CHAPTER 3

SATTELLITE IMAGE STUDY

Systematic approach of satellite imagery interpretation along with sufficient collateral imformation regarding topographic maps, geological map, arial photographs, field checking of the area is revealed in this chapter. The landsforms are classified into 3 units obviously. These geomorphological data will be considered together with anothers for precise conclusion. This study has also been done covering the adjacent area above and the gap along the study areas for better understanding in classification of geomorphological units.

3.1 MATERIALS AND METHODS

The band 1- 7 from satellite images LANSAT TM 7 which records the data with ETM+ (Enhance Thematic Mapper Plus) is the main courses used to generate the forms of true and false color composites, and in the gray tone, for the interpretation under cooperative work with another data as in Figure 3.1. The study is cited respectively as the following .

3.1.1 THE TOPOGRAPHIC MAPS SCALE 1: 500000 AND THE GEOLOGICAL MAPS SCALE 1 : 250000

The landsforms are outlined firstly from these maps depending on the contours, reliefs, drainage patterns, land using, rock boundaries, lineament structures, etc. In this step the study areas are classified into 3 categories being (i) the mountainous area comprising the Mesozoic rocks, (ii) the plain of sedimentary deposit (iii) the Quaternary igneous rocks which are rounded mounds, higher than the surrounding topography.

Topographic Map scale 1 : 50000
Map sheet : 5838 II, 5838 I, 5938 III, 5938 IV, 5938 II and 5937 I
geological map 1: 250000 Map sheet ND48-6

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Arial photo scale 1 : 50000 (primary zoning stage)

⇩

Map sheet 5838 II **(Amphoe Khunhan)** *Set M46* st 48 No.10432-10436 st 49 No. 19235 - 19240 st. 50 No. 10214 - 10219 st. 51 No. 10026 - 10031	**Map sheet 5837 I** **(Ban Phudin)** *Set M46 N-S* st 48 No.10439-10443 st 49A No.19226-10232 st 50 No.10221-10226 st 51 No.10018-10023	**Map sheet 5938 III** **(Amphoe Kantaralak)** *Set M46 N-S* st 52 No.10005-10011 st 53 No.9245-9251 st 54 No.9227-9233 st 55 No.9054-9060
Map sheet 5937 IV **(Ban Phum Charon)** *Set M46 N-S* st 52 No.10012-10017 st 53 No.9239-9244 st 54 No.9234-9238 st 55 No.9047-9053	**Map sheet 5938 II** **(Ban Kut Rue)** *Set M46* st 55A No.19451-19456 st 56 No.8399-8404 st 57 No.8227-8231 st 58 No.8204-8208 Set M47 st 59 No.8053-8055	**Map sheet 5937 I** **(Ban Nam Yuen)** *Set M46 N-S* st 55A No.19459-19461 st 56 No.8407-8413 st 57 No.8213-8293 st 58 No.8211-8212 Set M47 st 59 No.8037-8048

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Landsat –7 ETM+ (Enhance Thematic Mapper Plus)
Path/Row 127/ 050 (SURIN)
Path/Row 126/ 050 (UBON)
Date of acquisition are 20 December 1999 and 20 February 2002

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Field checking
The zoning of divided units were checked in field for correction

Figure 3.1 The layout of materials and methods for geomorphological study by using maps, aerial photos, and the satellite images, respectively.

3.1.2 THE AERIAL PHOTOGRAPHS

The gray tone aerial photographs which have different tonality, reality shapes, association to surrounding, texture and drainage patterns make more advantages for classifying the units, especially the plain of sedimentary deposit. The plain is composed of 4 subcategories: talus deposit; the mixed sediments which could not identify the processing of deposition clearly, the terrace deposit; the recent alluvial deposit, and the lineament structures could be seen more clearly. However, some places had not sharp boundaries. The satellite imagery study could help the boundaries distinguishingly.

3.1.3 SATELLITE IMAGERY STUDY

The images from LANSAT 7 – ETM + which are enhanced already, have 8 bands but the useful bands are bands 1 – 7. They are picked to compose together via RED: GREEN: BLUE color (RGB) to generate the true color composites, the false color composites and the other techniques to transform the images clearly (Figures 3.2 A - B). The satellite images which are composed and transformed by The Program ER-Mapper @ and the Figure operating as Adobe Photoshop@ are studied and generated to be the Figures with The Program Mapinfo @. This step used rather long period to make understanding about the program. The distinction of the important false color composites is revealed in Table 3.1. In spite of the study areas must use 2 sets of the satellite images joining together (Path/Row 127/ 050 (SURIN) and Path/Row 126/ 050 (UBON), the joining line is seen distinctively though the satellite images are adjusted before composing. This is presumed from the time of recording. This step, the units and the other compositions are visually interpreted for delineating various physiographic units as hard rock unit, the plain of sedimentary units and the igneous rock unit. Each unit is described and the sedimentary unit is further subdivided based on land parameters such as shape, texture, vegetation, landuse, and drainage pattern.

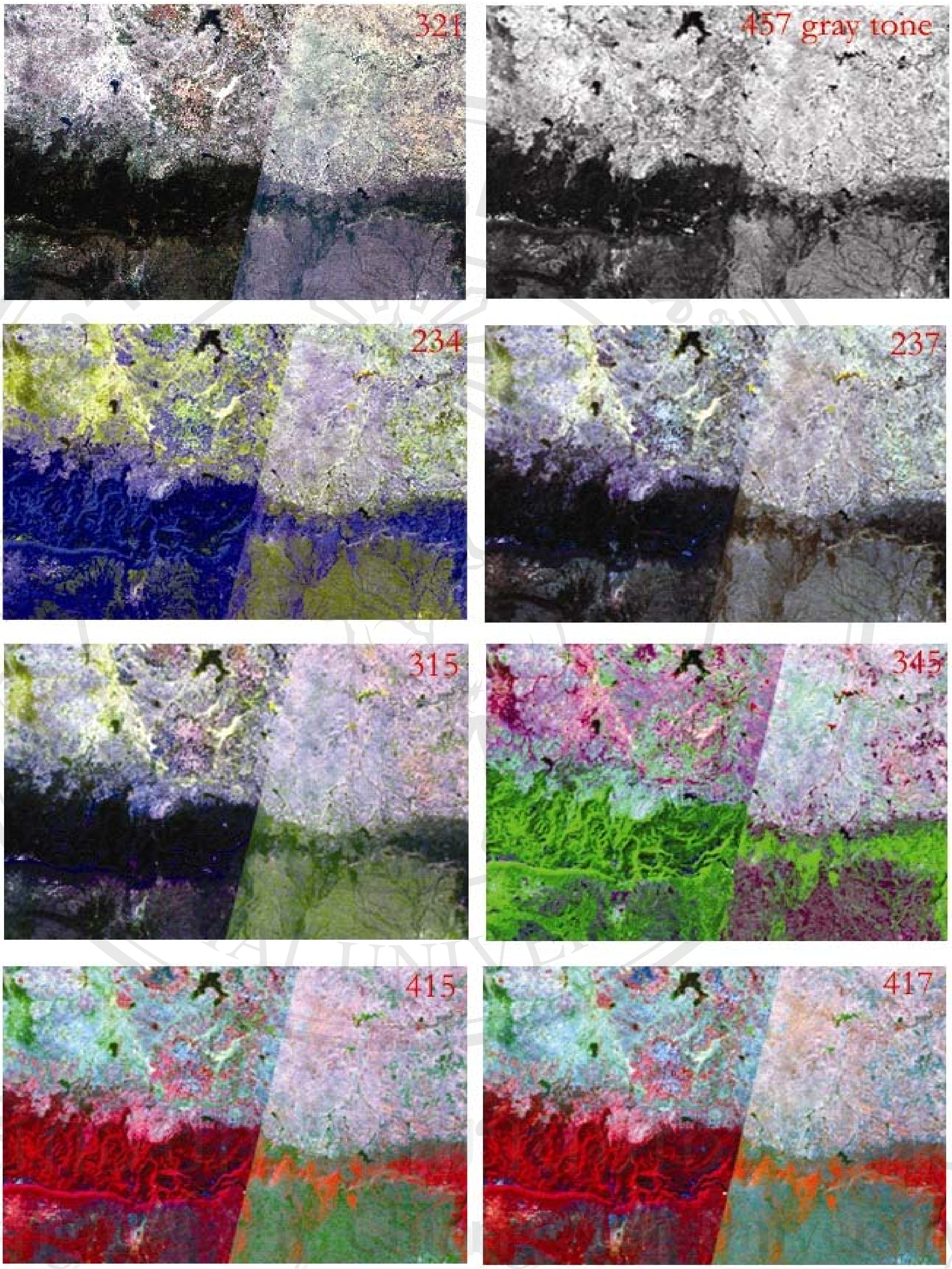

Figure 3.2 A The satellite images which are composed in varied RGB to the best result of study. The top left is the true color composites (RGB: 321) revealing the natural color of the study areas and the adjacent areas. The top right is the false color composites (RGB: 457) which is transformed to be gray tone. The others are the false color composites which show different distinctive geomorphs.

