from Young et al., 2009)

The Tat Ton National Park is a part of the Phu Laen Kha Mountain and located close to the Phu Laen Kha National Park. There are many beautiful cascades such as Tat Ton, Pha Lang, and Tat Fa, but the Tat Ton cascade is the most famous one in this area (Figure 5a). The Tat Ton cascade was grouped into the Niagara type of waterfall (Ahnert, 1998), the steep scarp is formed of the very resistant sandstone. The less resistant rocks are siltstone and mudstone. This type of waterfall is rare in Thailand; however, the Tat Ton cascade is the representative in this area. On the other hands, the Tat Fa cascade was grouped into the cascade type like the other previous listing (Figure 5b).

Cascades are geologically formed and represent major interruptions in river flow. The difference in rock types is the common conditions that gave rise to the cascades. The streams quickly erode the soft rock layers and steepen their gradient at the rock boundaries. The river cuts and exhumes a junction that is created between different rock beds. However, the character of rock formations and the geologic structures can cause the cascades. The geomorphology of the Northeastern part of Thailand is a high plateau

surrounded by a steep escarpment slope. This characteristic landform creates many cascades and rapids on the rivers. Whereas, the fault movement may encourage the establishment of a cascade because it can bring hard and soft rocks together. There are many factors that can make cascade worn away, especially the rapidity of erosion, which depends on the type of cascade, the height of cascade, the volume of flow, and structure of rocks involved. The cascade presents downward flow in wide rock plateau, which is a wonderful view, especially in the rainy season from May to August. The Pha Lang cascade is far away from the city on the Chaiyaphum-Nong Bua Daeng road approximately 32 kilometers While the Tat Fa cascade is located on the eastern flank of the headquarters and far away from the central city 25 kilometers on the Chaiyaphum-Kaeng Khro road.

Figure 5. The geodiversity of the Tat Ton National Park - a) Tat Ton Cascade and b) Tat Fah Cascade

The Phu Laen Kha National Park is a mountain in Khao Phang Hoei mountain range. There are massive jungles and watershed of many streams, which run to join the Chi River. Cliffs, mountain ridges, stone terraces, and strange rock formations are fascinating sights. There are many natural trails, which have outstanding rocks such as Pa Hin Ngam Chan Daeng, Phu Khi, Pa Hin Ngam Thung Khlong Chang flower field, and Pa Hin Prasat Viewpoint. The most famous attraction of this park is "Mo Hin Khao" that is the isolated pillars (Figure 6a), which are accessible from the Tat Ton National Park. Meanwhile, tourists can visit the Pha Hua Nak, which is the highest cliff in this area (Figure 6b). The road will reach all of the sites as long as you can drive.

The Cliff is a steep sloping rock which is very high, tilting and near vertical. It may be overhanging from the mountain and stand out in the high land. However, the cliff is formed as the result of fault movement and the differential resistance of rock. Cliffs are associated with several rock types such as limestones, sandstones, and gritstones. This research focuses on the sandstone cliff, which is valleys and around the edges of the plateau like this area. Isolated pillars of rock are also common at such sites. Throughout the world, sandstone cliffs and pillars are distinctive features of a sandstone terrain. Many sandstone cliffs and pillars are undercut towards their bases (Robinson & Williams, 1994). The layer of soft rock is more readily eroded, leading to the formation of a lowland. The resistant rock on the top of the layer will become the isolated pillars, which upright above

the new lower plain. The curve slopes on sandstones may be decorated by polygonal cracking, commonly called 'elephant skin weathering.' This form of tessellation should not be confused with patterns found on benches or platforms due to weathering and widening of intersecting joints (Young et al., 2009). However, most forms of tessellation are not related to jointing, being a surface phenomenon, which dies out within a few centimeters depth, and which follows the curvature of outcrops, even appearing on overhanging faces such as the surface of Mo Hin Khao and outcrops in the Phu Lan Kha National Park.

Figure 6. The geodiversity of the Phu Laen Kha National Park
a) Mo Hin Khao and b) Pha Hua Nak Viewpoint

CLASSIFICATION

The classification of the potential geosites in Chaiyaphum Region is shown in Table 2. It focuses on the hypothesis of many researchers such as Gray (2005), Brocx and Semeniuk (2007) and Đurović and Đurović (2010), and comprises geodiversity, scope and scale.

