โครงการเรียนการสอนเพื่อเสริมประสบการณ์

ระบบรอยแตกของแนวชั้นหินคดโค้งเลย ตามถนนหมายเลข 2196 อำเภอเขาค้อ จังหวัดเพชรบูรณ์

โดย

นาย ภูริณัฐ ธิโป

เลขประจำตัวนิสิต 5732745223

โครงการนี้เป็นส่วนหนึ่งของการศึกษาระดับปริญญาตรี

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2560

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FRACTURE SYSTEM OF LOEI FOLD BELT ALONG HIGHWAY NO. 2196 OF KHAO KHO DISTRICT, PHETCHABUN PROVINCE

MR. POORINUT THIPO

A Project Summitted in Partial Fulfilment of Requirements
for The Bachelor Degree of Science, Department of Geology,
Faculty Science, Chulalongkorn University
Academic Year 2017

Project Title	**FRACTURE SYSTEM OF LOEI FOLD BELT ALONG HIGHWAY NO.2196 OF KHAO KHO DISTRICT, PHETCHABUN PROVINCE**
By	**Mr. Poorinut Thipo**
Field of Study	**Geology**
Project Advisor	**Assoc. Prof. Dr. Pitsanupong Kanjanapayont**

Summited date.............................

Approval date.............................

....

Project Advisor

(Associate Professor Pitsanupong Kanjanapayont, Dr.rer.nat.)

หัวข้อโครงการ: ระบบรอยแตกบริเวณแนวชั้นหินคดโค้งเลย ตามถนนหมายเลข 2196 อำเภอเขาค้อ จังหวัดเพชรบูรณ์

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ภาควิชา: ธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

บทคัดย่อ

แนวชั้นหินคดโค้งเลยเป็นบริเวณที่มีโครงสร้างทางธรณีวิทยาที่ซับซ้อนเป็นผลมาจากการที่แผ่นจุลทวีปไซบุมาสุมุดตัวเข้าใต้แผ่นจุลทวีปอินโดจีนในช่วงไทรแอสซิก และมีทิศทางในการมุดตัวจากทิศตะวันตกไปทิศตะวันออก การศึกษานี้มุ่งเน้นศึกษาลักษณะธรณีวิทยาโครงสร้างและวิวัฒนาการของแนวชั้นหินคดโค้งเลย บริเวณถนนหมายเลข 2196 อำเภอเขาค้อ จังหวัดเพชรบูรณ์ จากการวิเคราะห์ข้อมูลธรณีวิทยาโครงสร้างในภาคสนามและในระดับจุลภาคพบรอยแตกหลัก 2 แนว ซึ่งเกิดขึ้นในหินเถ้าภูเขาไฟ นอกจากนี้ยังพบระบบรอยแตกย่อยที่สัมพันธ์กับรอยแตกหลักในแต่ละแนว โดยแนวที่ 1 วางตัวอยู่ในทิศตะวันออกเฉียงเหนือ-ตะวันตกเฉียงใต้ และมีมุมเอียงเทไปทางทิศตะวันตกถึงตะวันตกเฉียงเหนือ แนวที่ 2 วางตัวอยู่ในทิศตะวันออกเฉียงเหนือ-ตะวันตกเฉียงใต้ และมีมุมเอียงเทไปทางทิศตะวันออกถึงตะวันออกเฉียงใต้ ซึ่งทั้ง 2 แนวแตกหลักมีความสัมพันธ์กันโดยที่ รอยแตกแนวที่ 1 มีการเคลื่อนตัวเล็กน้อยจากอิทธิพลของรอยแตกแนวที่ 2 จากผลการศึกษาสามารถแบ่งลาดับวิวัฒนาการได้เป็น 2 ช่วง คือ 1.) ช่วงไทรแอสซิกตอนต้น เกิดแรงบีบอัดเข้ามาทางด้านทิศตะวันออก-ตะวันตก ทาให้เกิดการคดโค้งของบริเวณขอบจุลทวีปทั้งสอง 2.) ช่วงโอลิโกซีนถึงไมโอซีน เกิดการยืดออกของแผ่นทวีปทาให้ได้แอ่งตะกอนยุคเทอร์เทียรีในประเทศไทย ซึ่งเป็นอิทธิพลมาจากการชนกันของแผ่นเปลือกโลกอินเดียและยูเรเซีย

ภาควิชา...........ธรณีวิทยา.............ลายมือชื่อนิสิต..

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ปีการศึกษา.........2560...................

Project Title: **Fracture system of Loei Fold Belt along highway no. 2196 of Khao Kho district, Phetchabun province.**

Researcher: Poorinut Thipo

Advisor: Associate Professor Pitsanupong Kanjanapayont, Dr.rer.nat.

Department: Geology, Faculty of Science, Chulalongkorn University

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Abstract

The Loei Fold Belt is complex structural zone. It caused by Sibumasu sub-continent subducted from east to west into Indochina in Early Triassic. This study focused on geological characteristic and evolution of Loei Fold Belt along highway no.2196 of Khao Kho district, Phetchabun province. From field structural geology and micro-structural data analysis, there are 2 main trend fractures which took place in tuff. Moreover, minor related joint sets were founded in each main fracture. The first set is in the NE to SW direction and has W to NW dip direction. The second set is also in the NE to SW direction but has E to SE dip direction. From their relationship, the first trend has off-set from effect of the second trend. So, the second trend is younger than the first trend. The evolution of them can be separated in to 2 stages. Stage 1 took place in Early Triassic which was the beginning of E-W compression and made fold belt along 2 continental margins. Stage 2 took place from Oligocene to Miocene. It was extension phase in this stage from the effect of India collided with Eurasia.

Department: ....Geology.............Student's Signature...

Field of Study: ....Geology.............Advisor's Signature..

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List of contents

List of figures

Figure		Page

Figure		Page

Figure		Page

Figure Page

Figure		Page

Chapter 1 Introduction

Chapter 1

1.1 Introduction

Structural geology in Thailand is affected by the two plate tectonic events. First event was in Triassic. Sibumasu sub-continent, which can be comparable with Shan-Thai (Bunopas, 1981), collided with Indochina sub-continent (Metcalfe, 2011). The effect from this event makes the fold belts in the boarder of 2 sub-continents. They are Loei Fold Belt, in the east of Nan Suture, and Sukhothai Fold Belt, in the west of Nan Suture (Bunopas, 1981). Next, the second event was in Oligocene to Miocene. The India plate subducted along the Sumatra and passing northwards trough the Myanmar. The effect from the second event made the subduction roll back and Tertiary basins in Thailand (Morley., 2001).

So, the Phetchabun province is the affected area from the tectonic events because it has Loei Fold Belt and Phetchabun basin, one of Tertiary basins. This study focuses on the structural geology in terms of fracture systems to find the characteristic, relationship and analyze evolution of fracture in the Loei Fold Belt along highway no. 2196, Khao Kho district, Phetchabun province.

1.2 Objective

1.) To study the characteristic of fracture system at the study area

2.) To study the evolution of fracture system at the study area

1.3 Scope of the research

This research focus on the fracture systems by observing outcrops and collecting data from them. The data are collected along the highway no. 2196, Khao Kho district, Phetchabun province.

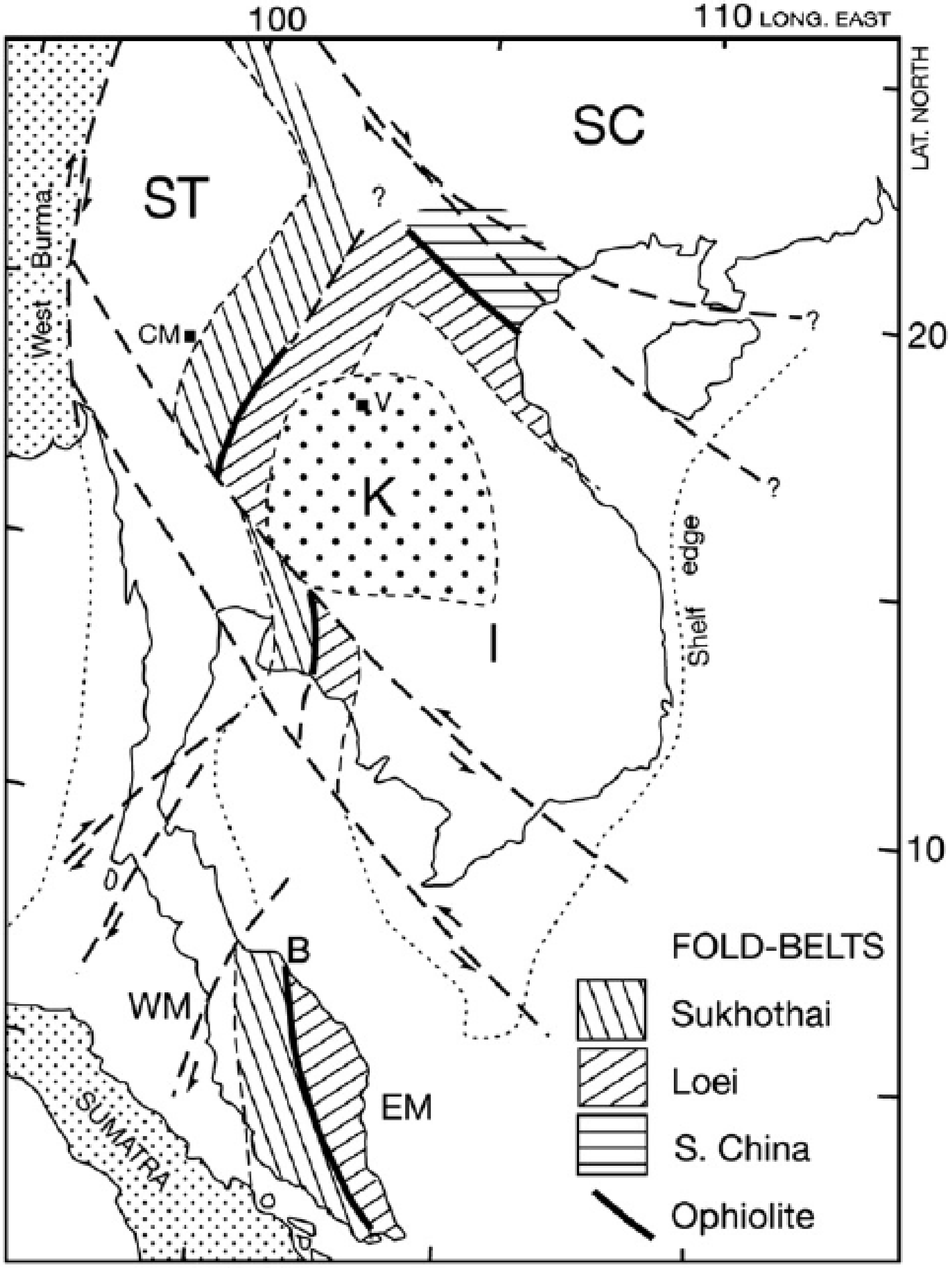

Fig 1.1 The boundary of Shan-Thai (SC), Indochina (I), Khorat Plateau (K), Loei Fold Belt and Sukhothai Fold Belt (Modified by Metcralfe, 2011)

1.4 Tectonic setting

Thailand composes of two major sub-continents. There are Sibumasu, which can be comparable with Shan-Thai (Bunopas, 1981), and Indochina. They collided during the Indosinian Orogeny after the subduction of the Paleo-Tethys Ocean that took place in the Devonian-Triassic (Sone & Metcalfe, 2008). The evidence of the collision is the two suture zones, Nan-Suture and Srakeaw sutures, laying along N-S trending.

In the Middle Devonian, the Paleo-Tethys started spreading. Then, the Tethys subducted under Indochina around the Late Carboniferous or Early Permian. It formed a magmatic arc along the western margin of Indochina called Sukhothai Arc. Moreover, this rapid subduction made the back-arc basin in the Early Permian. The back-arc closed in the Late Permian by the compression phase. The Sukhothai Arc became the part of Indochina during the closing of back-arc. The Paleo-Tethys continue subducted until the Late Triassic. The Sibumasu collided with the west of The Indochina. It built the major mountain range (Indosinian Orogeny). In the Lastest of the Triassic, Paleo-Tethys completely subducted into Indochina. This event made magmatism in Sukhothai Arc inactive (Sone & Metcalfe, 2008).

