國立中央大學應地所專題討論111-1學期

Characterization of shallow subsurface active deformation zone during the past 10 thousand years in alluvial plain area, southwestern Taiwan- a case of Chegualin fault

台灣西南部1萬年以來近地表的活動變形帶特徵化研究以車瓜林斷層為例

Chuan Ding[a,b], Maryline Le Béon[b], Chen-chau Lee[a], Shu-ken Ho[a], Jia-Jyun Dong[b]

[a] *Sinogeotech Inc., Taipei, Taiwan*

[b] *Graduate Institute of Applied Geology, National Central University, Zhongli, Taiwan*

* *Corresponding author:* Maryline Le Béon

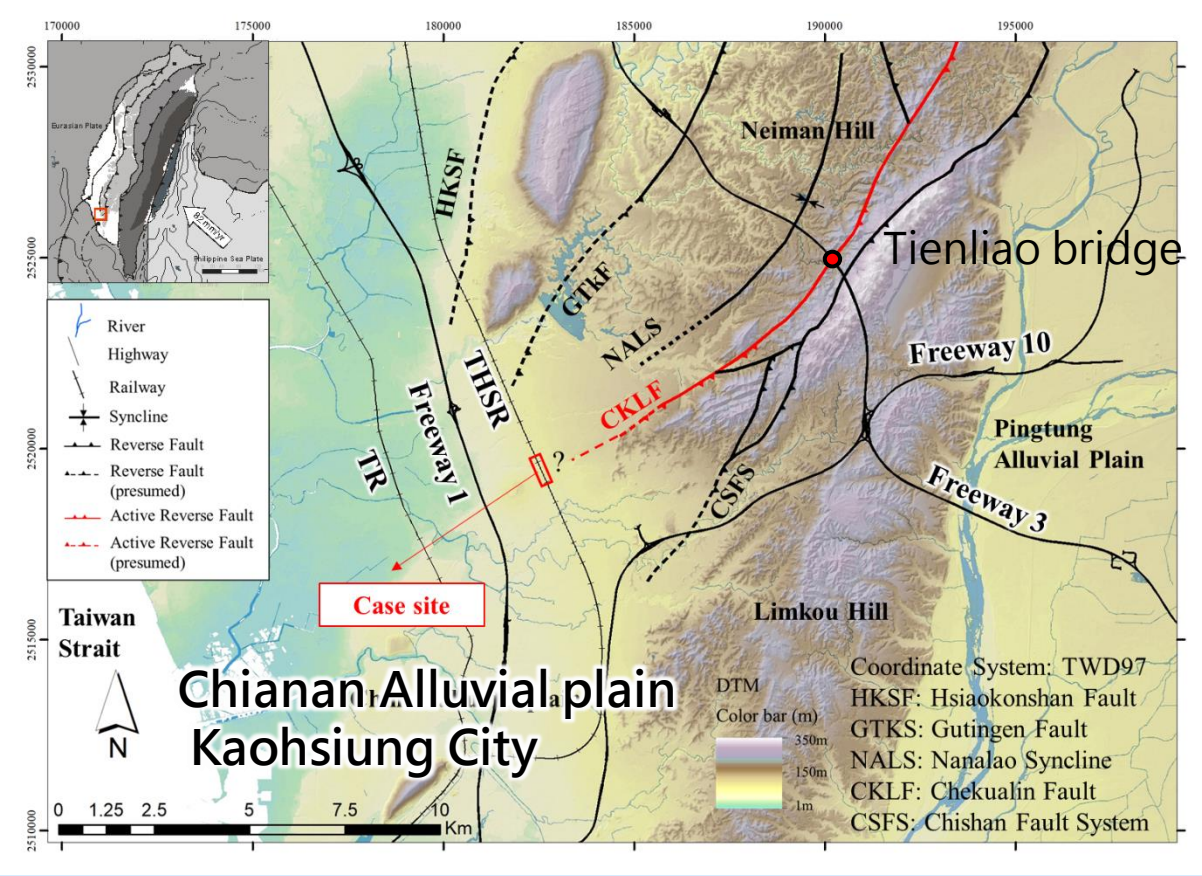
2023/1/13

- Introduction

1) Characteristics of modern active (deformation) zone
   - on-site monitoring data
2) Lateral distribution of modern active zone
   - surface rupture traced along morphotectonics features.
3) Characteristics of long-term active zone
   - Stratigraphic correlation by 2 transects
   - Nanno fossil, foraminifera chronology
   - Shear zone, bedding within bedrock and Holocene deposits.
4) Spatial and temporal variation of active zone - Long-term uplift rate
   - absolute dating method (eustatic sea level curve, paleo environment, sample height & C-14 dating)
   - Relative dating method - computed by isochron line
   - Long term vs. short-term uplift rates

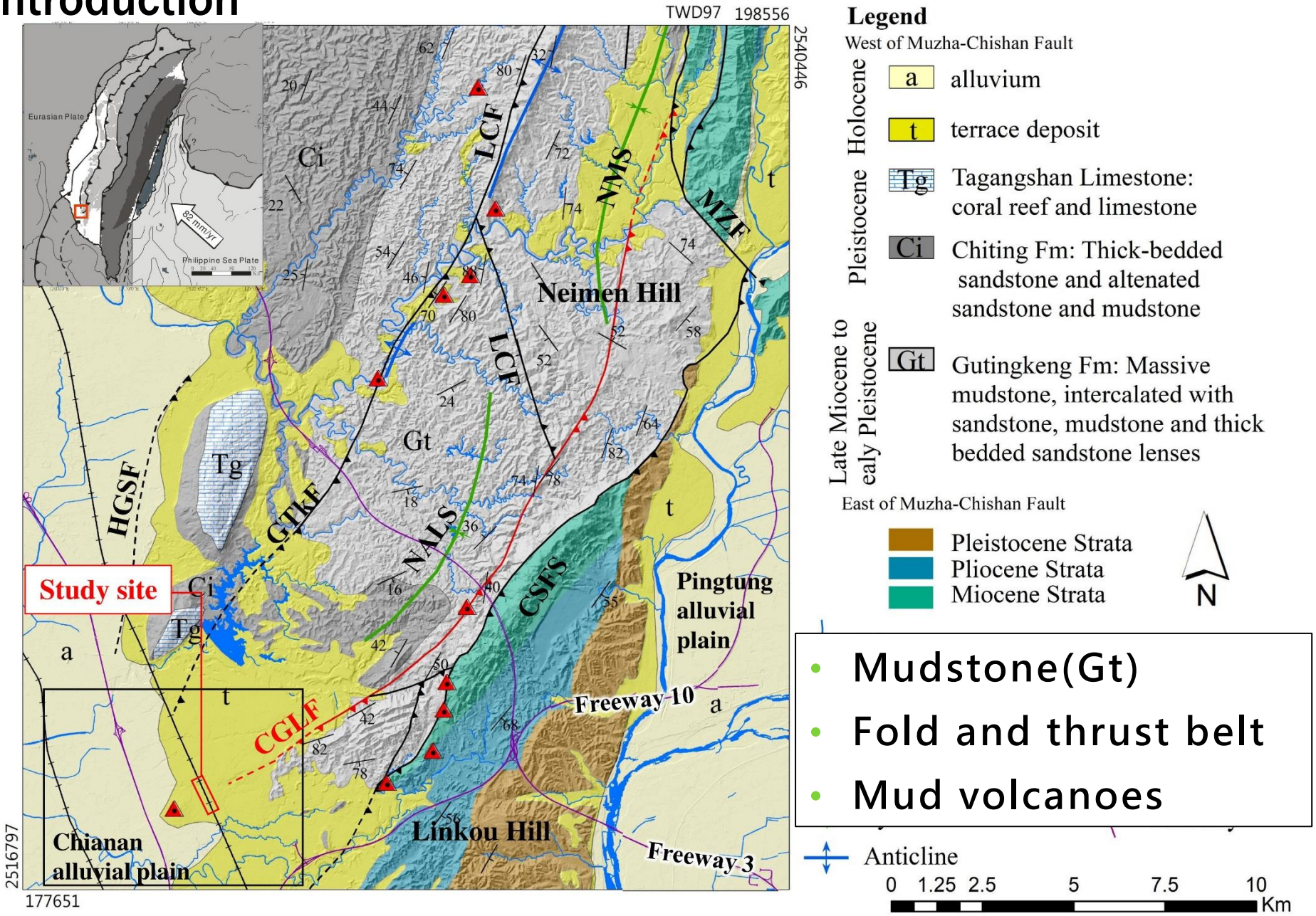
WHY?

- Creeping Active Fault Geohazard
- Metro Transits (Freeway, MRT)
- Still Unknown under Chianan Alluvial plain



CKLF = Chekualin fault

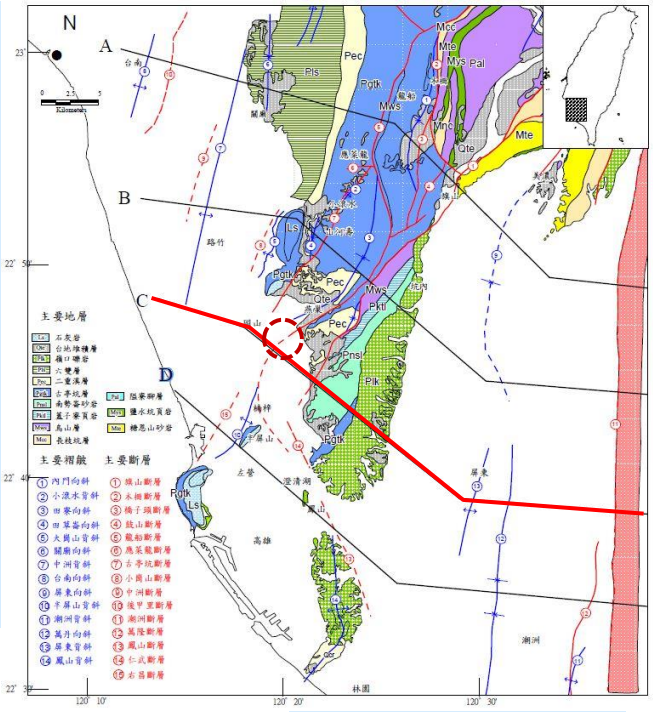
Introduction

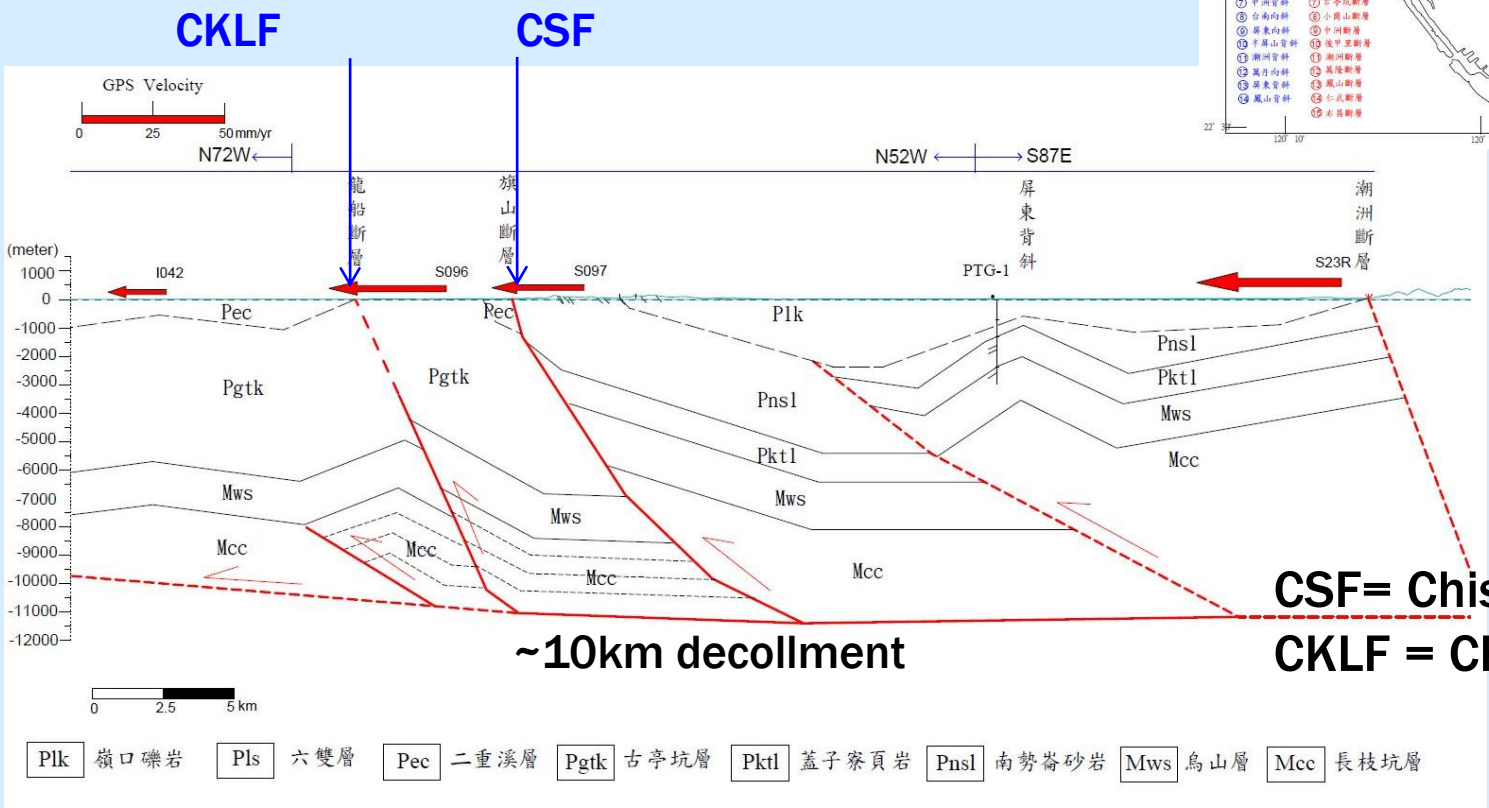


- Mudstone(Gt)
- Fold and thrust belt
- Mud volcanoes

- **High angle thrust fault**

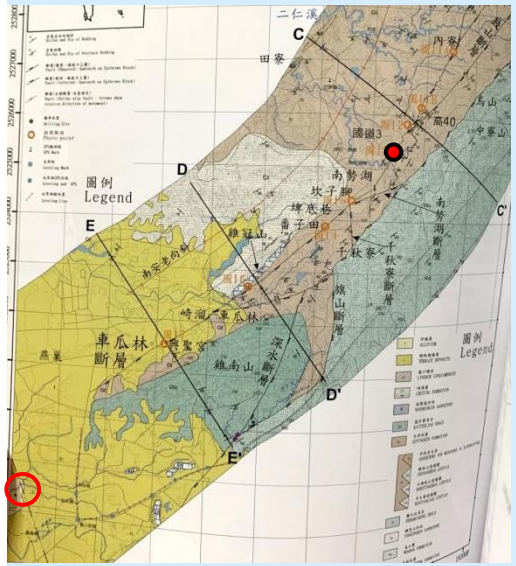
  Equilibrium Profile
  Cheng(2000)





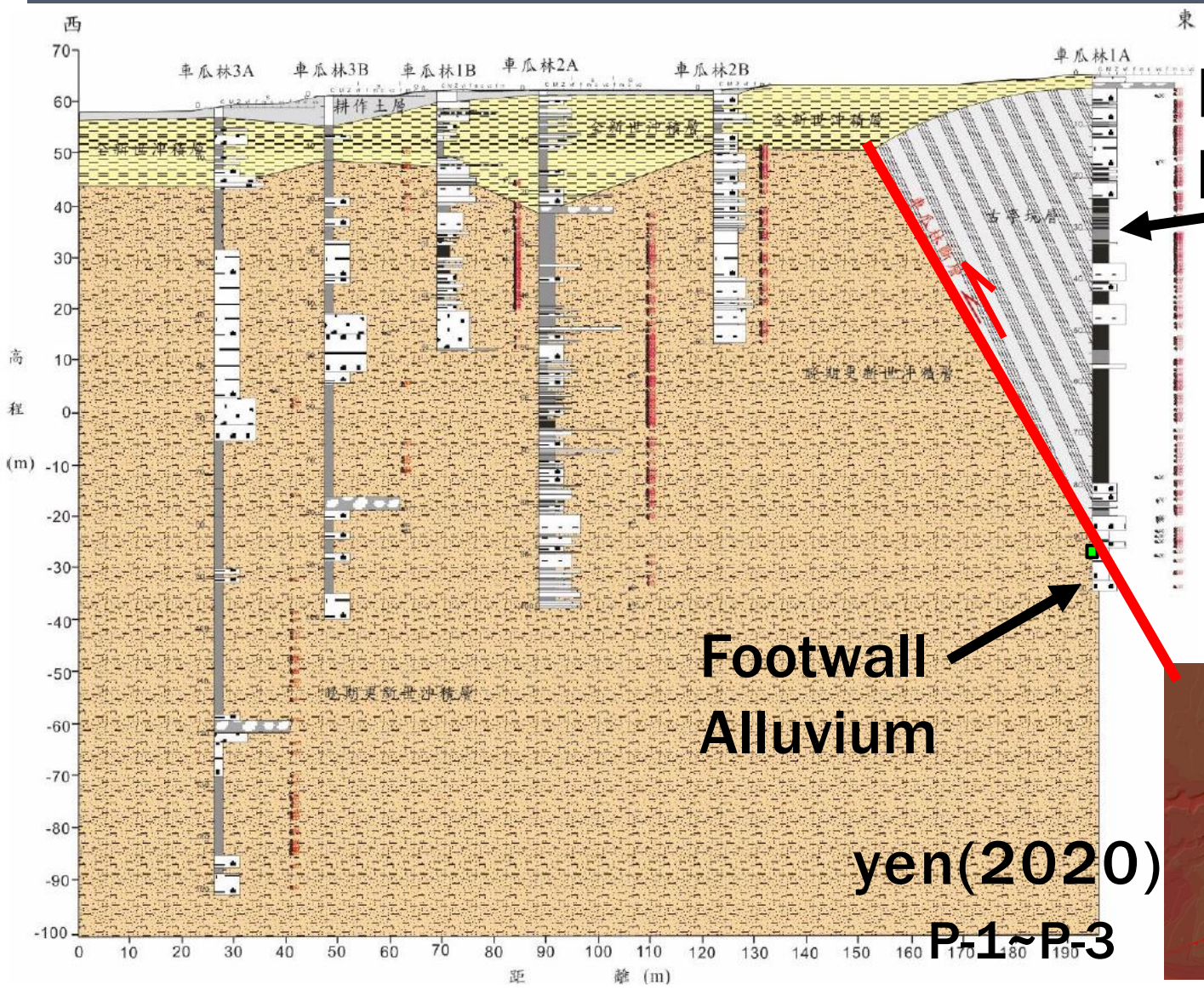
OUTCROPS FAULT ZONE FEATURES

- Widespread Shear Zone in hanging wall(>130m)
- Branch Faults
- Steeply hanging wall



Liu & Lin(2019)

BEDROCK THRUST ON OLDER ALLUVIUM(20~40KA)