Table2. Classification of potential geoheritage resources in Chaiyaphum Region

National Park	Geological Site	Geodiversity [a]	Scope [b]	Scale [c]
Pa Hin Ngam	Lan Hin Ngam	Rock	P, G, STG	Small
	Sut Phaen Din Cliff	Rock, landform/ landscape	P, G, STR	Medium
	Thep Phana Cascade	Rock, landform/ landscape	P, G, STR	Small
Sai Thong	Sai Thong Cascade	Rock, landform/ landscape	P, G, STR	Medium
	Hum Hod Cliff	Rock, landform/ landscape	P, G, STR	Medium
Tat Ton	Tat Ton Cascade	Rock, landform/ landscape	P, G, STR	Medium
	Tat Fah Cascade	Rock, landform/ landscape	P, G, STR	Small
	Pha Lang cascade	Rock, landform/ landscape	P, G, STR	Small
Phu Laen Kha	Mo Hin Khao	Rock, landform/ landscape	P, G, STG	Small
	Pa Hin Ngam Chan Daeng	Rock	P, G, STG	Small
	Pratu Khlong	Rock	P, G, STG	Small
	Pha Hua Nak Cliff	Rock, landform/ landscape	P, G, STR	Medium
	Pha Phae Cliff	Rock, landform/ landscape	P, G, STR	Small

P: petrological site, G: geomorphological site, STG: stratigraphic site, STR: structural site
[a] Gray 2005), [b] Brocx and Semeniuk 2007; Predrag and Mirela 2010, [c] Brocx and Semeniuk 2007

The geodiversity was divided by Gray (2005), in rocks, minerals, fossils, landforms, landscape, processes, soil and other resources. In addition, Brocx and Semeniuk (2007) and Đurović and Đurović (2010) classified the geological sites, including mineralogical, petrological, structural, stratigraphic, geomorphological, speleological and hydrological/hydrogeological sites. The scales of geological features comprise regional scale (>10000 km^2), large-scale (>100 km^2), medium scale (>1 km^2), small-scale (>10000 m^2), fine-scale (>1 m^2) and very fine scale (<1 mm^2) (Brocx & Semeniuk, 2007). The potential geosites in Chaiyaphum Region are made up of rocks, landform and landscape features including sandstone hills, cliffs, cascades and pillars. These geosites have the area between small to medium scales (Brocx & Semeniuk, 2007).

ASSESSMENT

The effective conservation and management depend on the geosite assessment as a potential resources for geotourism. The SWOT analysis in terms of the strengths, weaknesses, opportunities, and threats of potential geosite resources was used for assessment in this research (Table 3). The type of geoheritage conservation is part of the geoheritage evaluation, which comprises geosite, geomorphosite, geotope, geological monument, Geopark, National Park and World Heritage Site (Brocx & Semeniuk, 2011; Nazaruddin, 2015). The National Park is the natural area, which is established in both land and sea for ecological protection. Furthermore, it is the useful tool to conserve the integrity of natural systems for the next generations. In addition, the National Park manages many activities according to the environment and culture of the community, which have the advantage to the scientific, educational, recreational, and tourism opportunities. Meanwhile, the UNESCO World Heritage Sites are any cultural and/or natural sites, which are deemed to be unique and important in the future to the whole world for conservation. The World Heritage Site made up of cultural heritage sites and natural heritage sites, which are part of our shared global heritage (Nazaruddin, 2015). All of these geosites in the research are geoheritage resources, which are located in the national park of Thailand. These national parks have many rules to protect and conserve natural sites and geosites. The relatively high geodiversity of the study area makes the geosites in the Chaiyaphum Region outstanding and valuable.

Table 3. SWOT analysis to evaluate the potential geosite resources of the study area for conservation and development

SWOT	Remark
Strength	Good potential for research and education
	High aesthetic value of some sites
	Good potential for recreational activities
	Relatively high geodiversity of the study area
	Good accessibility
	Good management and protection from National Park
Weakness	Bad accessibility of some sites
	Lack of promotion of the area
Opportunity	Study area is suitable for research and educational activities
	Need geological knowledge panels to serve visitors
	Suitable for some recreational activities, such as hiking, swimming etc.
	Increase the attractiveness of the area and possible development of local community
	Cooperation between local authority, university, community, and government
Threat	Vandalism
	Encroachment on the public land

DISCUSSION FOR GEOTOURISM PLANNING

The examples selected for this research present the method to introduce the sedimentary geosites to travel industry. There are many interesting landforms in Thailand, which are managed as geosites. The tourists can focus on rocks and landforms in typical geosites such as a cliff, pillar and cascade. The travel route map of the potential geosite resources in Chaiyaphum Province was created in this research (Figure 7).