The collision between India and Eurasia plate was in Eocene to Neogene, also called the Himalayan Orogeny. The collision made the inversion of strike-slip fault in Thailand and resulted in regional uplift of the Korat Plateau, NE Thailand). The effected of strike-slip fault in Thailand ceased in 30 ma (Watcharanantakul, 2001). So, the Tertiary basin in Thailand caused by subduction rollback from the effected of India increase angle of subduction. It subducted steeply from Sumatra to northwards. (fig 1.3)

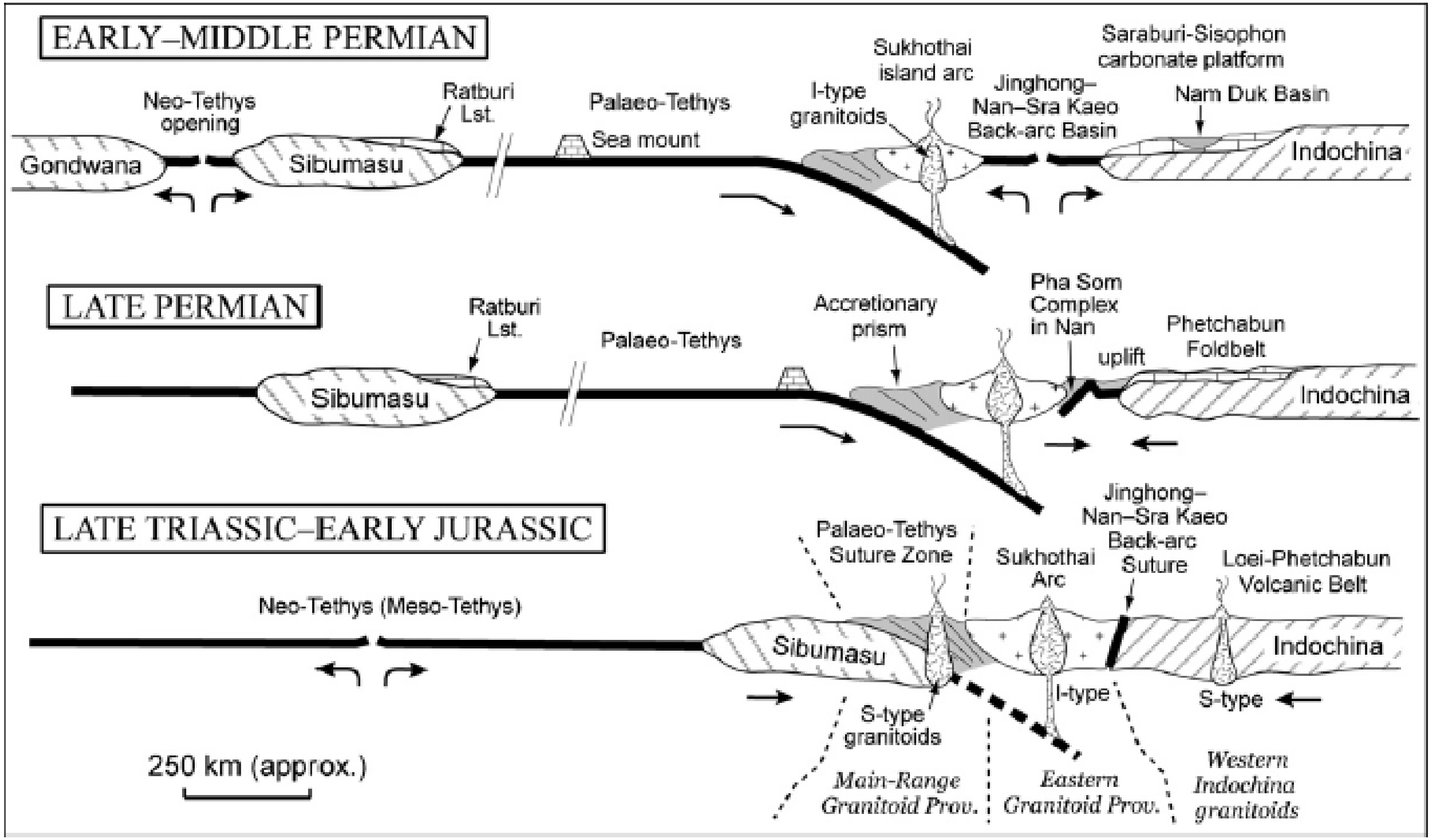

Fig 1.2 Tectonic evolution of mainland SE Asia during the Permian to Early Jurassic, with respect to the formations of the Palaeo-Tethys Suture Zone and the Jinghong–Nan–Sra Kaeo back-arc Basin suture. Vertical scale arbitrarily exaggerated (Sone and Metcalfe, 2008)

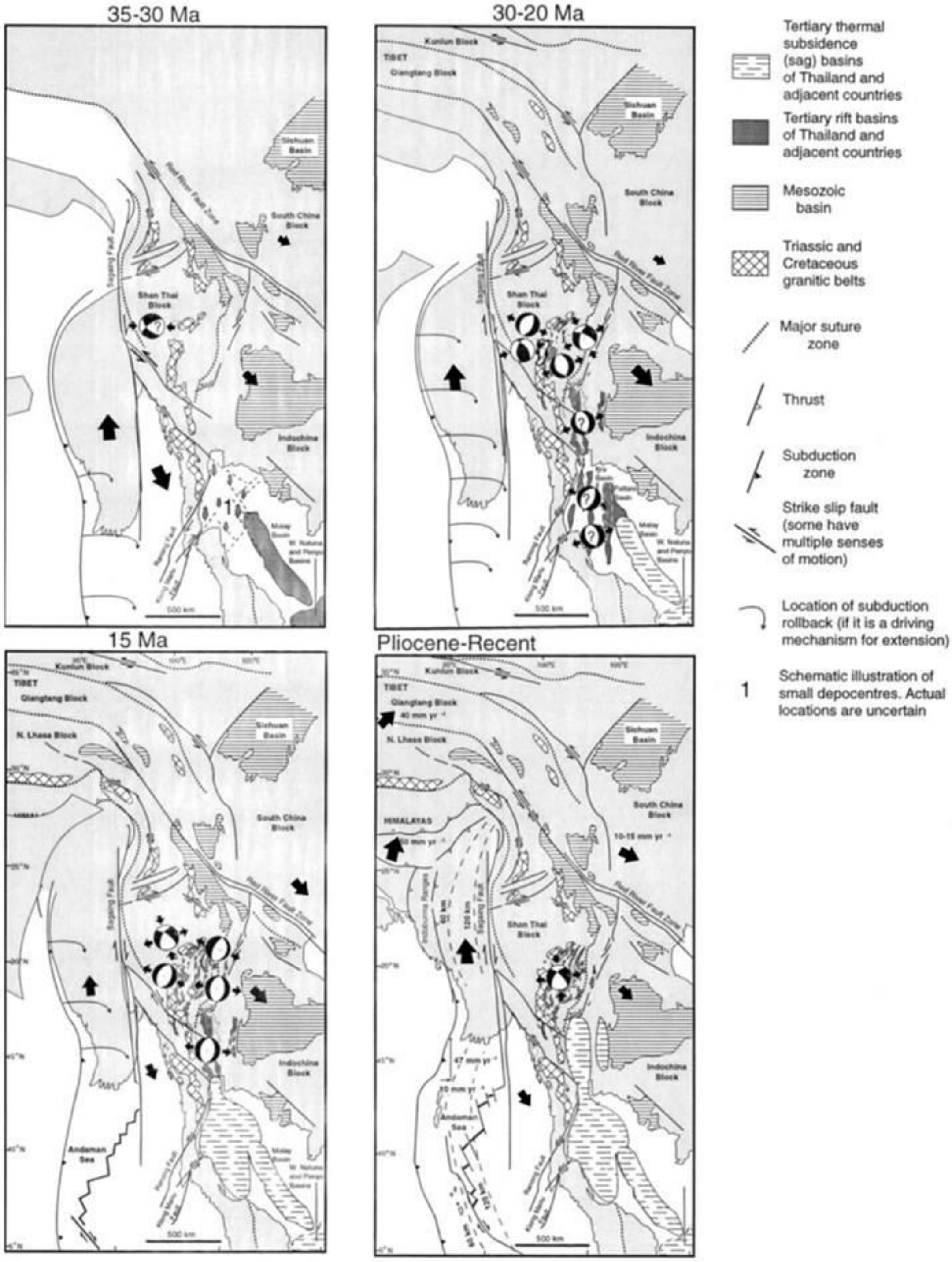

Fig 1.3 Geological evolution of SE Asia from the Oligocene to Present (Morley, 2001)

Chapter 2 Geological background and Methodology

Chapter 2

2.1 Geology in the study area

The study is in the western border of Indochina sub-continents. From the relationship between location and geological map from the Department of Mineral Resources (2010) defines the rocks in the study area into 2 main formations. There are Huai Hin Lat formation (TRhl) and Phu kradung formation (Jpk).

The Huai Hin Lat formation is in the eastern most of the study area (2007). It presents conglomerate, limestone conglomerate, grey to dark grey sandstone and siltstone (Iwai, 1964). The depositional age is Triassic from the dating data of its plant remnant (Konno and Asama, 1973), pollen and spores (Haile, 1973) and also vertebrate faunas. The depositional environment of this formation is fluvio-lacustrine environment indicated by fossils, which are fish fragment, turtle, amphibian and reptile. Chonglakmani and Sattayarak (1978) classified formation into 5 members. There are Mo member, Phu Hi member, Dat Fa member, Sam Khaen Conglomerate member and Pho Hai member.

The Phu kradung formation presents maroon siltstone, claystone and sandstone with greenish-grey calcareous conglomerate (Chaodumrong, 2013). From the bone fragments dating suggested the age that the formation is Middle to Upper Jurassic. Moreover, the depositional environment of this formation is fluvial deposit. Indicating from the upward sequence from top to bottom of conglomerate and channel sandstone to crevasse-splay facies and floodplain at the top.

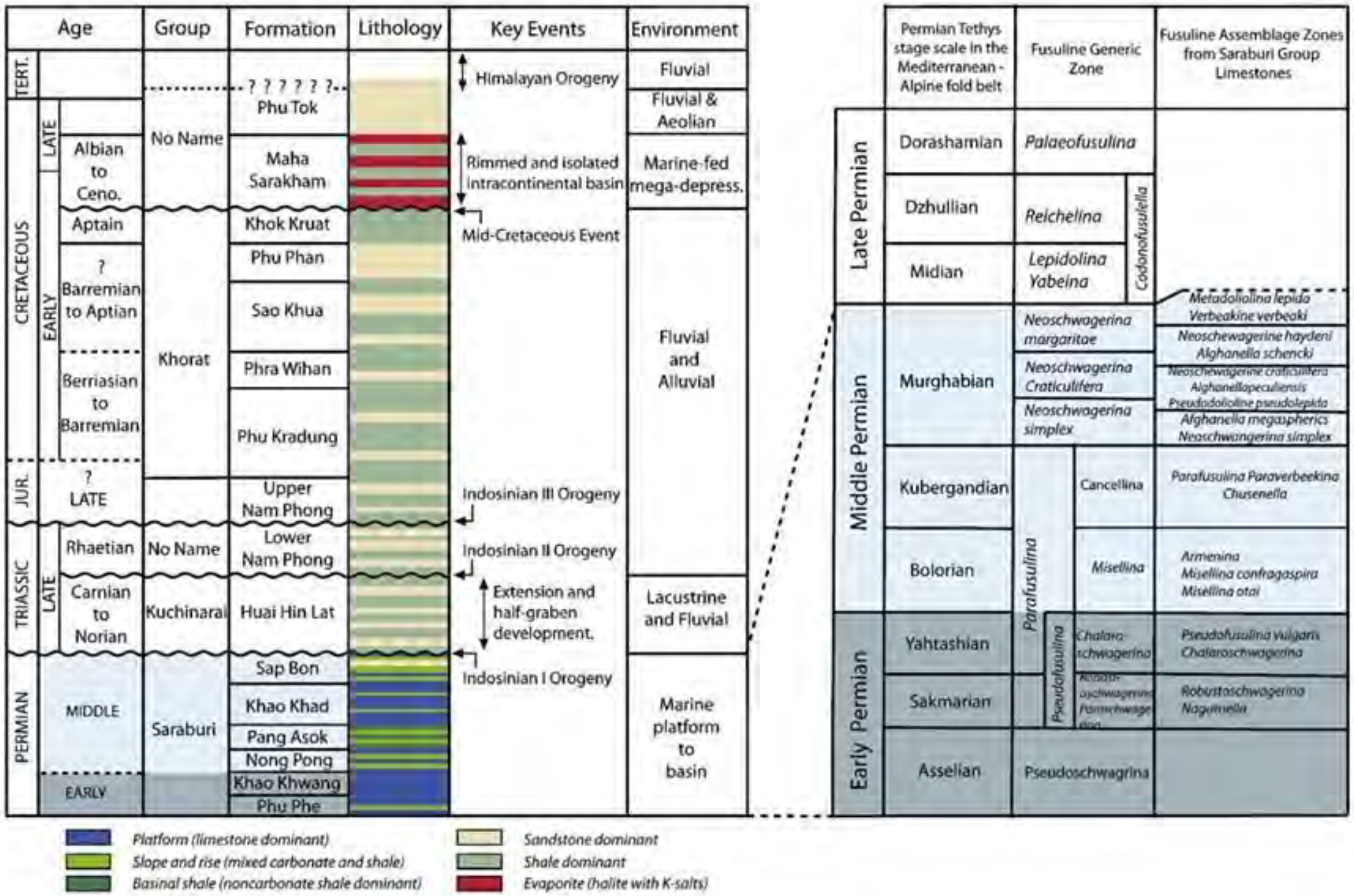

Fig 2.1 Regional stratigraphy and the fusulinid assemblage zones used for age subdivision (Warren et al., 2014)

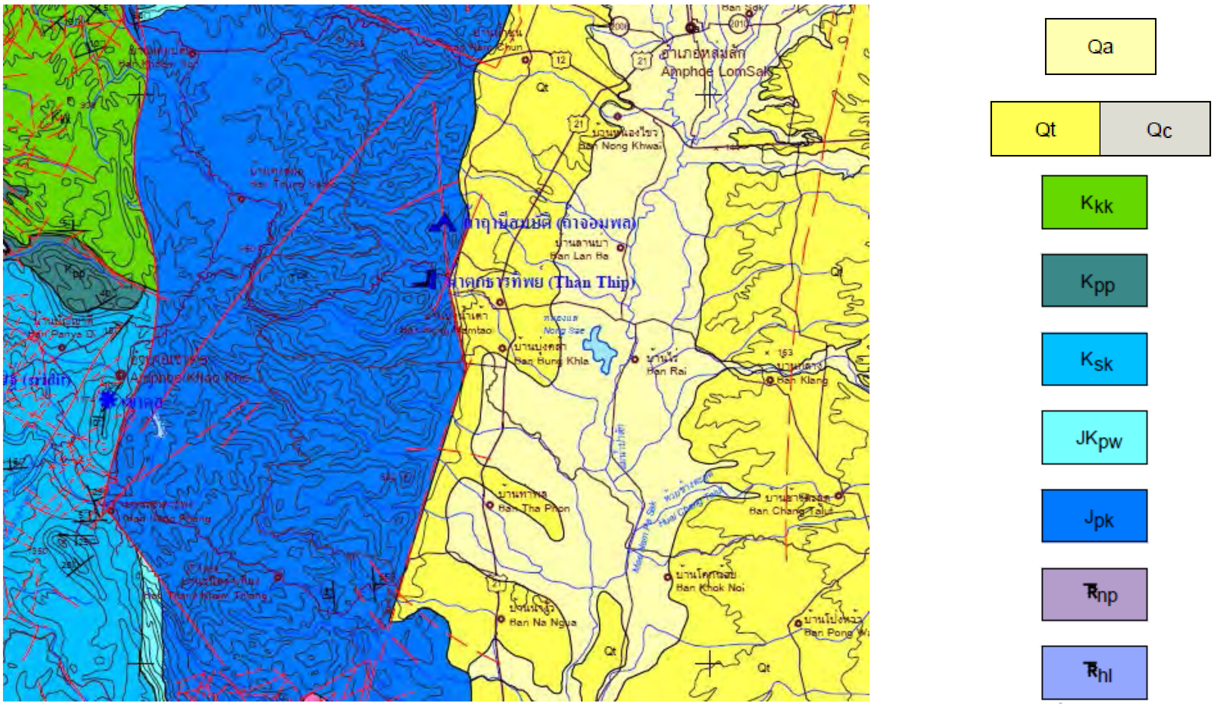

Fig 2.2 Geological Map (DMR, 2009)

