## Field Excursion Guidebook of the Symposium on

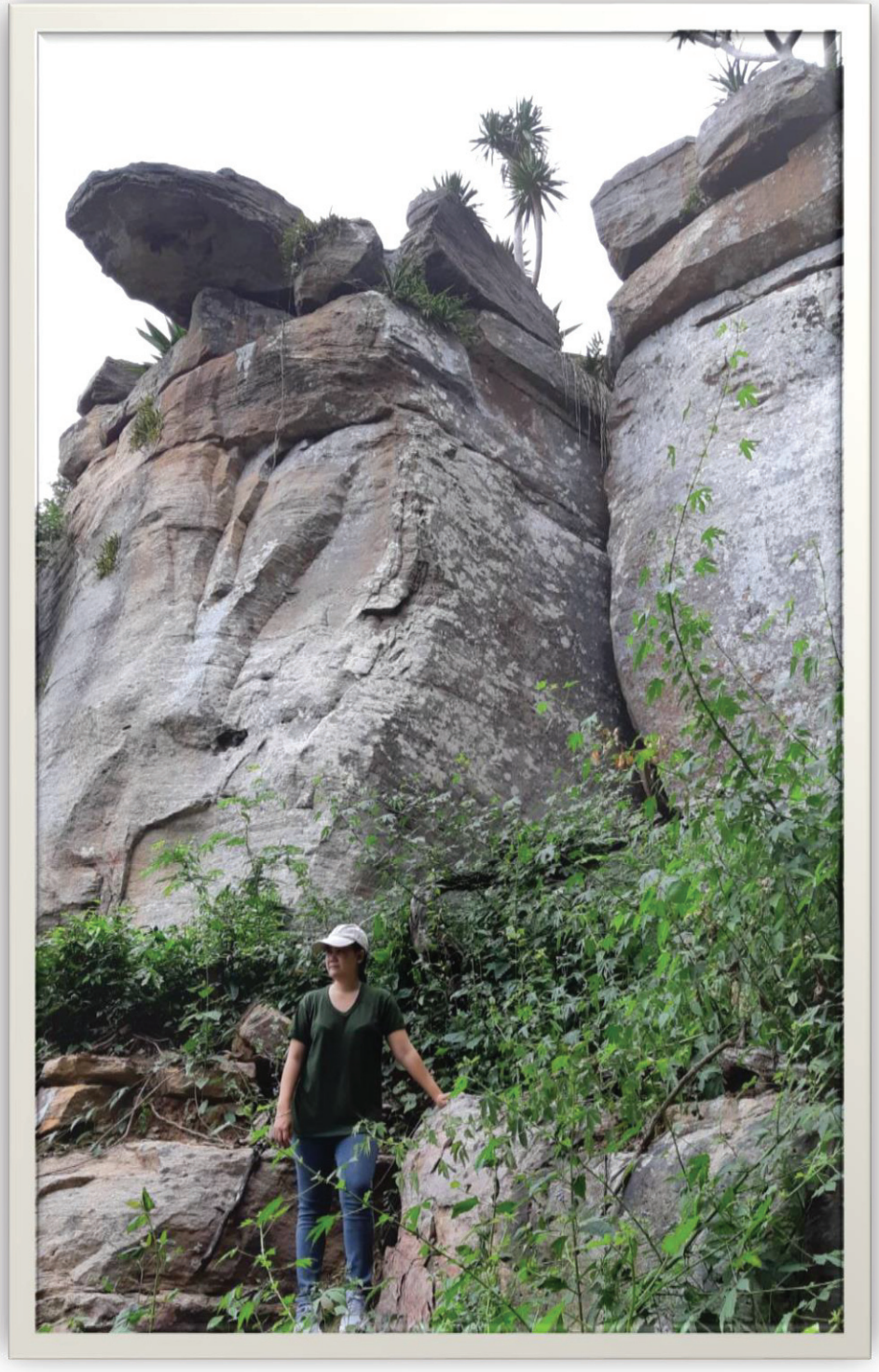
# Geological Significance of Khorat Geopark: Khorat Cuesta 2019

27 – 28 August 2019

Nakhon Ratchasima, Thailand

**Symposium on Geological Significance of Khorat Geopark:**

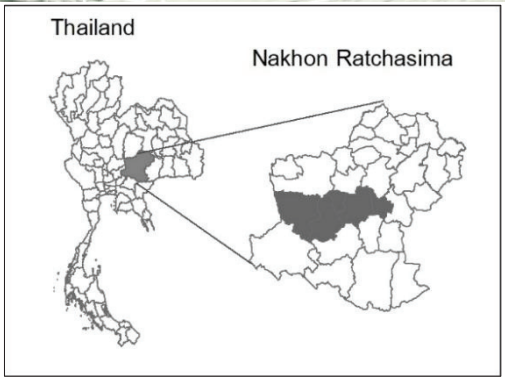
# Khorat Cuesta 2019

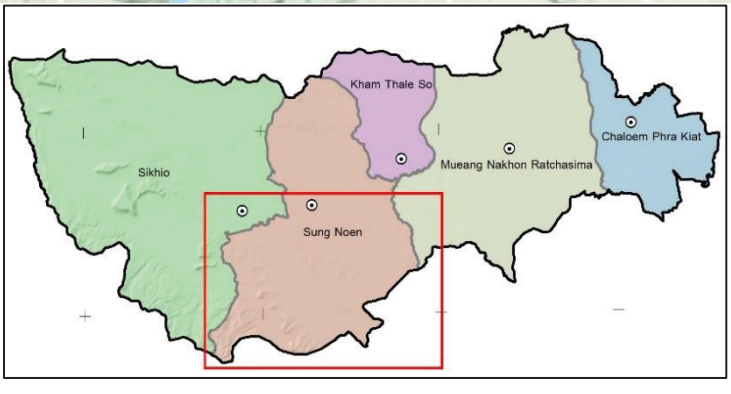


**27 – 28 August 21, 2019**

**Nakhon Ratchasima, Thailand**

# Field Excursion Route

## General geological description of Khorat Geopark

**General geology -** Topographic features of the Khorat Geopark are mainly controlled by rock types, stratigraphy and geological structures. The Earth crustal movement by tectonic uplift to be the plateau together with lateral movements gives rise to a gentle folding of the rocks to form Sakhon Nakhon and Khorat basins demarcated by the Phu Phan range. The Khorat basin is a flatland surrounded by the Phu Phan range to the north, Phetchabun and Dong Phayayen ranges to the west, Sankamphaeng and Phanom Dongrak ranges to the south, and highland to the east with high cliff river bank of the Mekong River. The rocks exposed on the west and east of the Khorat basin are demonstrated by traces of severe erosions in the forms of rock pillars like Mo Hin Khao and Pa Hin Ngam in Chaiyaphum and Sao Chaliang and Tana rapid in Ubon Ratchathani. The Khorat Geopark area is located in the southwest margin of the Khorat basin with diversified features described below.

