Basement rock structure and seepage analysis influences on dam foundation design: Khlong Kra Sae Project area, Bo Thong district, Chonburi province, Thailand.

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Content

1. Introduction
2. Geological investigation
3. Structural analysis and synthesis methods
4. Hydrogeological investigation
5. Finite element seepage analysis
6. Conclusions and discussion

1. Introduction

1. INTRODUCTION

Objective

- Analysis and synthesis rock structure in Klong Kra Sae Project, Bo Thong, Chonburi.
- Seepage analysis on foundation.

Expected Results

- Construction analysis and synthesis of rock structure modelling in project area.
- Analysis seepage zone on foundation.

1. Introduction

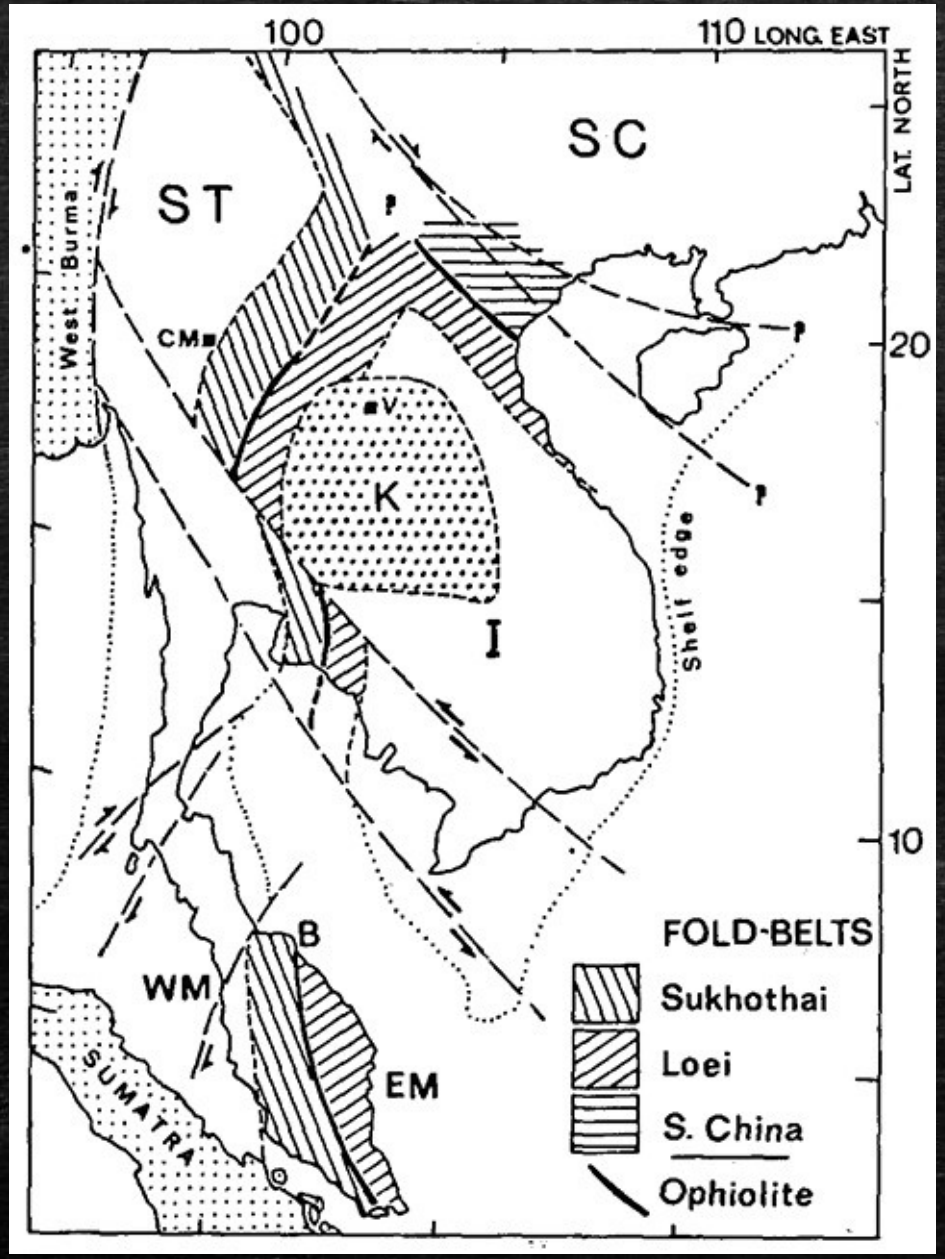


Plate Tectonic map of southeast Asia after plates collision

I = Indochina plate

ST= Shan-Thai Plate

SC = South-China, K = Khorat

CM = Chingmai, V = Vientiane

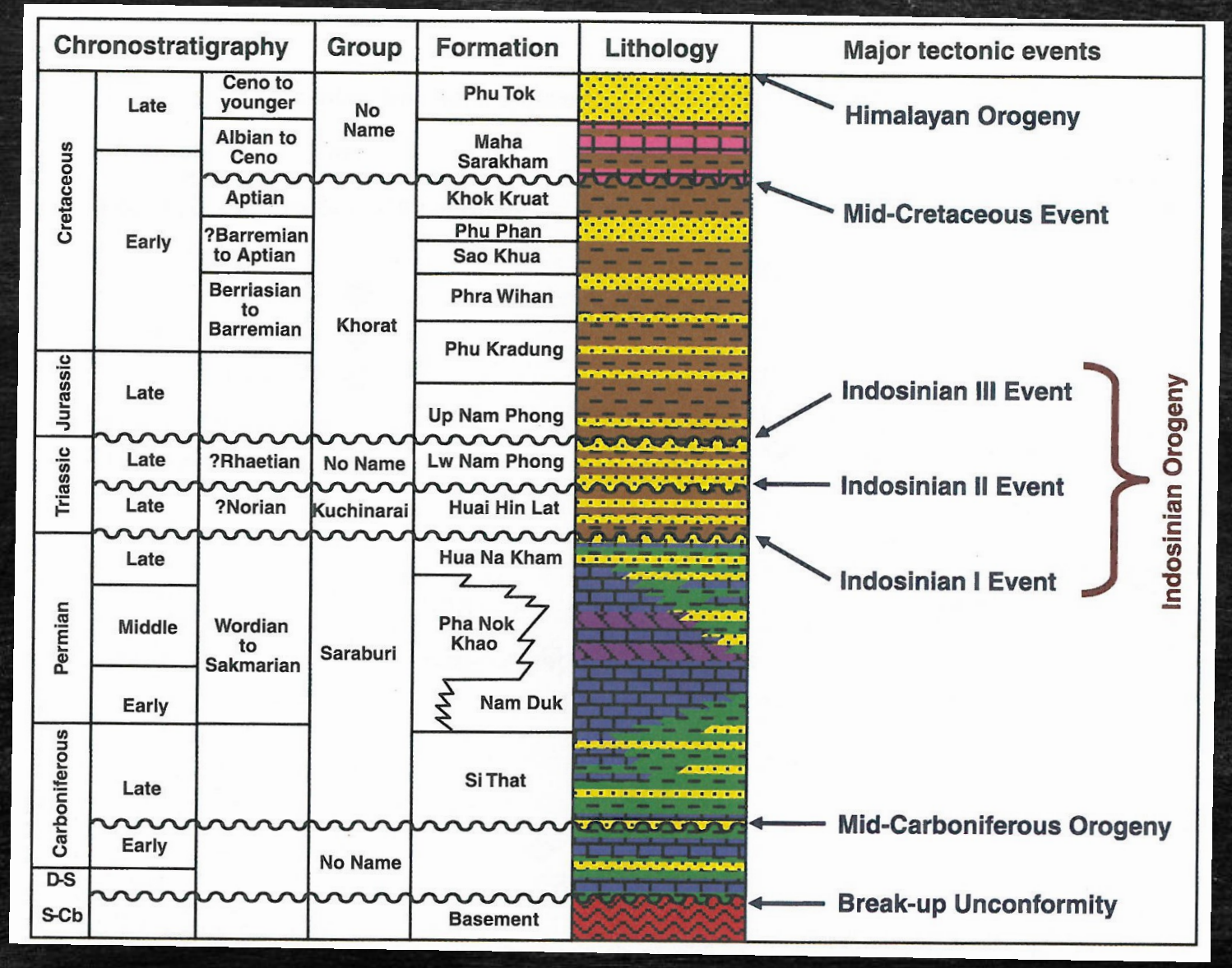
WM = West Malay Peninsular

EM = East Malay Peninsular,

B = Bentong Ophiolite line.

(after Bunopas, 1981)

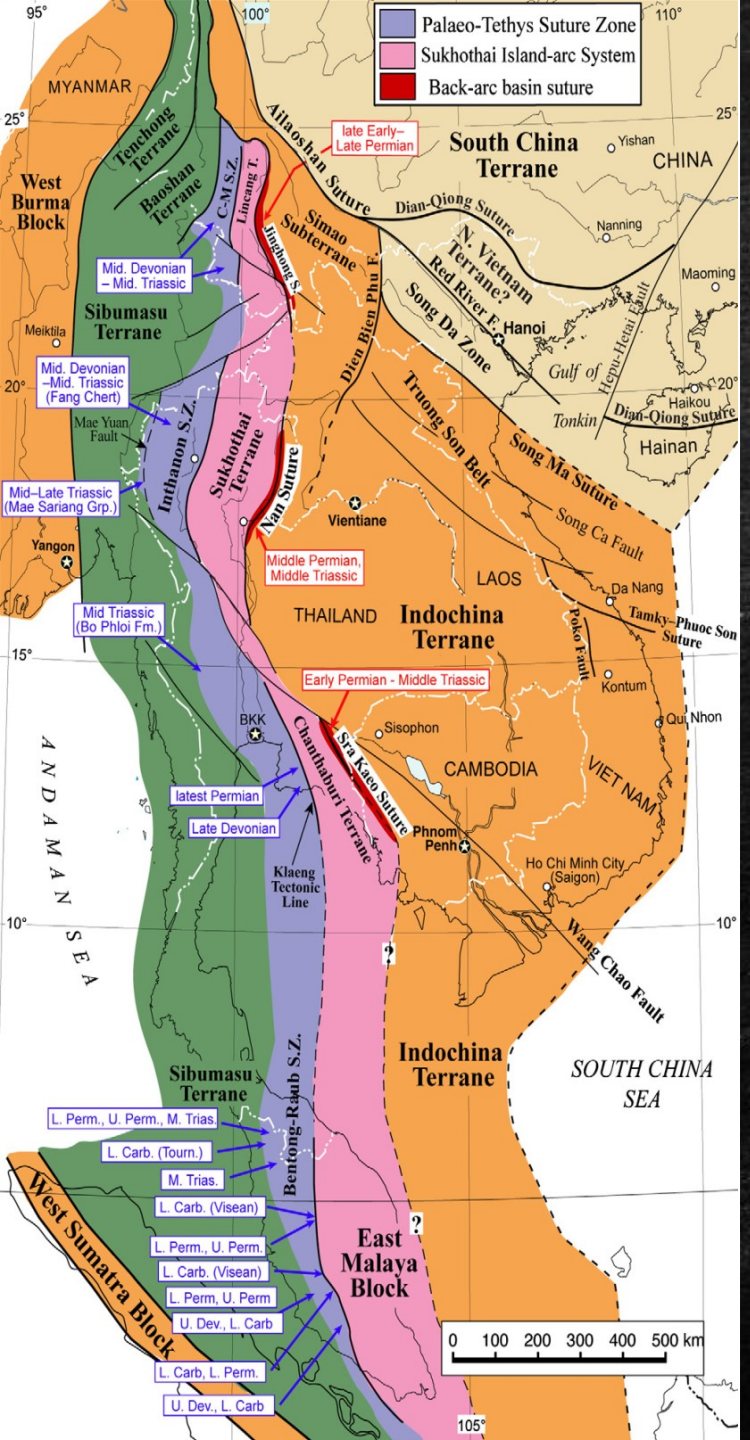
1. Introduction



OROGENY

(Booth and Sattayarak, 2011)

Indosinian Orogeny
(Devonian – Late Cretaceous)
(419 - 201 ma.)



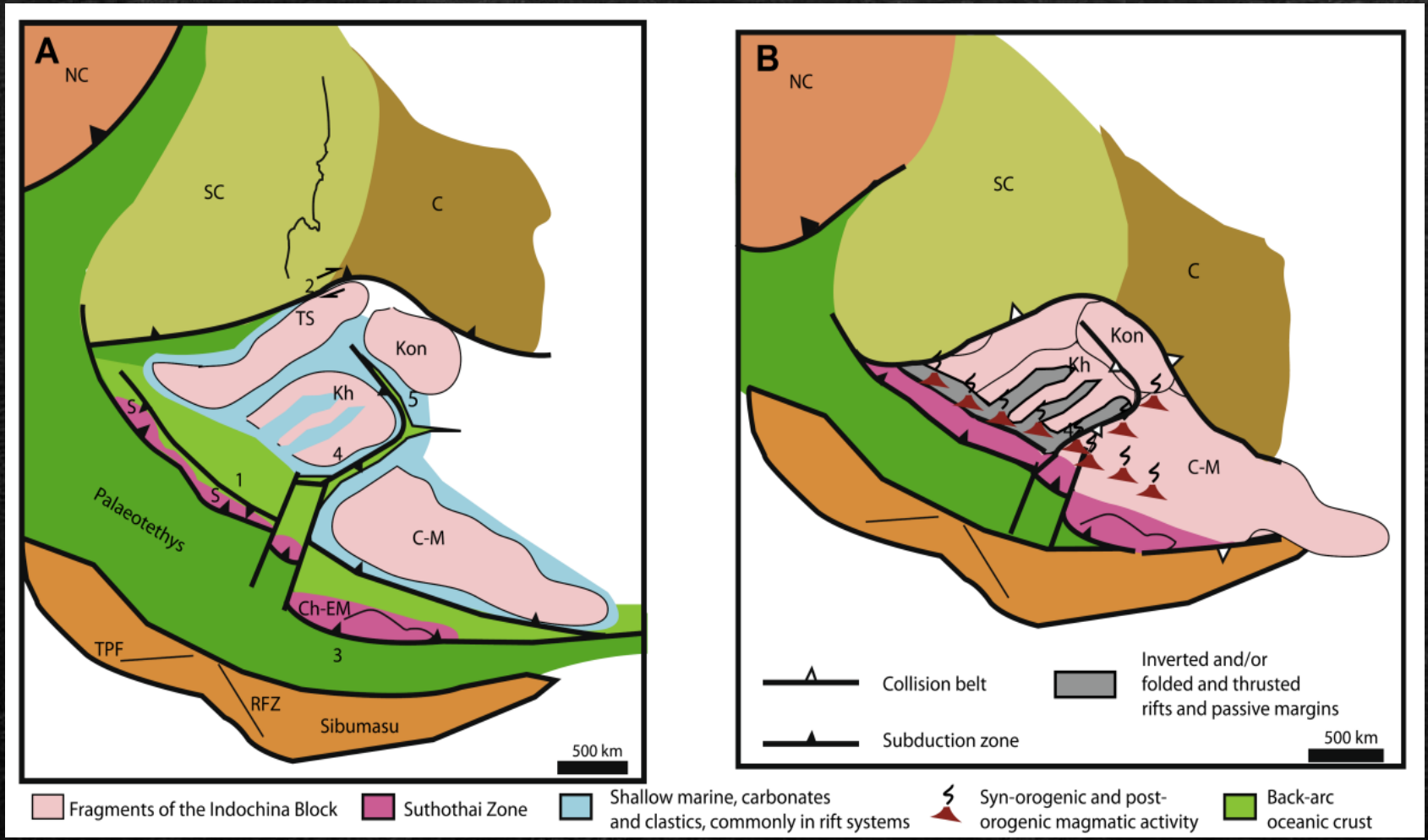
1. Introduction

Geotectonic evolution in Southeast Asia was divided by Tethyan to be 3 stage for instance;

1. Palaeo-Tethys = Devonian-Triassic
   (419 - 201 ma.)
2. Meso-Tethys = Late Early Permian-Late Cretaceous
   (272 - 66 ma.)
3. Ceno-Tethys = Late Triassic-Late Cretaceous
   (237 – 66 ma.)

(Modified after Metcalf, 2013)

1. Introduction



Rifting in the Khorat (A) Early Triassic (B) Middle Triassic,

NC=the North China,

SC=the South China,

C= Cathasian Block,

TS=Truong Son,

Kon=Kontum,

Kh=Khorat,

C-M=Cambodia, offshore Malaysia,

S=Shkhothai,

Ch-EM= Chanthaburi-East Malaysia.

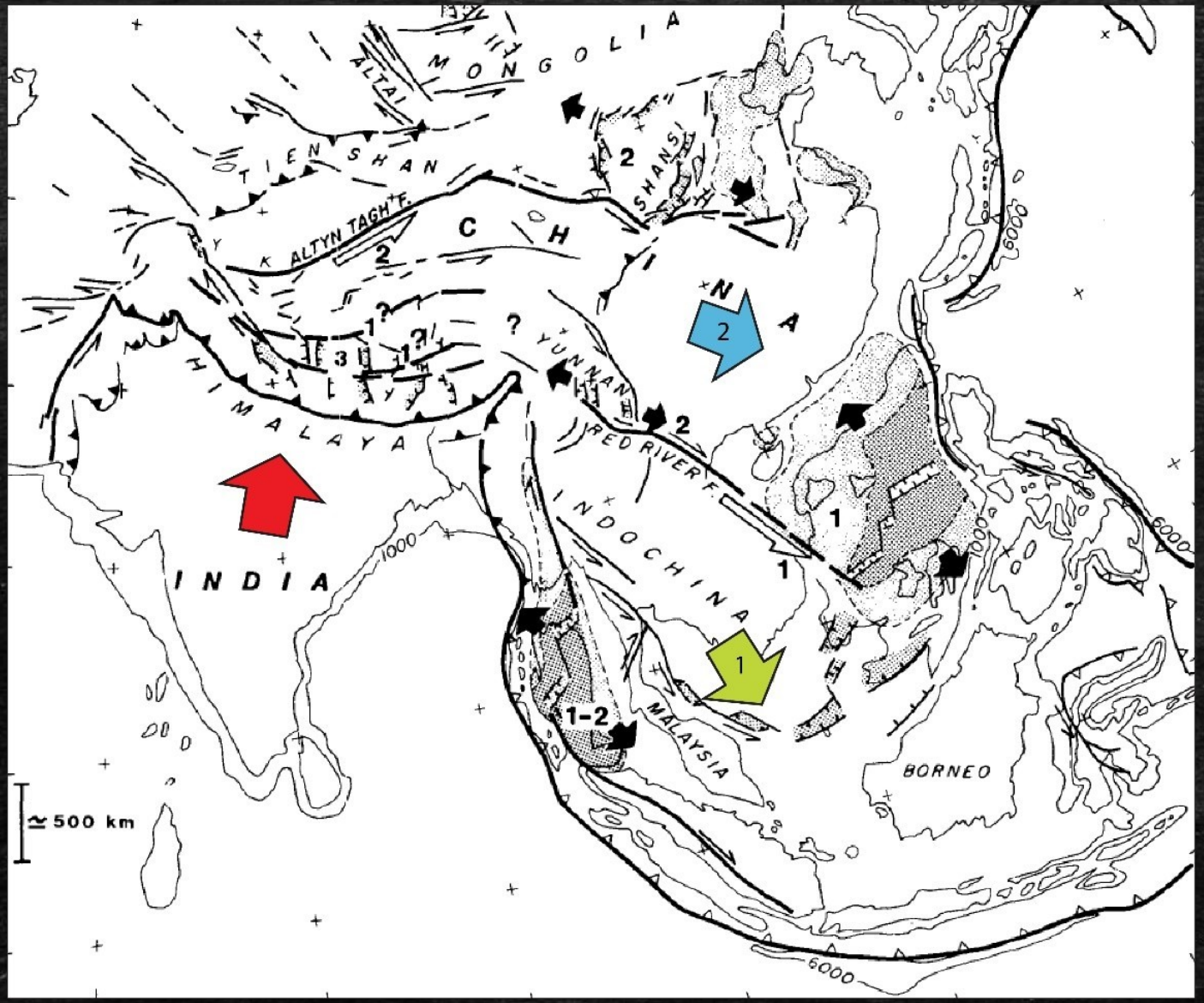
(Modified after Morley, 2013)