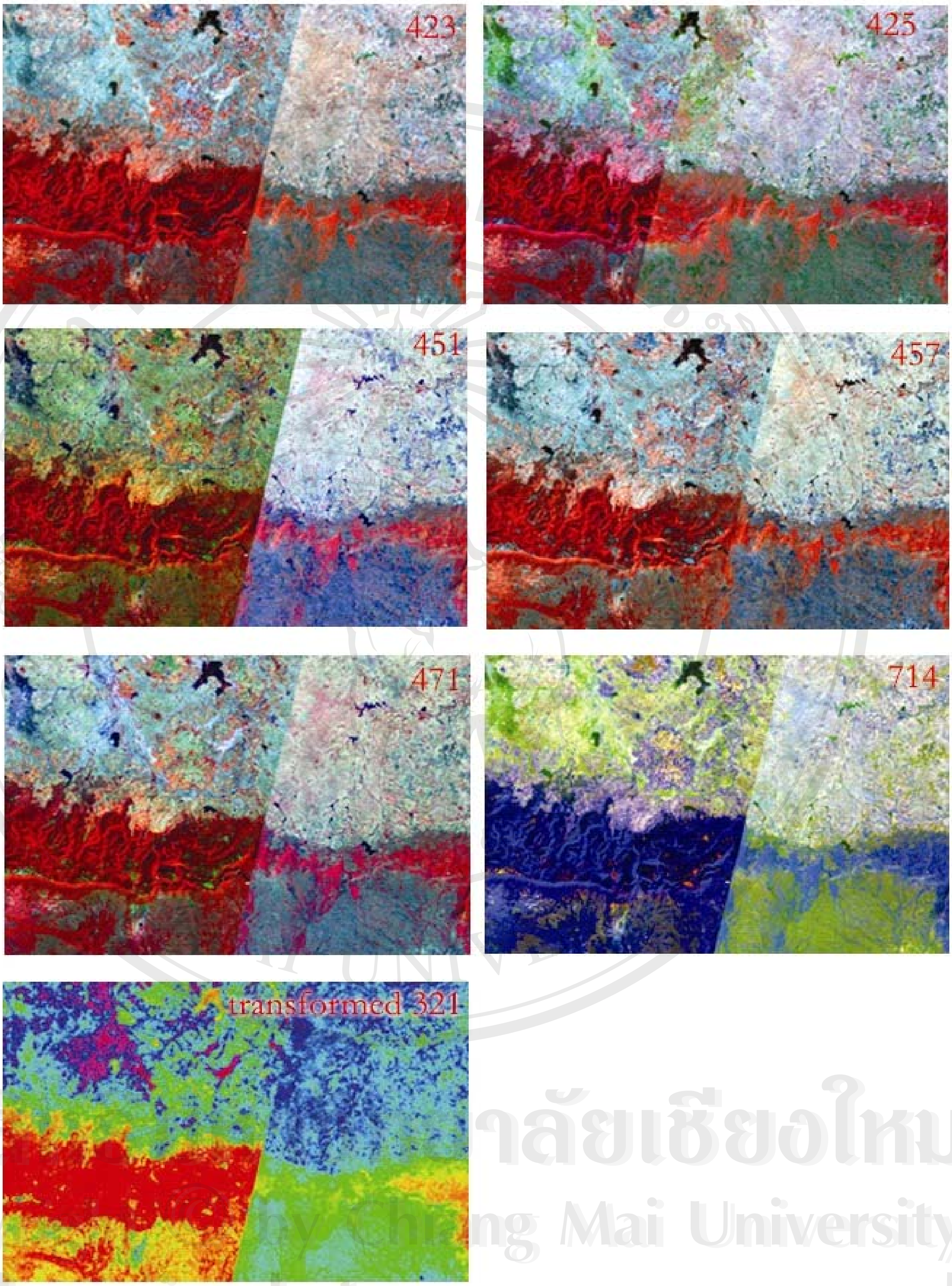

Figure 3.2 B Additional false color composites which show different distinctive geomorphs. The last is the true color composites (RGB: 321) which is transformed for classifying the geomorphological units.

Table 3.1 The distinction of the other true and false color composites (RGB).

True and false color composites	Distinction	Remark
321	natural color , good for test real eyed view	
234	clear tonality, clear texture difference, clear boundaries	- one of the best result
235	clear texture, clear basaltic rock (seen in yellowish – green color)	
237	as 234 but basaltic rock more little dull	
315	rather clear recent alluvium	
345	clear difference of terrace and recent alluvium	
415	clear talus unit, vivid orange color of basaltic rock, red color dense vegetation of the mountainous area, clear lineament structures	
417	orange/ yellowish orange color of basaltic rock, clear lineament structures especially in hard rock unit	
423	clear drainage patterns, clear boundaries of units, yellowish orange color of basaltic rock	
425	clear hard rock unit, orange/ yellowish orange color of basaltic rock, clear texture	- one of the best result - vivid color than 415, 417, 423
451	clear texture, clear hard rock unit, clear drainage patterns, clear lineament structures	
452	the same as 451	
453	clear lineament structures, clear texture, clear drainage patterns, more different tonality, yellowish orange color of basaltic rock	- one of the best result - vivid color
457	clear difference of terrace and recent alluvium, vivid orange of basalt, red color water and humid area	- one of the best result - vivid color
471	clear tonality, clear texture, clear basaltic rock, clear mountainous area	- one of the best result - vivid color
714	clear texture, vivid orange of basalt, red color water and humid area	
4	clear lineament structure	- one of the best result
6-1	clear boundary of talus unit	
7	clear boundary of basaltic unit	- one of the best result

3.1.4 FIELD CHECK

The boundaries from office work are checked in field for some points being doubtful, and more details of drainage patterns, some lineament structures. The rock and the sediment samples are also collected for sedimentological analysis.

3.2 RESULT AND DISCUSSION

The described materials and methodology especially the technique of image transformation of The Program ER-Mapper @, can distinguish the units rather clearly. The map program (which is hit during writing this thesis) as The Program google earth@ which could support the newest satellite images in true color pictures is interested. The figures from The Program google earth@ are studied and transformed by the other program. The results are rather good and supported the data to divide the rock units (Figures 3.3 A - B). The different surface features or landforms could be divided into 3 units, and the sedimentary unit is divided into 4 sub units as follows (Figure 3.4). The lineament structures affected to the depositon of the sediments and erupting of the igneous rocks, are also studied (Figure 3.5).

3.2.1 The hard rock unit

3.2.2 The plain of sedimentary unit

3.2.2.1 The talus unit
3.2.2.2 The mixed sediment unit
3.2.2.3The terrace unit
3.2.2.4 The recent floodplain unit

3.2.3 The igneous rock unit

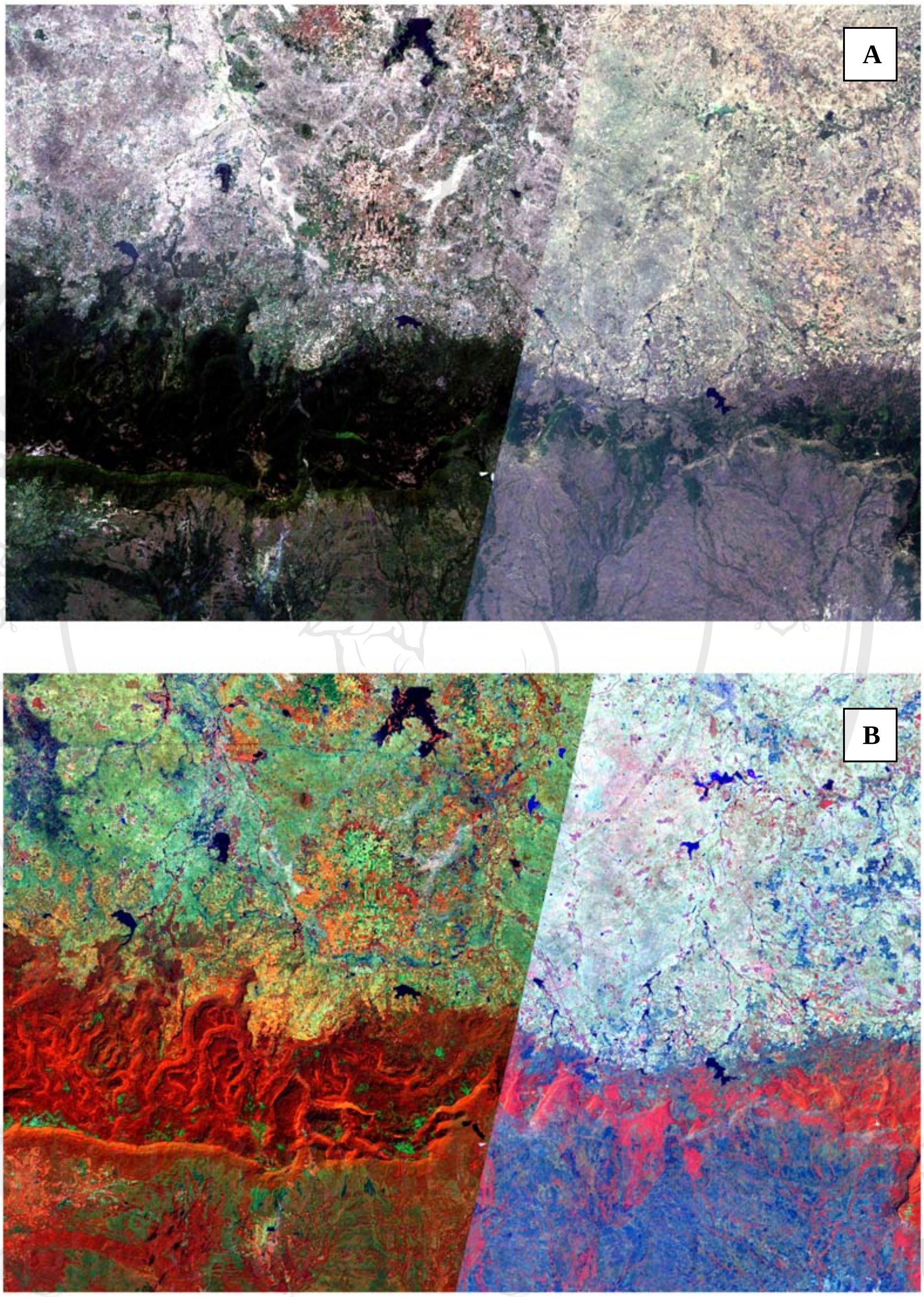

Figure 3.3 (A) The true color composites (RGB: 321) (B) The false color composites (RGB: 451) of the study areas and the vicinities, which can illustrate clearly that the false color composites can make more useful to divided the rock units.