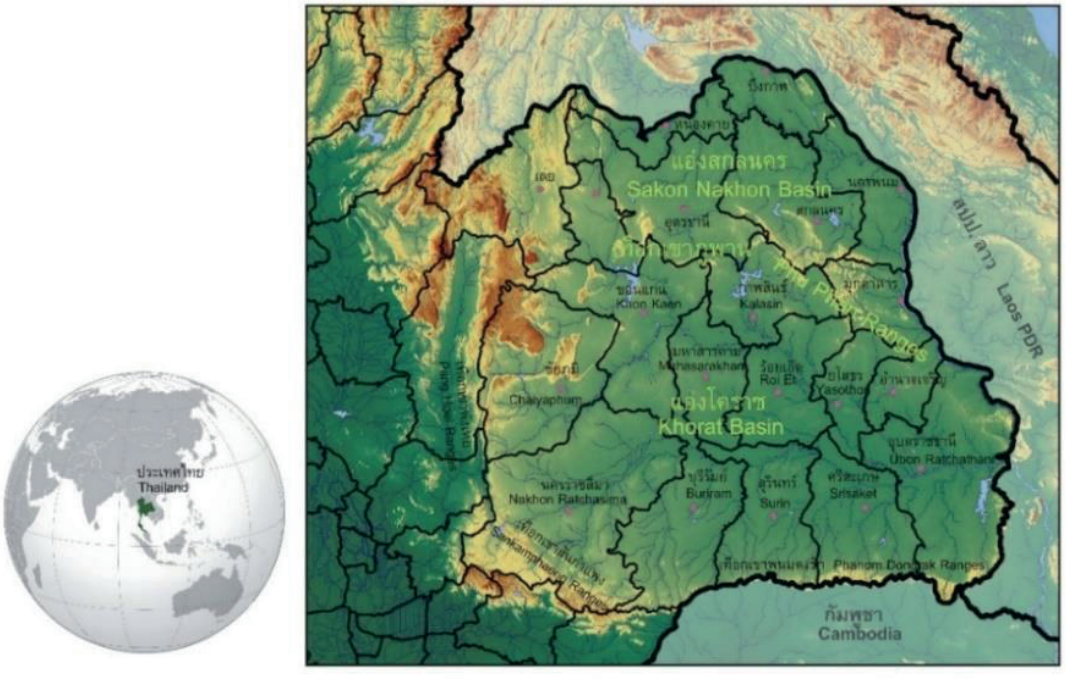



Fig. 1 Map of northeastern Thailand showing a plateau composed of Sakol Nakhon basin in the north and Khorat basin in the south (Source: https://maps-for-free.com/)

**Stratigraphy -** At least nine rock formations along the basin margin have been highly uplifted than that the basin center. These processes have made the rock strata gently tilted from the margin to the center of the basin. As well as, the exposed rock strata are also different resistance to the erosions shaping the area into a landform with high and low alternately (Fig. 1). The rock formations are described below.

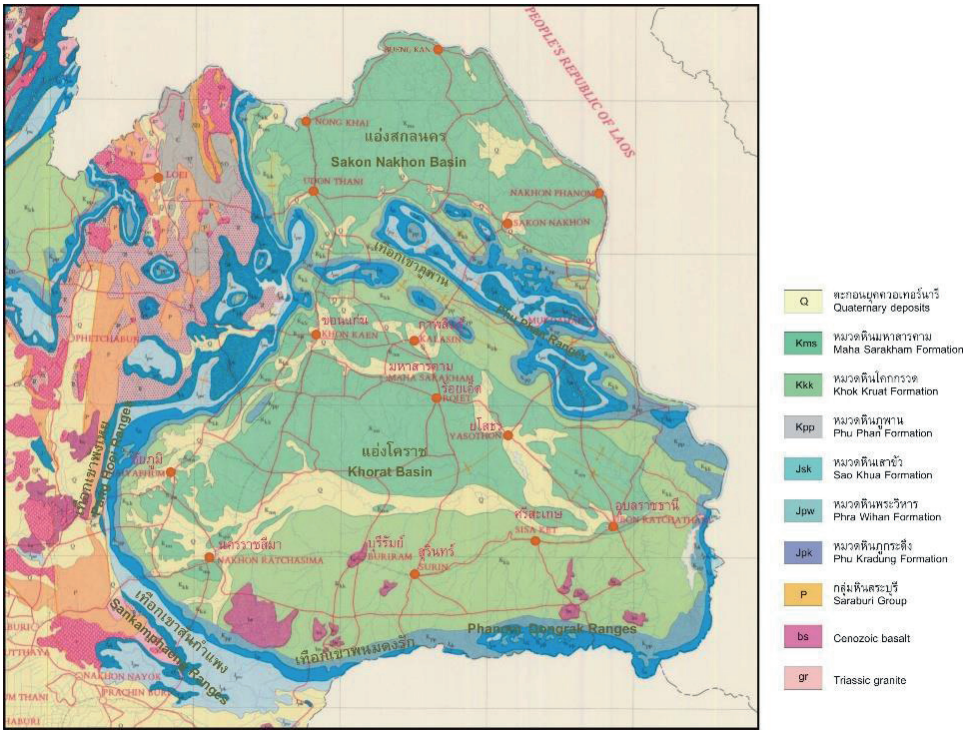



Fig. 2 Geological map of northeastern Thailand showing the Khorat basin that older rock formations are along the basin margin and younger towards the basin center (Geological Survey Division, 1987)