Himalayan Orogeny

(Cenozoic)

(66 ma. - recent)

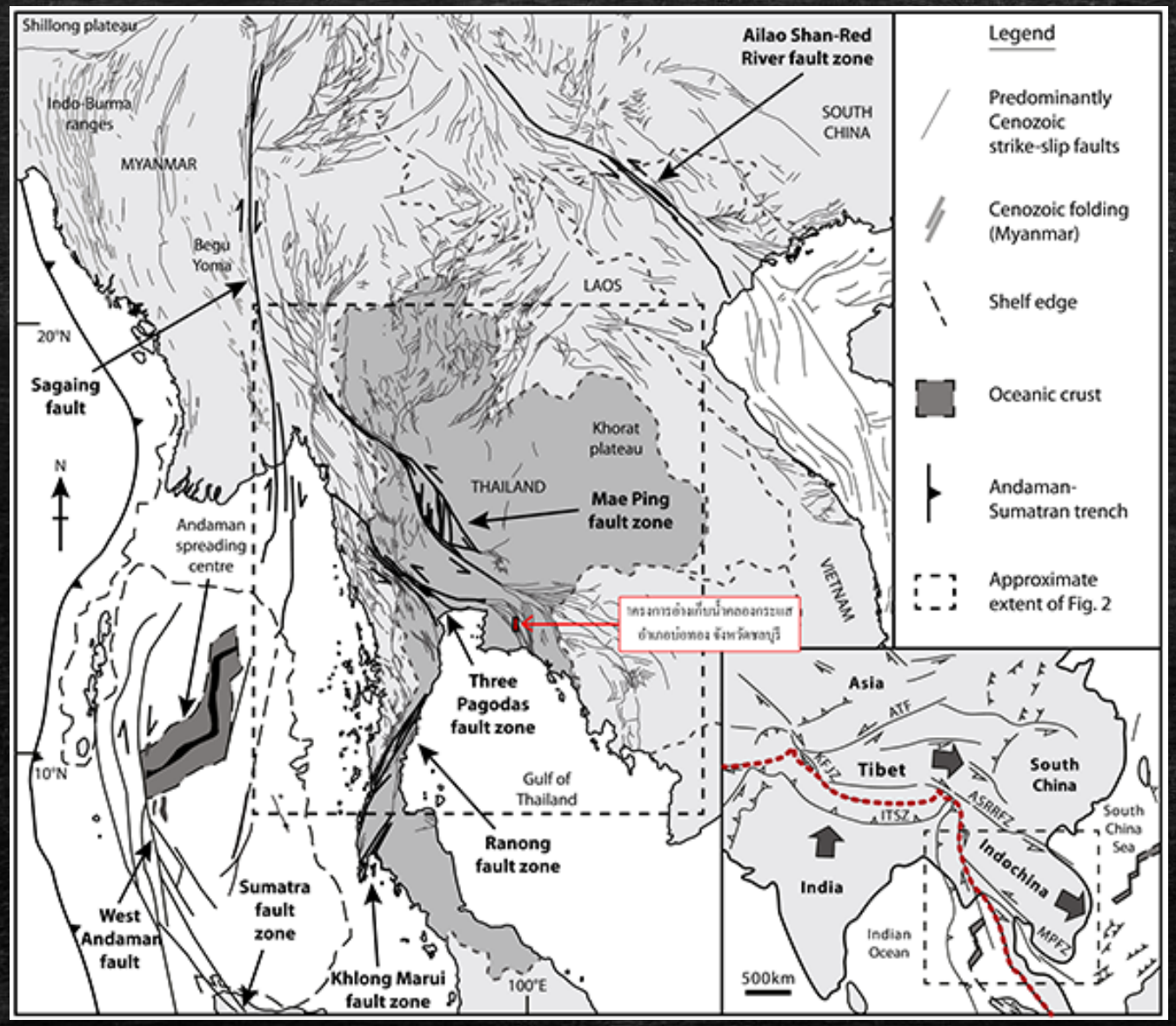
1. Introduction



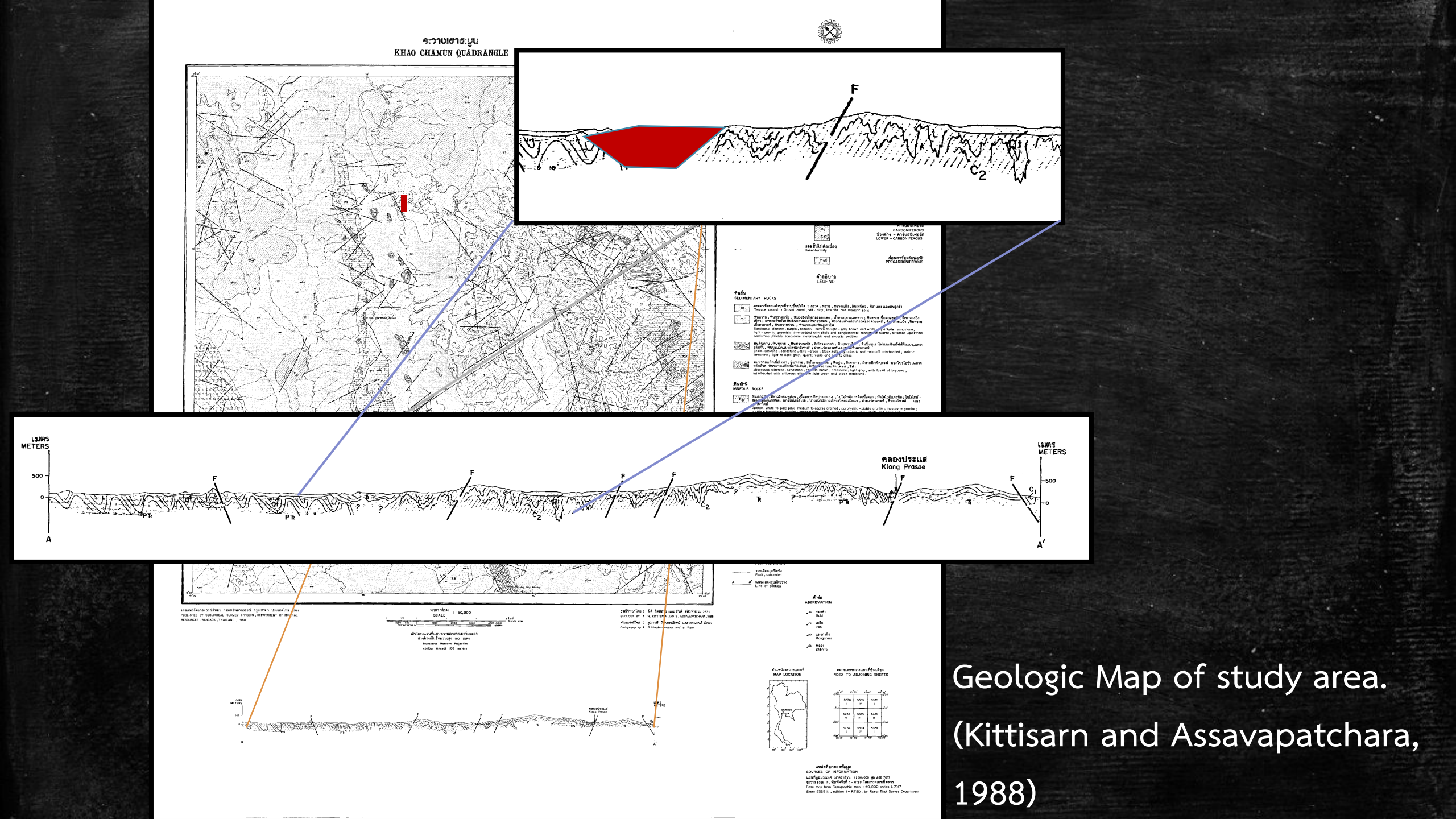
Himalayan Orogeny

(Tapponnier, 1986)

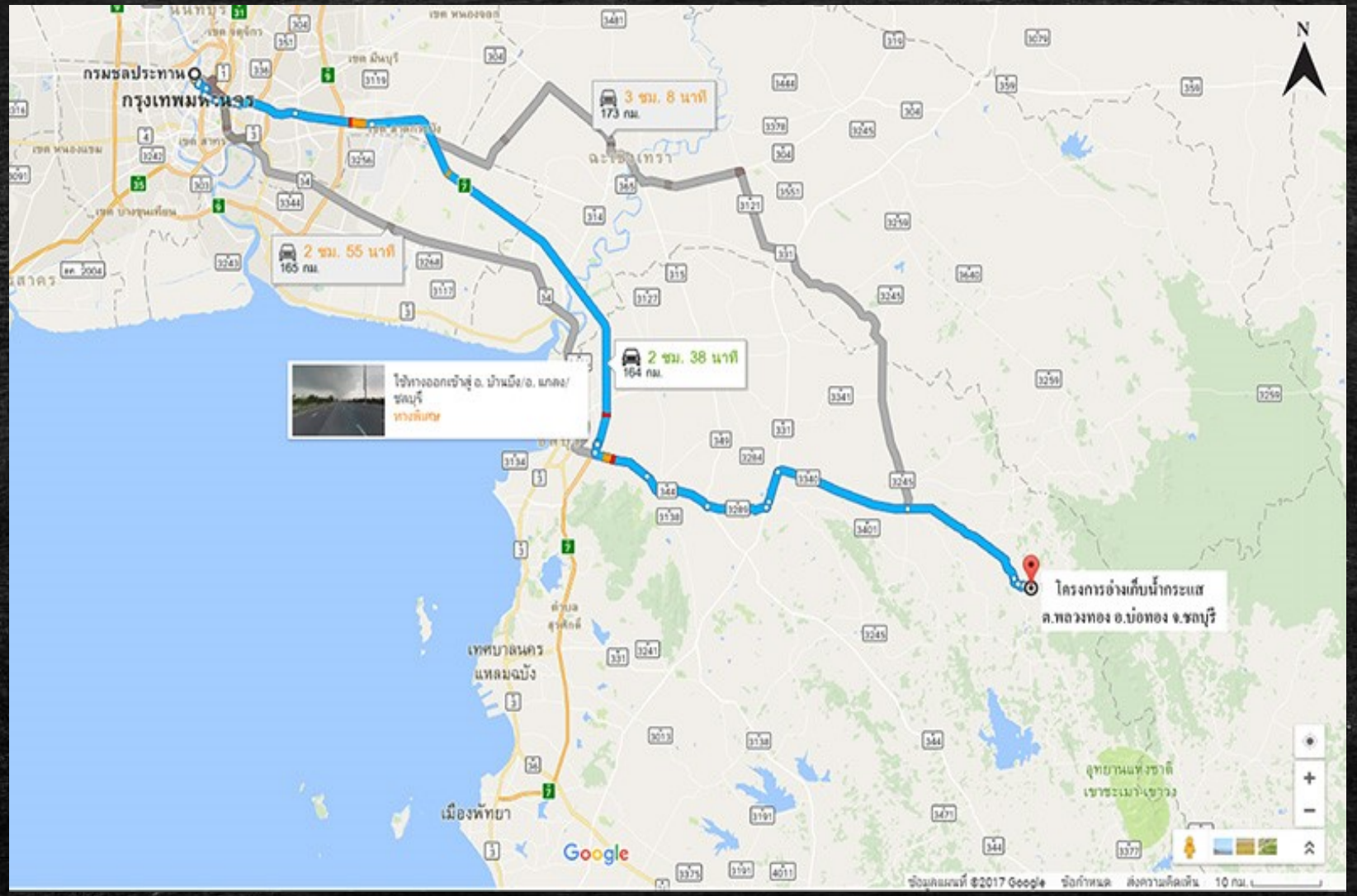
1. Introduction

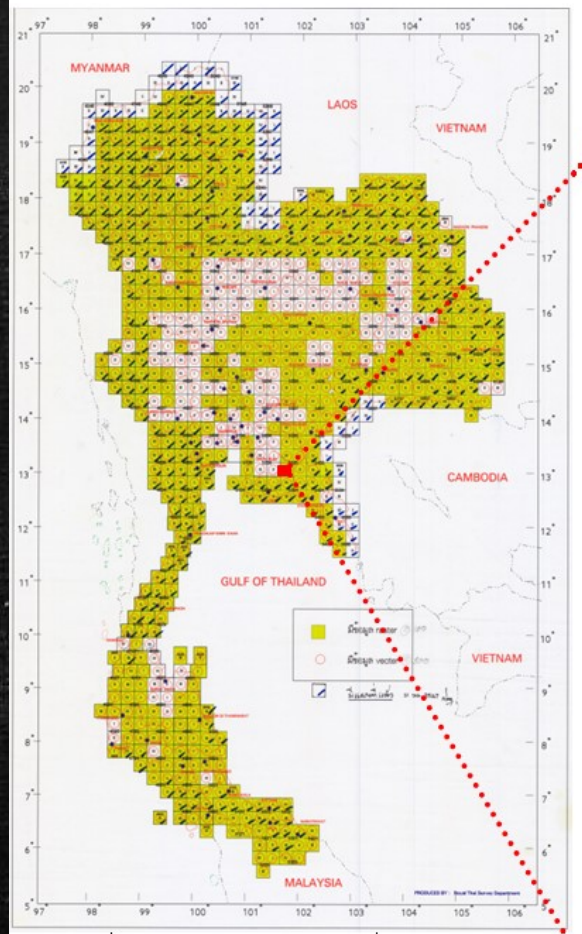


Strike – slip faults after Himalayan Orogeny (Palin et al., 2013)



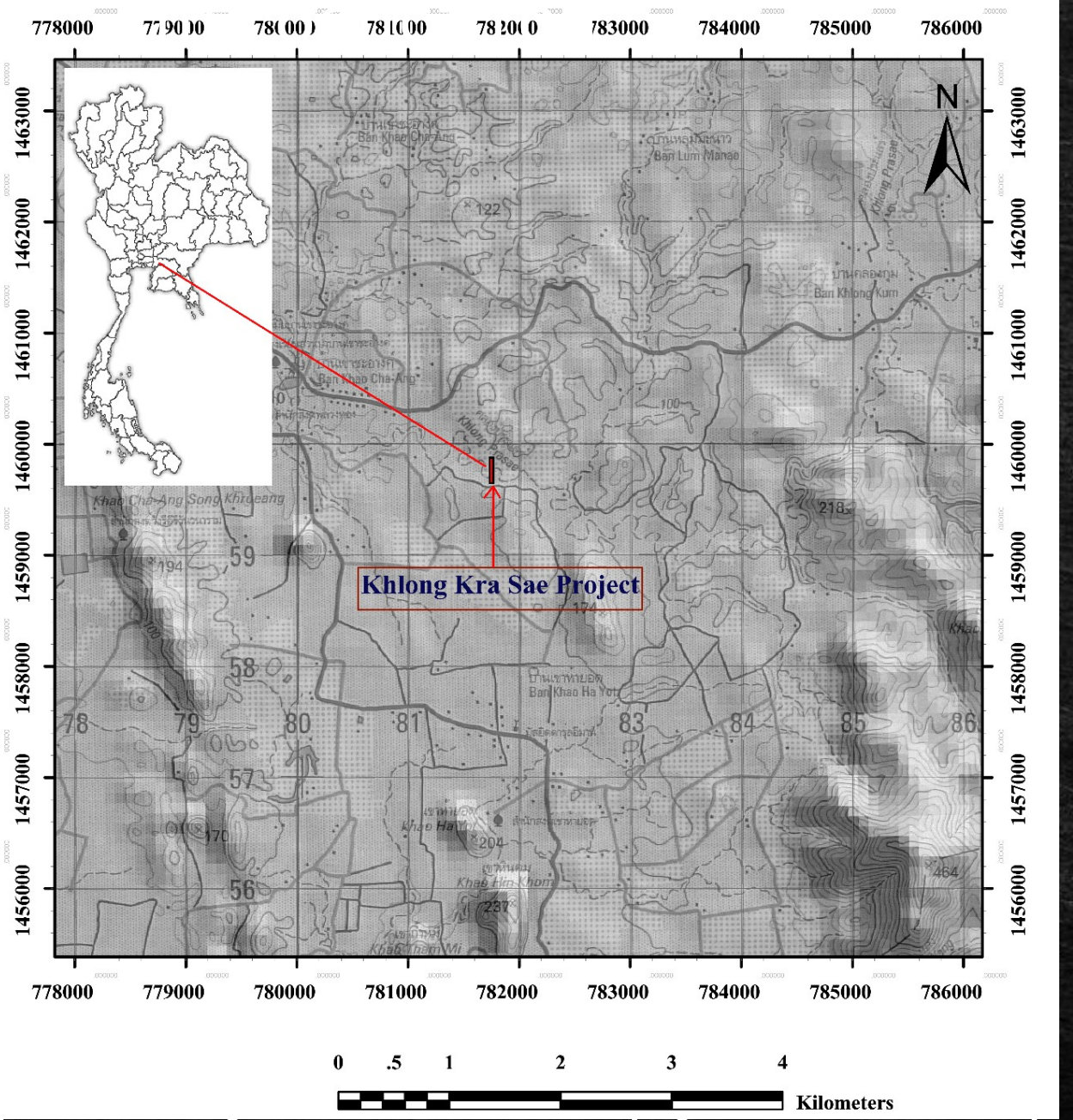
Geologic Map of study area. (Kittisarn and Assavapatchara, 1988)


กรมชลประทาน
กรุงเทพมหานคร
3 ชม. 8 นาที
173 กม.
2 ชม. 55 นาที
165 กม.
2 ชม. 38 นาที
164 กม.
ใช้ทางออกเข้าสู่ อ. บ้านบึง/อ. แกลง/
ชลบุรี
ทางพิเศษ
โครงการอ่างเก็บน้ำกระแส
ต.พลวงทอง อ.บ่อทอง จ.ชลบุรี
เทศบาลนคร
แหลมฉบัง
เมืองพัทยา
Google
N



