Geomorphology and Formation of Gravel Beds along the Ping and the Wang Rivers at Tak, Northern Thailand

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Abstract

Gravel beds along the Ping and the Wang Rivers at Tak, northern Thailand reveal their unpaired terrace pattern. The unusual level of terraces is of interest because it is likely to be related to neo-tectonic uplifting along part of the Mae Ping fault zone. Three levels of terraces were caused by at least three meandered belts perhaps due to the fluctuation of base levels which corresponded to a global change in climatic conditions during the Quaternary. The depositional characteristics of terraces are presented in this paper with the introduction of a typical stratigraphy for each terrace level. Multiple fining upward sequences of terrace deposits represent a frequency of avulsion within a narrow and limited meander belt. Gravels are composed of quartzite, quartz, granite and are sub-rounded to well-rounded with a high sphericity. Petrified wood of several sizes occur and some are preserved almost in their complete shape. The uplift-like features in terrace deposits may be an additional evidence of the active fault responsible for unusual high level of terrace along the Mae Ping fault zone.

Keywords: Gravel bed, Ping, Wang, neo-tectonic, meandered belts, petrified wood

1. Introduction

Geomorphological studies in Thailand have expanded since the pioneer studies were published in the past decades. Several have focused mostly on the Central Plain where the evidence of the Holocene sea-level changes has been found (Koeningswald, 1959; Takaya, 1968; Thiramongkol, 1983). Some researchers reported their observations from the northern Thailand with a view to find the relationship of the Quaternary deposition within its limited basin morphology (Kaewyana, 1985). Further researches have geomorphic discussion on the formation of landforms and its related depositional characteristics (Bishop and Godley, 1994; Choowong, 2002). However, most of studies were confined to geomorphic processes rather than their application to geo-hazard research.

The role of active faults have become the main concern for assessing their direct linkage to the evaluation of earthquake potential especially in the western and northern Thailand (Morley, 2002; Fenton et al., 2003; Rhodes et al., 2004; Songmuang et al., 2007) As such a systematic approach in analyzing geomorphological features for inferring the possibility of spatial and vertical active fault movements has become necessary. The result of our geomorphological and sedimentological field observations in gravel bed deposits found along terrace landforms of the Ping and the Wang Rivers is presented here (Figure 1). Systematic detailed analyses on the morphology and sedimentology were employed in order to reveal how terraces here were formed. Special attention is also paid to the observation made at the western bank of the Ping terrace deposits where we recognized the clue of several faults cutting through the terrace deposits.