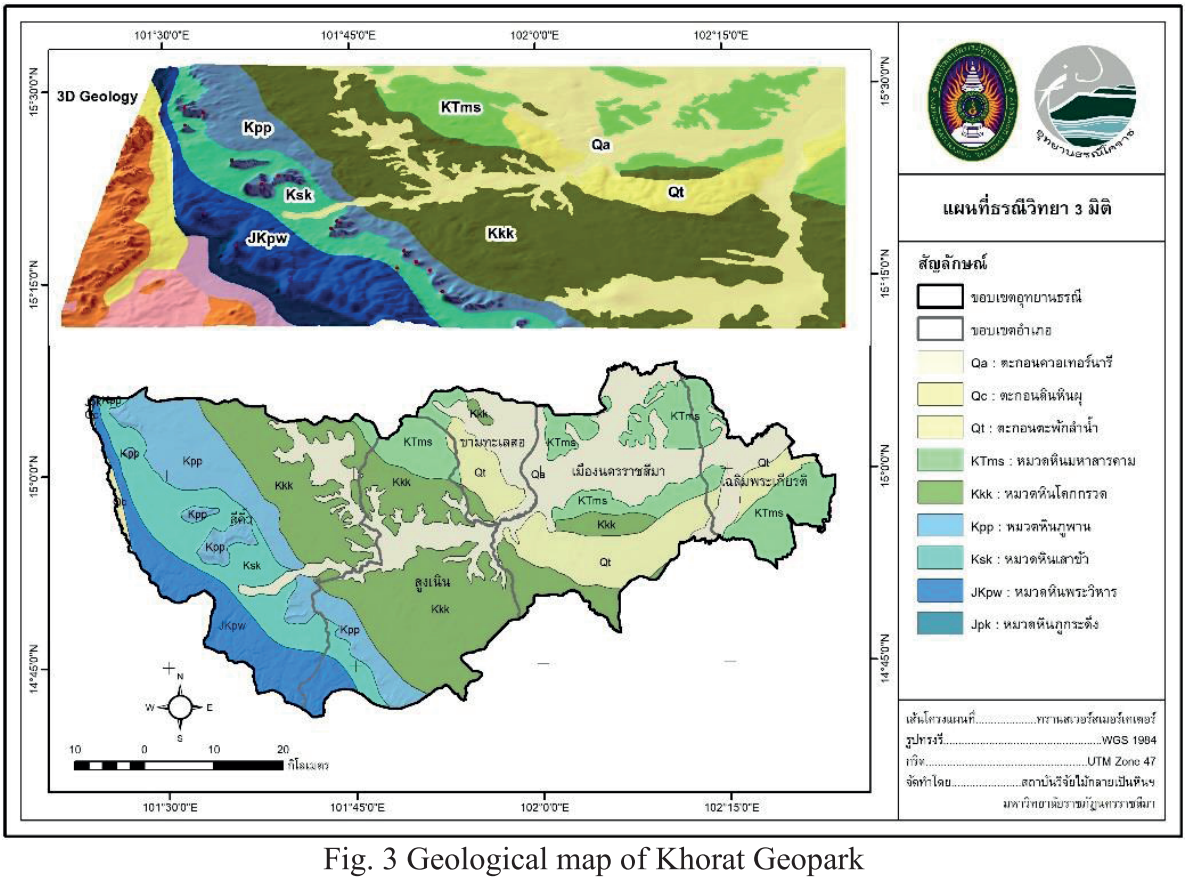



Fig. 3 Geological map of Khorat Geopark

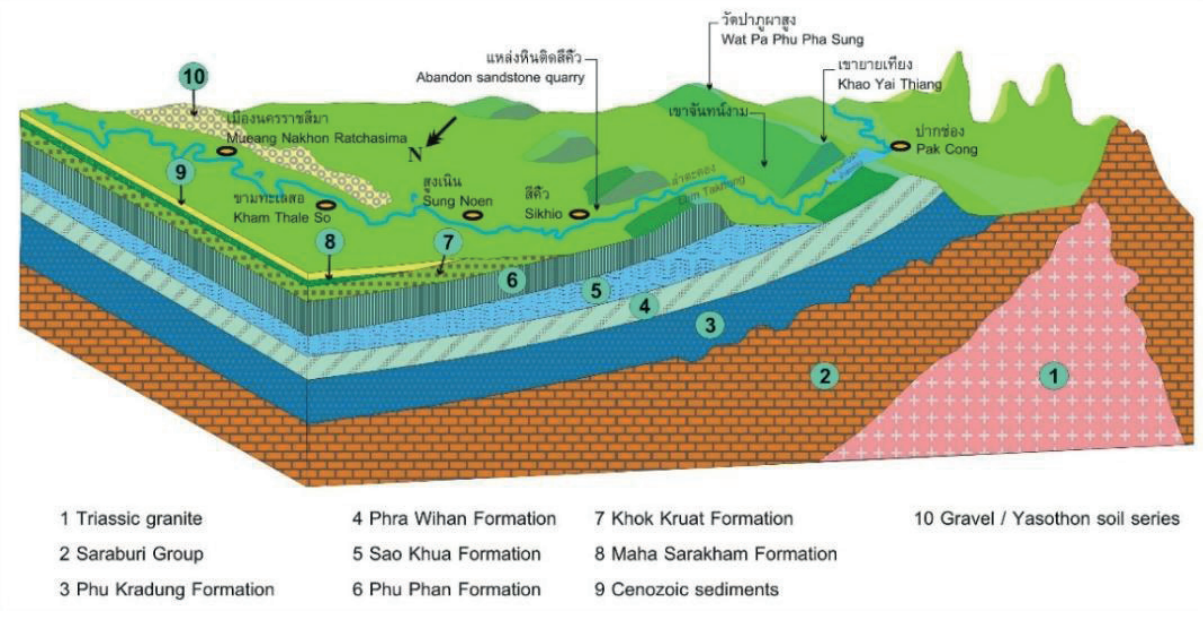



Fig. 4 A block model showing rock stratigraphic succession in the area of Khorat Geopark

**1) Phu Kradung Formation** (number 3) is Late Jurassic-Early Cretaceous rocks composed mostly of siltstone and shale, purplish red, thick beds, calcareous, with calcareous nodules; sandstone intercalated, greenish grey, fined to medium grained, composed of quartz and mica, poorly cemented. The rock formation is low resistive mainly exposed along the foothills, along Mittraphap Road beside the Lam Takhong reservoir.

**2) Phra Wihan Formation** (number 4) is Jurassic medium to coarse sandstone with white, yellow and pale brown in colors. Cementing material is silica with high resistance from weathering and erosion. Cross beddings as primary rock structure are generally revealed. The rock formation is a high resistive property exposed as a high mountain underlain by the less resistive Phu Kradung Formation. The rock beds are gently tilted towards the basin center forming a cuesta mountain with escarpment on the southwest side and dip slope on the northeast side. Trace of the divides of the mountain is partly used to define a boundary of the Khorat Geopark area. Geological sites on this rock formation are Khao Khanan Chit, Khao Yai Thiang, Khao Chan Ngam, Wa Phu Kaeo waterfall and Wat Pa Phu Pha Sung.

**3) Sao Khua Formation** (number 5) is a Cretaceous sandstone formation overlaying the Phra Wihan Formation. It is a less resistive property exposed in the low-laying area with soil and vegetation covered as a narrow valley, 1-2 km, sandwiched by the two ranges of mountains. No rock types can be described in the Khorat Geopark area.