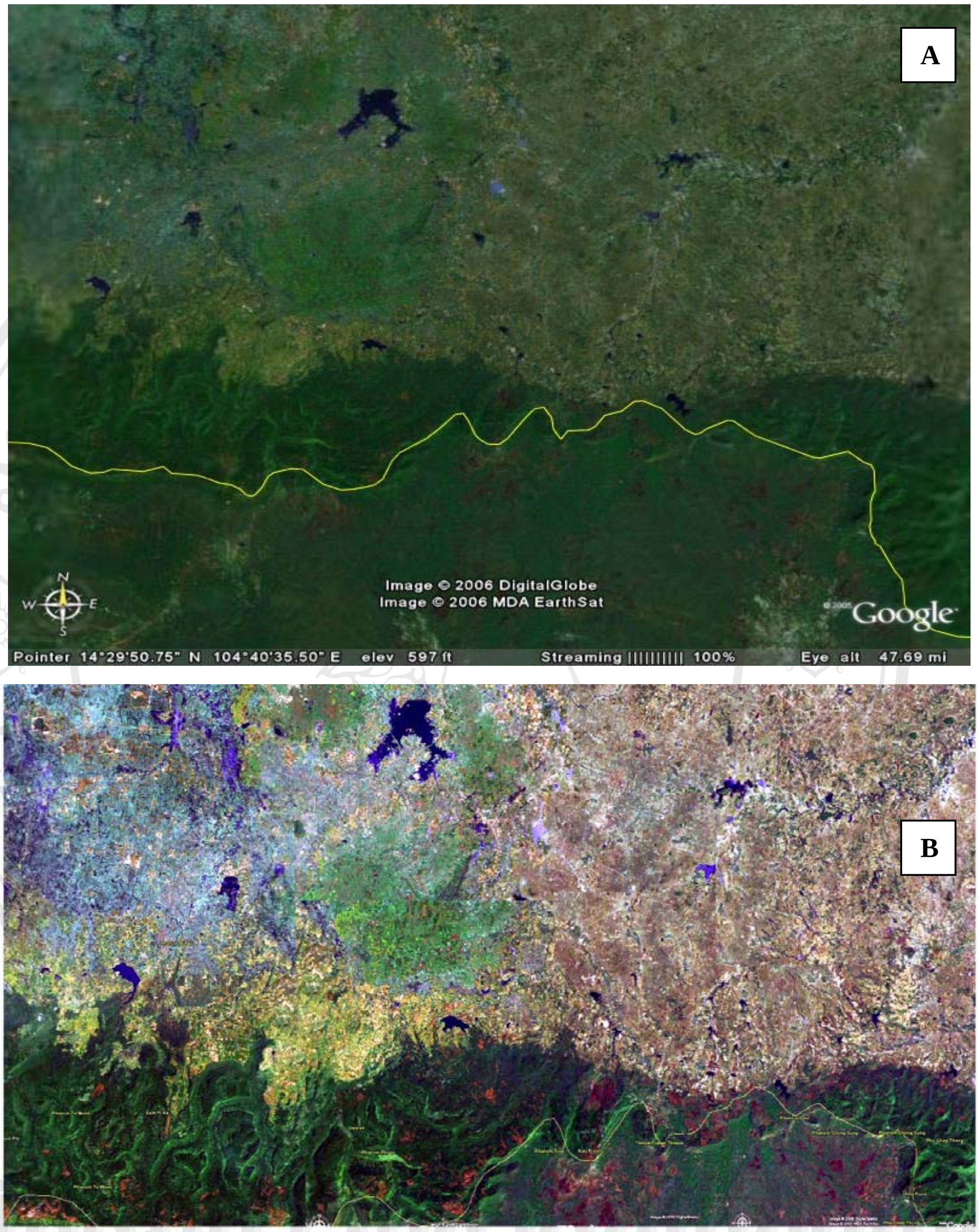

Figure 3.3 B (A)The figures of the study areas and the vicinities from The Program google earth@ 2006. (B) The figure was transformed for better clear surface features.

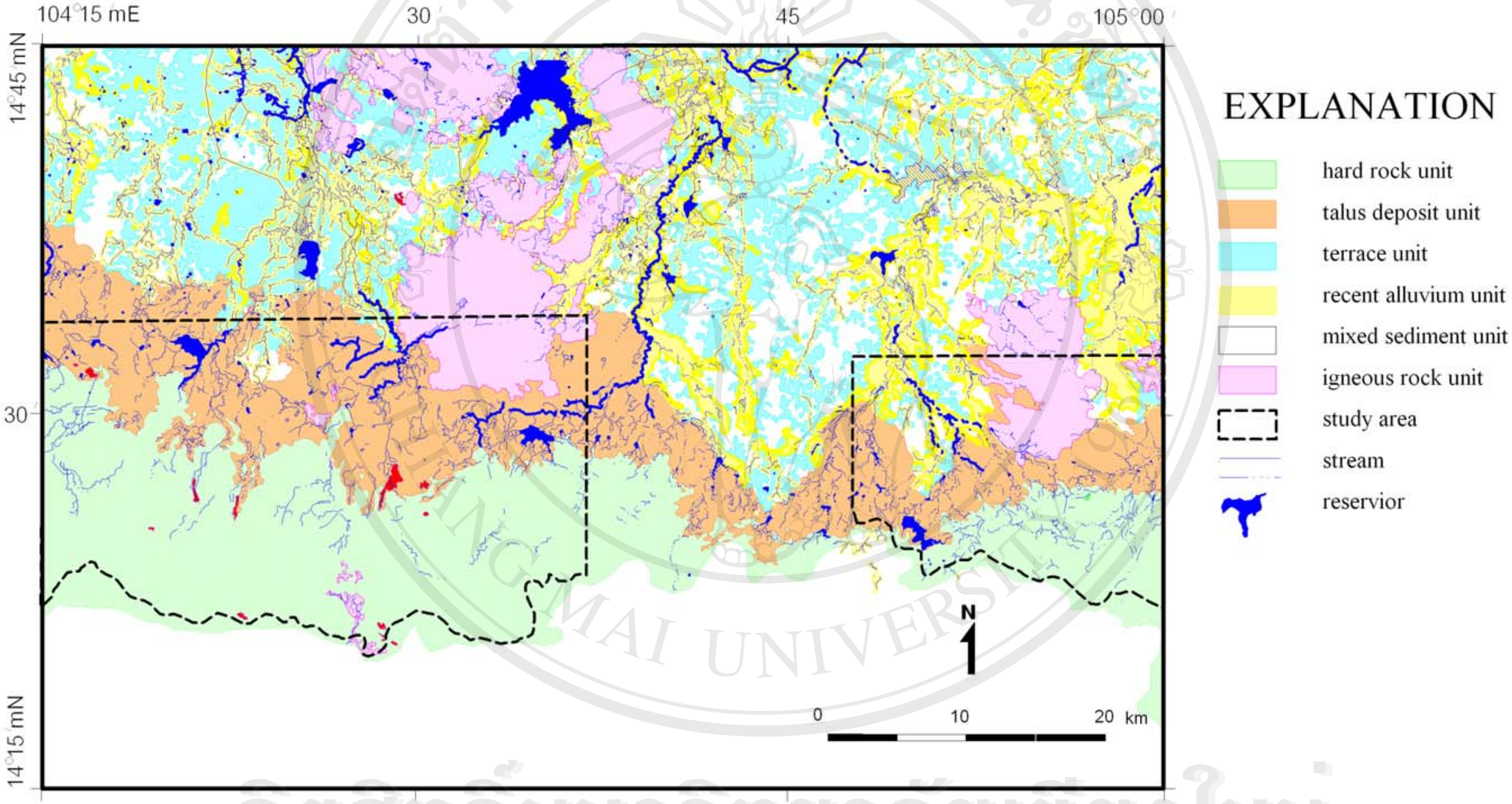

Figure 3.4 The results of classifying the surface landforms which the adjacent areas were studied together for more understanding. The study areas comprise other landsforms from the south to north direction: the hard rock unit in the mountainous area; the plain of sediments where was subcategorized being the talus deposit unit at the foothill, and the mixed sediment unit, the terrace unit, the recent floodplain ; and the volcanic outcrops which intruded the other unit.

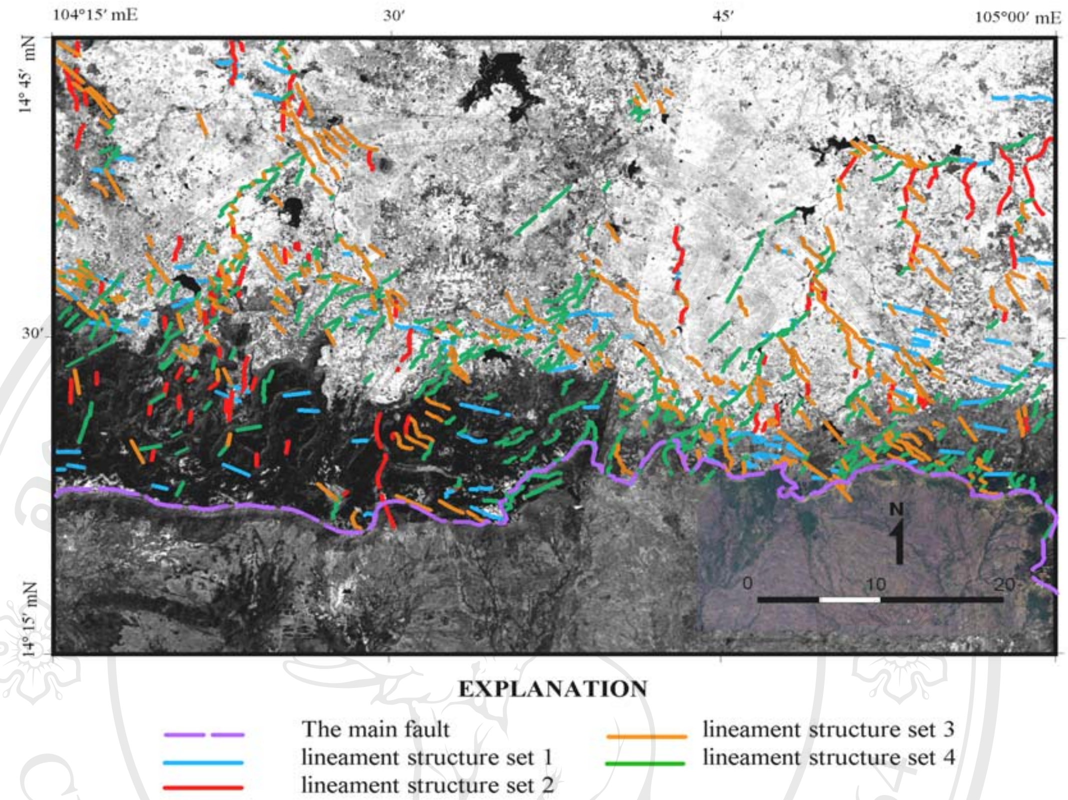

Figure 3.5 The lineament structures which are discovered after studying from the landsat images. There are 4 sets in various directions. The biggest normal fault lies along the scarp (labeled by the violet line).

Additional lineament structures are studied and presented together with the units. The description of the studies stated about the composition of the images: tonality, color, texture, pattern, shape, size, and the composition of geology: drainage pattern and density, vegetation cover, landform, geological structure, lithology and boundary.

3.2.1 THE HARD ROCK UNIT

Based on the landsat images false color composites (RGB) 234, 415, 417, 425, 453, it is illustrated that this unit is the southern – most part of the study areas in the mountainous area. The distinctive characteristic of this zone is the macro-normal fault dividing Thai (uptrow side) apart from Cambodia (downtrow side) (Figure 3.5). It is rather with almost 90^o dip scarp plane. The hard rock unit is assumed beginning from the fault scarp line, exposed to the north (Figure 3.3 A – B and Figure 3.4). The unit is represented by the Phanom Dongrak mountainous area. It reveals the groups of mesa consisting of sandstone, conglomeratic sandstone, siltstone, and shale.