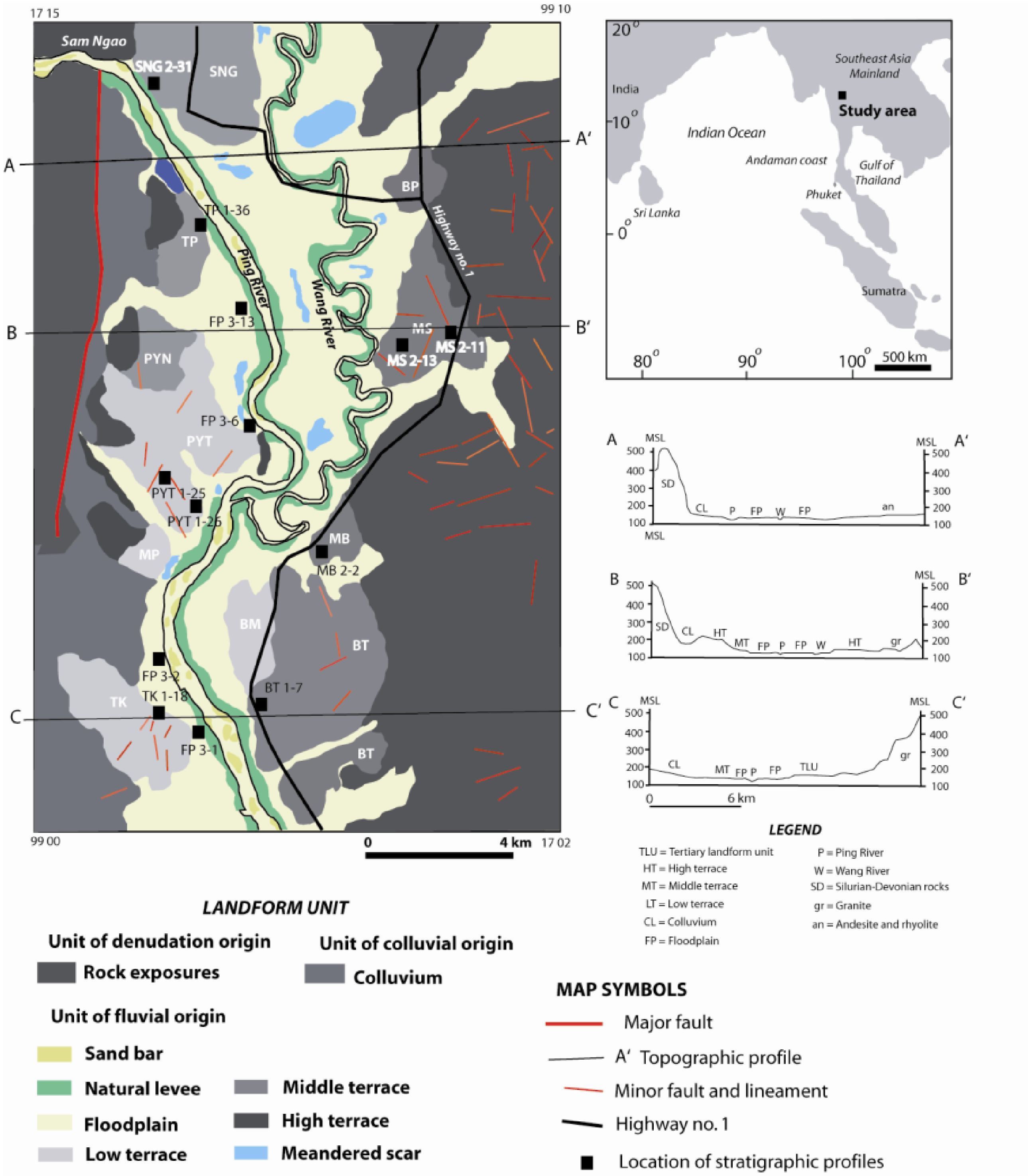

Figure 1: Geomorphological map with three topographic profiles across the Ping and the Wang River. Locations of typical stratigraphic column indicated as black squares (as shown in stratigraphic columns in figure 2).

2. Materials and methods

A diverse array of aerial photographs was interpreted to classify all the types of dominant landforms along the two main rivers. We used a series of air-photos taken in 1965 covering Thailand topographic map sheet 4843 III, priority area 6 number 15. They cover strip number 47, 48 and 49 with negative number of 8593-8596, 8598-8602 and 11179-11181, respectively. The unconsolidated material with rock debris and gravels were analyzed by classical morphometric method suggested by Cailleux (1956) (in Thiramongkol, 1975). After one square meter block sampling was scoped, 50 gravels within the block were collected from 53 localities (Figure 1). A total of 72 sand samples were taken for sieving test, while finer particles were tested by hydrometer (Bowles, 1992). Long topographic east-west profiles across terraces were done by SOKKIA camera. A total of 44 stratigraphic columns were made from open quarries (see locations in figure 1).

3. Results

3.1 Landforms classification

Geomorphological features in the area were subdivided into three main units; that include 1) unit of denudation origin, 2) unit of colluvial origin and 3) unit of fluvial origin. First unit of denudation is commonly dominated by the *in situ* bedrocks. Bedrocks in the area are exposed at the rim of avulsion plain. Rocks in the west side of fluvial plain contain highly weathered Precambrian gneiss, Silurian-Devonian quartzite of the Don Chai Group (Piyasin, 1974; Boripatkosol et al., 1989). They occur at a maximum elevation of 681 m above the present mean sea level (MSL), whereas the lower Triassic granite is exposed extensively in the southeast part of the area at elevation from 400-500 m above MSL. Lower Triassic rhyolitic tuff cover the hills in area to the northeast with 189 m elevation above MSL and approximately have 60 m relief above surrounding ground surface. The detailed description of landform units in this paper will be focused on the two latter units that are of colluvial and fluvial origin.