บ้านสีระมัน

L7018 5335 III



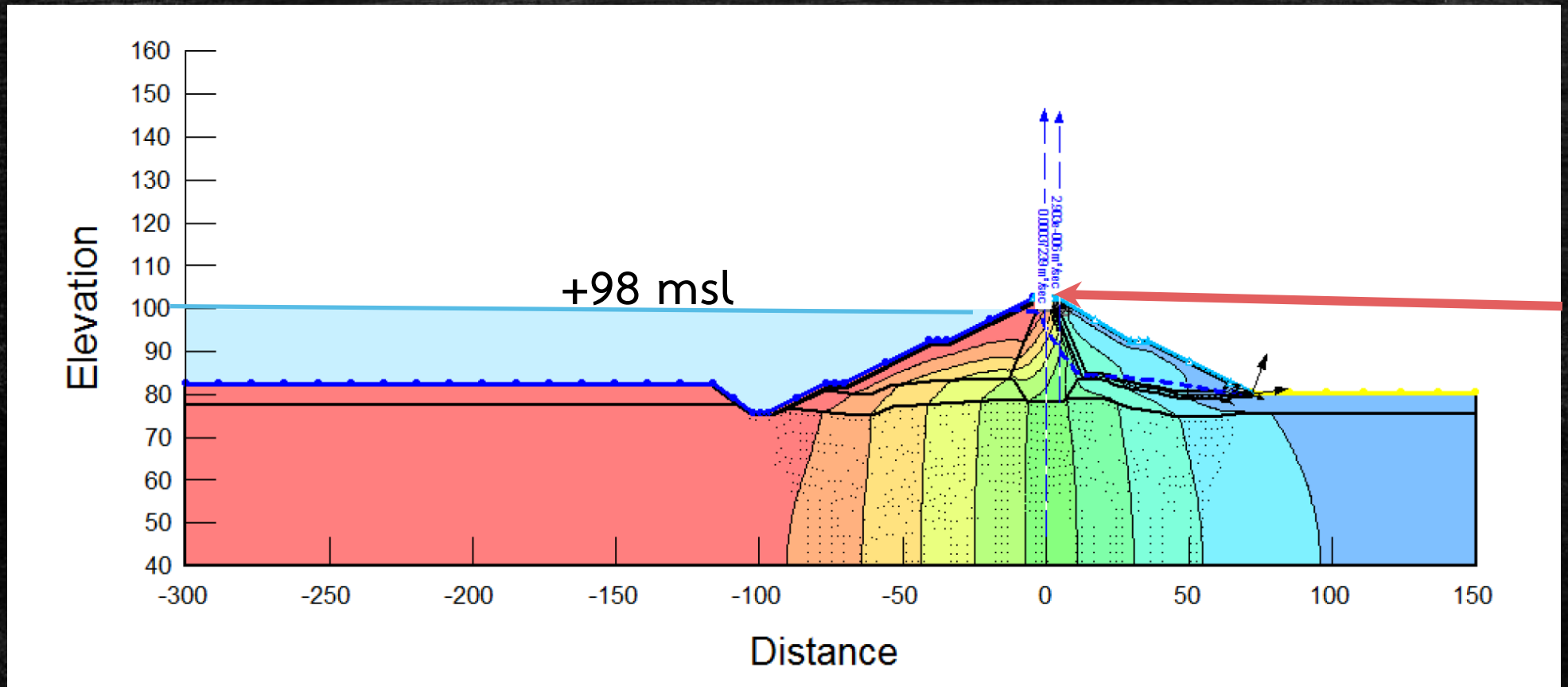
Location of Kra Sae Project (after RTSD, 1999)

Project Detail

Dam type = Zone Type;

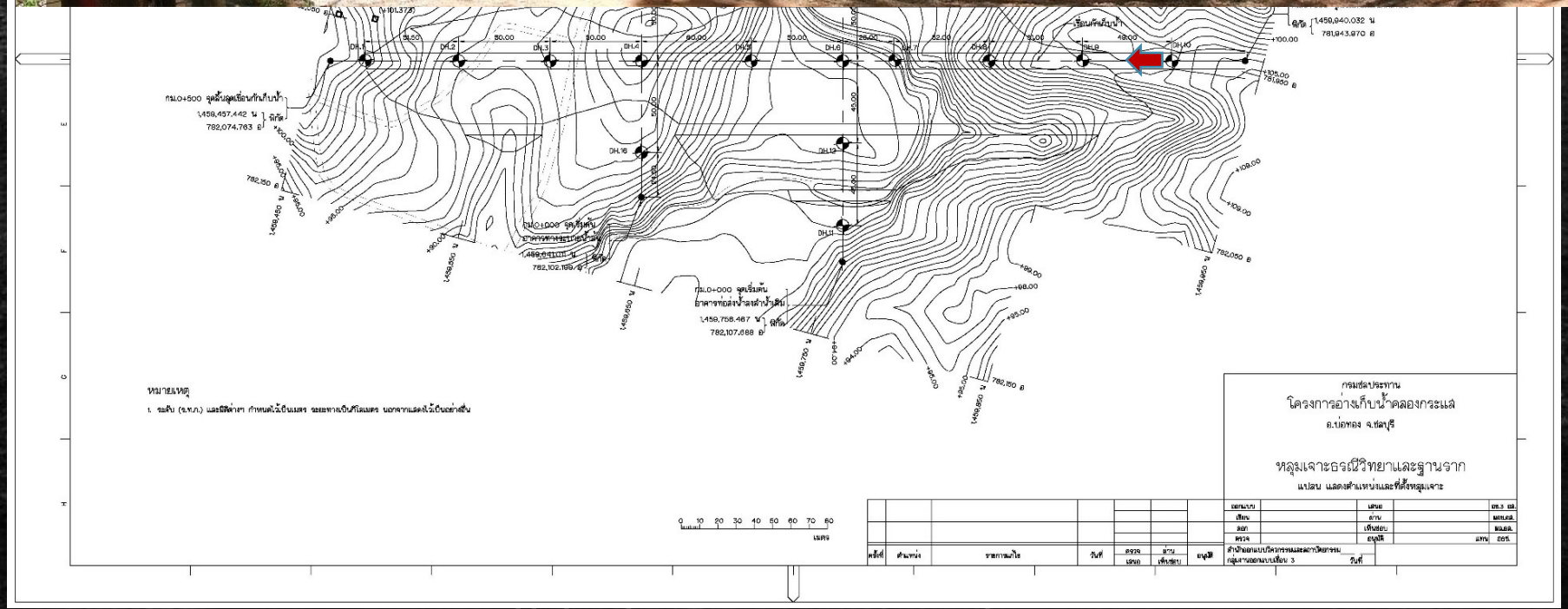
long 441 m. wide 8 m.

high 21 m.



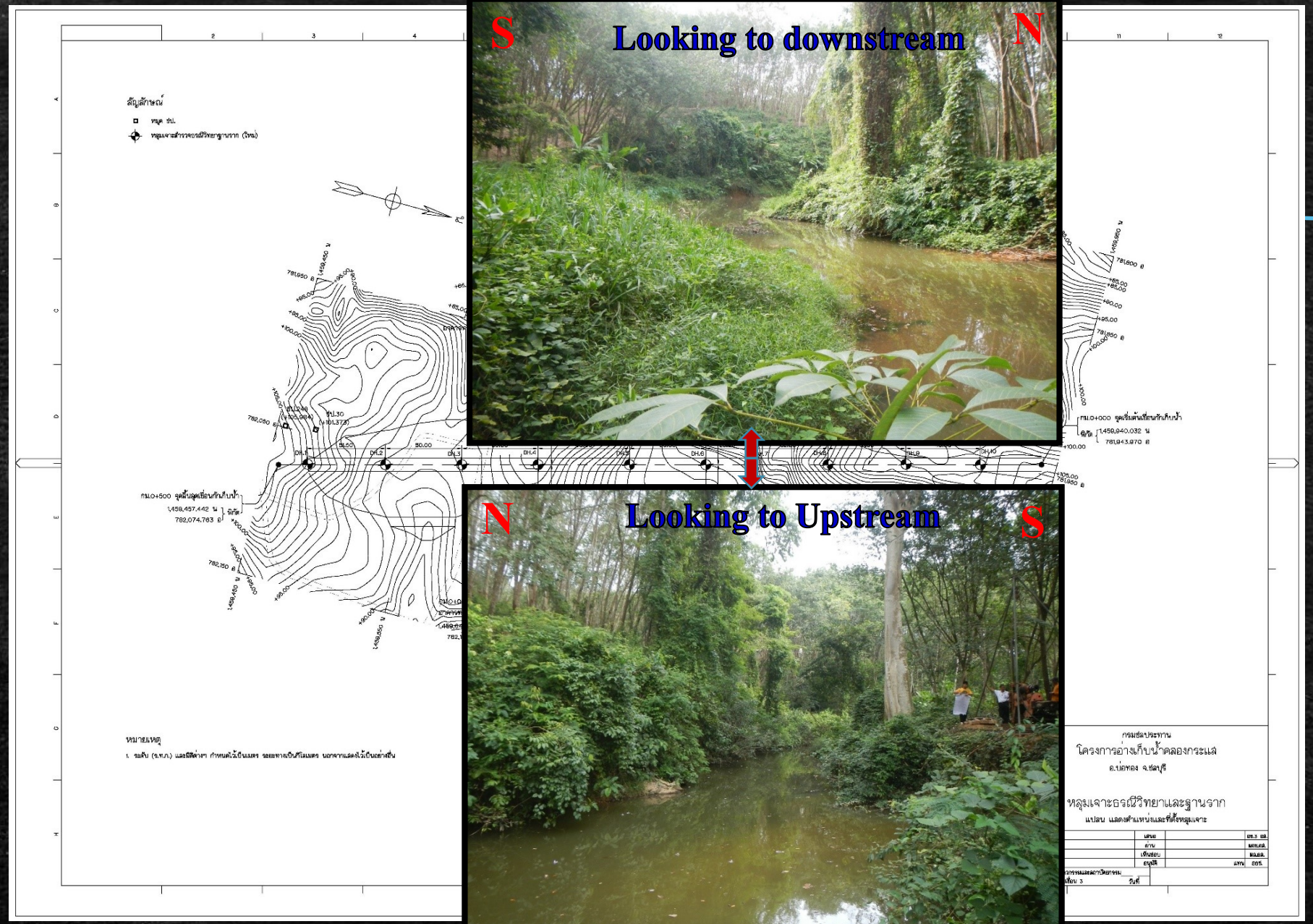
Drill holes Map in Study area

(Dam design group 3, 2016)



Drill holes Map in Study area

(Dam design group 3, 2016)



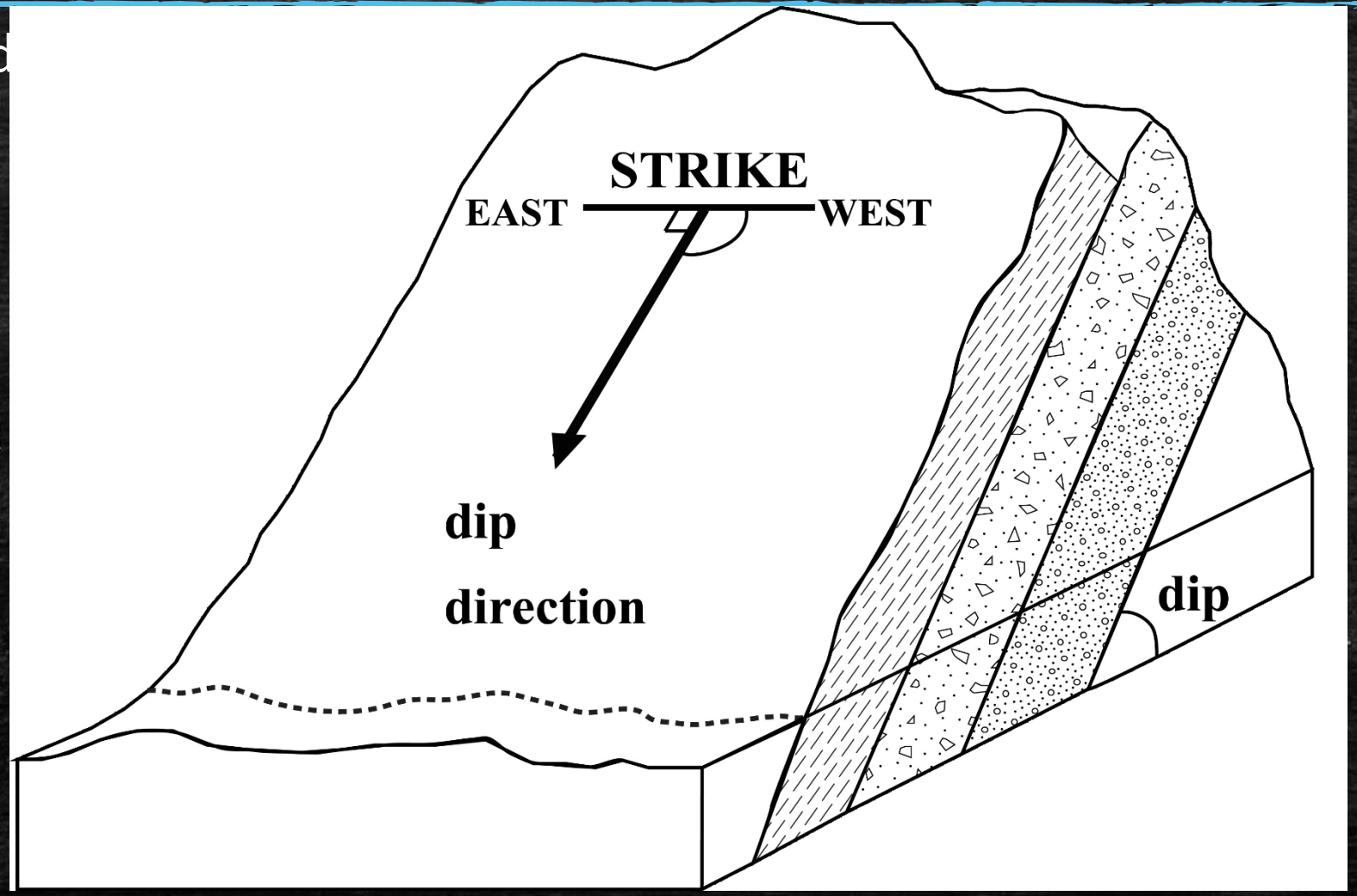
Drill holes Map in Study area

(Dam design group 3, 2016)

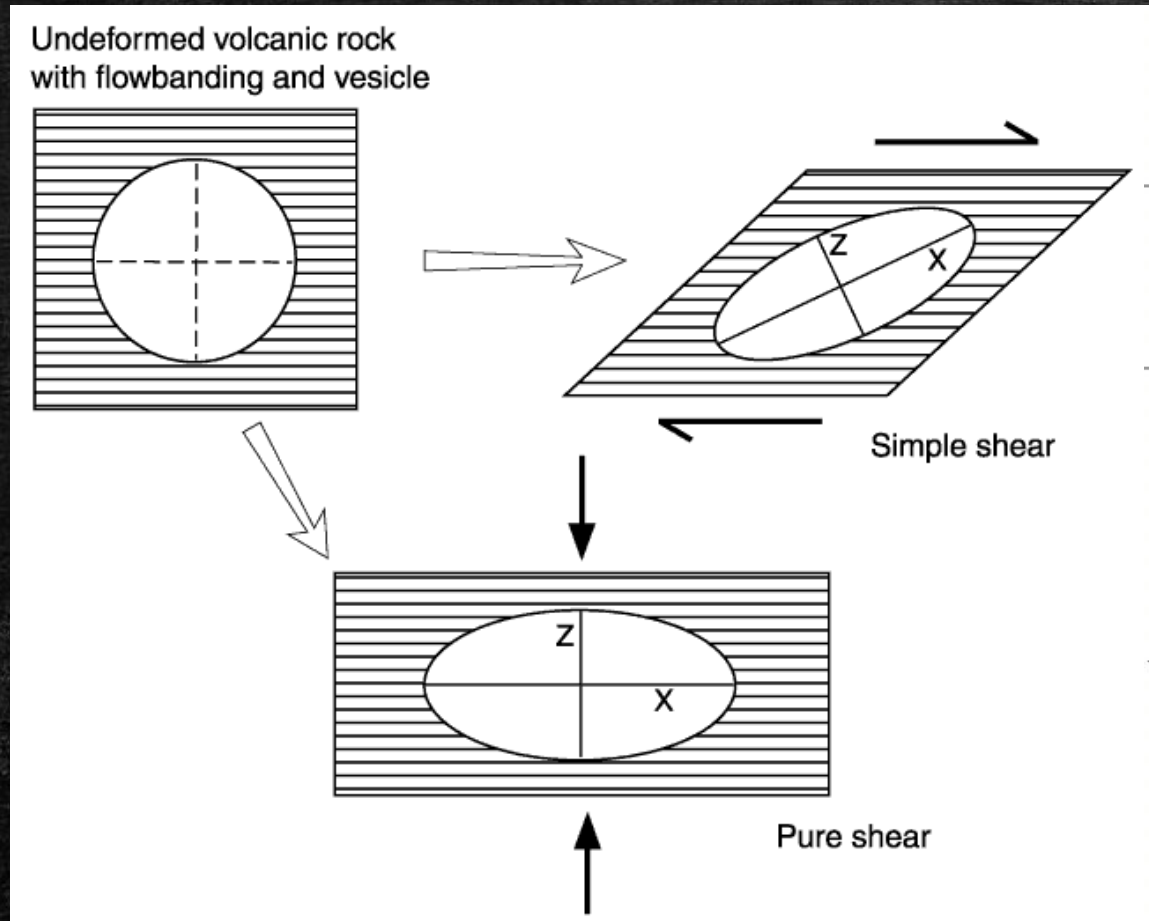
2. Geological investigation

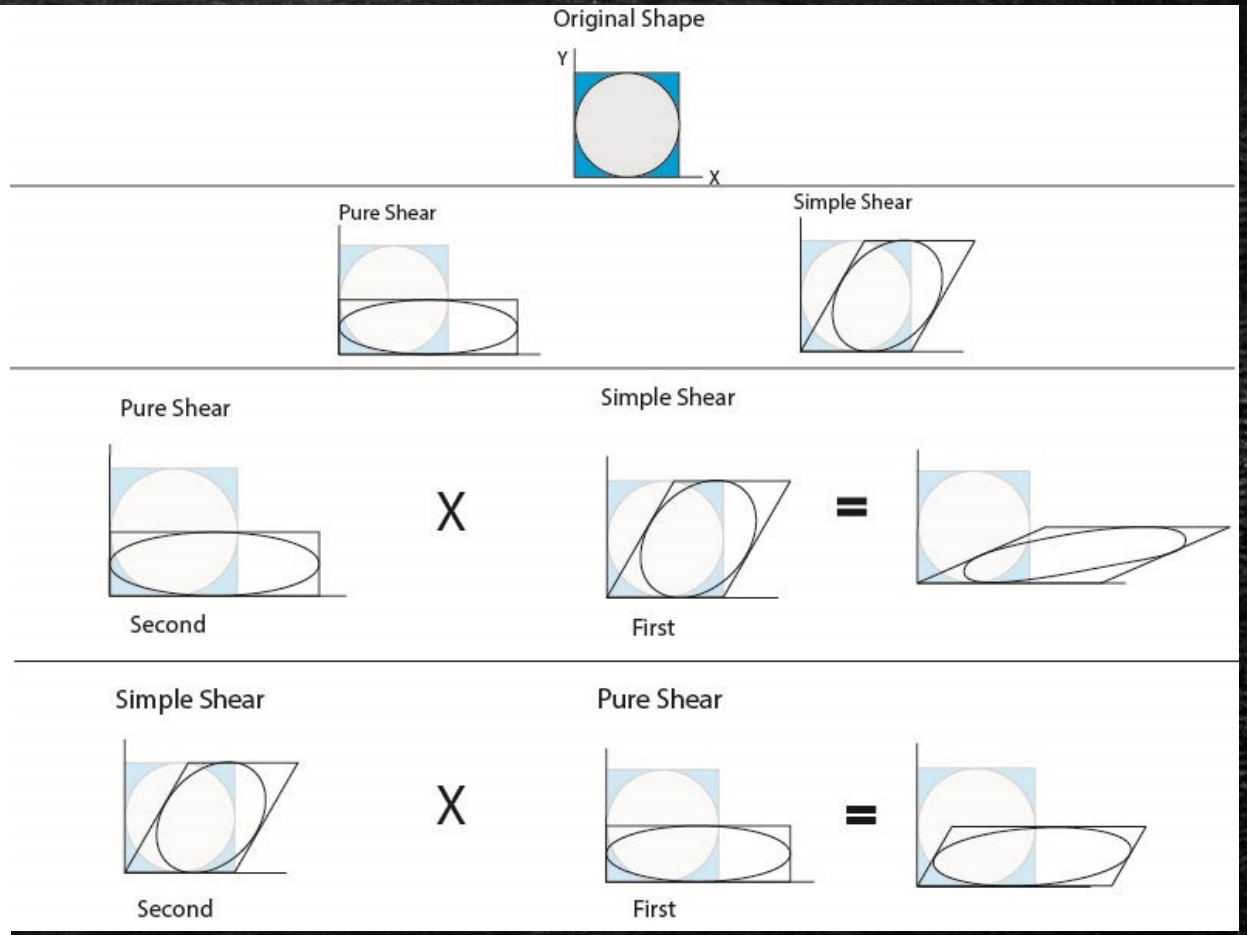
Rock Structures

Bedd



Progressive deformation.