**4) Phu Phan Formation** (number 6) is a Cretaceous medium to coarse-grained sandstone formation with brown to reddish brown in colors with cross beddings in general. It is a high resistive rock formation from weathering and erosion overlaying the Sao Khua Formation. It is formed as a broken mountain range consisting of a series of isolated hills separated by wind gaps and water gaps. Each isolated hill is still formed as a cuesta mountain with escarpment on the southwest side and dip slope on the northeast side. The geological sites in this rock formation are Sikhio sandstone quarry, Mor Ja Bok potholes, and Khao Sam Sib Srang.

**5) Khok Kruat Formation** (number 7) is a Cretaceous rock formation overlaying the Phu Phan Formation but the rock strata are lesser tilted than the underlying rock formations. It consists of two parts, the lower part is a thick sequence of fine to medium-grained

non-calcaleous sandstone clearly exposed on the riverbeds and banks of the Lam Takhong River such as Wang Nen waterfall where the riverbed is a gentle dip of sandstone beds with water flows similar to a rapid. There are some flowing artesian wells in the area of Ban Ma Kluea Mai but the aquifer might be from a contact boundary between the two rock formations beneath the ground surface. It might be the result from their surface elevations about 220 meters whereas the maximum water level in the Lam Takhong reservoir is about 261 meters above sea level.

The upper part of the rock formation is calcareous conglomeratic sandstone mainly exposed in Khok Kruat and Suranaree areas. The areas are dominated by undulating terrain where abundant occurrences of fossils were discovered and studied including iguadodon dinosaurs like *Ratchasimasaurus suranareae*, *Siamodon nimngami*, *Sirindhorna khoratensis*, crocodile *Khoratosuchus jintasakuli*, turtles *Kizylkumemys khoratensis* and *Shachemys* sp., hybodont shark *Thaiodus ruja*, as well as animal bones, fish scales, carnosaur teeth, and petrified woods.

**6) Maha Sarakham Formation** (number 8) is a Cretaceous rock formation with mudstone and rock salt beds alternation overlies the Khok Kruat Formation with no any outcrops in the Khorat Geopark area. However, there is a report studying the potash and rock salt deposits from seven core holes in Chaloem Phra Kiat drilled by the Department of Mineral Resources that found two beds of the rock salts. The potash minerals, both carnallite and sylvite, were found only from the lower salt bed and the origin of the sylvite deposits in Thailand can be explained by the salt dome theory (Suwanich, 2010). These salt beds can be dissolved and seeped up to contaminate with groundwater and even some surface water sources. An area in the north of Kham Thale So has been developed as a salt solution mine by injecting surface water to dissolve the salt beds and then pumping up to the salt evaporation ponds for salt production.

**7) Cenozoic rocks** are divided into 3 groups:

7.1) Gravel deposits (number 10) are greatly varied in thickness consisting of sub-rounded to well-rounded gravels as the river origins. They are over 10 km south of the modern river widely distributed in the south of Kham Thale So, Khok Kruat, Suranaree, and further extending to the east. Petrified woods were found in the gravel deposits especially in Ban Krok Duean Ha, Suranaree, where many large and long fossil logs were discovered. Some of them were studied where the fossil woods are comparable well with the modern trees found in the mix, deciduous dipterocarp, and dry evergreen forests. They were assigned at least 17 species from 10 genera of 7 families of dicotyledons, including cf. *Mangiferoxylon* spp., Anacardiaceae, *Canarium* sp., *Terminalia* spp., *Combretum* sp., *Irvingia* sp., *Cynometroxylon* spp., cf. *Millettia* spp., *Careya* spp., and *Azadirachta* sp. (Boonchai, 2008). The oldest age of sediments is unknown but it is younger towards the north until the recent sediments in the modern rivers.

7.2) Sand deposits (number 9) are unsolidated sediments composed mostly of sand with unclear ages but fossils discovered from the sand deposits are as old as Miocene. They are widely distributed over the areas of Tha Chang, Chang Thong and Phra Phut in Chaloem Phra Kiat from the Mun riverbanks and far away. The sand has been used as commercial construction materials from many sand pits. Abundant fossil logs and animal bones were found from place to place particularly the nine genera of proboscideans including *Prodeinotherium, Gomphotherium, Tetralophodon, Sinomastodon, Protanancus, Stegolophodon, Stegodon, Zygolophodon and Elephas*. Other fossils were also found namely hippos, rhinos, bovines, pigs, deer, barking deer, orangutans, giraffes, chalicotheres, saber-toothed cats, turtles, soft-shelled turtles, crocodiles, fish and mollusks. The precise stratigraphic positions of the fossils are still uncertain due to they came from sand pumping from the sand

productions. Some tektites were also found as floated specimens on the ground surface. In addition, abundant and diversified fossils were also found from a dug pond many years ago in Khok Sung, Mueang Nakhon Ratchasima. The fossils include petrified logs and seeds, stegodons, hyenas, bovines, deer, rhinos, hippos, turtles, soft-shelled turtles, gavials, etc.

7.3) Yasothon soils are deep red to orangish brown soil series generally overlaying the gravel bed. Ferricretes are usually found at the interface between the gravel bed and the Yasothon soils. The basal part of the soil is characterized by angular coarse sand to granule grains mainly composed of quartz and other rock fragments. It shows finning upwards sedimentary structure clearly visible at the basal part about 30 cm thick. The upper part is fine sand without any sedimentary structures even the bedding. Tektites were mainly discovered as floated specimens but some *in situ* tektites were also found at the interface between the gravel bed and the Yasothon soil as well as common occurrences in some soil pits northwest of the Khon Kaen bypass highway (Satarugsa, 1987; Songtham *et al*., 2012). Many tektites from Southeast Asia and Australia were dated with ages ranging from 0.7 to 0.8 million years old closely related to a meteorite impact event (Stauffer, 1978; Ford, 1988; Blum *et al*., 1992; Izett and Obradovich, 1992; Schnetzler, 1992; Koeberl, 1994; Kunz *et al*., 1995; Hou *et al*., 2000; Ma *et al*., 2004).