3.1.1 Colluvial origin

Colluvial origin landforms form at the scarp of Silurian-Devonian hill in the east of the area. Part of colluvial slope is gently convex and extends up to 200 m from its source. Colluvium consists mainly of quartzite rock fragments in the pebble size range subangular to angular and very poorly sorted. Colluvial deposit at Sam Ngao (see location in figure 1) was eroded away and now persists as cliff along the Ping River. Thus, this characteristic landform may reflect either some degree of erosion by meandering of the Ping or reveals an evidence for uplift due to possible fault movement.

The area within a limit and small intermontane basin enables the Ping and the Wang to meander to form the characteristic fluvial landforms inside the basin. Most dominate landform here exists as unpaired terrace represented by extensive deposition of gravel beds at both eastern and western sides of the basin. However, in terms of landform classification, we subdivided fluvial origin unit into four landforms. They include 1) Tertiary piedmont plain 2) terraces, 3) floodplain, 4) point bar and sand bar. Tertiary landforms were undulating terrain previously and are currently dissected by small streams some of which are more possibly developing along a set of minor fault ruptures. The direction of possible fault ruptures detected from air-photos is mainly in NEE-SWW direction. Sediments contain semi-consolidated pebbly sand in the lower part and are superimposed by unconsolidated gravels (Figure 2). Gravels include quartzite, quartz, chert, sandstone, meta-sandstone and pebbly sandstone. Part of high terrace superimposed on Tertiary deposits was observed at the northern part of the area. It lies over 180 m above MSL with a relief about 60 m above ground surface. The high terrace here is characterized by unconsolidated gravel beds with some fragments of petrified wood. The gravels are composed of subrounded to well rounded quartz, quartzite, schist, sandstone, meta-sandstone and pebbly sandstone.

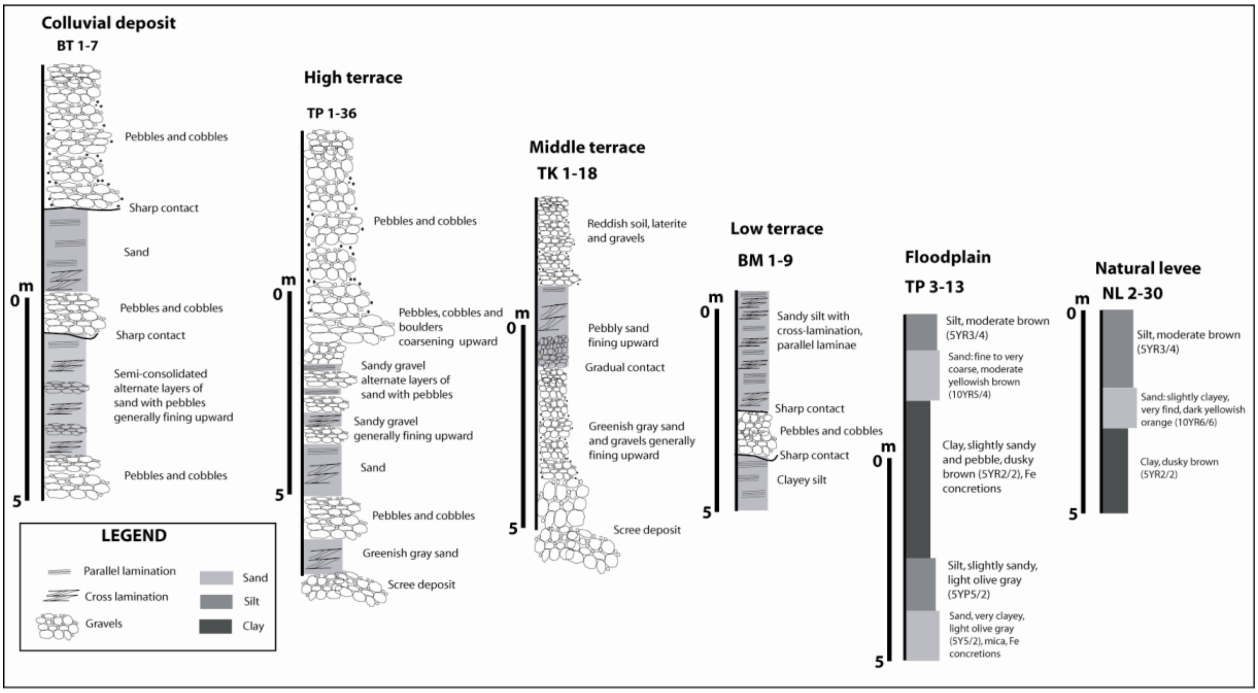

Figure 2: Typical stratigraphic columns representing type of deposition along the Ping and the Wang River. Note that lithologic logs of floodplain and natural levee were done from auger coring samples. Multiple fining upward sequences are recognized from all stratigraphic columns, but localized coarsening upward was seen only from the middle stratigraphy of high terrace.