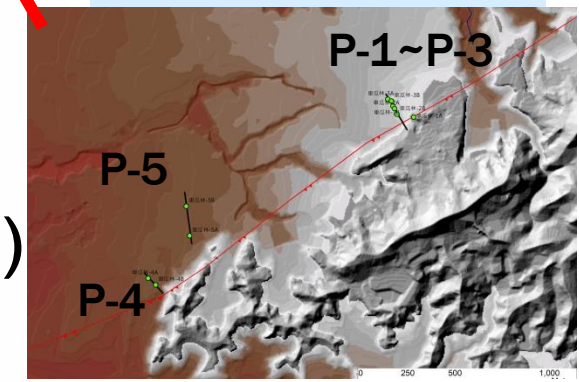


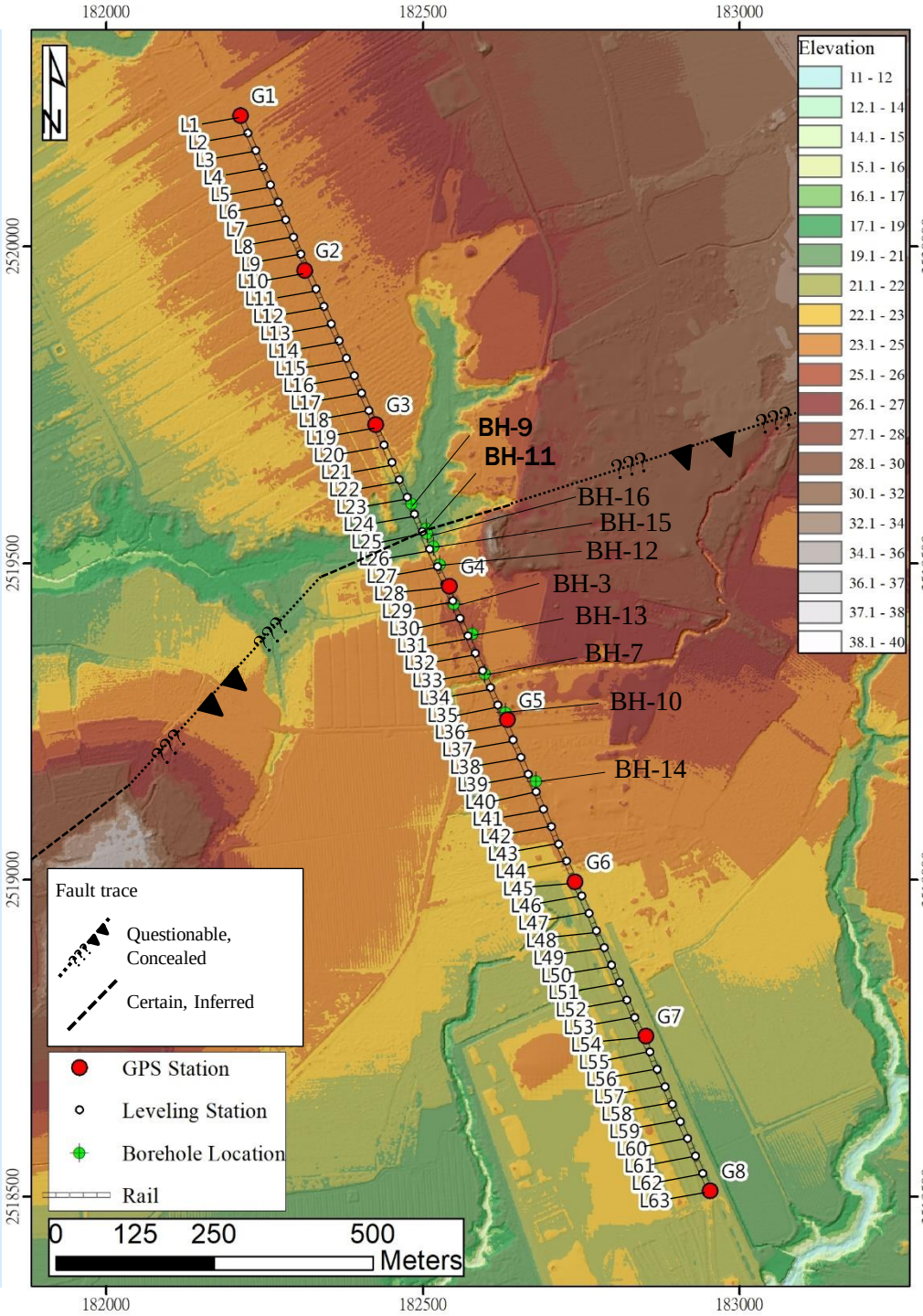
Hanging wall bedrock

Footwall Alluvium

yen(2020)

P-1~P-3




182000
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2520000
2519500
2519000
2518500
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14.1 - 15
15.1 - 16
16.1 - 17
17.1 - 19
19.1 - 21
21.1 - 22
22.1 - 23
23.1 - 25
25.1 - 26
26.1 - 27
27.1 - 28
28.1 - 30
30.1 - 32
32.1 - 34
34.1 - 36
36.1 - 37
37.1 - 38
38.1 - 40
G1
G2
G3
G4
G5
G6
G7
G8
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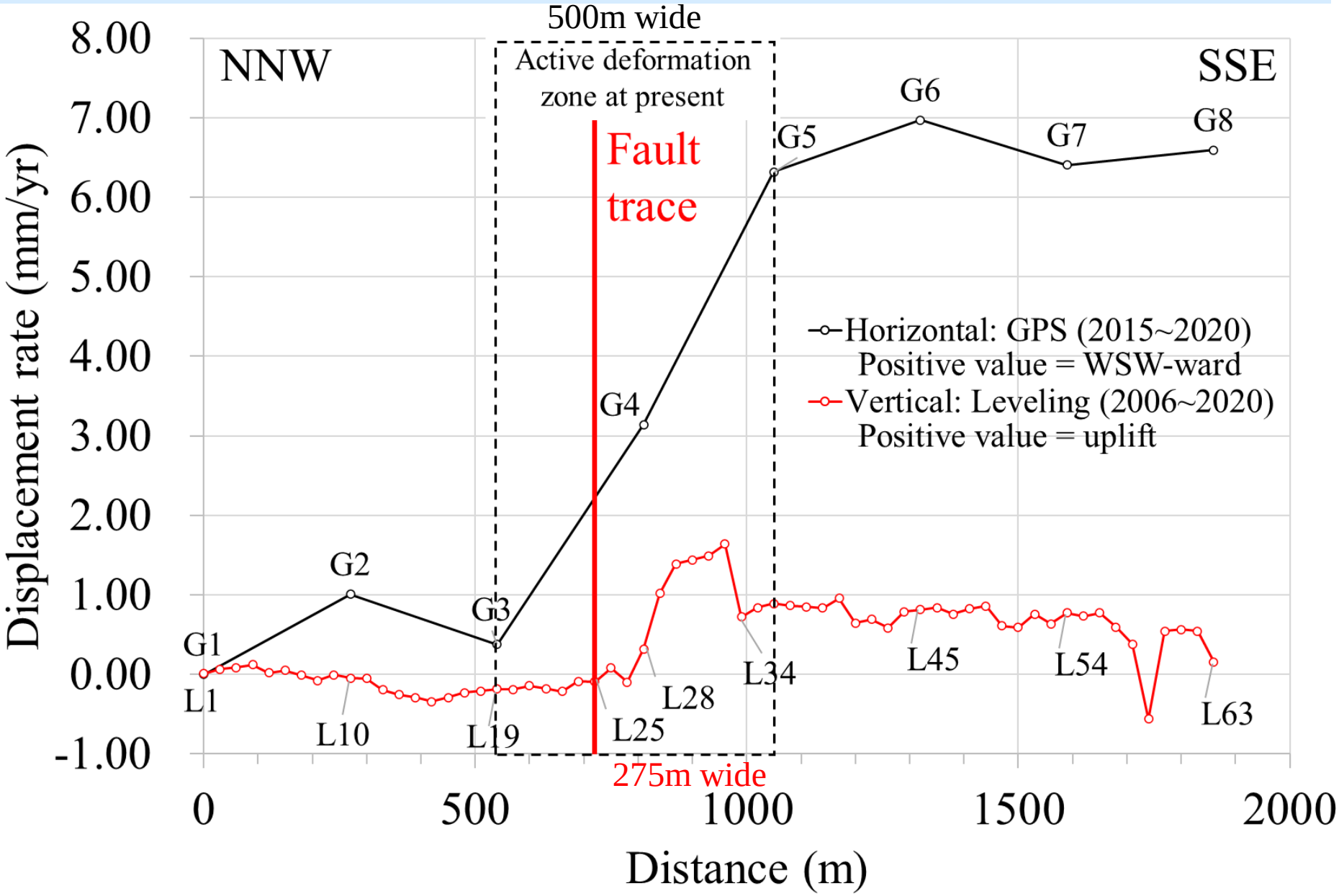
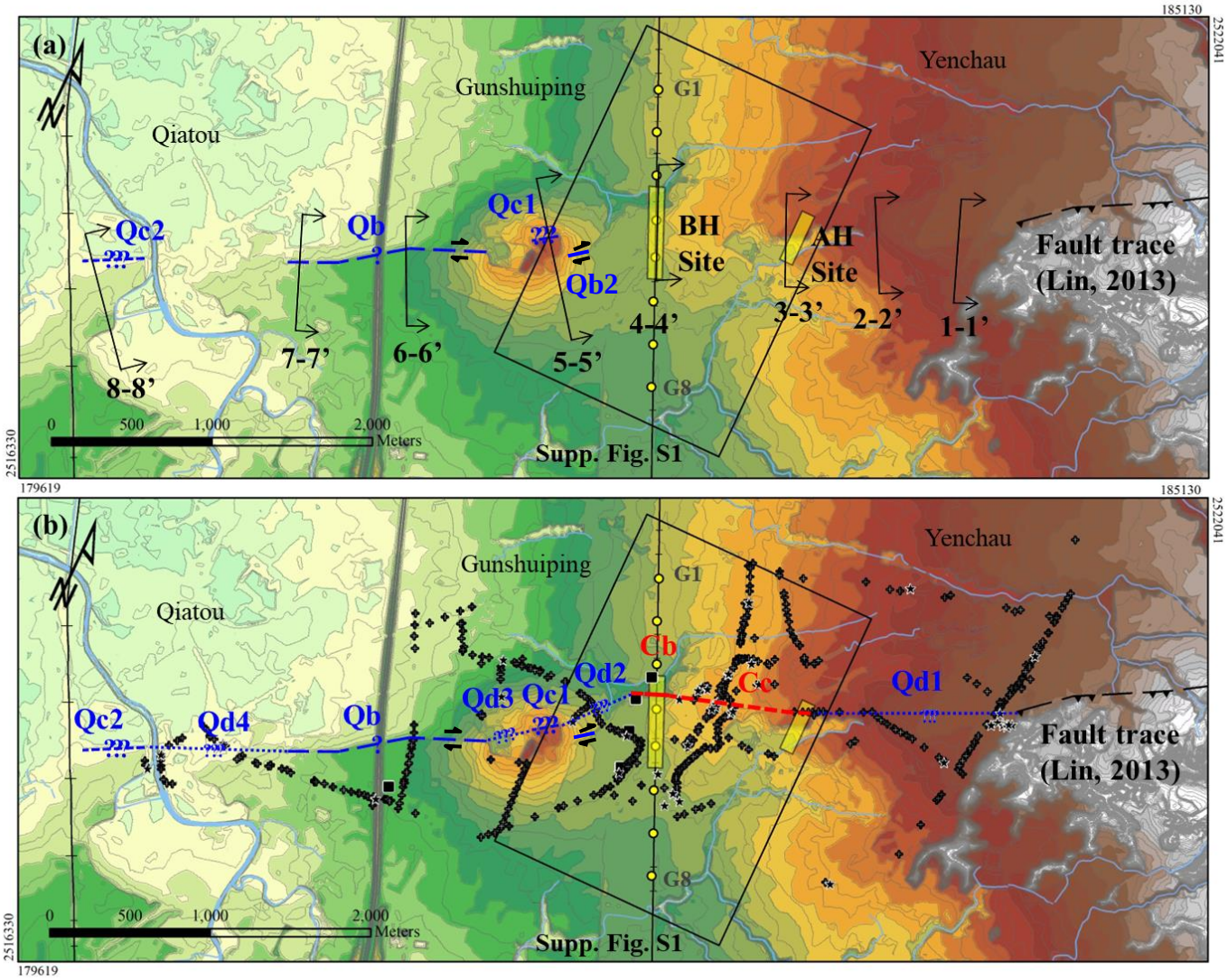
BH-9
BH-11
BH-16
BH-15
BH-12
BH-3
BH-13
BH-7
BH-10
BH-14
???
Fault trace
Questionable, Concealed
Certain, Inferred
GPS Station
Leveling Station
Borehole Location
Rail
0 125 250 500
Meters

Characteristics of modern active zone - on-site monitoring data



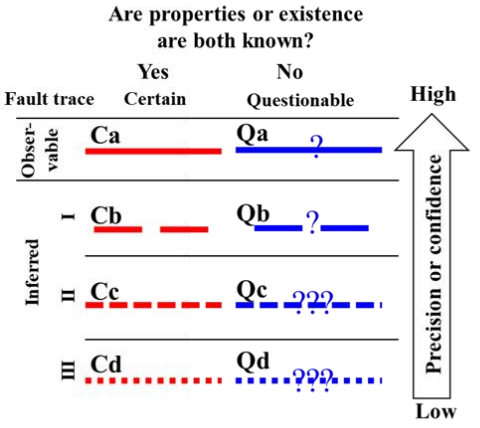
Lateral distribution of modern active zone -surface rupture traced along morphotectonics features

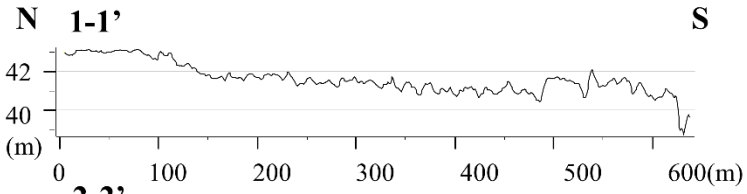


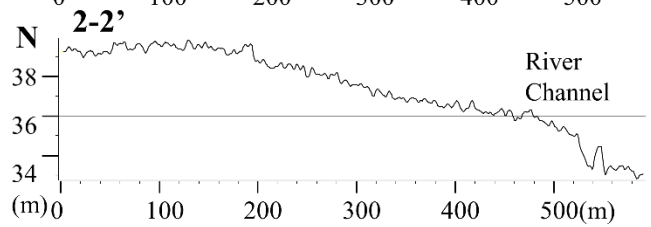
Highway
Railway
River
Topographic contour line (1m interval)
Topographic profile
Borehole transect site
GPS station (G1 ~ G8)
Inclined poles
Inclined electric tower
Cracks

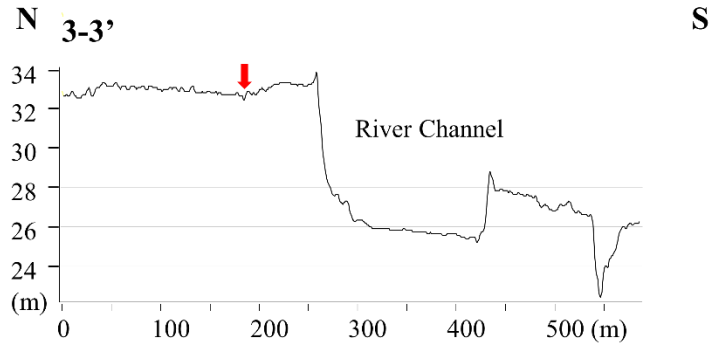
Elevation(m)

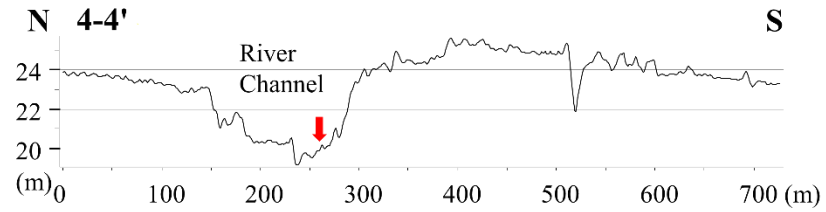
1 - 2	17 - 19	34 - 37	51 - 53
2 - 4	19 - 21	37 - 39	53 - 56
4 - 6	21 - 23	39 - 41	56 - 58
6 - 8	23 - 25	41 - 43	58 - 60
8 - 10	25 - 27	43 - 45	60 - 62
10 - 13	27 - 30	45 - 47	>62
13 - 15	30 - 32	47 - 49	
15 - 17	32 - 34	49 - 51	