From Figure 3.3A, the false color composites (RGB: 451) illustrate this unit in red and orange colors, showing the shape of the hard rock unit is seen in loaves of sandstones, rather rounded and divided by the gullies. Certainly, these loaves are composed of the mesa and butte hills, and scarp continuously in the mountainous area. Separated from other units, the hard rock unit displays dark tonality and smooth texture, signifying the same material. In spite of many mesa seen in this unit, it is interpreted that the dip angle of the initial planes of this hard rocks is rather horizontal. The vegetation which reflect the red color in even texture (Figure 3.3 A), exhibits that the surface of this unit is still densely vegetated, and the true color composites (RGB:321) (Figure 3.3 A) and the figure captured from the true color of The google earth@ (Figure 3.3 B) affirmed them. The density of pattern displays medium - widely spaced and rather have same patterns (Figures 3.5 – 3.7), and almost without rills or gullies on their surface. Those reflects that water should run as sheet runoffs mostly, and the unit is the granular and permeable rocks. On the other hand, the drainage patterns are also reflected by the structural controls. The pattern of drainage revealed in the unit, are rather straight lines which have angular tributaries (Figures 3.6 – 3.7).

The drainage system in the area of this unit are commonly sheet runoffs due to rather horizontal dip angle of beds. However, there are rills and gullies developed running into bigger streams. In this unit, there are only the angulated drainage patterns is seen. Almost whole of the drainage system are composed of 1st order rills and gullies running to 2nd order of structural controlling streams displaying straight line. Along channel of them, the V – shape valley, scarp terraces, occasional cliffs with hardly cover sediments, small waterfalls from the abruptly changed base level are the common features in this unit.

Some straight line streams are truncated by another straight lines and somewhere appeared the extrusive rocks (they are cited later), these characteristics entirely reflect the dislocation controlled (Figure 3.5). Compared to the characteristics of streams of other units, the drainages appearing on this unit are arranged in the mountainous tract because of the V shape valley, high dip angles of terraces, prevalent erosion in depth than width.

The lineament structures are mostly seen in this unit, and are developed to be gullies in some places. It is hard to classify the lineament structures in the study areas. They are composed of the fractures, joints, faults, rock boundaries and some lines which cannot be classified reasonably. However, the lineament structures are grouped into 4 sets following their directions (Figure 3.5). The explanation of all 4 lineaments is used to refer to the lineament structures of the other following geomorphologic units.

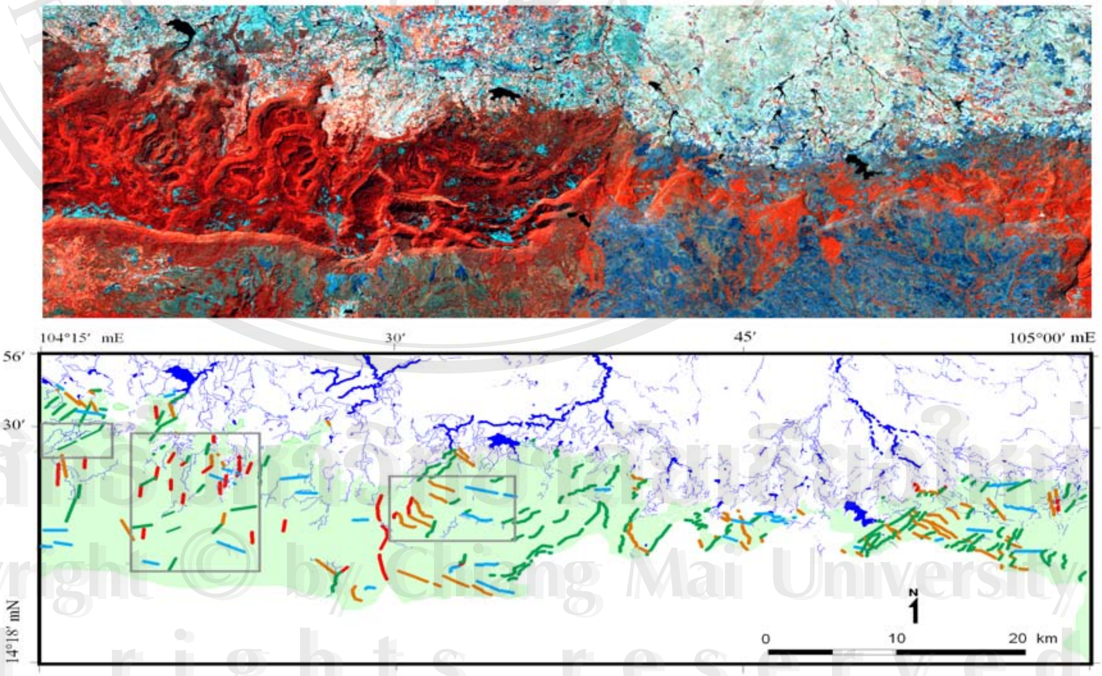

Figure 3.6 The hard rock unit and the drainage system on its surface and the lineament structures occurred In the gray boxes showing the angulated drainage patterns are effected from the lineament structures. The false color composites (RGB: 457) is picked for comparison.

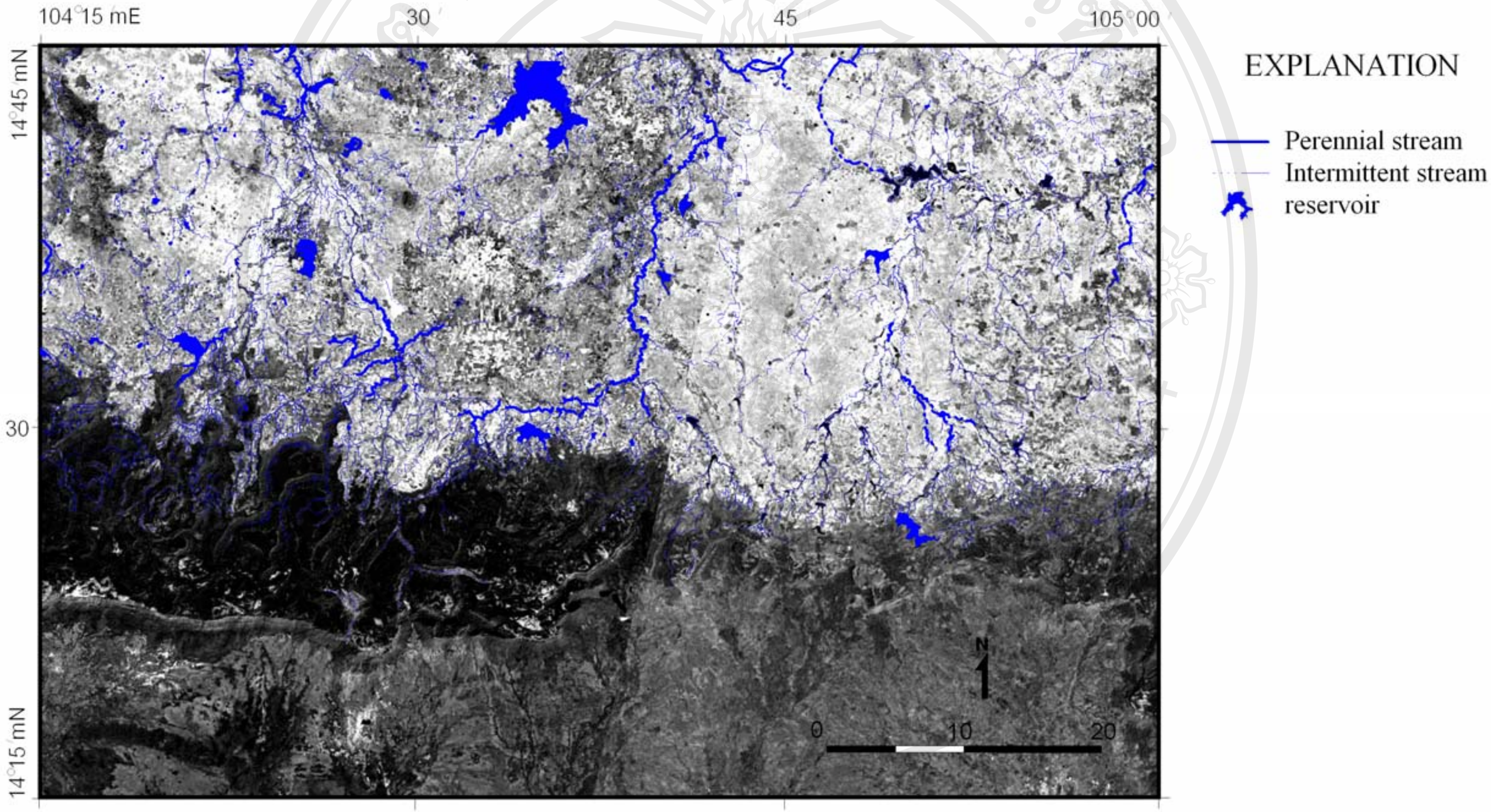

Figure 3.7 The drainage system of the study and adjacent areas.

Set 1 is rather parallel (not more than 15 $^{\circ}$ approximately) to the major normal fault scarp as labeled by the pale blue lines in the Figure 3.5. Most of them developed near the biggest scarp are located at the most south rim of the study areas. Some may be underneath the plain of sedimentary unit. They are noticed that the set is being the results of the major normal fault.

Set 2 (labeled by the red lines) is aligned in the NS direction followed distinguishably by the streams in hard rocks. Compared to the First set, this set is more widespread and in places the set is dislocated their lines by the other sets (Figure 3.8). It was presumed that the N-S direction lineament is generated before the NW-SE direction (set 3) and the NE-SW direction (set 4) which will be mentioned later.

Set 3 (labeled by the orange lines) is aligned in the NW – SE direction, and is widespread throughout the whole study areas, rather plentiful and could be followed distinguishably even though in the sedimentary outcropping areas. It is possible that the third group is generated before the Forth group (NE-SW) because some of them is dislocated by the Forth group (Figure 3.9).

Set4 (labeled by the dark green line) is aligned in NE – SW direction, scattering mostly in the north zone of the study areas. Some of which have ability to be cut by the younger lineaments but the dislocations are not seen clearly. It is presumed that this group is the youngest lineament structures occurring in the study areas because it has always truncated the former 3 groups at their tips (Figure 3.8 – Figure 3.9).

Comparing to the previous study in the larger scale about the lineament on the Khorat Plateau, Chuaviroj (1997) stated the 3 main fault systems (Figure 3.10). The N-S direction is associated to the Indosinian Orogeny, the NW-SE direction and the NE-SW direction are associated to the Himalayan Orogeny.

