The Abdus Salam International Centre for Theoretical Physics

2464-5

Earthquake Tectonics and Hazards on the Continents

17 - 28 June 2013

Recognizing and characterizing normal faults and earthquakes in USA and China

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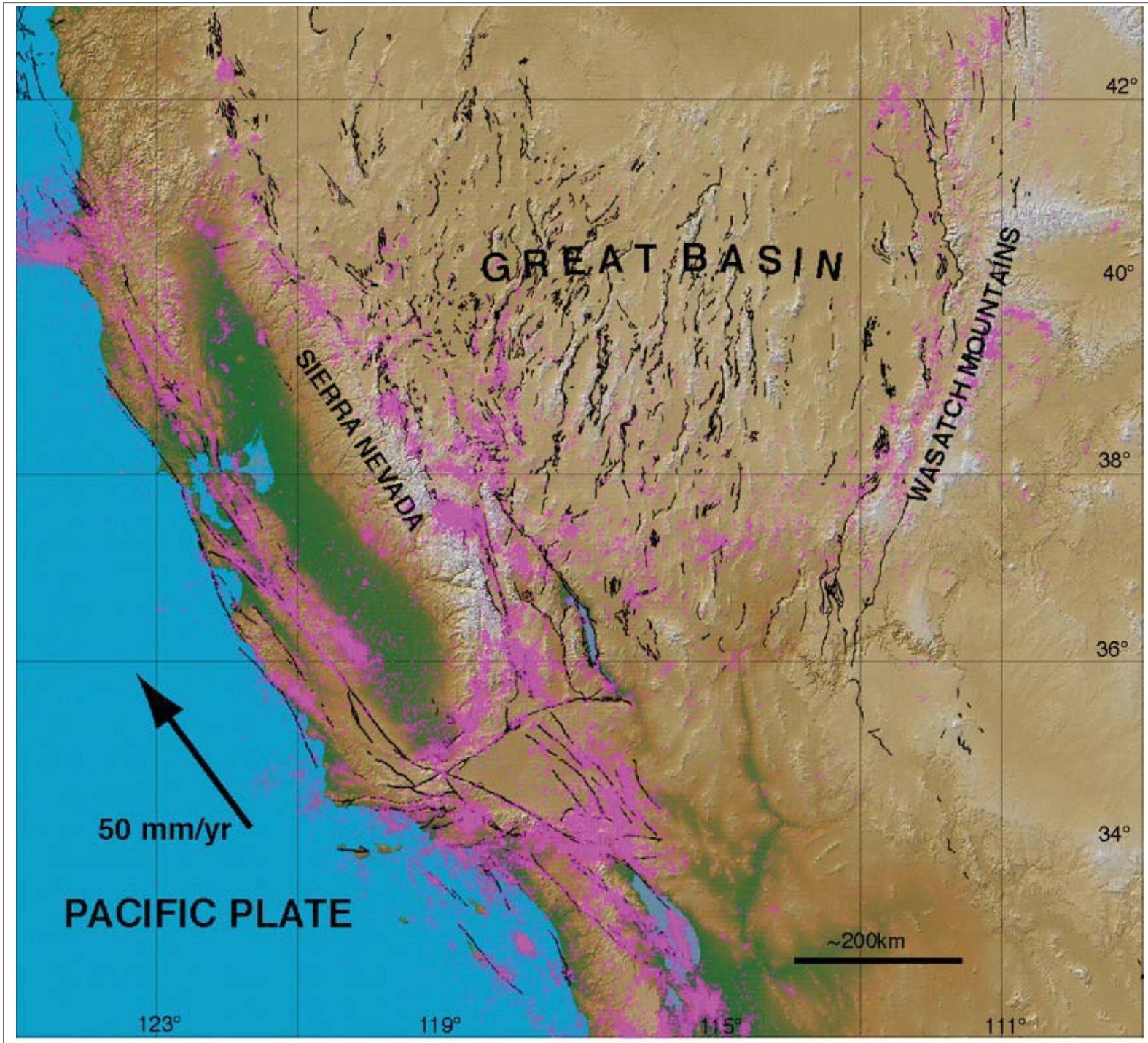


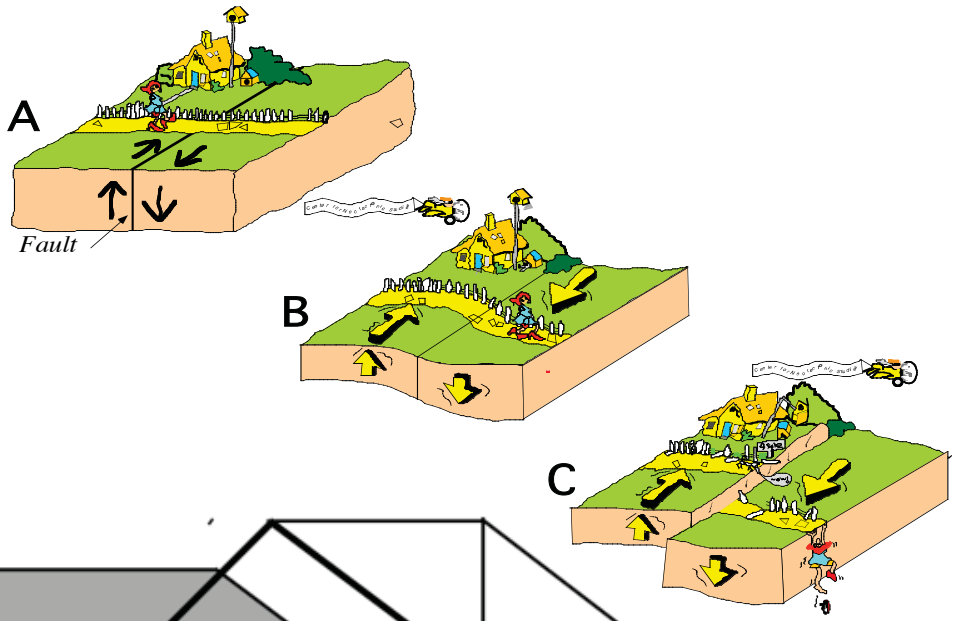
Each one of these lines is the intersection of a fault that intersects the surface of the earth.

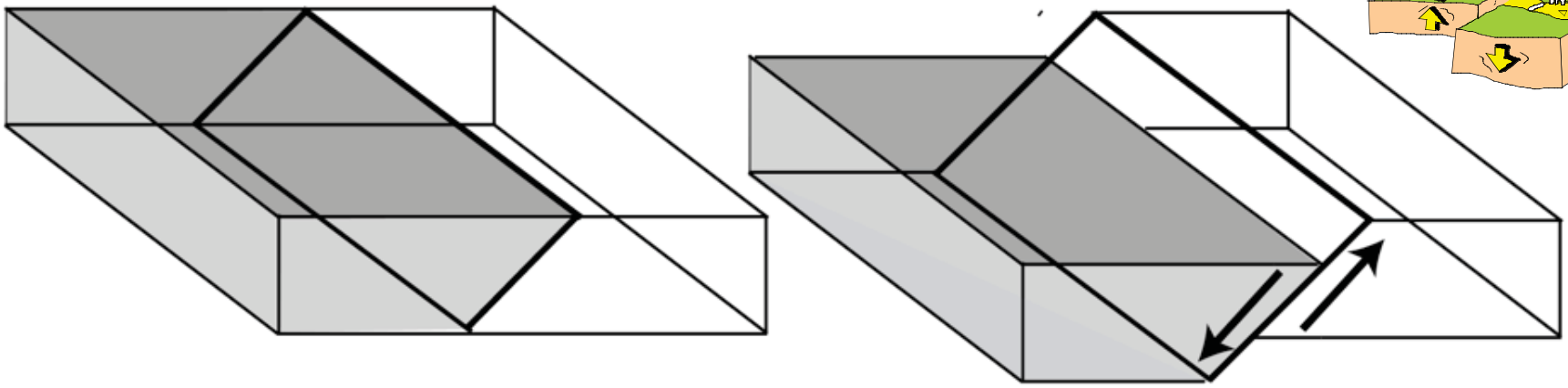
Each is capable of producing a big earthquake.

The pink dots are tiny earthquakes recorded recently - much smaller than can occur on faults

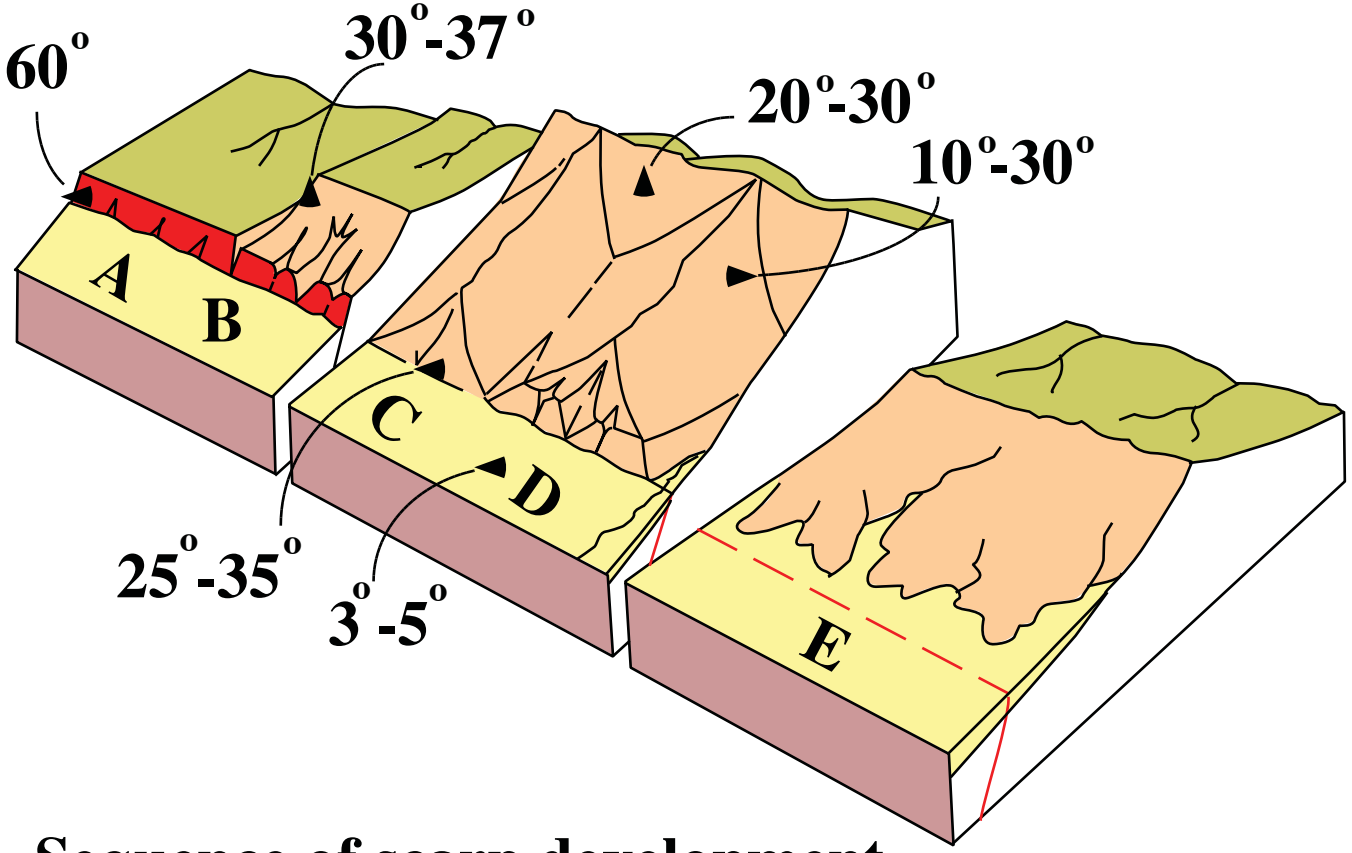
The mountains of the western united states are the result of displacement that occurs on Normal faults.

Normal Fault...

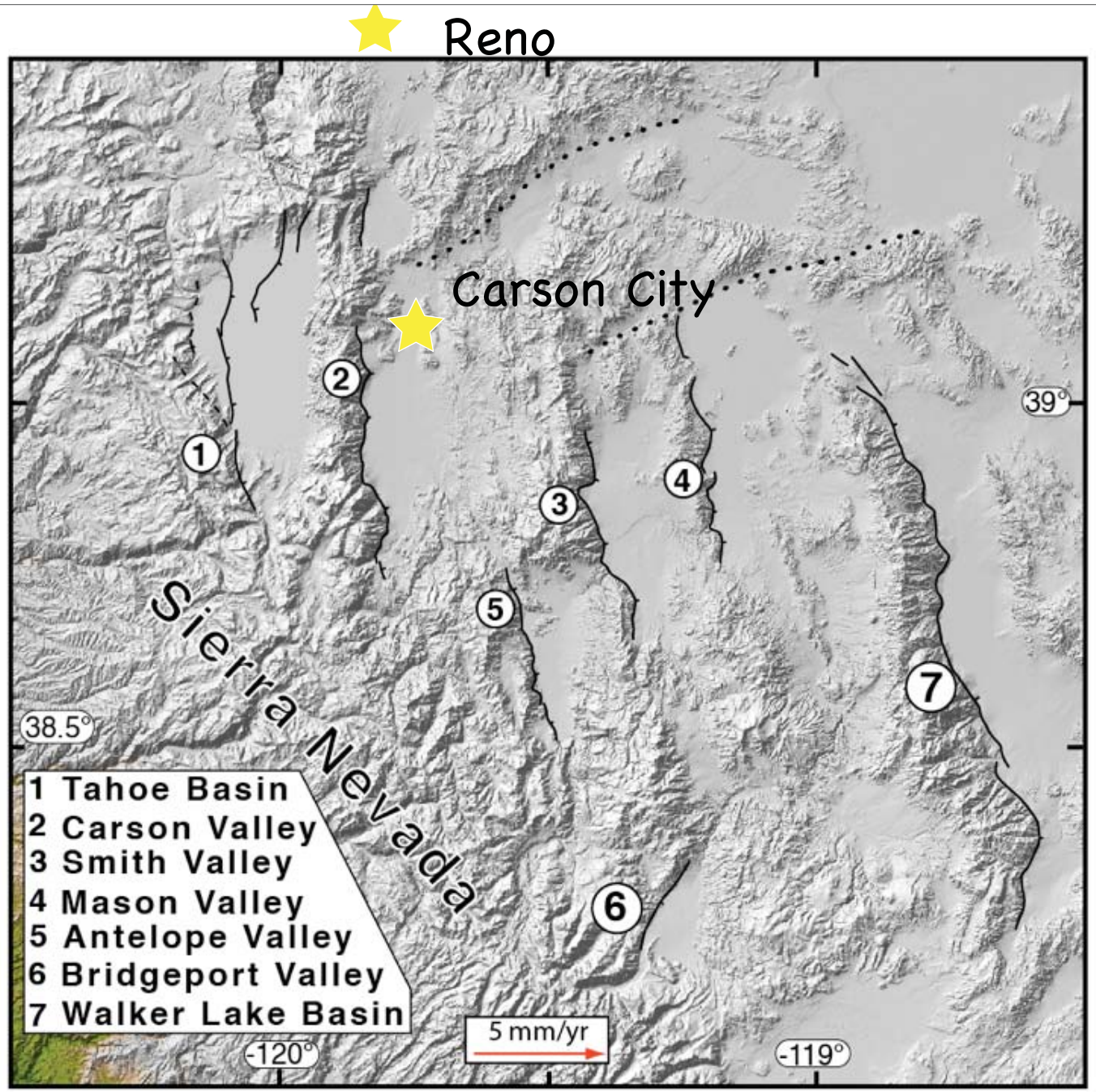


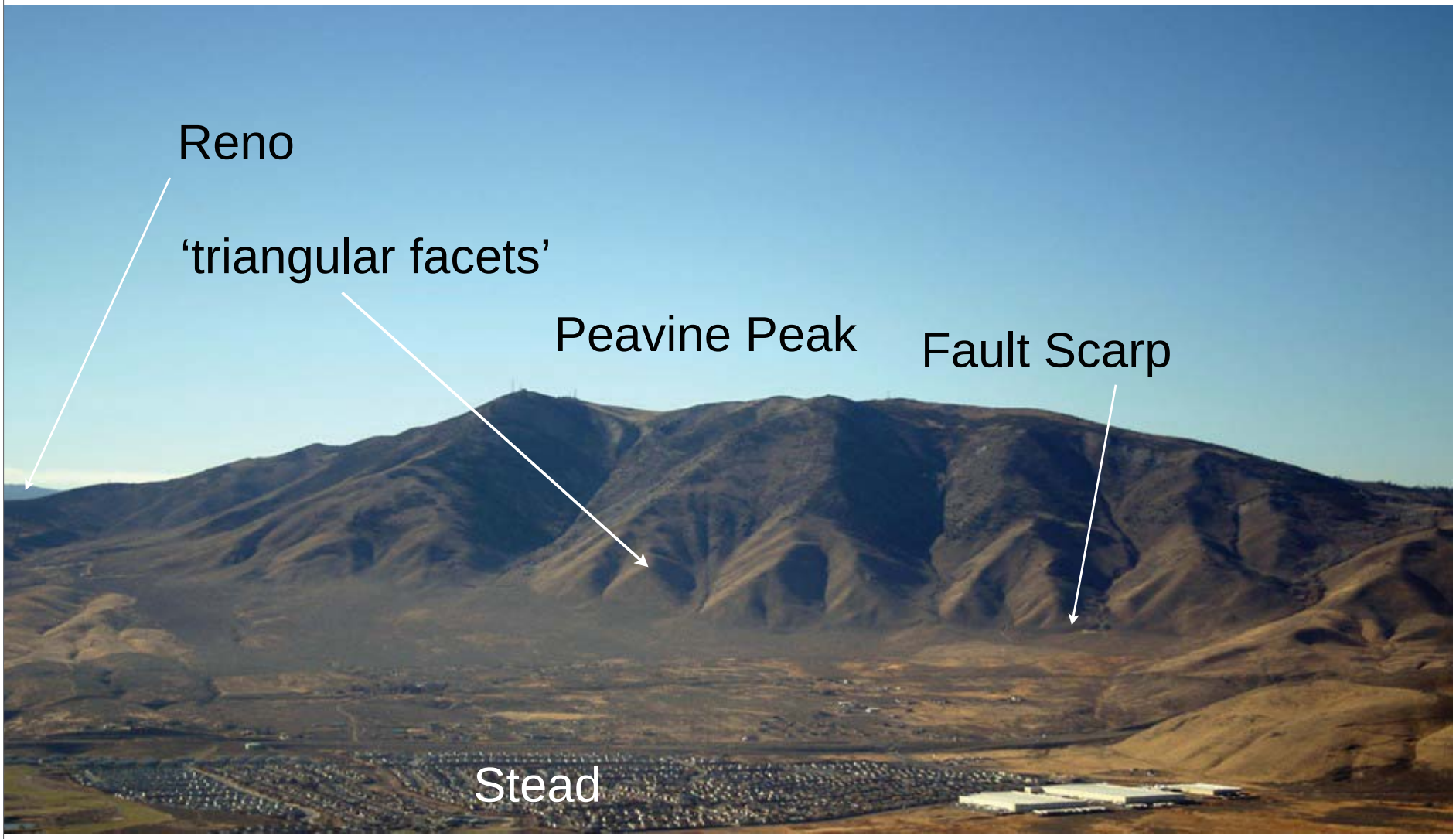


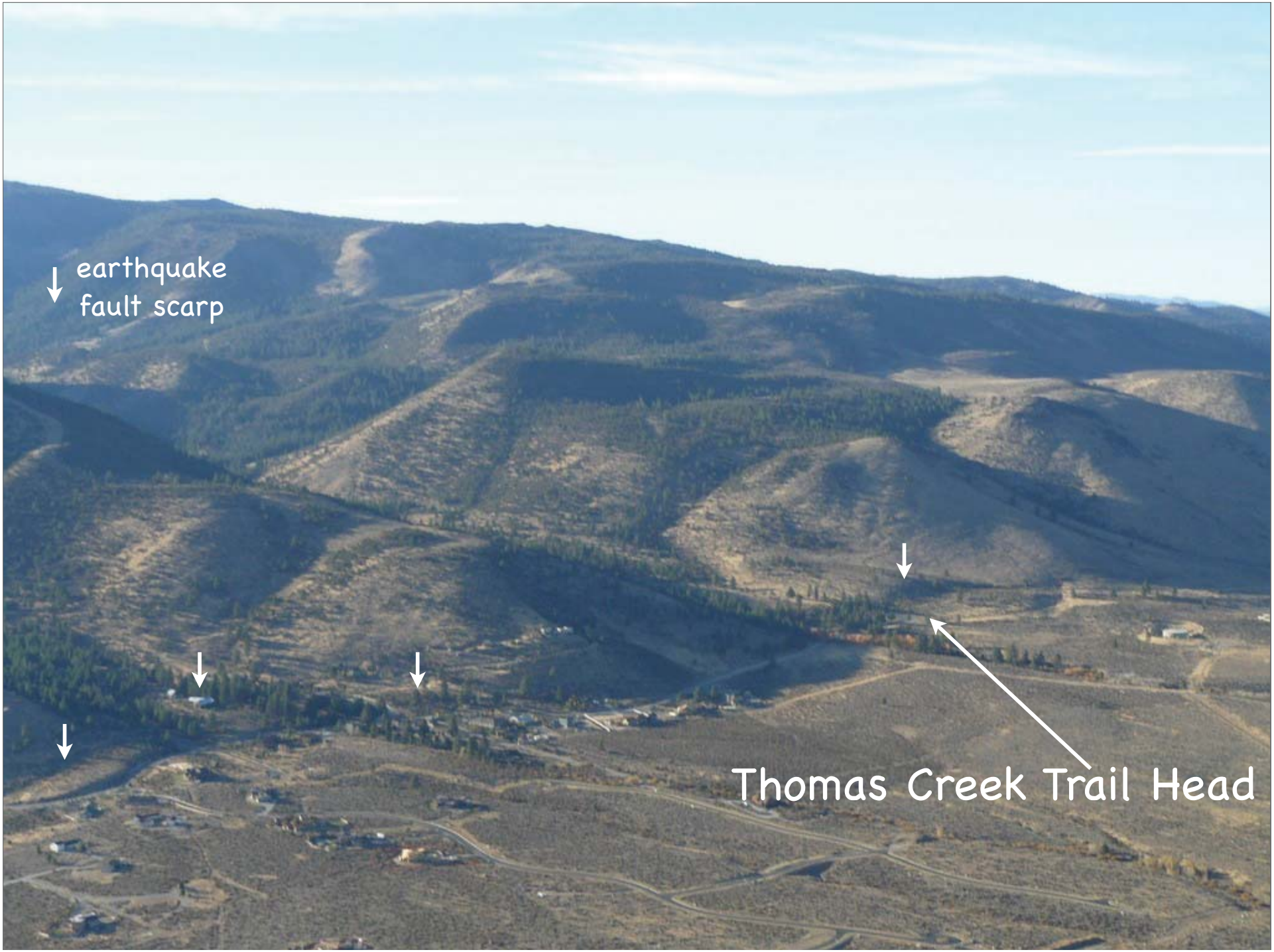
The Physiography and Morphology resulting from repeated normal fault earthquakes is distinct from strike-slip (or thrust)