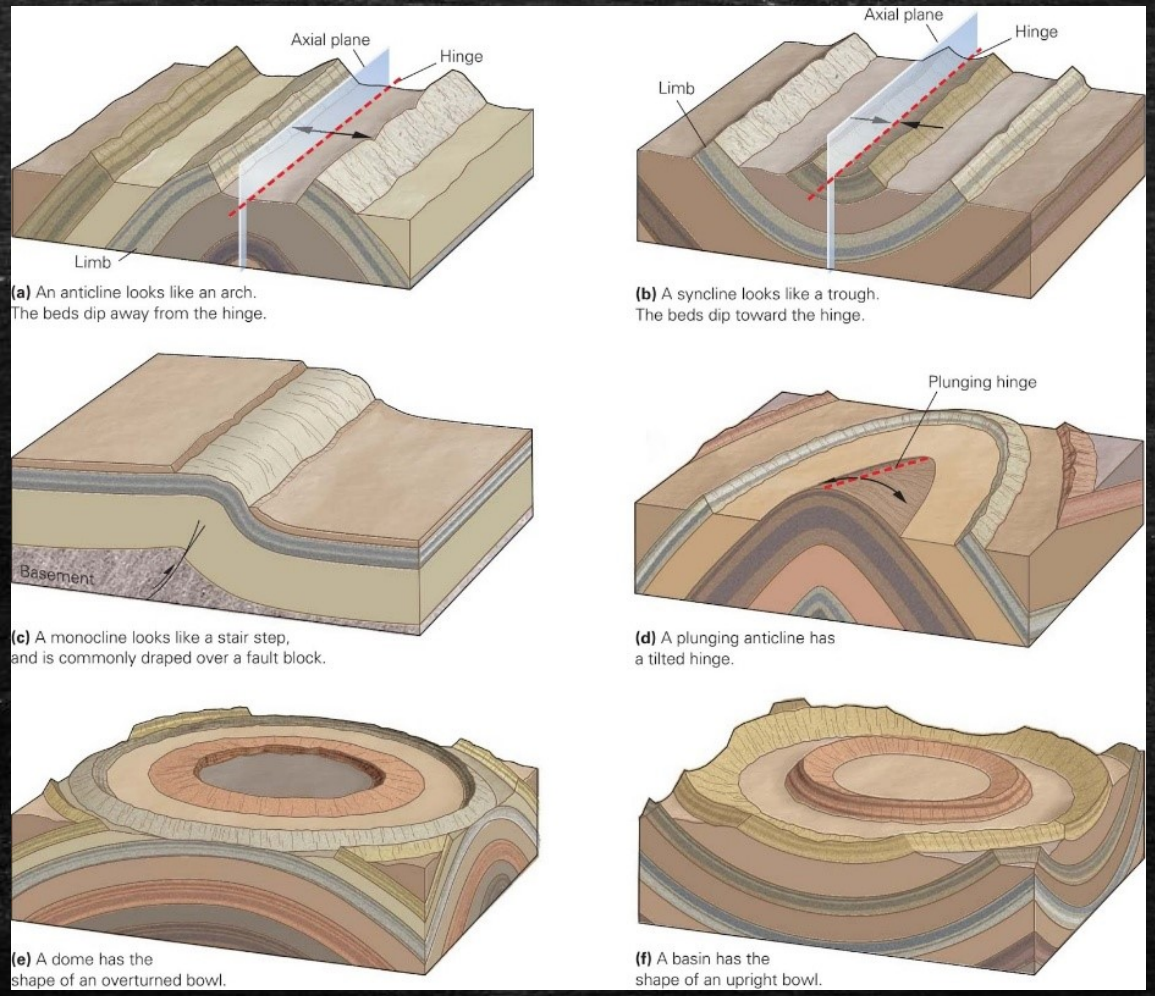




Ramsay and Huber (1987)

Rock Structures

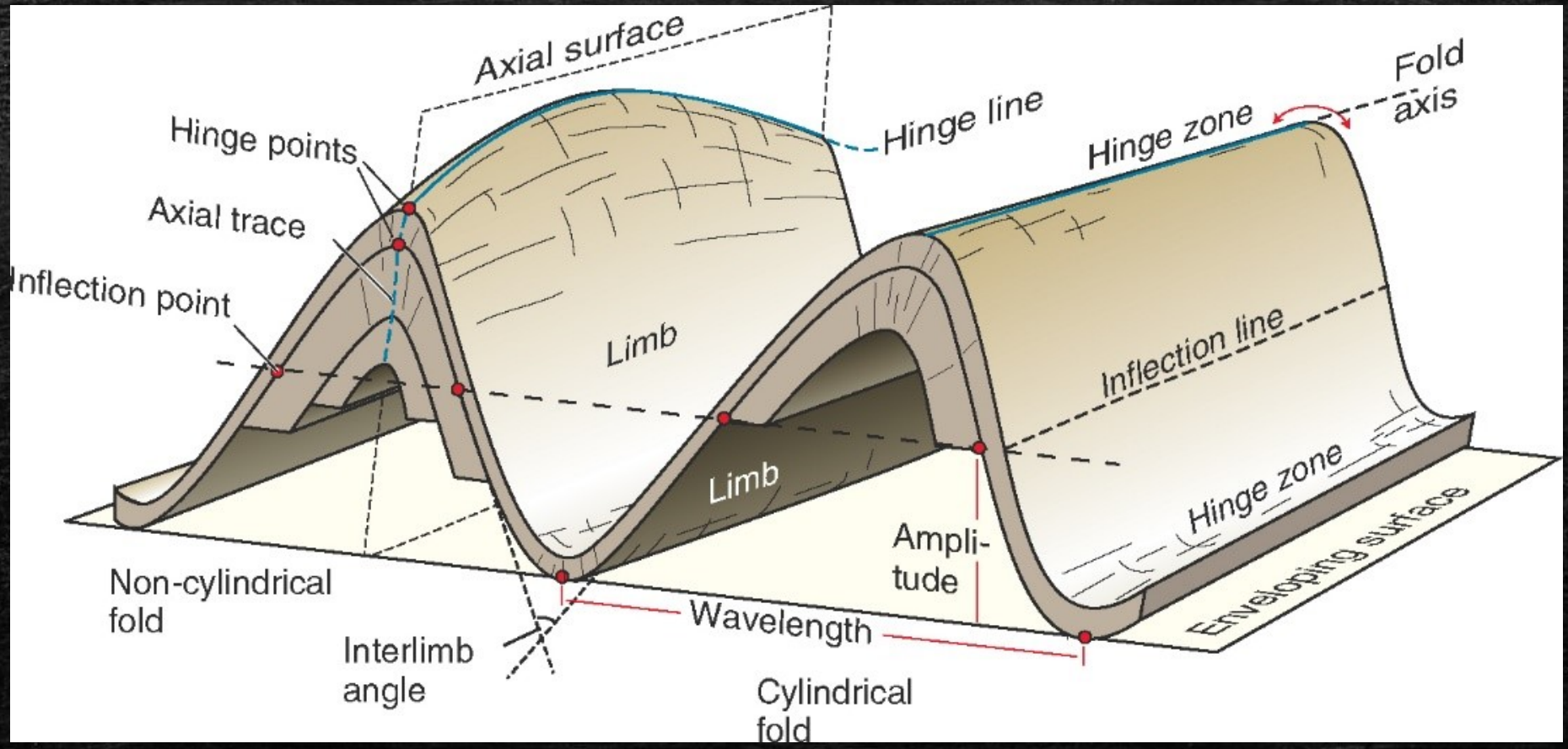
Rocks Folding



http://geologylearn.blogspot.com/2016/03/folds-and-foliations.html

Rock Structures

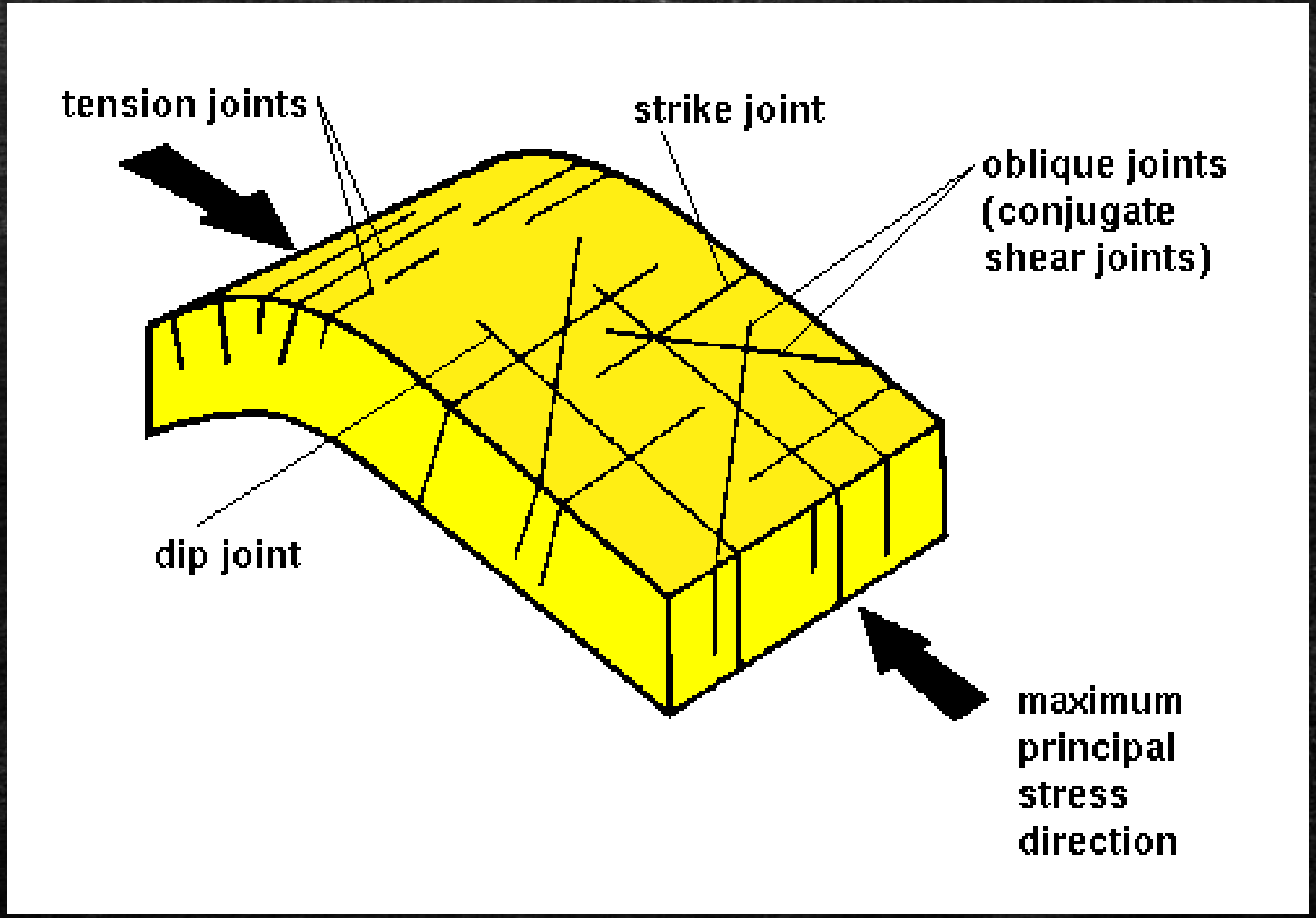
Fold Geometry



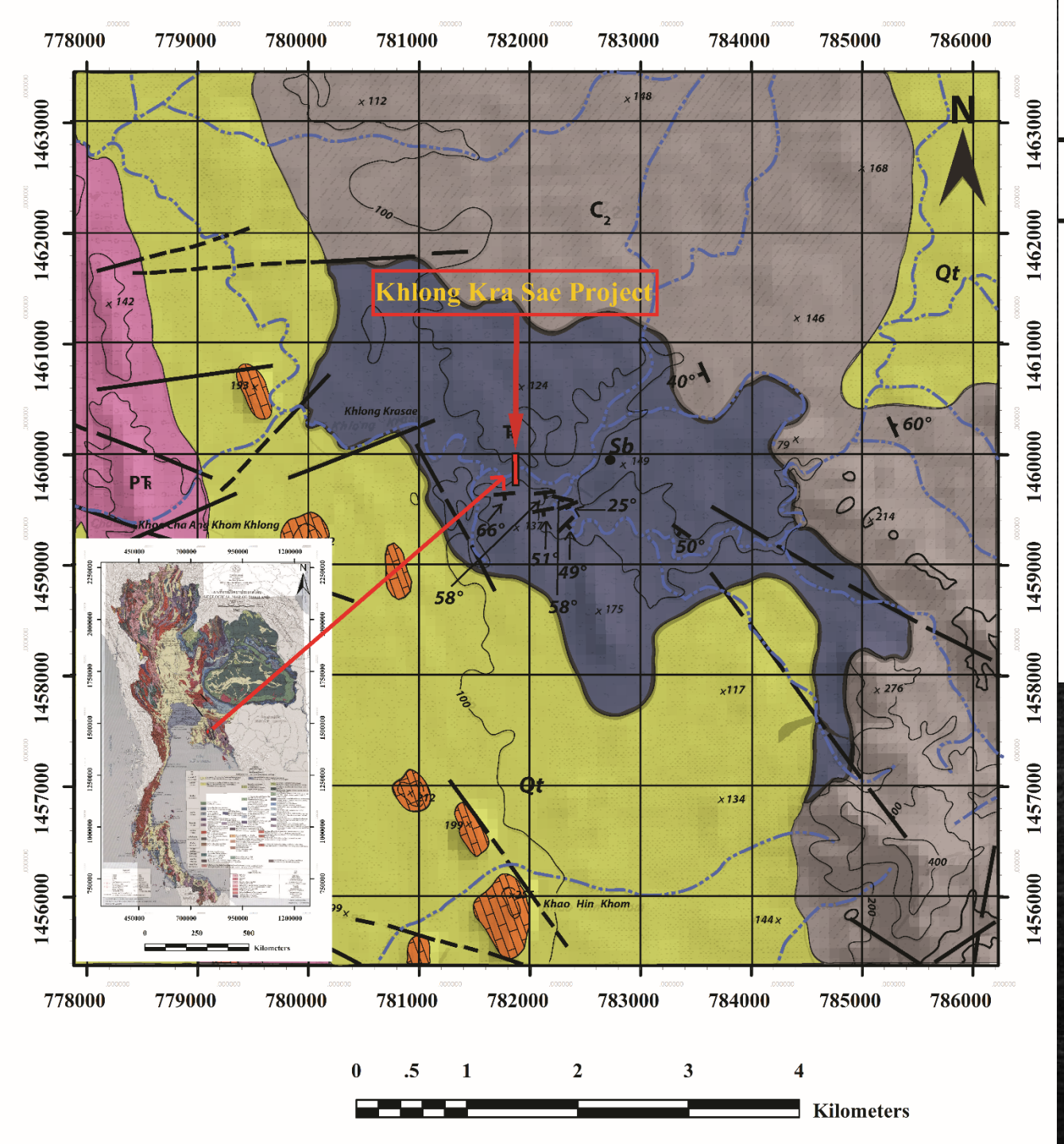
(Fossen, H., 2010)

Rock Structures

Joint Patterns



http://www.geologyin.com/2014/10/joints-terminology-brittle-deformation.html



Correlation of map units

Age	Description
Quaternary	Qt — Terrace deposit : Gravel, sand, silt, clay, laterite and lateritic soils.
Unconformity	
Triassic	Tr — Sandstone siltstone, Purple, reddish brown to light grey brown and white; quartzite sandstone, light grey to greenish; interbedded with shale and conglomerate consists of quartz, siltstone, quartzitic sandstone, friable sandstone metamorphic and volcanic pebbles.
Unconformity	
Triassic - Permian	PTr — Shale, siltstone, sandstone, olive-green; black slate; pyroclastic and metatuff interbedded; oolithic limestone; light to dark grey; quartz veins and quartz dikes.
Carboniferous	C_2 — Phyllite pale, white, grey and yellowish grey; black slate; graphitic schist; phylitic schist; amphibolite; actinolite-tremolite schist; quartz schist; quartz veins and quartz dikes.