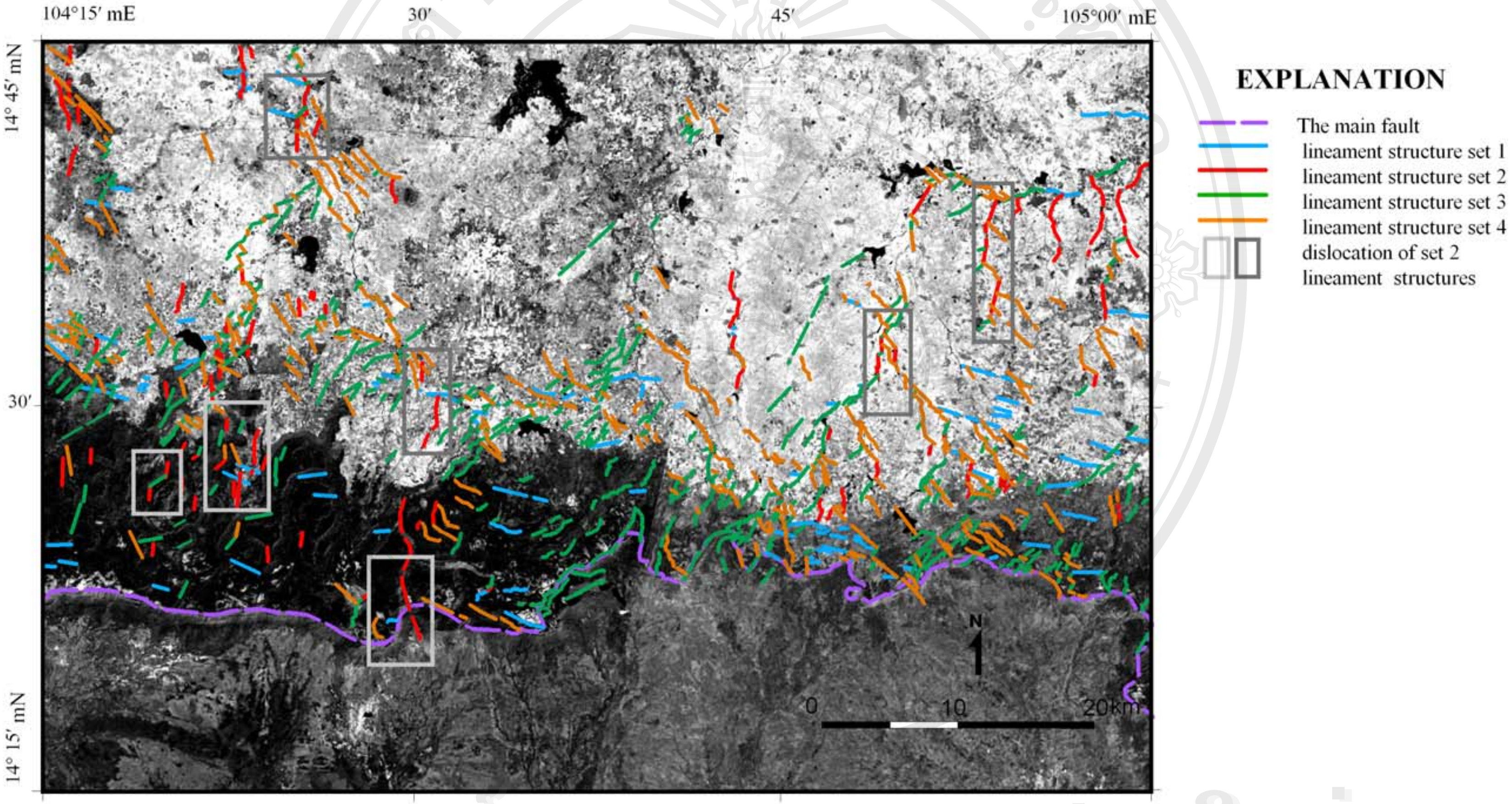

Figure 3.8 The dislocation of set 2 lineament structures as indicated in boxes due to the other set lineament structures

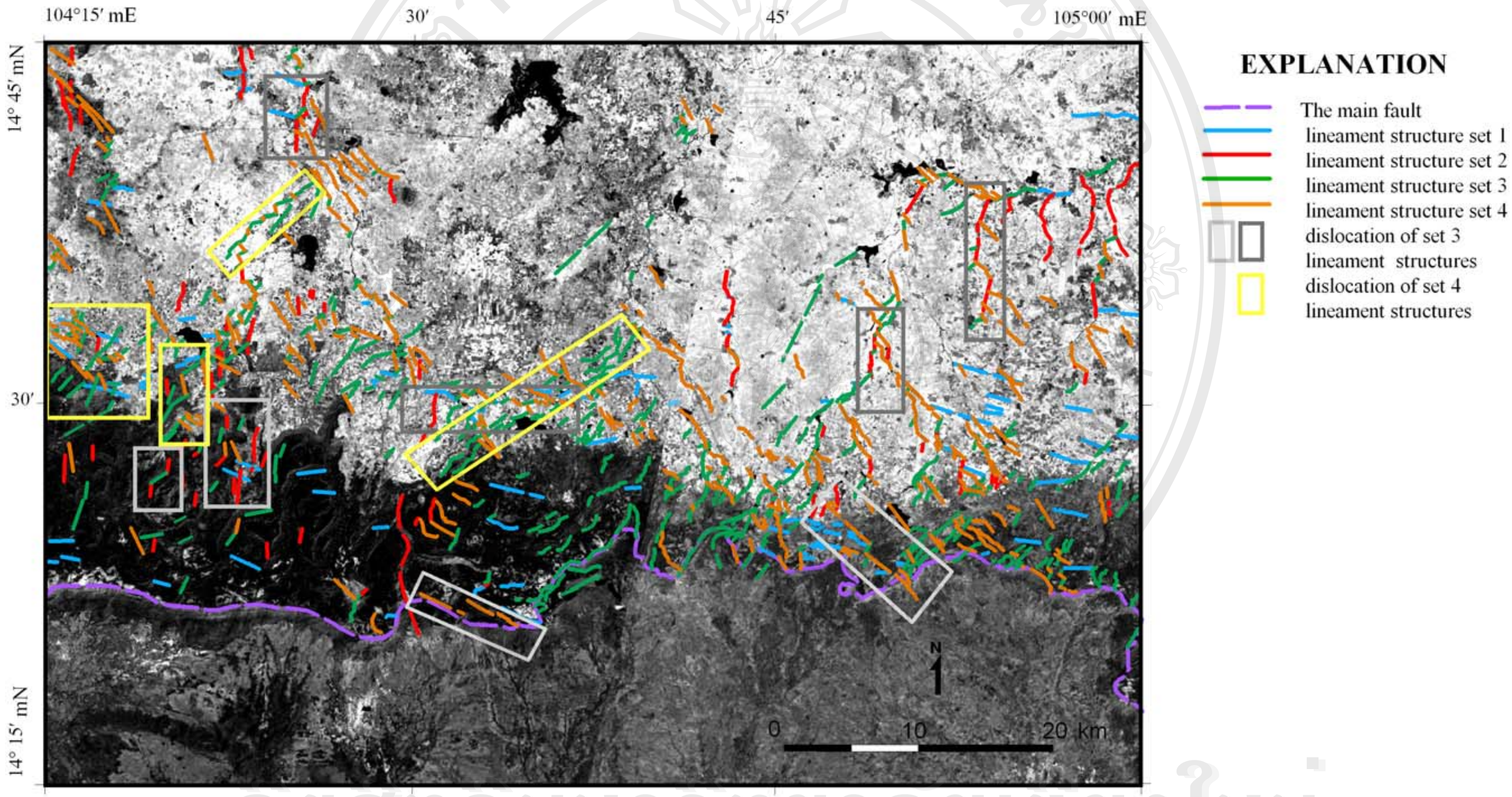

Figure 3.9 The dislocation of set 3 lineament structure (the locations are bounded with gray) color boxes, and the dislocation of set 4 lineament structure (the location were bounded with the yellow color boxes).

It is noticed that the areas around the volcanic rocks and the area where the gemstones occurred, the conjugated points of different lineament structures (Figure 3.11) will be considered. The points should be associated with the eruption of the extrusive rocks and the lineaments should also be occurred beneath the volcanic unit.

Some lineament structures could be extended into Cambodia, that might be associated with the gemstone deposits there. Further detailed study for this assumption is needed.

3.2.2 THE PLAIN OF SEDIMENTARY UNIT

This unit extends from the foothill of the hard rock unit downward to the north. This area is the zone where deposition by the gravity and fluvial agents. The unit can be subdivided into 4 sub-units comprising the talus, the mixed sediment, the terrace , and the recent floodplain units (Figure 3.4).

3.2.2.1 THE TALUS DEPOSIT UNIT

It is the production of gravity erosion collaborated to water erosion. According to the false color composite (RGB: 415), this unit is distinguished by the rounded texture which is different from the mountainous hard rock unit on higher relief and alluvial deposit unit on lower relief (Figure 3.12). The talus deposit unit was received the sediments derived from the underlying mountainous - hard rock unit which tilts gently to the north. The relief of the talus deposit unit is gradually lower than the mountainous area.

Comparing the sedimentary unit which is described later, the ununiformal tonality, granular texture showing angular shape in this unit imply that the talus unit composed of coarser materials than those in the sedimentary unit.

