Some geological signatures created by the cuesta formation in Khorat Geopark, NE Thailand

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Abstract

Cuestas in the Khorat Geopark are considered as a geoheritage with international geological significance in terms of outstanding landforms and their international publications. It is the south-westernmost demarcation of the geopark area with prominent escarpments and dip slopes for human settlements under sustainable uses. Its formation produced some geological remnants that can be used to trace back its long geological history. An antecedent or superimposed river, Lam Takhong, has continuously carved the cuestas forming large water gaps where a dam and reservoir can be developed. Traces of gravel terraces and sand deposits together with Late Cenozoic fossil fauna and flora are considered as the results of the cuesta formation. These geological signatures left behind the cuesta formation play a significant role for better understanding the geological background of the whole geopark area.

Introduction

The Khorat Geopark area is geologically varied from the south-westernmost to north-easternmost sides. It is underlain by older rock formation as old as Permian. The oldest Mesozoic rock unit is the Phu Kradung Formation and younger in succession are Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, and Maha Sarakham formations (Fig. 1). Likewise, the geomorphologic landforms are also varied from cuestas to undulating terrains and then low-lying flat plains as well as varied from dry evergreen vegetation on mountaintops and some dip slope areas to dry dipterocarp forests on dip slope and undulating areas and then grasslands on low-lying flat plains. These geographical and geological variations are basically on the function
of tectonic uplift of the area. Of most significance on landscape in the Khorat Geopark are cuestas. They are characterized by a double-chain of mountains circling along the margin of the Khorat basin. These cuestas have been formed by gradual tectonic uplift forming the Khorat Plateau with the cuestas extending from Nakhon Ratchasima to Buri Ram, Surin, Si Sa Ket, Ubon Ratchathani, Mukdahan, Kalasin, Khon Kaen, and Chaiyaphum provinces. Many geological processes producing some geological signatures left behind the cuesta formation are escarpments and dip slopes, water gaps and wind gaps, gravel terraces, and fossil deposits.

**Escarps and dip slopes**

There are two series of escarpments and dip slopes of the two cuesta mountain chains, Khao Yai Thiang and Khao Sap Pradu escarpments separated by a long narrow valley (Fig. 2). The higher series of Khao Yai Thiang escarpments is at the outermost margin of the Khorat basin with cliff elevations between around 350 and 700 meters above mean sea level. The dip slopes are capped by hard sandstone of Cretaceous Phra Wihan Formation underlain by softer sandstone of Jurassic-Cretaceous Phu Kradung Formation. The chains of mountains have been cut by rivers and divided into segments. Each segment contains a steep cliff, escarpment, and dip slope on the opposite side. Both escarpments and dip slopes show a degree of dissection by rainwater and runoffs between moderate and strong levels. Because of the softer Phu Kradung Formation overlain by the stronger Phra Wihan Formation, it shows features of caves along the Phu Kradung Formation with sandstone ledges of the Phra Wihan Formation on top. There are features of cracks on the sandstone ledges with many rock slides, rock falls and caves along the cliffs clearly visible in the area of Phu Pha Sung.

The dip slope areas are mostly capped by the Phra Wihan Formation sandstone characterized by traces of erosion in forms of creeks along the dipping directions. However, some Sao Khua Formation sandstones are sparsely exposed as outcrops as well as floated rocks. Abundant large sandstone boulders are accumulated along the down slope area as found in the Khao Chan Nang.

Another chain of cuesta is a series of lower isolated hills separated by water gaps and wind gaps. These isolated hills are regarded as a former continuous cuesta mountain chain. Examples of these hills are Khao Kradon (657 m), Khao Phrik (689 m), Khao Sadao (575 m), Khao Sap Pradu (452 m), Khao Pha (465 m), Khao Puen Taek (476 m), Khao Sam Sip Sang (415 m), and Khao Khiec (482 m) (Fig. 2). Each isolated cuesta clearly shows the escarpment and dip slope on opposite sides of the cuesta series. These cuestas are capped by the Cretaceous
Phu Phan Formation sandstone underlain by softer Sao Khua Formation sandstone. A long narrow valley between the two cuesta mountain chains is thus supported by the Sao Khua Formation as a low-lying area mostly covered by Quaternary sediments except along the creeks. Surface elevation of the valley ranges from 250 to 330 meters above mean sea level. Potholes are generally formed on the hilltops such as in Wat Mo Cha Bok, even on the higher hill, Khao Sam Sip Sang, presumably formed by runoffs during heavy rainfalls in association with joint sets of the rocks.

**Water gaps and wind gaps**

A water gap is a gap that flowing water has carved through a mountain ridge during mountain building simultaneous with down penetration of an antecedent or superimposed river. There are many water gaps and many antecedent or superimposed rivers on these cuestas in northeast Thailand. Lam Takhong is a main antecedent river in the Khorat Geopark. It is originated from Khao Yai flowing through Pak Chong, with a water gap between Khao Yai Thiang and Khao Khanan Chit (Lam Takhong reservoir), Sikhio, Sung Noen, Kham Thale So, Mueang Nakhon Ratchasima districts, and meeting the Mun River in Chaloem Phra Kiat District. The water gap between Khao Yai Thiang and Khao Khanan Chit is about 6 kilometers wide between mountaintops upstream and about 2 kilometers wide on the downstream portion. Water level of the Lam Takhong reservoir averages 278 meters above mean sea level, whereas the upper pond on Khao Yai Thiang is at 652 meters above mean sea level. The water level difference between the reservoir in the water gap and the artificial upper pond on the cuesta has allowed the Electricity Generating Authority of Thailand (EGAT) to set up a reverse pumping unit for electricity generating together with 14 wind turbines (Fig. 3).