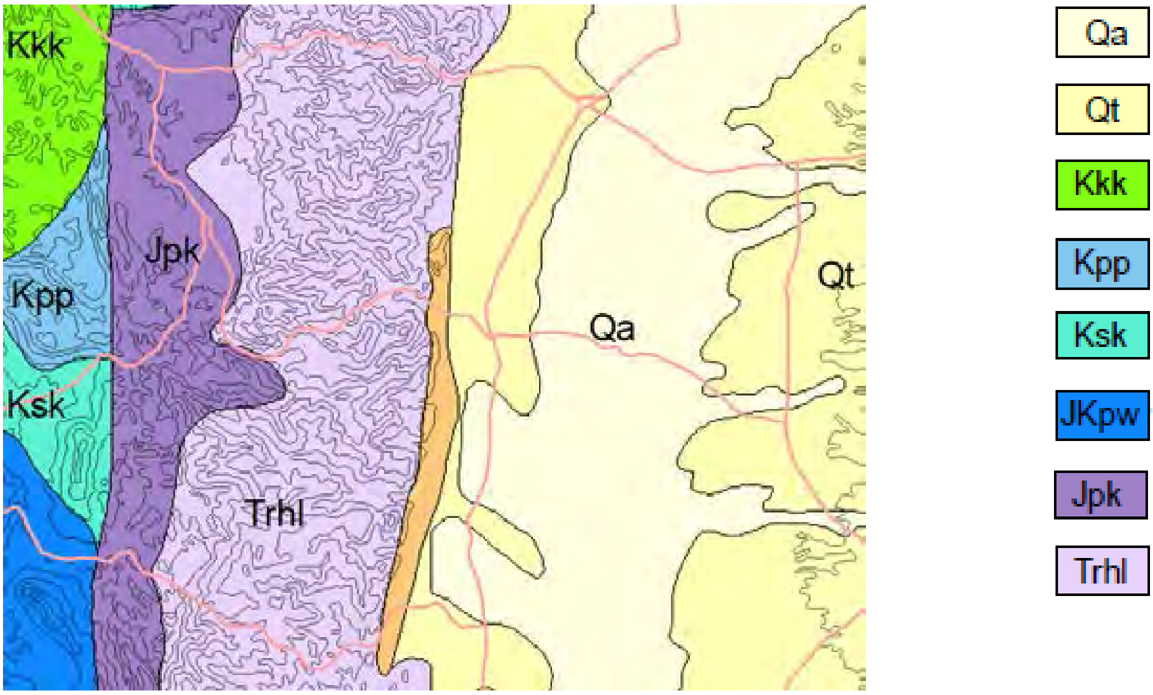

Fig 2.3 Geological Map (DMR, 2007)

2.2 Fracture

Fracture can be normally found in the rocks. If we can collect them into a group, it will be fractures system which are developed from one or more tectonic event (Peecock, 2017). He can be divided into a group from their trend, type, and age. He can determine the relationship of them from these following.

2.2.1 Type of fractures

2.2.1.1 **Extensional fractures** or opening-mode such as joint, vein, dykes.

2.2.1.2 **Contractional fractures** or closing- mode such as stylolite, compaction band.

2.2.1.3 **Shearing-mode fractures** such as faults, deformation band.

2.2.1.4 **Combined fractures** which involve two modes above such as compaction shear band

2.2.2 Geometry and Topology

The natural fracture can be divided into geometry and topology from these following.

2.2.2.1 **Geometry** has 5 types (Fig). There are isolated, approaching, abutting, branching and cross-cutting

2.2.2.2 **Topology** has 3 types from the node. There are I-node, Y-node and X-node.

2.2.3 Relative age

He identified the initial and subsequence fractures which we consider from cross-cutting relationship and displacement.

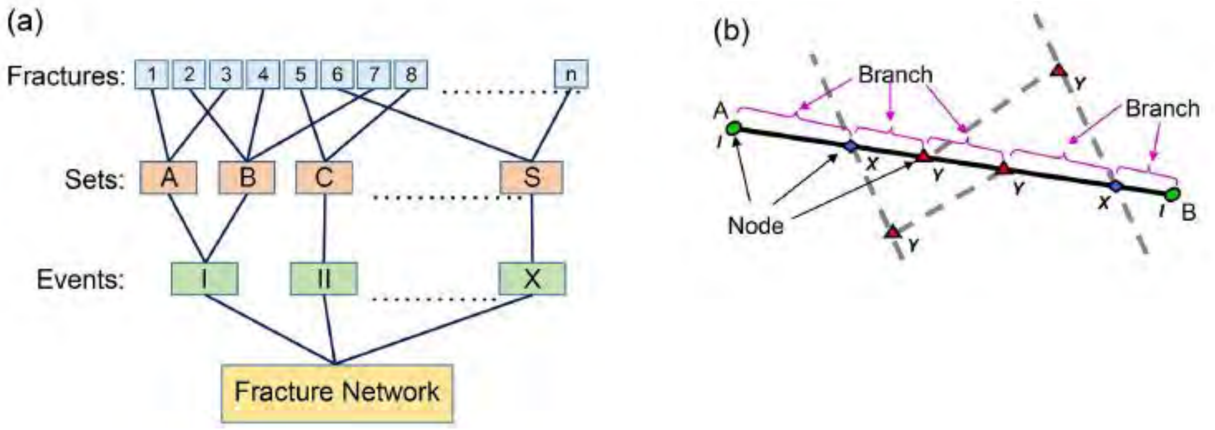

Fig 2.4 Fracture networks and interactions. (a) Fractures (1… n) can be divided into different sets, which may have been formed in a series of different events. (b) Fractures meet at nodes between which the fractures can be divided into branches (Peacock et al., 2018)

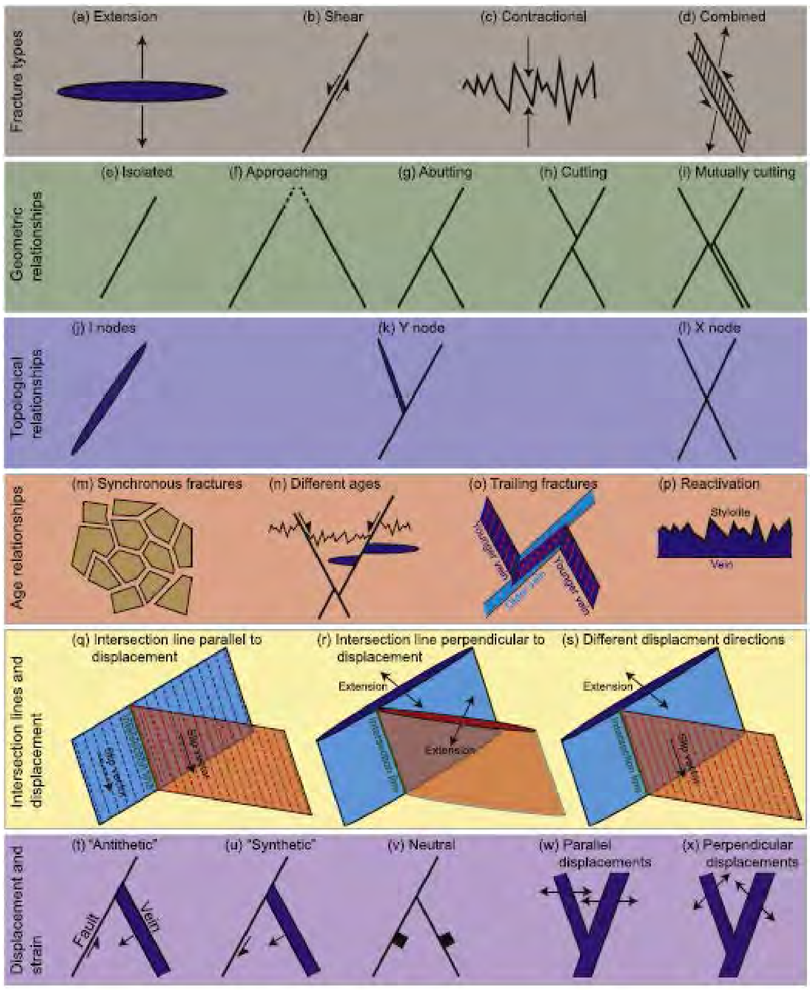

Fig 2.5 Classification of intersecting fractures, generalising the scheme for interacting faults (Peacock et al., 2018)

2.3 Methodology

The methodology of research can be divided into 6 main parts.

1.) Literature review

2.) Basic data collecting

3.) Field exploration

4.) Data analysis

5.) Discussion and conclusion

6.) Presentation and report writing

2.3.1. Literature review

Previous studies and reports about structural geology and Tectonics were reviewed especially. In addition, the program and data collecting method which are suitable for field exploration and interpreting data were favorable tested and practiced. For example, illustrator, ArcMap, Grapher, GeoRose.

2.3.2. Basic data collecting

The basic data which used in this study is collected from website. There are Geological maps 1:250000 of Phetchabun province from Department of Mineral Resources (2007 and 2009) and the digital elevation map in the study area.

2.3.3. Field exploration

The 8 road-cut outcrops were collected the structural feature and general geological data, which are bedding plane, fault plane, joint, mode of fracture and others, by taking photo and measuring data. The individual outcrop was identified location by UTM system and plotted into the final maps.

2.3.4 Data Analysis

All data from the field were analyzed in the programs. After that, the data from the programs was interpreted again to diagnose the structural geology in the study area and found the relationship of fractures of each station.

2.3.5 Discussion and conclusion

Collect all analyzed data to discuss in term of structural geology, which are structural of fractures and evolution model of fractures in the study area. They were discussed with the related studies and previous works and conclusion respectively.

2.3.6 Presentation and report

Fig 2.6 outcrop at the study area

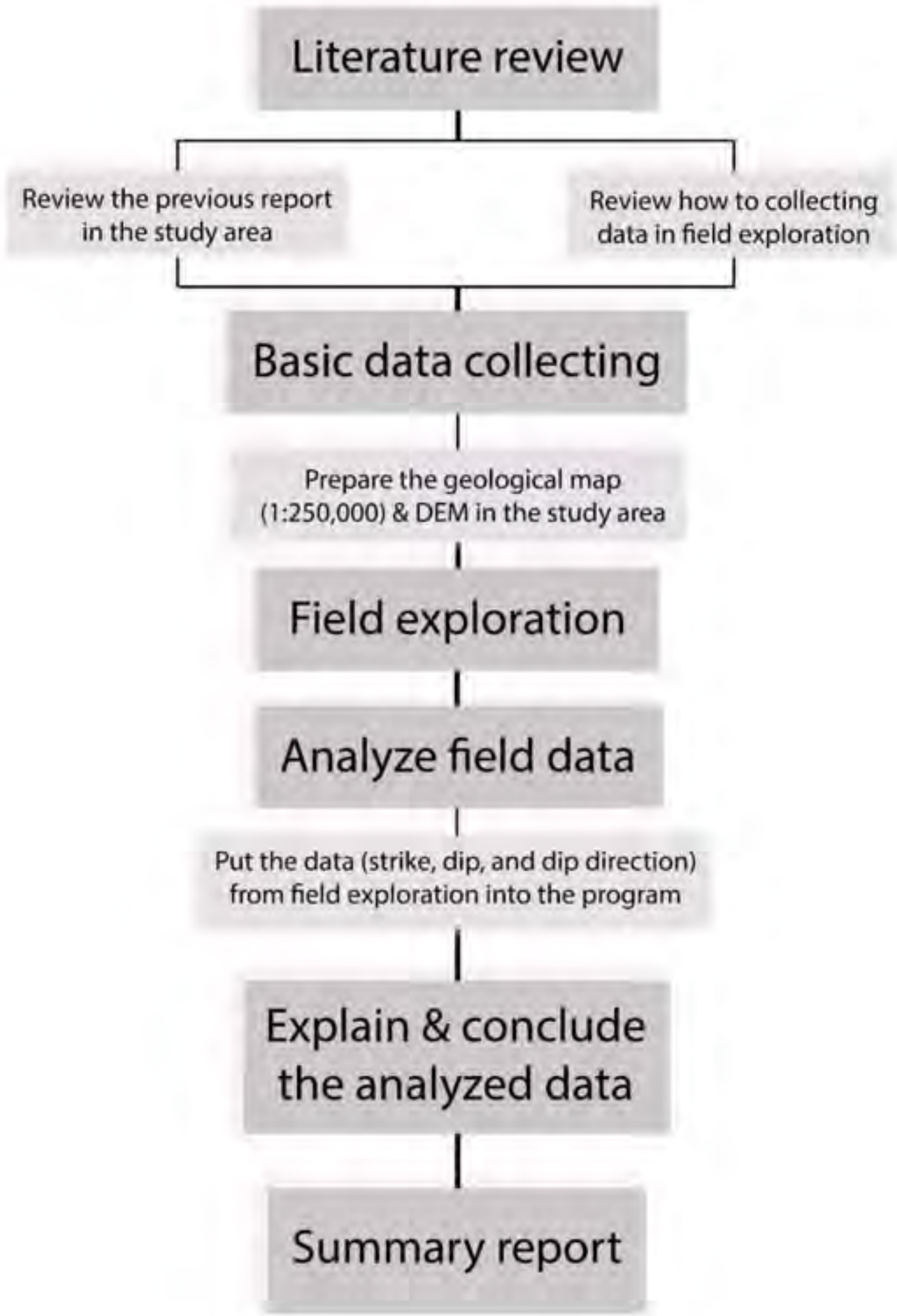

Fig 2.7 Researcher's work flow

Chapter 3 Results

Chapter 3

The result of 8 road-cut outcrops, from east to west along highway no. 2196, from field exploration. So, they can be divided into 2 parts, which are Lithology and Structural geology.