**Post Field Trip**

Symposium on Geological Significance of Khorat Geopark: Khorat Cuesta 2019

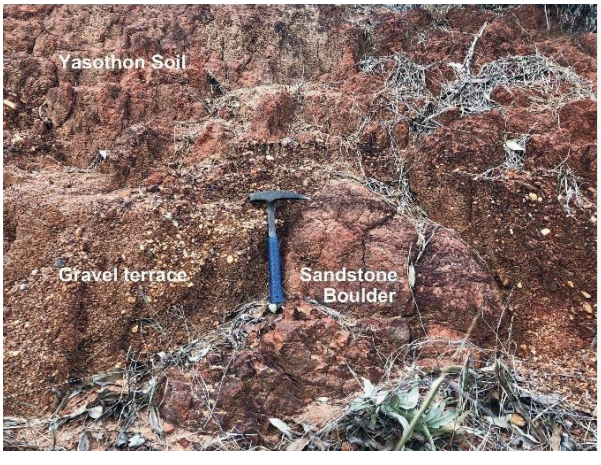
**Stop 1: Yasothon Soil and Gravel Terrace Deposit**

Location: Khorat Fossil Museum, Ban Krok Duean Ha

Coordinate: 14.858938°N / 102.031182°E

Altitude: 272 m.

Description: An exposure of soil profile in a small area consisting of two soil units. The underlying unit is a gravel terrace with a piece of petrified wood fragment embedded by the gravels. The gravels are characterized by subangular to rounded representing river gravel deposited in a channel of a river, poorly cemented. The overlying unit is fine sand, deep reddish orange in color, with angular granules of quartz and rock fragments coarser at the base and fining upwards and turned into fine sand within a range of about 30 centimeters. Further up portion is fine sand, well sorted, and structureless. A piece of tektite was discovered and collected from the base of the Yasothon soil unit.




Yasothon Soil and Gravel Terrace Deposit at Khorat Fossil Museum, Ban Krok Duean Ha

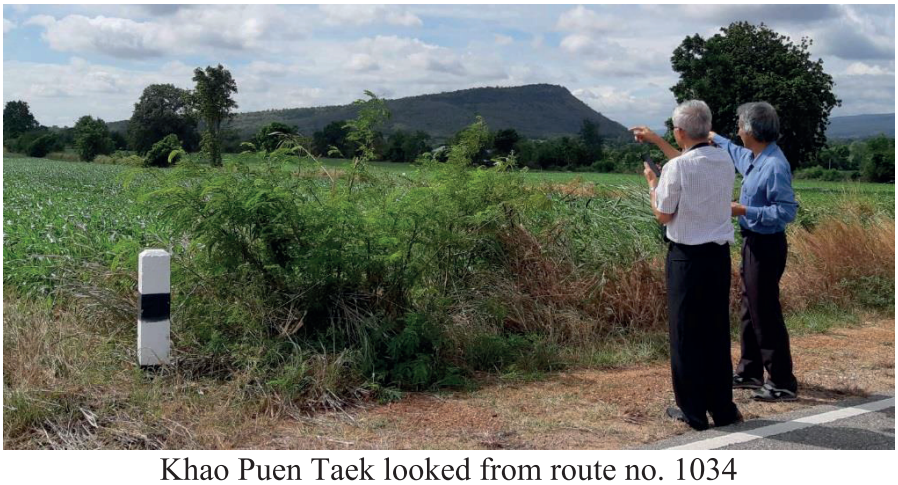
**Stop 2: Khao Puen Taek**

Location: Wat Pa Pha Puen Taek, Ban Thung Sabaeng, on the route no. NR.1034

Coordinate: 14.78041°N / 101.74302°E

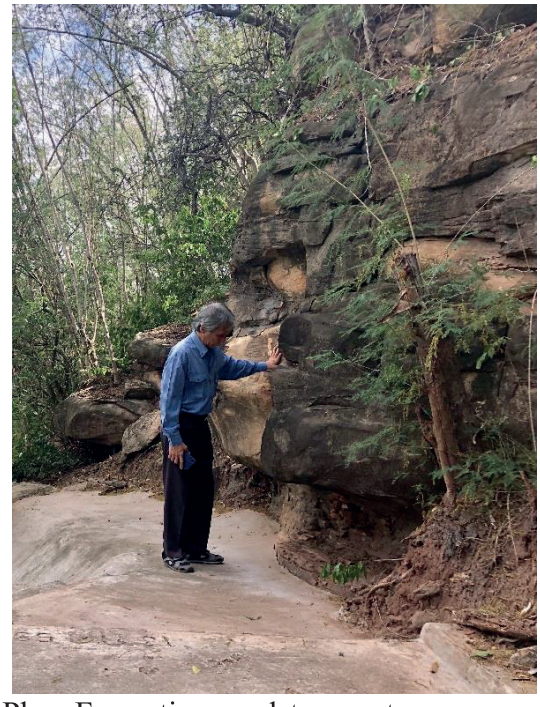
Altitude: 338 m.

Description: On the route no. NR.1034 at km 7.2, when looking south, we can see an isolated hill, Khao Puen Taek, on the left-hand side and far way on the right-hand side we can see two isolated hills, Khao Pha and Khao Sap Pradu. The Khao Puen Taek seen from the road is characterized as a form of cuesta with dip slope on the left and escarpment on the right. The highest peak of the hill is about 475 meters whereas the lower surface elevation is about 370 meters above mean sea level. The dip slope is on the northeast side in opposite with the escarpment.

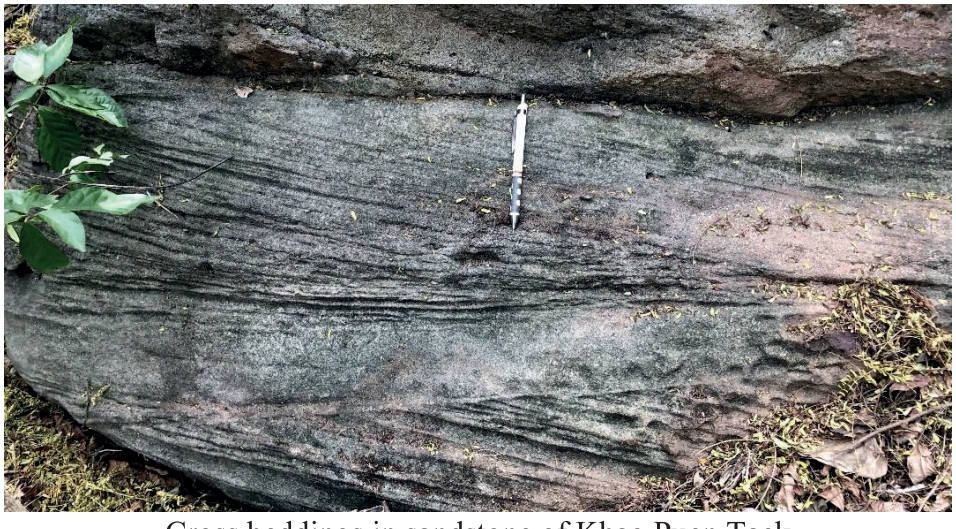


Khao Puen Taek looked from route no. 1034

Sandstone outcrop on Khao Puen Taek along the way up to a pavilion over the escarpment reveals sandstone beds of which dip direction is measurable to the northeast with dip angle about 7 degree. The sandstone is regarded as of the Phu Phan Formation.