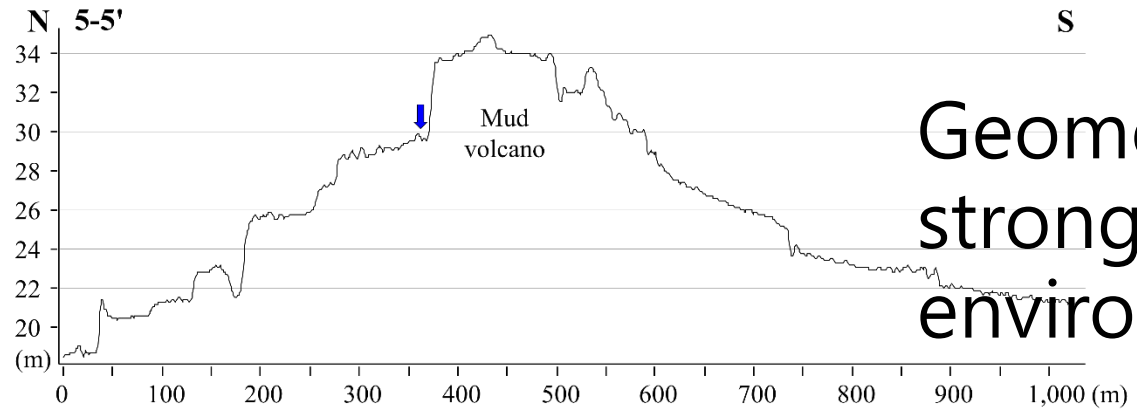


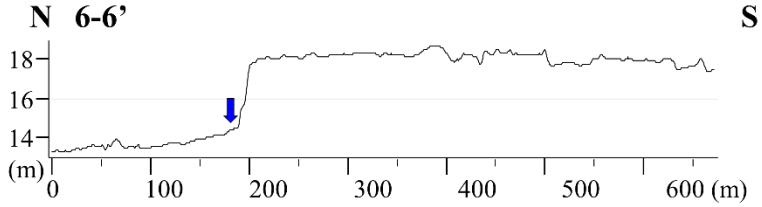


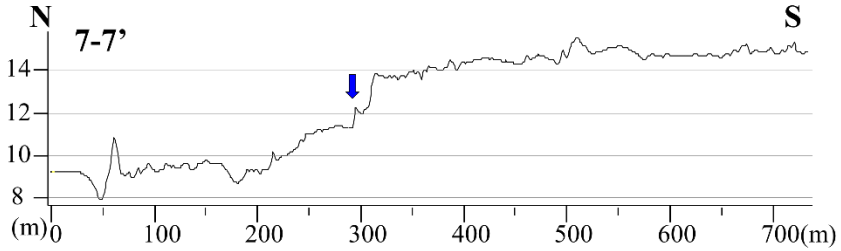


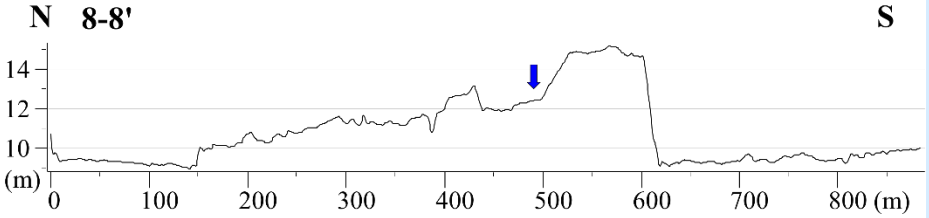








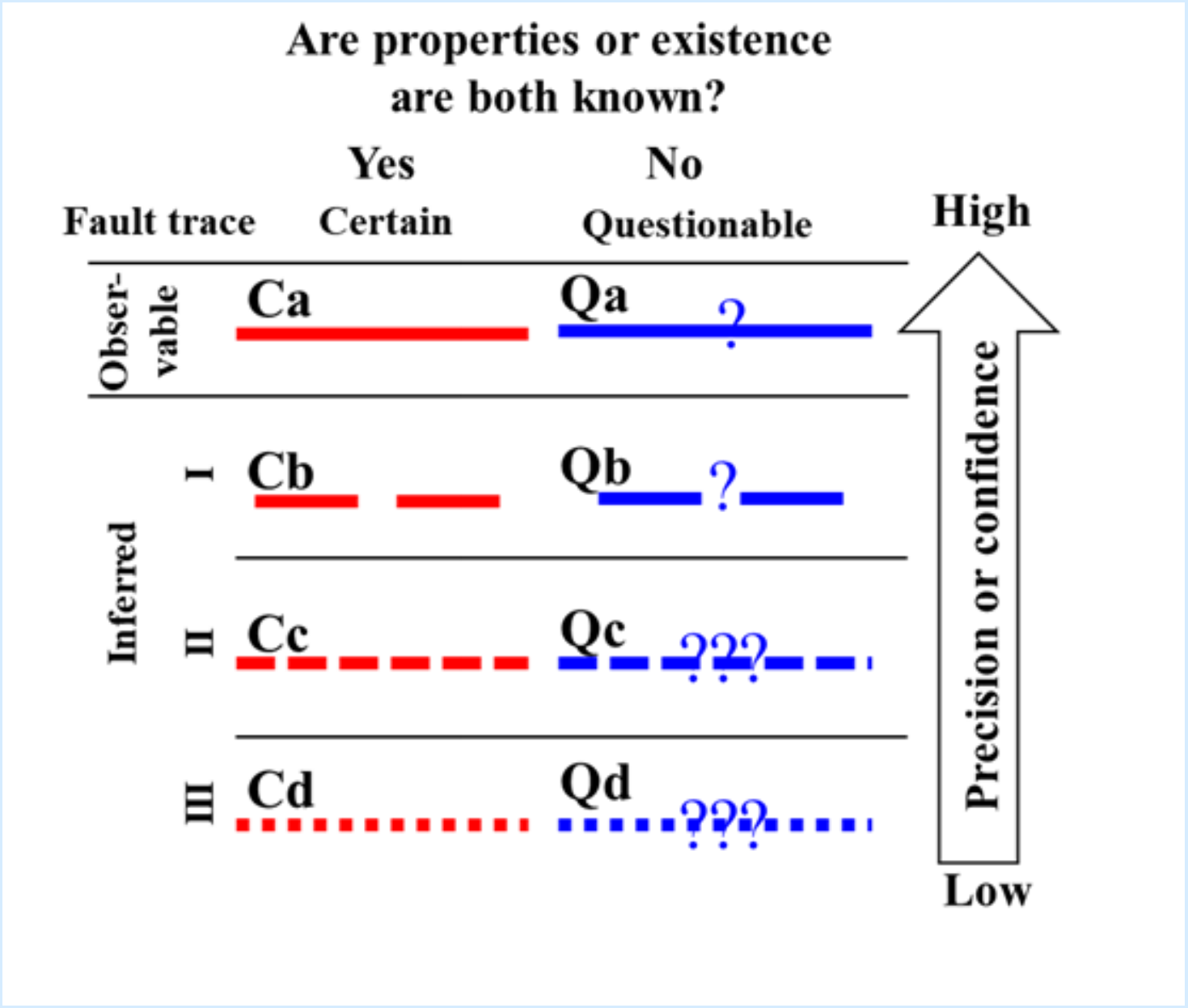




Fault scarp identified by borehole transect

Fault Scarps identified by tecto-geomorphic analysis

Geomorphological setting strongly eroded environment


Are properties or existence are both known?
Yes
No
Fault trace
Certain
Questionable
High
Obser-vable
Ca
Qa
?
Inferred
I
Cb
Qb
?
II
Cc
Qc
???
III
Cd
Qd
???
Precision or confidence
Low

Classification	Confidence	Precision (Uncertainty of location of fault trace)
Observable (a)	Direct evidences (fault outcrop)	Might be within 1 meter
inferred I (b)	Multiple evidences and convincing results (topography, trenches or dense boreholes…) but no fault exposed directly	Might be within 10 meters
inferred II (c)	Single evidence only or vague results (Morphotectonic, geophysics)	Might be within 30 meters
inferred III (d)	Explanation of connections of 2 segments of faults	Might be larger than 50 meters

Note: “Observable” is referred as a breakthrough fault with fault outcrop exposure and “Inferred I~III” might be referred as blind faults.

a.

b.

c.

d.

e.

f.

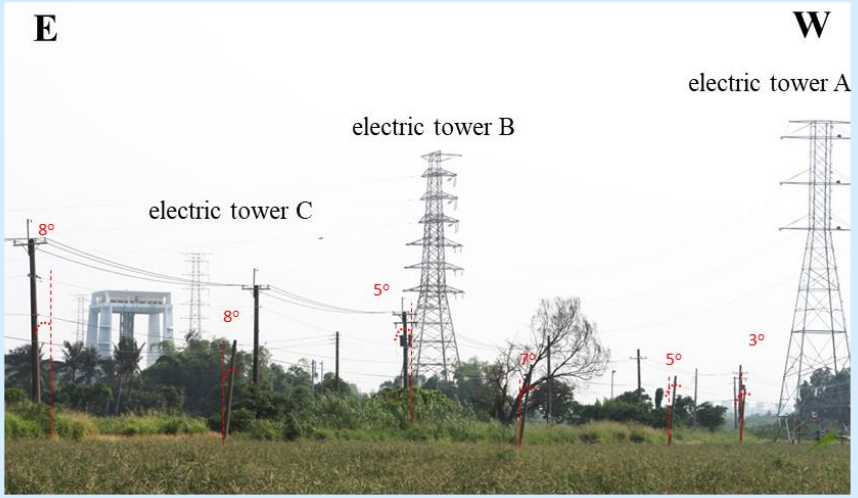
g.

h.

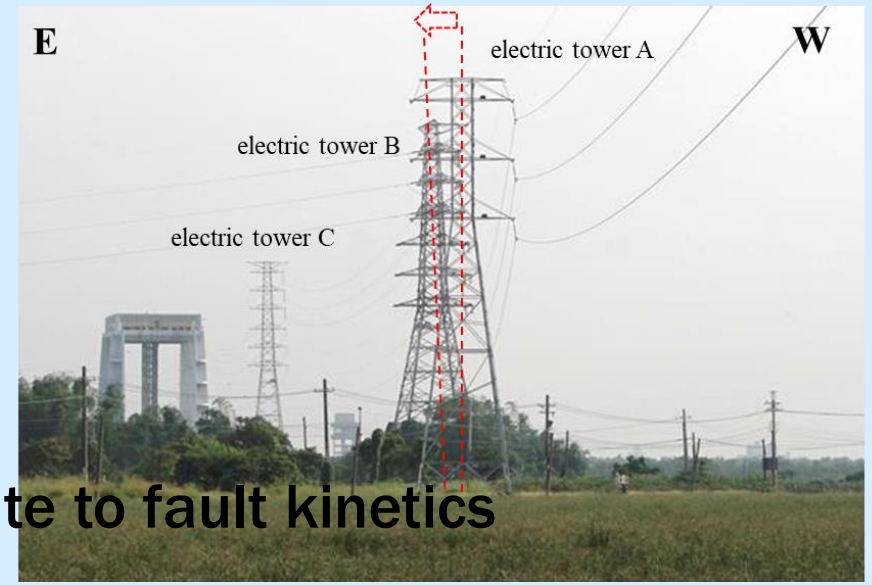
i.

j.

k.



l.



- Cracks Directions may not corelate to fault kinetics
  - Structural adjustment space
- Compression of ground surface by tectonic movements

m.

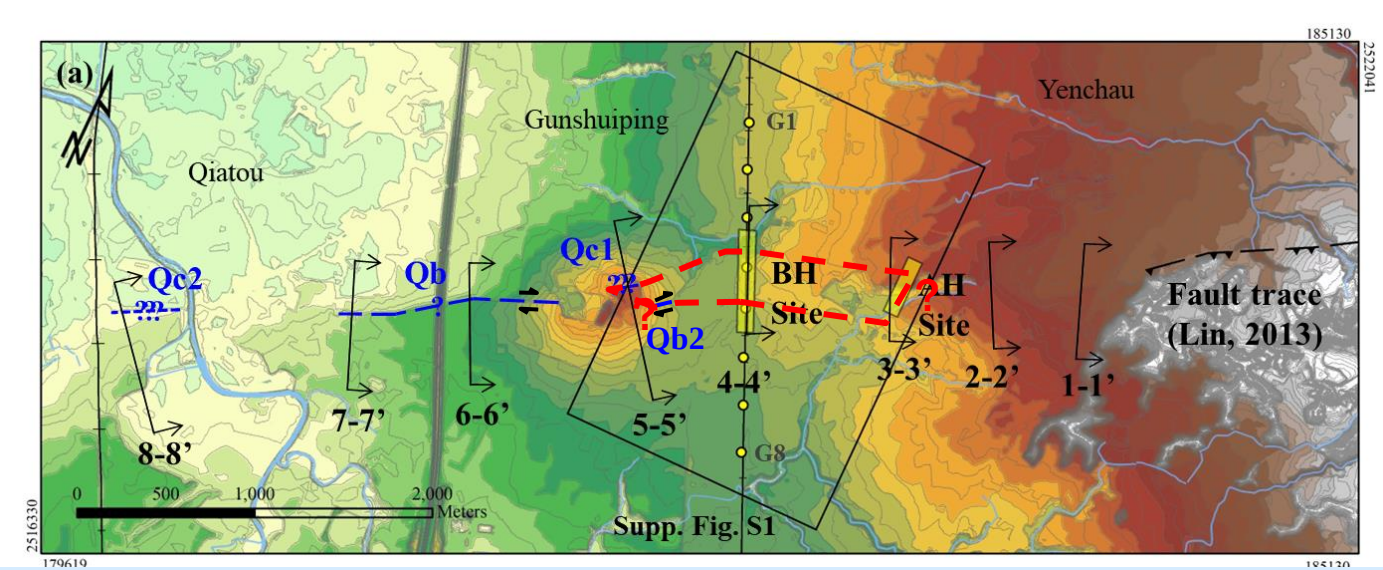
n.

o.

p.

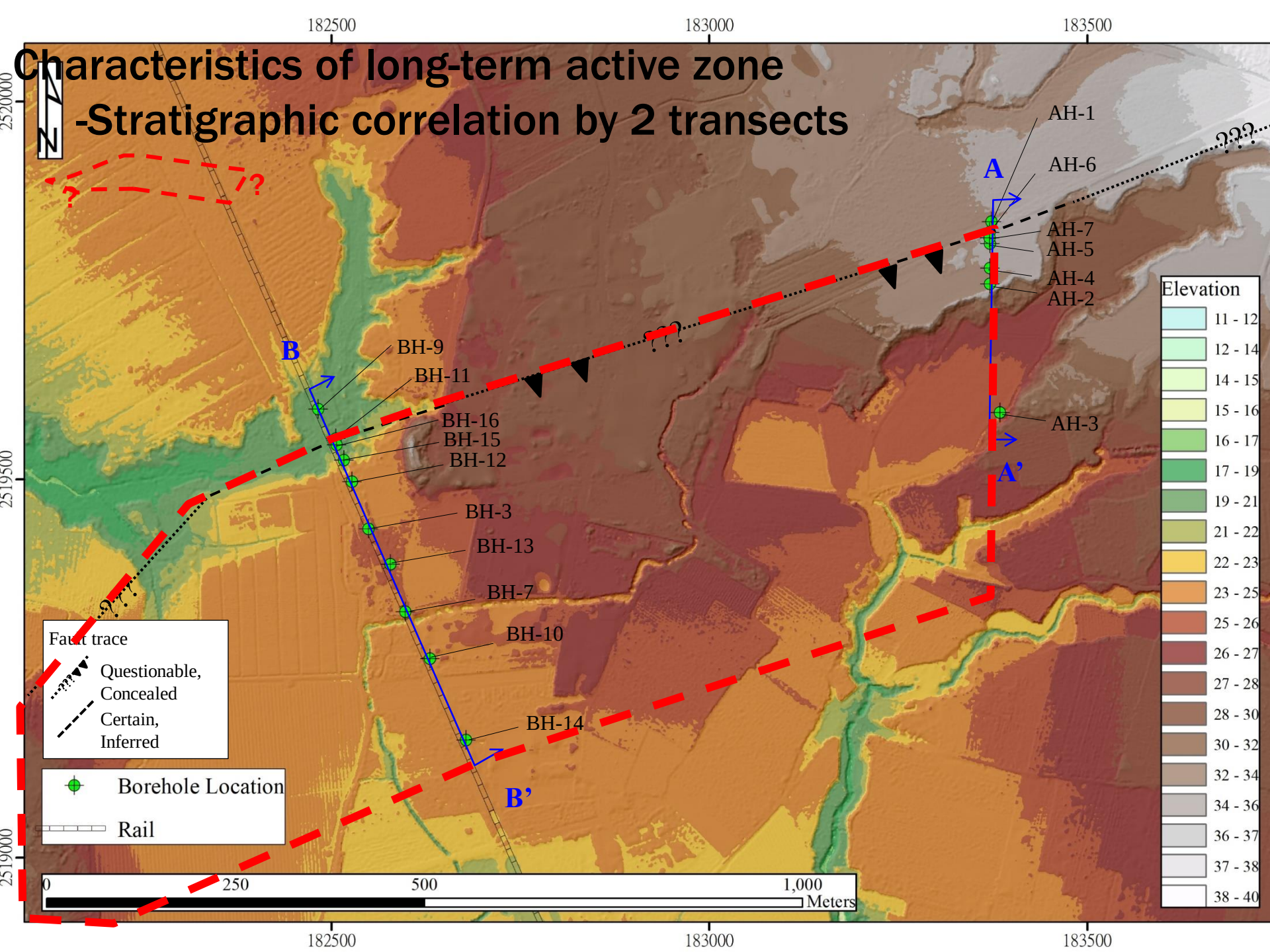
q.

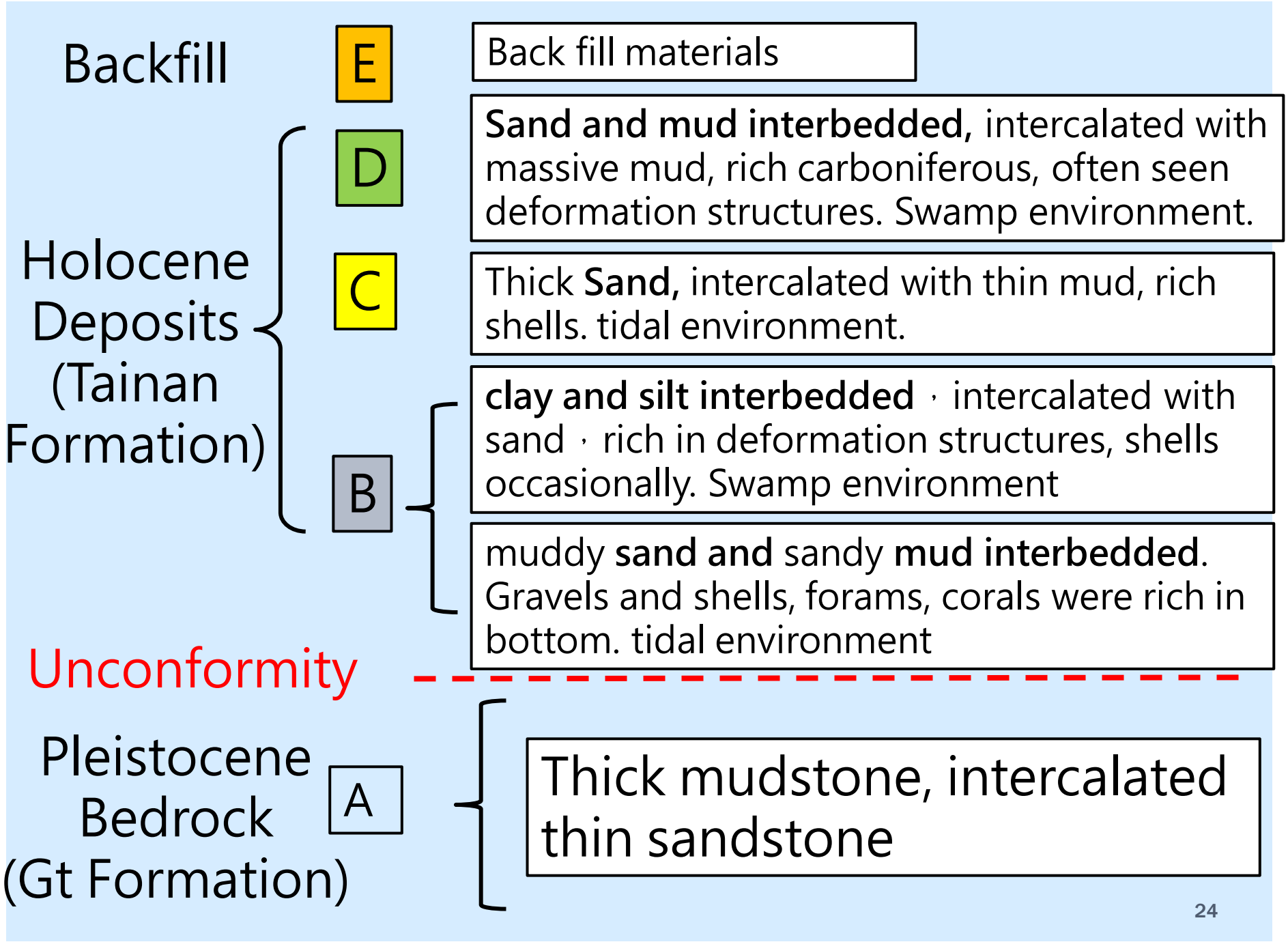
Lateral distribution of modern active zone
-surface rupture traced along morphotectonics features