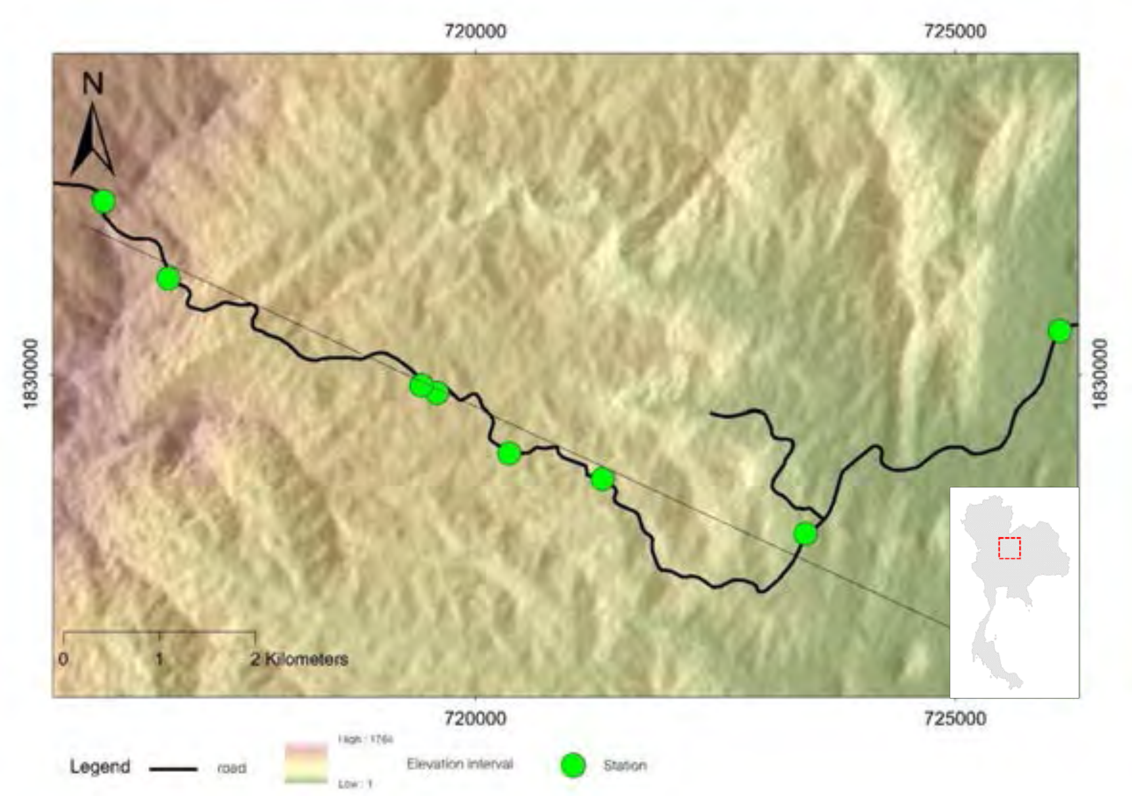

Fig 3.1 Digital Elevation Map (scale 1:15 m) of the study area**.** Low area is green and high area is pink

3.1 Lithology

The lithology along the road that we collect data is grey to black tuff. These rocks laid down in the N-S trends. Their beds are sub-vertical to vertical (very steep dip angle) and has approximately 10-30 cm thick (Fig. A and B). Their clasts are hornblende, plagioclase and some pyroxene. They also poorly sorted, low sphericity and angular to sub-angular roundness (Fig. C and D).

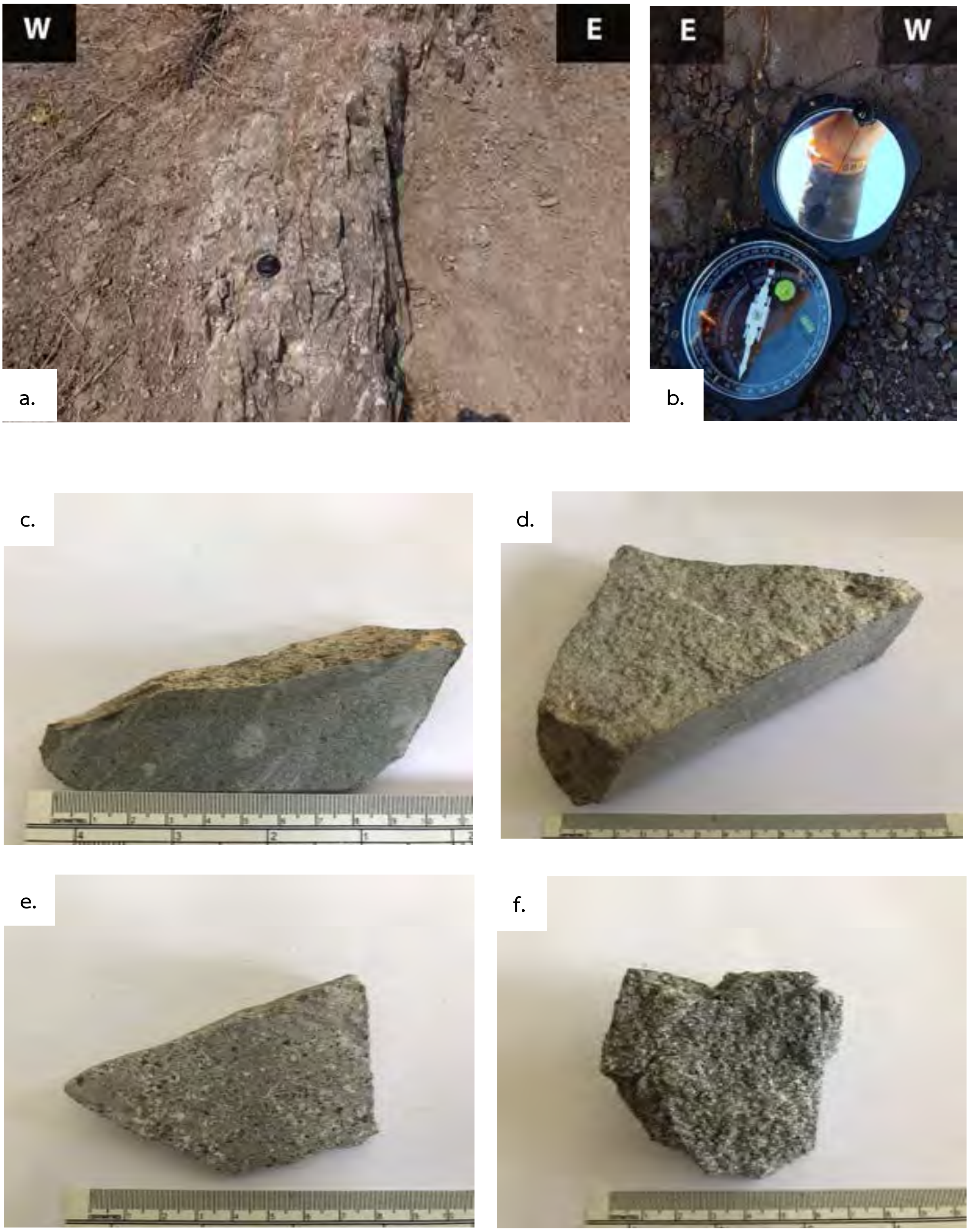

Fig 3.2 Rock sample and bedding in the study area. (a) and (b) show bedding of rocks in the study area. (c), (d), (e) and (f) are rock sample of study area

From the results in the thin section showed that these rocks have hornblende 25– 30%, plagioclase 55%, chlorite 15% and olivine 1% or less. In addition, they showed opening fractures which is filled by silica and plagioclase.