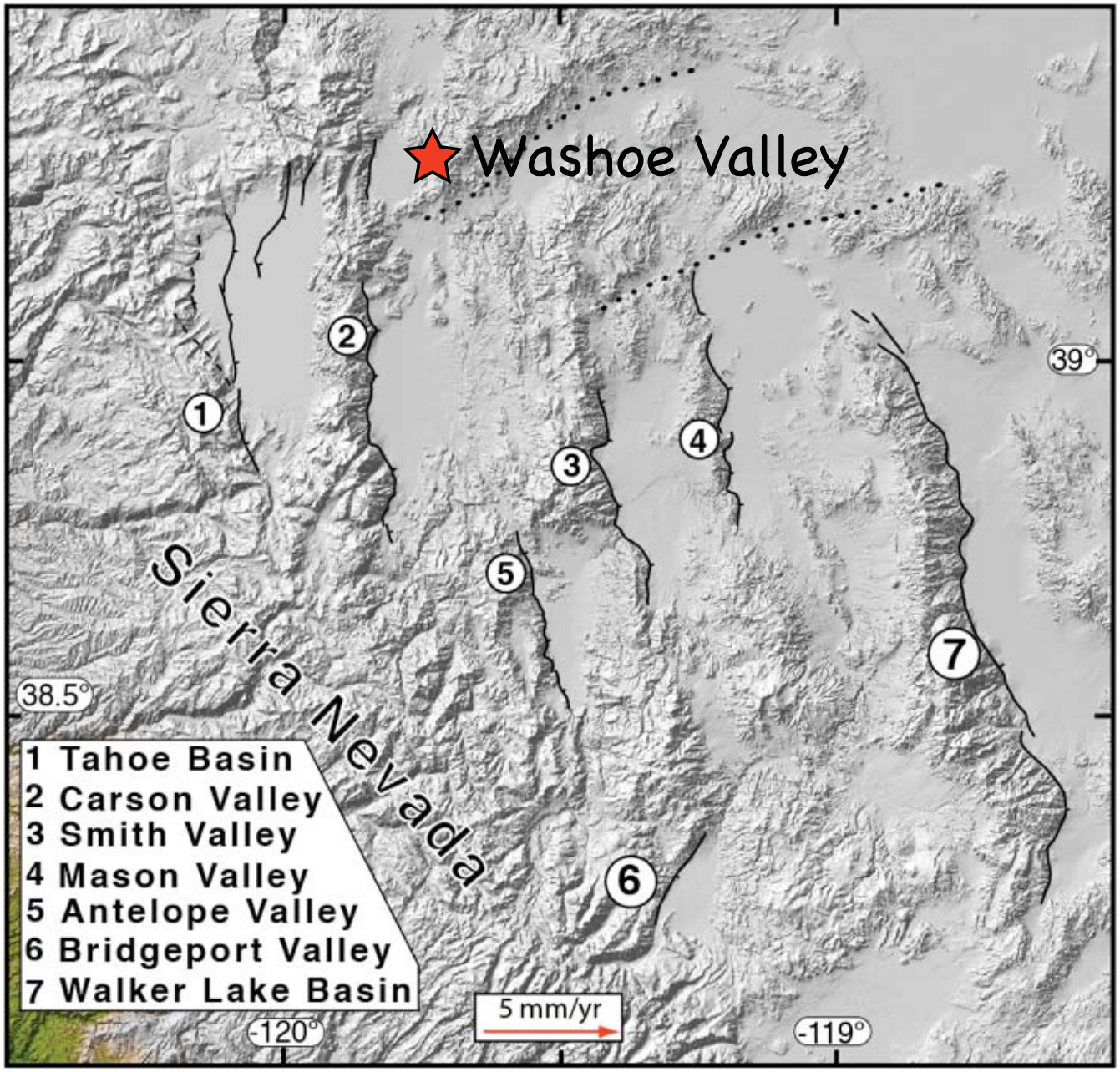
Sequence of scarp development
Wallace 1978