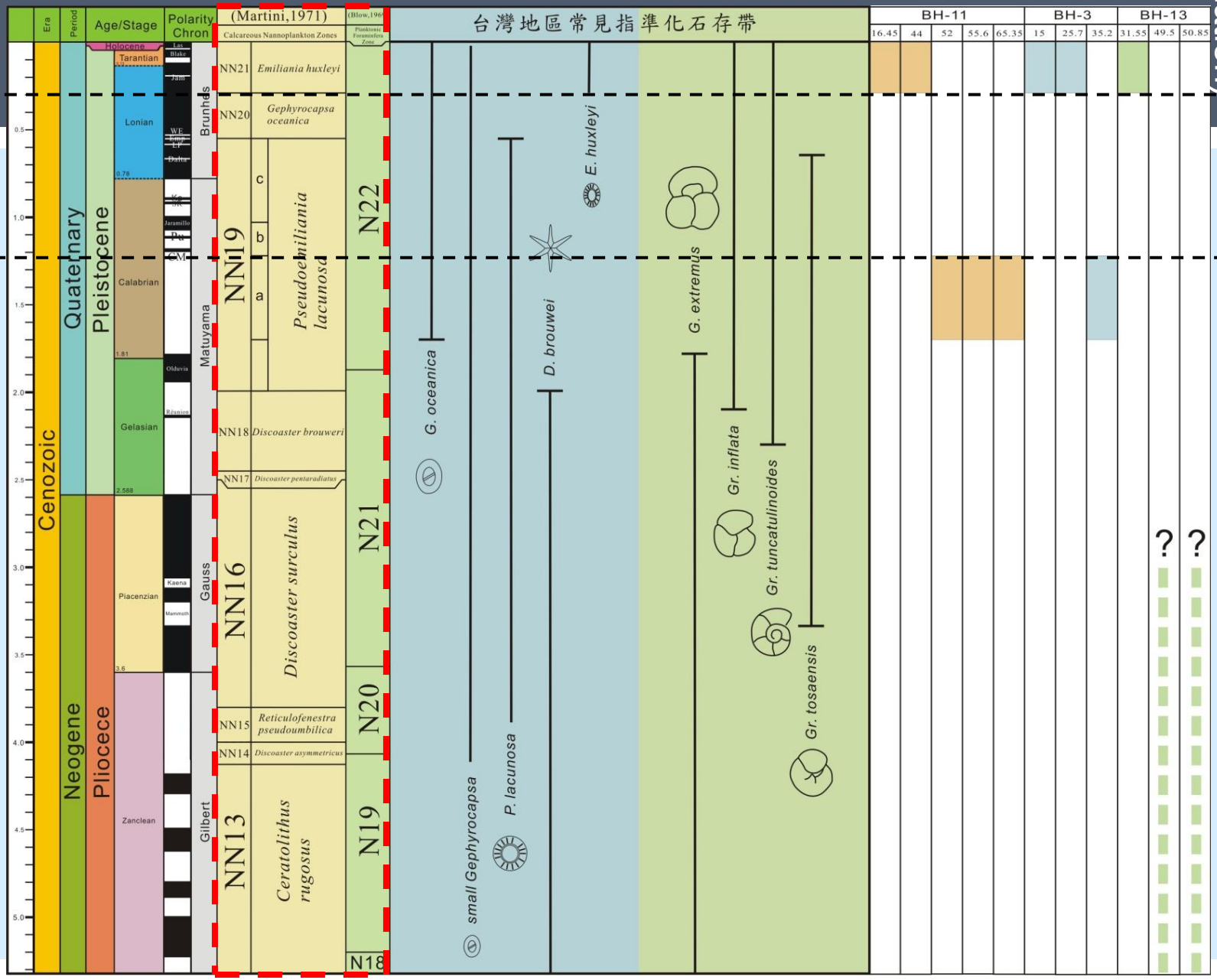
Active zone?

- Characteristics of long-term active zone
  -Stratigraphic correlation by 2 transects
  -Nanno fossil, foraminifera chronology
  -Shear zone, bedding within bedrock and Holocene deposits.


Characteristics of long-term active zone
-Stratigraphic correlation by 2 transects
182500
183000
183500
2520000
2519500
2519000
N
A
A'
B
B'
AH-1
AH-6
AH-7
AH-5
AH-4
AH-2
AH-3
BH-9
BH-11
BH-16
BH-15
BH-12
BH-3
BH-13
BH-7
BH-10
BH-14
Elevation
11 - 12
12 - 14
14 - 15
15 - 16
16 - 17
17 - 19
19 - 21
21 - 22
22 - 23
23 - 25
25 - 26
26 - 27
27 - 28
28 - 30
30 - 32
32 - 34
34 - 36
36 - 37
37 - 38
38 - 40
Fault trace
Questionable, Concealed
Certain, Inferred
Borehole Location
Rail
0
250
500
1,000
Meters


Backfill
E
Back fill materials
Holocene Deposits (Tainan Formation)
D
Sand and mud interbedded, intercalated with massive mud, rich carboniferous, often seen deformation structures. Swamp environment.
C
Thick Sand, intercalated with thin mud, rich shells. tidal environment.
B
clay and silt interbedded · intercalated with sand · rich in deformation structures, shells occasionally. Swamp environment
muddy sand and sandy mud interbedded. Gravels and shells, forams, corals were rich in bottom. tidal environment
Unconformity
Pleistocene Bedrock (Gt Formation)
A
Thick mudstone, intercalated thin sandstone

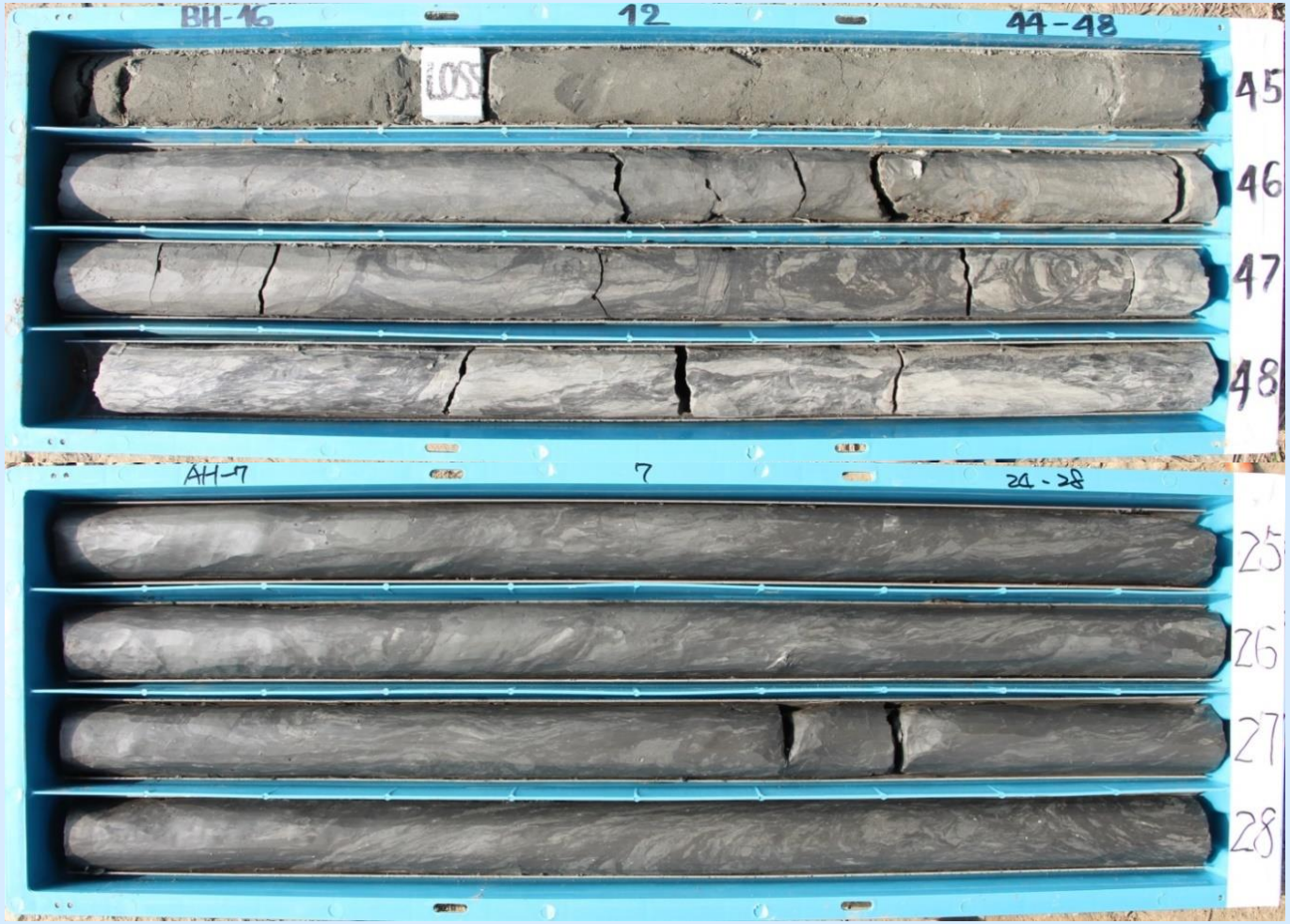
NANNOFOSSIL AND FORAMINIFERA



areous

No	Sample Name	Species		Biozones		Strata
		Foraminifera	Calcareous Nannofossil	Foraminifera	Calcareous Nannofossil	
B1	BH-3-15.00-15.30m	Operculina spp.	E. huxleyi	N22	NN21	Tainan Formation
B2	BH-3-25.70-25.90m	Operculina spp.	E. huxleyi	N22	NN21	Tainan Formation
B3	BH-3-35.20-35.40m	G. tosaensis, G. inflata, Sa. Dehiscensc, & G. obliquus (reworked)	G. oceanica	N22	NN 19a	Gutingkeng Formation
B4	BH-11-16.45-16.60m	Operculina spp.	E. huxleyi	N22	NN21	Tainan Formation
B5	BH-11-44.00-44.30m	Operculina spp.	E. huxleyi	N22	NN21	Tainan Formation
B6	BH-11-52.00-52.20m	G. truncatulinoides, G. inflata & G. tosaensis	G. oceanica	N22	NN 19a	Gutingkeng Formation
B7	BH-11-55.60-55.80m	G. truncatulinoides & G. inflata	G. oceanica	N22	NN 19a	Gutingkeng Formation
B8	BH-11-65.35-65.50m	G. truncatulinoides, G. inflata &G. tosaensis	G. oceanica	N22	NN 19a	Gutingkeng Formation
B9	BH-13-31.55-31.60m	Operculina spp.	E. huxleyi	N22	NN21	Tainan Formation
B10	BH-13-49.50-49.60m	-	Cy. floridanus (reworked), S .moriformisb (reworked)	Older than or equal to N21	Older than or equal to NN16	Gutingkeng Formation
B11	BH-13-50.85-51.00m	G. obliquus (reworked), G. altispira (reworked), Ss. Seminulina (reworked)	-	Older than /	Older than or	Gutingkeng

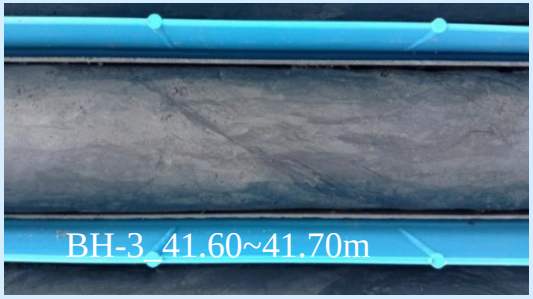
Layer A, Hanging wall

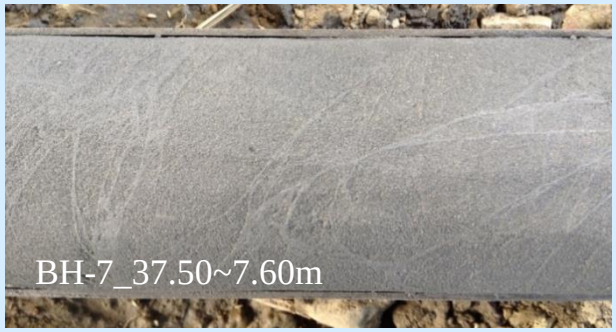


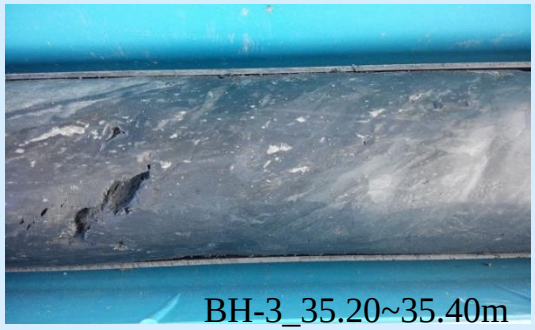
- Fault gauge
- Fault breccia

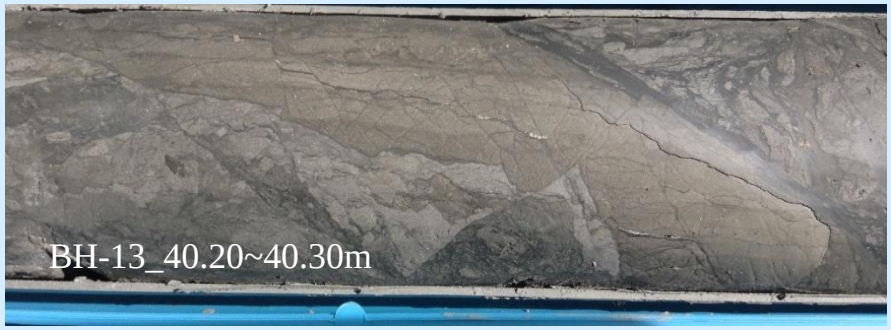
Thickness>4m

Layer A, Hanging wall

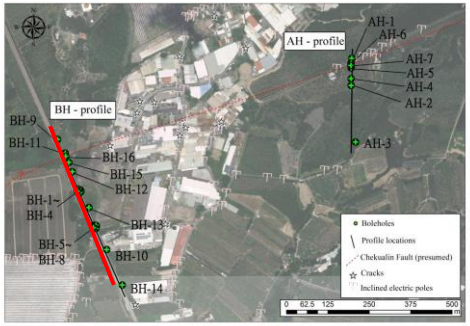




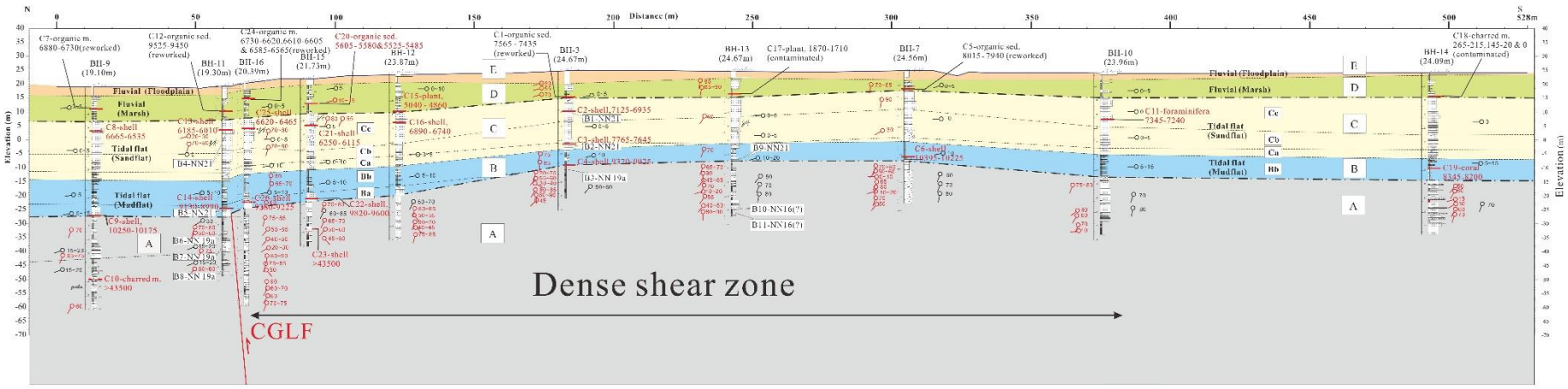




- Fault gauge
- Fault breccia
- Web Structure



B-B’



Back Fill — E — Back fill materials.

Holocene Deposits (Tainan Formation)
Nano fossil zone:NN 21
14C age:within 10,000 yr cal BP

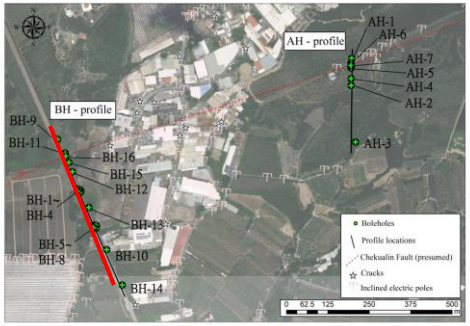
- D — Sand and mud interbedded, intercalated with massive mud, rich in organic materials, common syn-depositional deformation structures.
- C — Cc: Thick sand, rich in shells.
  - Cb: Muddy sand, intercalated with thin mud, rich in shells.
  - Ca: Muddy sand and mud interbedded, rich in shells.
- B — Bb: Clay and silt interbedded, intercalated with sand, occasional shells.
  - Ba: Muddy sand and sandy mud interbedded, gravel, shells and foraminifera were abundant at bottom.