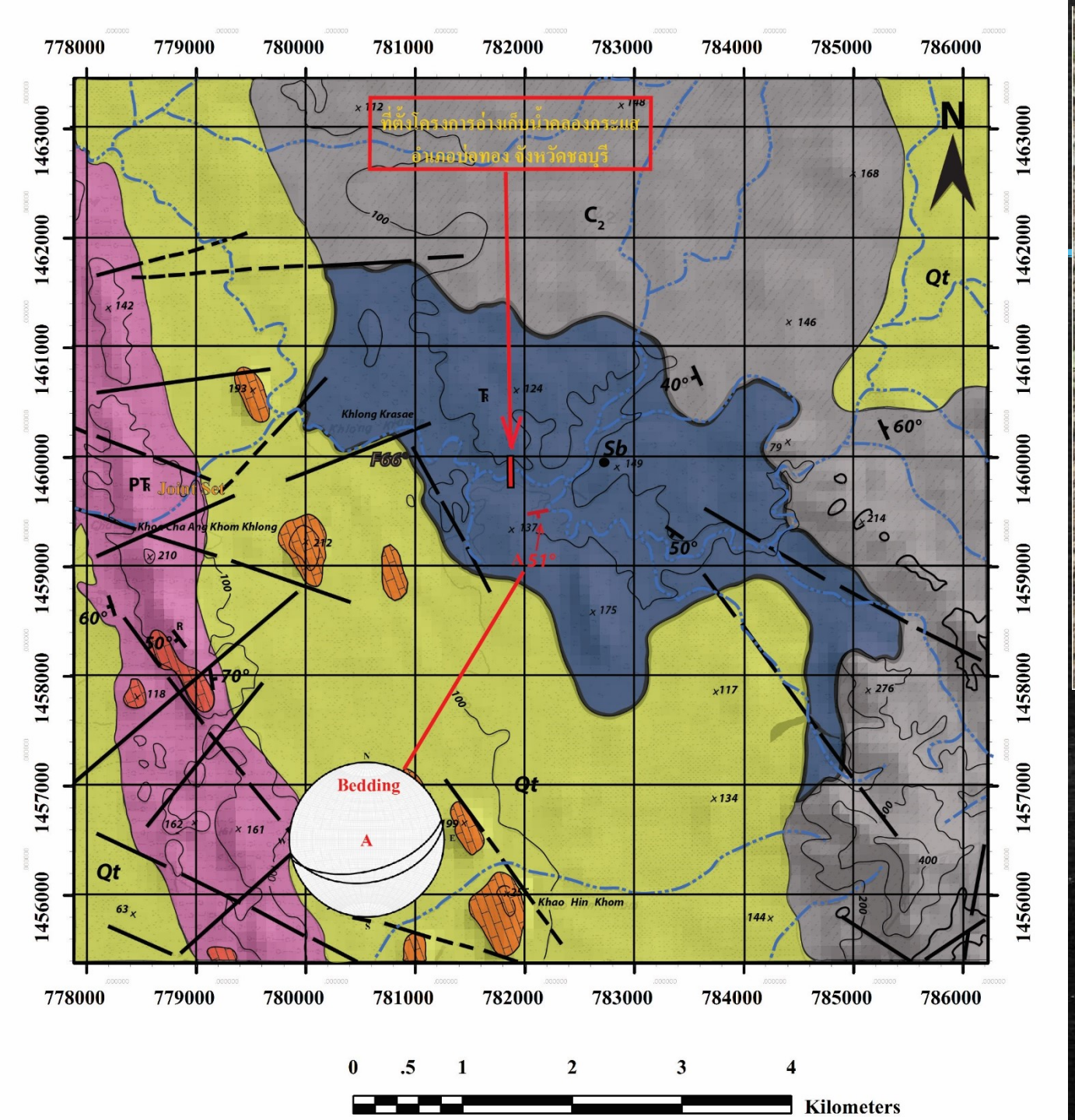
Symbols

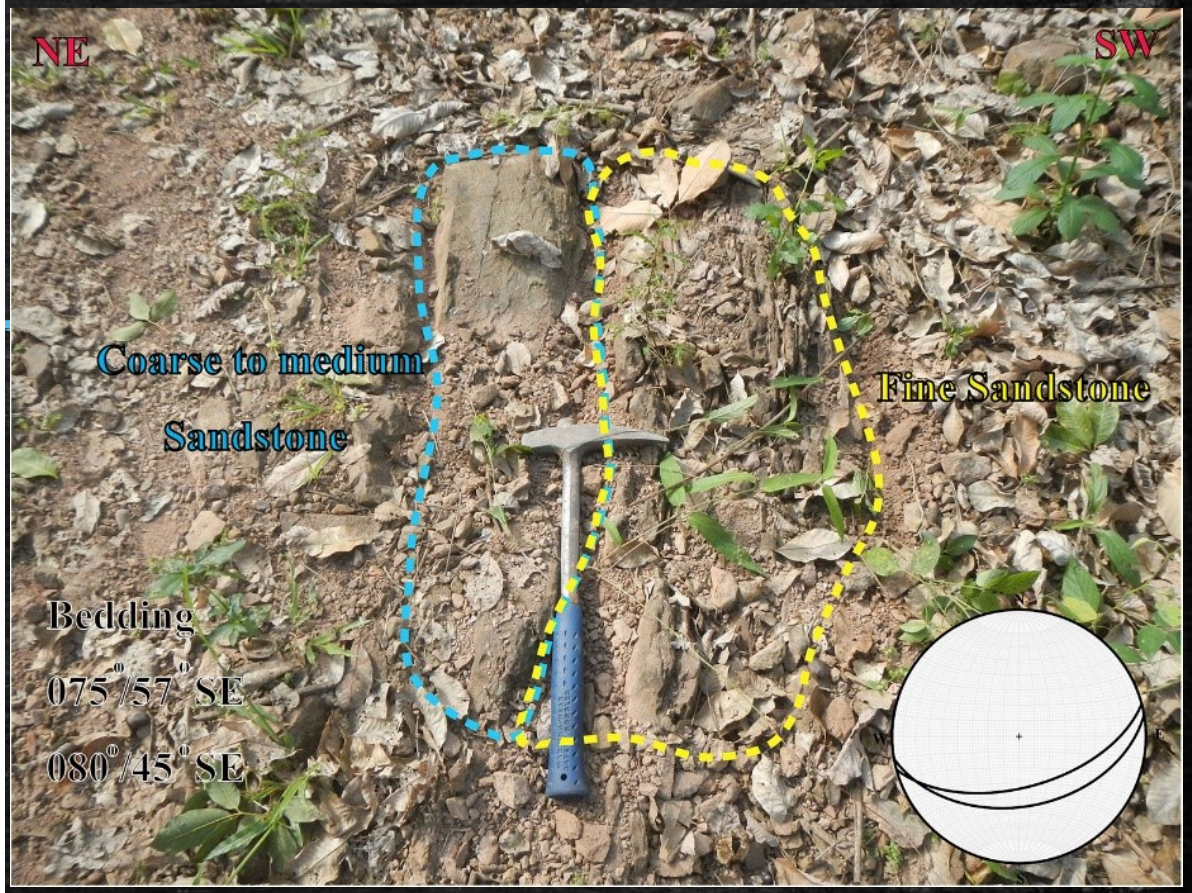
- 40° — Strike and dip of beds.
- 60° — Strike and dip of foliation.
- Contact.
- Fault approximate.
- Fault, concealed.
- 400 — Countour line.
- × 175 — Spot elevation in meters.
- Drainage.

Abbreviation

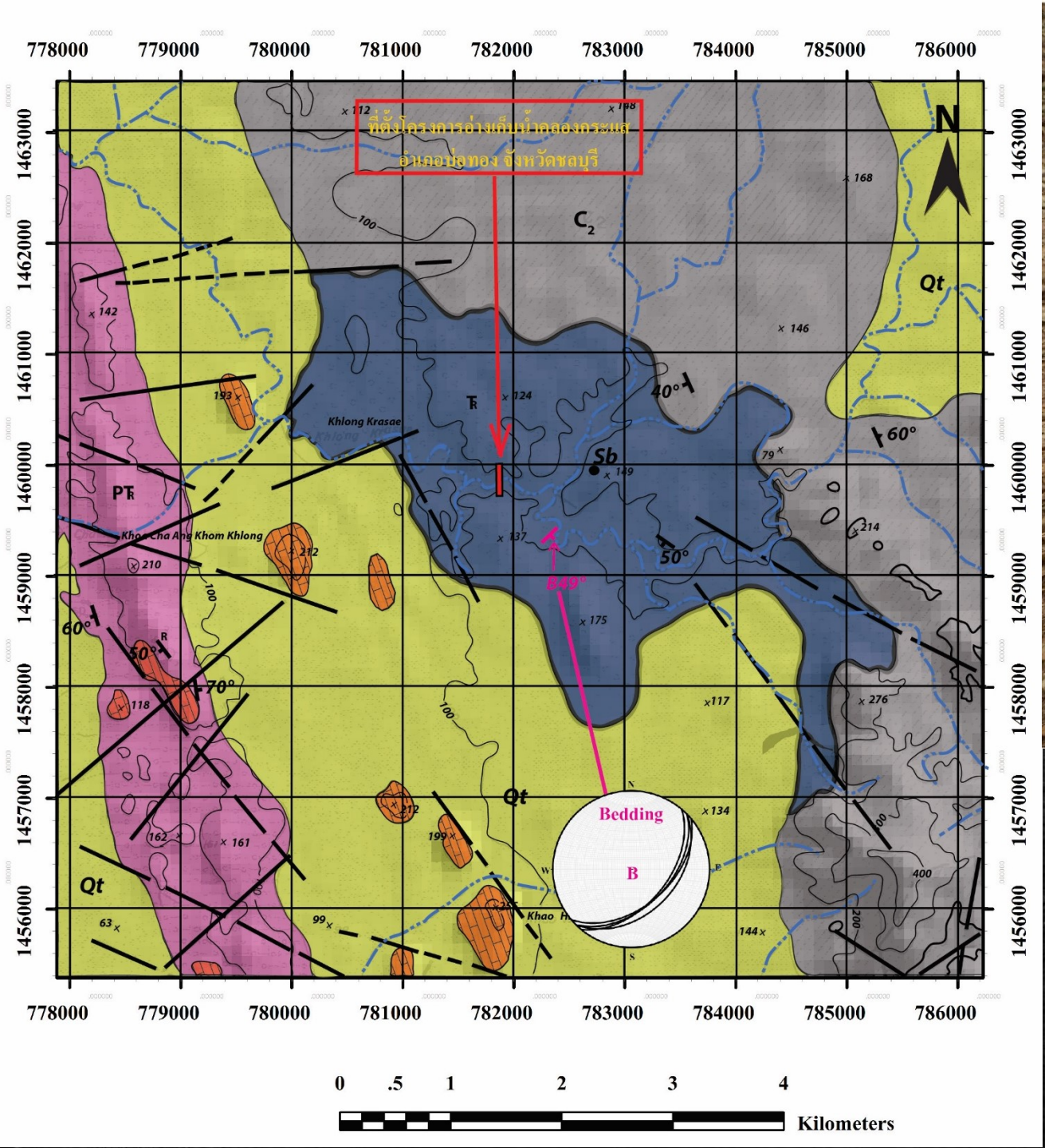
- Sb — Stibnite.

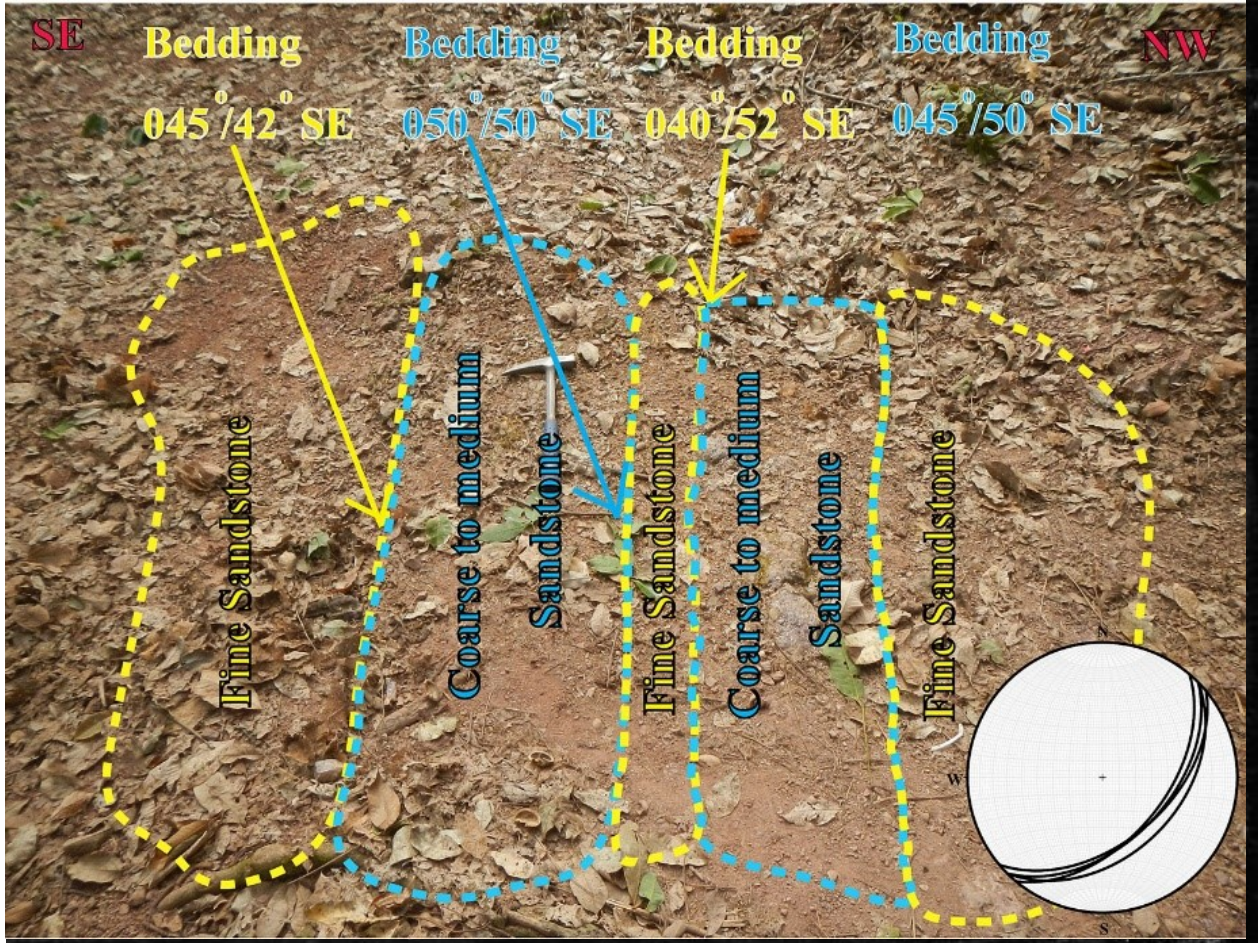
Geological map in scale 1: 50,000 and outcrop in dam reservoir (after Kittisarn and Assavapatchara, 1988)



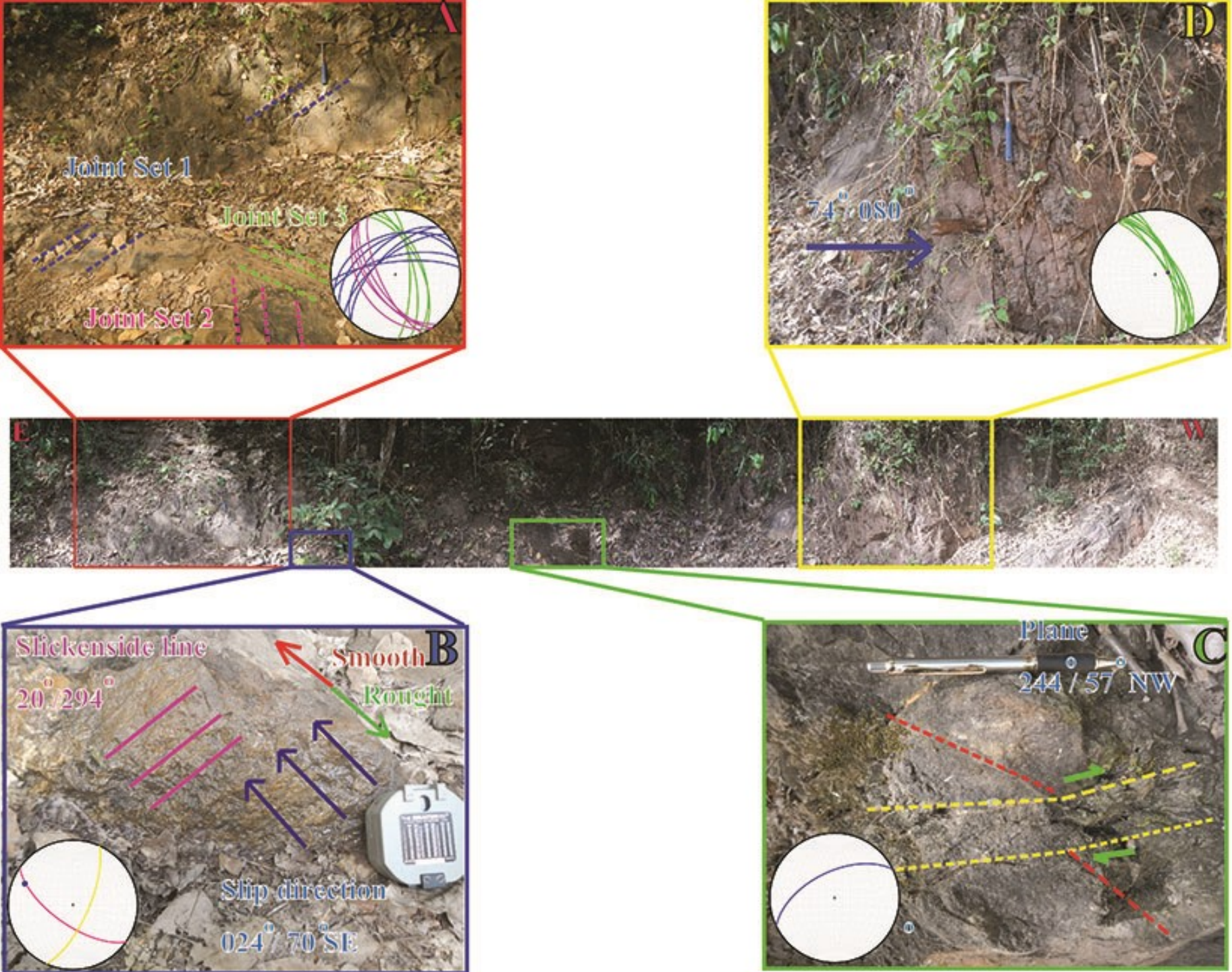


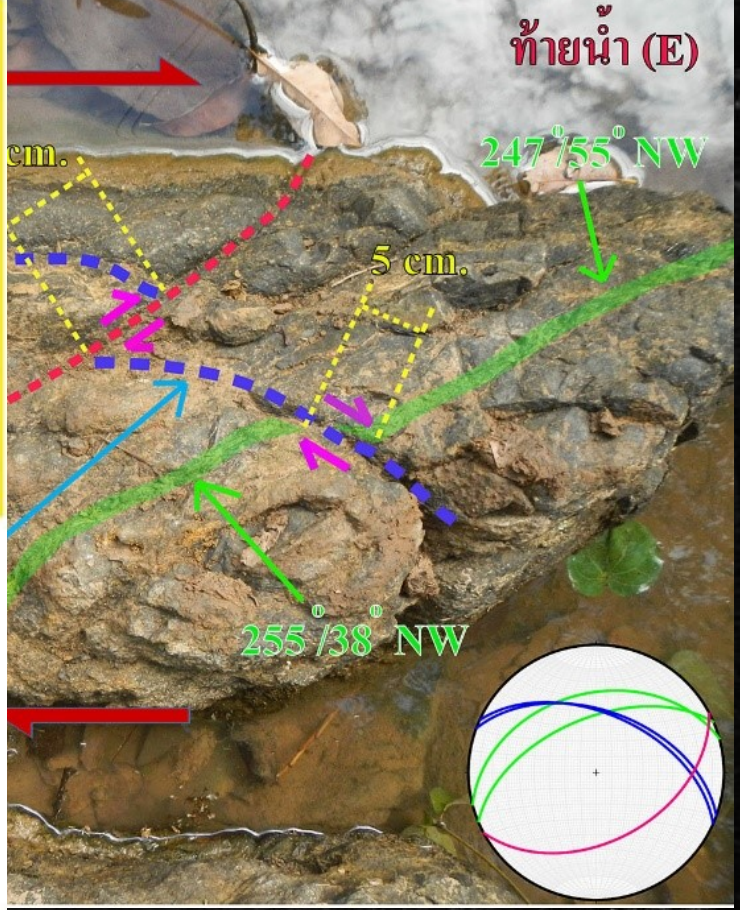
Station A; Far from CL dam in SE direction about 280 meters.