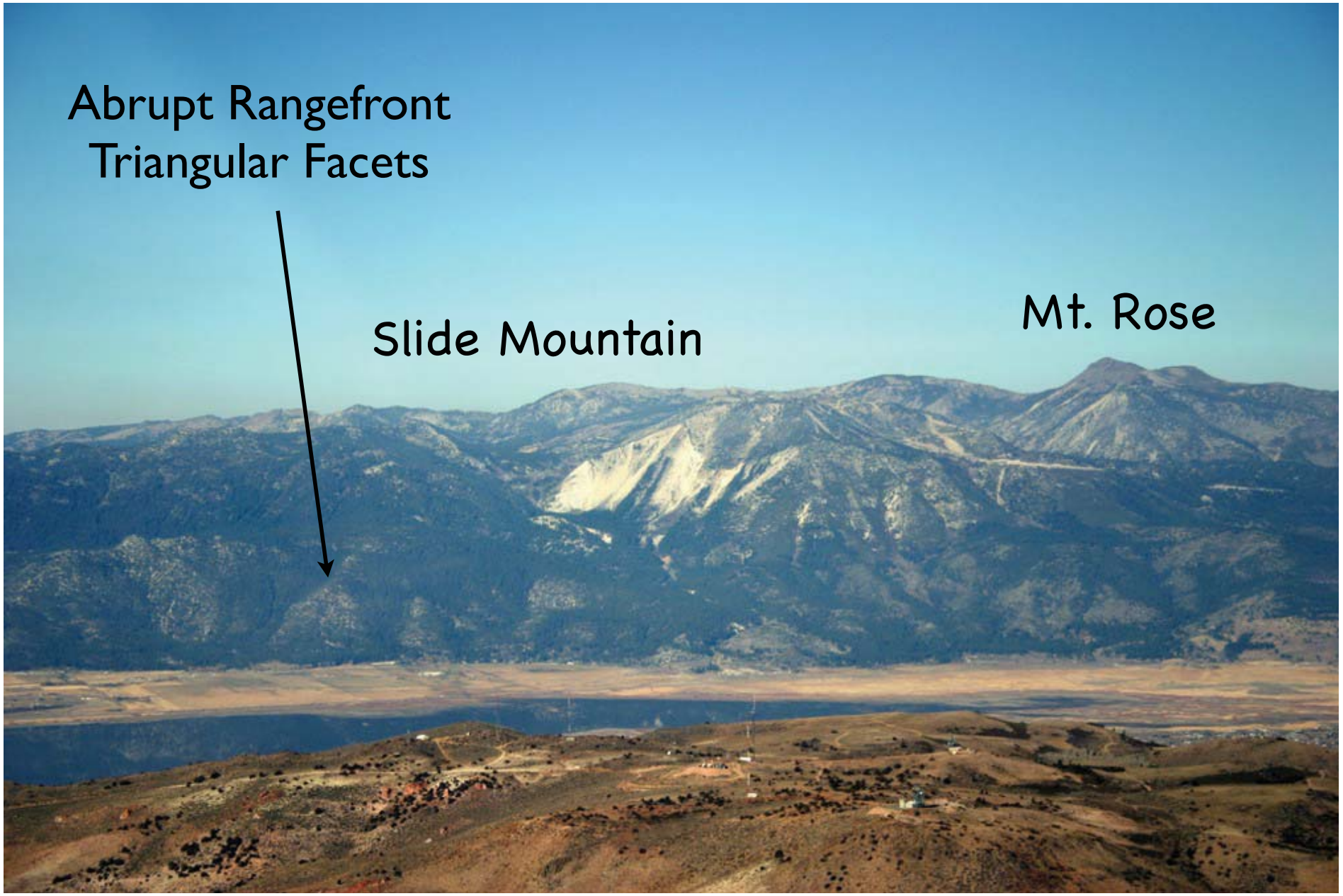

Reno
Carson City
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°


Reno
‘triangular facets’
Peavine Peak
Fault Scarp
Stead

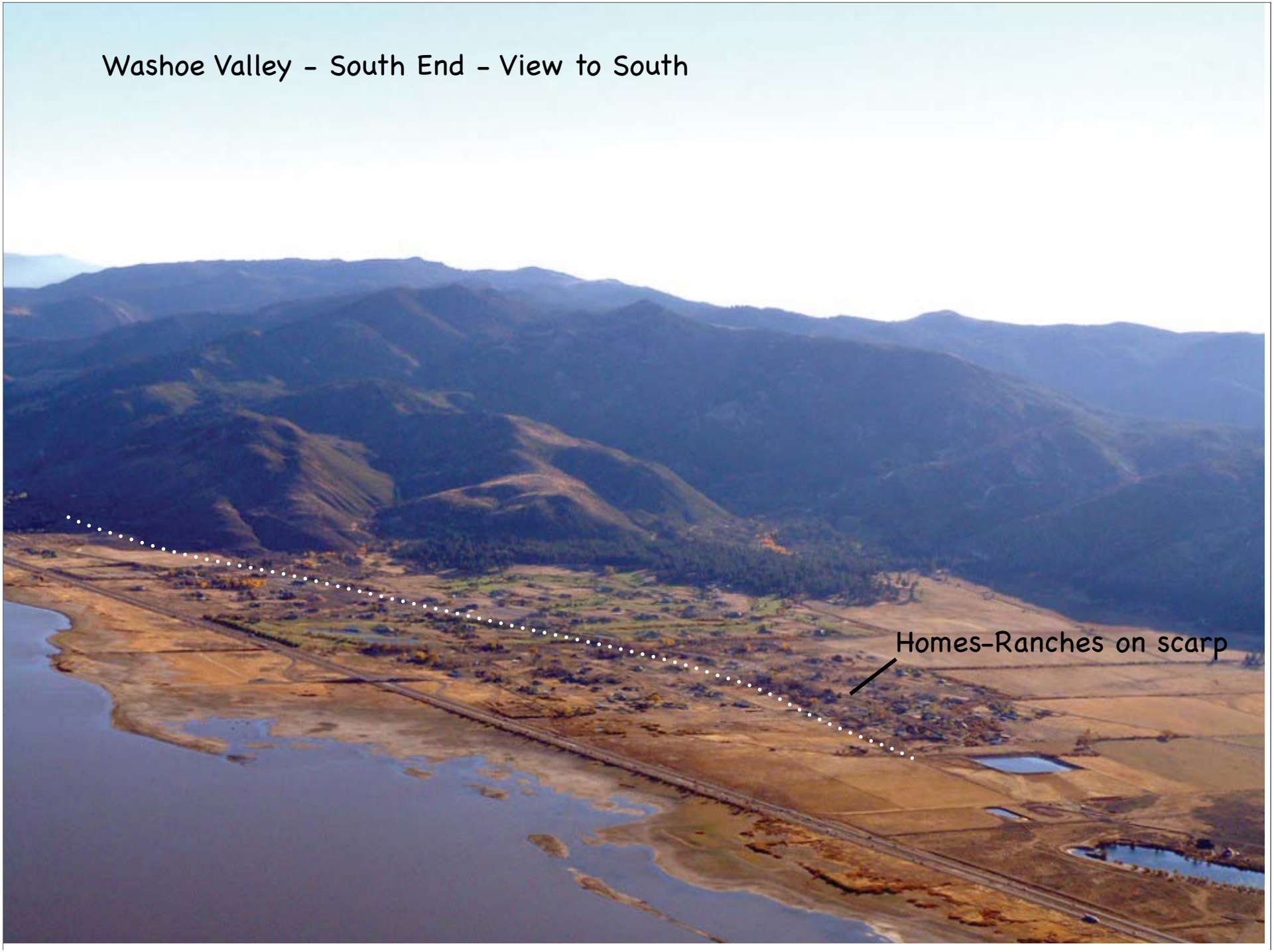

earthquake
fault scarp
Thomas Creek Trail Head

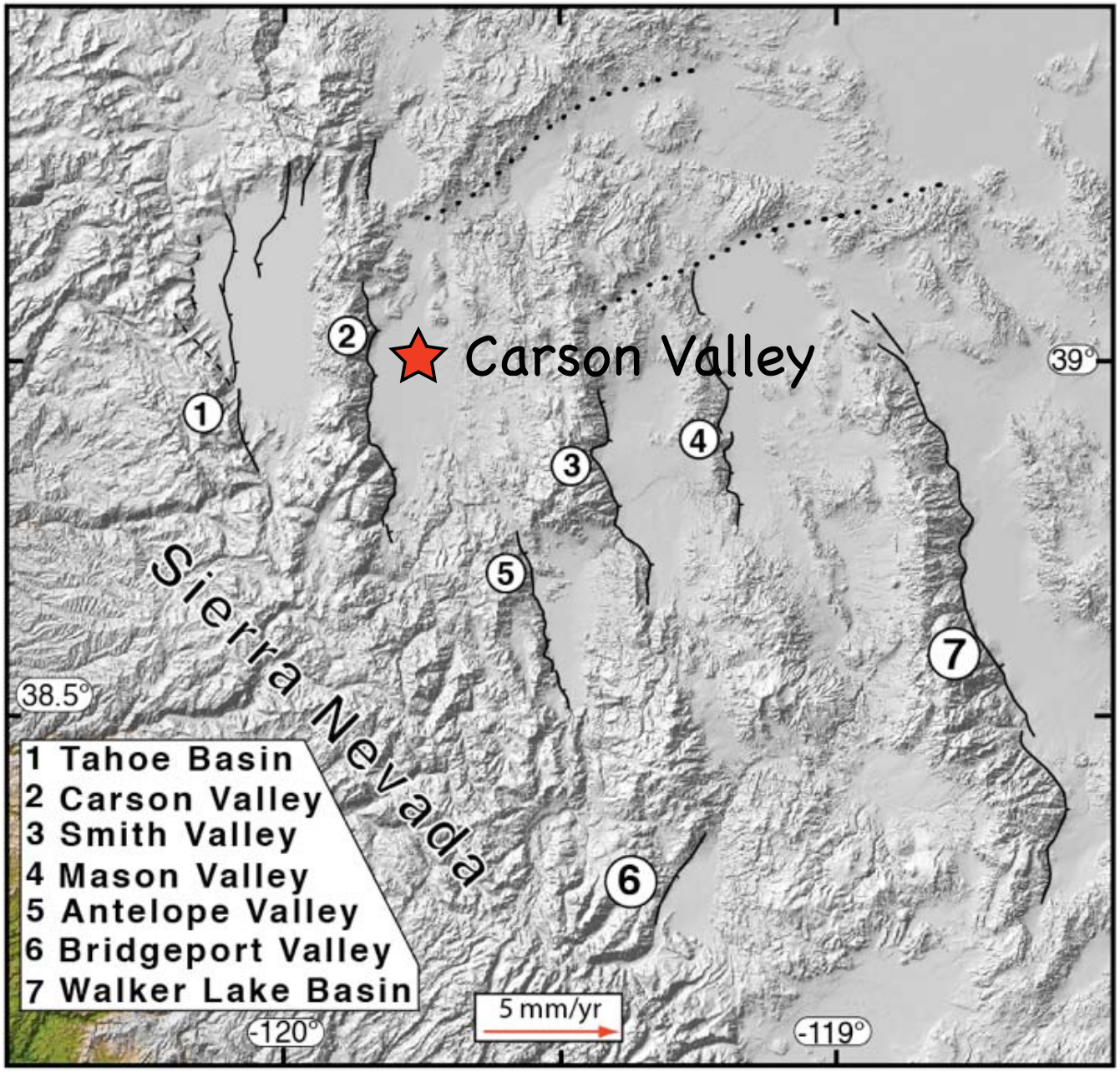

higher
fan terrace
surface
lower
fan terrace
surface
Thomas Creek Trail Head

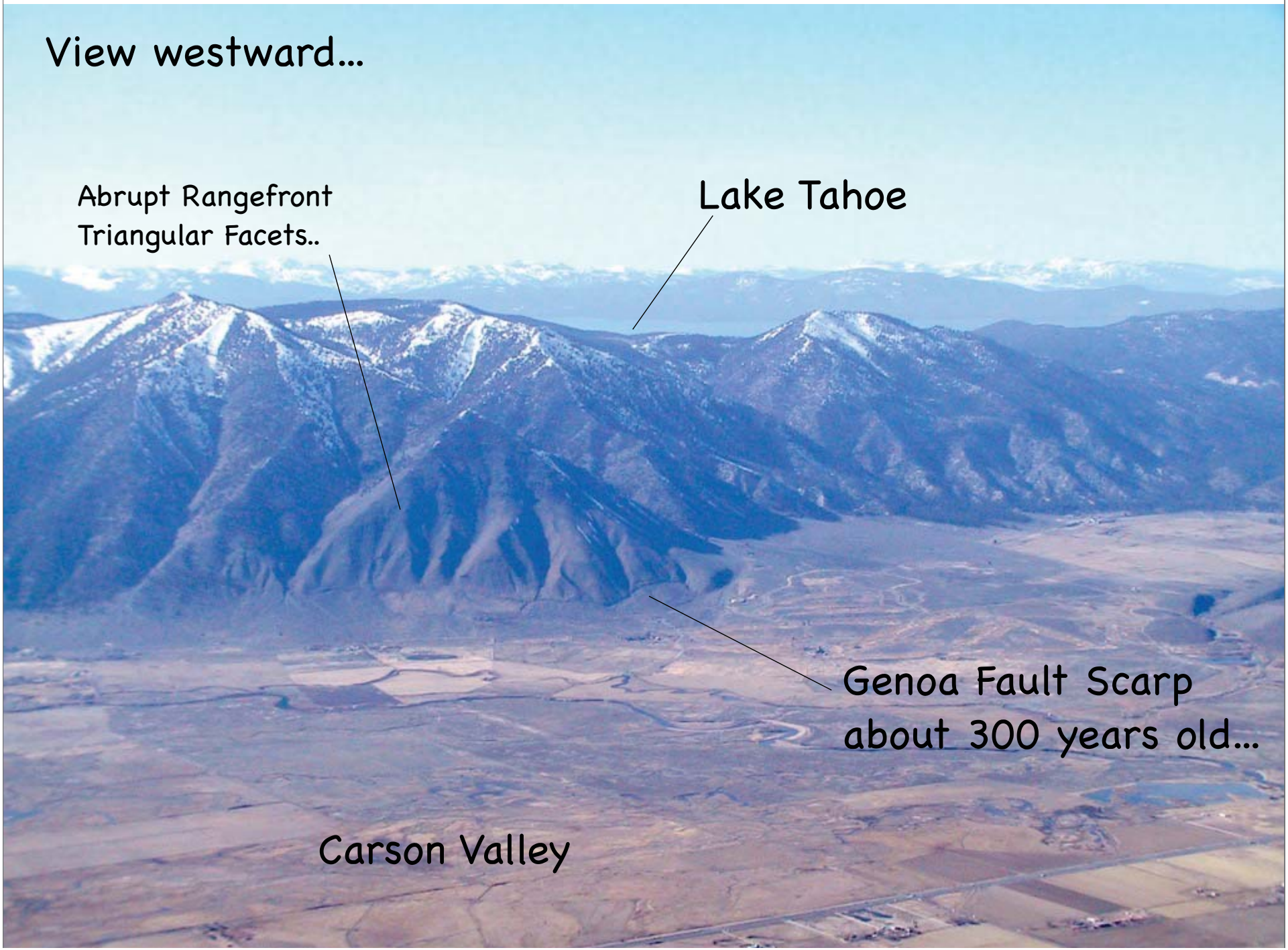

Washoe Valley
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°


Abrupt Rangefront
Triangular Facets
Slide Mountain
Mt. Rose

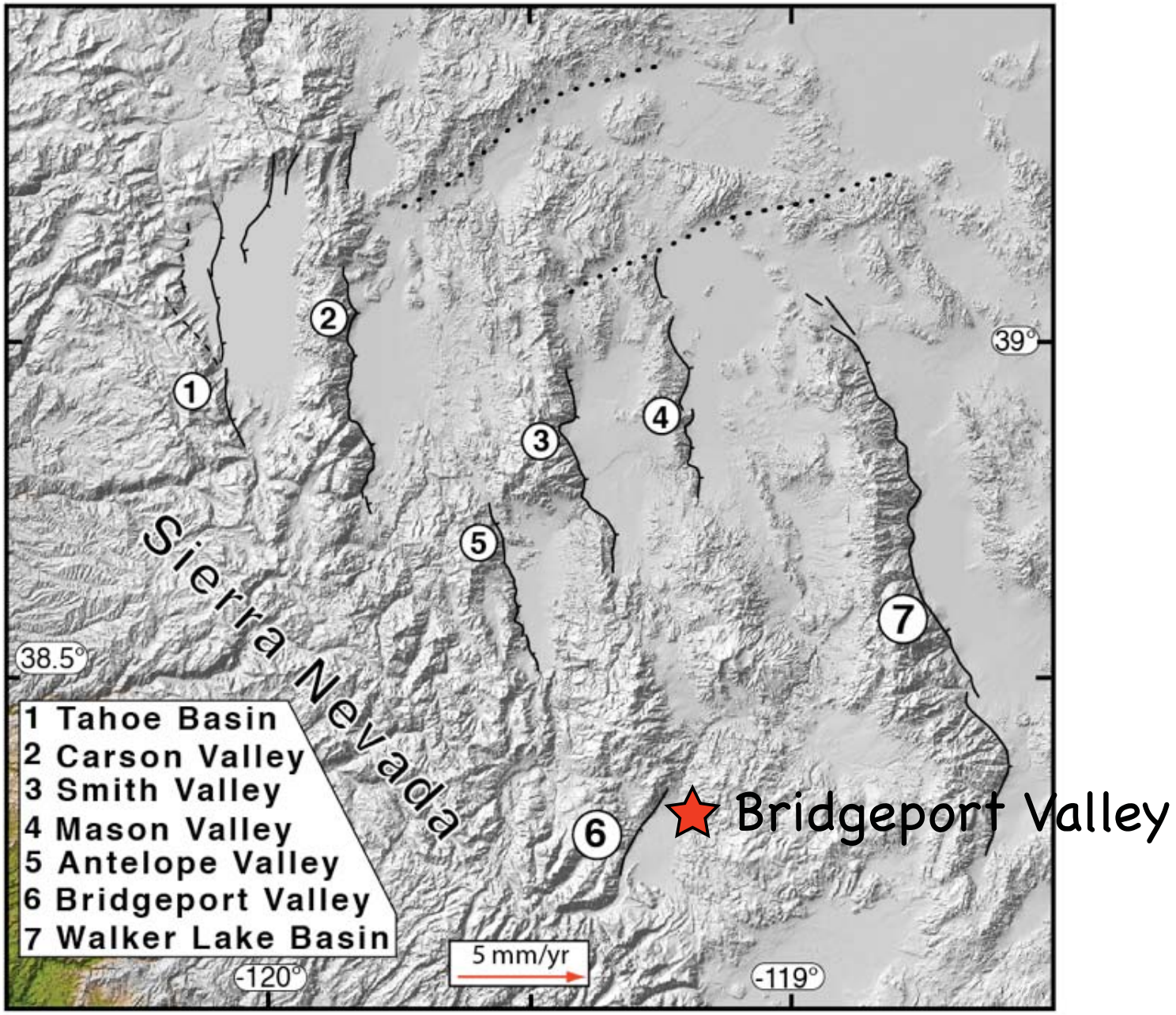

Washoe Valley view to southwest
Sharp Rangefront Triangular Facets

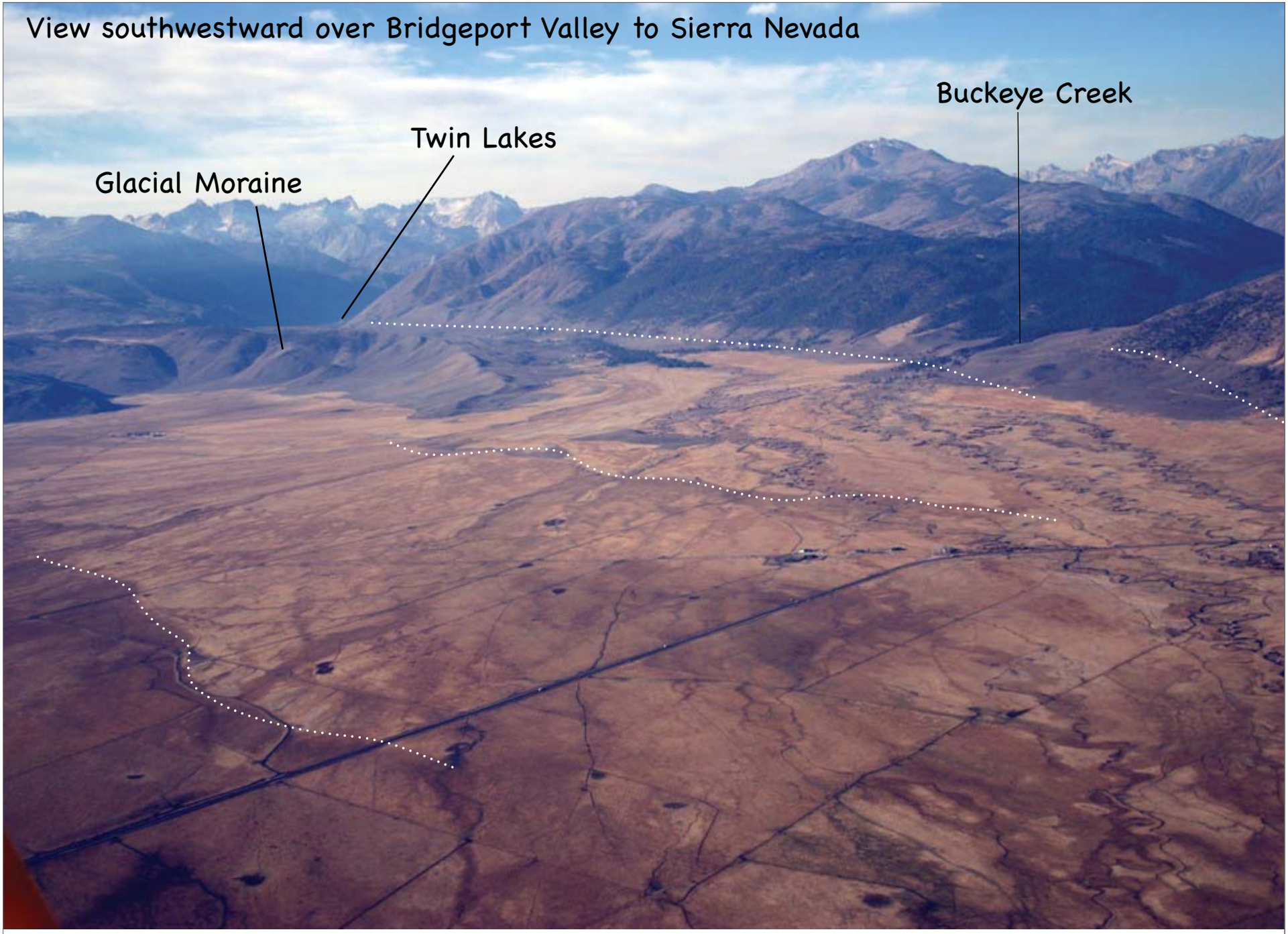

Washoe Valley - South End - View to South
Homes-Ranches on scarp

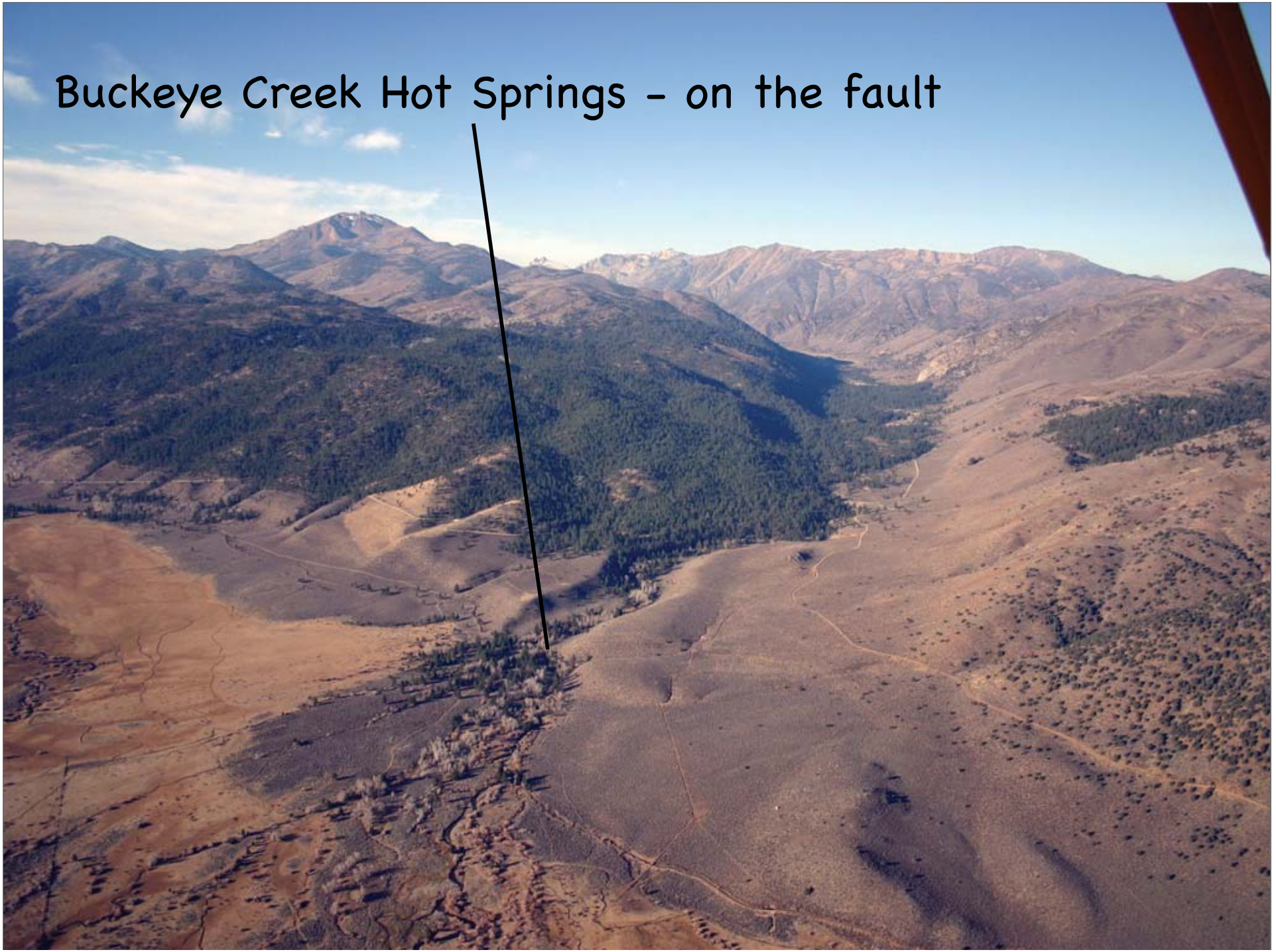

Carson Valley
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°

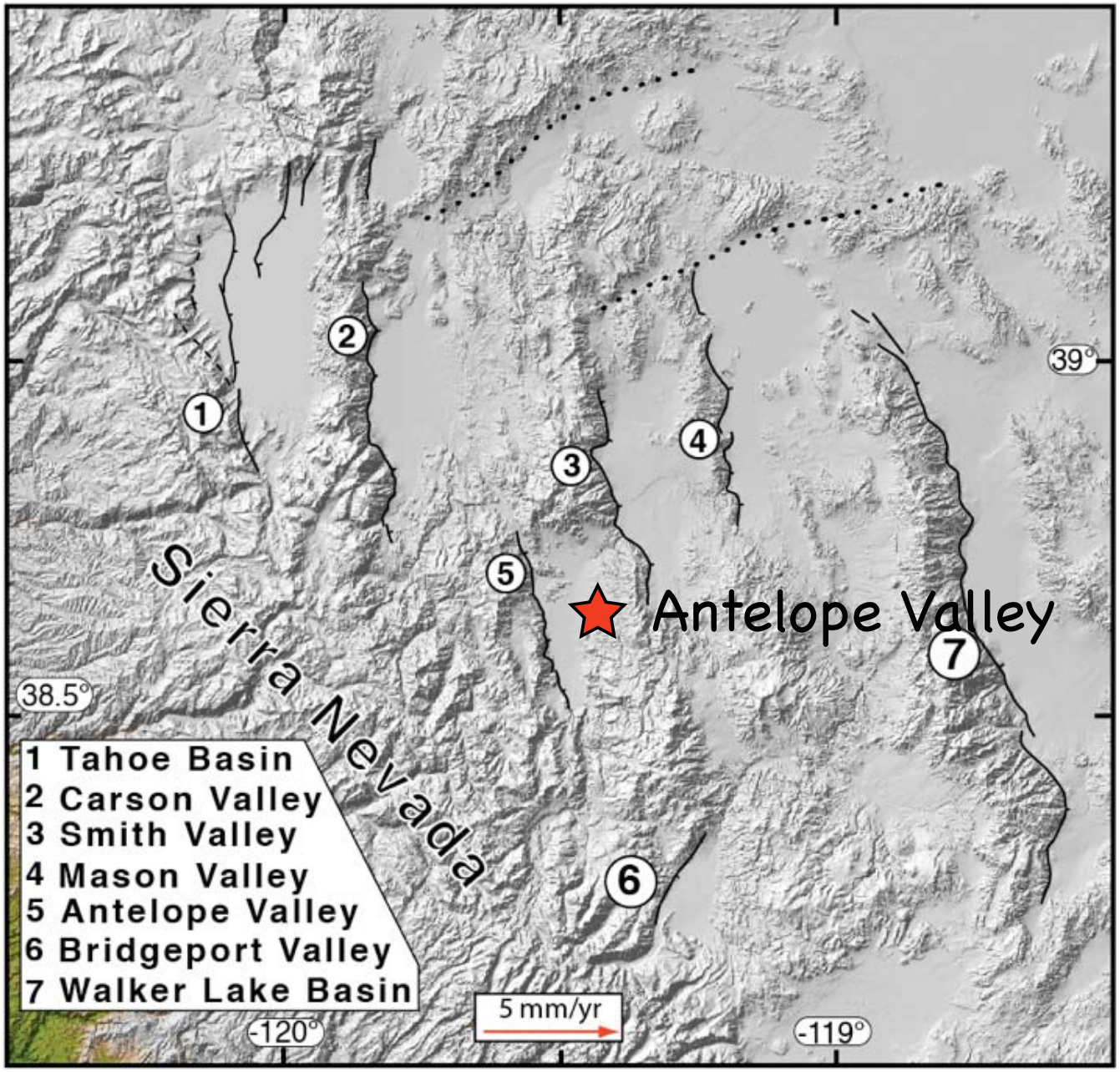

View westward...
Abrupt Rangefront
Triangular Facets..
Lake Tahoe
Genoa Fault Scarp
about 300 years old...
Carson Valley

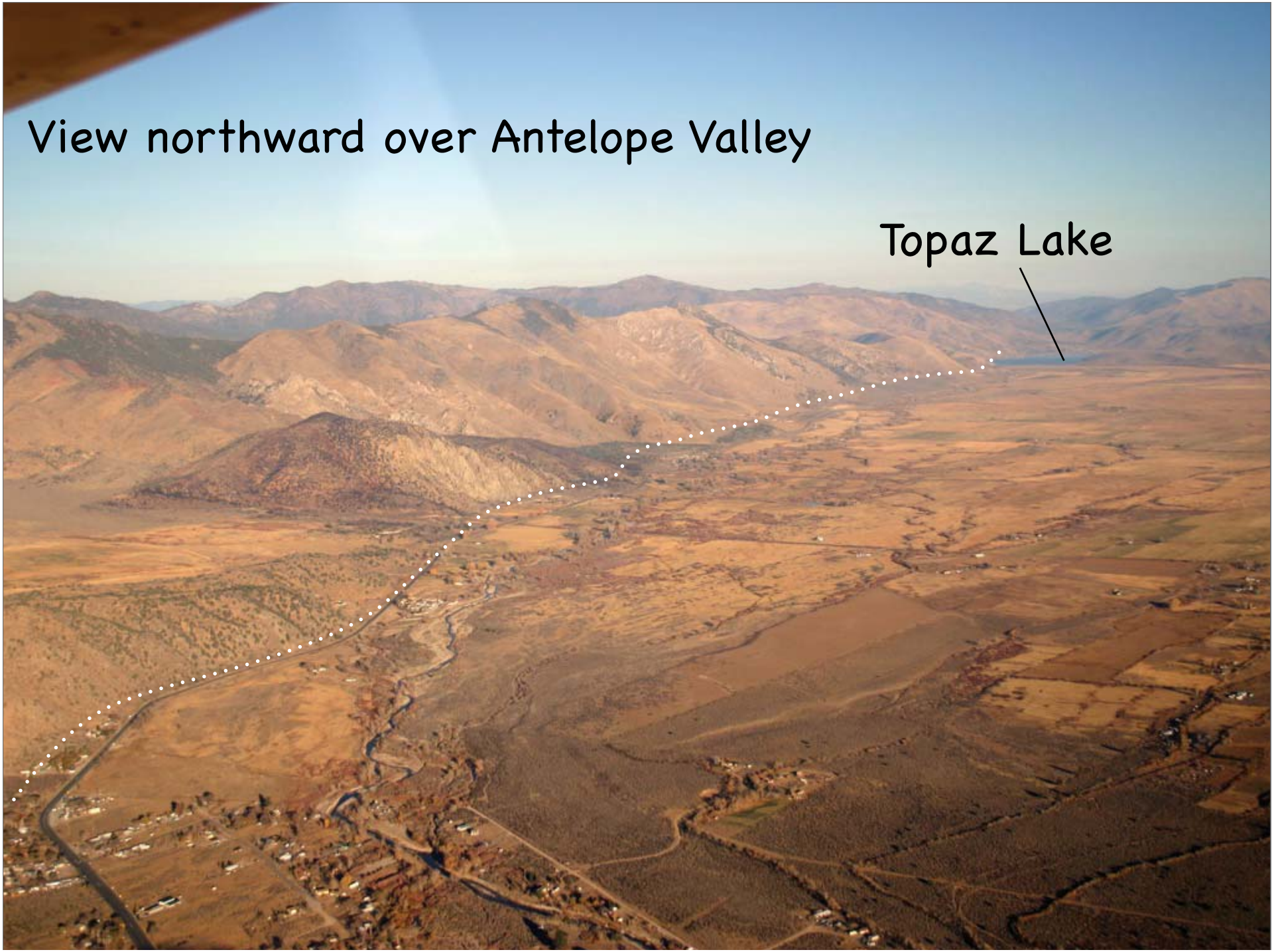

Carson City
Fault


1
2
3
4
5
6
7
Sierra Nevada
39°
38.5°
-120°
-119°
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
Bridgeport Valley


View southwestward over Bridgeport Valley to Sierra Nevada
Buckeye Creek
Twin Lakes
Glacial Moraine

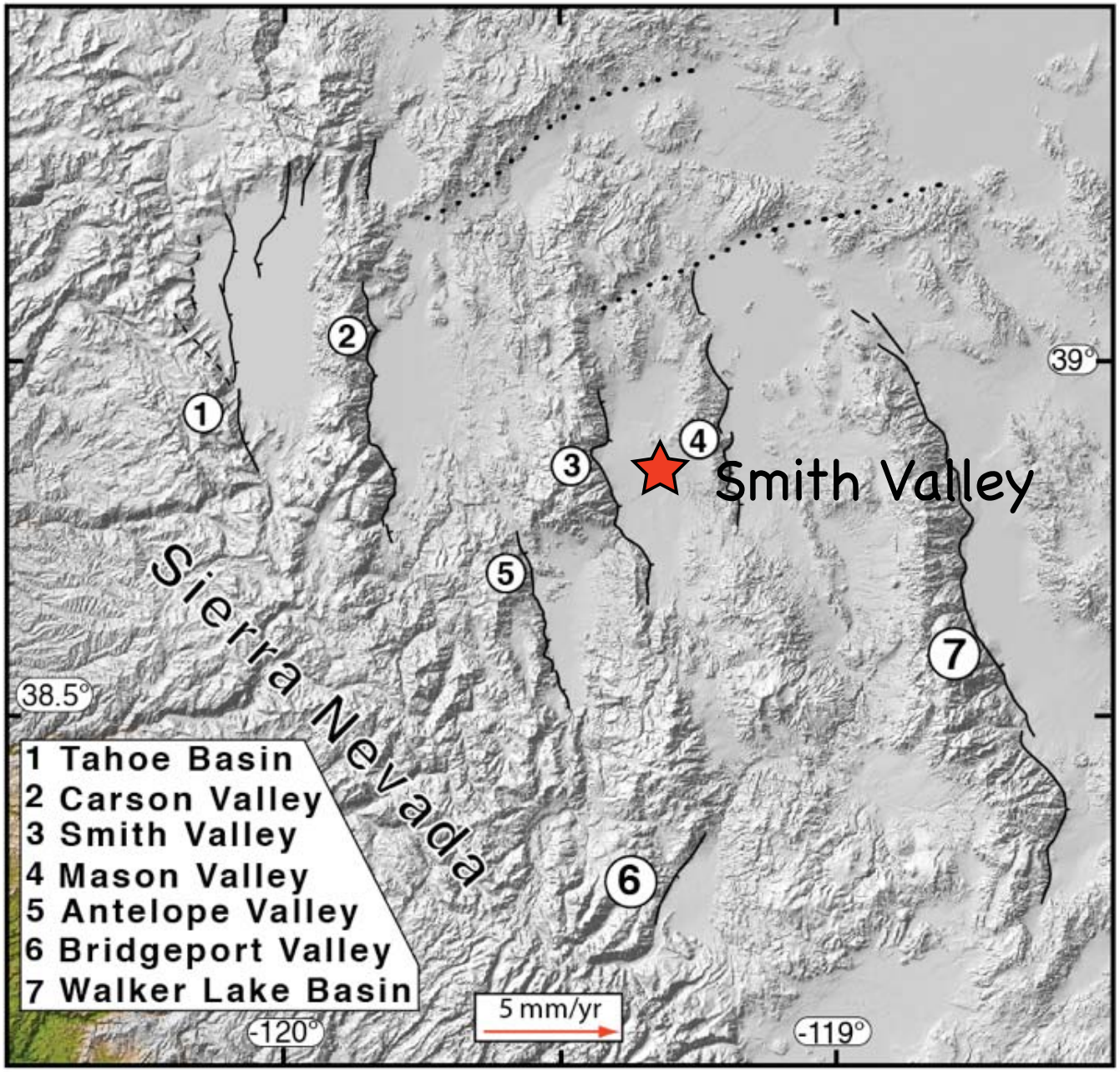

Buckeye Creek Hot Springs - on the fault


Sierra Nevada
Antelope Valley
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°


View northward over Antelope Valley
Topaz Lake


Scarp of Last Earthquake
NORTH
CALIFORNIA
89
Jct 4 18
Markleeville 22
Lake Tahoe 51