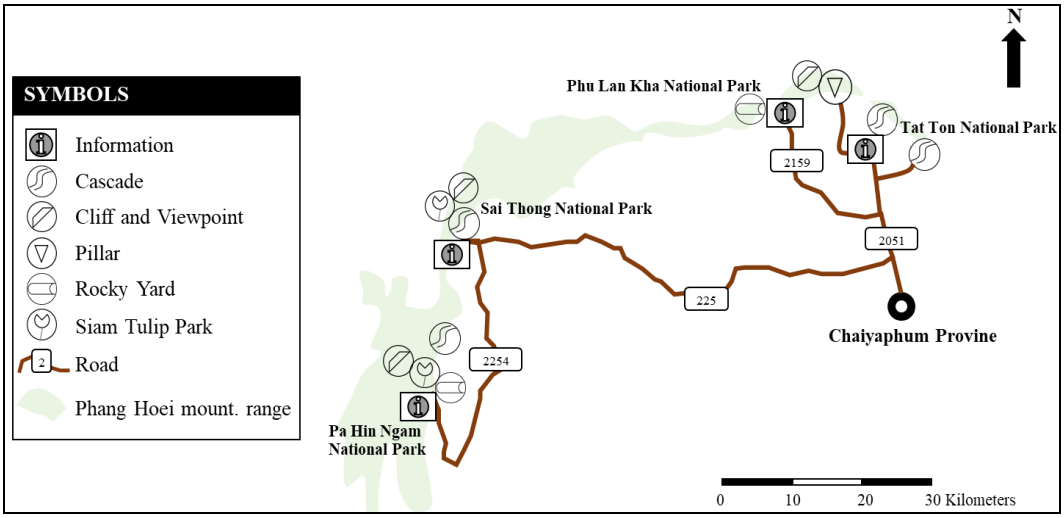

Figure 7. Travel route of the potential geosite resources in Chaiyaphum Province

However, in the four case study sites, the tourists cannot receive any explanation on the spot about the geological background. The sedimentary rocks have both soft and hard layers which are caused by the differential ratio of their erosion. The soft sedimentary layers are easily eroded, while the hard layers are more resistant to erosion. In this assumption, the differential erosion ratio of the rock layers creates the outstanding landform and geomorphology including previously listed geosites. These study sites are regarded as the local peculiarities, which should have more value to the geoscientific sites. The accessibility of the four locations is comfortable and the tourists can walk from the parking areas for nearest distances. Thus, all of the studied areas have significant aesthetic values, which comprise the exhibitions of rocks and harmonious cultural-landscapes announcement. However, an important geomorphological component is still missing. The most visible part of sedimentary rocks geosites are apparently considered as more landscape curiosities rather than features of significance. All of the geosites, which are distributed in four national parks are close to one another. This research provides the geotourism data for planning the travel route in Chaiyaphum province. The tourists can travel to the Pa Hin Ngam National Park, Sai Thong National Park, Tat Ton National Park, and Phu Laen Kha National Park respectively. These four national parks are part of the famous National Parks in Thailand, which are the natural attraction and advertised as both interesting and easily accessibility sites. National parks are the geosites and natural sites, with legal forms to protect these areas for purposes of sustainable aesthetic value. The information center at the park headquarters advises and helps the tourists. National Parks are effectively designed with road leading to the developed parking areas and

information panels. However, there is no interpretation of the geodiversity and rock occurrence in the park. Due to their large site and having various geosites, they are mainly developed as recreation areas. Thus, the tourists frequently visit them for amusement. Facilities in the national parks include a small hall, viewing points, rock exhibition, and accommodation. All of the previous listings are the important components of the travel industry, which can be managed for sustainable development in the economy, society, earth sciences, and culture of the community.

CONCLUSION

The diverse geological features of the Chaiyaphum Region are essential parts of the geological heritage. This research studies 4 National Parks and three groups of dominant geosites, which are the geomorphological features such as cliff, pillar and cascade. It assumes the erosion and weathering trend of sedimentary rocks which will destroy geosites and create a way for tourists to understand the geological processes and be aware of the needed conservation. In the case of pillars, they are exposed to a higher risk of being destroyed by man- or nature than other landforms. However, the destruction of these landforms cannot be estimated as the violence of water volume which can destroy the pattern of cliff and cascade. The edge of Khorat Plateau and the area nearby are well suitable for geotourism development. Both geoconservation and geotourism can be encouraged by the established natural protectorate in promoting the new type of tourism in Thailand, resulting to economic, scientific, and social developments.