3.1.2 Fluvial origin

High terrace

High terraces form as a low hilly terrain, generally occurring as discontinuous terrains on both sides of the two main rivers (see locations of high terrace in figure 1). They lie in an elevation between 176-180 m above MSL with a relief between 46-50 m higher from the next lower middle terrace level. They are gently undulating, generally characterized by gravel beds and localized hard lateritic features. Multiple fining upward sequences of high terrace deposit (Figure 2) has a thickness of about 15-20 m in the northern part at Sam Ngao (SNG in figure 1). Gravels consist of rounded to well rounded quartz, quartzite, schist and sandstone. Honeycomb structured laterite (2.1m thick) superimposed by lateritic gravel were typically and regionally recognized. Localized large petrified wood are preserved within high terrace deposit (Figure 3 from Choowong, 2009). The only way to estimate the age of high terrace is by comparing thickness of lateritic gravels with those reported from the Central Plain by Takaya (1968). With the thickness of laterite ranging from 0.7 to 2.1 m, it can relatively be inferred as the early Pleistocene (Bhongaraya, 1998).

Middle terrace

The best locality of middle terrace is at the western side of the Ping River (see PYT in figure 1). Middle terraces here occur as an extensive flat terrain and forms gentle slope with low relief amplitude at elevation about 167 m above MSL. The level of middle terrace is generally between 5-20 m above present floodplain and shows low degree of dissection than that of high terrace. The deposit is mainly characterized by reddish brown gravel beds overlying on saprolite layers of weathered bedrocks. Local fault recognized inside saprolite layer does not continue throughout terrace at this location. The texture of middle terrace deposits is for the most part similar to those recognized from high terrace (Figure 2). The thickness of lateritic layer only differs from high terrace deposit. With an average 25 cm thickness of hard pan laterite found in middle terrace, it can be correlated with the relative age of similar laterite from the Central Plain as formed during middle Pleistocene.

Figure 3: Largest petrified wood in complete shape in the high terrace deposit at the eastern part of the Ping River. Small fragments of petrified wood were also observed in middle terrace in several localities (picture from Choowong, 2009 in press).

Low terrace

Due to a humid climate with frequent flooding conditions, the low terrace rarely persisted. Some well preserved low terraces are recognized at Ban Pa Tang, Ban Mae Payuap and Ban Mai (BP, MP and BM respectively in figure 1). Generally, low terrace lies about 130 m above MSL with a relief less than 5 m above floodplain. The deposit is predominantly of sandy alluvium with gravels generally a few meters thick (Figure 2). Gravel beds consist of poorly sorted, subrounded and iron concretions. If the laterite is not well developed in low terrace deposit it indicates that the deposit is not a recent one. We inferred the relative age of low terrace as probably from late Pleistocene.

Floodplain and natural levee

With a limited and narrow avulsion belt of both two main rivers, the floodplain occurs as flat terrain and now manifested as a paddy field. Floodplain lies between 122-130 m above MSL and consists of overbank silty clay underlain by sand sheets belonging to a former natural levee deposit. Overbank clay varies in thickness from 0.5 to 5 m, with a small amount of mica flakes and calcareous sand. Recent natural levee is characterized by numerous interfigering and overlapping lenses of sandy material capped by recent muddy sediments.

Point bar and sand bar

Point bar is the most conspicuous geomorphic feature along the Ping and the Wang Rivers. It indicates the meander course with extensive bed load sediments. Point bar sediments contain quartz sand with imbrication of pebbles composed of quartzite and sandstone mainly. At point bar surface, cross bedding of current ripple is a sedimentary structure. Sand bar or channel and is also recognized where braided stream forms.

3.2 Morphometric analysis in gravels

Morphometric analysis in pebble includes roundness and pebble association. Frequency histograms of roundness indices of gravels are presented together with the histograms of flatness-indices. The roundness indices of river gravels show maximum values in the subrounded and rounded, well-rounded class (100-200, 200-300, and > 300 respectively). The occurrence of pebbles up to class 500 indicates in general that pebbles are rounded to well-rounded. Basically, the high degree of smoothness of the gravels confirms their deposition by some kind of fluvial process and most likely by rivers (Thiramongkol, 1975). Results from morphometric analysis in gravels collected from all terrace deposits are mostly rounded to well-rounded indicating long distance of transportation from their sources.