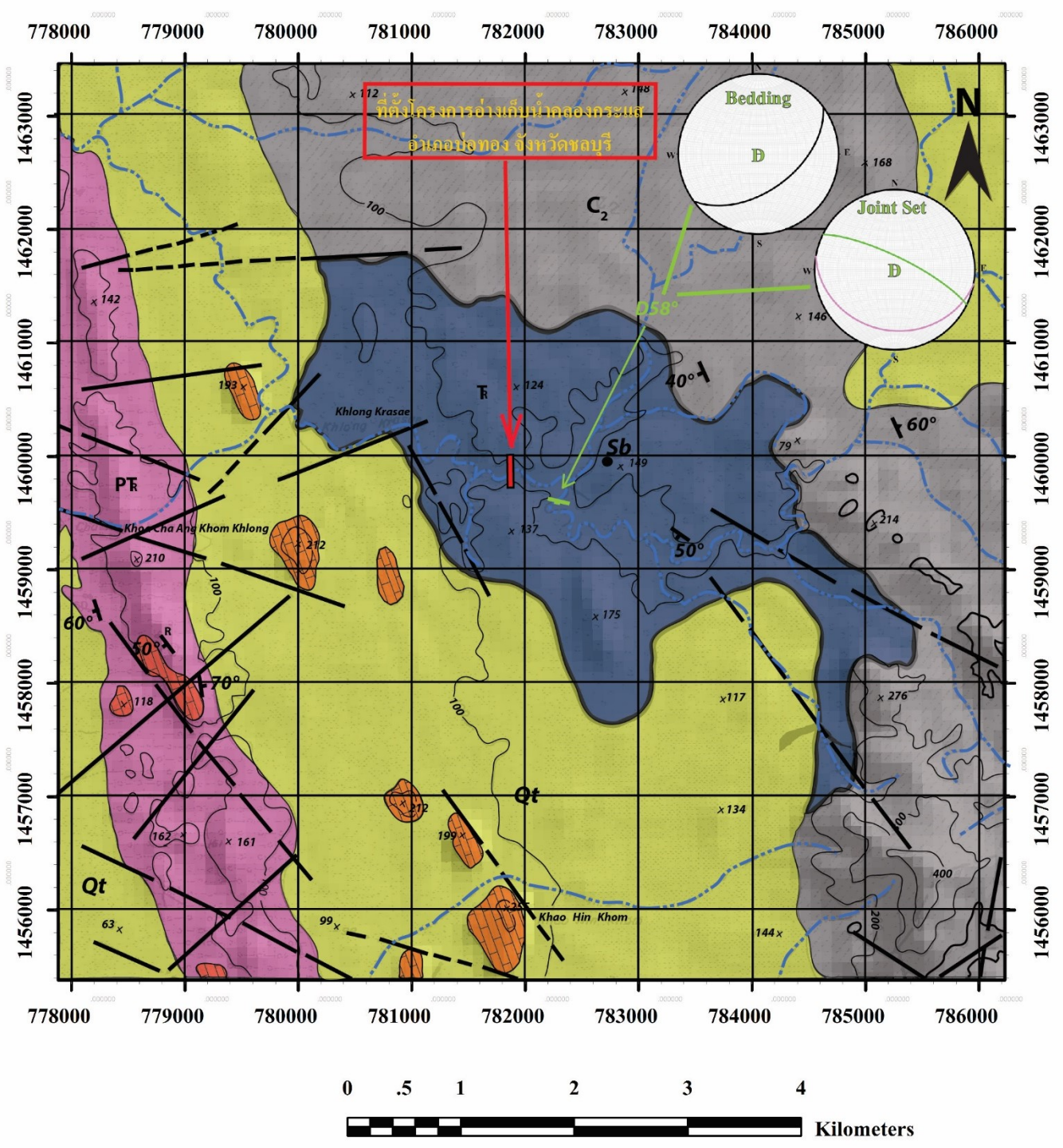
Station B; Far from CL dam in SE direction about 520 meters.



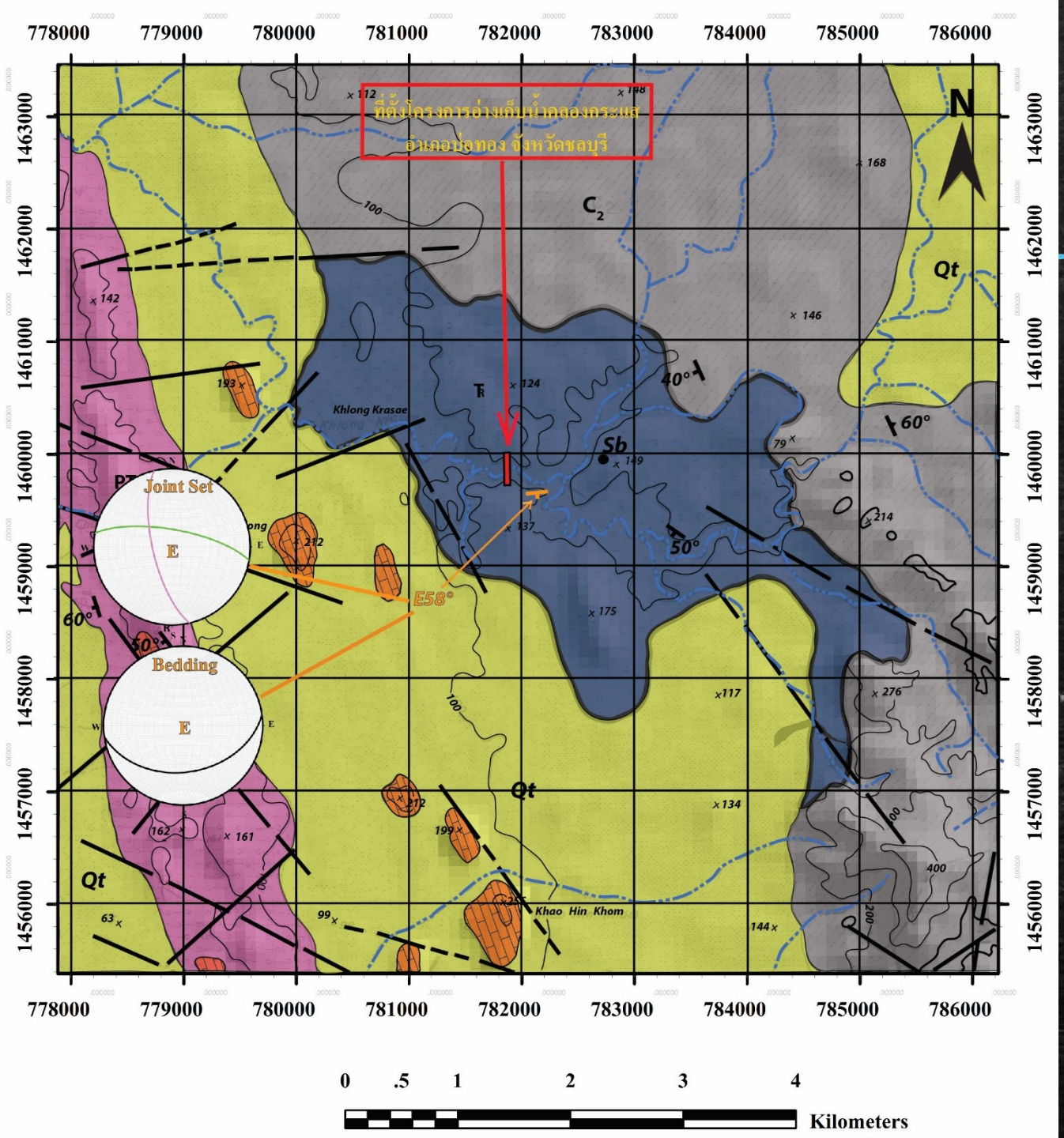


from CL dam in SE

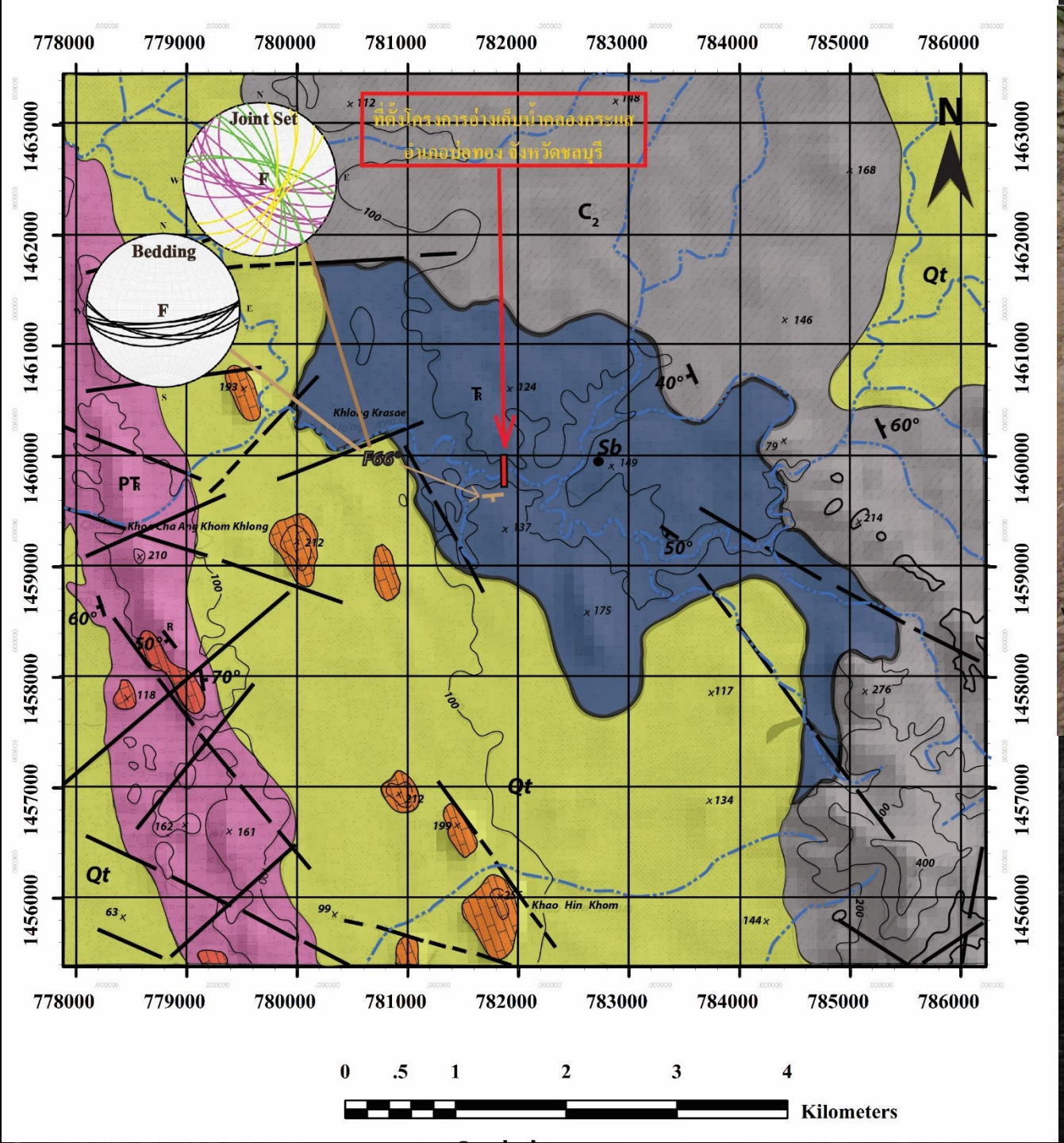
ut 370 meters.



Station D; Far from CL dam in SE direction about 370 meters.

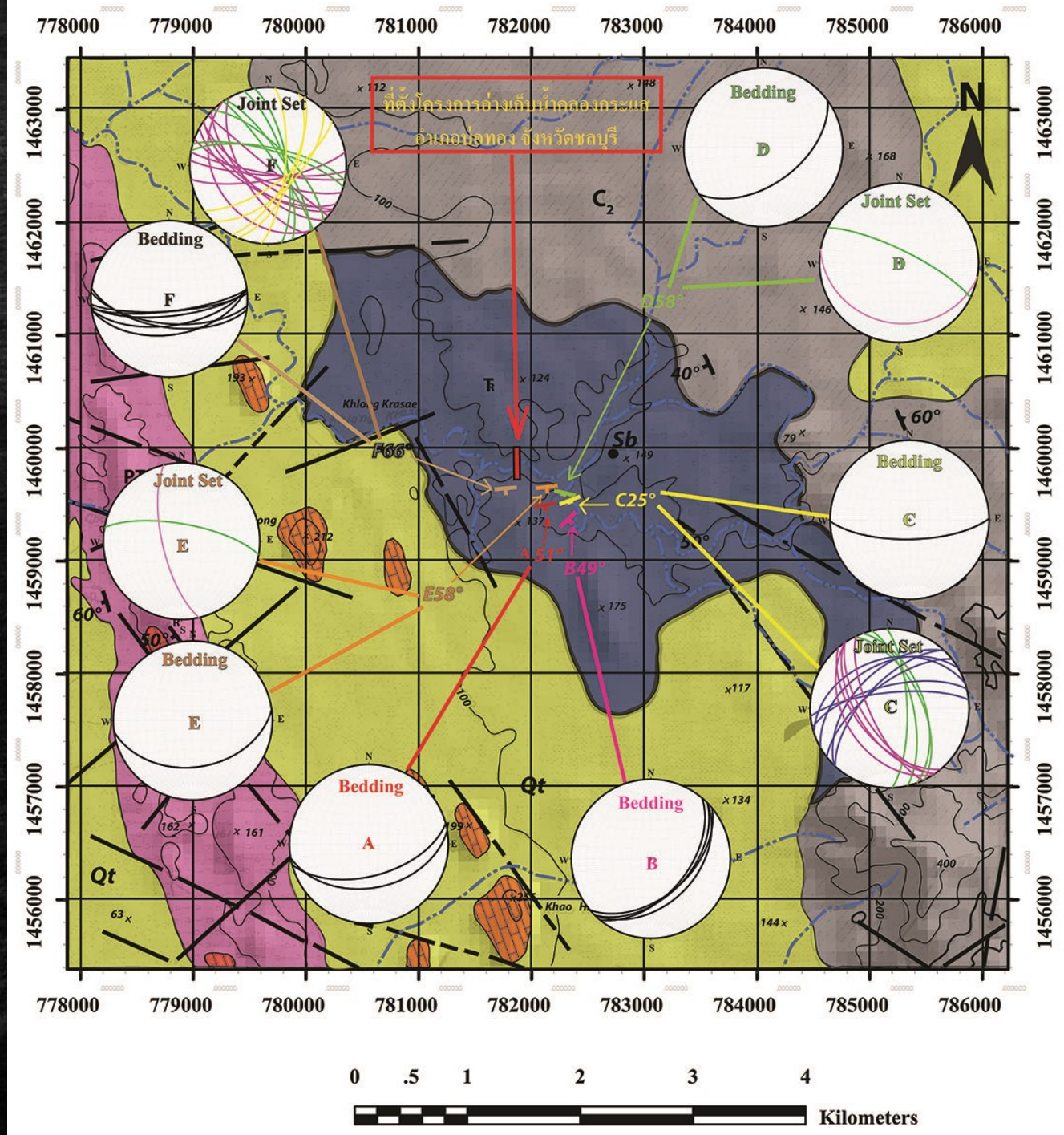


Station E; Far from CL dam in S direction about 180 meters.



Station F; Far from CL dam in SW direction about 305 meters.

3. Structural analysis and synthesis methods


778000
779000
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781000
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783000
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785000
786000
1463000
1462000
1461000
1460000
1459000
1458000
1457000
1456000
ที่ตั้งโครงการอ่างเก็บน้ำคลองกระแส
อำเภอบ้านทอง จังหวัดชลบุรี
N
Joint Set
F
Bedding
F
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Đ
Joint Set
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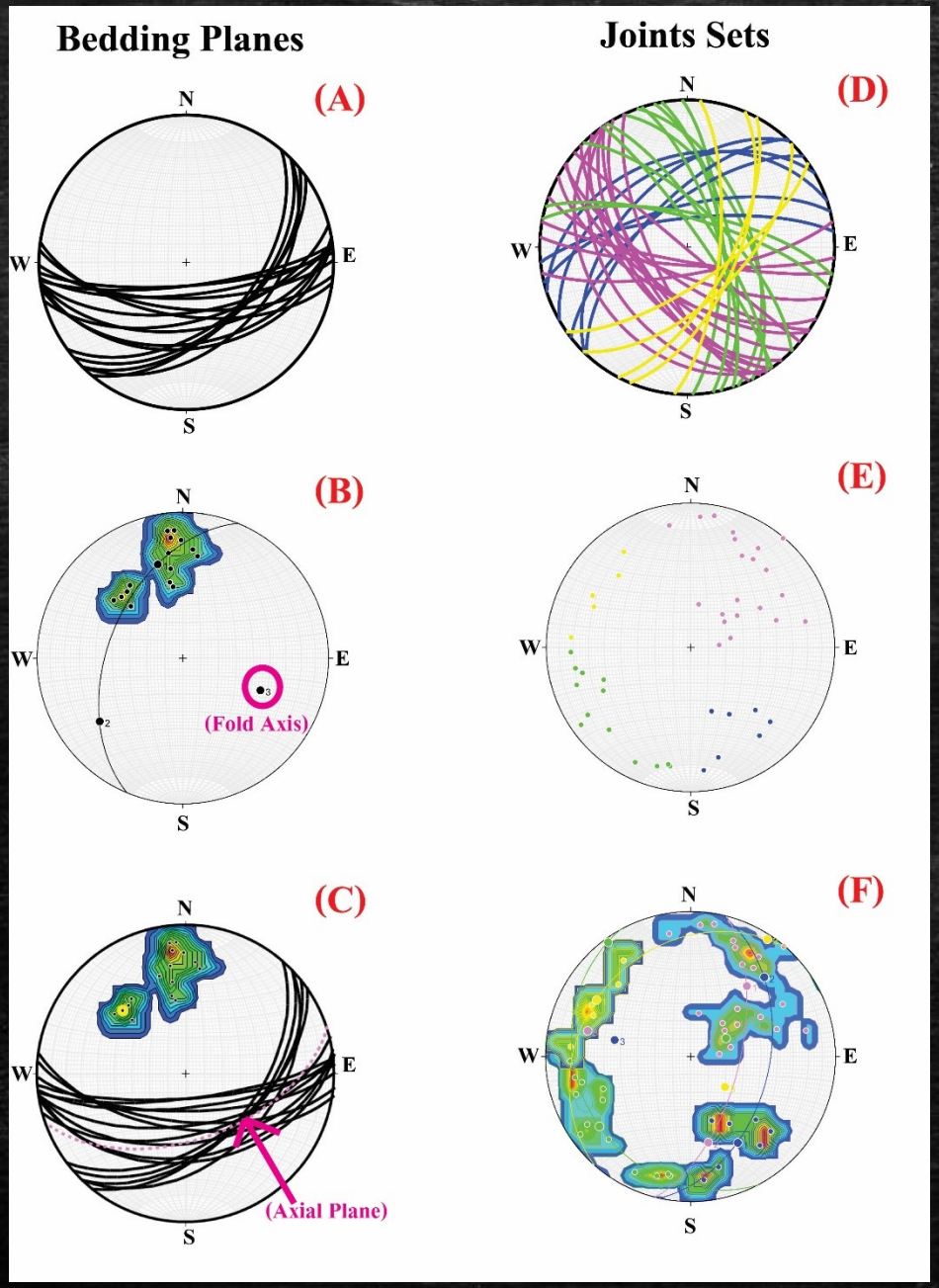
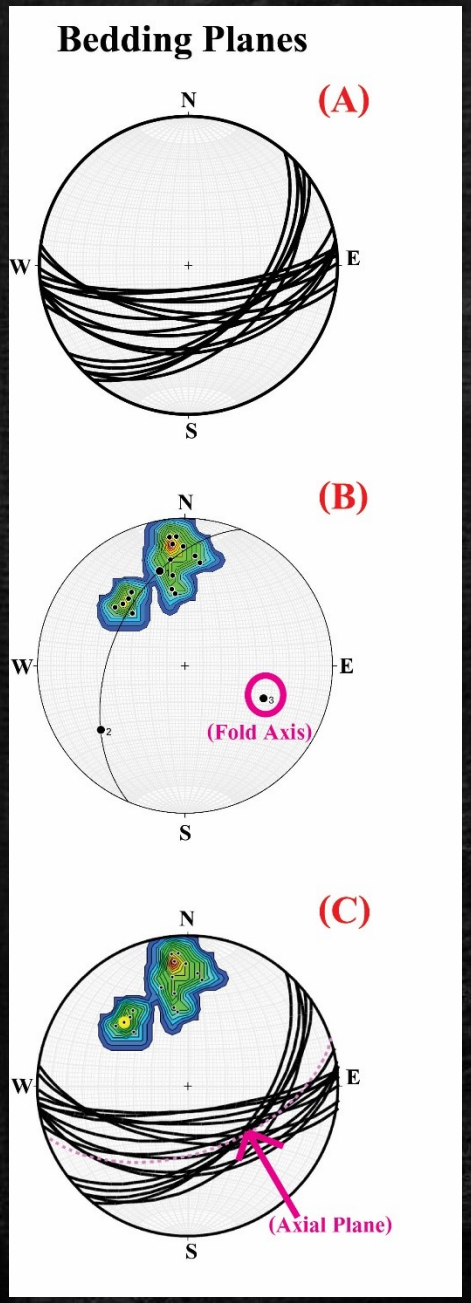
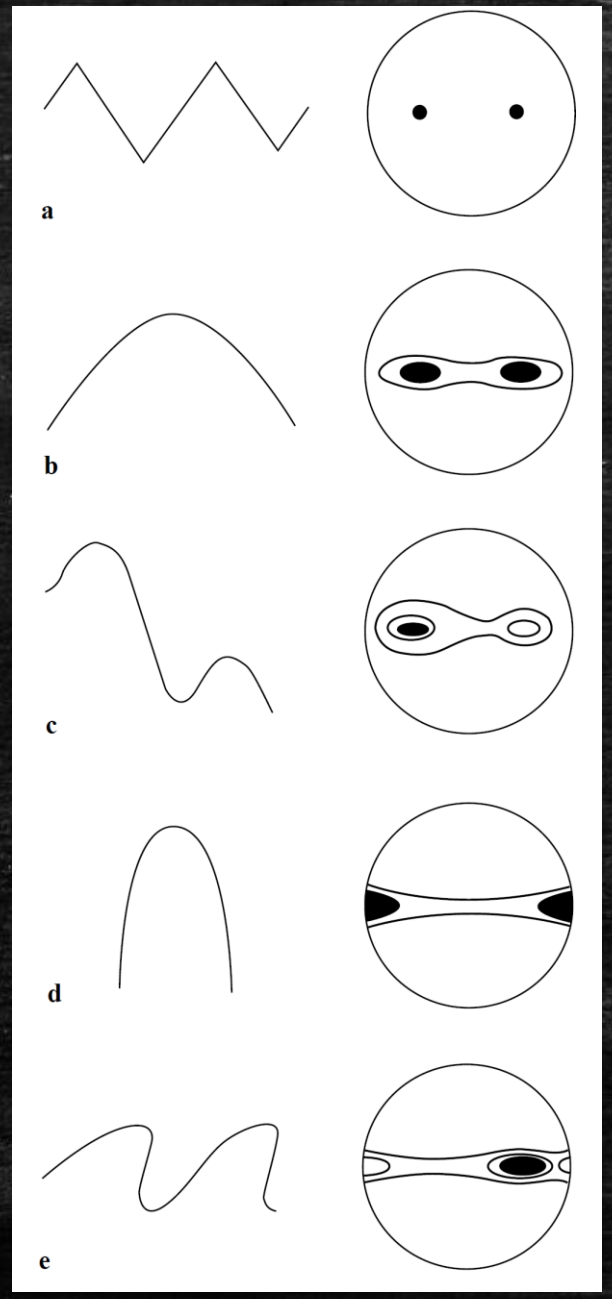
Joint Set
E
Bedding
E
Bedding
A
Bedding
B
Bedding
C
Joint Set
C
C_2
T
Sb
Qt
PT
Khlong Krasae
F66°
E58°
C25°
A51°
B49°
0 .5 1 2 3 4
Kilometers