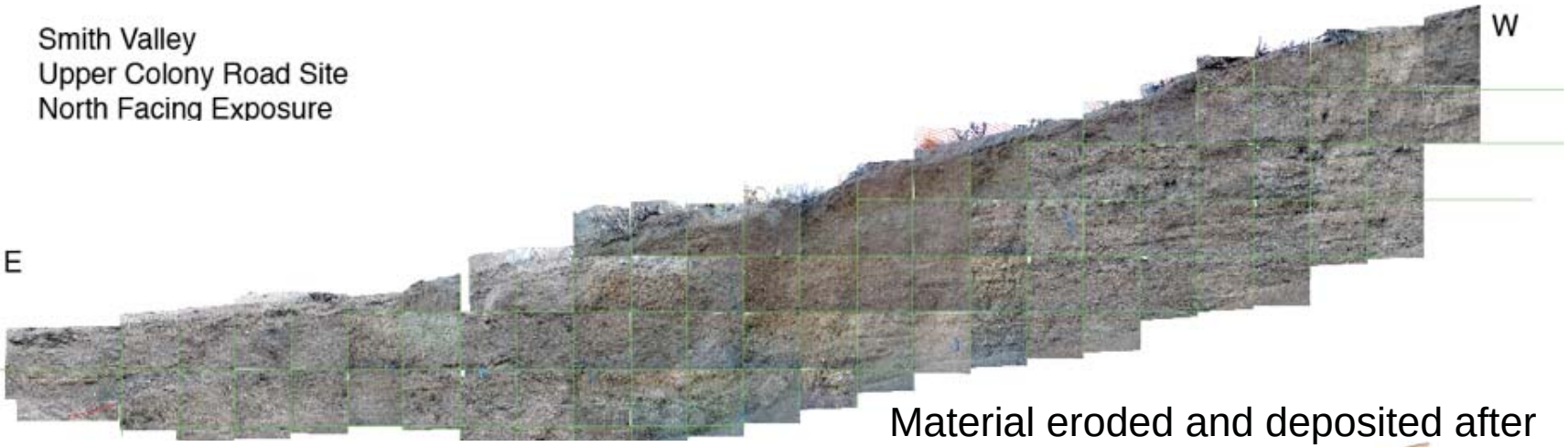

WineGlass Canyon


Smith Valley
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°

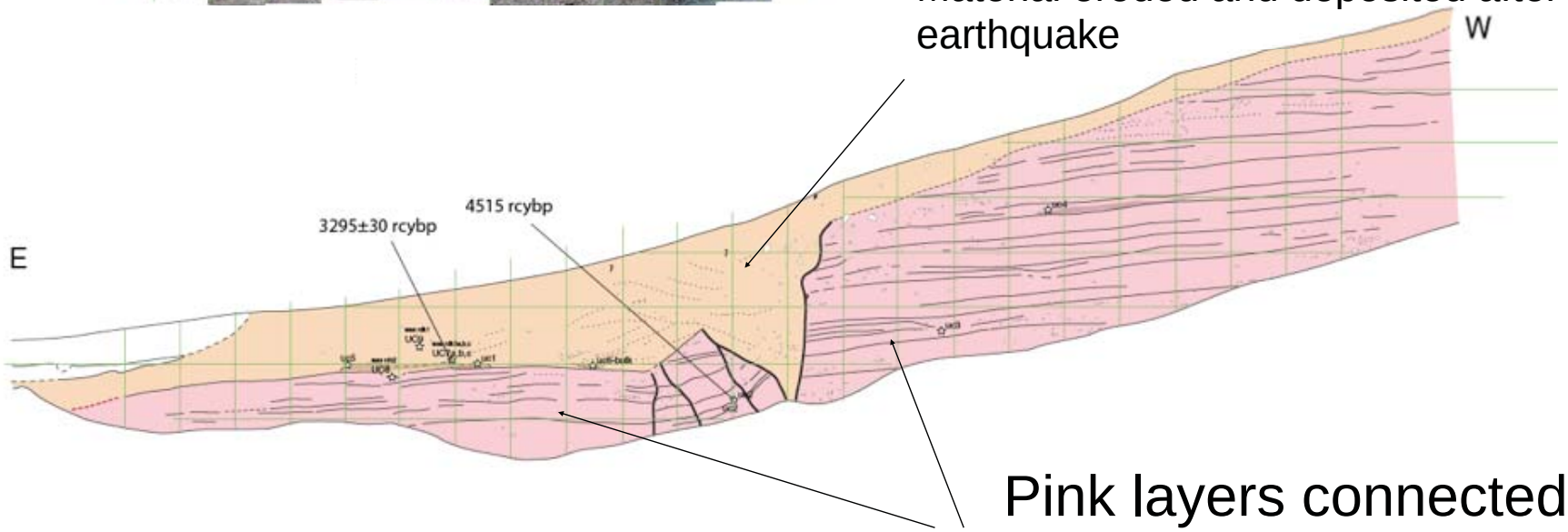
View to Northwest over Smith Valley


View westward over Upper
Colony Road - Smith Valley

Jerry and the class…

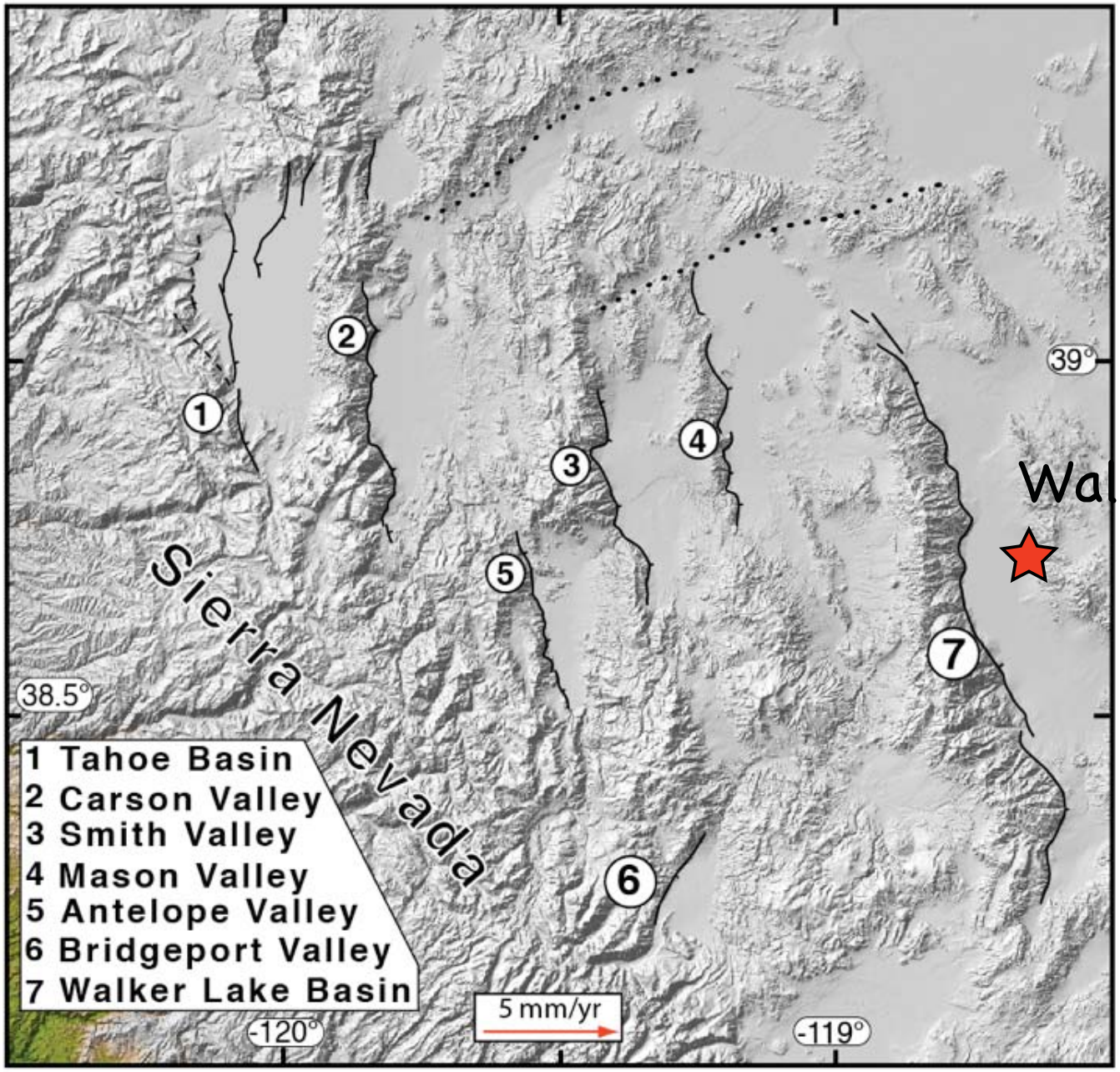


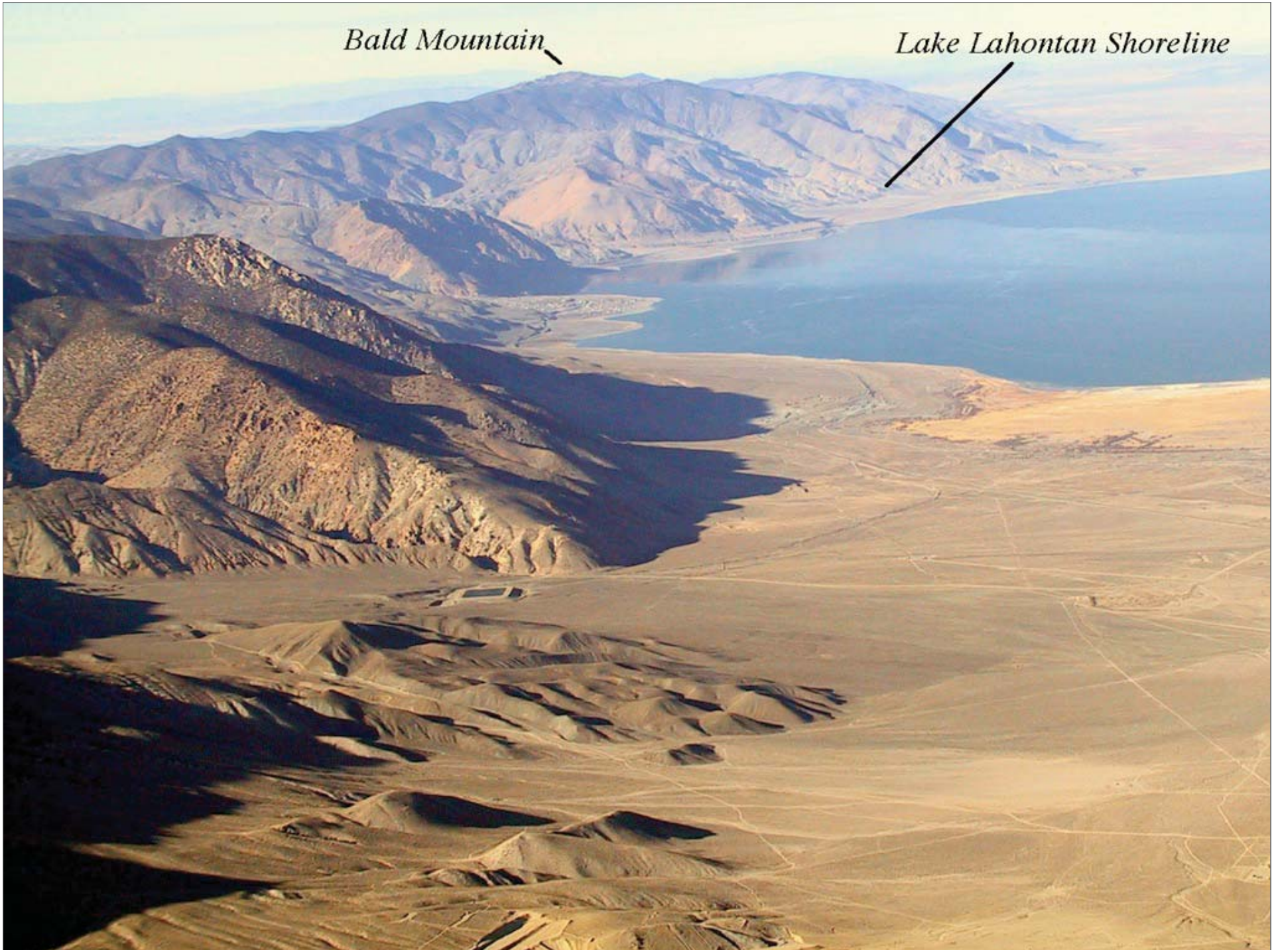
Material eroded and deposited after earthquake

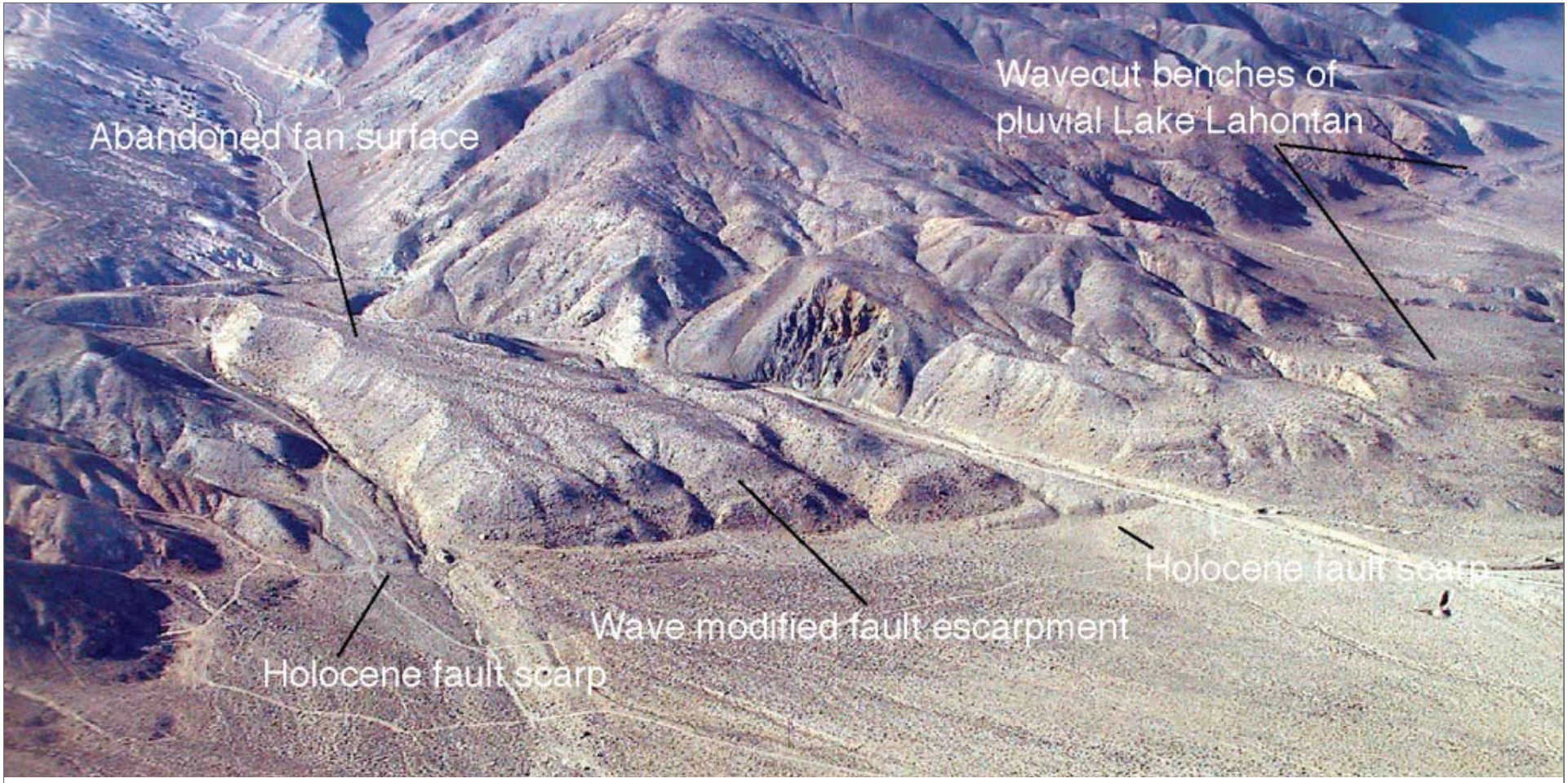


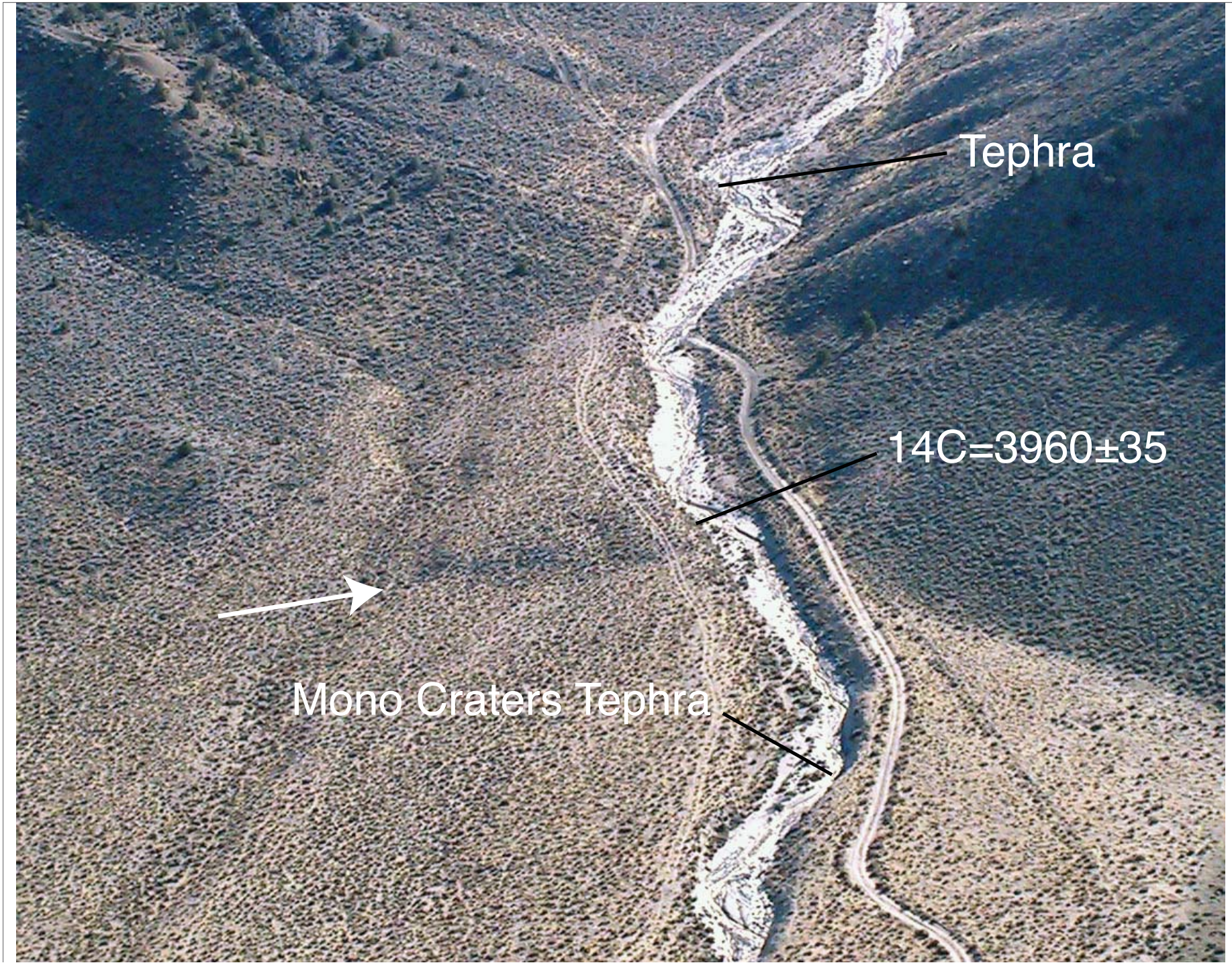
Pink layers connected before earthquake

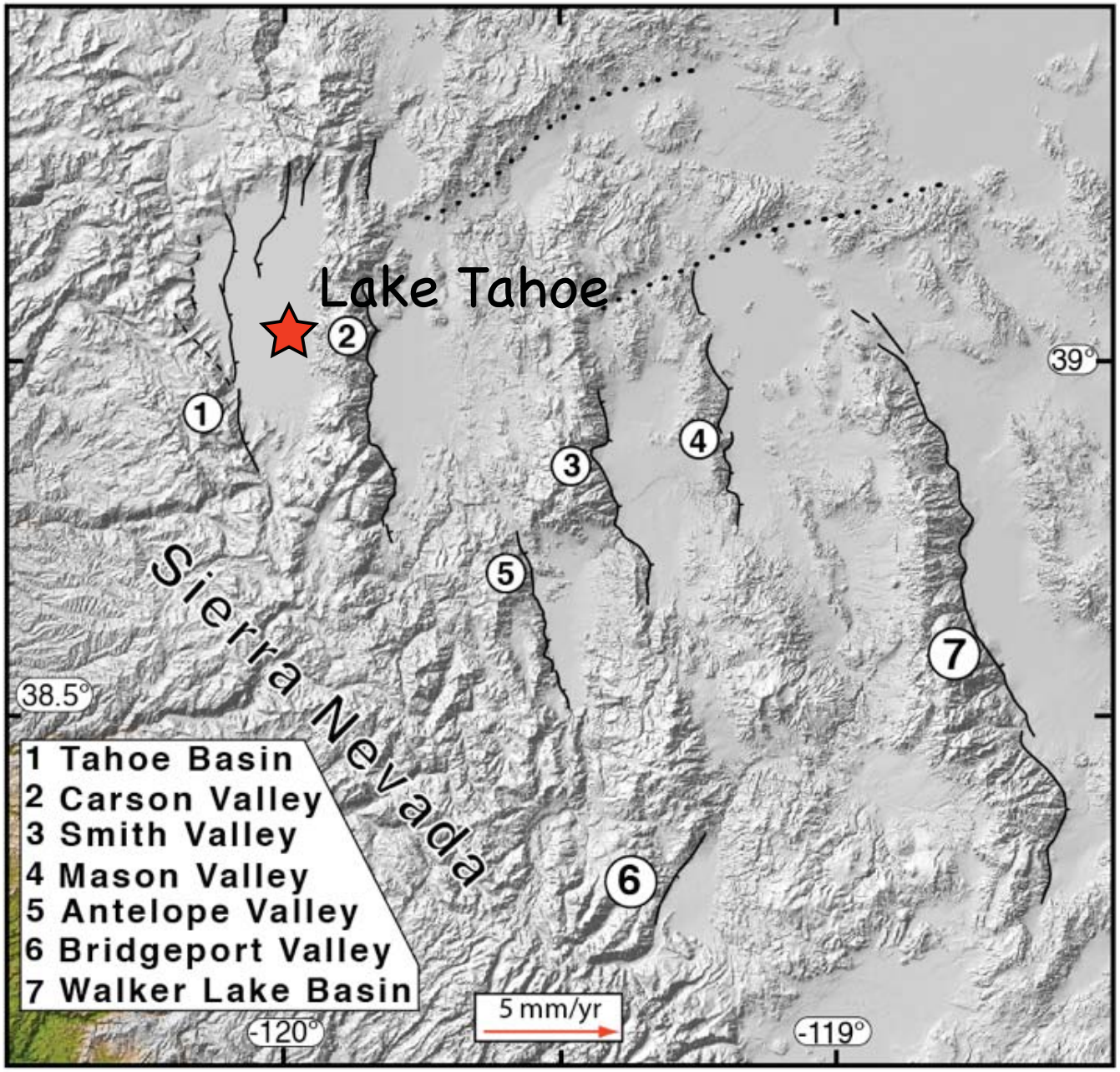
Radiocarbon dating of charcoal shows earthquake occurred between about 3300 and 4500 years ago….