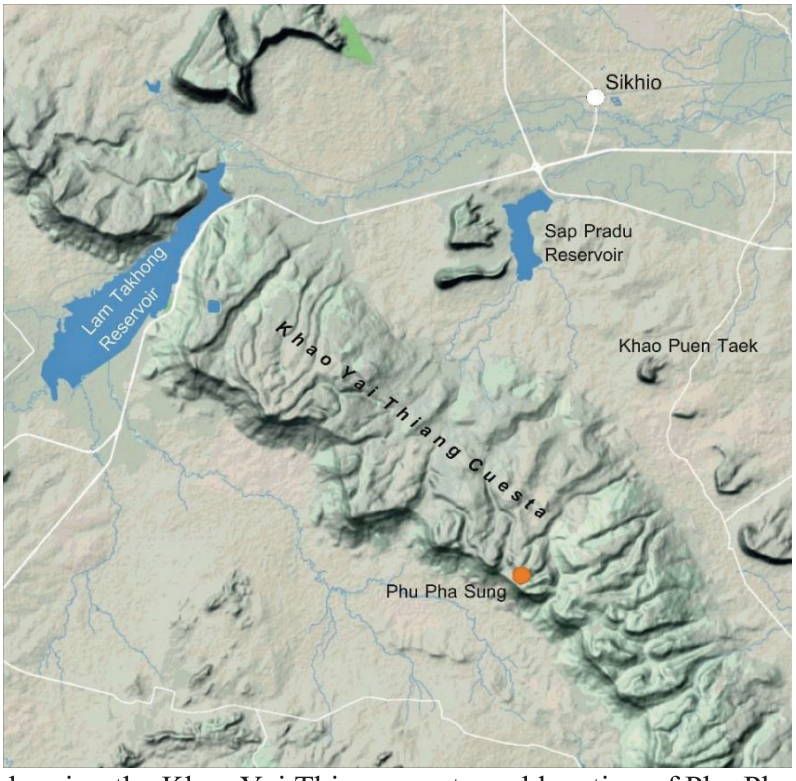
Phu Phan Formation sandstone outcrop exposed on the escarpment of the Khao Puen Taek



Cross beddings in sandstone of Khao Puen Taek

**Stop 3: Phu Pha Sung**

Location: Wat Pa Phu Pha Sung, Ban Dong Ma Fai
Coordinate: 14.68254°N / 101.69421°E
Altitude: 676 m.

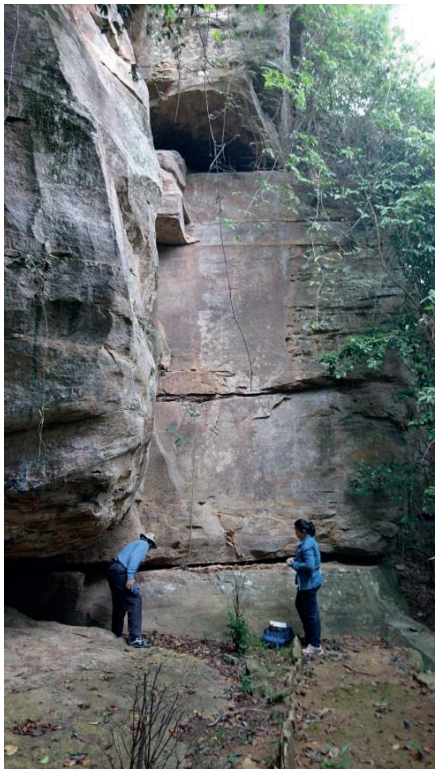


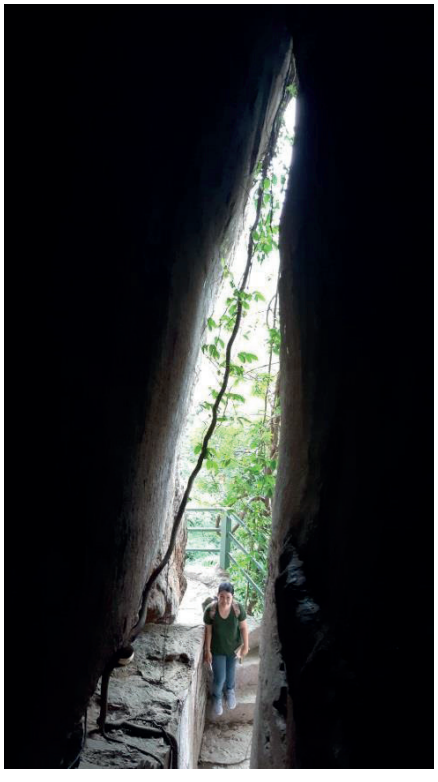

Map showing the Khao Yai Thiang cuesta and location of Phu Pha Sung

Description: The area is on the peak of a mountain ridge which divides the dip slope and escarpment from each other with elevation about 650 - 710 meters above mean sea level. Alignment of the peak and escarpment is around NW-SE direction. Both escarpment and dip slope areas have been dissected by creeks giving rise to irregular steep cliff with deep water channels flowing down along the dip slope. The surface elevation down below the escarpment is about 350 meters above mean sea level, the cliff is thus about 350 meters high. Vegetation of the area is dry evergreen forests with some vulnerable species of animals like Southern pig-tailed macaque.

The dip slope is capped by harder sandstone of Phra Wihan Formation and underlain by softer Phu Kradung Formation sandstone. The easier weathering and erosion of the Phu Kradung Formation gives rise to form caves under the harder Phra Wihan Formation sandstone ledges. Whenever the sandstone ledges unable to maintain their weighs: the rock cracks, rock creeps, rock slides and rock falls can then be taken place, the escarpment is therefore developed proceeding into the dip slope direction.

Pha Sam Liam is developed along a steep cliff by rock cracks, rock creeps, rock slides and rock falls. Large and thick sandstone slabs were moved from their original positions in different ways and different distances to be ledges outstretched over the high cliff: to be caves and narrow gaps. Monks from the monastery helped together to pave the trails, build the bridges, staircases, rooms and toilet as well as electricity. This locality demonstrates instability of the cliff and having risk. This location was developed for monks in meditation and forbidden for general people and tourists.





Phu Pha Sung is a sandstone ledge outstretched over the cliff. It is a good location for scenic lookout to see views down below the cliff. Khao Phaeng Ma is far away beyond the rugged limestone mountains within a large canyon. The location is good to view a horizon of trace fossils, burrows.