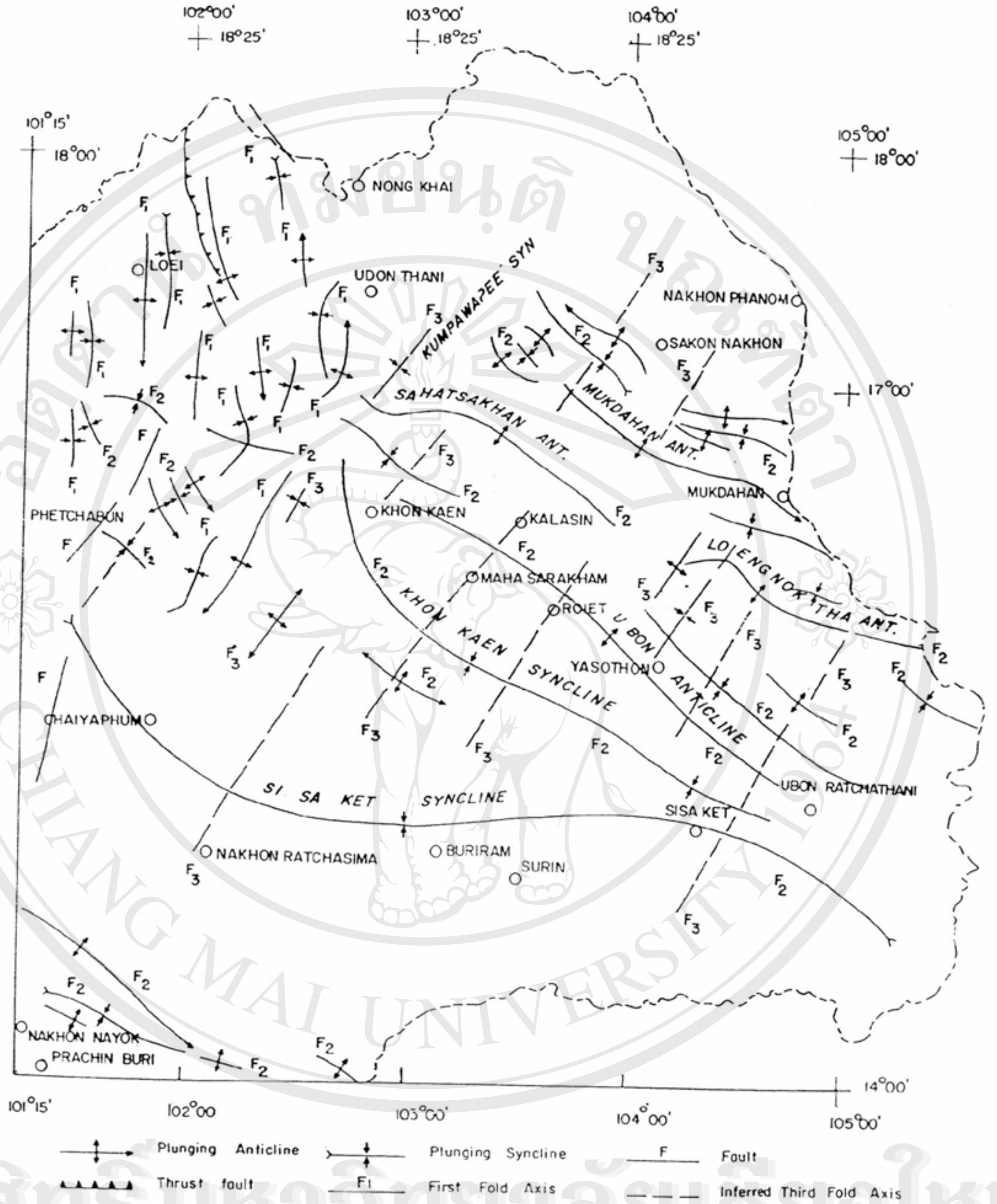

Figure 3.10 The geological structures of the Khorat Plateau [modified from Chuaviroj (1997) *in* Monjai (2001)].

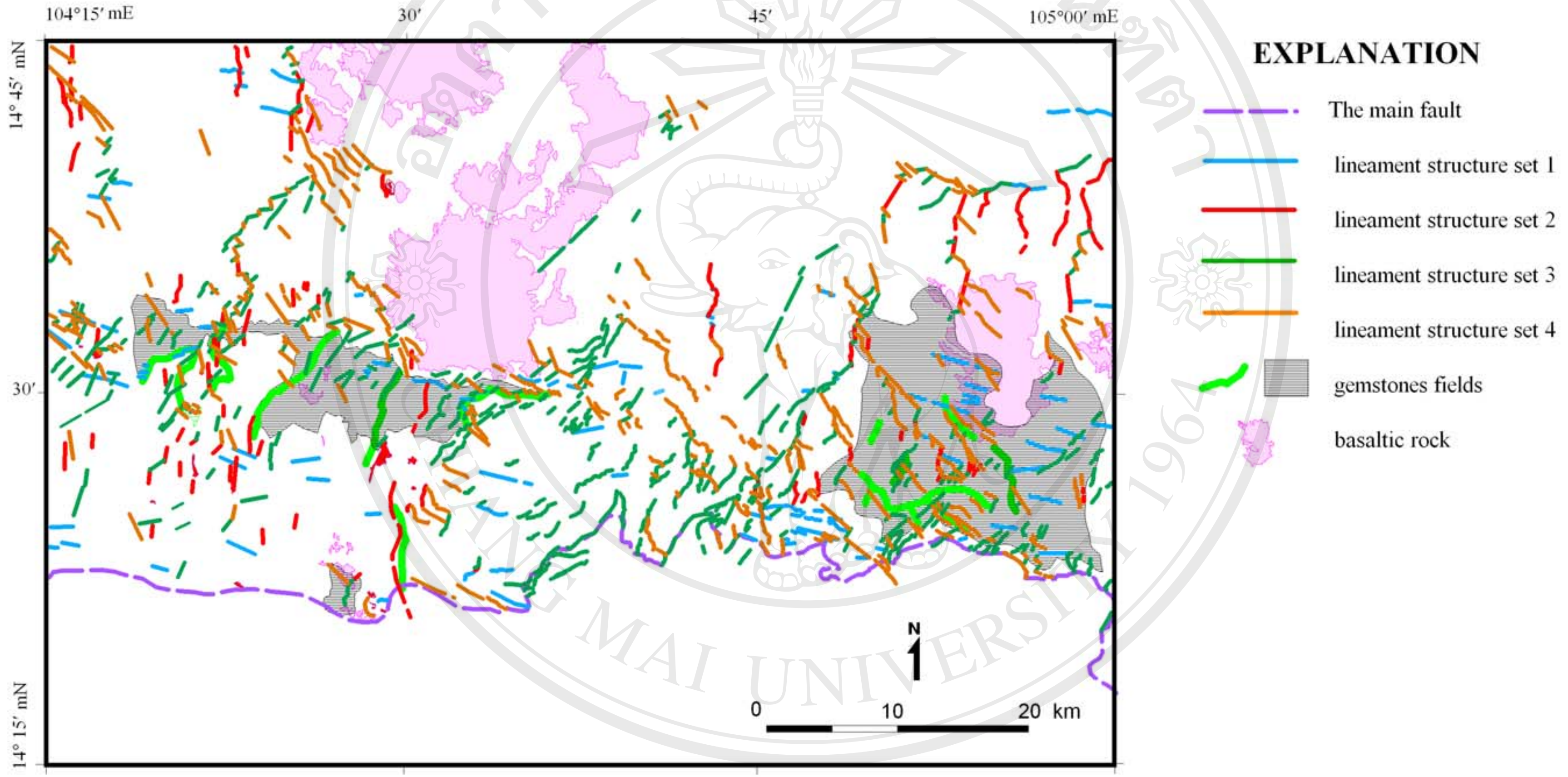

Figure 3.11 The conjugated lineament structuctures around the basaltic outcrops and gemstone fields. This is presumed to associate with the basaltic eruptions and gemstones they carried up to the surface.

Thus this unit should have higher ability of porosity comparing to the sedimentary unit. The appearing cultivation in the unit is an example of this (Figure 3.12).

According to data from field observation, the materials of this unit comprise various sizes of blocks, boulders, gravel, and sand. Most of them consist of sand which was generated from water transporting from higher mountains plus together with the residual weathering of blocks or boulders of sandstones. The characteristic of dip direction is gentle from south to north (not more than 10 ^{o}) forming rather flat area, or could be called “pan landform” with approximately 0.3 – 1.0 m thick.

It is noticed that there is the vegetation in the fine texture areas more than in the coarse texture areas (Figure 3.12). This can be explained by the water capability along grains of finer sediments such as sand which is more than along coarser grains such as boulders or blocks.

In Figure 3.12, the drainage pattern and density are different from those of the other units. The stream density along the talus unit is obviously wide - space (but more closely than in the hard rock unit). The porosity of sediments in the talus unit is high porosity, thus most water should run beneath the surface as called “the internal drainage pattern”. However, the drainage patterns on surface are controlled by the structural features, i.e., fault lines are still extended from the hard rock unit. The fractures occurring in the basement rocks underlying the sediments so the thin talus pan still reflected the structures beneath. The lineament structures are mostly remarked from the drainage patterns. The drainage system of this unit is composed of rills and gullies about 1 -3 orders. Most of them show angular pattern, but some of them appear on the area which contains much sands resulting in formation of water tributaries as the dendritic drainage pattern (Figure 3.12).

The streams which have angular drainage pattern in this talus area are developed from the lineament structures and the gemstones are discovered in these channels. The orientation of the angular drainage pattern is divided into 4 the NS direction is the dominant one (Figure 3.4, 3.8, 3.9). In spite of the Talus unit is

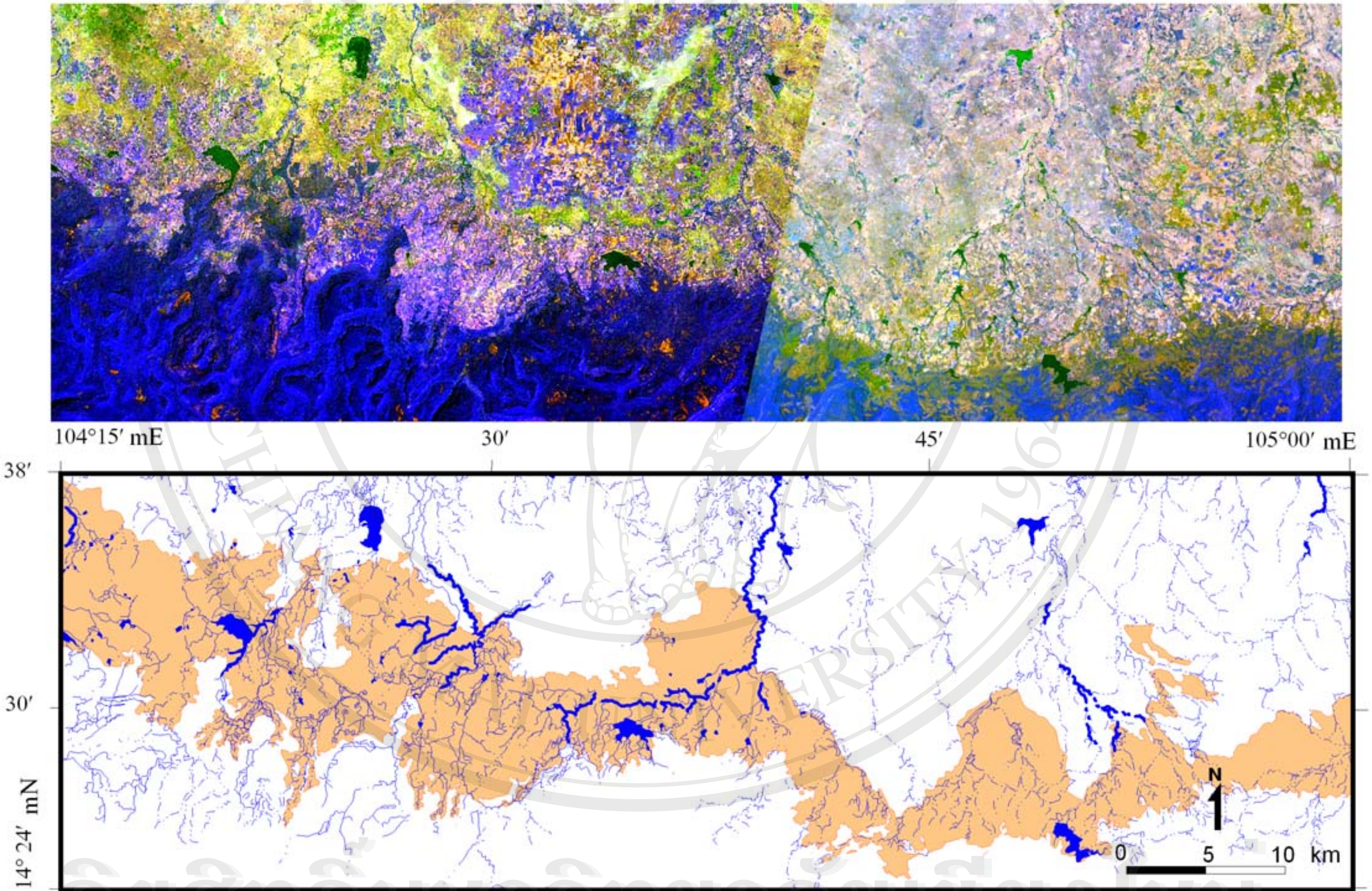

Figure 3.12 The talus unit (orange color) shows the boundary and the drainage patterns on its surface. The upper is the false color composites (RGB: 471) for comparison, that the granular texture of the cultivation and natural vegetation are together. The drainage has widely space (not more closely than in the hard rock unit). The water tributaries began to form the dendritic drainage pattern.

directions depending on the lineament structures as in the hard rock unit. However, the area contains the sediments which are derived directly from the hard rock unit, including the gemstone. It is signified that the gemstones are confined to the channels of this unit even though some of small size gemstones are transported to the lower areas (Figure 3.13).