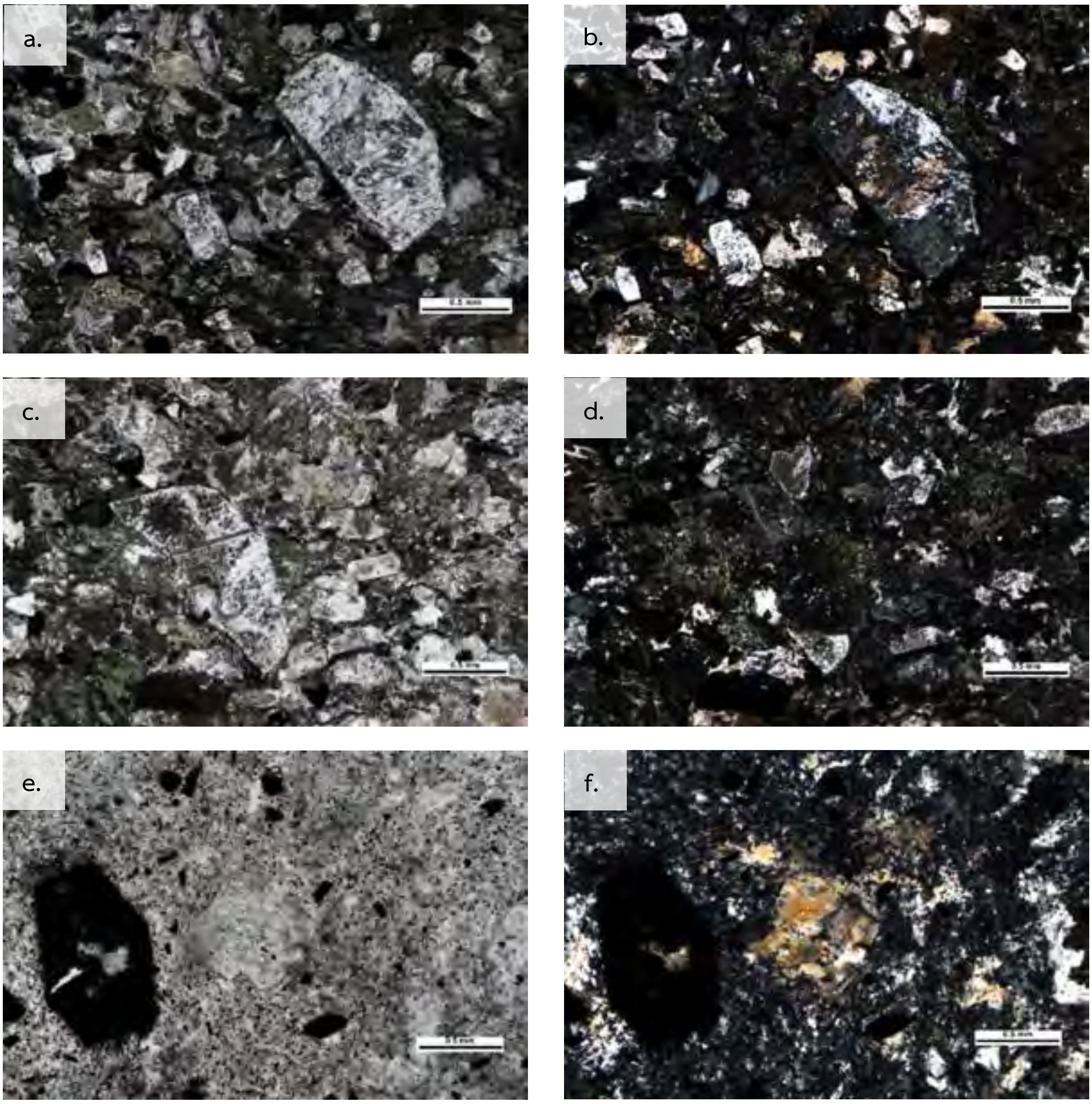

Fig 3.3 Thin sections. (a), (c) and (e) are PPL. (b), (d) and (f) are XPL

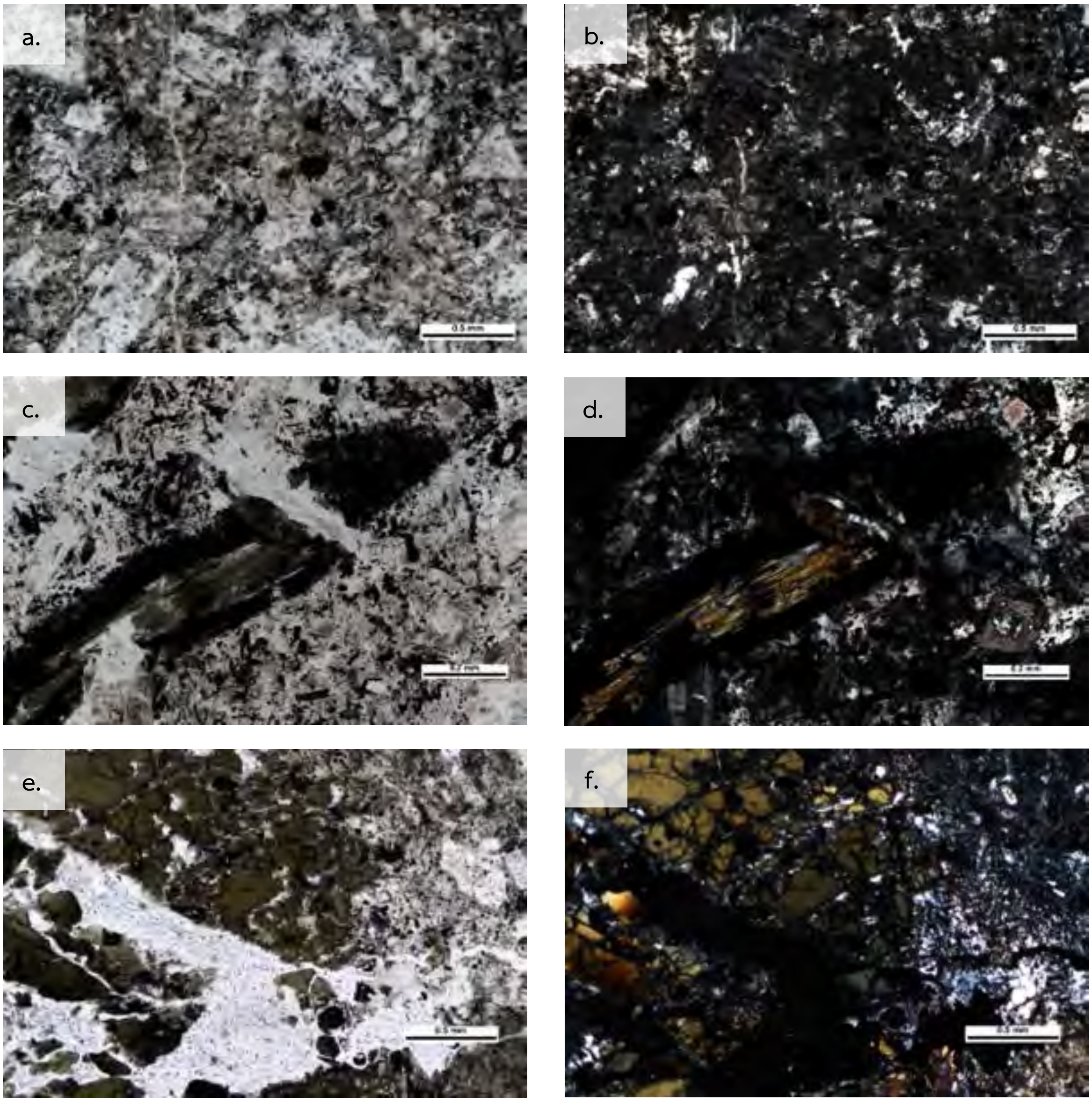

Fig 3.4 Thin sections. (a), (c) and (e) are PPL. (b), (d) and (f) are XPL

3.2 Structural geology

3.2.1 Fracture

Almost of the rocks from the field obsevation have 2 main trends, which are North to South and Northwest to Southeast direction, and also found the 2 joint sets in the same trends. The fracture of each station is presented in the following below.

Station 1

Station 1 is located in the eastern most of the study area. Outcrop is more than 10 meters long and 3 meters high. Fractures in this station are East to West direction. There are opening mode fracture, joint sets, and sliding mode fracture, Trust fault. The Fault has dip angle around 15 to 30.

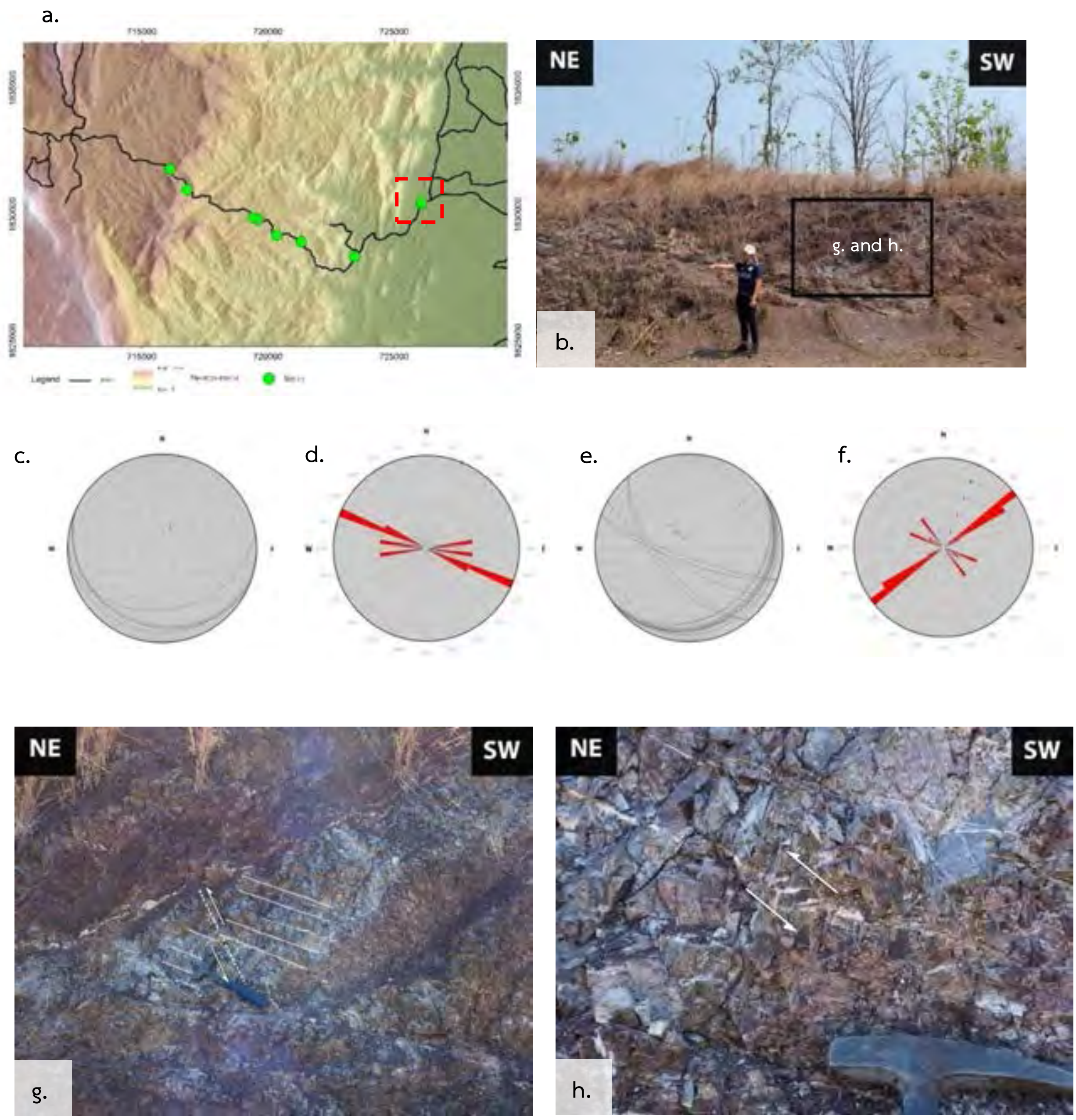

Fig 3.5 The outcrop station 1. (a) location in the dem map. (b) overview of outcrop in the station. (c) and (d) stereonet and rose diagram of fractures. (e) and (f) stereonet and rose diagram of joints. (g) and (f) joint sets and sense of movement.

Station2

Station 2 far from station 1 around 2 kilometers. Outcrop is 5 meters long and 3 meters high. Fractures in this station are North to South direction. There are 3 joint sets.

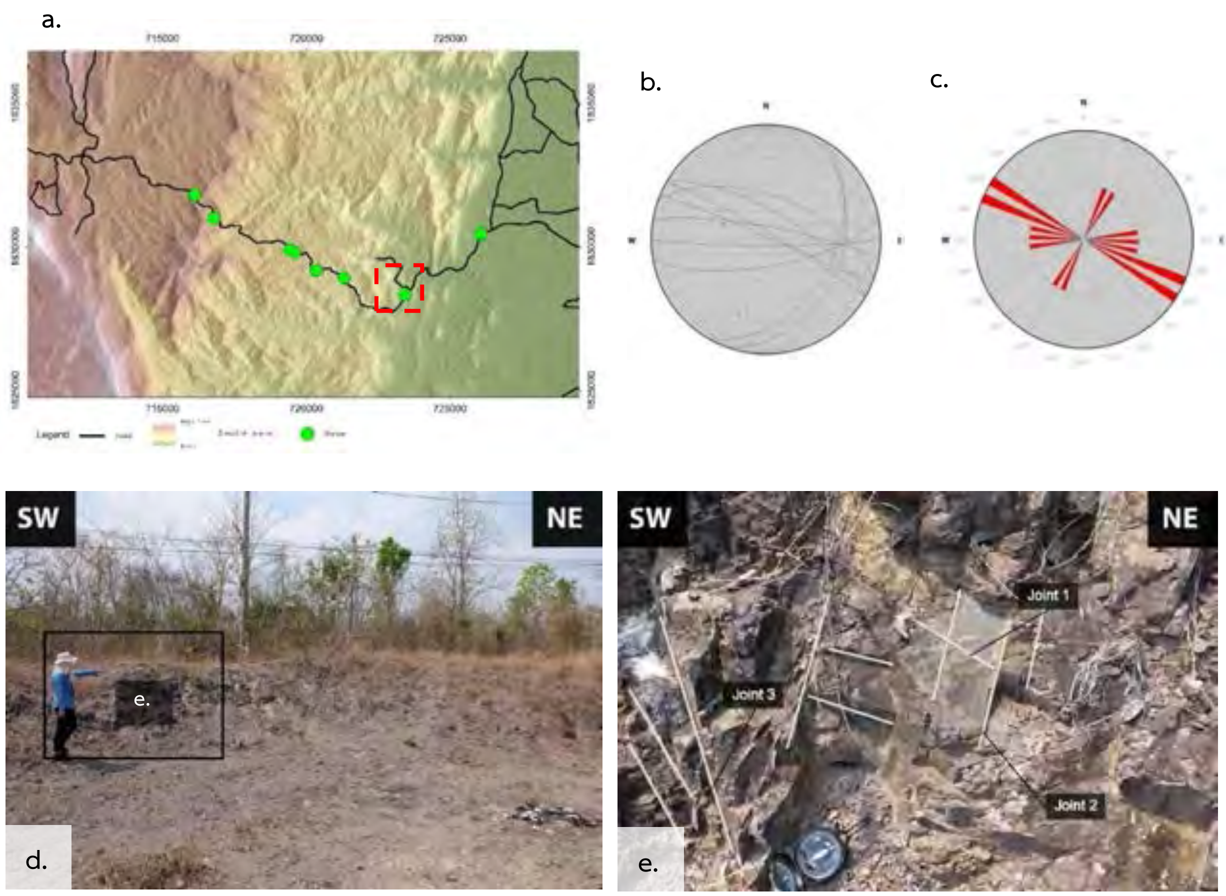

Fig 3.6 The outcrop station 2. (a) location in the dem map. (b) and (c) stereonet and rose diagram of joints. (d) overview of outcrop. (e) orientation of joint sets at outcrop.

Station 3

Station 3 far from station 2 around 1 kilometer. Outcrop is more than 50 meters long and 5 meters high. Fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, Normal fault. The Fault has dip angle around 60 to 80.

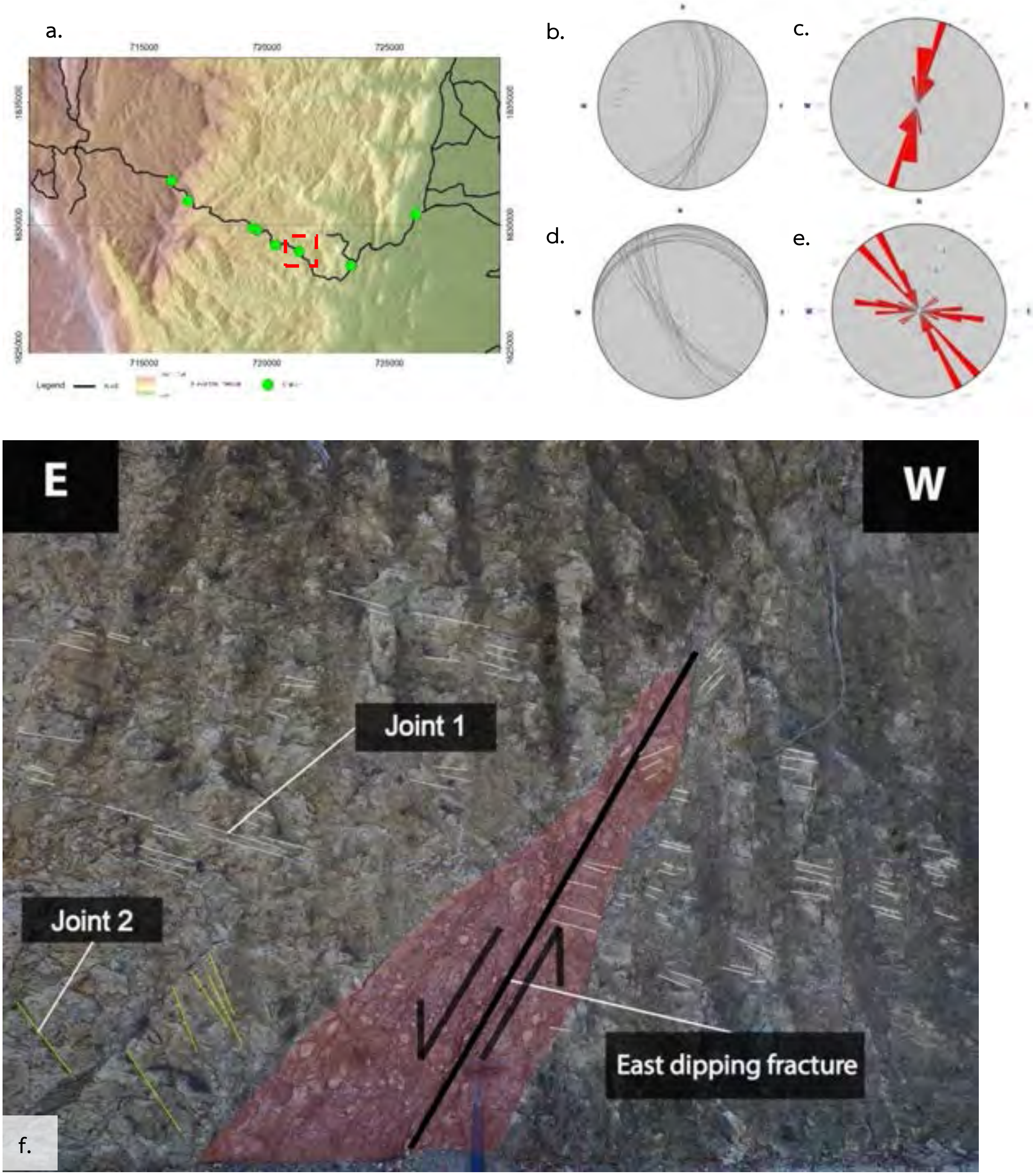

Fig 3.7 The outcrop station 3. (a) location in the dem map. (b) and (c) stereonet and rose diagram of fractures. (d) and (e) stereonet and rose diagram of joints. (f) orientation of joint sets, fracture and sense of movement.