Walker Lake
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°

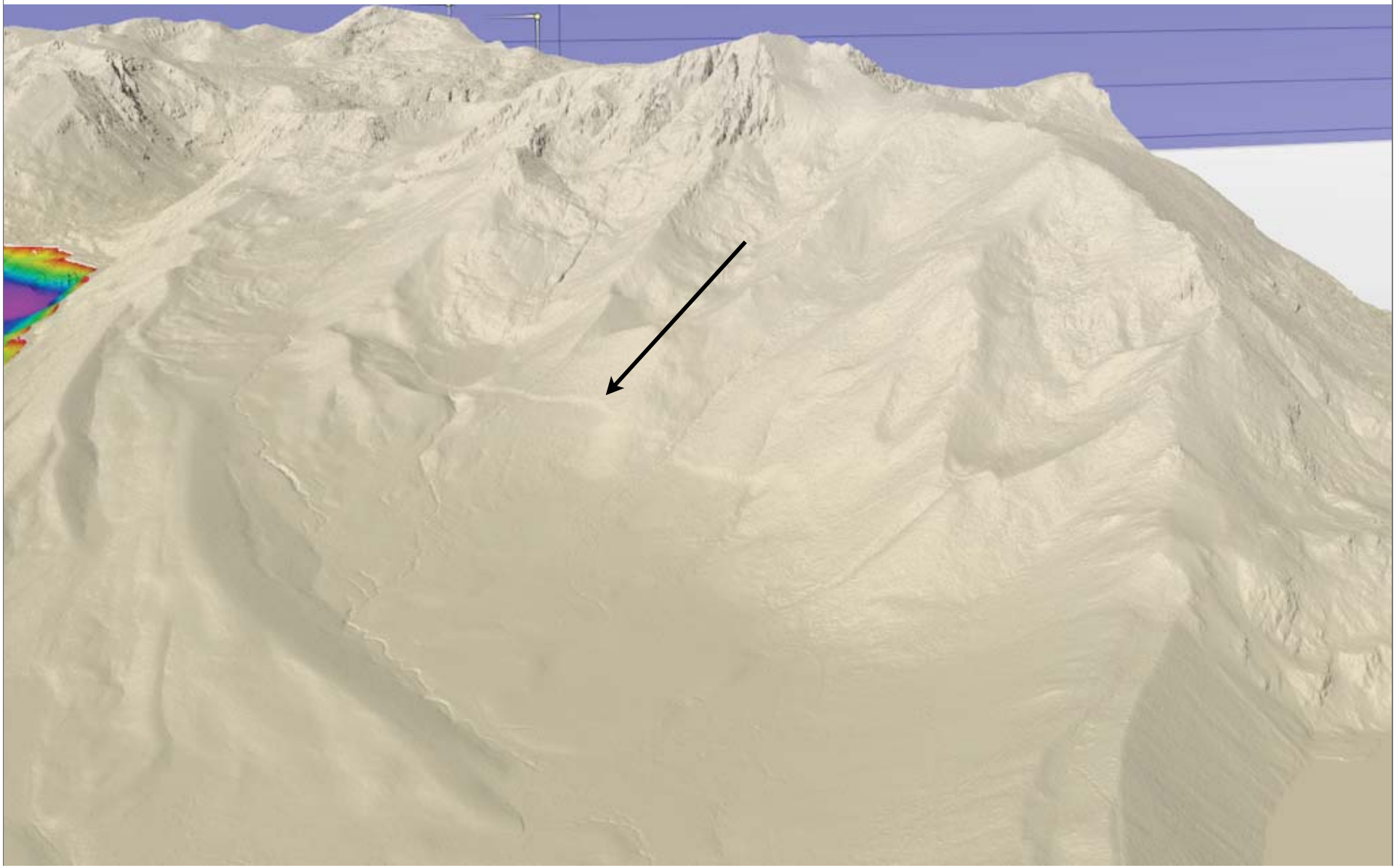

Bald Mountain
Lake Lahontan Shoreline


Abandoned fan surface
Wavecut benches of
pluvial Lake Lahontan
Holocene fault scarp
Wave modified fault escarpment
Holocene fault scarp


Tephra
14C=3960±35
Mono Craters Tephra

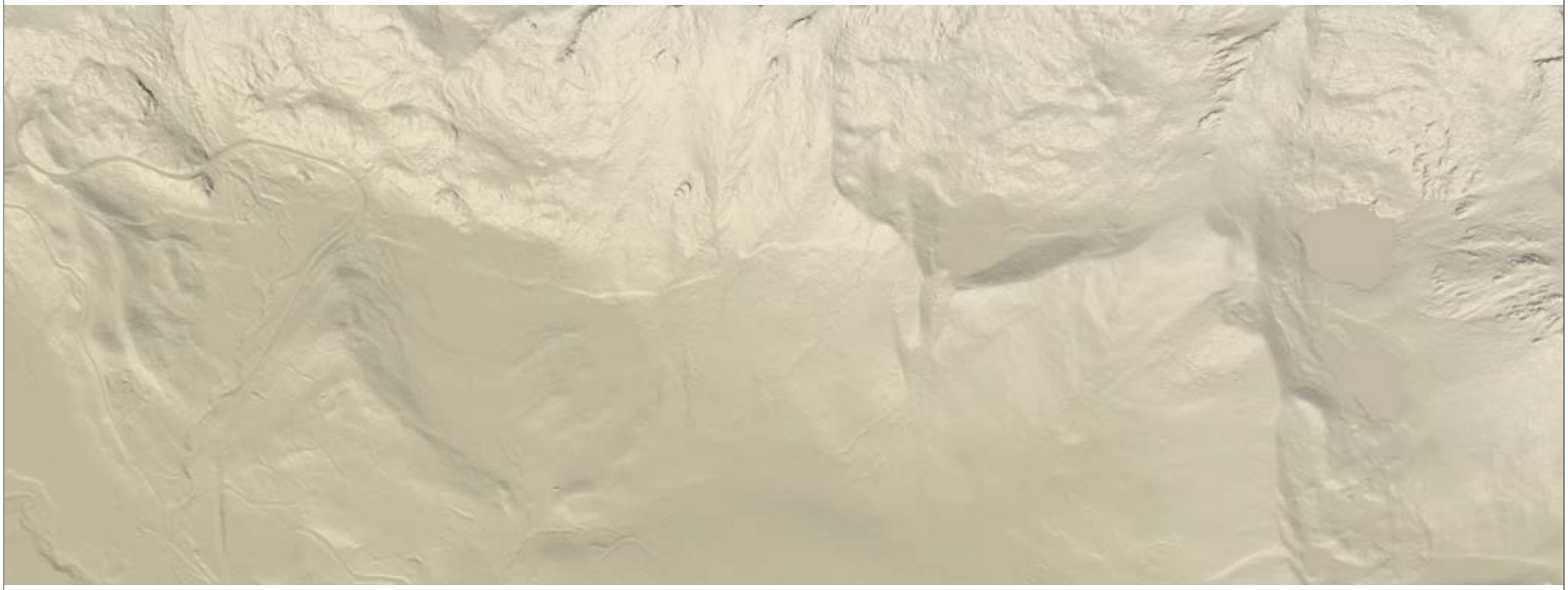

Lake Tahoe
Sierra Nevada
1 Tahoe Basin
2 Carson Valley
3 Smith Valley
4 Mason Valley
5 Antelope Valley
6 Bridgeport Valley
7 Walker Lake Basin
5 mm/yr
39°
38.5°
-120°
-119°

Cascade Lake



Echo Summit

West Tahoe Fault

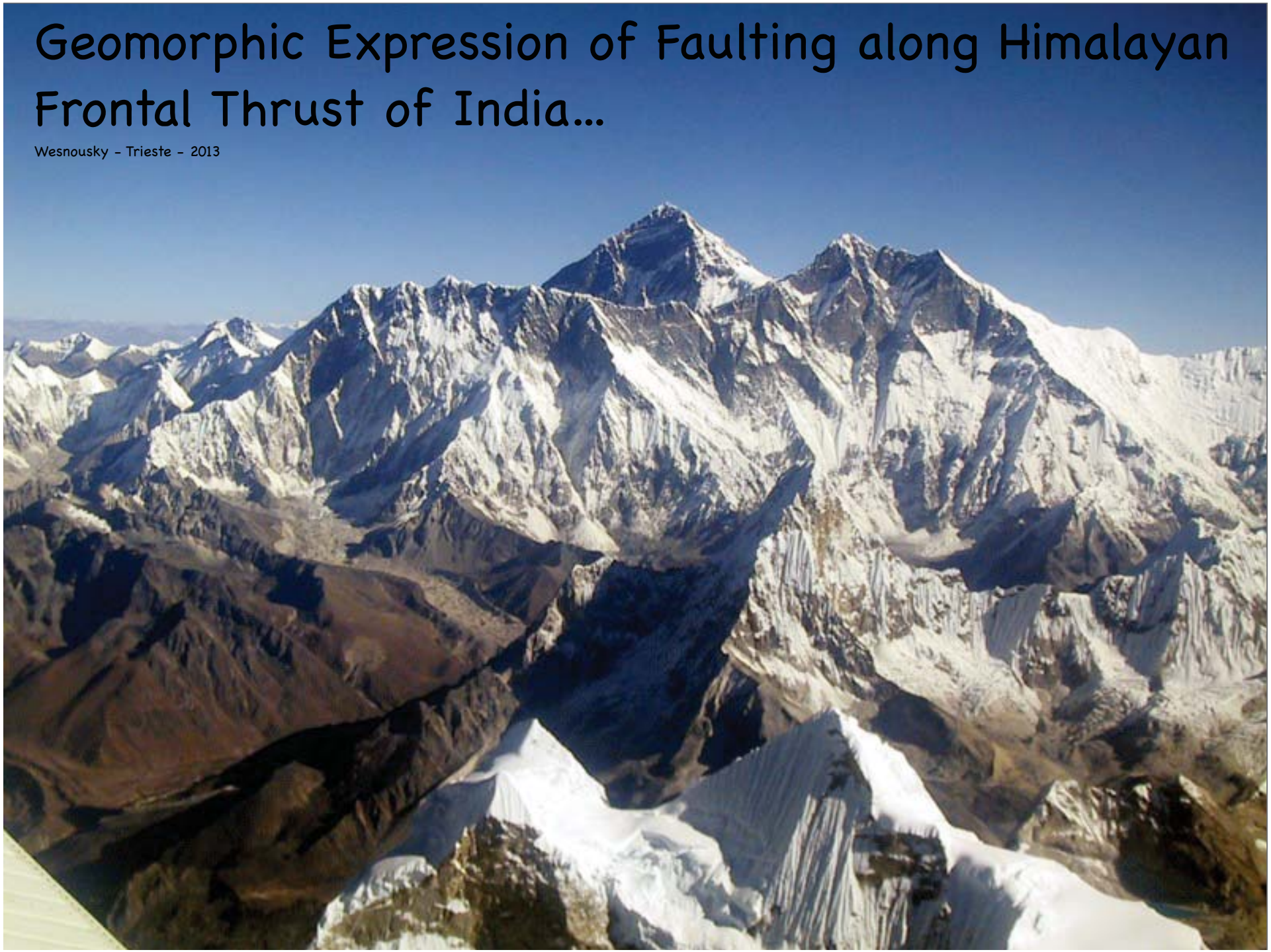


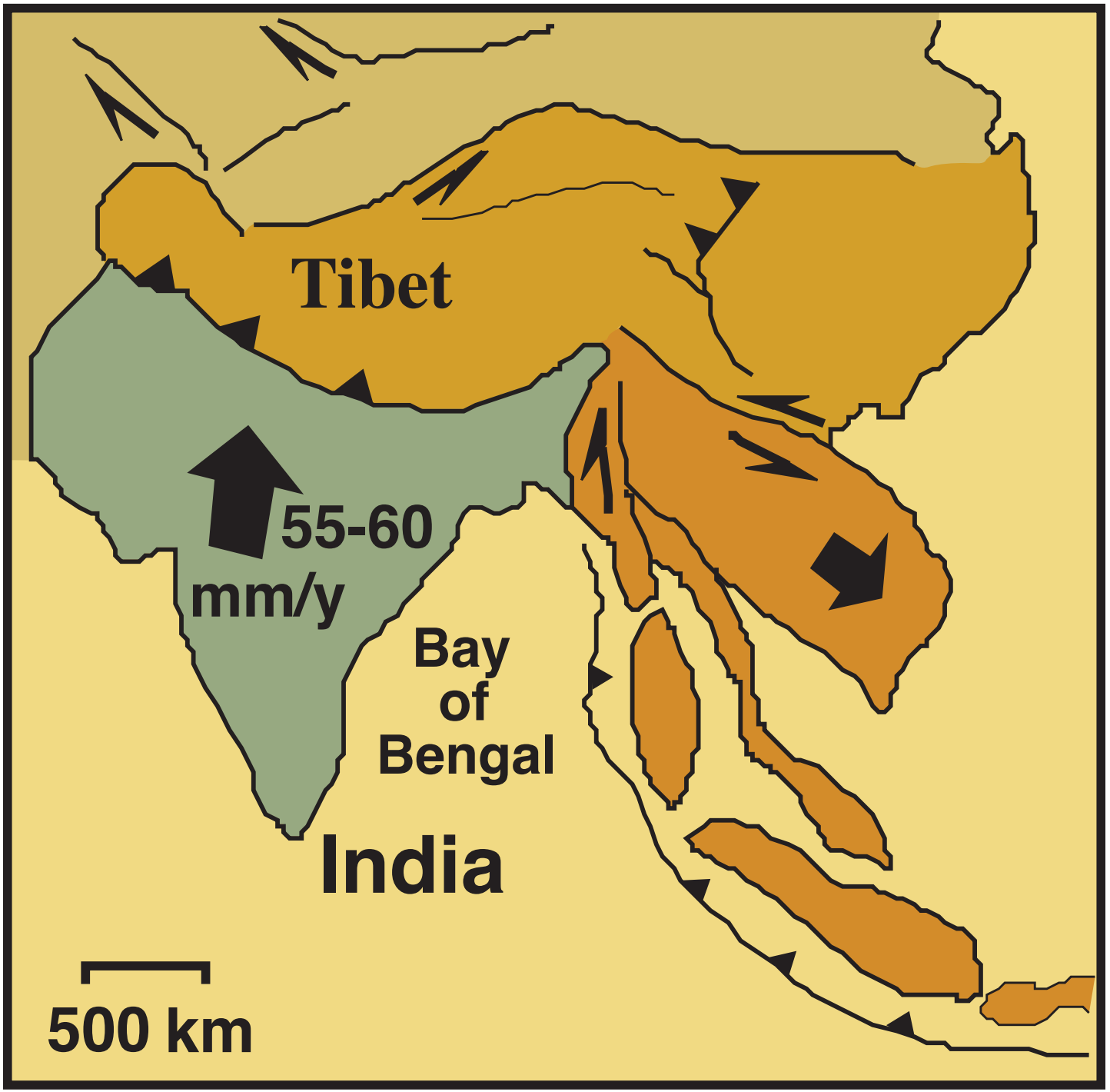
Wed Aft - Wesnousky - 0.5 hour

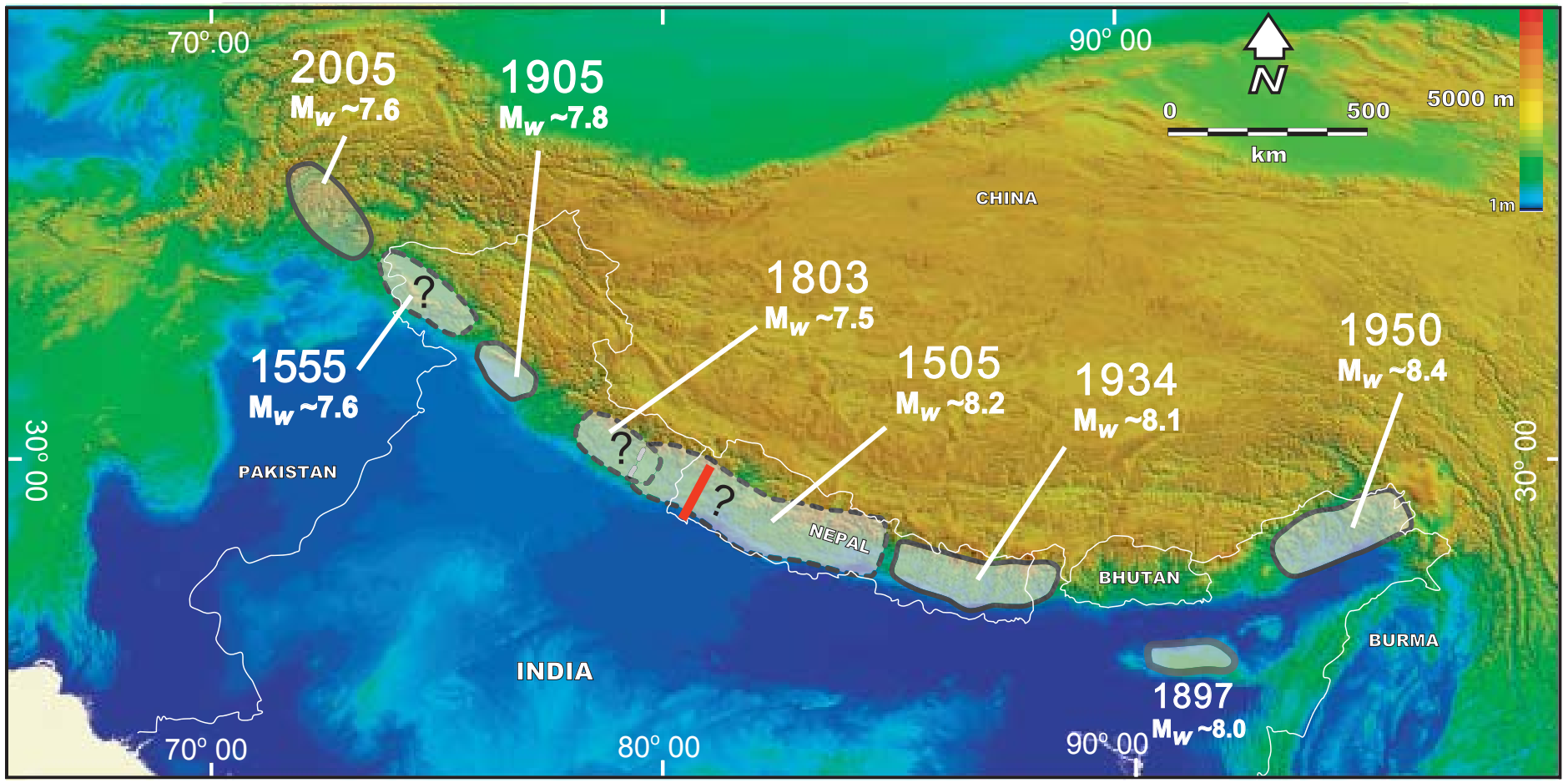
Thrust Faults - How to Recognize Geomorphically - The Himalaya as an example.

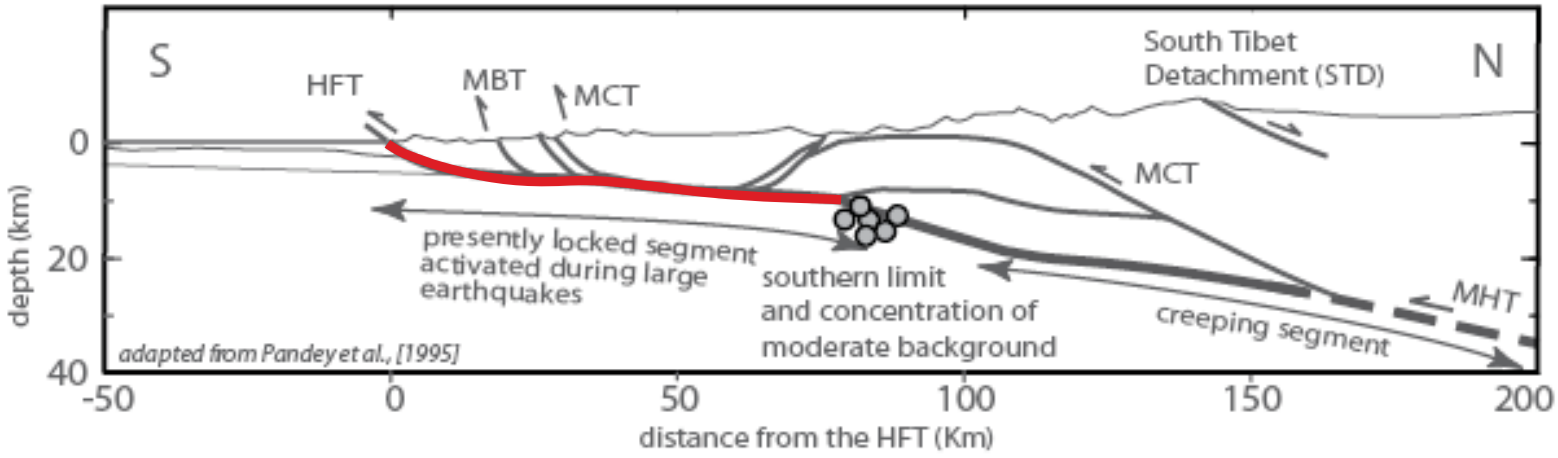
Geomorphic Expression of Faulting along Himalayan Frontal Thrust of India…