Phu Pha Sung

Trace fossils on Phu Pha Sung

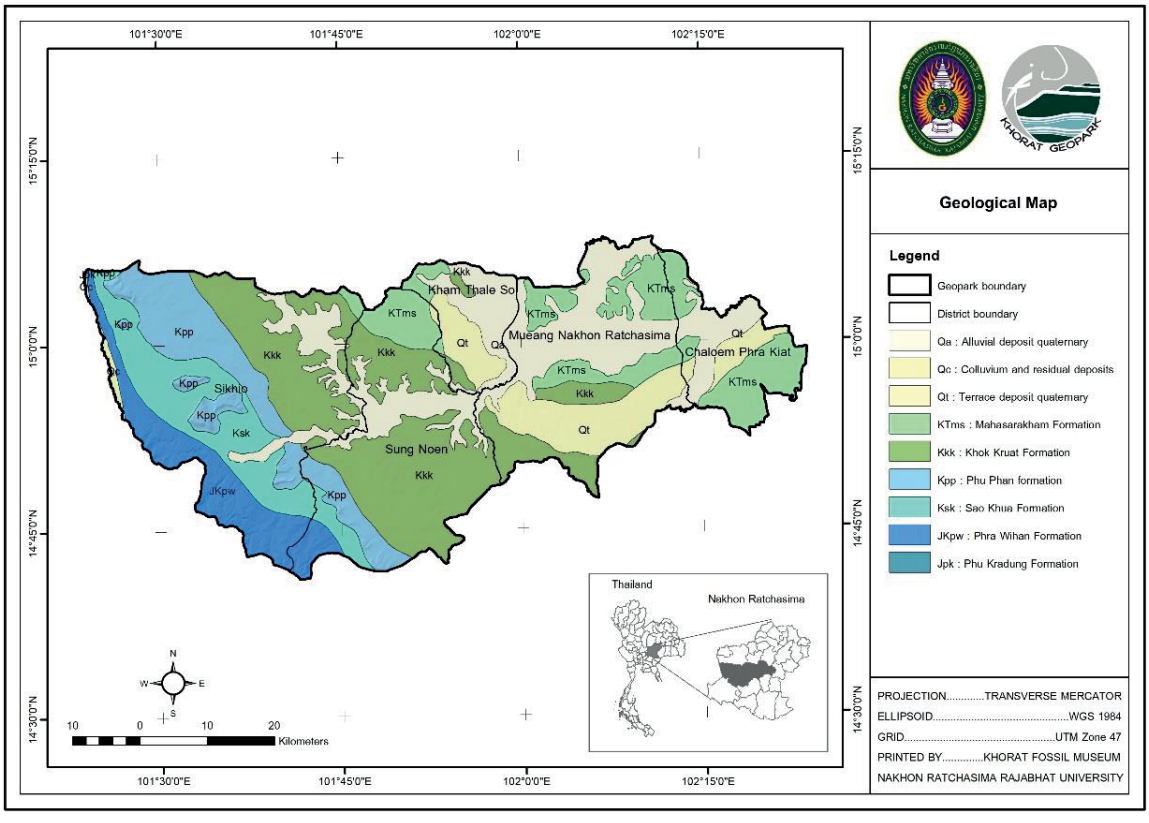
Pha Tarn Lom and Pha Rak Sai is cliffs developed by rock weathering and erosion with a banyan tree protruding its roots down along the cliff, the cliff is good demonstration of diversified cross bedding structures in the sandstone. The cliff is also developed into caves along the softer rock strata sandwiched by harder rocks.


Pha Tarn Lom

Pha Rak Sai

Wiman Thip is the cliff with man-made infrastructures including bridges along the cliff with a souvenir shop with coffee breaks and scenic view points. A stop before entering the Phra Thatu Chompha pagoda is an exposure of well-preserved burrow horizon. The monastery is preparing to protect and conserve.