Pleistocene Bedrock (Gt Formation) — A — Thick mudstone, intercalated with thin sandstone.
Nanno fossil zone: NN19 a ~ ≦NN16 (ca. 0.65 ma~ 3.12 ma);
C-14 age: >45,000 yr

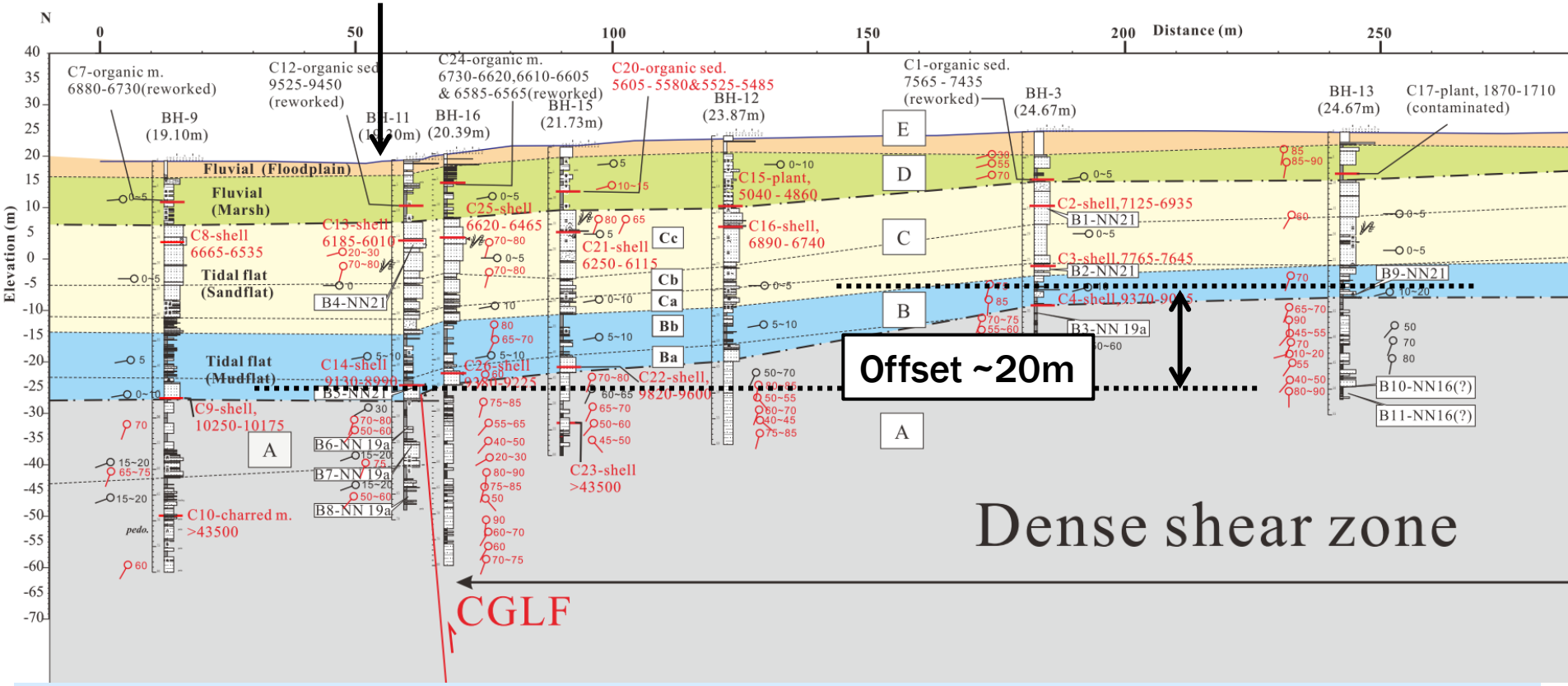
Thrust fault
Topography
Lithological correlatoin line
Uncomformity
Mud intrusion (with shear plane)
80 Bedding plane (dip angle)
70 Shear plane (dip angle)

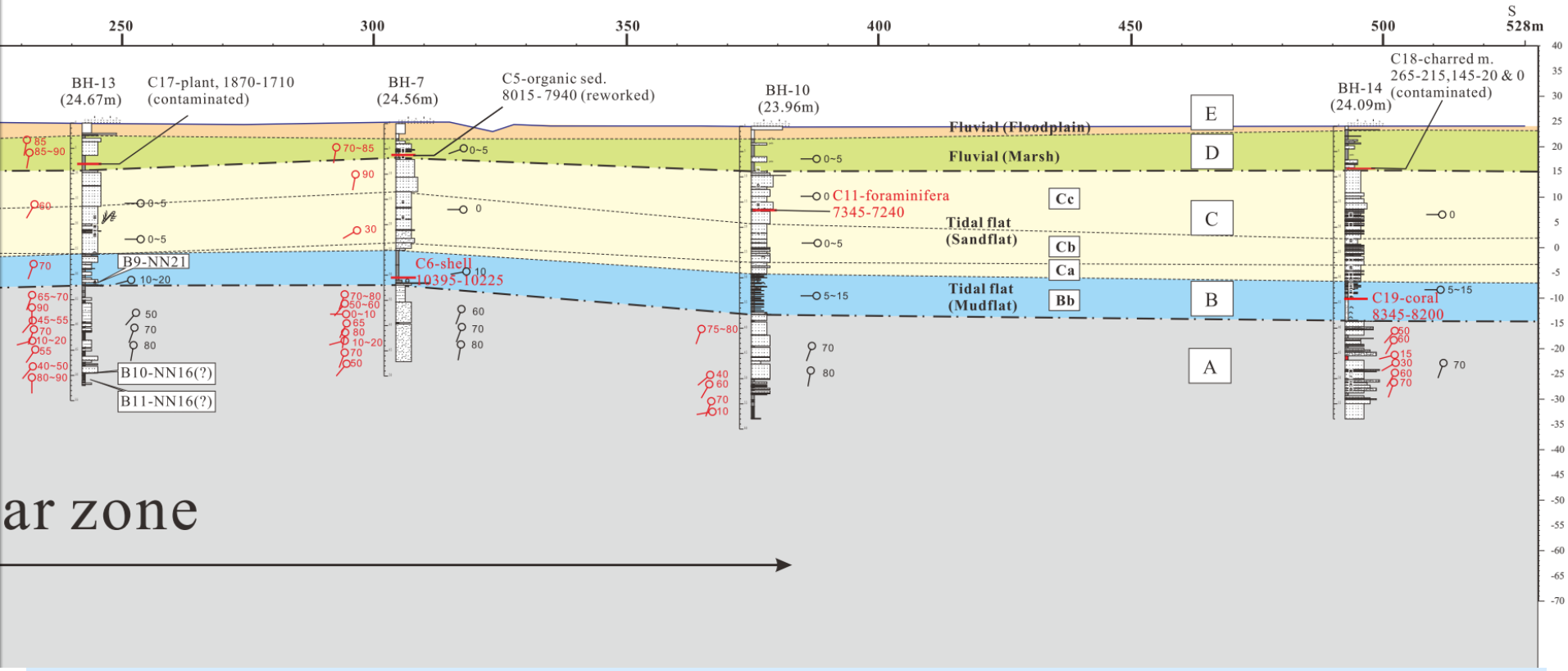
Foraminifera and Nanno fossil biozone
^{14}C age calibrated year (within 2 sigma)

Fluvial (flood plain)
Fluvial (swamp)
Tidal flat (sand flat)
Tidal flat (mud flat)
Bedrock


AH - profile
AH-1
AH-6
AH-7
AH-5
AH-4
AH-2
AH-3
BH - profile
BH-9
BH-11
BH-16
BH-15
BH-12
BH-1~
BH-4
BH-13
BH-5~
BH-8
BH-10
BH-14
Boleholes
Profile locations
Chekualin Fault (presumed)
Cracks
Inclined electric poles

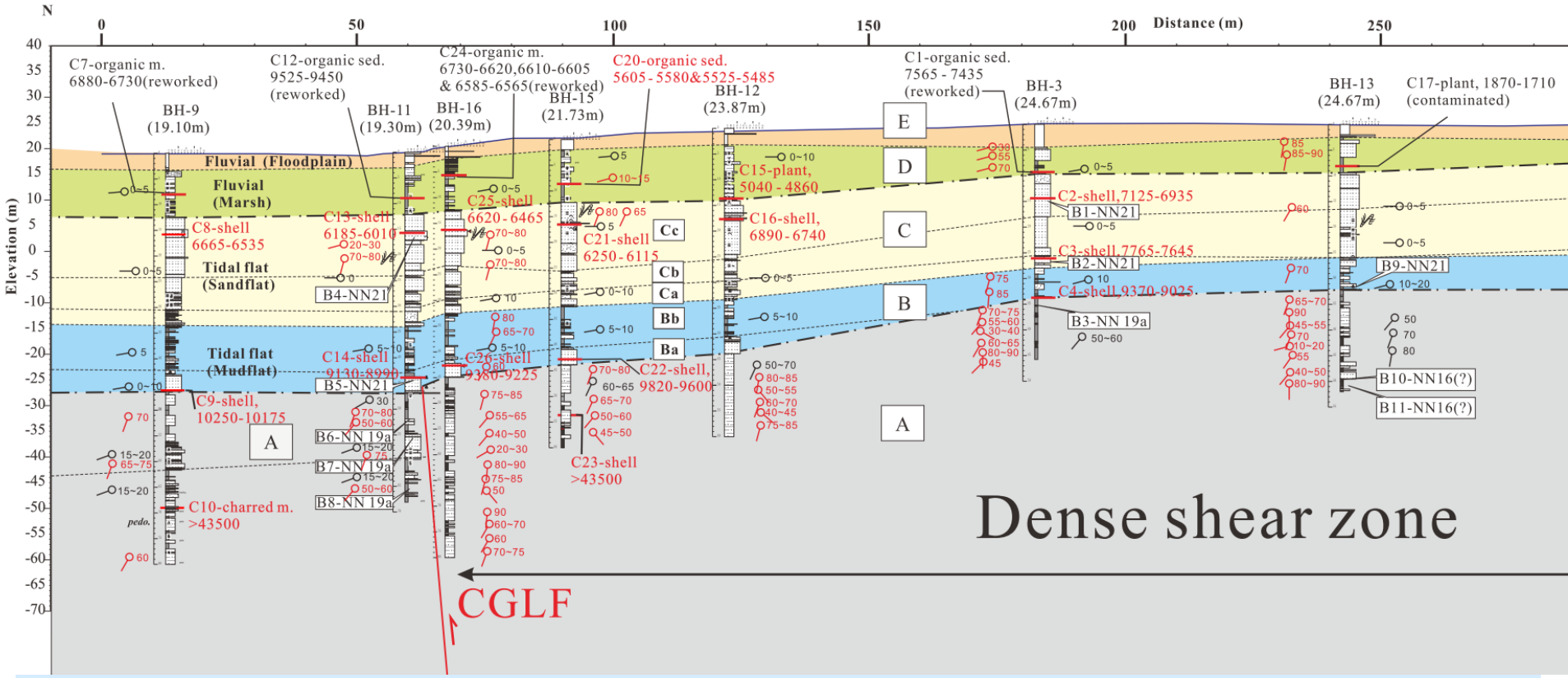
B-B’


N
Distance (m)
Elevation (m)
C7-organic m.
6880-6730(reworked)
C12-organic sed.
9525-9450
(reworked)
C24-organic m.
6730-6620,6610-6605
& 6585-6565(reworked)
C20-organic sed.
5605 - 5580&5525-5485
C1-organic sed.
7565 - 7435
(reworked)
BH-9
(19.10m)
BH-11
BH-16
(20.39m)
BH-15
(21.73m)
BH-12
(23.87m)
BH-3
(24.67m)
BH-13
(24.67m)
C17-plant, 1870-1710
(contaminated)
Fluvial (Floodplain)
Fluvial
(Marsh)
Tidal flat
(Sandflat)
Tidal flat
(Mudflat)
C8-shell
6665-6535
C13-shell
6185-6010
C25-shell
6620 - 6465
C21-shell
6250 - 6115
C15-plant,
5040 - 4860
C16-shell,
6890 - 6740
C2-shell,7125-6935
C3-shell,7765-7645
C4-shell,9370-9005
B1-NN21
B2-NN21
B3-NN 19a
B4-NN21
B5-NN21
B6-NN 19a
B7-NN 19a
B8-NN 19a
B9-NN21
B10-NN16(?)
B11-NN16(?)
C9-shell,
10250-10175
C10-charred m.
>43500
C14-shell
9130-8990
C22-shell,
9820-9600
C23-shell
>43500
A
B
C
D
E
Cc
Cb
Ca
Bb
Ba
Offset ~20m
Dense shear zone
CGLF


250
300
350
400
450
500
S
528m
BH-13
(24.67m)
C17-plant, 1870-1710
(contaminated)
BH-7
(24.56m)
C5-organic sed.
8015 - 7940 (reworked)
BH-10
(23.96m)
BH-14
(24.09m)
C18-charred m.
265-215,145-20 & 0
(contaminated)
Fluvial (Floodplain)
Fluvial (Marsh)
Tidal flat
(Sandflat)
Tidal flat
(Mudflat)
E
D
C
B
A
Cc
Cb
Ca
Bb
C11-foraminifera
7345-7240
C6-shell
10395-10225
C19-coral
8345-8200
B9-NN21
B10-NN16(?)
B11-NN16(?)

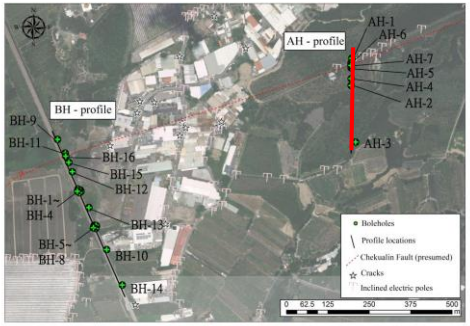
ar zone

DISCUSSION-THE CHANGE OF ACTIVE ZONE THROUGH TIME

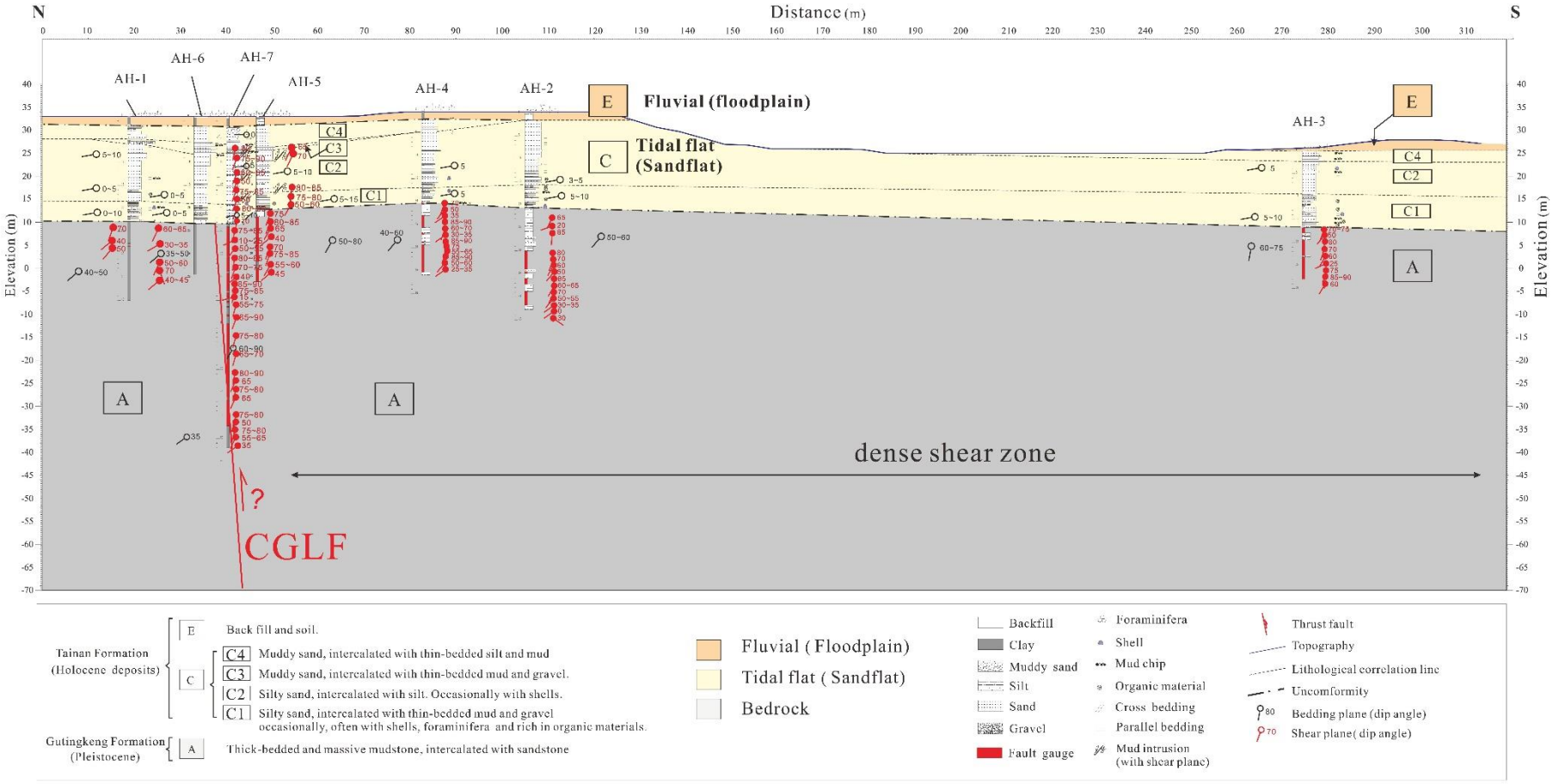


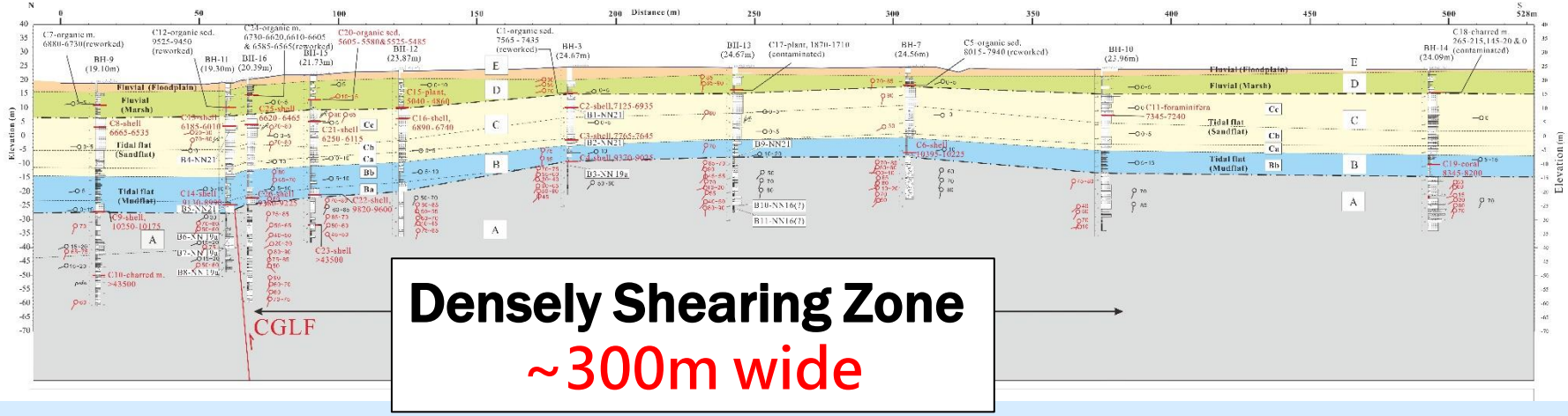
Growth Strata

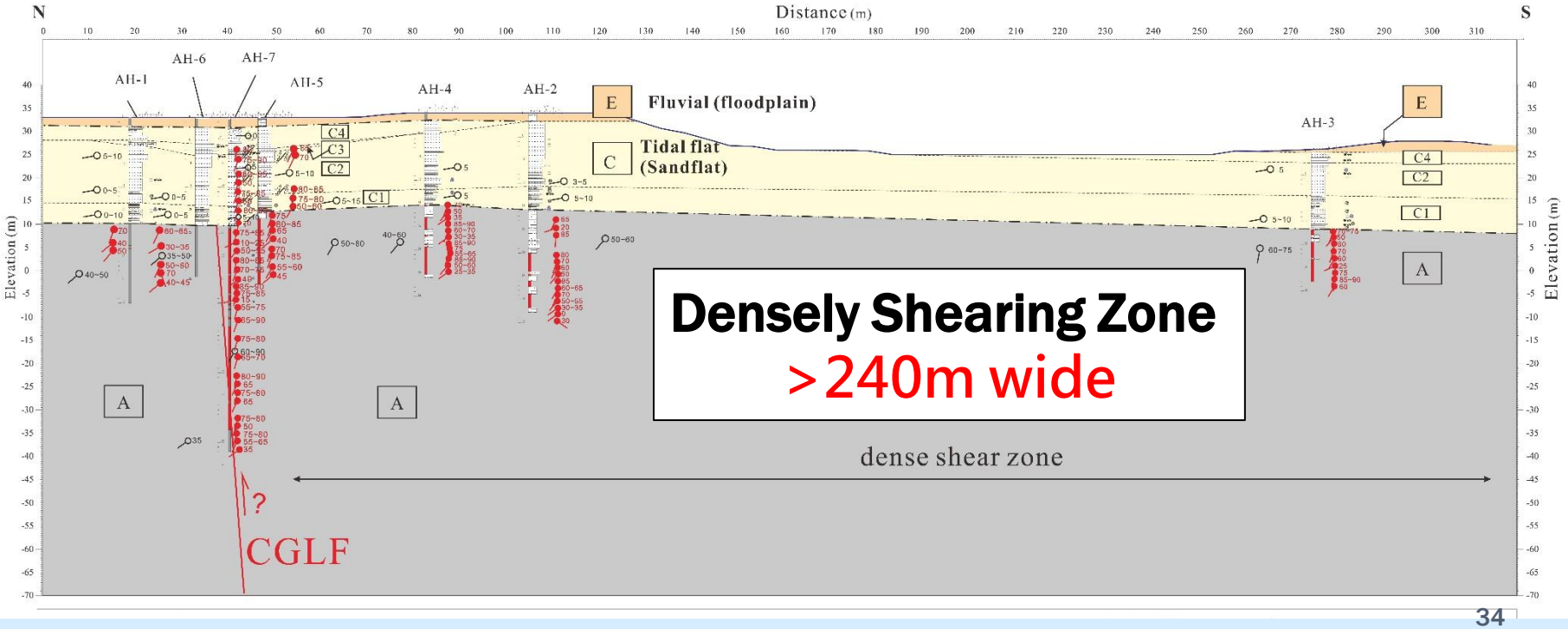
- B、C、D bottom: more shallower, more gentler for Layer B~25°，C~20°，D~5°
- Footwall thickening