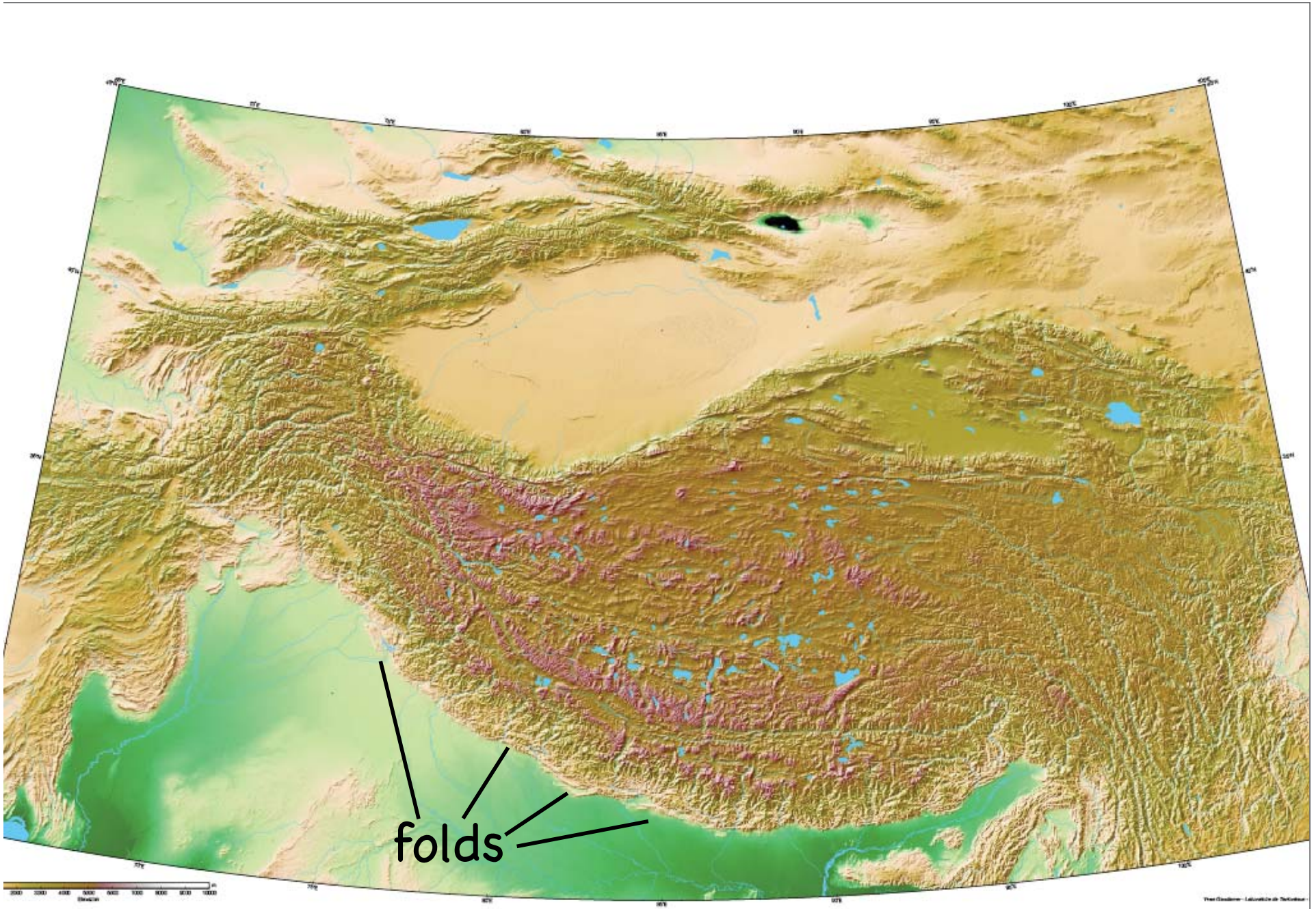
Wesnousky - Trieste - 2013

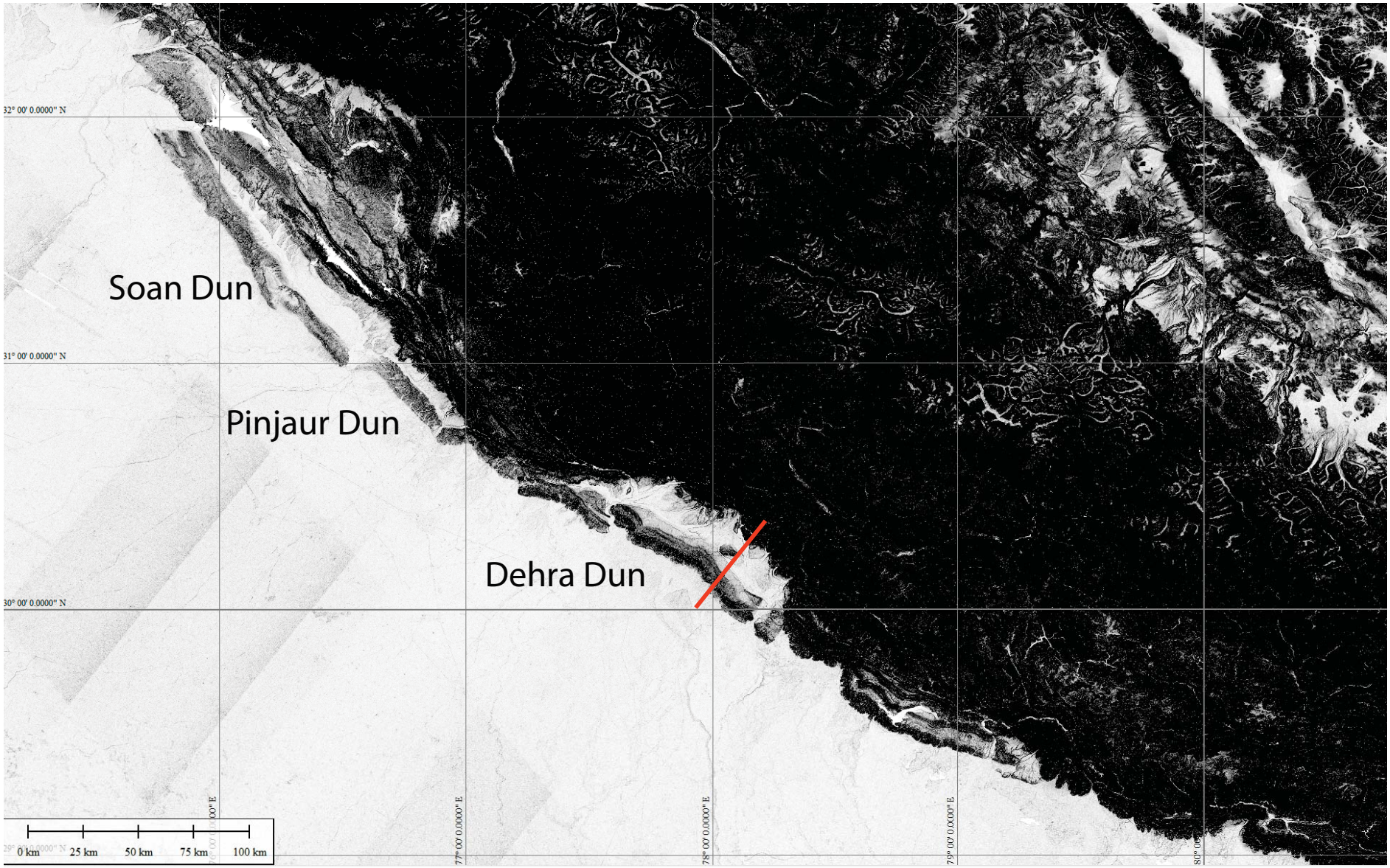



Tibet
55-60
mm/y
Bay
of
Bengal
India
500 km

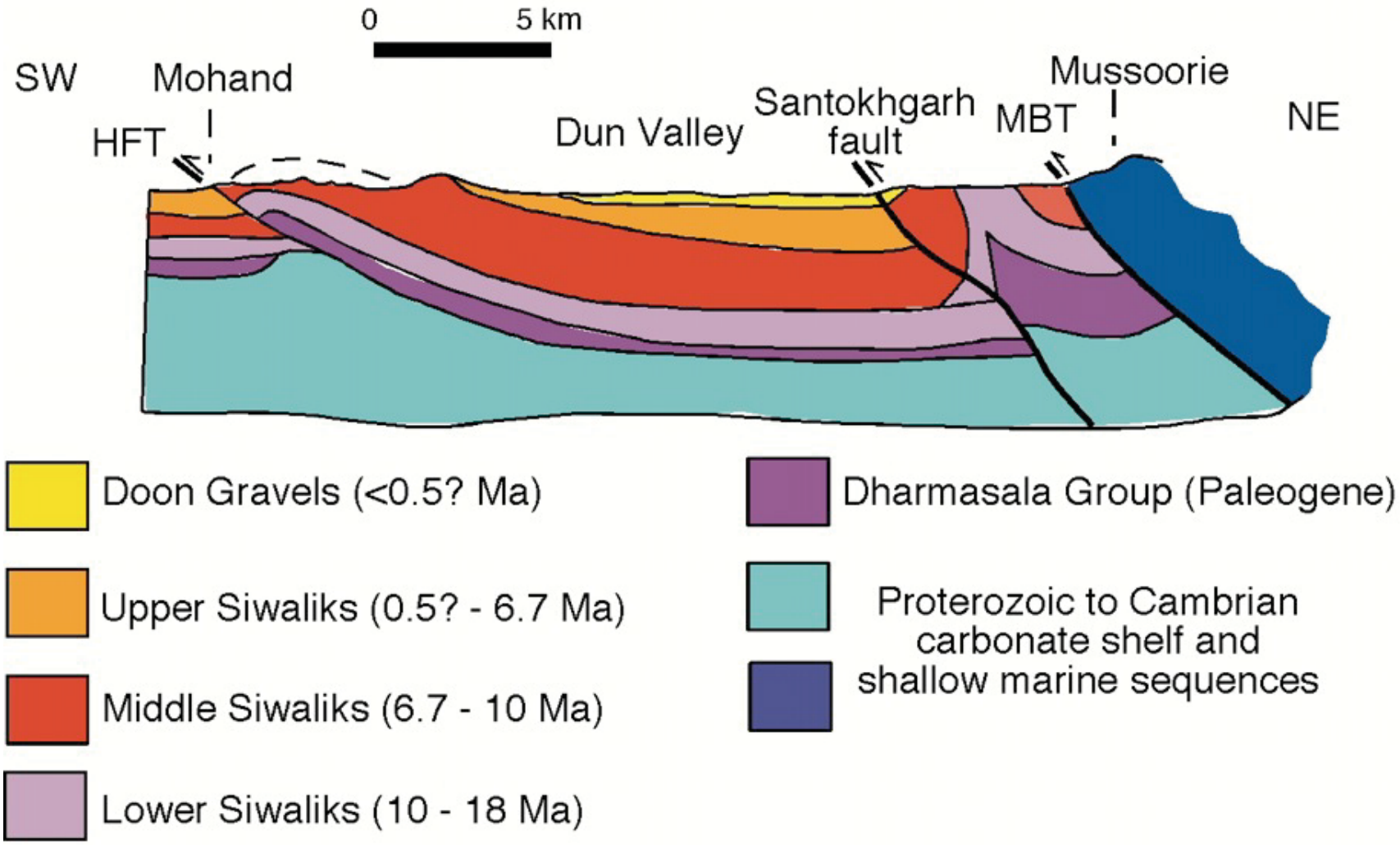

70° 00
90° 00
N
0
500
km
5000 m
1m
2005
M_W ~7.6
1905
M_W ~7.8
1803
M_W ~7.5
1555
M_W ~7.6
1505
M_W ~8.2
1934
M_W ~8.1
1950
M_W ~8.4
1897
M_W ~8.0
?
CHINA
PAKISTAN
NEPAL
BHUTAN
BURMA
INDIA
30° 00
70° 00
80° 00
90° 00

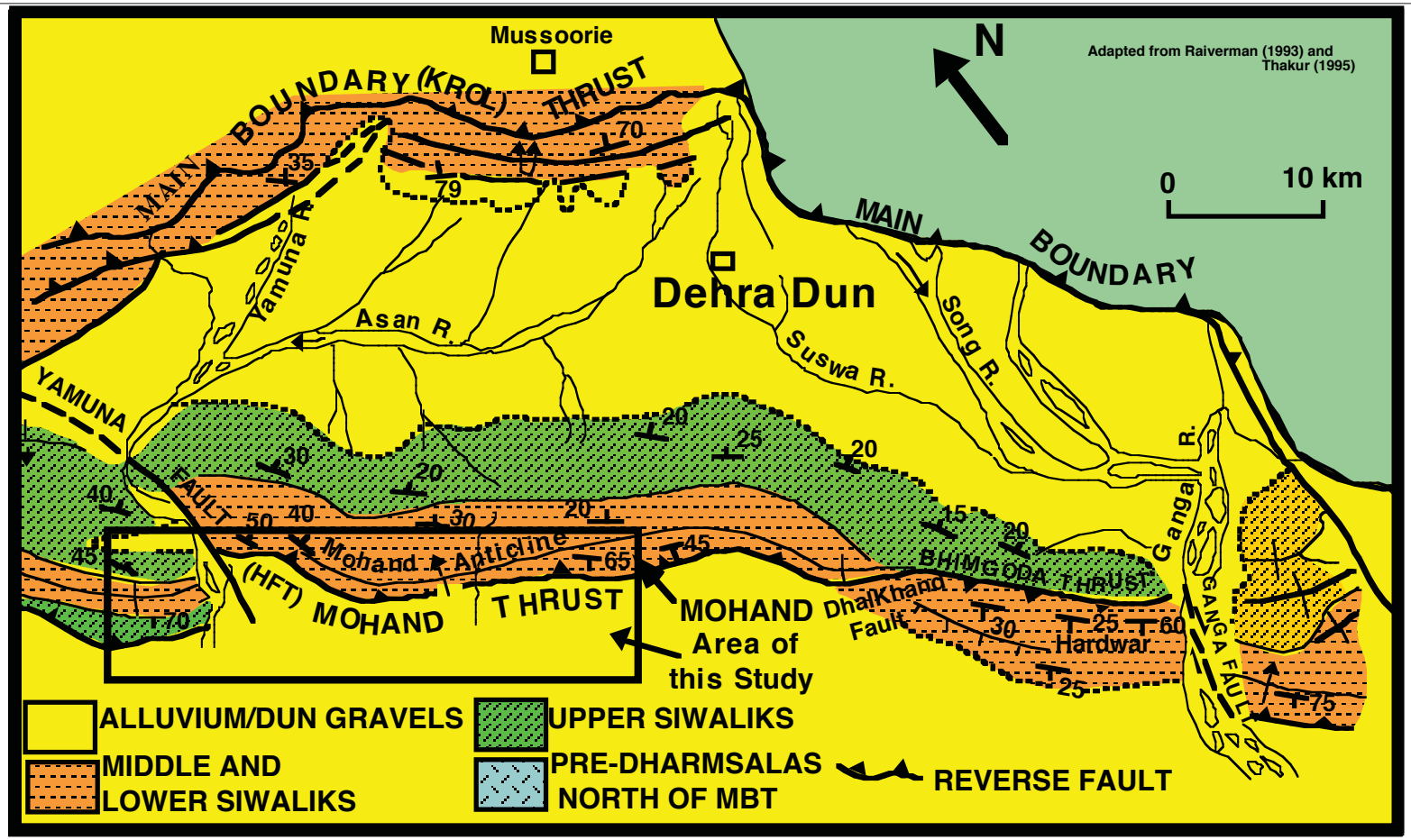

S
N
HFT
MBT
MCT
South Tibet
Detachment (STD)
MCT
presently locked segment
activated during large
earthquakes
southern limit
and concentration of
moderate background
creeping segment
MHT
adapted from Pandey et al., [1995]
depth (km)
0
20
40
-50
0
50
100
150
200
distance from the HFT (Km)

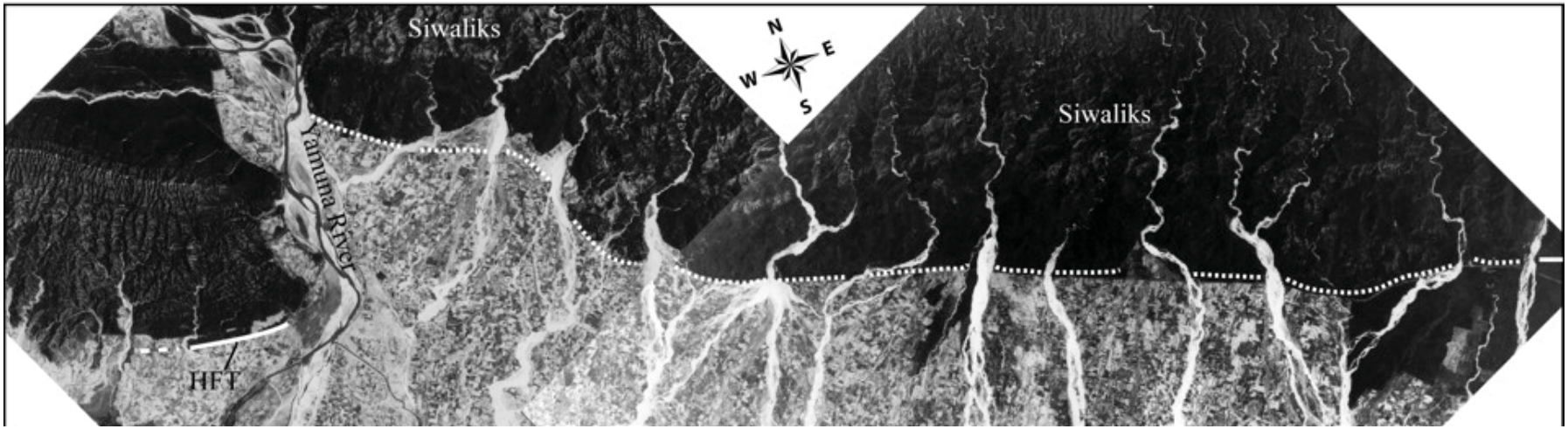

folds


Soan Dun
Pinjaur Dun
Dehra Dun
32° 00' 0.0000" N
31° 00' 0.0000" N
30° 00' 0.0000" N
77° 00' 0.0000" E
78° 00' 0.0000" E
79° 00' 0.0000" E
0 km
25 km
50 km
75 km
100 km

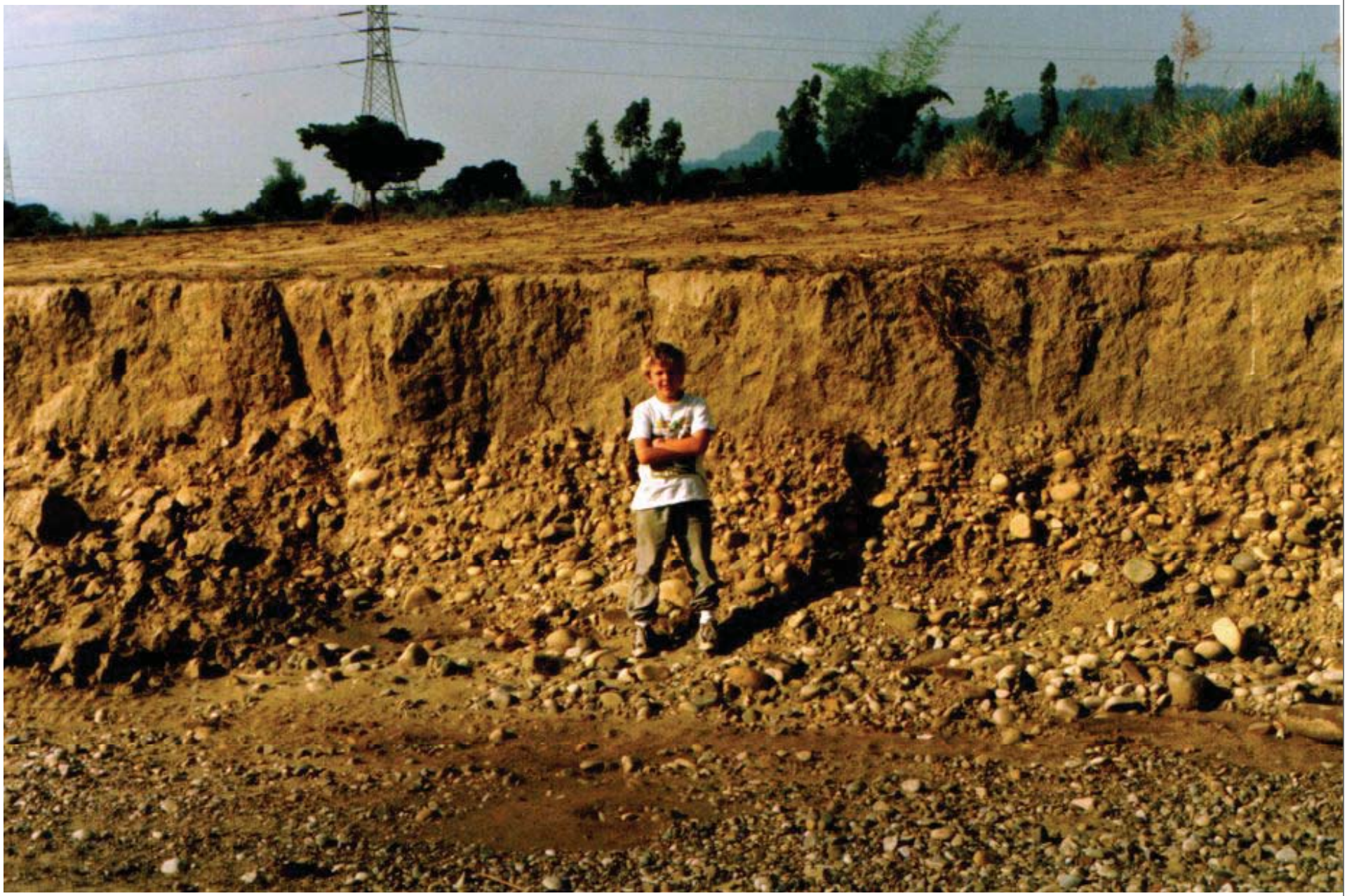
Geological cross-section across Dun Valley (after Raiverman et al, 1983)

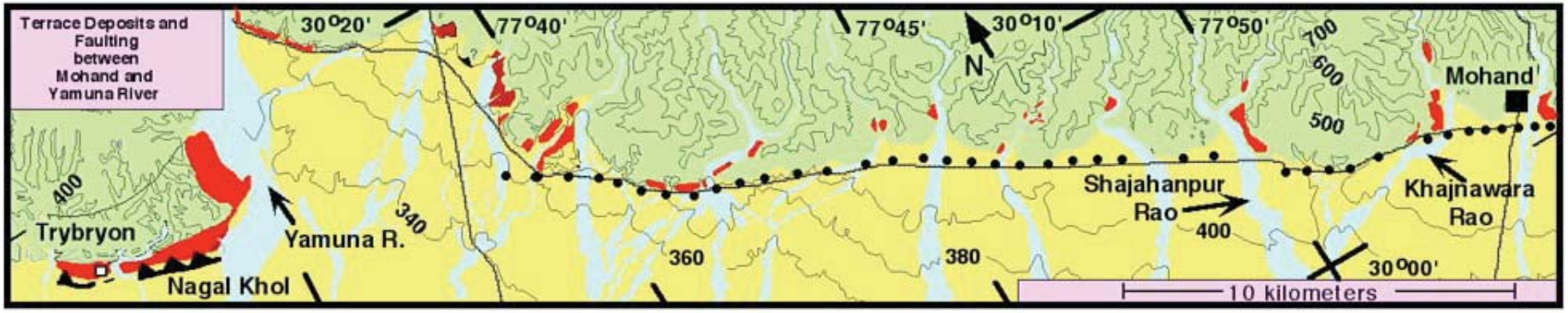



Mussoorie
N
Adapted from Raiverman (1993) and Thakur (1995)
0
10 km
MAIN BOUNDARY (KROL) THRUST
MAIN BOUNDARY
Yamuna R.
Asan R.
Dehra Dun
Song R.
Suswa R.
YAMUNA
FAULT
Mohand Anticline
(HFT) MOHAND THRUST
MOHAND Area of this Study
BHIMGODA THRUST
Dhalkhand Fault
Hardwar
Ganga R.
GANGA FAULT
ALLUVIUM/DUN GRAVELS
UPPER SIWALIKS
MIDDLE AND LOWER SIWALIKS
PRE-DHARMSALAS NORTH OF MBT
REVERSE FAULT

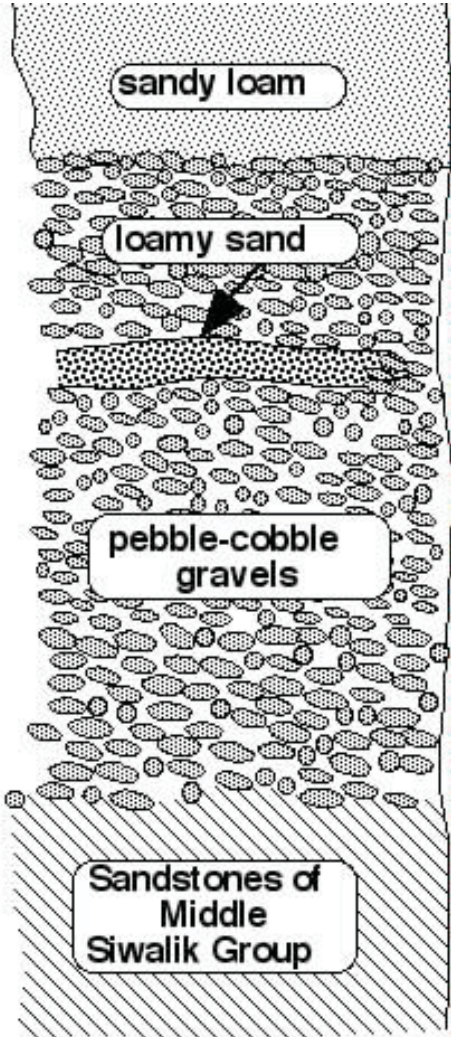

Siwaliks
N
E
W
S
Yamuna River
HFT
Siwaliks

The HFT and the southern limit of the Himlaya are marked by ~500 m uplift of Siwaliks above the adjacent Indo-Gangetic Plain--~1000 m above sea level.