The pebble association or composition analysis was carried out from the three units of landforms. At Tertiary landform unit, pebbles contain about 40 % of schist up stream and decrease s to 20 % downstream. Quartzite, quartz, sandstone and meta-sandstone form the rest of the pebbles. All pebbles are from Silurian-Devonian bedrocks. We suggest that a roundness of pebble schist might be the good key to infer the distance of bedload transportation from its source. Apart from quartzite, quartz, sandstone, meta-sandstone and schist, the well recognized pebbles of tuff dominate the high and middle terrace deposits. Interestingly, the low terrace deposit is rich in quartz pebbles than the high and middle terraces. Further the low terraces are well preserved at the southeast part of the area. This indicates a local source of quartz dykes similar to those seen in the extensive exposure of granite at a similar location nearby.

3.3 Grain size analysis

Grain size of sand and finer sediments was analyzed from the deposits within terrace and floodplain landforms. The high percentage of quartz and mica indicates that the source for the major river sand is the gneiss and quartz-schist. Overall, all sand and finer particles collected from floodplain are very poorly to poorly sorted (Figure 4A), and very positive to positive skewed with generally mesokurtic kurtosis class. At natural levee, grain size analysis shows the deposit falls in very fine sand to clay in size, very poorly sorted in general, very positive to positive skewed, and mesokurtic kurtosis in average (Figure 4B).

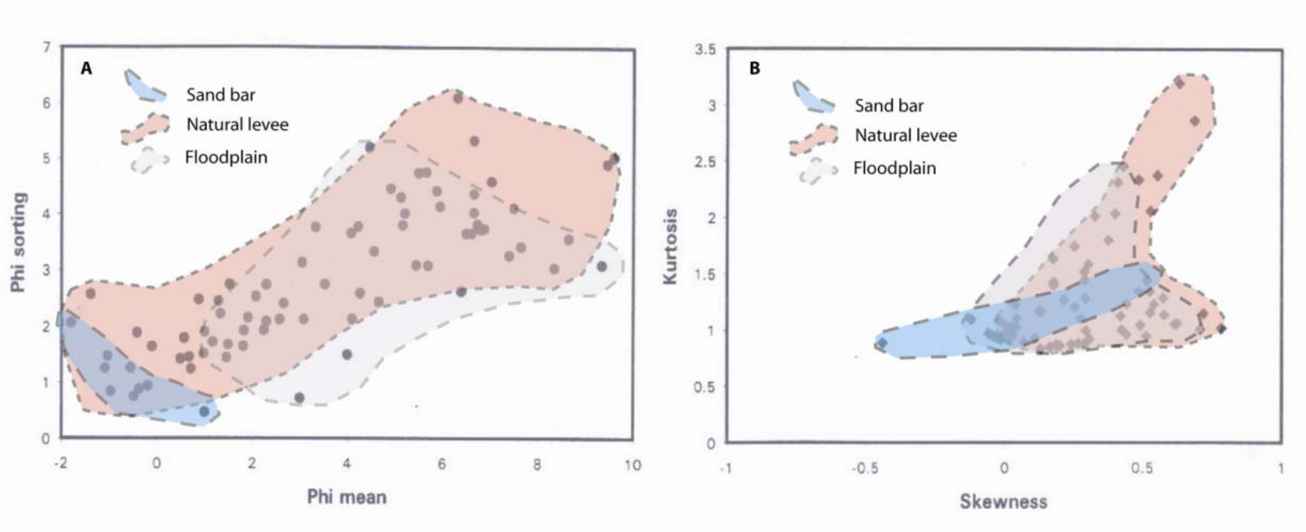

Figure 4: Statistic parameters from grain size analysis of floodplain, natural levee and sand bar. Overlapping of sorting (phi) and mean grain size (phi) among three deposits (A) and (B) shows kurtosis versus skewness from all three deposits.