All of streams in the talus unit have generated the water recharges and sediments for the lower floodplain where it is divided into the mixed sedimentary, the terrace and recent floodplain units. The first and the second forms surrounding and generally higher relief than the third. *The mixed unit* is the area of the sediments generating from mixing of residual soil, fluvial sediments and loess (not clearly be identified). *The terrace unit* is mostly around the recent unit. It is mostly generated from paleo fluvial deposition and has higher relief than the recent unit. *The recent unit* is the fluvial deposit in the recent floodplains. The false color images and the image which are enhanced or transformed by the Program ER-Mapper@ can distinguish those 3 unit clearly (Figure 3.2 - 3.4). The false color images (RGB) composing the band 1 and band 5 as 471 and 453. generate good results for distinguishing the sediments by the level of moisture, chlorophyll in vegetation. Because the band 1 reflected greenish blue of water, the band 3 reflected the Chlorophyll of vegetation and the band 5 reflected the moisture of ground and vegetation (Bereau of Economic Mineral, 2005).

3.2.2.2 THE MIXED UNIT

The mixed unit can be distinguished in the false color images (RGB) 453 and 471. This unit is lighter tonality, smooth texture, paler color comparing to the other surrounded units because of the lower level of moisture in the soil.

The mixed sedimentary unit has always surrounded the terrace and the recent floodplain units in the higher relief. The vegetation or cultivation is not abundant because of low moisture. However, some places occur the traces of dendritic drainage patterns (Figure 3.3A – B, Figure 3.14). Some channels are still being the tributaries of the recent fluvial system.

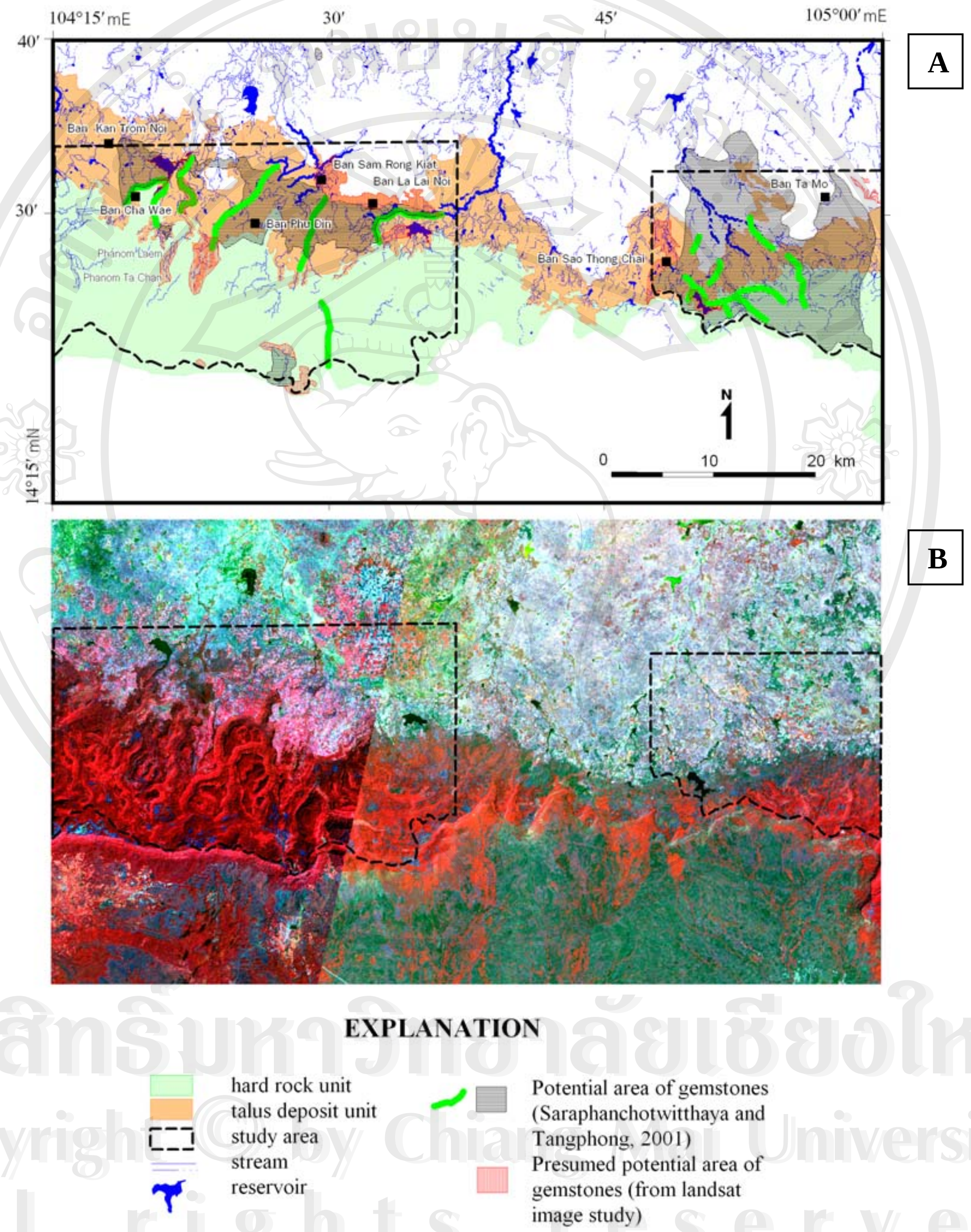

Figure 3.13 (A) The potential area and the additional presumed area of gemstone deposit, most of the areas are in the talus unit , some are in the hard rock unit. (B) The false color composites (RGB: 425) is illustrated for comparison.

The lineament structures are followed from the traces of paleo channels (Figure 3.5). Most of lineament structures are set 3 and 4 and some are in set 2. This is another reason supporting they are younger than the set 1 and 2 because they could be seen in the sedimentary cover.

3.2.2.3 THE TERRACE UNIT

This unit has lower moisture than the recent floodplain so the false color composites (RGB) are always illustrated the same color but paler tone (Figures 3.2 – 3.3, Figure 3.5). Additional study from the transformed figures (Figure 3.2 B and Figure 3.3 B) is supplied to distinguish the terrace unit. Generally, the terrace unit surrounds the recent floodplain unit but some places are scattering in small patches. It reflects the old floodplains which are wider than the recent floodplain. The vegetation in this unit is equally dense as in the recent floodplain unit because the local people made cultivation continuously. Hence it is difficult to separate them by the vegetation. However, the field observation makes the better decision.

Generally, the terrace is higher relief and has coarser sediments than of the recent floodplain. Hence, the permeability of the sediments plays an important role for the internal drainage in the terrace unit. The drainage patterns are also not seen clearly on the surface of this unit except some places where the tributaries of the recent unit cut trough. The lineament structures occurring on the surface of the terrace unit have continued from the mixed sediment unit and the recent floodplain unit. The set 3 and 4 are noticed.

The terrace and the recent floodplain units have the locations containing the derived sediments from the talus unit, concluding the sediments from the gemstone – bearing basaltis rocks which originated previously. Hence, some parts of the terrace unit contain gemstones. This idea will be proven by borehole – drilling in Chapter 5.