AH - profile
AH-1
AH-6
AH-7
AH-5
AH-4
AH-2
AH-3
BH - profile
BH-9
BH-11
BH-16
BH-15
BH-12
BH-1~
BH-4
BH-13
BH-5~
BH-8
BH-10
BH-14
Boleholes
Profile locations
Chekualin Fault (presumed)
Cracks
Inclined electric poles
0 62.5 125 250 375 500 m

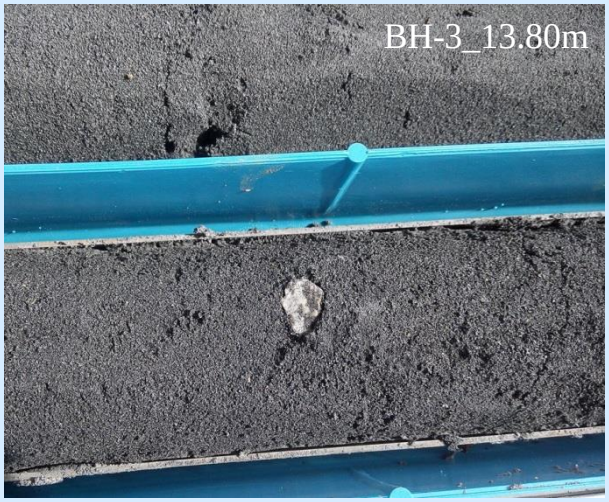
A-A’


N
S
Distance (m)
Elevation (m)
AH-1
AH-6
AH-7
AH-5
AH-4
AH-2
AH-3
E
Fluvial (floodplain)
C
Tidal flat
(Sandflat)
C4
C3
C2
C1
A
dense shear zone
?
CGLF
Tainan Formation
(Holocene deposits)
E
Back fill and soil.
C
C4 Muddy sand, intercalated with thin-bedded silt and mud
C3 Muddy sand, intercalated with thin-bedded mud and gravel.
C2 Silty sand, intercalated with silt. Occasionally with shells.
C1 Silty sand, intercalated with thin-bedded mud and gravel occasionally, often with shells, foraminifera and rich in organic materials.
Gutingkeng Formation
(Pleistocene)
A
Thick-bedded and massive mudstone, intercalated with sandstone
Fluvial (Floodplain)
Tidal flat (Sandflat)
Bedrock
Backfill
Clay
Muddy sand
Silt
Sand
Gravel
Fault gauge
Foraminifera
Shell
Mud chip
Organic material
Cross bedding
Parallel bedding
Mud intrusion
(with shear plane)
Thrust fault
Topography
Lithological correlation line
Uncomformity
Bedding plane (dip angle)
Shear plane(dip angle)


Densely Shearing Zone
~300m wide
CGLF
Distance (m)
Elevation (m)
Fluvial (Floodplain)
Fluvial (Marsh)
Tidal flat (Sandflat)
Tidal flat (Mudflat)


Densely Shearing Zone
>240m wide
dense shear zone
CGLF
Distance (m)
Elevation (m)
Fluvial (floodplain)
Tidal flat (Sandflat)
AH-1
AH-6
AH-7
AH-5
AH-4
AH-2
AH-3

HOLOCENE DEPOSITS (TAINAN FORMATION)



Deformed Holocene strata
Shear band

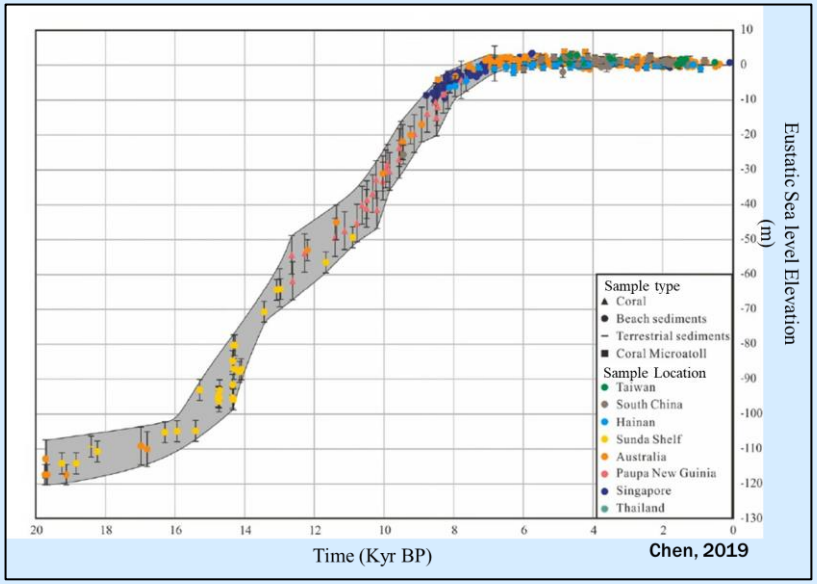
BH-3_31.75~32.00m
Layer B, shear plane 85~90°

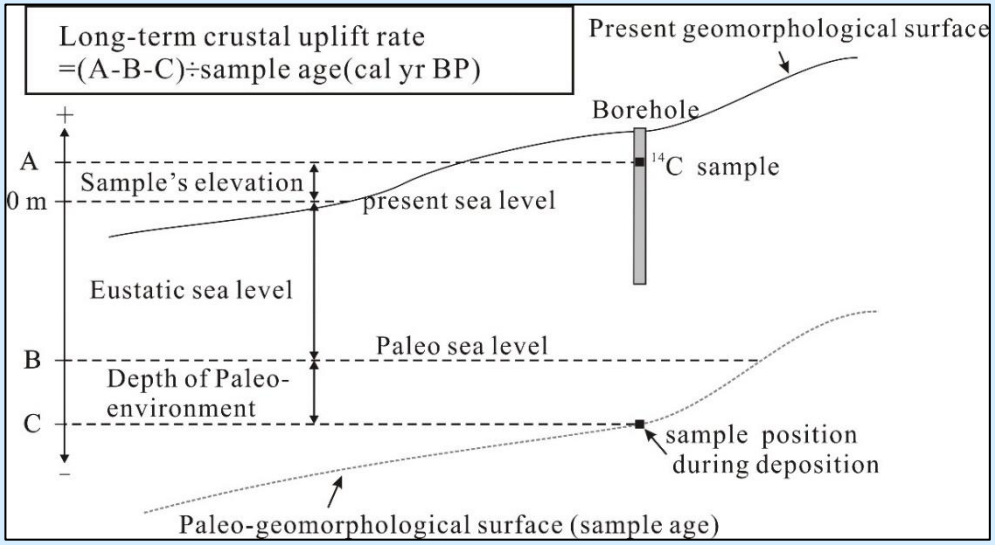
BH-13_3.35~3.65m
Layer **D shear plane** 80°

AH-7_10.00-10.25m · Layer **C** **shear plane**

- Spatial and temporal variation of active zone
  - Long-term uplift rate
    1. absolute dating method (eustatic sea level curve, paleo environment, sample height & C-14 dating)
    2. Relative dating method - computed by isochron line
    - Long term vs. short-term uplift rates

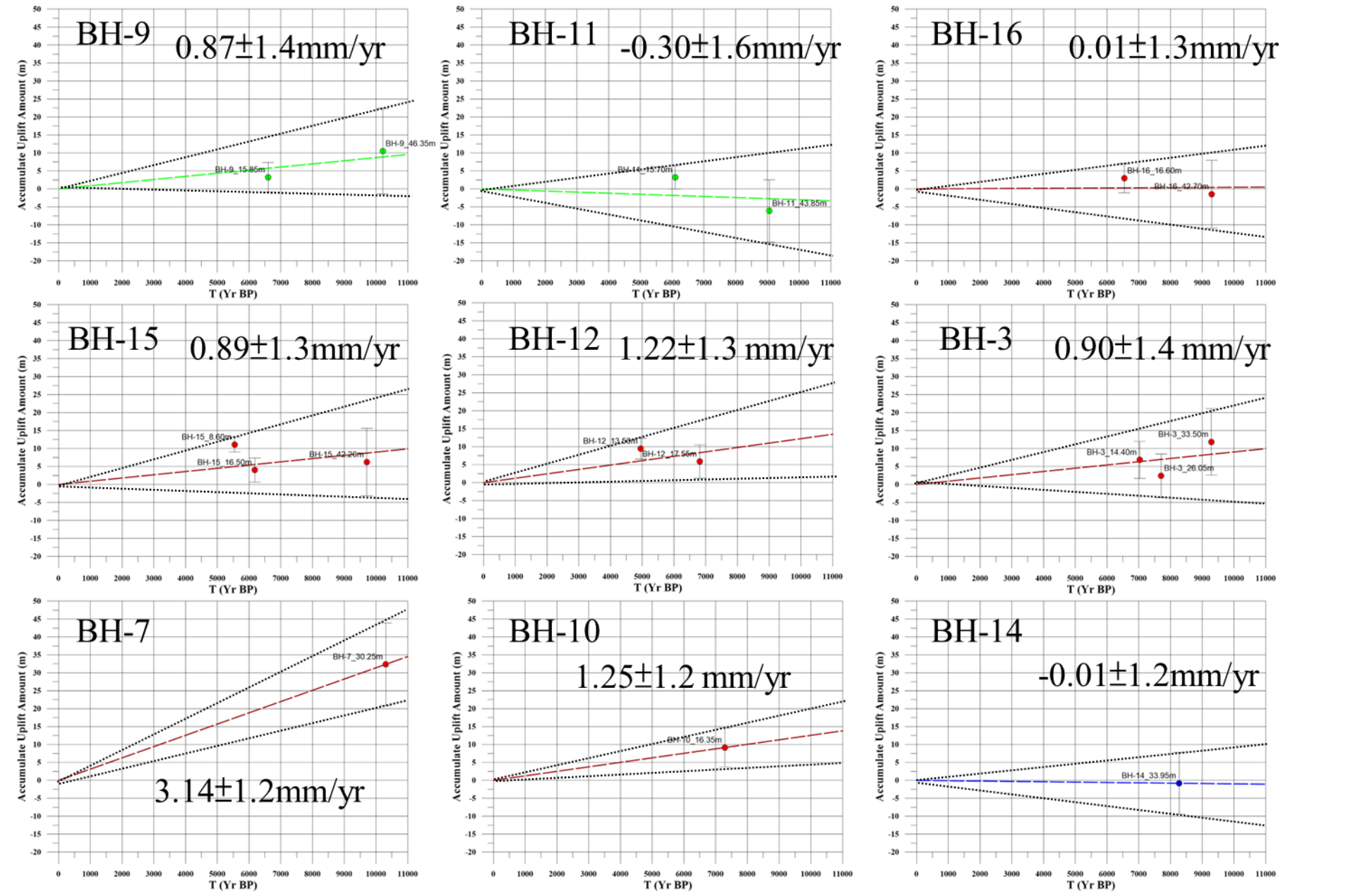
- **Absolute dating method (eustatic sea level curve, paleo environment, sample height & C-14 dating)**



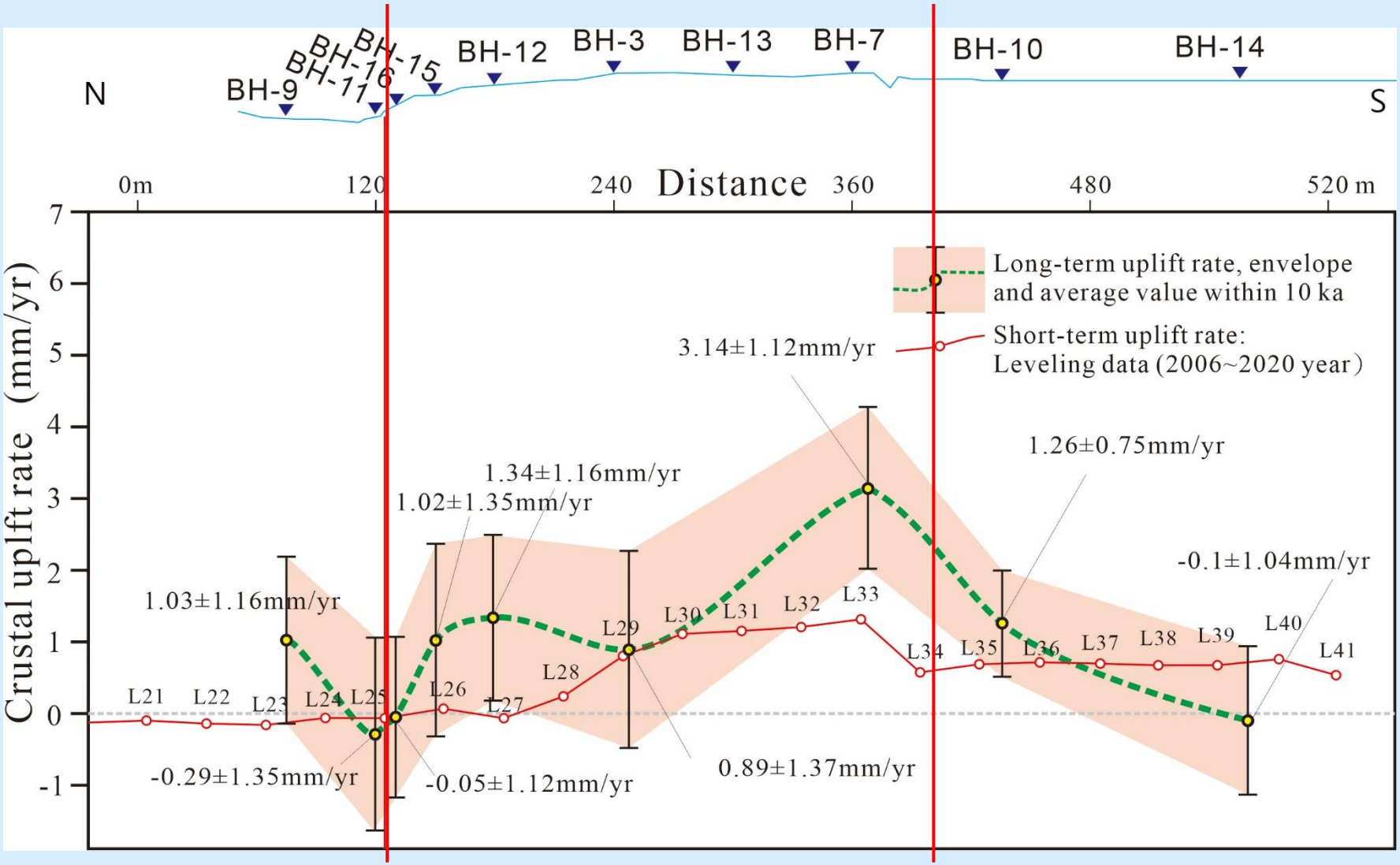


Sample Number	Sample Material	Borehole Elevation (m)	Sample Depth (m)	Sample Elevation (m)	Paleo Sea Level Elevation(m)	Paleo Environmental Depth(m)	Carbon-14 Dating (Calibrated yr BP)	Vertical Displacement(m)	Uplift rate(mm/yr)
BH-3_14.40m	Shell	24.67	14.40	10.27	-0.1± 3.1	2~ -2	7030 ± 95	10.42 ± 5.15	1.48 ± 0.73
BH-3_26.05m	Shell	24.67	26.05	-1.38	-3.7± 4.0	2~ -2	7705 ± 60	2.40 ± 6.08	0.31 ± 0.79
BH-3_33.50m	Shell& Foraminifera	24.67	33.50	-8.83	-20.6± 7.2	2~ -2	9288 ± 83	11.83 ± 9.23	1.27 ± 0.99
BH-7_30.25m	Foraminifera	24.56	30.25	-5.69	-38.0± 9.5	2~ -2	10310 ± 85	32.38 ± 11.54	3.14 ± 1.12
BH-9_15.85m	Shell	19.89	15.85	4.04	0.8± 2.1	2~ -2	6600 ± 65	3.24 ± 4.10	0.49 ± 0.62
BH-9_46.35m	Shell	19.89	46.35	-26.46	-36.9± 9.8	2~ -2	10213 ± 38	10.49 ± 11.89	1.03 ± 1.16
BH-11_15.70m	Shell	20.17	15.70	4.47	1.2± 1.2	2~ -2	6098 ± 88	3.22 ± 3.25	0.53 ± 0.53
BH-11_43.85m	Shell	20.17	43.85	-23.68	-17.5± 6.6	2~ -2	9060 ± 70	-6.13 ± 8.67	-0.68 ± 0.96
BH-14_33.95m	Coral	24.09	33.95	-9.86	-9.0± 6.5	2~ -2	8273 ± 73	-0.81 ± 8.58	-0.10 ± 1.04
BH-10_16.35m	Foraminifera	23.96	16.35	7.61	-1.5± 3.4	2~ -2	7293 ± 53	9.16 ± 5.45	1.26 ± 0.75
BH-12_17.55m	Shell	23.87	17.55	6.32	0.4± 2.6	2~ -2	6815 ± 75	5.86 ± 4.64	0.86 ± 0.68
BH-12_13.50m	Plant material	23.87	13.50	10.37	0.9± 0.9	2~ -2	4950 ± 90	9.46 ± 2.91	1.91 ± 0.59
BH-15_42.20m	Shell	21.73	42.20	-20.47	-26.6± 7.3	2~ -2	9710 ± 110	6.23 ± 9.38	0.64 ± 0.97
BH-15_16.50m	Shell	21.73	16.50	5.23	1.2± 1.3	2~ -2	6183 ± 68	4.02 ± 3.37	0.65 ± 0.54
BH-15_8.60m	Organic sediment	21.73	8.60	13.13	1.0± 1.0	2~ 0	5545 ± 60	11.08 ± 2.05	2.00 ± 0.37
BH-16_42.70m	Shell	20.39	42.70	-22.31	-20.8± 7.4	2~ -2	9303 ± 78	-1.47 ± 9.43	-0.16 ± 1.01
BH-16_16.60m	Shell	20.39	16.60	3.79	0.84± 2.0	2~ -2	6543 ± 78	2.95 ± 4.04	0.45 ± 0.62