Wiman Thip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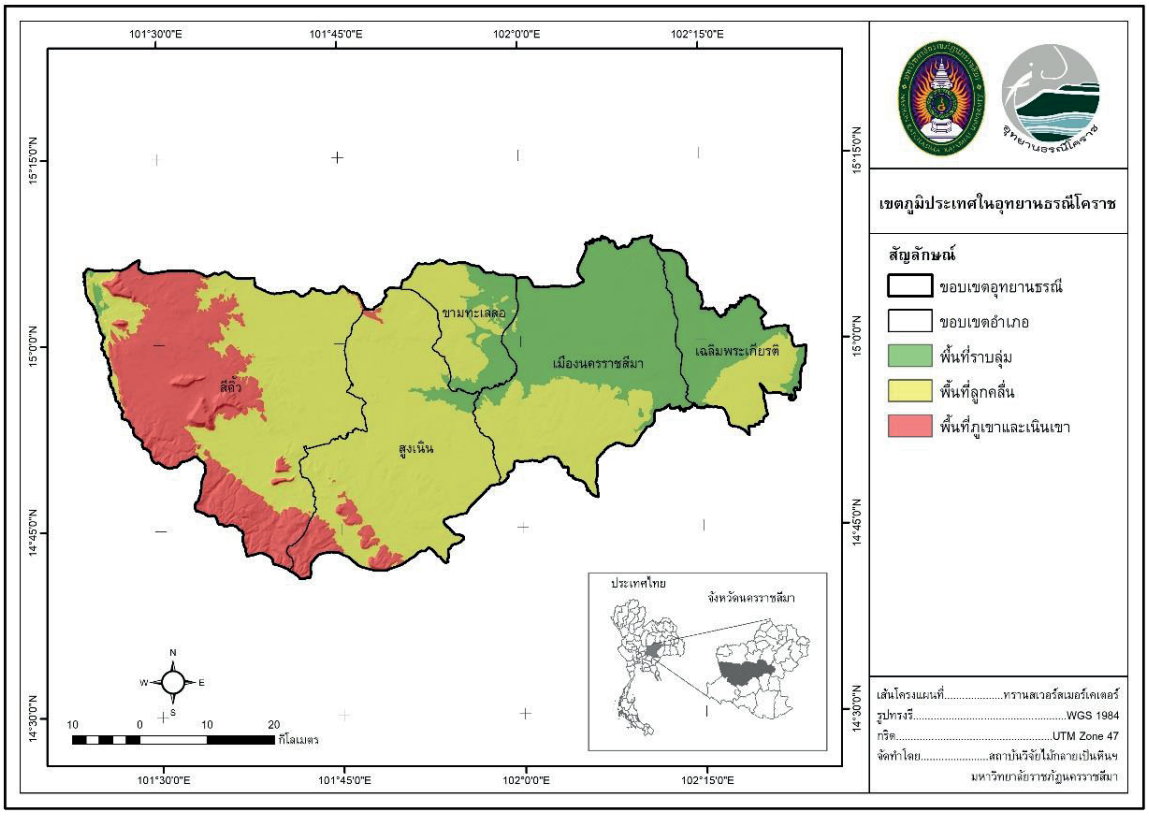
KHORAT GEOPARK
Geological Map
Legend
Geopark boundary
District boundary
Qa : Alluvial deposit quaternary
Qc : Colluvium and residual deposits
Qt : Terrace deposit quaternary
KTms : Mahasarakham Formation
Kkk : Khok Kruat Formation
Kpp : Phu Phan formation
Ksk : Sao Khua Formation
JKpw : Phra Wihan Formation
Jpk : Phu Kradung Formation
Kham Thale So
Mueang Nakhon Ratchasima
Chaloem Phra Kiat
Sung Noen
Sikhio
Thailand
Nakhon Ratchasima
Kilometers
PROJECTION.....TRANSVERSE MERCATOR
ELLIPSOID.....WGS 1984
GRID.....UTM Zone 47
PRINTED BY.....KHORAT FOSSIL MUSEUM
NAKHON RATCHASIMA RAJABHAT UNIVERSITY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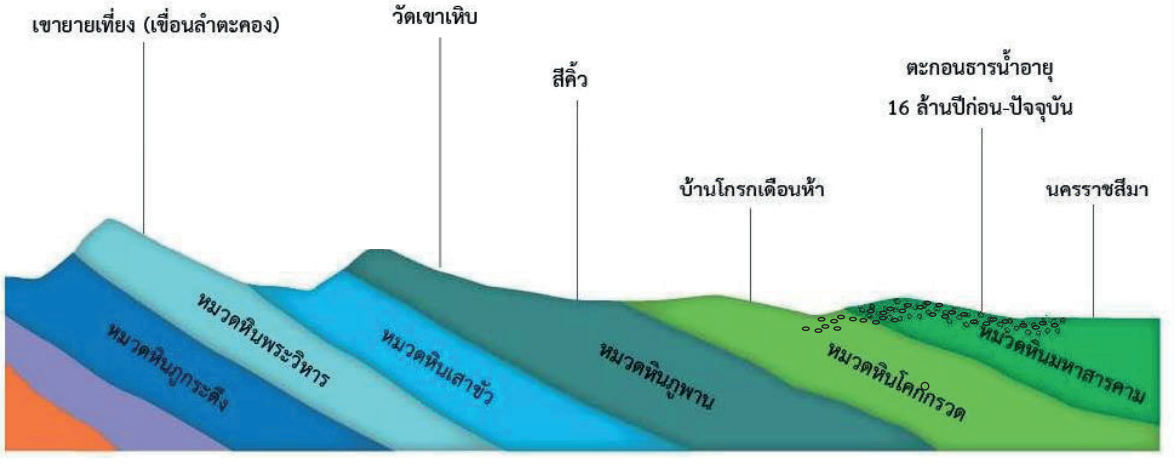
สัญลักษณ์
ขอบเขตอุทยานธรณี
ขอบเขตอำเภอ
พื้นที่ราบลุ่ม
พื้นที่ลูกคลื่น
พื้นที่ภูเขาและเนินเขา
เส้นโครงแผนที่.....ทรานสเวอร์สเมอร์เคเตอร์
รูปทรงรี.....WGS 1984
กริด.....UTM Zone 47
จัดทำโดย.....สถาบันวิจัยไม้กลายเป็นหินฯ
มหาวิทยาลัยราชภัฏนครราชสีมา


เขายายเที่ยง (เขื่อนลำตะคอง)
วัดเขาเหิบ
สีคิ้ว
ตะกอนธารน้ำอายุ
16 ล้านปีก่อน-ปัจจุบัน
บ้านโกรกเดือนห้า
นครราชสีมา
หมวดหินพระวิหาร
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หมวดหินภูพาน
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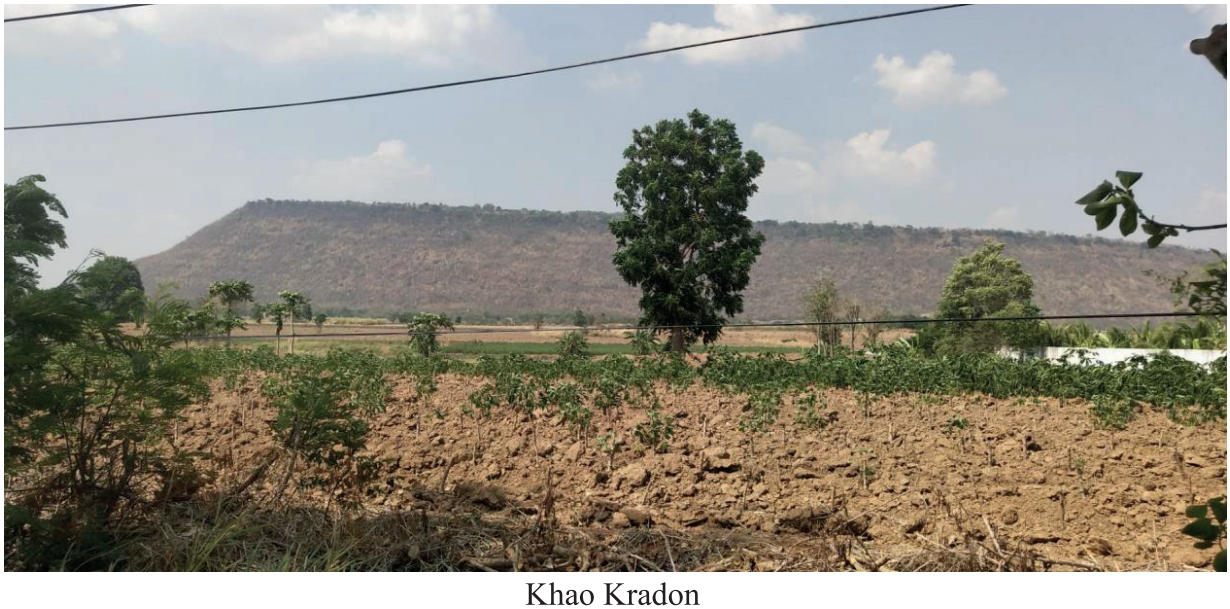
Khao Pong Nok and Khao Khanan Chit



Khao Kradon

Khao Khanan Chit

Khao Phrik (Escarpment)

Khao Phrik (Dip slope)

Khao Yai Thiang

Khao Puen Taek

Khao Sam Sib Sang

Khao Khieo

Sikhio – Sungnoen Cuesta Plain Area

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