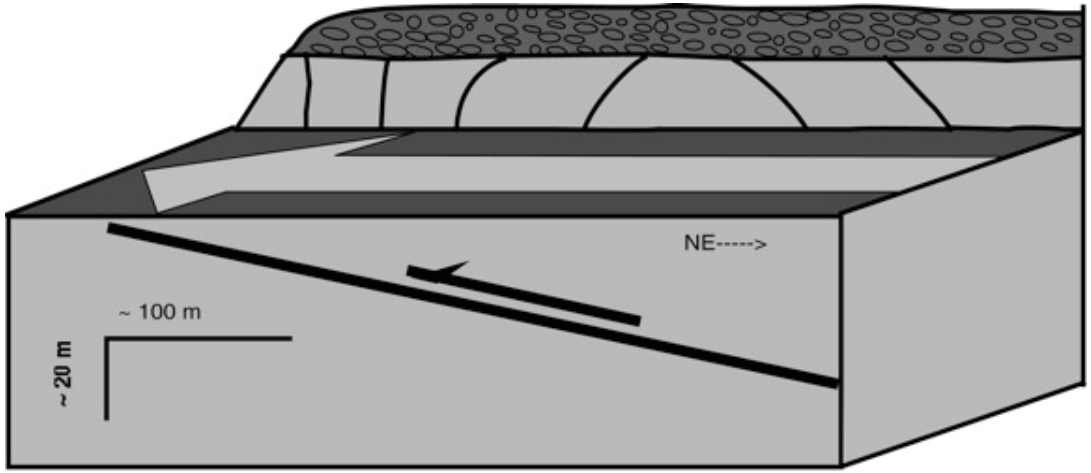



Terrace Deposits and Faulting between Mohand and Yamuna River
30°20'
77°40'
77°45'
30°10'
77°50'
N
700
600
500
Mohand
400
340
Trybryon
Yamuna R.
360
380
Shajahanpur Rao
400
Khajnawara Rao
30°00'
Nagal Khol
10 kilometers

10 meters


sandy loam
loamy sand
pebble-cobble gravels
Sandstones of Middle Siwalik Group

Uplift, Fault Slip and Convergence Rate



Dip = 30°

Uplift = 20 to 30 m

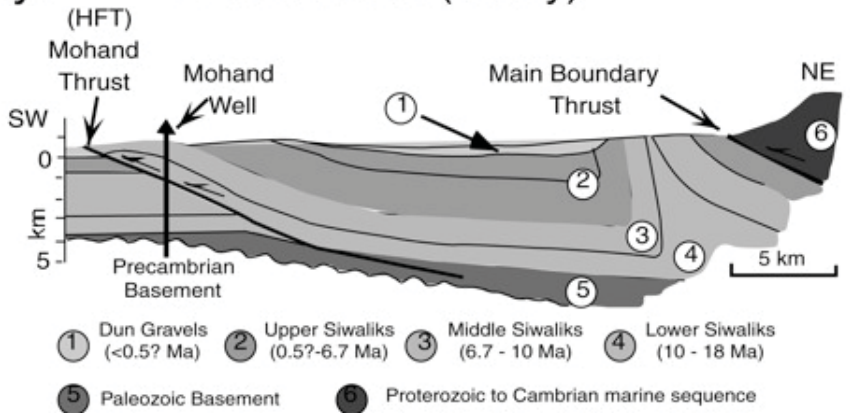
Age < 3663 ± 215 ybp

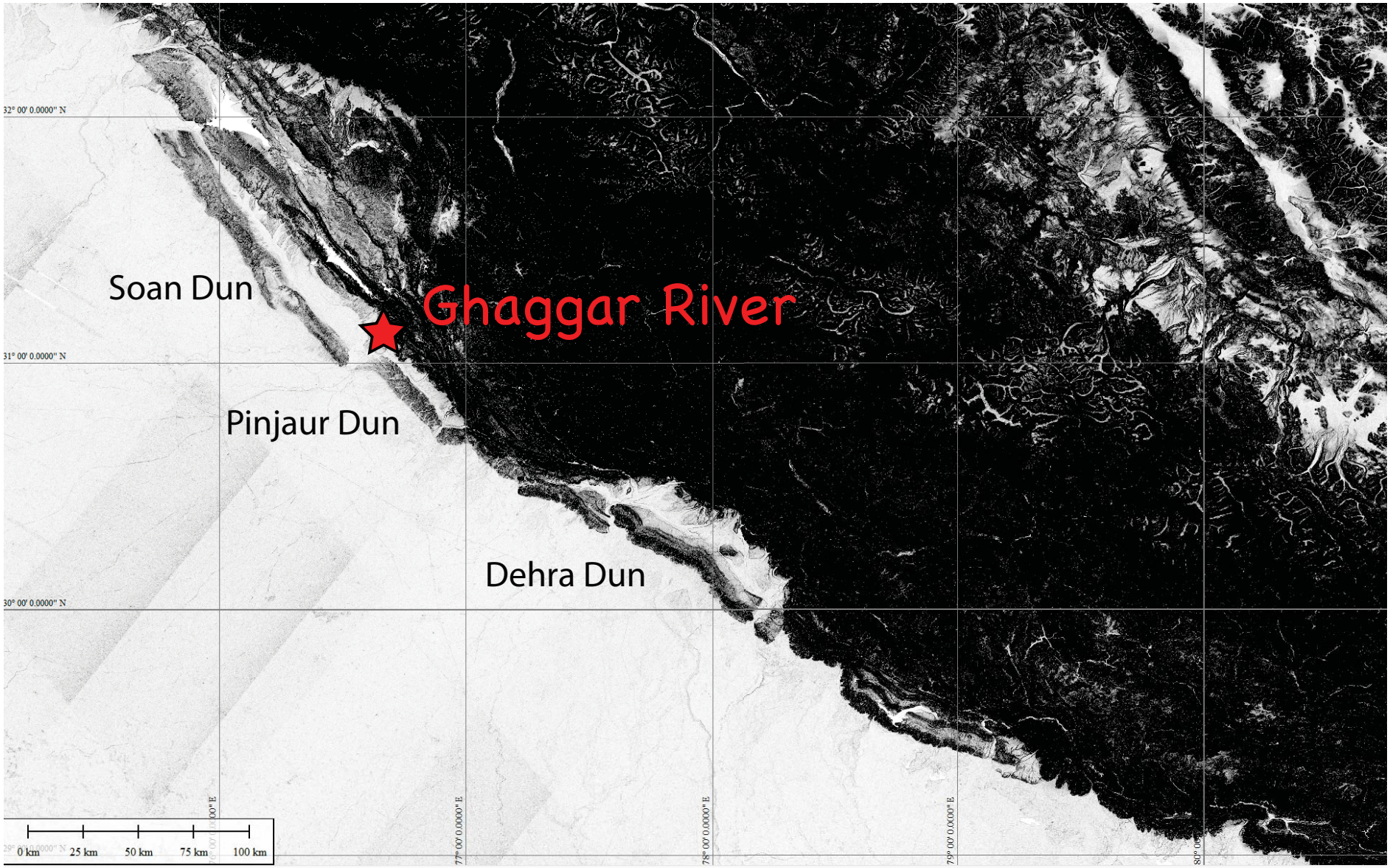
Uplift Rate > 6.9 mm/yr

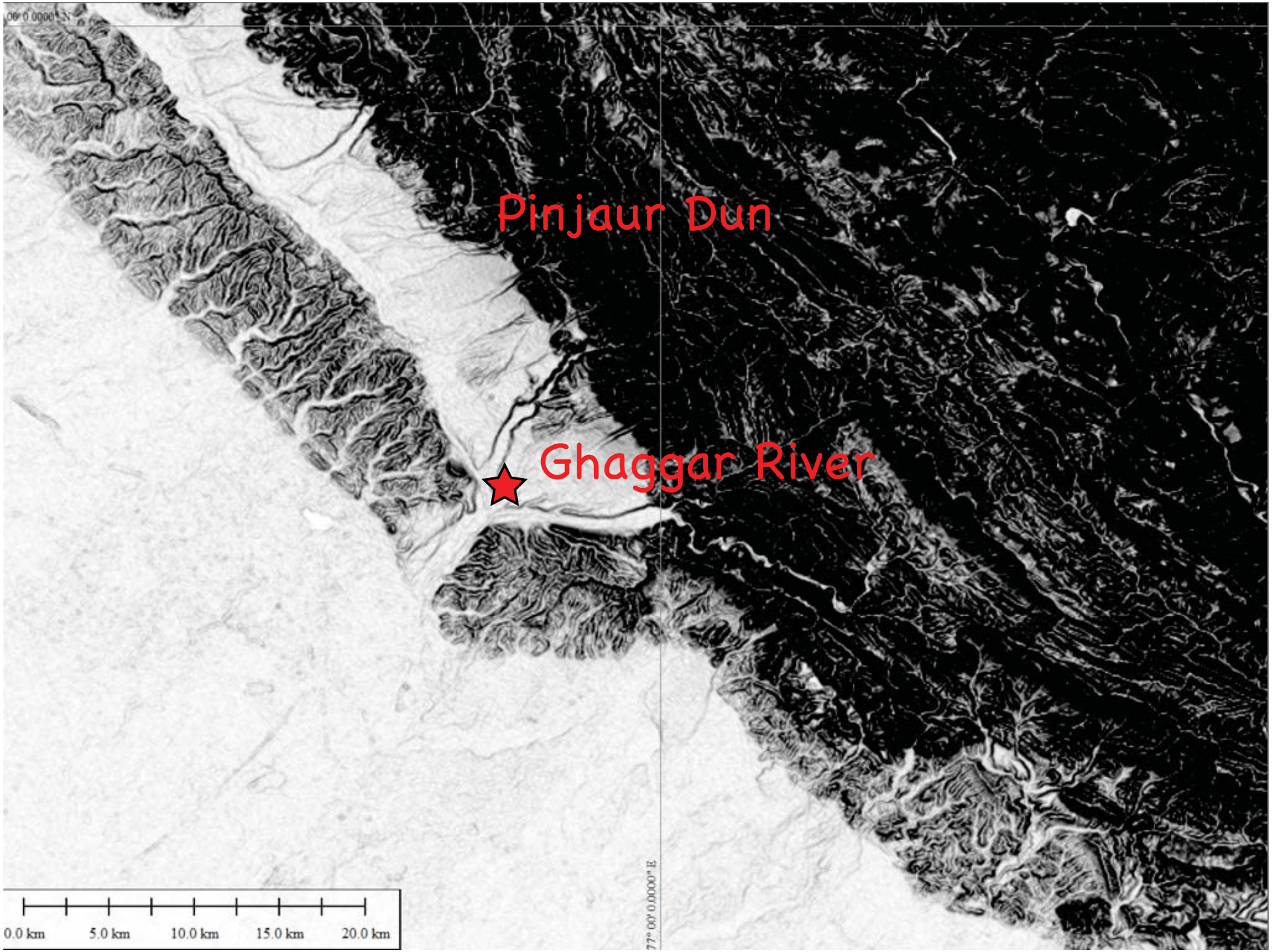
Convergence > 11.9 ± 3.1 mm/yr

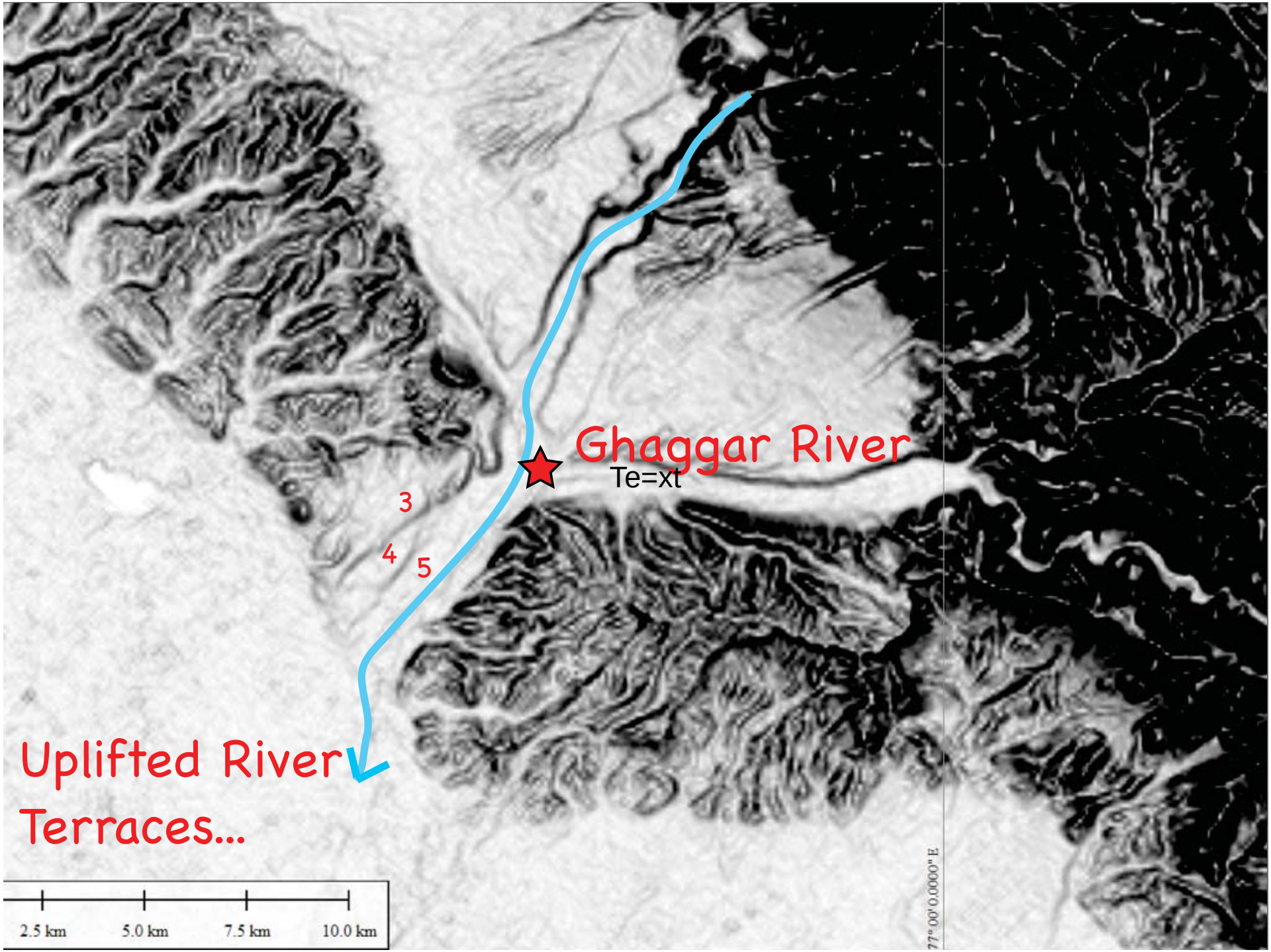
Fault Slip Rate > 13.8 ±3.6 mm/yr

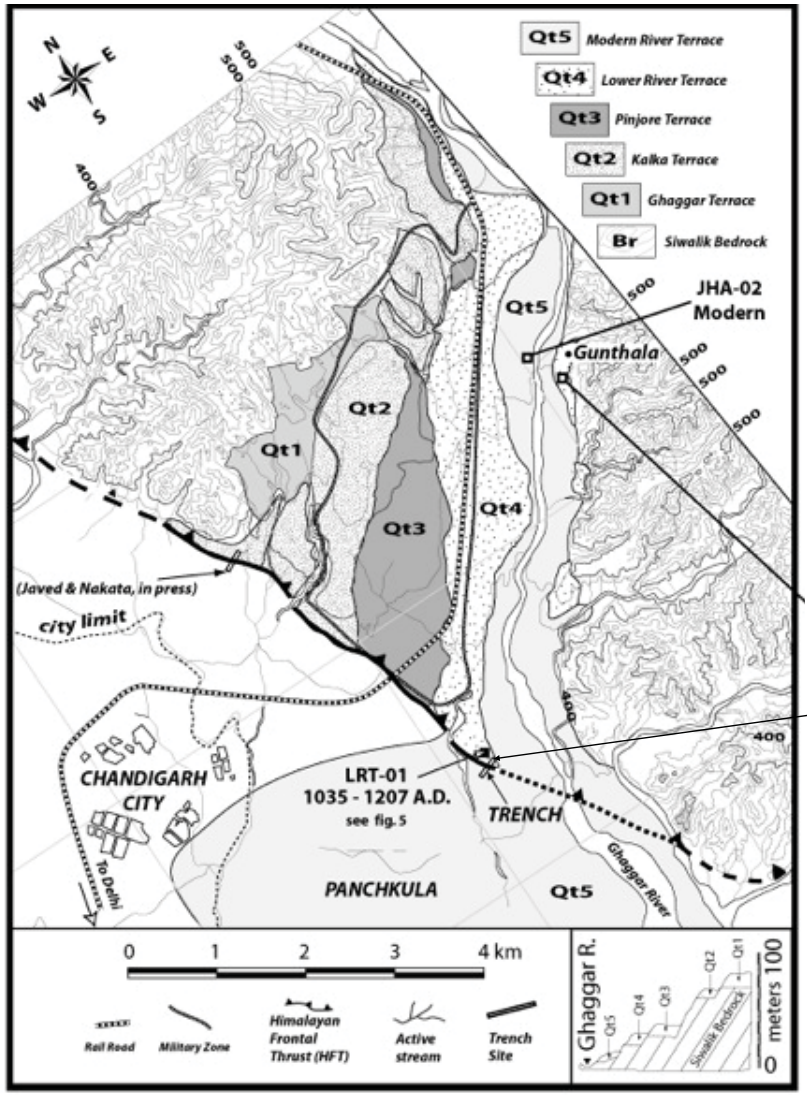
DEHRA DUN (Valley)