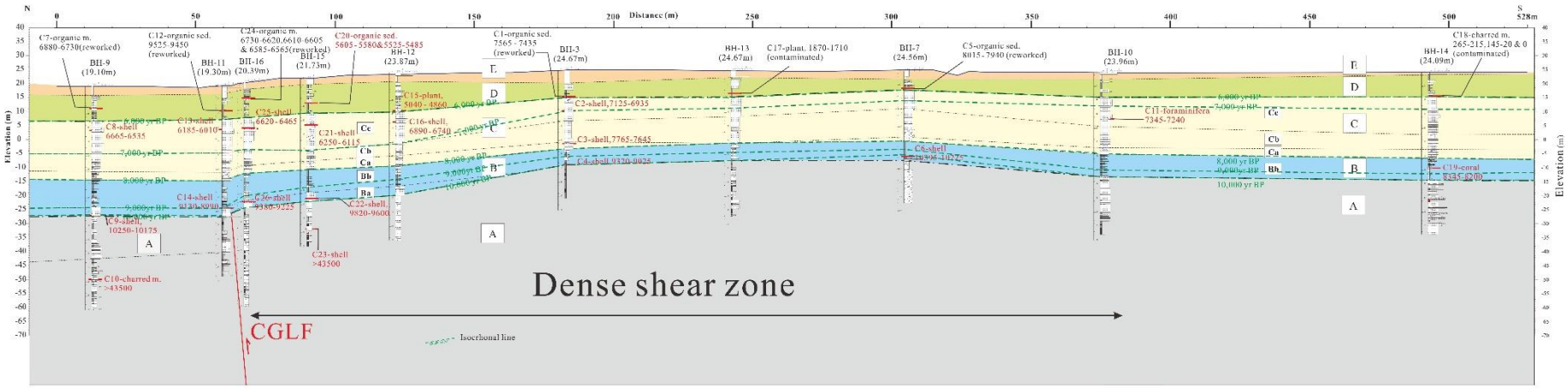
- Tidal flat-swamps. half fresh water and half salty - very shallow marine deposits


BH-9
0.87±1.4mm/yr
BH-9_46.35m
BH-9_15.85m
BH-11
-0.30±1.6mm/yr
BH-11_15.70m
BH-11_43.85m
BH-16
0.01±1.3mm/yr
BH-16_16.60m
BH-16_42.70m
BH-15
0.89±1.3mm/yr
BH-15_8.60m
BH-15_16.50m
BH-15_42.20m
BH-12
1.22±1.3 mm/yr
BH-12_13.50m
BH-12_17.55m
BH-3
0.90±1.4 mm/yr
BH-3_33.50m
BH-3_14.40m
BH-3_26.05m
BH-7
3.14±1.2mm/yr
BH-7_30.25m
BH-10
1.25±1.2 mm/yr
BH-10_16.35m
BH-14
-0.01±1.2mm/yr
BH-14_33.95m
Accumulate Uplift Amount (m)
T (Yr BP)
Hanging-wall sample inside shear zone samples
Hanging-wall sample outside shear zone samples
Footwall samples
Hanging-wall sample inside shear zone fit-lines
Hanging-wall sample outside shear zone fit-line
Footwall fit-lines

future work- footwall as base point to redraw



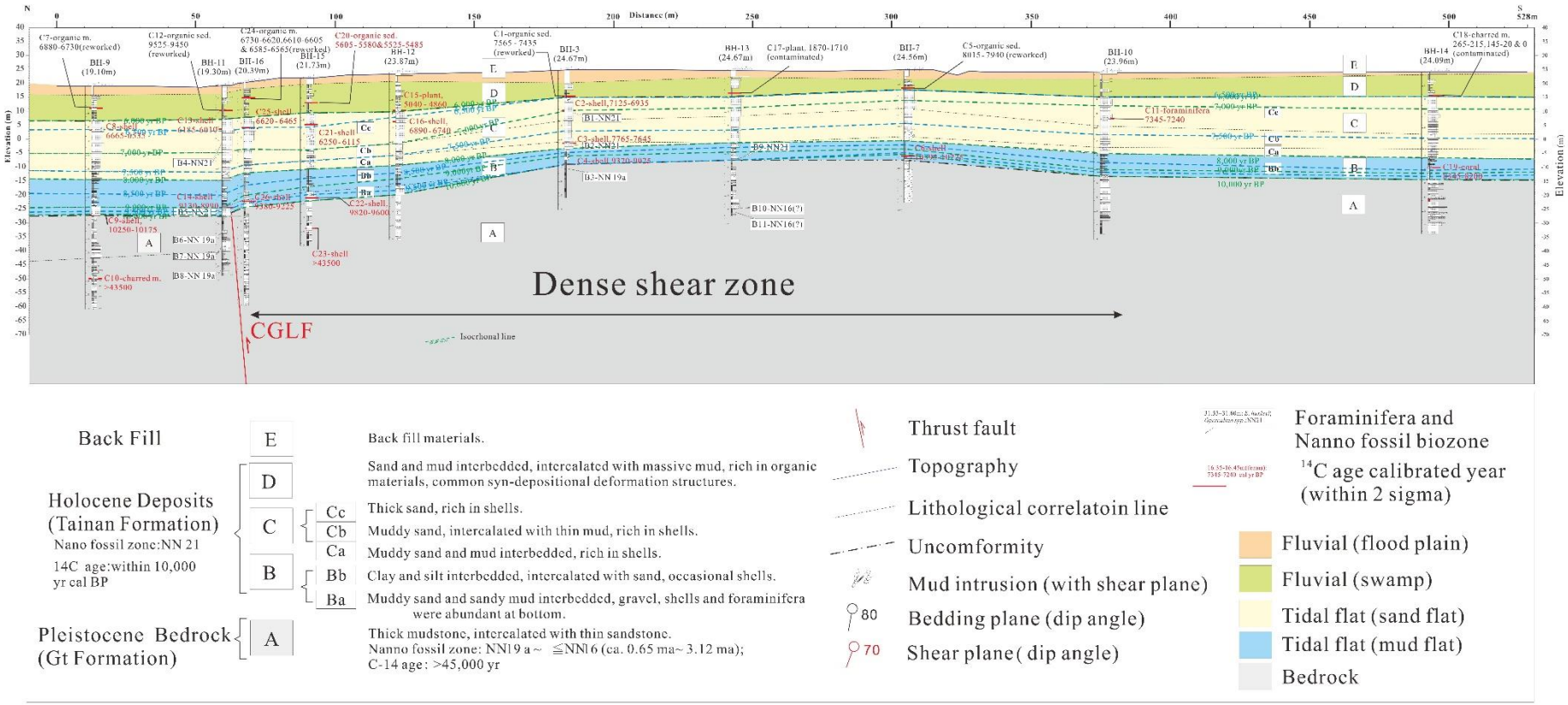
■Relative dating method - computed by isochron line

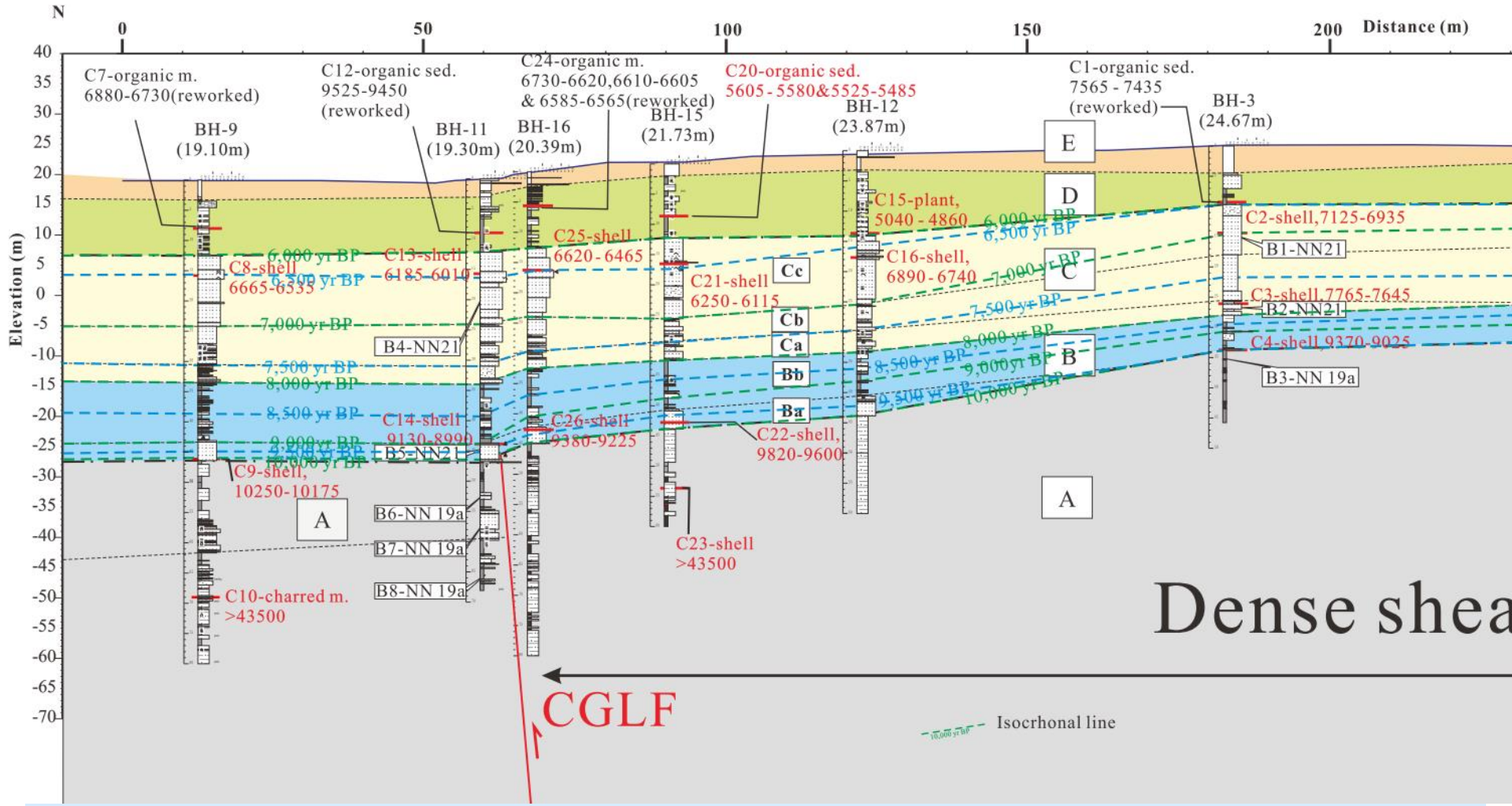


- assumptions

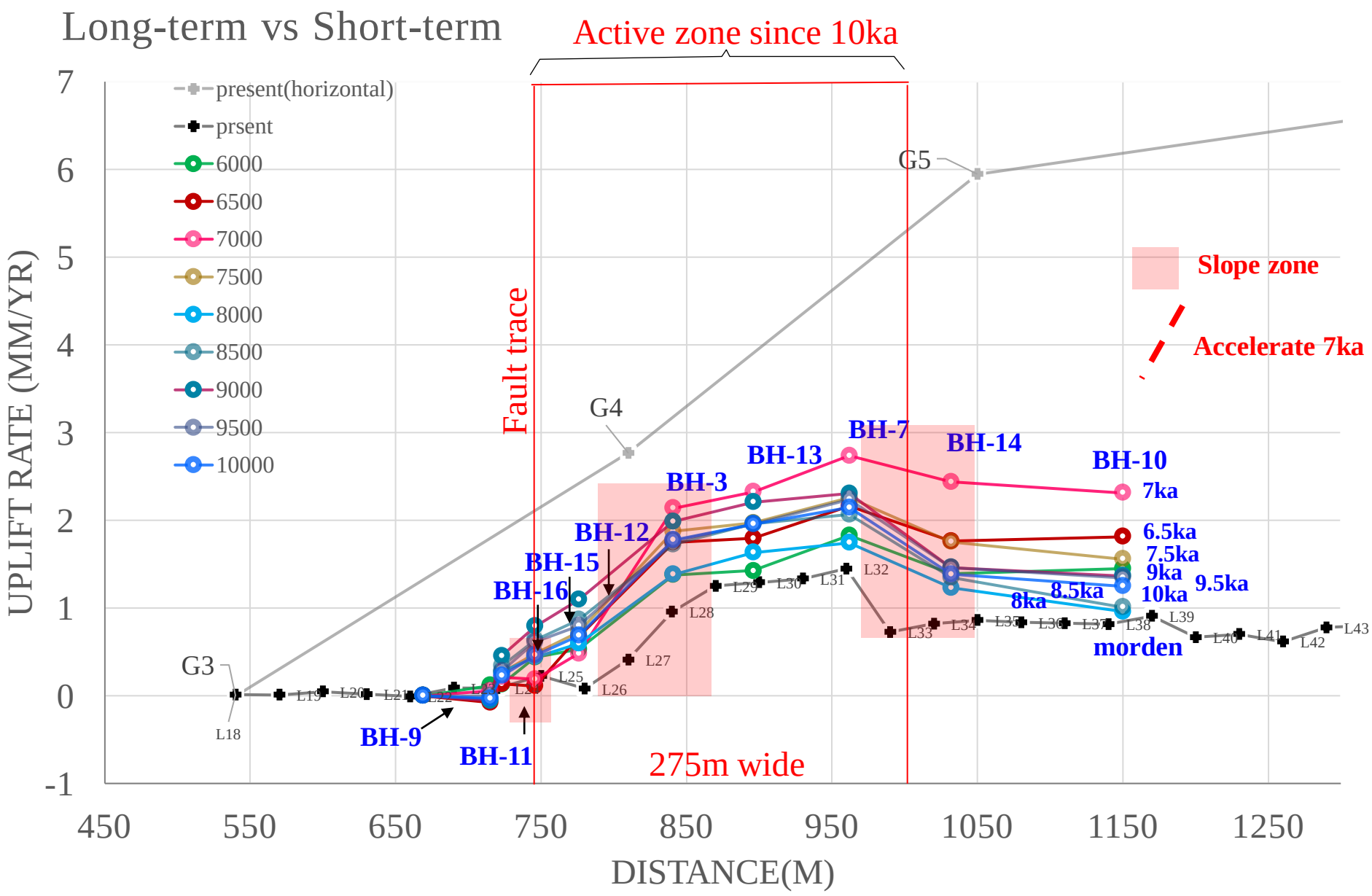
1. Horizontal isochron (time line) in the begging
2. Stratigraphic boundary correspond with time line
3. No lateral sedimentary environment change
4. Constant sedimentary rate within 1 layer

■Relative dating method - computed by isochron line

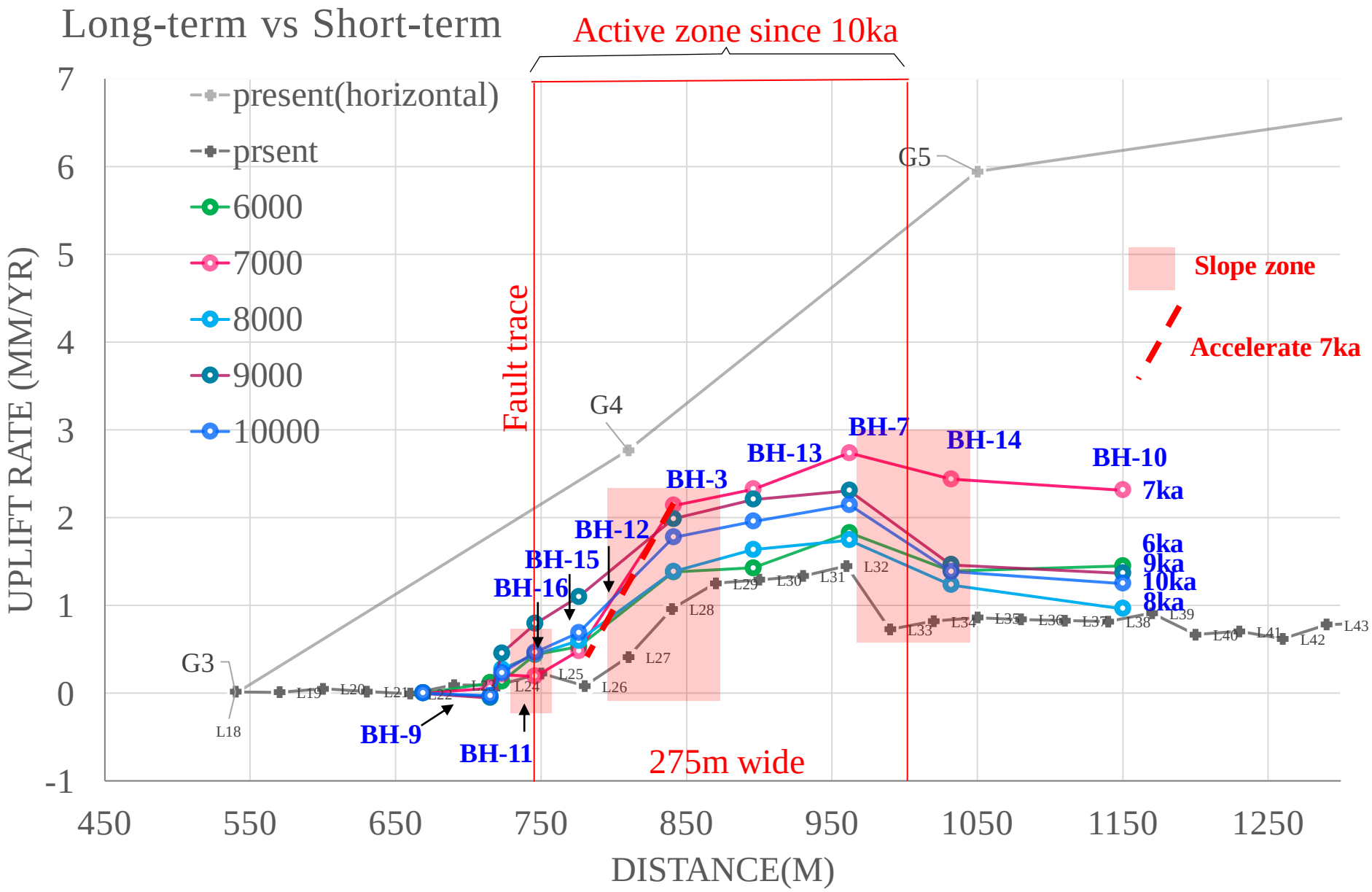



N
0
50
100
150
200
Distance (m)
Elevation (m)
C7-organic m.
6880-6730(reworked)
C12-organic sed.
9525-9450
(reworked)
C24-organic m.
6730-6620,6610-6605
& 6585-6565(reworked)
C20-organic sed.
5605 - 5580&5525-5485
C1-organic sed.
7565 - 7435
(reworked)
BH-9
(19.10m)
BH-11
(19.30m)
BH-16
(20.39m)
BH-15
(21.73m)
BH-12
(23.87m)
BH-3
(24.67m)
E
D
C
B
A
Cc
Cb
Ca
Bb
Ba
C15-plant,
5040 - 4860
C16-shell,
6890 - 6740
C2-shell,7125-6935
B1-NN21
C3-shell,7765-7645
B2-NN21
C4-shell,9370-9025
B3-NN 19a
6,000 yr BP
6,500 yr BP
7,000 yr BP
7,500 yr BP
8,000 yr BP
8,500 yr BP
9,000 yr BP
9,500 yr BP
10,000 yr BP
C8-shell,
6665-6535
C13-shell
6185-6010
C25-shell
6620 - 6465
C21-shell
6250 - 6115
B4-NN21
C14-shell
9130-8990
C26-shell
9380-9225
C22-shell,
9820-9600
B5-NN21
C9-shell,
10250-10175
B6-NN 19a
B7-NN 19a
B8-NN 19a
C23-shell
>43500
C10-charred m.
>43500
CGLF
Isocrhonal line
Dense shea