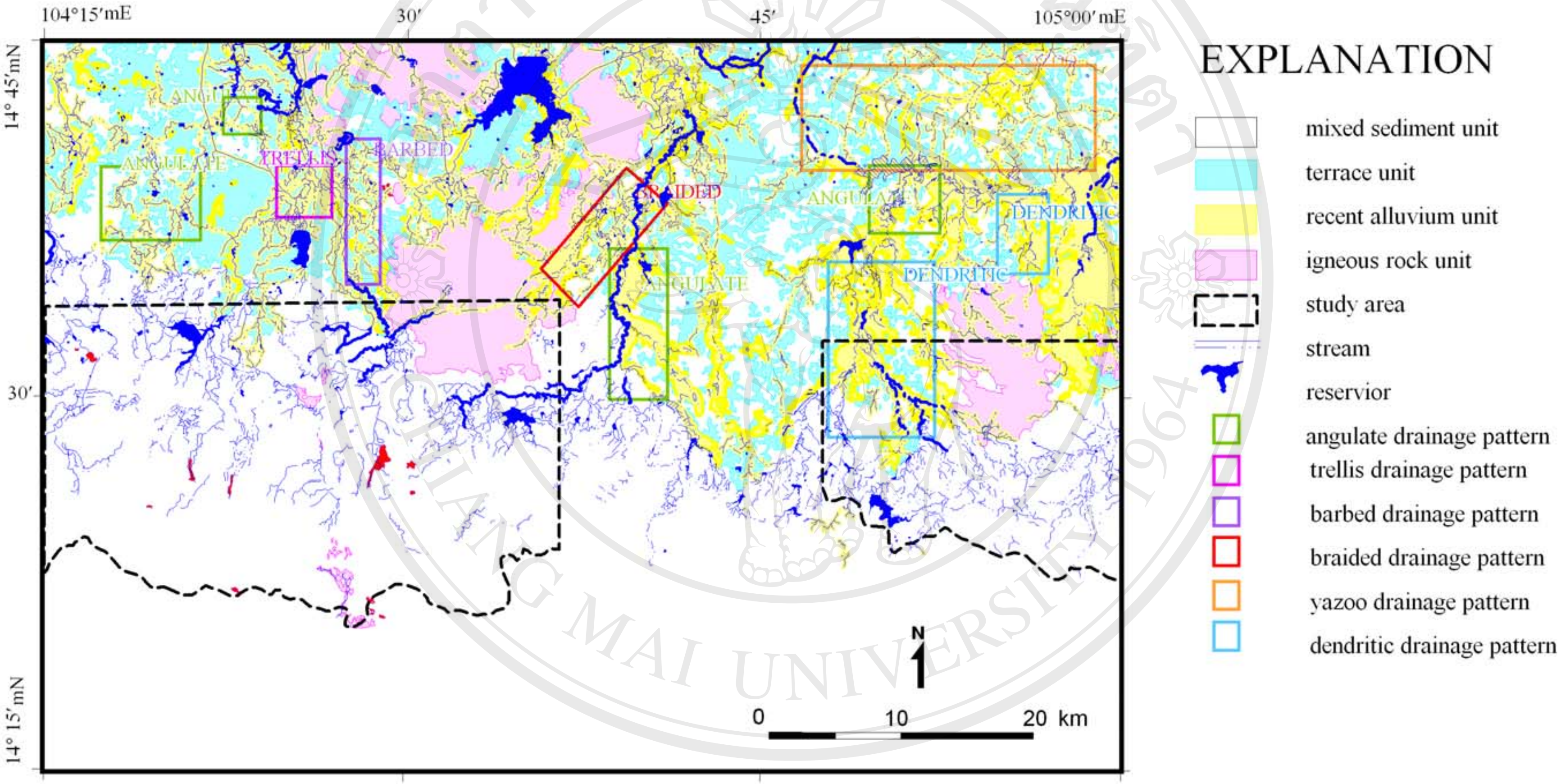

Figure 3.14 The drainage patterns appearing on the surfaces of the mixed sediment, the terrace, and recent floodplain units. Most of them reflects distinguishly controlling structures. The density of drainages is more closely spaced than those of the other units.

3.2.2.4 THE RECENT FLOODPLAIN UNIT

This unit is composed of the sediments in channels and their floodplain cutting into older floodplain (the terrace unit). It has lowest relief compared to the other units. It reveals more vivid color and darker tonality than the terrace unit but the same smooth texture, and the cultivation is made along the channels (Figures 3.2 –3.3, Figure 3.13).

The drainage patterns occurring on the plain of sedimentary unit are rather complexed because of the tributaries of 3 fluvial systems, from west to east: The Mae Tha, the Huai Ka Yung and the Lam Som systems (Figure 3.14). The drainage patterns in this unit are composed of : the angulate, trellis, barbed, braided, dendritic, and yazoo drainage patterns (Figure 3.14). The streams of this unit are elongated to the North obviously. They reflect the dip direction of the basement rocks. Some of the drainages reflect the controlling by lineament structures. It is noticed from the angular angles of their jointings and their confused patterns (Figure 3.14).

The gemstones are discovered in the gravel beds of this unit in small amount comparing to the thicker gravel bed of the paleochannel gravel beds. Moreover the gemstones which are discovered in this unit are always small sizes because they are reworked by the rivers activity from the older deposits.

The study of fluvial actions in the study areas and their vicinities stated that the drainage basins have more distinctively erosional and transportational activities more activities than depositional aspects because they are in the early maturity stage. The sediments are deposited remarkably in the alluvial fan and fluvial environments.

3.2.3 THE IGNEOUS ROCK UNIT

This rock unit intruded the other units scatteringly as large and small bodies (Figure 3.4). The large body can be seen clearly in the natural color composites

(Figure 3.3A) but small bodies are more difficult to be seen. Therefore the false color composites (RGB) are important to distinguish the areas covered by the basaltic soil. The small body – basaltic rocks, mostly decayed into lateritic soil, are related to the gemstone occurring in the study areas than the larger bodies. The false color composites (RGB) 235, 237, 417, 425, 453, 457, 471 illustrated distinctive - basaltic areas, those are rather different than surrounding.

<u>Color and tonality</u> Even though the true color composite (RGB:321) is not clear for bounding the igneous rock unit, many false color composites (RGB) produce the better results. For example, the 415 and 471 produce the vivid orange hues, and the 235 and 237 produce the yellowish green hue. Whereas the locations having the same color as the well known basalts are bounded, the unproved basalt localities are illustrated differently (Figure 3.4).

The tonality of the igneous rock unit in all false color composites are also dark tonality comparing to the surrounding topography because of the iron oxide in the rocks. The iron-oxide stained sediments near the volcanic areas illustrate in the same color but lighter tonality around them.

<u>Texture</u> It is exhibited that the igneous rock unit areas have coarser texture than the alluvial sediments surrounding them. They are composed of many square objects (Figure 3.3A, Figures 3.11 - 12). The angular objects are the cultivated fields which reflect the abundance of the volcanic soil for the vegetation.

<u>Pattern and shape</u> Either the larger bodies or the small bodies are also the same patterns. The irregular shapes of basalts enlarge from one or more than one centers, dipping gently (not more than 6-10^{o}). The streams running on them make their forms elongate to the north upon the dip direction of basement rock.

<u>Size</u> From the Landsat images, the volcanic rocks can be divided into 2 bodies *(i) larger bodies*, covered about 20-140 square kilometers, can be noticed

clearly from the natural color composites and *(ii) the smalller bodies* covered about 0.1-1 square kilometer.

The drainage patterns They are not noticed remarkably on the surface of rocks. Most of the igneous rocks are decayed to be very fine soil so the water is easy to permeate into soil. However, some parts of dendritic drainage patterns cut into the basaltic rocks and radial drainage patterns occur around them (Figure 3.15).

The lineament structures are not seen on the volcanic rock unit clearly. Most exhibit around the outcrops. It is possible that they intruded along some lineaments beneath them. The noticed lineament structures consist of the set 1, 3, 4 (Figure 3.15).

The larger body - volcanic rocks are investigated in the field and not have been associated with the gemstones except for sediments underlying them. For example, in the east study area, some gemstones are discovered in the paleochannel sediments. Moreover, the basaltic rocks of Phu Kra Jiew (from a quarry located at the east of the study areas) exhibit the xenoliths in the texture like the corundum bearing basalt of Chanthaburi Province but the recent phase has no potential of gemstones. Hence it is possible that the preview gemstone – bearing basalts may erupted at the same locations of the recent basalts.

Hughes (1990) mentioned about the gemstones and the basaltic rocks in Indochina and stated that basalts could be classified into 2 sets; the smaller and the larger bodies. The smaller bodies provide the corundum, zircon and garnet to the surface whereas the larger bodies contain only zircon. However, the larger bodies may carry the corundum together during their initial stage. This means the possibility to have the gemstone deposits beneath the the larger bodies.

After study the composition of many landsat images, new small bodies of basalt rock are located as shown in Figure 3.15. These possible – new basaltic outcrops signify new gemstone deposits, especially in the regions where gemstones have never been reported.

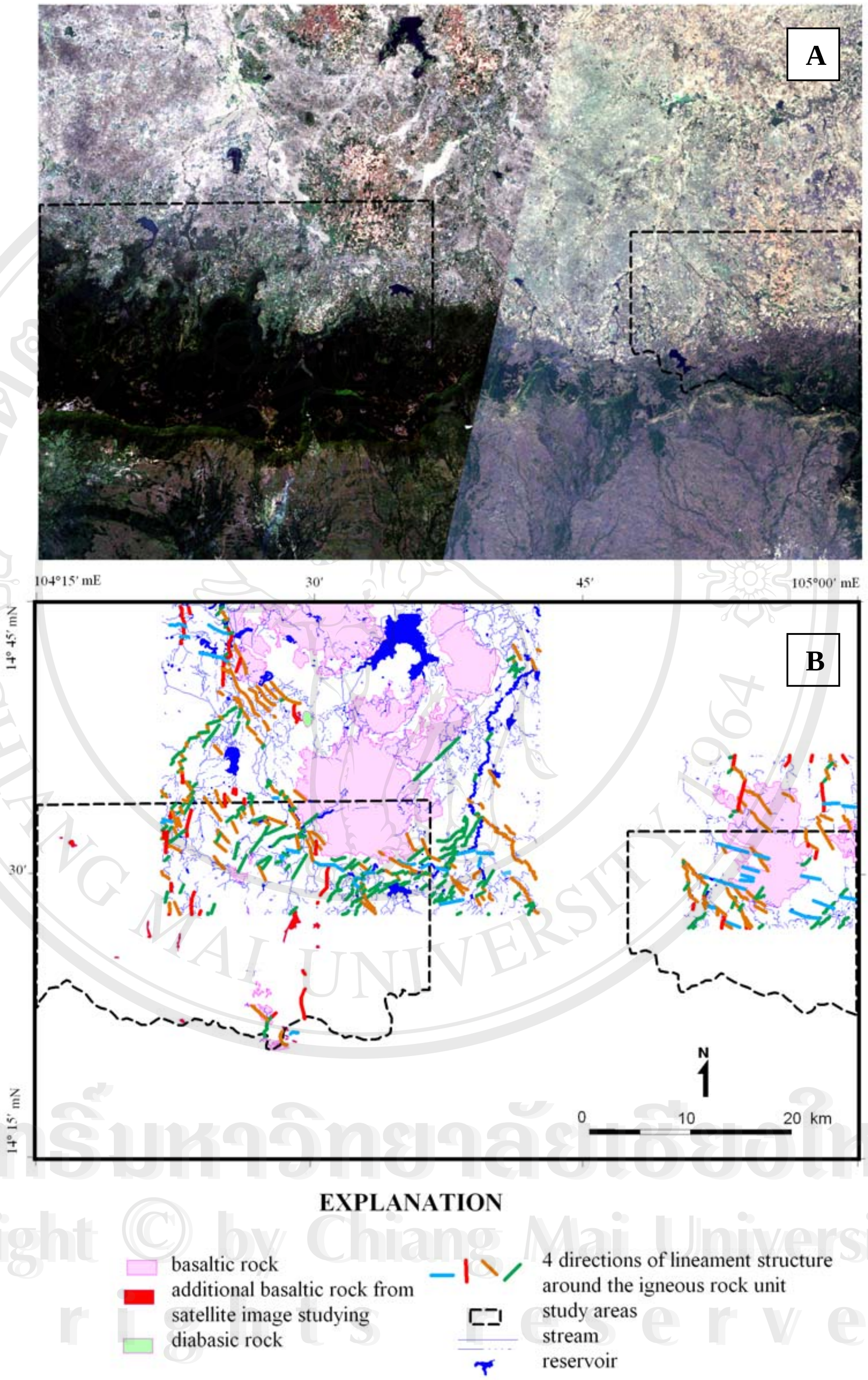

Figure 3.15 (A) The true color composites (RGB: 321) is delineated to show (B) the boundaries of the igneous rocks. The large bodies show the radial drainage patterns.