Acknowledgements

The authors would like to thank the authorities of the National Park for their obligingness. Dr. Panu Trivej of the Department of Earth Sciences, Kasetsart University is thanked for his comments and reviews on the manuscript for English language clarity. Thanks to the Science Achievement Scholarship of Thailand (SAST) for the funding, which supported this research.

REFERENCES

AbdelMaksoud, K., M., Al-Metwaly, W., M., Ruban, D., A., & Yashalova, N., N. (2018). Geological heritage under strong urbanization pressure: El-Mokattam and Abu Roash as examples from Cairo, Egypt. *in Journal of African Earth Sciences*, vol, 141, p. 86-93, Elsevier Science, Amsterdam.

Ahnert, F. (1998), *Introduction to Geomorphology*. Arnold, Routledge, p. 352.

Boonsoong, A., Panjasawatwong, Y., & Metparsopsan, K. (2011). Petrochemistry and tectonic setting of mafic volcanic rocks in the Chon Daen–Wang Pong area, *Phetchabun*, Thailand. in Island Arc, Vol, 20, p. 107-124, Blackwell Publishing Asia, Queensland.

Brilha, J. (2016). Inventory and quantitative assessment of geosites and geodiversity sites: a review. in *Geoheritage*, vol, 8, p. 119-134, Springer, Heidelberg.

Brocx, M., & Semeniuk, V. (2007). Geoheritage and geoconservation—history, definition, scope, and scale. in *Journal of the Royal Society of Western Australia Abbreviation*, vol, 90, p. 53–80, Royal Society of Western Australia Inc., South Perth.

Chichester, J., & Gray, M. (2004). *Geodiversity: valuing and conserving abiotic nature*. John Wiley, Chichester, p. 508.

Demarest, M. (1997). Understanding knowledge management. in *Long range planning*, vol, 30, p. 374-384, Elsevier Science, Amsterdam.

Đurović, P., & Đurović, M. (2010). Inventory of geoheritage sites – the base of geotourism development in Montenegro. in *Geographica Pannonica*, vol, 14, p. 126–132, Department of Geography, Tourism and Hotel Management within the Faculty of Sciences, University of Novi Sad.

Gray, M. (2005). *Geodiversity and geoconservation: what, why, and how?* in The George Wright Forum, p. 4-12, The George Wright Society, Michigan.

Gray, M. (2011). *Other nature: Geodiversity and geosystem services*. in *Environmental Conservation,* vol, 38, p. 271-274, Cambridge University Press.