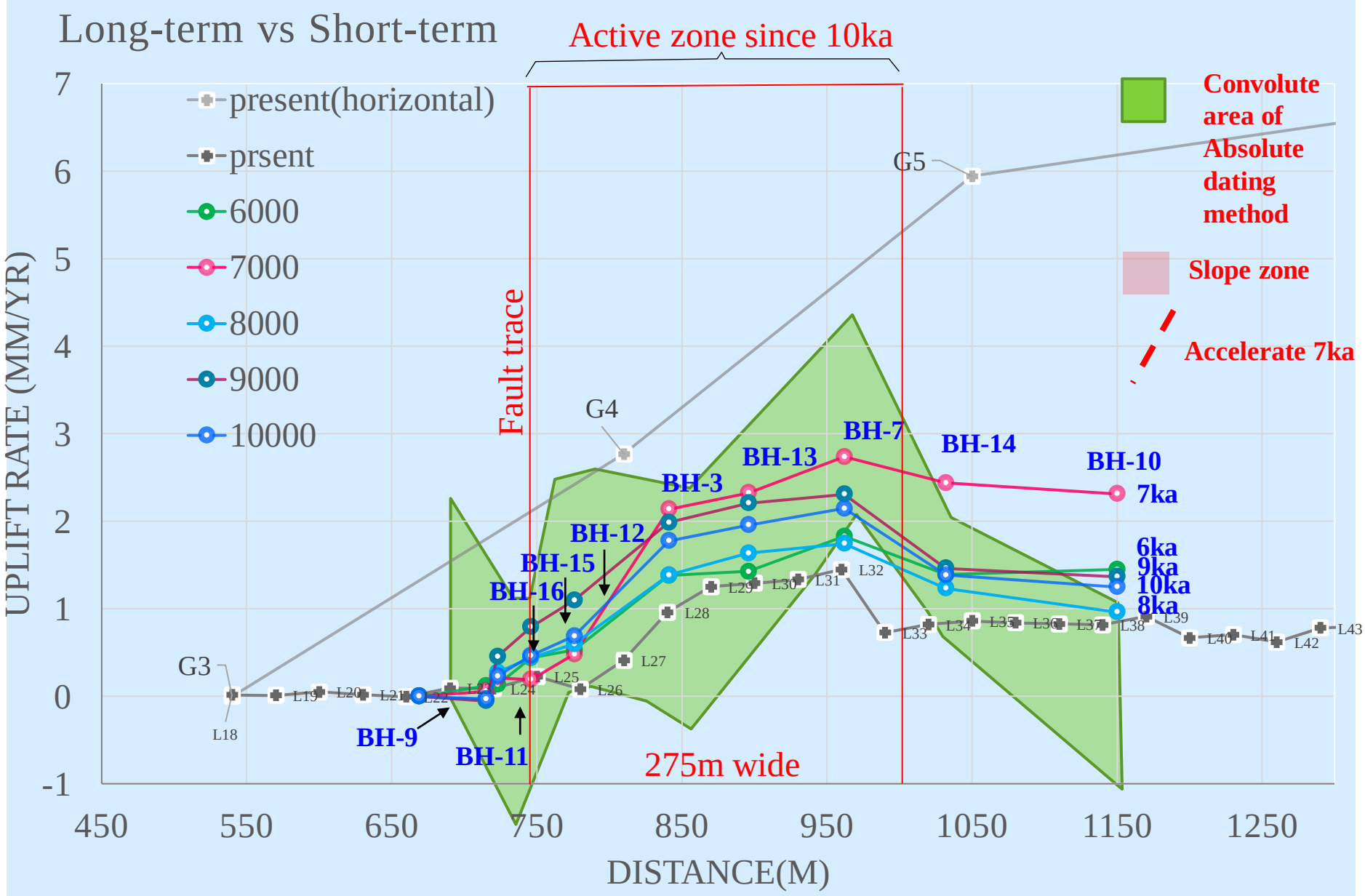
■ Relative dating method - computed by isochron line



■ Relative dating method - computed by isochron line



■ Relative dating method - computed by isochron line



Absolute dating method:

- Objective (but with large uncertainty)
- Low temporal resolution (Only 10 ka)

Relative dating method:

- Subjective (Avoid uncertainty)
- High temporal resolution (0.5~1.0 ka)

CONCLUSION

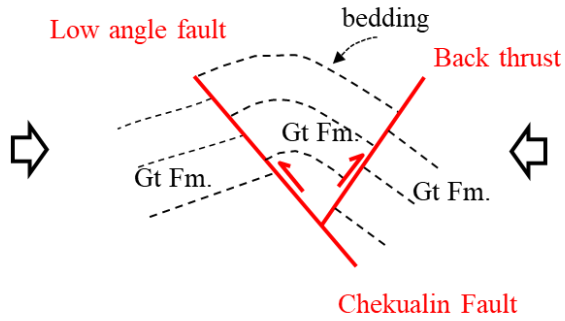
- Short-term uplift rate derived by on-site monitoring data shows the width of the modern active zone is about 275 meters.
- Surface rupture traced along morphotectonics features show that there is no obvious lineation east of the site connected to previous reported fault scarp. However, the belt-like significant structural anomalies show the distribution of the modern active zone can reach to 1.5 km width and 5.8 km long.
- The deformation zone of bedrock is about 300m wide defined by highly sheared thick fault gouge, and the Holocene growth strata are also disturbed and sheared by active fault. The estimated fault angle exceeds 70 degrees.

CONCLUSION

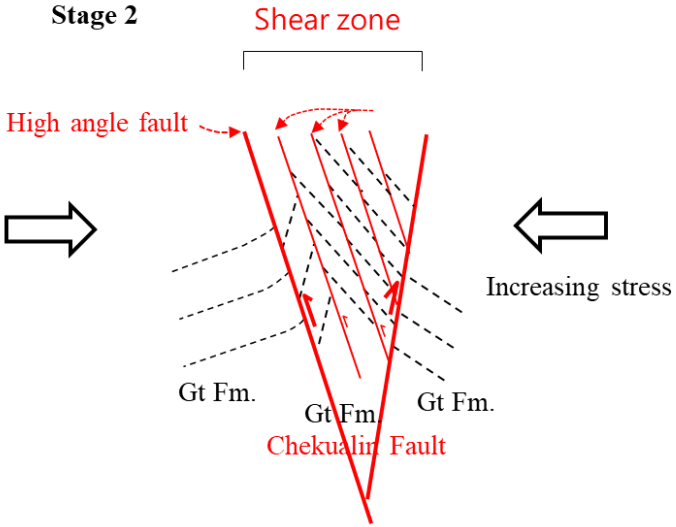
- The long-term uplift rate
  - calculated by the absolute dating method shows a cross-fault active zone (3.1±1.1 mm/yr maximum in the hanging wall, and -0.29±1.35 mm/yr minimum in the footwall).
  - The relative dating method shows that the range and deformation trend since 10ka are consistent with modern active zone. Furthermore, the 7ka isochron line has a rapid uplift between BH-12 and BH-3.
- The variation from long-term (late Pleistocene to Holocene) to short-term (modern) active zones of the Chegualin fault are always consist with same location, similar trend, thus and it is speculated that they will deform in the same way in the future.

THANK YOU!

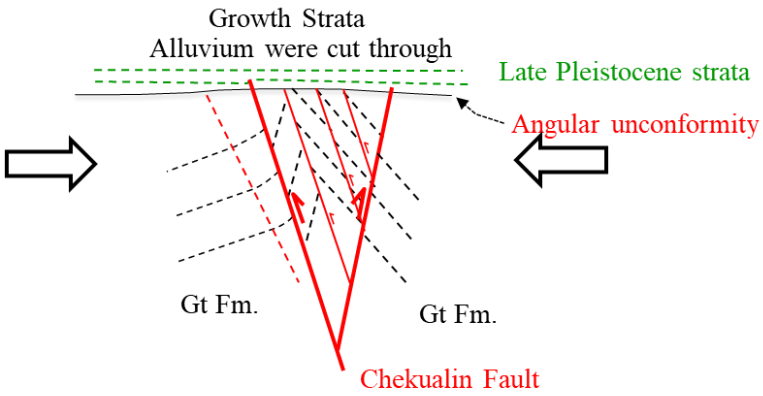
Stage 1



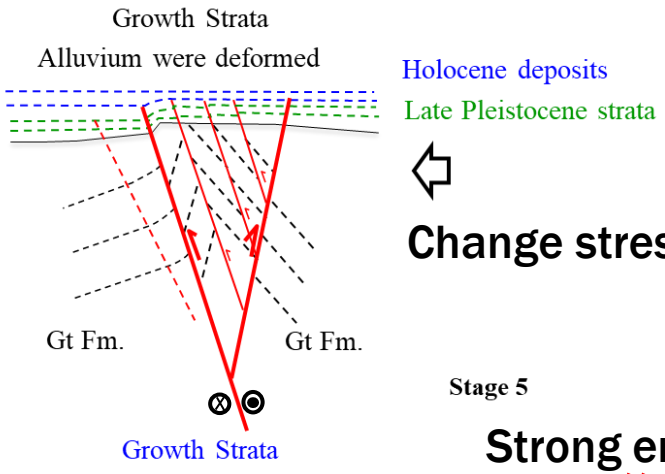
Stage 2



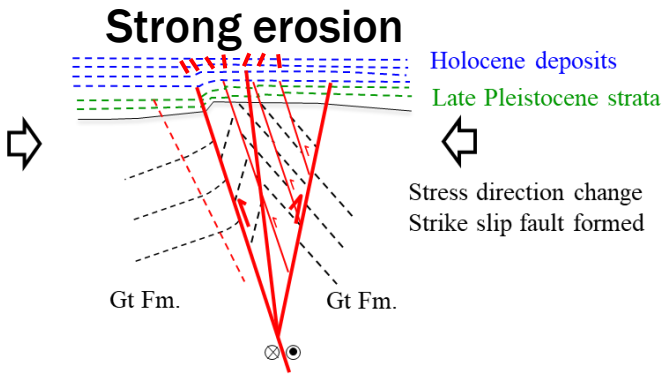
Stage 3



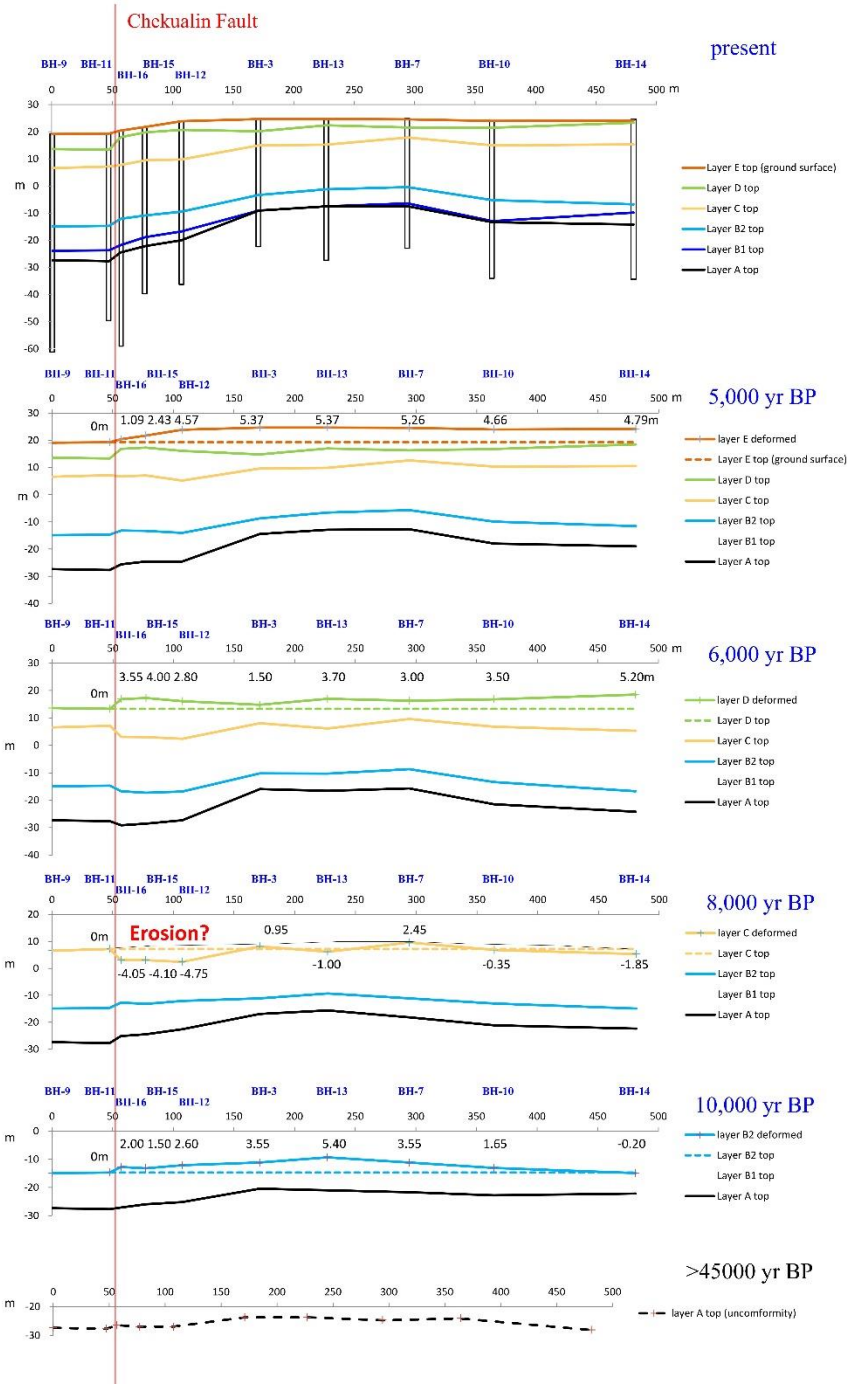
Stage 4



Stage 5



Evolution of Chegualin Fault active zone



Strata Formed age & Relative uplift rate:

Layer E
5,000 yr BP~present

Offset (Max~min):
5.37m~1.09m
Average rate:
0.65 ±0.43 mm/yr

Layer D
6,000~5,000 yr BP

Offset (Max~min):
5.20m~1.50m
Average rate:
3.35±1.85 mm/yr

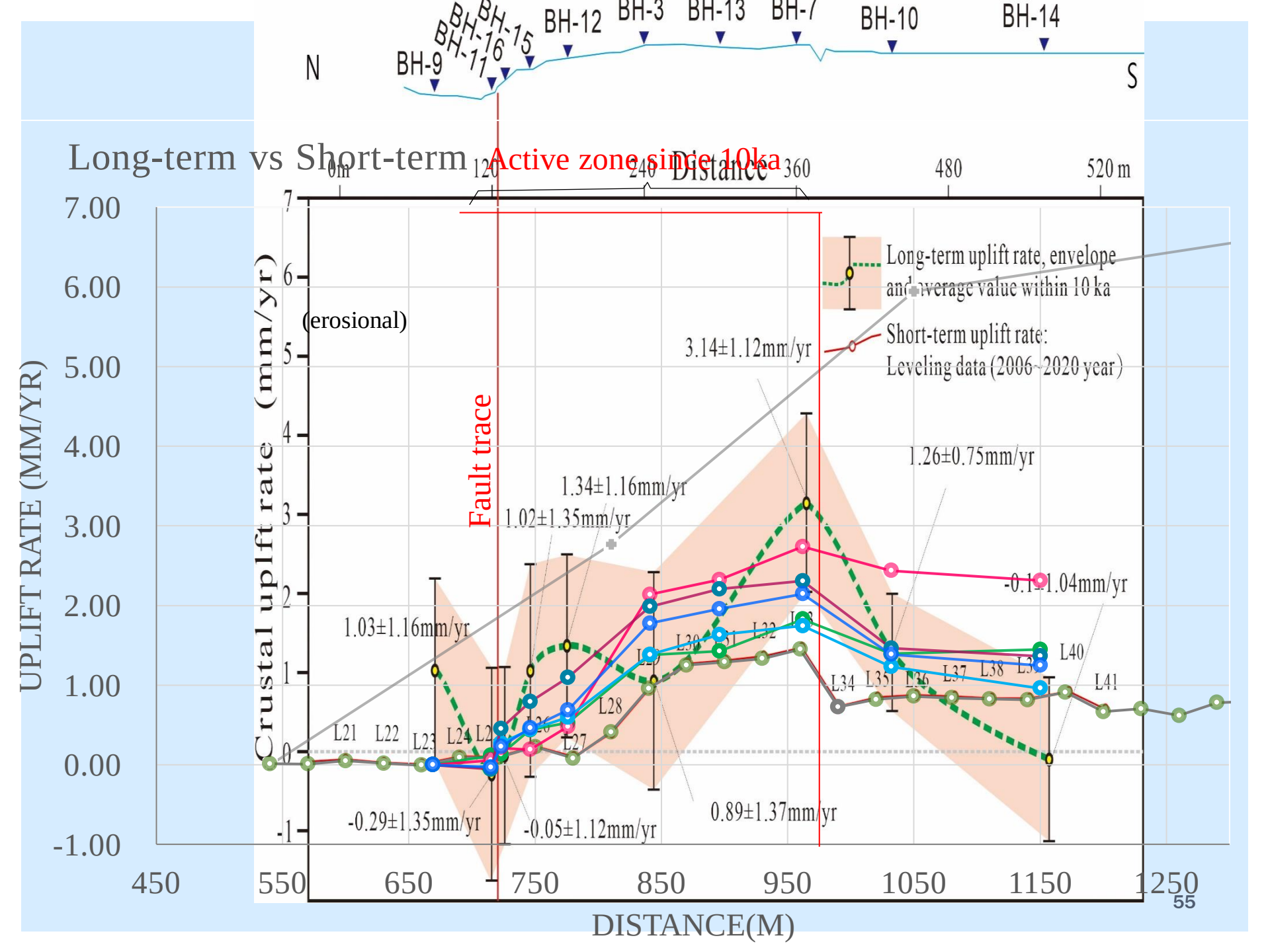
Layer C
8,000~6,000 yr BP

Offset (Max~min):
2.45m~-4.75m
Average rate:
0.85±0.38 mm/yr
(ignored erosion)

Layer B
10,000~8,000 yr BP

Offset (Max~min):
5.40m ~ -0.20m
Average rate:
1.30±1.40 mm/yr

FUTURE WORK
EXTRACT EVERY POINT TO DETERMINE DEFORMATION RATE


BH-9
BH-11
BH-16
BH-15
BH-12
BH-3
BH-13
BH-7
BH-10
BH-14
N
S
Long-term vs Short-term
Active zone since 10ka
Distance
0m
120
240
360
480
520 m
Fault trace
(erosional)
Long-term uplift rate, envelope and average value within 10 ka
Short-term uplift rate:
Leveling data (2006~2020 year)
3.14±1.12mm/yr
1.26±0.75mm/yr
1.34±1.16mm/yr
1.02±1.35mm/yr
1.03±1.16mm/yr
-0.29±1.35mm/yr
-0.05±1.12mm/yr
0.89±1.37mm/yr
Crustal uplft rate (mm/yr)
UPLIFT RATE (MM/YR)
DISTANCE(M)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
450
550
650
750
850
950
1050
1150
1250
L21
L22
L23
L24
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