Structural rock basement analysis



Structural rock basement synthesis

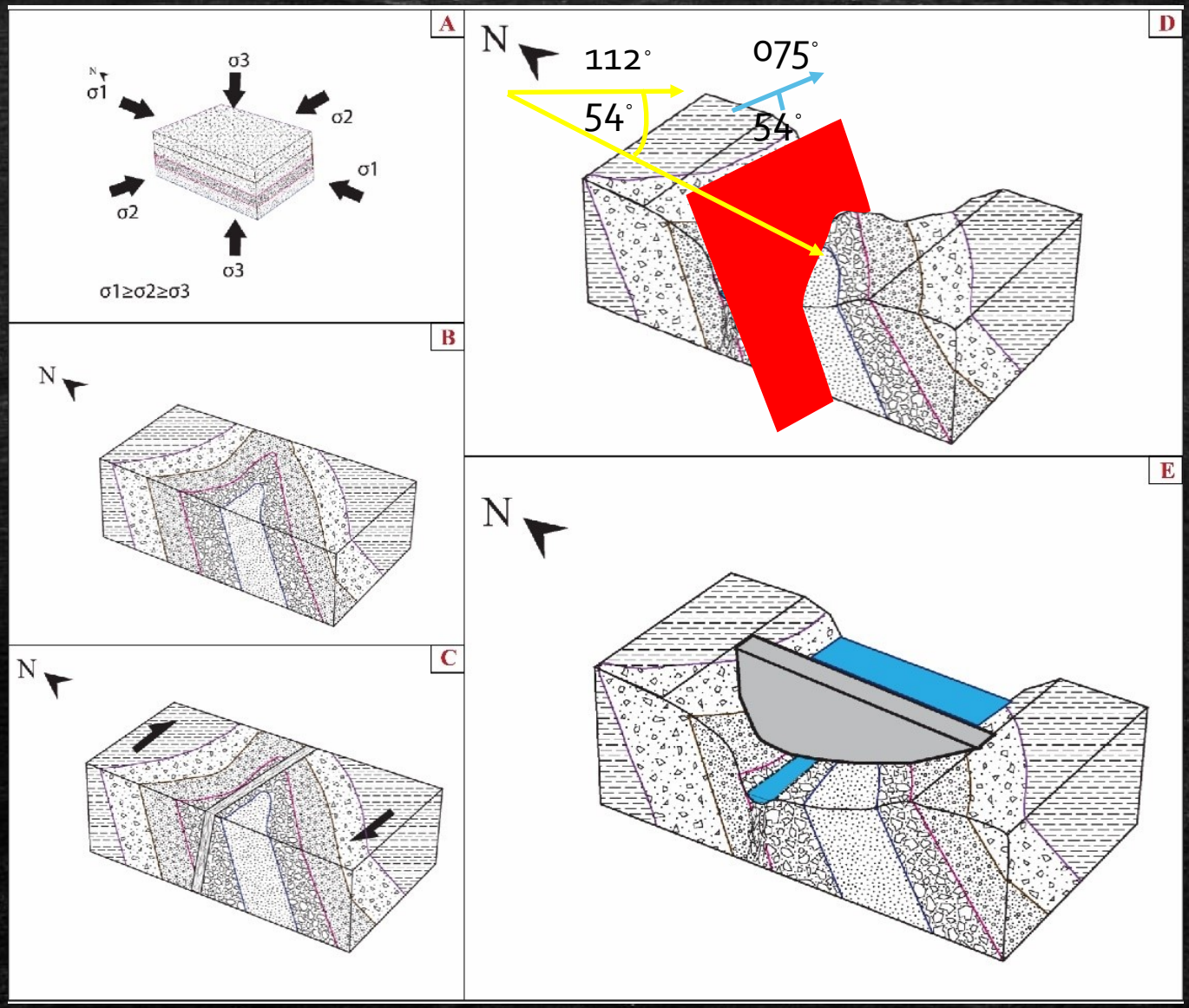




- overturn fold has axial plane about 071°/54°SE which fold axis has Trend about 112° and Plunge about 42°.

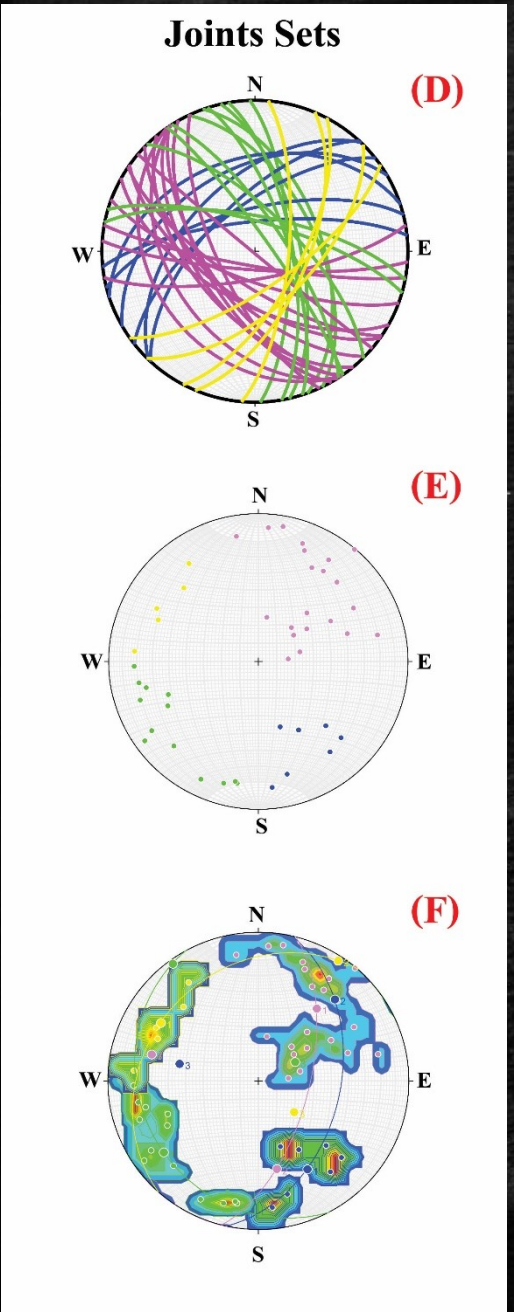
Profiles and corresponding contoured p-diagrams of variously shaped folds ((c, d, and e after Ragan, 1985) Rowland et al.,2007)

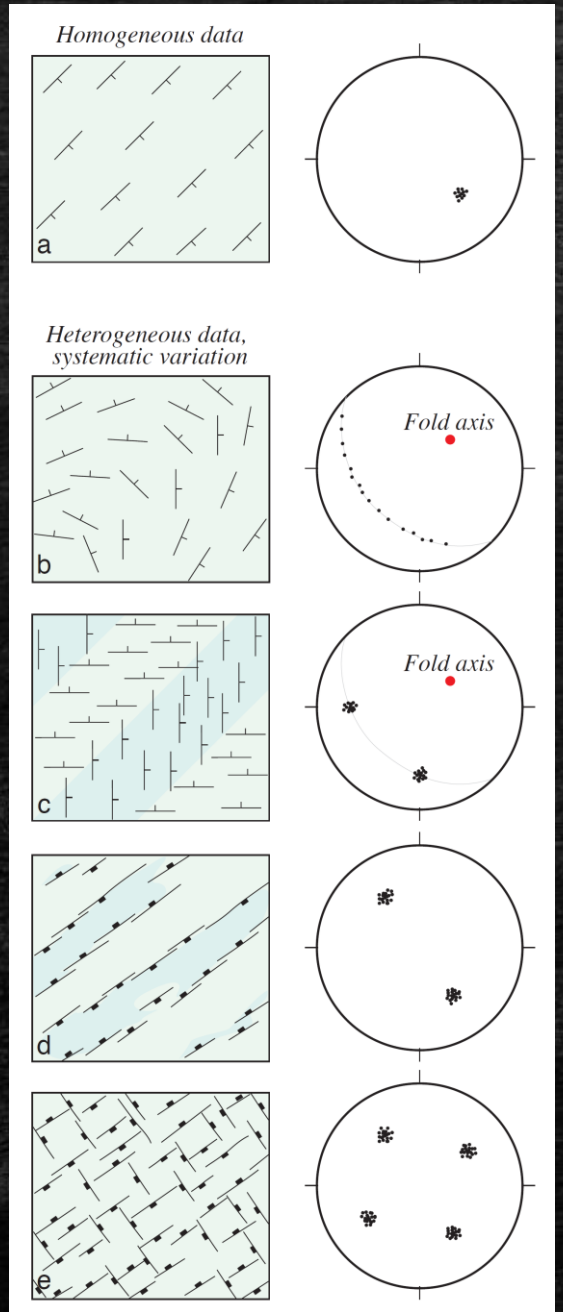
Idealized modeling from synthesis rock structure



Bedding synthesis result shows overturn fold which has axial plane about 071◦/54◦SE which fold axis has Trend about 112◦ and Plunge about 42◦.

Structural rock basement synthesis





Synthetic structural data sets showing different degree of homogeneity.

a) Synthetic homogeneous set of strike and dip measurements.

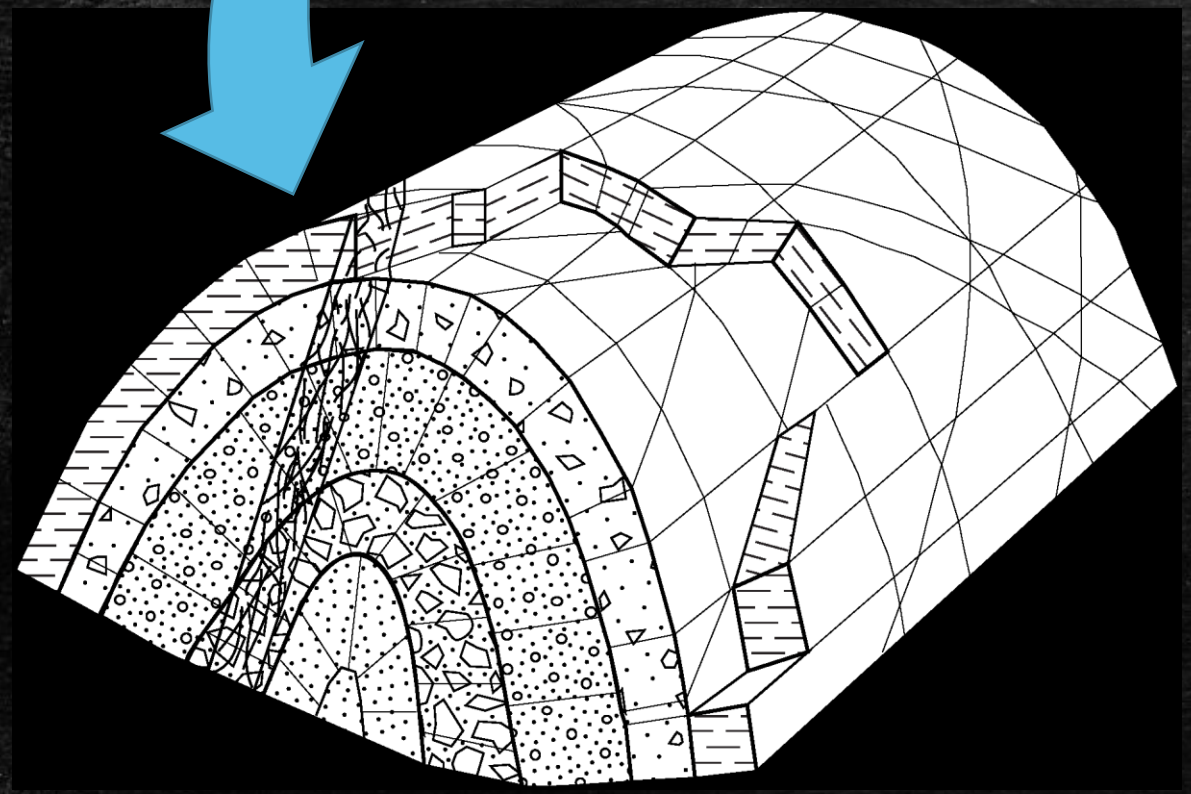
b) Systematic variation in layer orientation measurements.

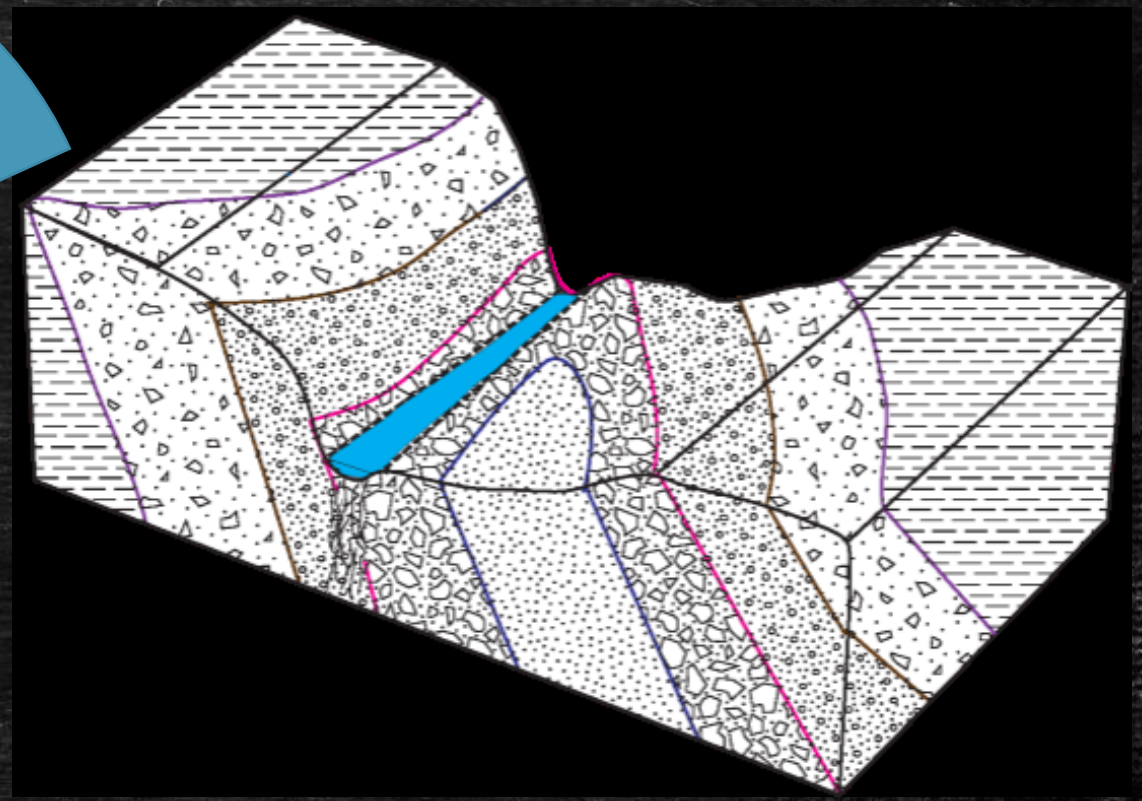
c) Homogeneous subareas due to kink- or chevron folding.

d-e) Systematic fracture systems. Note how the systematics are reflected in the strereonets.