Gray, M. (2013). *Geodiversity. Valuing and Conserving Abiotic Nature*, Wiley-Blackwell. Chichester, p. 115.
Habibi, T., Golubova, N., V., & Ruban, D., A. (2018), New evidence of highly-complex geological heritage in Iran: Miocene sections in the Zagros Fold-Thrust Belt. in *GeoResJ*, vol, 13, p. 96-102, Elsevier Science, Amsterdam.
Habibi, T., & Ruban, D., A. (2017). Outstanding diversity of heritage features in large geological bodies: The Gachsaran Formation in southwest Iran. in *Journal of African Earth Sciences*, vol, 133, p. 1-6, Elsevier Science, Amsterdam.
Habibi, T., & Ruban, D., A. (2018). Geoheritage of the Neyriz ophiolite-related radiolarite sequence (Cretaceous; southwest Iran): First report and evaluation in regional and global contexts. in *Journal of African Earth Sciences*, vol, 145, p. 227-233, Elsevier Science, Amsterdam.
Hahn, L. (1982). Stratigraphy and marine ingressions of the Mesozoic Khorat Group in Northeastern Thailand. in *Geologische Jahrbuch*, vol, 43, p. 7-35, German Geological Survey BGR, Hannover.
Henriques, M., H., Pena dos Reis, R., Brilha, J., & Mota, T. (2011). Geoconservation as an emerging geoscience. in *Geoheritage*, vol, 3, p. 117-128, Springer, Heidelberg.
Hose, T., A. (1995). Selling the story of Britain's stone. in *Environmental Interpretation*, vol, 10, p. 16–17, North American Press.
Hose, T., A. (2000). *Geological Interpretation and Geoconservation Promotion for Tourists*. in Barretino, D., Wimbledon, W., A., P., Gallego, E. (eds.), Geological Heritage: Its Conservation and Management, Sociedad Geologica de Espana/Instituto Technologico GeoMinero de Espana/ProGEO, Madrid, p. 127-146.
Hose, T., A. (2008). *Towards a history of geotourism: definitions, antecedents, and the future*. in Burek, C., V., Prosser, C., D., (eds) The history of geoconservation. The Geological Society, London, p. 37–60.
Hose, T., A. (2012). Editorial: geotourism and geoconservation. in *Geoheritage*, vol, 4, p. 1–6, Springer, Heidelberg.
Kamvong, T., Charusiri, P., & Intasopa, B., S. (2006). *Petrochemical characteristics of igneous rocks from the Wang Pong area, Phetchabun, North Central Thailand: implication for tectonic setting*. in *Journal of Geological Society of Thailand*, vol, 1, p. 9-26, Geological Society of Thailand, Bangkok.
Komoo, I. (2004). *Geoheritage conservation and its potential for geopark development in Asia – Oceania*. in Leman, M., S., Komoo, I., (eds) Geological heritage of Malaysia (theoritical framework and assessment of geoheritage), LESTARI UKM, Bangi, p. 221–230.
Liebowitz, J. (1999). *Knowledgemanagement handbook*. CRC Press, Boca Raton, p. 21.
Meesook, A. (2000). Cretaceous environment of northeastern Thailand. in *Cretaceous environment of Asia*, vol, 17, p. 207-223, Elsevier Science, Amsterdam.
Mikhailenko, A., V., Nazarenko, O., V., Ruban, D., A., & Zayats, P., P. (2017). Aesthetics-based classification of geological structures in outcrops for geotourism purposes: a tentative proposal. in *Geologos*, vol, 23, p. 45–52, Instytut Geologii UAM, Poznań.
Nazaruddin, D., A. (2015). Systematic Studies of Geoheritage in Jeli District, Kelantan, Malaysia. in *Geoheritage*, vol, 9, p.19–33, Springer, Heidelberg.
Nazaruddin, D., A. (2016). Geoheritage from the remote rainforest: hidden treasures in the upstream of the Pertang River, Taman Negara Kuala Koh (National Park). Kelantan, Malaysia, in *Environmental Earth Sciences*, vol, 75, p. 1-12, Springer, Heidelberg.
Neches, I., M. (2016). Geodiversity beyond material evidence: Geosite Type based interpretation of geological heritage. in *Proceedings of the Geologists' Association*, vol, 127, p. 78-89, Elsevier Science, Amsterdam.
Newsome, D., & Dowling, R., K. (2010). *Geotourism: The tourism of geology and landscape*. Goodfellow Publishers Limited, Oxford, p. 246.
Newsome, D., Dowling, R., & Leung, Y., F. (2012). *The nature and management of geotourism: A case study of two established iconic geotourism destinations*. in Tourism Management Perspectives, vol, 2, p. 19–27, Elsevier Science, Amsterdam.
Panizza, M. (2001). *Geomorphosites: concepts, methods and examples of geomorphological survey*. in Chinese Science Bulletin, Suppl, 46, p. 4–6, Springer, Heidelberg.
Pralong, J., P. (2005). *A method for assessing tourist potential and use of geomorphological sites*. in Geomorphologie: relief, processus, environnement, vol, 3, p. 189–196, revues.org, Paris.
Prosser, C., D. (2013). *Our rich and varied geoconservation portfolio: the foundation for the future*. in Proceedings of the Geologists Association, vol, 124, p. 568–580, Elsevier Science, Amsterdam.
Reynard, E. (2008). *Scientific research and tourist promotion of geomorphological heritage*. in Geografia Fisica e Dinamica Quaternaria, vol, 31, p. 225–230, Comitato Glaciologico Italiano, Torino.
Reynard, E., & Coratza, P. (2013). *Scientific research on geomorphosites. A review of the activities of the IAG working group on geomorphosites over the last twelve years*. in Geografia Fisica e Dinamica Quaternaria, vol, 36, p. 159–168, Comitato Glaciologico Italiano, Torino.
Reynard, E., Fontana, G., Kozlik, L., & Scapozza, C. (2007). A method for assessing <<scientific>> and <<additional values>> of geomorphosites, in Geographica Helvetica, vol, 62, p. 148–158, Copernicus GmbH, Göttingen.

Robinson, D., A., Robinson, D., A., Williams, R., B., G., & Robinson, D., A. (1994). *Sandstone weathering and landforms in Britain and Europe*. in Robinson, D., A., Williams, R., B., G., (eds) Rock Weathering and Landform Evolution, Wiley, Chichester, p. 371–392.