Station 4

Station 4 far from station 3 around 500 meters. Outcrop is 20 meters long and 7 meters high. Fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, Normal fault and Thrust fault. The Faults have dip angle around 10 to 60.

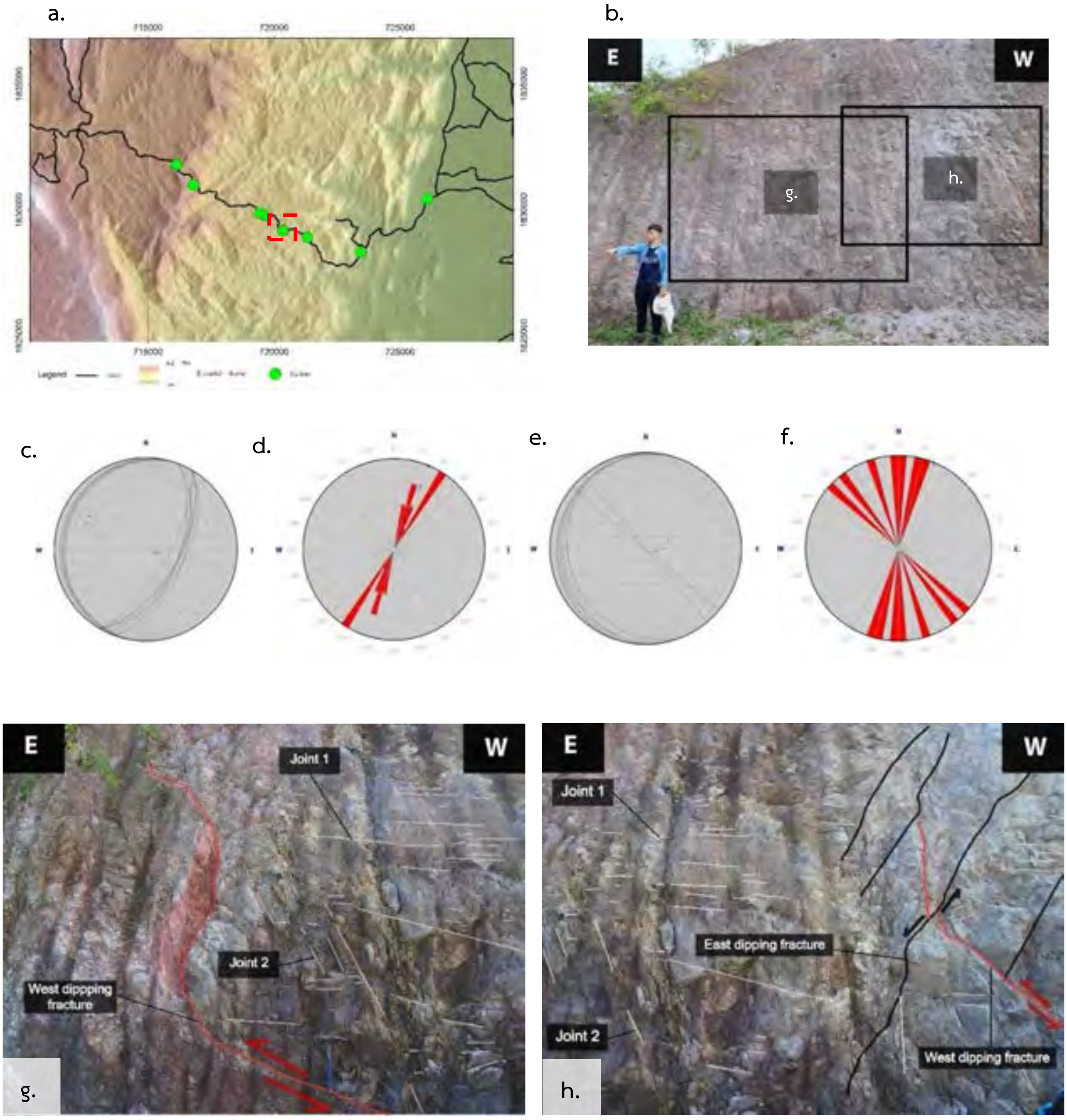

Fig 3.8 The outcrop station 4. (a) location in the dem map. (b) overview structural detail of outcrop. (c) and (d) stereonet and rose diagram of fractures. (e) and (f) stereonet and rose diagram of joints. (g) and (f) joint sets, east dipping fracture, west dipping frature and sense of movement.

Station 5

Station 5 far from station 4 around 500 meters. Outcrop is more than 20 meters long and 10 meters high. Most of fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, Normal fault and Thrust fault. The Faults have dip angle around 10 to 85.

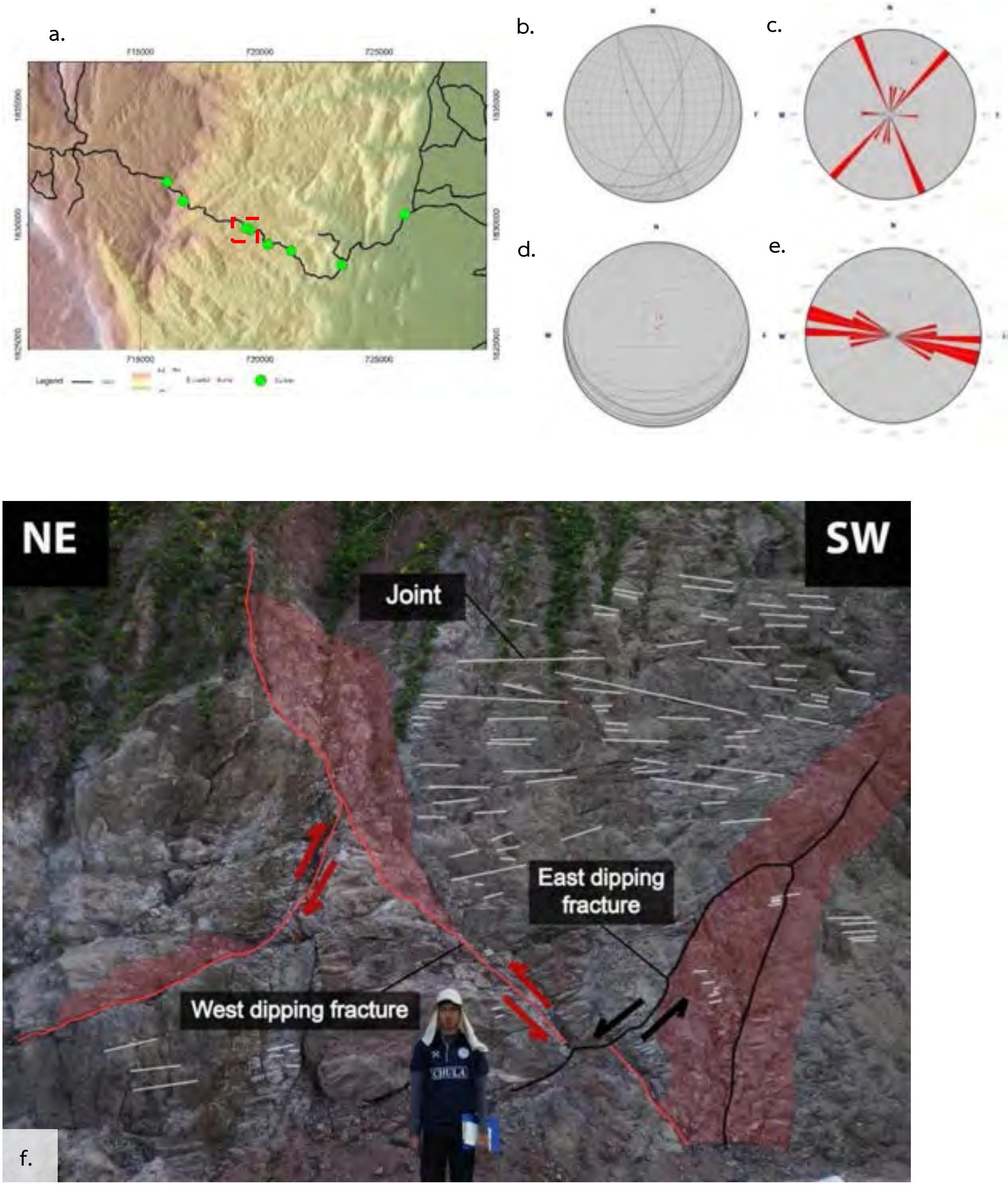

Fig 3.9 The outcrop station 5. (a) location in the dem map. (b) and (c) stereonet and rose diagram of fractures. (d) and (e) stereonet and rose diagram of joints. (f) orientation of joint sets, east dipping fracture, west dipping fracture and sense of movement.

Station 6

Station 6 is very close to station 5. It far from station 5 around 100 meters. Outcrop is more than 20 meters long and 10 meters high. Most of fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, fault. The Fault have dip angle around 65 to 85.

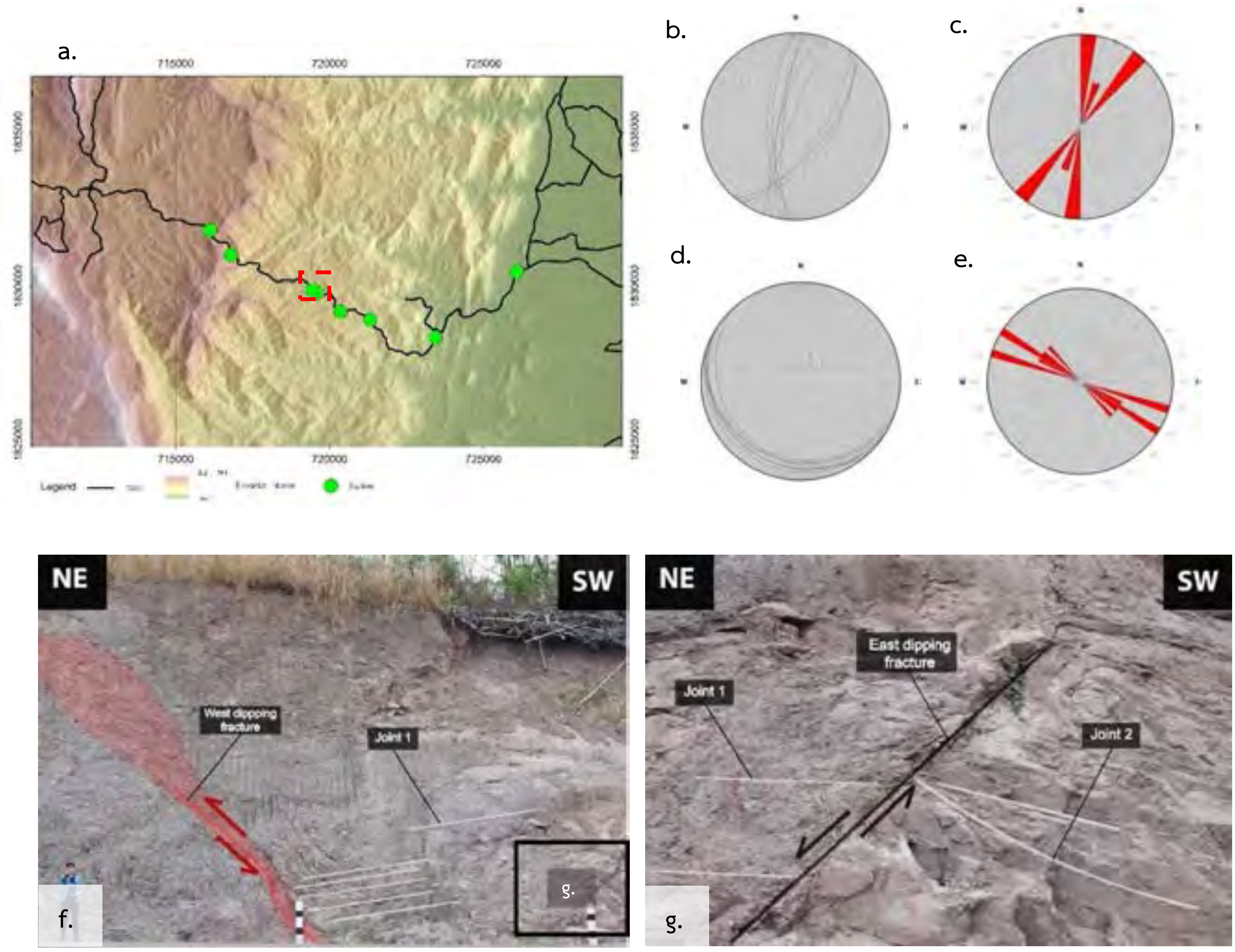

Fig 3.10 The outcrop station 6. (a) location in the dem map. (b) and (c) stereonet and rose diagram of fractures. (d) and (e) stereonet and rose diagram of joints. (f) orientation of joint sets, west dipping fracture and sense of movement. (g) joint sets, east dipping fracture and sense of movement.

Station 7

Station 7 far from station 6 around 2 kilometers. Outcrop is more than 10 meters long and 10 meters high. Fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, fault. The Faults have dip angle around 15 to 30.