There are many gaps along the Khao Sap Pradu escarpments that seem to be large wind gaps between the nearby isolated hills but the gaps are actually water gaps. There are many creeks and streams between the gaps such as Huai Rong between Khao Kradon and Khao Phrik, Lam Takhong between Khao Phrik and Khao Sap Pradu. Sap Pradu reservoir is between Khao Sap Pradu and Khao Puen Taek where an earth fill dam blocks Huai Sap Takhian and Huai Wa Phu Kaeo originating from the Khao Yai Thiang dip slope. These geomorphologic landforms have been created during the cuesta formation.

**Gravel terraces**

With the formation of the water gaps, the cuestas have been gradually eroded with time and developed into some large water gaps. The sediments from the water gap formation,
generally sands and finer sediments, have been carried away downstream and deposited somewhere. These sediments were generally eroded from sandstone of the Mesozoic Khorat Group.

The gravel deposits in the Khorat basin occur along the north of Chi River and the south of Mun River as high terraces. From the occurrences of the gravel deposits in correspondence with positions of the Mun River and Chi River, it can be said that the gravel deposits are of a fluvial system. The gravels are subangular to rounded, poorly to moderately well-sorted, and often set in a matrix of yellow or rubefied sand, weakly developed imbrication, fractured pebbles and the frequent occurrence of fragments of petrified wood, some of large size, suggesting that the gravels are the product of fluvial processes of moderate to high energy. However, the environment of deposition was arid to semi-arid, as evidenced by the secondary characteristics of the gravels: surface polish, faceting, and rubefaction of the sand matrix (Parry, 1996).

Field observations reveal that the gravels are coarser on the west and finer on the east of the Khorat basin. These gravel deposits are regarded as of Proto-Mun and Proto-Chi rivers as the Chi River has been shifted southwards and the Mun River has been shifted northwards leaving the gravel deposits behind. Therefore, the ages of the gravels must be older in the north of Chi River and in the south of Mun River and younger towards the modern rivers (Fig. 4). These gravel deposits are regarded as being caused by a Quaternary tectonic uplift converting a low-lying flat area into a basin in the plateau. Occurrences of gravels with fossil fusulinids and corals inside confirm that the gravels are of allochthonous origins and originated outside the Khorat basin upstream from such Permian rocks (Fig. 5). A detailed examination of the composition of these high terrace gravels reveals an allochthonous origin with a provenance in the Western Highland of Thailand (Parry, 1996).

These gravel deposits are covered by the Yasothon soil series with Australasian tektites occurring at the interface between the two sediment units (Satarugsa, 1987; Songtham et al., 2012) (Fig. 6). This soil series is about 3 to 5 meters thick widely distributed on the undulating terrains. It is characterized by fine-grained sands, reddish orange to yellow in color, and structureless. The basal part of the soil series contains angular granules to pebbles of quartz and rock fragments with fining upward into fine sands. The genesis of this soil series has been claimed as sediments derived from the impacts of some extraterrestrial objects the same as the Australasian tektite strewnfield (Songtham et al., 2012).
Fossil deposits

Discoveries of abundant fossils from Quaternary sand deposits in Chaloem Phra Kiat areas have been claimed to be much older than we thought. There are many fossil records such as a new orangutan relative *Khoratpithecus piriyi* and proboscidean *Zygolophodon* from the Late Miocene (Chaimanee et al., 2004; Duangkrayom et al., 2016). These Miocene fossils must be from a Miocene rock formation but the rock formation was completely destroyed by a long continuous erosion caused by the tectonic uplift and superimposed rivers. These fossil deposits are evidence showing that there were some Neogene rock formations with abundant fauna and flora that were removed and redeposited into the younger sediments caused by the cuesta formation.

Conclusions

There are four geological signatures created by the cuesta formation in Khorat Geopark. 1) Two mountain chains, each of which has escarpment and dip slope; the escarpment is good for scenic viewpoints and dip slope areas provide for sustainable uses under protection and conservation, such as in Wat Pa Phu Pha Sung, Khao Yai Thiang, and Ban Dong Ma Fai. 2) Water gaps created by tectonic uplift and down cutting of a superimposed river that provide locations for dam construction to create an artificial reservoir for water supply and electricity generating. 3) Gravel terrace deposits formed by the superimposed rivers during the cuesta formation have left geological evidence of ancient rivers and petrified wood covered with sediments and 0.77 – 0.78 Ma Australasian tektites as a good age marker. 4) Fossil deposits indicate that there were some Miocene fossil-bearing rock formations that were completely destroyed during the cuesta formation as good indication of plant and animal communities and their paleoenvironments. This paper provides information and technical ideas for further research to get a better understanding of the geological history of the Khorat Geopark area.

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References

Fig. 1 3D geological block model showing general stratigraphic and geomorphologic features of the Khorat Geopark area
Fig. 2 Relief map showing two Khao Yai Thiang and Khao Sap Pradu escarpments in the Khorat Geopark area

Fig. 3 Upper pond for a reverse pumping unit and wind turbines on the Khao Yai Thiang cuesta
Fig. 4 Map of northeast Thailand showing river basin and gravel terrace deposits

Fig. 5 A fusulinid-bearing gravel from Pa Hub Yai, Chaloem Phra Kiat, Nakhon Ratchasima
Fig. 6 A gravel deposit overlain by the Yasothon soil with a tektite occurrence near the Petrified Wood Museum, Suranaree Subdistrict, Mueang Nakhon Ratchasima