Robinson, E., R. (1970). *Mechanical disintegration of the Navajo sandstone in Zion Canyon, Utah*. Geological Society of America Bulletin, vol, 81, p. 2799-2806, Geological Society of America, Colorado.

Ruban, D., A. (2005). *Geologitcheskie pamjatniki: kratkij obzor klassifikatsionnykh priznakov (Geological monuments: brief review of classification criteria)*. Izves-tija Vysshikh Utchebnykh Zavedenij, Geologija i Razvedka, No, 4, p. 67–69.

Ruban, D., A. (2010). Quantification of geodiversity and its loss. in *Proceedings of the Geologists' Association*, vol, 121, p. 326–333, Elsevier Science, Amsterdam.

Ruban, D., A. (2015). *Geotourism* — A geographical review of the literature. in *Tourism Management Perspectives*, vol, 15, p. 1-15, Elsevier Science, Amsterdam.

Ruban, D., A., & Kuo, I. (2010). Essentials of geological heritage site (geosite) management: a conceptual assessment of interests and conflicts. in *Natura Nascosta*, vol, 41, p. 16–31, Gruppo Speleologico Monfalconese, Gorizia.

Ruban, D., A., Zorina, S., O., & Conrad, C., P. (2010). No global-scale transgressive-regressive cycles in the Thanetian (Paleocene): evidence from interregional correlation Palaeogeography. in *Palaeogeography Palaeoclimatology Palaeoecology*, vol, 295, p. 226-235, Elsevier Science, Amsterdam.

Sallam, E., S., Abd El-Aal, A., K., Fedorov, Y., A., Bobrysheva, O., R., & Ruban, D., A. (2018b). Geological heritage as a new kind of natural resource in the Siwa Oasis, Egypt: The first assessment, comparison to the Russian South, and sustainable development issues. in *Journal of African Earth Sciences*, vol, 144, p. 151-160, Elsevier Science, Amsterdam.

Sallam, E., S., Fathy, E., E., Ruban, D., A., Ponedelnik, A., A., & Yashalova, N., N. (2018a). Geological heritage diversity in the Faiyum Oasis (Egypt): A comprehensive assessment. in J*ournal of African Earth Sciences*, vol, 140, p. 212-224, Elsevier Science, Amsterdam.

Sallam, E., S., Ponedelnik, A., A., Tiess, G., Yashalova, N., N., & Ruban, D., A. (2017). The geological heritage of the KurkureDungul area in southern Egypt. in *Journal of African Earth Sciences*, vol, 137, p. 103-115, Elsevier Science, Amsterdam.

Singtuen, M., & Won-In, K. (2017). Geotourism and Sustainable Development Perspectives of the Khao Phra Wihan National Park on the Southern Edge of the Khorat Plateau, Thailand, in *Proceedings of the 8th International Conference on Environment*, Agriculture, Biology and Natural Sciences (EABNS-2017), p. 35-41, Universal Researchers in Engineering, Bangkok.

Singtuen, V., & won-in, K., (2018). An Assessment of the Potential Island for Geotourism Value in Ko Kham Undersea Park, Chonburi, Gulf oThailand. in Proceedings of the "Regional Geoheritage Conference 2018" with the theme "Geoheritages for People", p. 11-18, Department of Mineral Resources Thailand, Bangkok.

Wimbledon, W., A. (1996). Geosite–a new conservation initiative. in *Episodes*, vol, 19, p. 87–88, Geological Society of Korea, Seoul.

Wimbledon, W., A., P., & Smith-Meyer, S. (2012). Geoheritage in Europe and its Conservation. Uppsala, Sweden: ProGEO, p. 405.

Young, R., W., Wray, R., A., L., & Young, A., R., M. (2009). *Sandstone Landforms*. Cambridge University Press, p. 314.

*** (2011). ProGEO - The European Association for the Conservation of the Geological Heritage. *Conserving our shared geoheritage – a protocol on geoconservation principles, Sustainable Site Use, Management, Field Work*, Fossil and Mineral Collecting. 10, p. 32 Geoheritage (2017), vol, 9, p. 19–33. http://www.progeo.se/progeo-protocol-definitions-20110915.pdf [Accessed on 15 June 2018]

*** (2007). DMR, *Geologic map of Chaiyaphum Province, scale 1:1000000* Department of Mineral Resources Thailand, Bangkok.

*** (2012). GSA, *Geoheritage*, in Geological Society of America Position Statement, p. 56-58, Washington, DC.

Submitted:	Revised:	Accepted and published online
24.04.2018	07.09.2018	10.09.2018