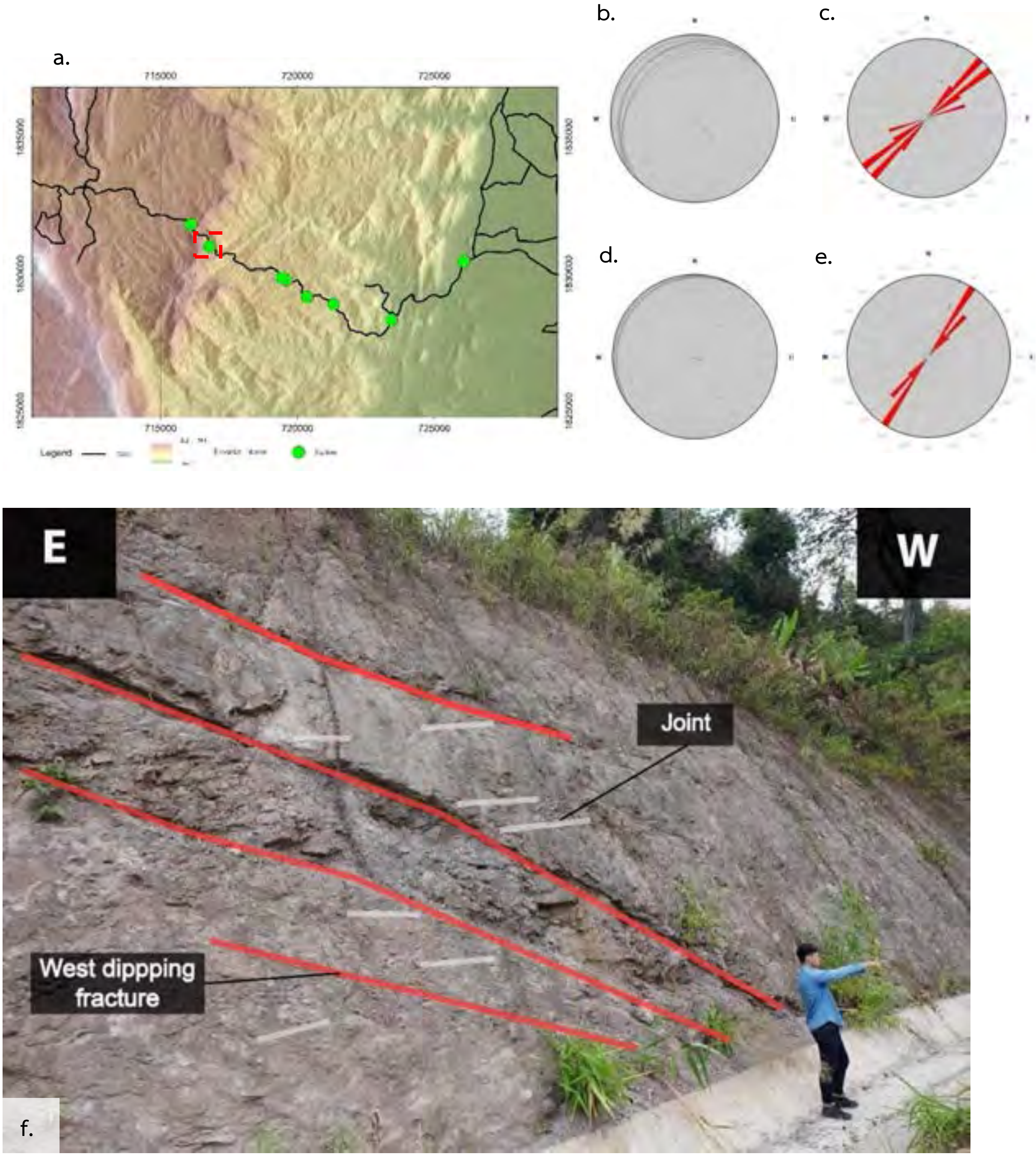

Fig 3.11 The outcrop station 7. (a) location in the dem map. (b) and (c) stereonet and rose diagram of fractures. (d) and (e) stereonet and rose diagram of joints. (f) orientation of joint sets and west dipping fracture.

Station 8

Station 8 is the last station. It far from station 7 around 1 kilometer. Outcrop is more than 20 meters long and 10 meters high. Fractures in this station are North to South direction. There are opening mode fracture, joint sets, and sliding mode fracture, fault. The Faults have dip angle around 10 to 30.

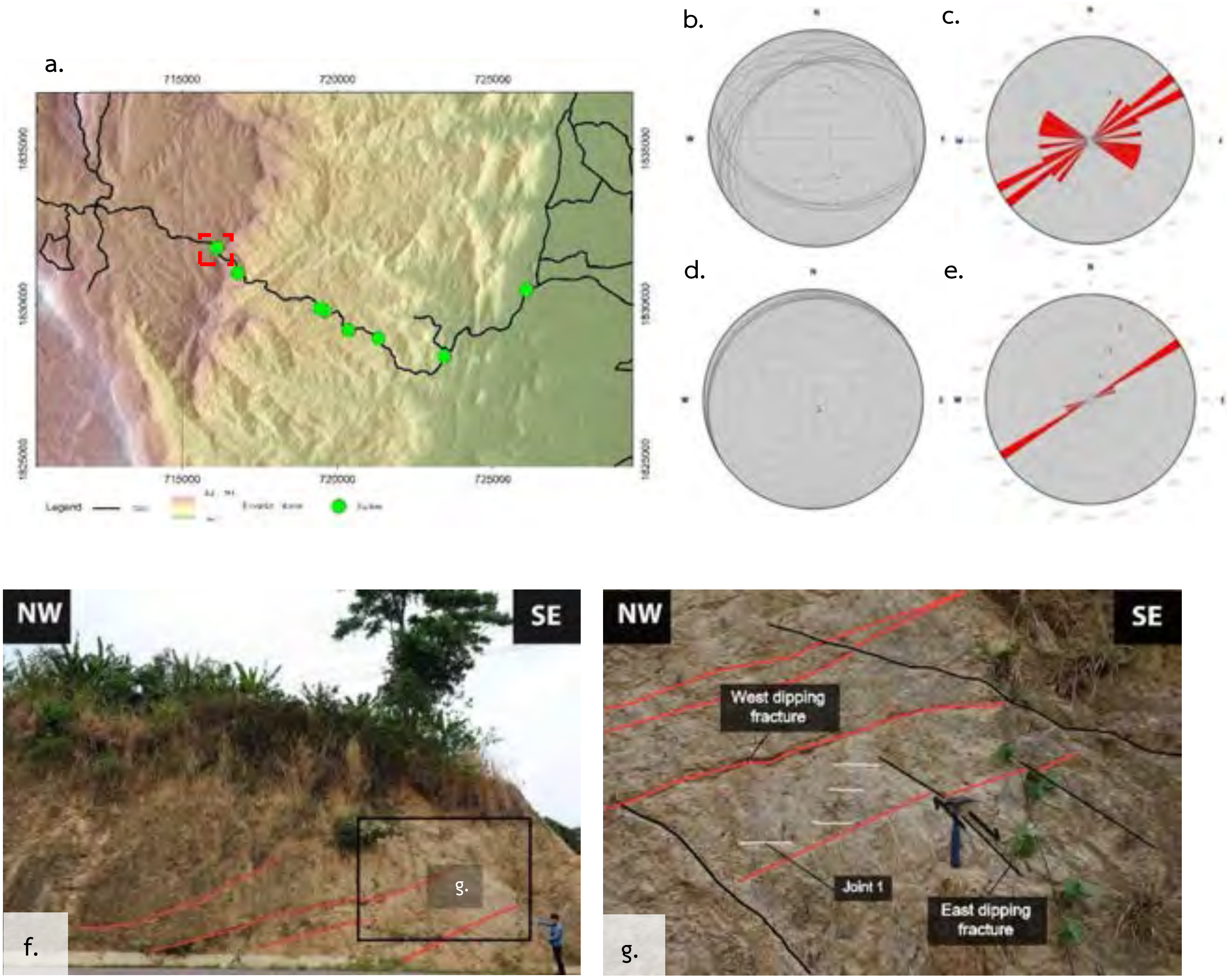

Fig 3.12 The outcrop station 8. (a) location in the dem map. (b) and (c) stereonet and rose diagram of fractures. (d) and (e) stereonet and rose diagram of joints. (f) overview structural detail of outcrop. (g) joint sets, west dipping fracture, east dipping fracture and sense of movement.

Chapter 4 Discussion

Chapter 4

From the 2 main results, Lithology and Structural geology, in chapter 3 can be explain in groups of fracture, structural style of fracture and evolution model of fracture along highway no.2196, Khao Kho district, Phetchabun province.

4.1 Groups of fracture

- **West dipping fractures**

The west dipping fracture are lying on N-S and NW-SE direction and have dip angle from 5° to 45°. They show movement and fractures that related them. They found in station 1, 4, 5, 6, 7 and 8.

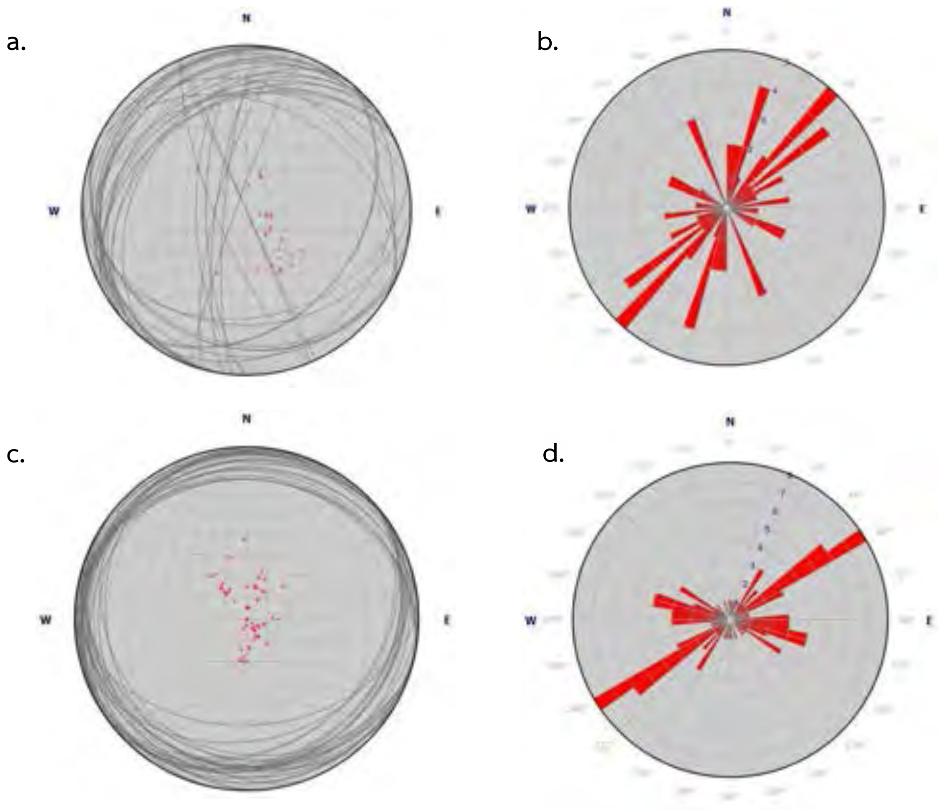

Fig 4.1 (a) stereonet data of west dipping fractures (40 data) in station station 1, 4, 5, 6, 7 and 8. (b) rose diagram of west dipping fractures in station 1, 4, 5, 6, 7 and 8. (c) stereonet data of joints (56 data) which is related west dipping fractures in station 1, 4, 5, 6, 7 and 8. (d) rose diagram of joints which is related thrust faults in station 1, 4, 5, 6, 7 and 8.

- **East dipping fractures**

The East dipping fractures are lying on N-W direction and have dip angle from 60° to 75°. They found in station 3, 4 and 5. They show movement and fractures that related them. The fractures also have high dip angle (Fig 4.4c).

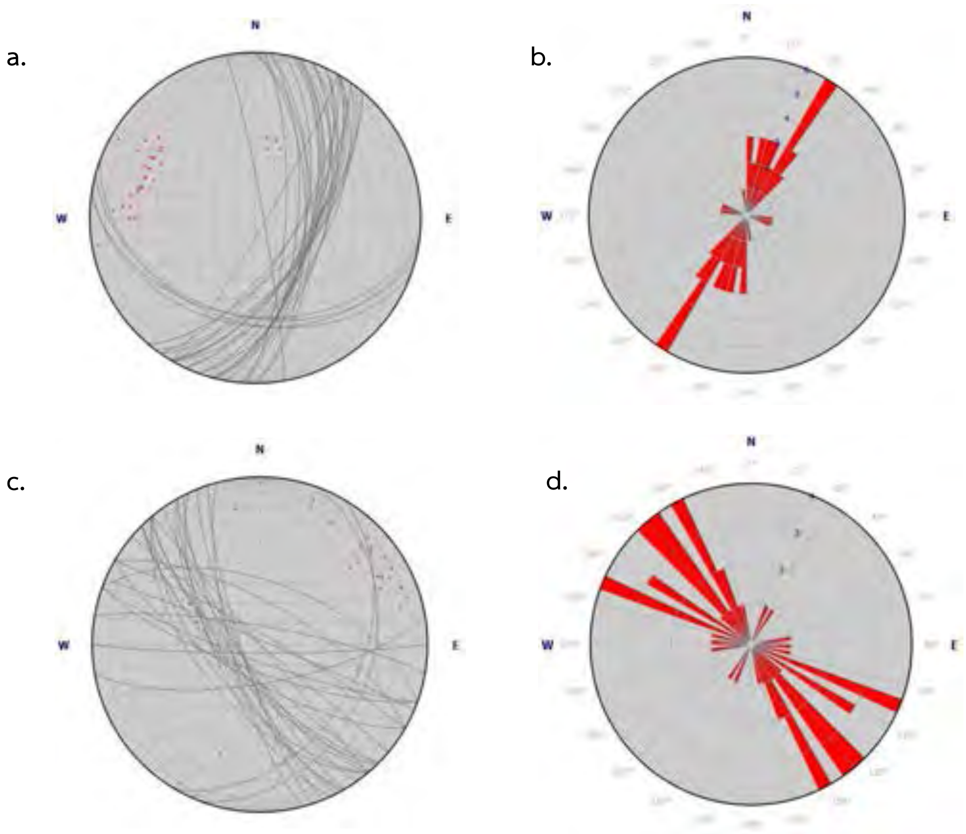

Fig 4.2 (a) stereonet of east dipping fractures (32 data) in station 3, 4 and 5. (b) rose diagram of east dipping fractures in station 3, 4 and 5. (c) stereonet of fractures (30 data) which are related east dipping fractures in station 3, 4 and 5. (d) rose diagram of fractures which is related east dipping fractures in station 3, 4 and 5.