4. Discussion

4.1 Evolution of Ping and Wang meandered belts

Since the variations of global climatic changes during the Quaternary had led to the adjustment of base level worldwide, these changes are acceptable to be responsible for the formation of terraces in a global scale as well. In our area, several outcrops of Tertiary landform unit show sharp contact between semi-consolidated pebbly sandstone and conglomerate with the overlying younger sediments. We believe that the extensive deposition of those semi-consolidated sediments may have occurred under a humid condition in tropical regime during the interglacial period whilst the base level had undergone several fluctuations. The younger sediment on the top was, then, probably deposited under sub-aerial erosion which was mostly pronounced during the alternate period of drier and cooler climatic fluctuations. Younger sediment deposited by a result of subsidence probably accompanied and covered the older semi-consolidated pebbly sandstone and conglomerate bed beneath. Similarly, there is a sharp lithological discontinuity between the younger sediments in the upper part and the lateritic gravel beds in the lower part of high terrace. This can be explained that the lower gravel beds may have accumulated after the post glacial period followed by the erosion during dryer period and the phenomena repeated and continued as a cycle as above.

Our hypothesis on the evolution of fluvial landforms in this area is divided into two phases. Phase I extends the formation of landforms from Tertiary to middle Pleistocene. After tectonic subsidence in the basin and some other intermontane basins in northern Thailand became abandoned since the late Tertiary, the accumulation of alluvium has deposited consequently. Then, the uplifting of alluvium has later on led to sub-aerial erosion. This led to extensive deposition of braided river system within a limited and narrow meandered basin. In our area, three levels of terrace reflect their avulsions in at least three meandered belts probably started from the late Tertiary to late Pleistocene. Phase II represents extensive formation of floodplain during the late Pleistocene to recent. Alluvial plain has been started its deposition due to the braided of only the Ping River. Meanwhile, the Wang River meandered extensively and looked likely that the avulsion of the Wang is limited to the present time. On the other hand, the Ping shows formation of floodplain, natural levee, point bar and sand bar as a result of braiding and meandering until the present time.

4.2 Neo-tectonic setting

The ideas regarding neo-tectonism related to unusual high level of terrace are still open to discussion. In fact, the principal factors usually regarded as being responsible for alternating episodes of terrace deposits are possibly due to tectonic or climatic change. Kukal (1971) mentioned that most tectonic subsidence has caused the deposition of up to several hundred meters thick of complex sediments. In Thailand, the terraces found at various levels reflect the effect of both former climatic changes and neo-tectonism (Thiramongkol, 1983). In this regard, tectonic movements seem to have influenced the mode of geomorphic evolution in this area as well as a rapid denudation in humid condition. Since rapid erosion of the weak rocks under prevailing humid conditions had also been a factor leading to the variations of local base level (i.e. local fluctuation), unusual level of unpaired terraces is one ample clue to indicate that the present topographic relief probably originated as a result of tectonism during Tertiary and may have extended into the late Pleistocene (?) or, perhaps, to the Holocene (?).

5. Conclusions

1. The geomorphological unit from our study area can be subdivided into three units; denudation, colluvial and fluvial origins. The first unit of denudation is related to high weathering on bedrocks of Silurian-Devonian age. Colluvium is dominant within the second type. The unit of fluvial origin started forming since Tertiary to recent.
2. The features of each terrace deposit are comparatively similar in their roundness of pebble and they slightly differ in pebble association. They reflect a difference degree of dissection and diagenesis. Their relief and lateritic features can be relatively inferred the age of deposition. Three levels of terrace were caused by at least three meandered belts possibly formed by the fluctuation of base levels which may regionally correspond to a global change in climatic conditions during the glacial and interglacial of the Quaternary.
3. From thickness of the sediments, the broad area of terraces and the petrology, it can be concluded that the material from Tertiary landform units and terraces was deposited by system of braided and then meandered rivers. These two major rivers flowed through the zone of intramontane plains. Multiple fining upward sequences of terrace deposits represent a frequency of avulsion within a narrow and limited meander belt.
4. Tectonism occurred either during or after the formation of terraces, especially at the west bank of the Ping River. Unusual level of the terraces may be related to neo-tectonic uplifting along part of the Mae Ping fault zone. The morphology of terrace confirmed that post-tectonism may occur after the formation of low terrace in the late Pleistocene. We suggest that more work on dating the age of terrace deposit will assist in a better understanding in the history of possible young fault movement along the Mae Ping fault zone as now it becomes one of the issues for earthquake mitigation in Thailand.

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