(Fossen, H., 2010)

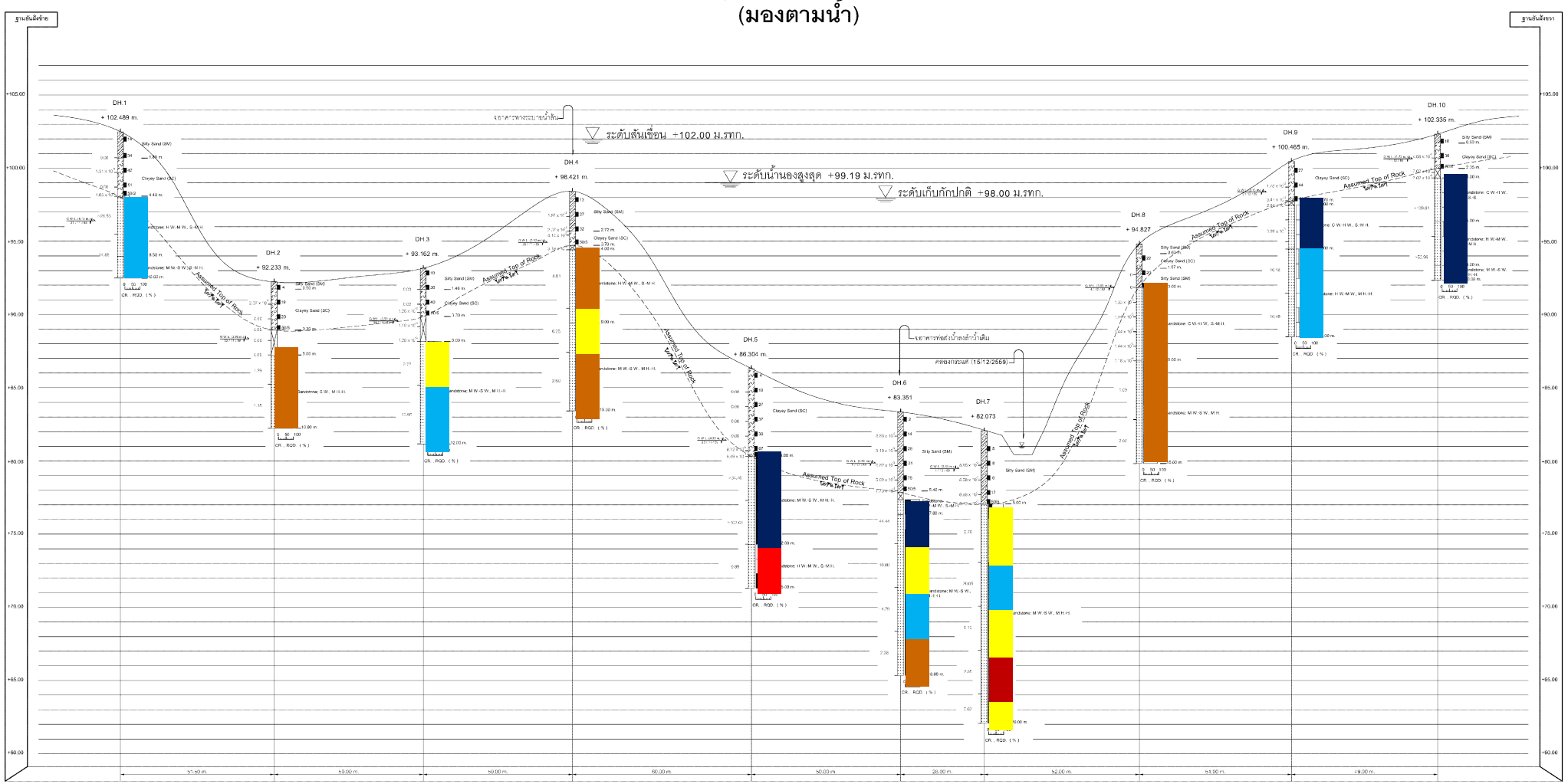
Idealized modeling from synthesis rock structure

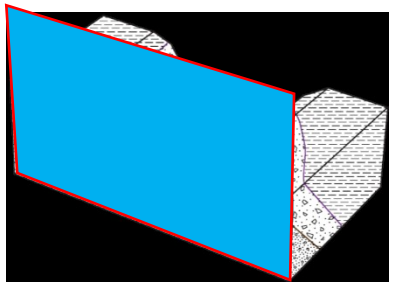




4. Hydrogeological investigation

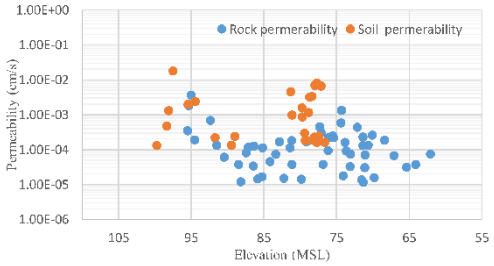
รูปตัดธรณีวิทยาฐานรากตามแนวศูนย์กลางเขื่อน
(มองตามน้ำ)





DEGREE OF PERMEABILITY

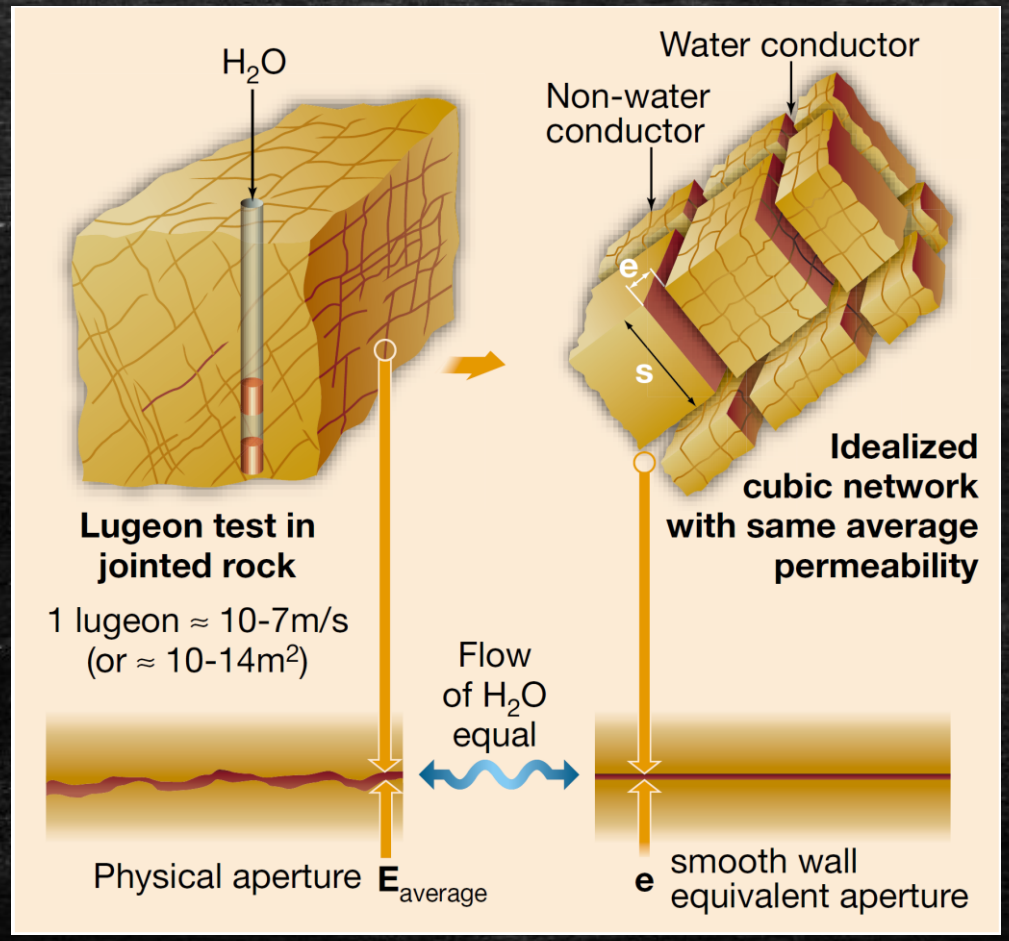
1 = < 1	Lugeon	or	$< 1 \times 10^{-5}$ cm./sec.
2 = 1 - 5	Lugeon	or	$1 \times 10^{-5} - 5 \times 10^{-5}$ cm./sec.
3 = 5 - 10	Lugeon	or	$5 \times 10^{-5} - 1 \times 10^{-4}$ cm./sec.
4 = 10 - 50	Lugeon	or	$1 \times 10^{-4} - 5 \times 10^{-4}$ cm./sec.
5 = > 50	Lugeon	or	$> 5 \times 10^{-4}$ cm./sec.



Wyllie & Mah, 2004

K primary - Seepage flow through intact rock is negligible essentially all.

K secondary - flow occurs along the discontinuity.



Graphical explanation of the effective hydraulic opening (from Barton, 2004a)

5. Finite element seepage analysis

Finite element seepage analysis

SEEP/W (GEO-SLOPE, 1999) model water pressure of soil and rock foundations in saturate and unsaturated condition with steady state flow. The ratio of the permeability in the vertical direction to that in the horizontal direction (Ky/Kx)

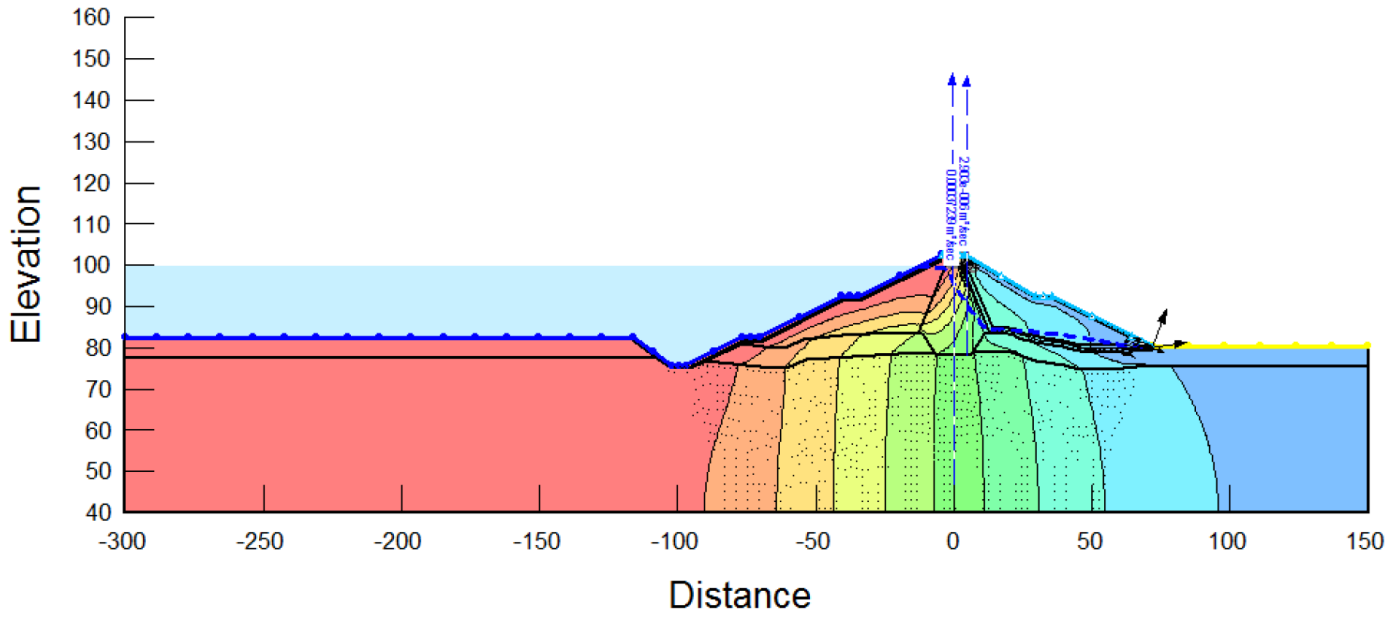
Ky = Permeability in vertical direction.

Kx = Permeability in horizontal direction.

seepage analysis was tested with various anisotropic permeability ratio to 0.1, 0.2, 0.5, 1.0, 2.0, 5.0 and 10.0 to seepage model

Table 1 Materials properties assumed for modeling.

Materials	Model	K_{Sat} (m/sec)
Foundation 1	Saturated Only	$1.00E^{-04}$
Foundation 2	Saturated Only	$1.00E^{-05}$
Core Zone	Saturated / Unsaturated	$1.00E^{-07}$
Random Zone	Saturated / Unsaturated	$1.00E^{-05}$



Finite elements seepage analysis of total head and flux value in case of HWL, permeability ratio equal to 1

Table 2 Results of flux value in various ratio in case of full supply level (FWL).

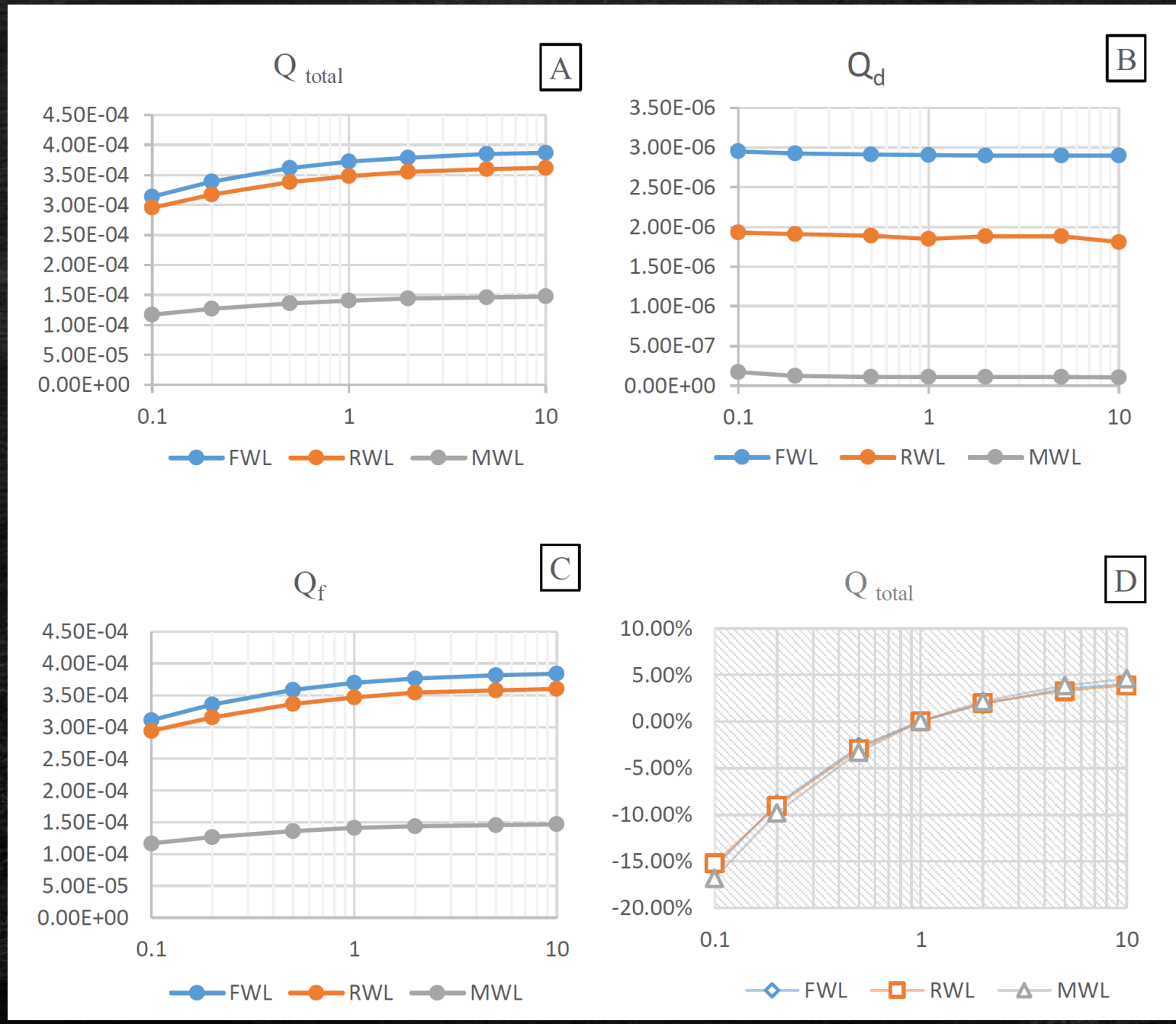
Ratio	Q_{total} (m^3/sec)	Q_d (m^3/sec)	Q_f (m^3/sec)
0.10	$3.14E^{-04}$	$2.9513E^{-06}$	$3.1086E^{-04}$
0.20	$3.39E^{-04}$	$2.9272E^{-06}$	$3.3596E^{-04}$
0.50	$3.62E^{-04}$	$2.9092E^{-06}$	$3.5862E^{-04}$
1.00	$3.72E^{-04}$	$2.9030E^{-06}$	$3.6949E^{-04}$
2.00	$3.79E^{-04}$	$2.8996E^{-06}$	$3.7644E^{-04}$
5.00	$3.85E^{-04}$	$2.8986E^{-06}$	$3.8166E^{-04}$
10.00	$3.87E^{-04}$	$2.8988E^{-06}$	$3.8391E^{-04}$

Table 3 Results of flux value in various ratio in case of retention water level (RWL).

Ratio	Q_{total} (m^3/sec)	Q_d (m^3/sec)	Q_f (m^3/sec)
0.10	$2.96E^{-04}$	$1.93E^{-06}$	$2.94E^{-04}$
0.20	$3.17E^{-04}$	$1.91E^{-06}$	$3.15E^{-04}$
0.50	$3.38E^{-04}$	$1.89E^{-06}$	$3.36E^{-04}$
1.00	$3.49E^{-04}$	$1.85E^{-06}$	$3.47E^{-04}$
2.00	$3.56E^{-04}$	$1.88E^{-06}$	$3.54E^{-04}$
5.00	$3.60E^{-04}$	$1.88E^{-06}$	$3.58E^{-04}$
10.00	$3.62E^{-04}$	$1.81E^{-06}$	$3.60E^{-04}$

Table 4 Results of flux value in various ratio in case of minimum water level (MWL).

Ratio	Q_{total} (m^3/sec)	Q_d (m^3/sec)	Q_f (m^3/sec)
0.10	$1.17E^{-04}$	$1.71E^{-07}$	$1.17E^{-04}$
0.20	$1.27E^{-04}$	$1.23E^{-07}$	$1.27E^{-04}$
0.50	$1.36E^{-04}$	$1.09E^{-07}$	$1.36E^{-04}$
1.00	$1.41E^{-04}$	$1.07E^{-07}$	$1.41E^{-04}$
2.00	$1.44E^{-04}$	$1.06E^{-07}$	$1.44E^{-04}$
5.00	$1.46E^{-04}$	$1.06E^{-07}$	$1.46E^{-04}$
10.00	$1.47E^{-04}$	$1.05E^{-07}$	$1.47E^{-04}$


Q total
A
4.50E-04
4.00E-04
3.50E-04
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0.1
1
10
FWL
RWL
MWL
Qd
B
3.50E-06
3.00E-06
2.50E-06
2.00E-06
1.50E-06
1.00E-06
5.00E-07
0.00E+00
0.1
1
10
FWL
RWL
MWL
Qf
C
4.50E-04
4.00E-04
3.50E-04
3.00E-04
2.50E-04
2.00E-04
1.50E-04
1.00E-04
5.00E-05
0.00E+00
0.1
1
10
FWL
RWL
MWL
Q total
D
10.00%
5.00%
0.00%
-5.00%
-10.00%
-15.00%
-20.00%
0.1
1
10
FWL
RWL
MWL

Conclusion and discussion

1. Kra Sae Project consists on the Triassic rock which compose of reddish brown to grey sandstone.

2. Bedding of basement rock present two major strike directions are as follows NE SW and E-W. Bedding synthesis result shows overturn fold which has axial plane about 071°/54°SE which fold axis has Trend about 112° and Plunge about 42°.

3. Joint Patterns show 4 patterns of dip direction are dip to NW, SE, NE and SW. The synthesis of joint patterns in Triassic rock illustrate joint net that have spacing between each joint around 3 cm up to 30 cm.

4. foundation in case of vertical permeability flow (Ky) more than horizontal permeability flow (Kx).

5. Results from numerical modeling are corresponding to geological investigation, it was showed that orientation of bedding are perpendicular with center line of dam and joints are cutting into the rock mass and illustrates rock mass to blocky. That's discontinuity pattern causes an affect to vertical discontinuity is continuous more than horizontal discontinuity.

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สำนักออกแบบวิศวกรรมและสถาปัตยกรรม

สำนักชลประทานที่ 8

Thank you for your attention