4.2 Structural Style of fracture

The evidence of brittle deformation in the study area is 2 main groups fracture. **The first group** is West dipping fracture. They lie in Northeast-Southwest direction and have low dip angle (5-45 degree). Moreover, their movement is approximately from west to east. From the Anderson's classification (1950) suggested that there are reverse or thrust fault. But in the study area there were not actually reverse fault because they had a curve plane. So, the first group is Reverse fault with curve plane also call "Listric reverse fault". In addition, they have joints that also low angle. **The second group** is East dipping fracture. They lie in Northeast to Southwest direction. These fractures have very high dip angle. From the similarly Anderson's classification suggested that there are normal faults. These 2 groups fracture have cross cutting relationship. The reverse faults have displacement from effect of normal faults. So, many evidences indicated that normal faults were younger than reverse faults.

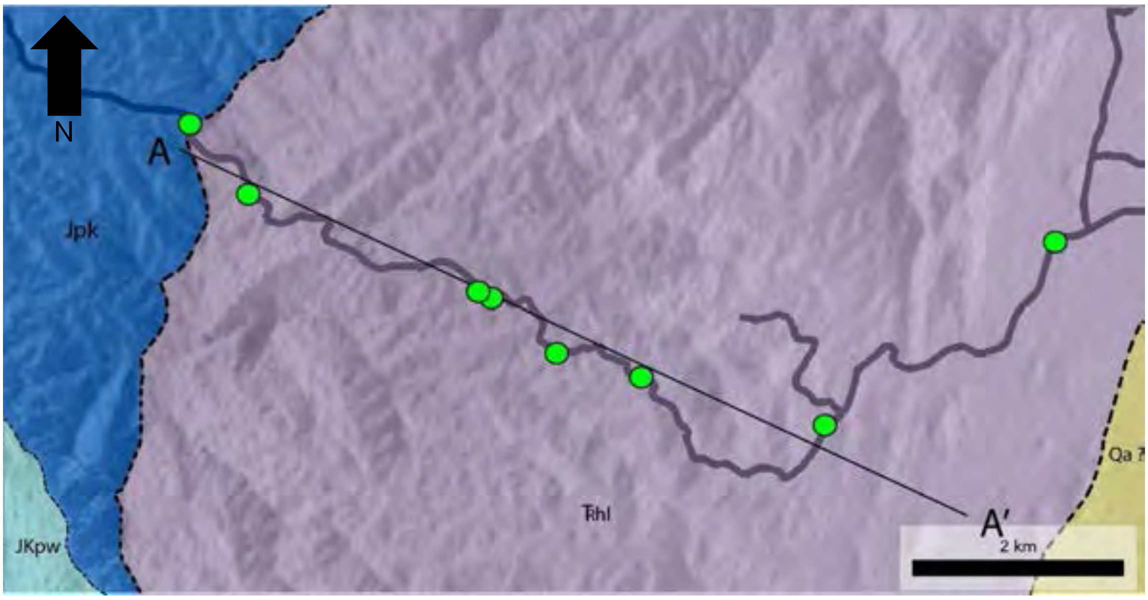

Fig 4.3 Rock units, stations and cross-section line in the study area.

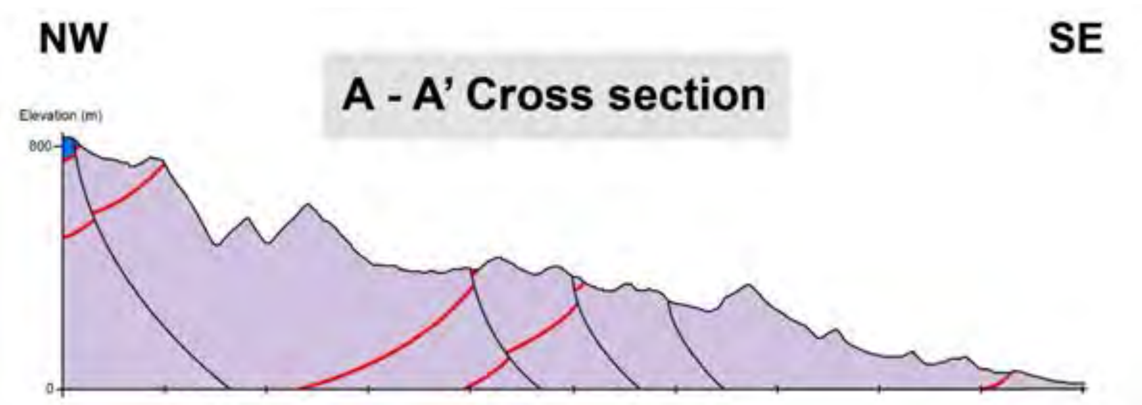

Fig 4.4 The A-A' cross-section profile

4.3 Evolution model of fracture

The evidence from all fractures and all analyzed data were take place in Huai Hin Lat formation that is in the Triassic. So, the relative age of fractures is 245 million years or earlier. They can be explained the evolution of them into 2 stages.

Stage I: Triassic

from Shan Thai sub-continent subducted into Indochina from west to east made compression force in E-W direction. This force made Indosinian orogeny. It also made first fracture group, which are reverse fault and low angle joint (opening mode fracture). These reverse faults have geometry like listric fault (Fig 25).

Stage II: Oligocene to Miocene

This period happened in Oligocene to Miocene. The effect from the strike-slip in this period ceased from the evidence of ramp-flat detachment in Pattani basin, one of Tertiary basins in Thailand. So, the Phetchabun basin and others Tertiary basins in Thailand was formed by intra-continental extension caused by subduction rollback under continental crust in the beginning of Oligocene. Moreover, these tension forces created the normal faults in the study area (Fig 26).

Stage I: Triassic

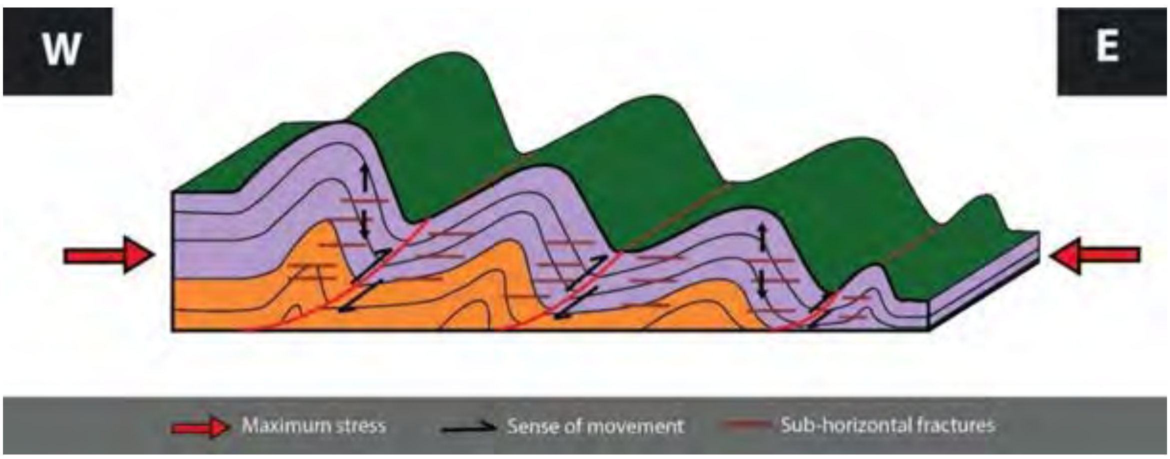

Fig 4.5 Evolution of fracture stage I

Stage II: Oligocene to Miocene

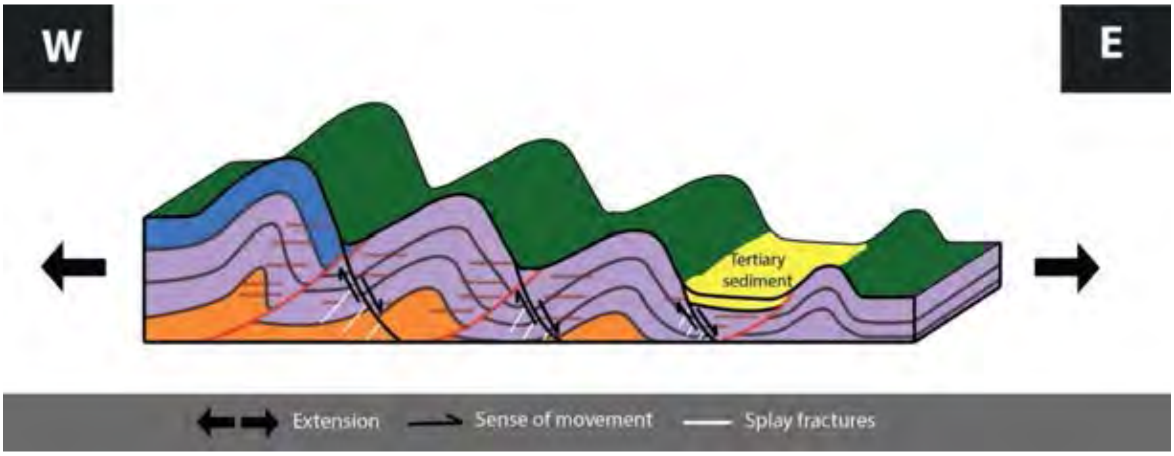

Fig 4.6 Evolution of fracture stage II

Chapter 5 Conclusion

Chapter 5

Conclusion

From the result in the field exploration and the analyzed data which is showed into rose diagram and stereonet and discussion about structural style and evolution of fractures along the highway no.2196, Kho-Kho district, Phetchabun province can be summarized from these following.

- The rocks in study area are suggested to be Huai Hin Lat formation in the geological map. It is grey to black tuff with sub-vertical bedding and can be correlated to andesitic tuffs of Jungyusuk & Khositanont (1992).
- Fractures in the study area can be divided into 2 groups, normal faults and reverse faults. The Normal faults have high dip angle, dipping to the east and have splay fracture. Reverse faults have low dip angle, dipping to the west and have related joints which also have low angle.
- The Evolution of fractures can be separated into 2 stages as follows;
    - Stage I: Triassic (E-W compression) created the Loei Fold Belt, reverse faults and low dip angle joints.
    - Stage II: Oligocene to Miocene (E-W extension) created Tertiary basin in Thailand and normal faults.

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Appendix

St1	Strike	Dip direction	Dip angle
Reverse fault	115	205	18
	80	170	35
	110	200	20
	112	202	18
	95	185	12
Joint1	60	150	16
	50	140	19
	50	140	26
	55	145	20
	50	140	16
	50	140	15
	55	145	26
	55	145	15
	50	140	18
	55	145	10
Joint2	140	230	65
	140	230	60
	110	200	77
	120	210	73
	110	200	82
Bed	348	78	85
	355	85	83
	5	95	85

St2	Strike	Dip direction	Dip angle
Joint1	300	30	85
	280	10	81
	300	30	70
	293	23	88
	290	20	59
Joint2	20	110	33

	30	120	40
Joint3	80	170	71
	90	180	86

St3	Strike	Dip direction	Dip angle
Normal Fault	20	110	60
	30	120	62
	35	125	60
	25	115	63
	5	95	65
	350	80	86
	5	95	69
	15	105	60
	15	105	55
	0	90	65
	15	105	61
	13	103	62
	14	104	62
	3	93	75
Joint1	280	10	15
	265	355	14
	230	320	15
	240	330	5
	275	5	3
	265	355	13
	270	0	20
	275	5	20
	275	5	18
	290	20	5
	280	10	20
Joint2	151	241	72
	139	229	77
	155	245	68
	135	225	74
	136	226	72

	153	243	76
	165	255	76
	162	252	81
	150	240	80
	135	225	80
	140	230	75
	150	240	70
	145	235	80
	158	248	80

St4	Strike	Dip direction	Dip angle
Reverse Fault	195	285	7
	196	286	13
	195	285	10
	190	280	12
	190	280	10
Normal fault	30	120	70
	25	115	60
	20	110	60
	30	120	61
	31	121	60
	30	120	55
	20	110	55
Joint1	177	267	12
	193	283	9
	198	288	8
	161	251	20
	180	270	15
Joint2	130	220	90
	140	230	90
Bed	160	250	90
	165	255	90

St5	Strike	Dip direction	Dip angle
Reverse fault 1	40	130	32
	90	180	31
	42	132	32
	40	130	15
Reverse fault 2	157	247	75
	155	245	90
	157	247	90
Normal fault	30	120	85
	0	90	62
	10	100	65
Joint1	88	178	38
	75	165	30
	90	180	15
	90	180	5
	100	190	5
	102	192	5
	110	200	15
	105	195	16
	120	210	10
	105	195	15

St6	Strike	Dip direction	Dip angle
Fault1	180	270	65
	180	270	70
	185	275	79
	200	290	85
	195	285	75
	188	278	75
Fault2	40	130	65
	35	125	70
	40	130	65
	37	127	60
Joint1	138	228	23
	107	197	20

	115	205	20
	120	210	10
	125	215	15
	120	210	15
	108	198	23

St7	Strike	Dip direction	Dip angle
Fault1	215	305	15
	220	310	15
	220	310	23
	235	325	29
	231	321	15
	230	320	25
	250	340	6
Joint1	220	310	0
	225	315	5
	210	300	6
	214	304	0
	214	304	7
	220	310	0
	218	308	3

St8	Strike	Dip direction	Dip angle
Fault1	225	315	32
	215	305	34
	240	330	34
	230	320	35
	242	332	35
	230	320	15
	245	335	30
	260	350	30
	295	25	35
	300	30	25

Fault2	100	190	35
	110	200	37
	105	195	40
	98	188	40
Joint1	250	340	10
	235	325	10
	235	325	7
	240	330	9
	237	327	10
	235	325	6