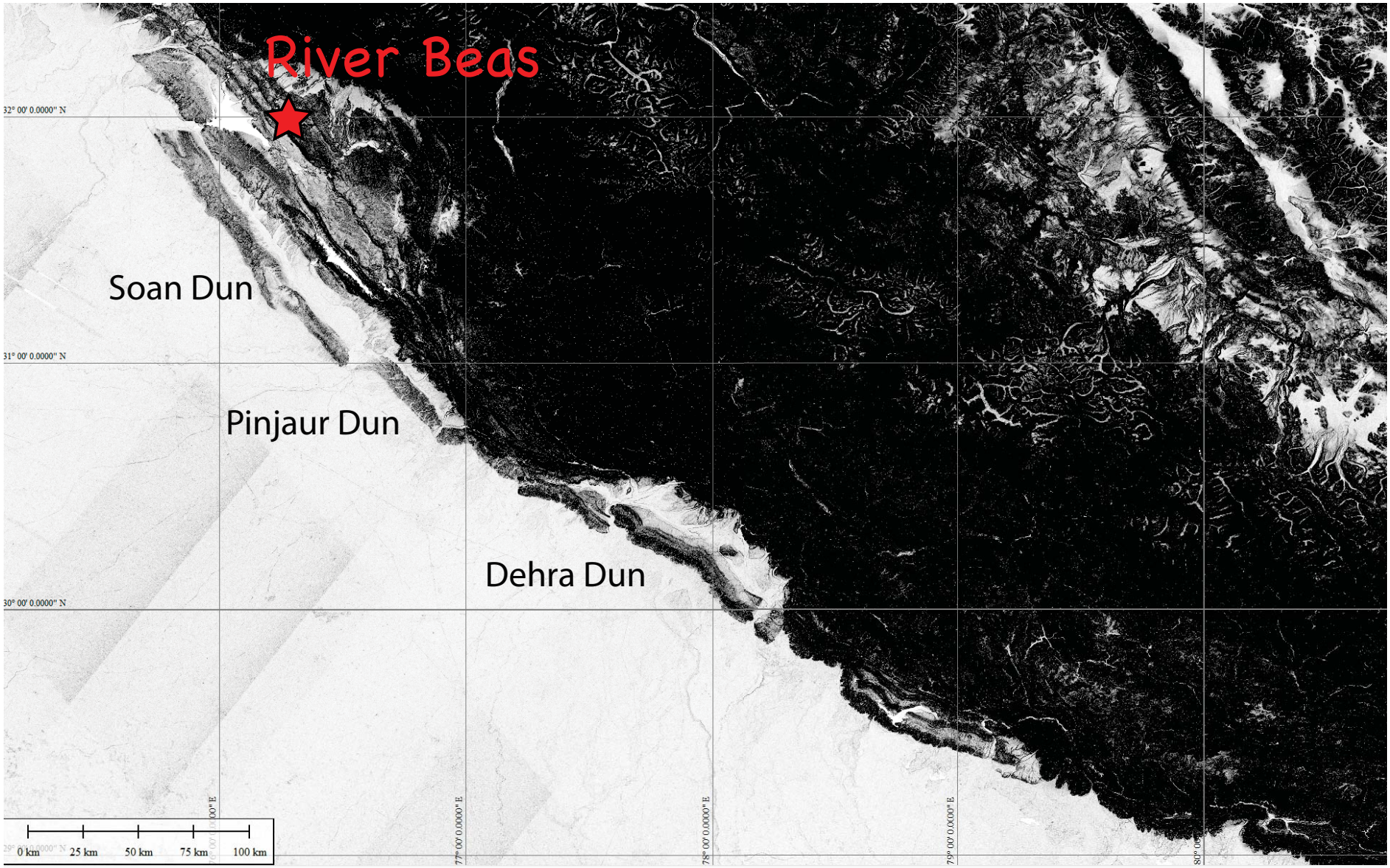


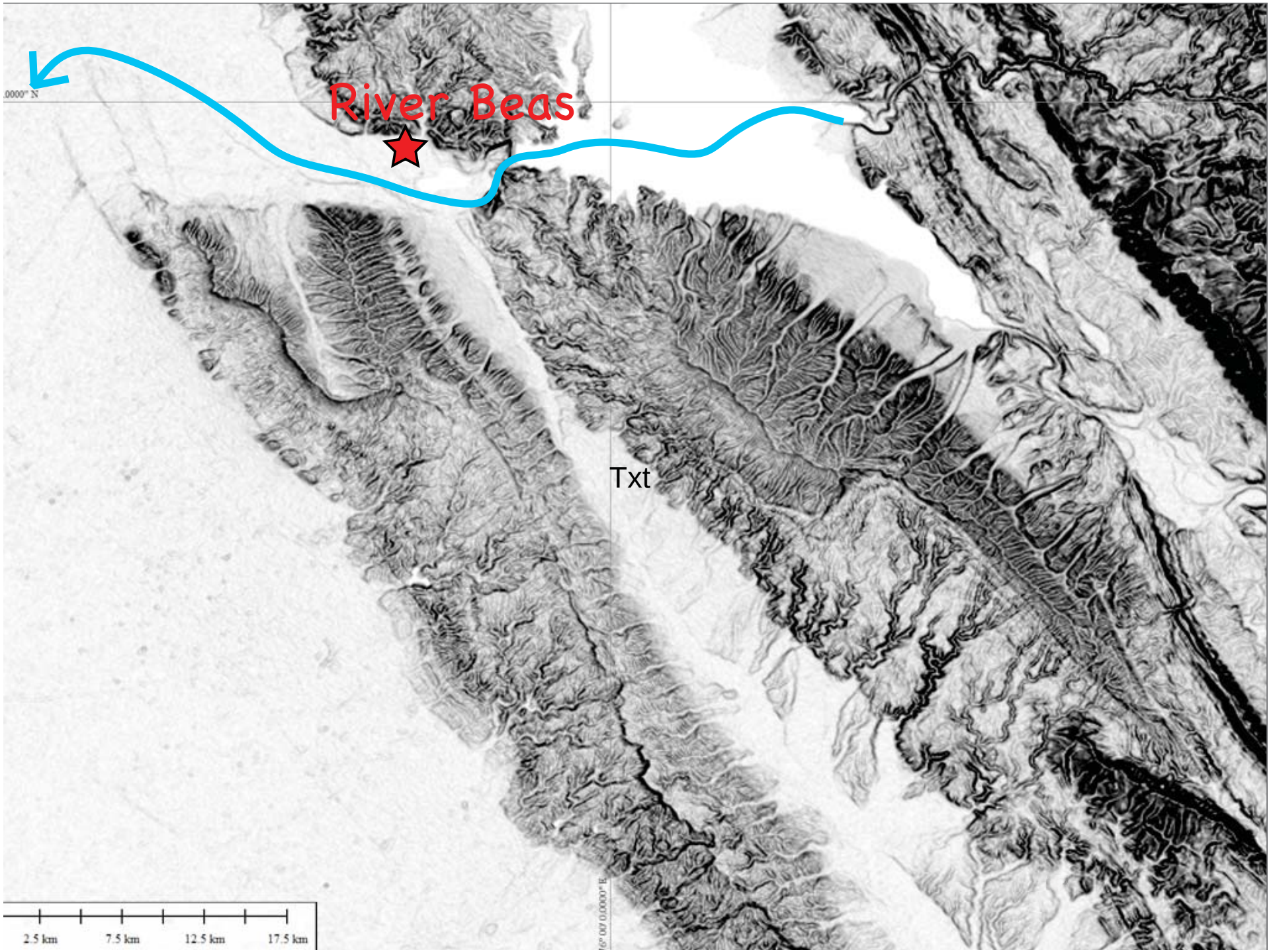

Soan Dun
Ghaggar River
Pinjaur Dun
Dehra Dun
32° 00' 0.0000" N
31° 00' 0.0000" N
30° 00' 0.0000" N
77° 00' 0.0000" E
78° 00' 0.0000" E
79° 00' 0.0000" E
0 km
25 km
50 km
75 km
100 km

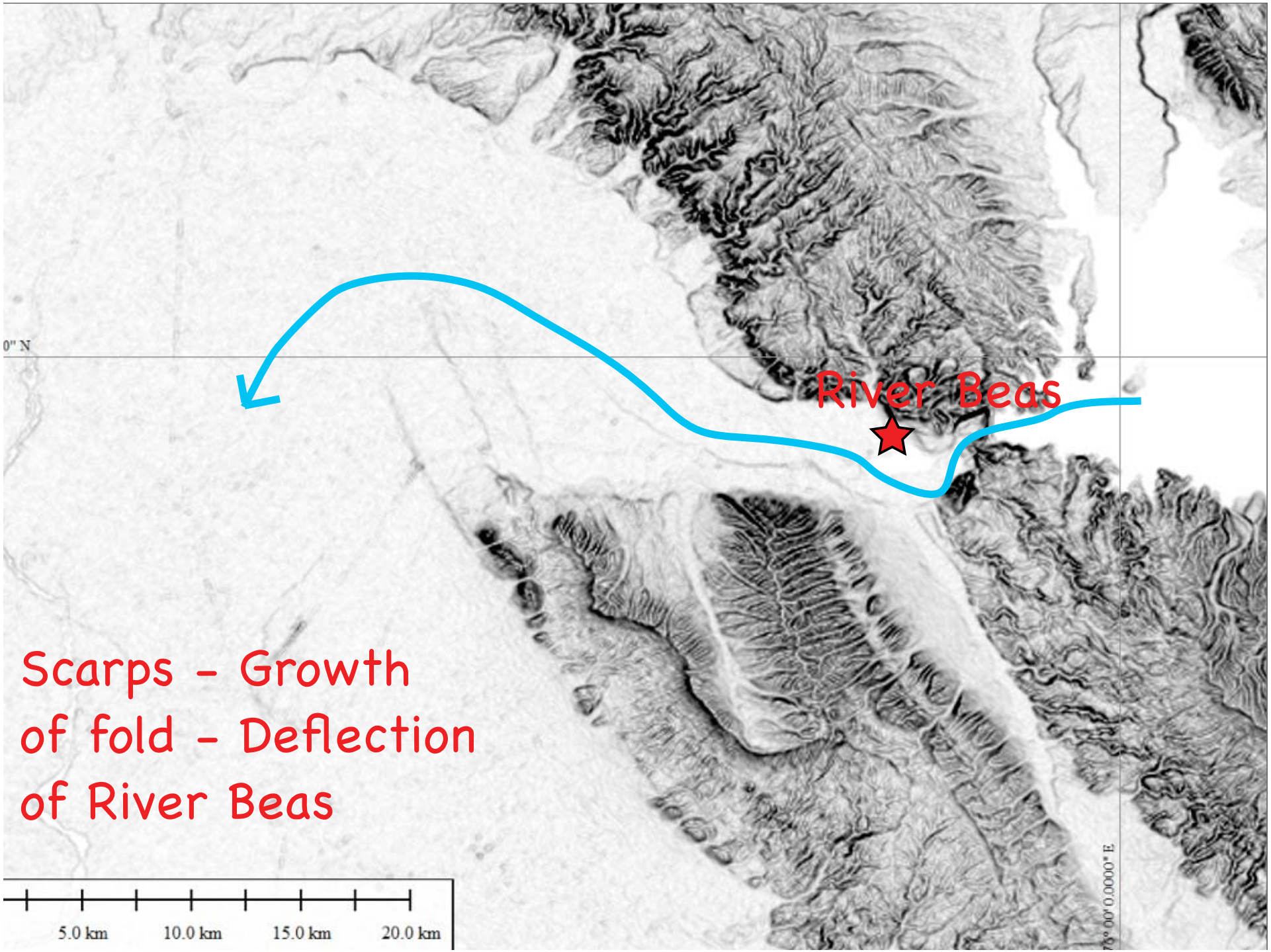

Pinjaur Dun
Ghaggar River
0.0 km
5.0 km
10.0 km
15.0 km
20.0 km

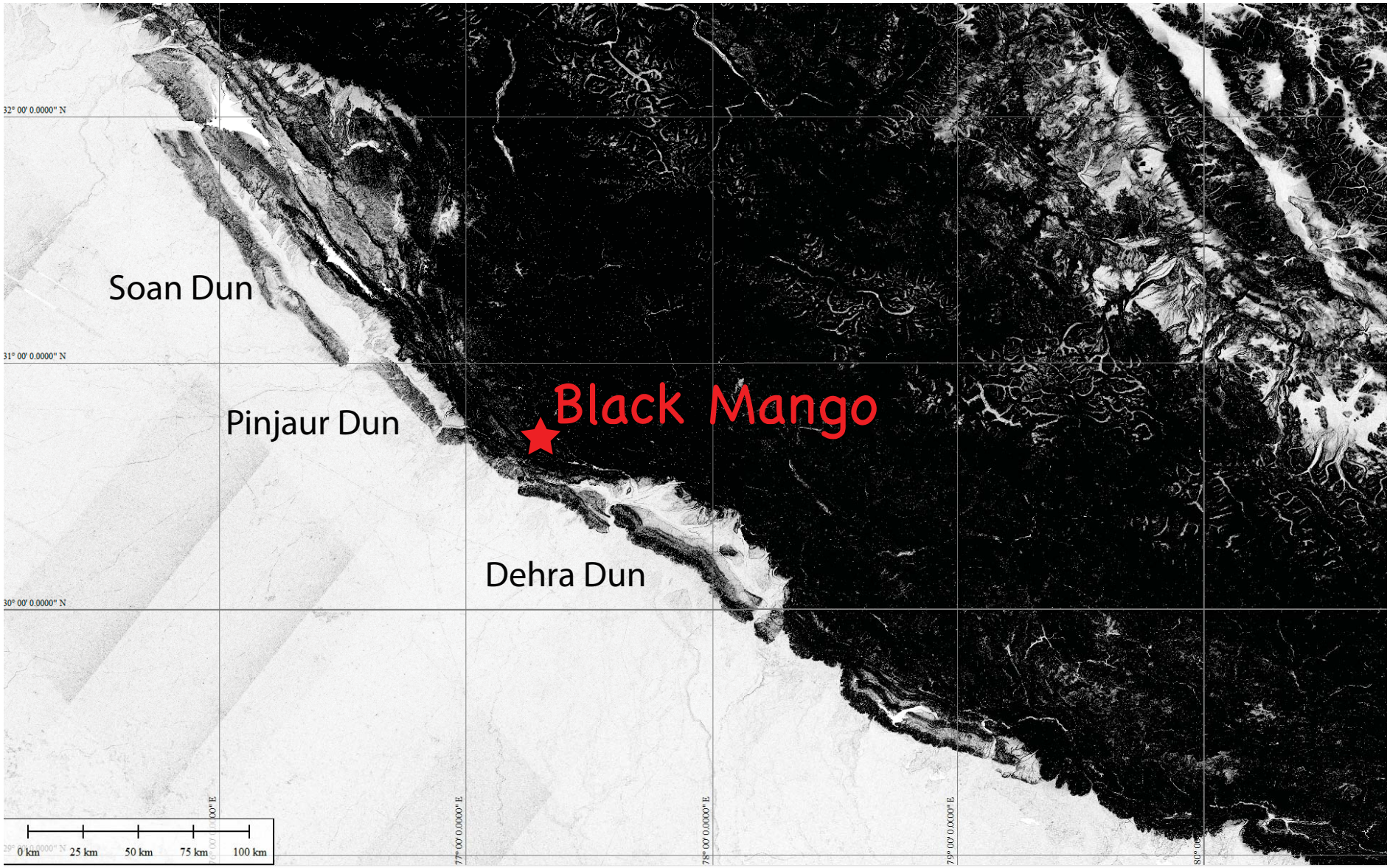

Ghaggar River
Te=xt
3
4
5
Uplifted River
Terraces...
2.5 km
5.0 km
7.5 km
10.0 km
77° 00' 0.0000" E

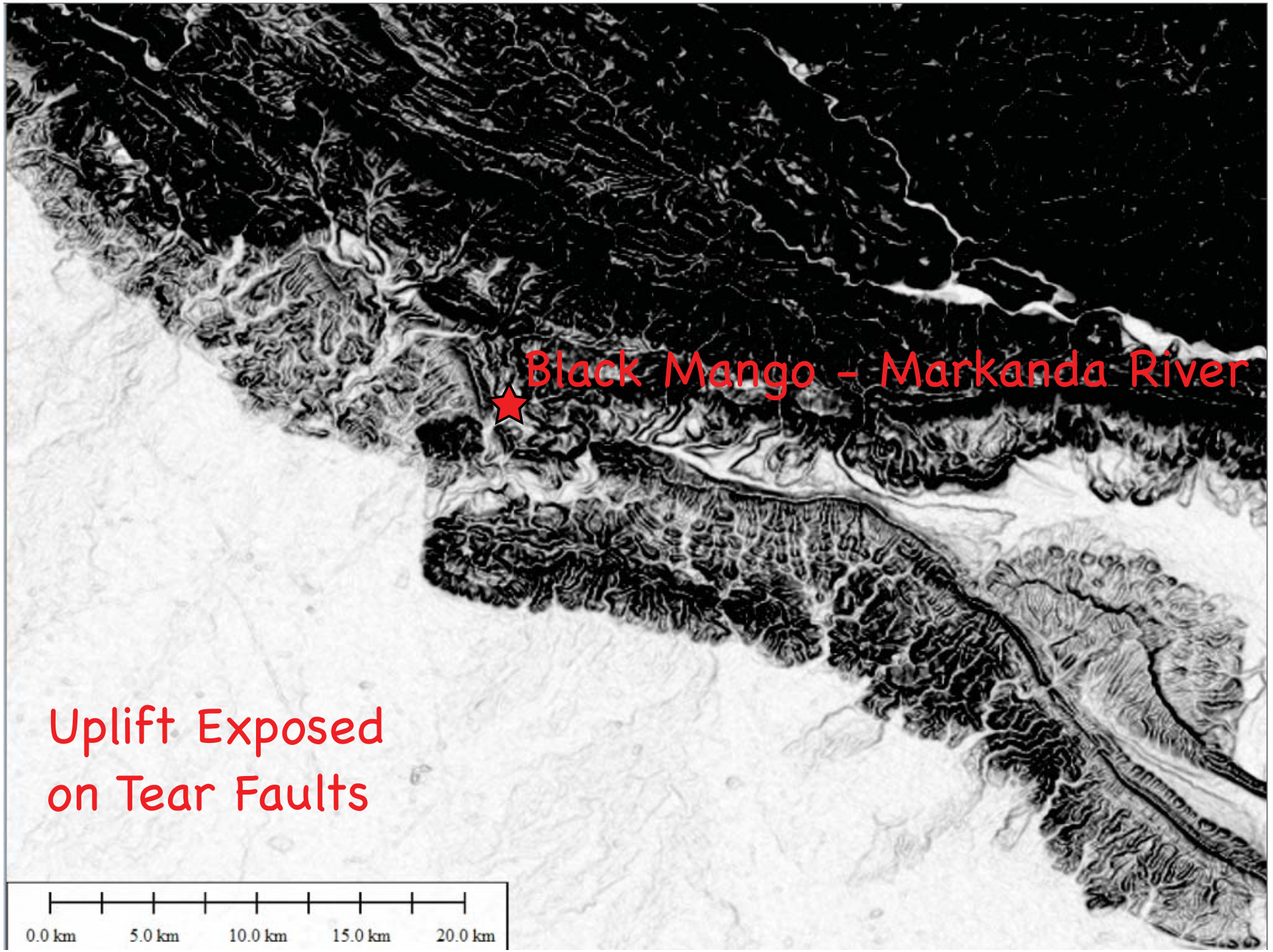

Qt5 Modern River Terrace
Qt4 Lower River Terrace
Qt3 Pinjore Terrace
Qt2 Kalka Terrace
Qt1 Ghaggar Terrace
Br Siwalik Bedrock
JHA-02
Modern
Gunthala
(Javed & Nakata, in press)
city limit
CHANDIGARH
CITY
LRT-01
1035 - 1207 A.D.
see fig. 5
TRENCH
PANCHKULA
To Delhi
Ghaggar River
0 1 2 3 4 km
Rail Road
Military Zone
Himalayan Frontal Thrust (HFT)
Active stream
Trench Site
Ghaggar R.
Siwalik Bedrock
meters 100
0


River Beas
Soan Dun
Pinjaur Dun
Dehra Dun
32° 00' 0.0000" N
31° 00' 0.0000" N
30° 00' 0.0000" N
77° 00' 0.0000" E
78° 00' 0.0000" E
79° 00' 0.0000" E
0 km
25 km
50 km
75 km
100 km

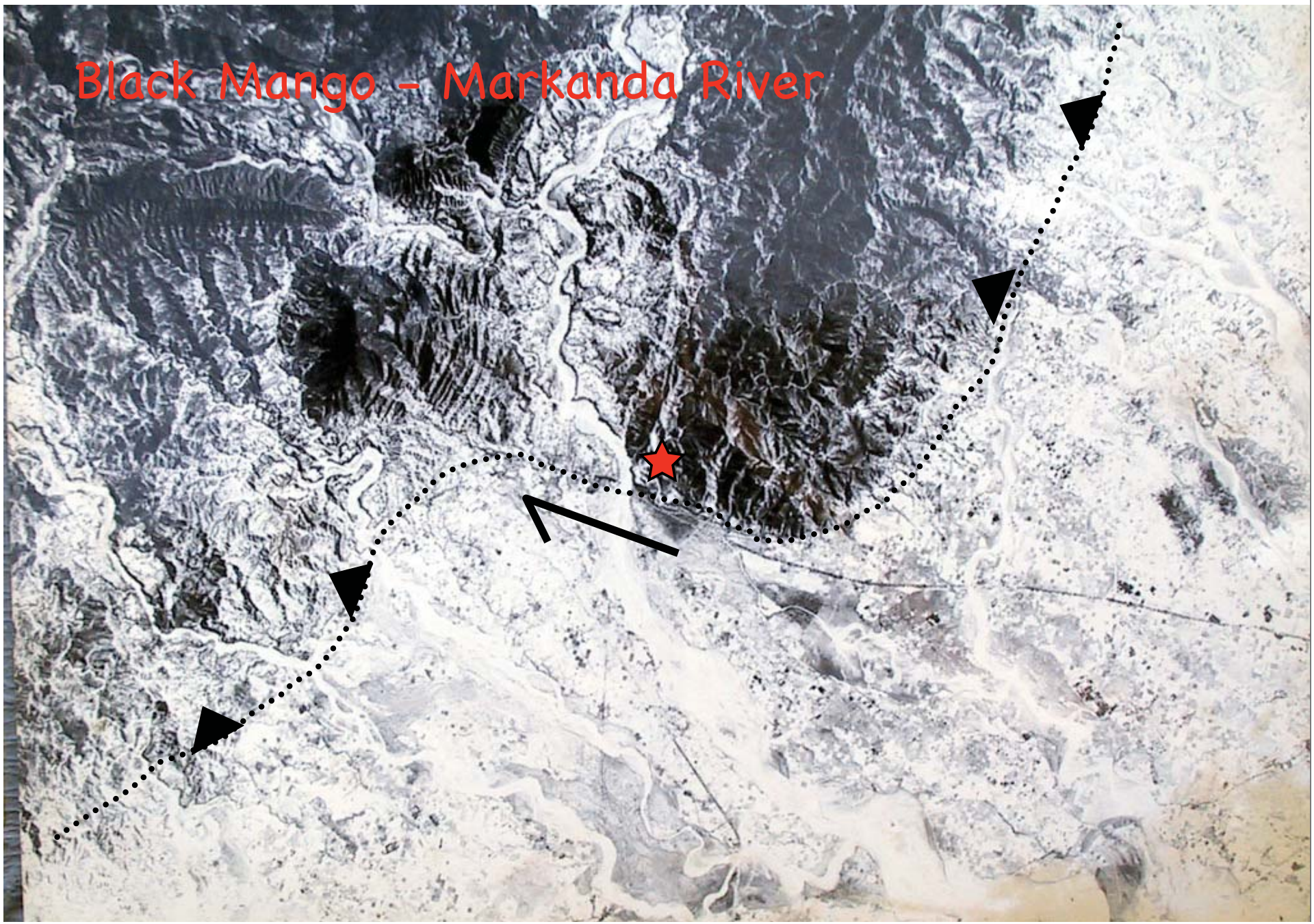

River Beas
Txt
2.5 km
7.5 km
12.5 km
17.5 km


River Beas
Scarps - Growth
of fold - Deflection
of River Beas
5.0 km
10.0 km
15.0 km
20.0 km


Soan Dun
Pinjaur Dun
Black Mango
Dehra Dun
32° 00' 0.0000" N
31° 00' 0.0000" N
30° 00' 0.0000" N
77° 00' 0.0000" E
78° 00' 0.0000" E
79° 00' 0.0000" E
0 km
25 km
50 km
75 km
100 km

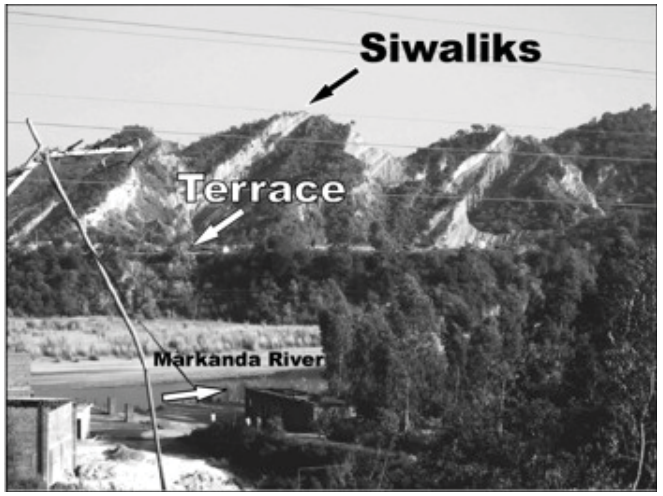

Black Mango - Markanda River
Uplift Exposed
on Tear Faults
0.0 km
5.0 km
10.0 km
15.0 km
20.0 km

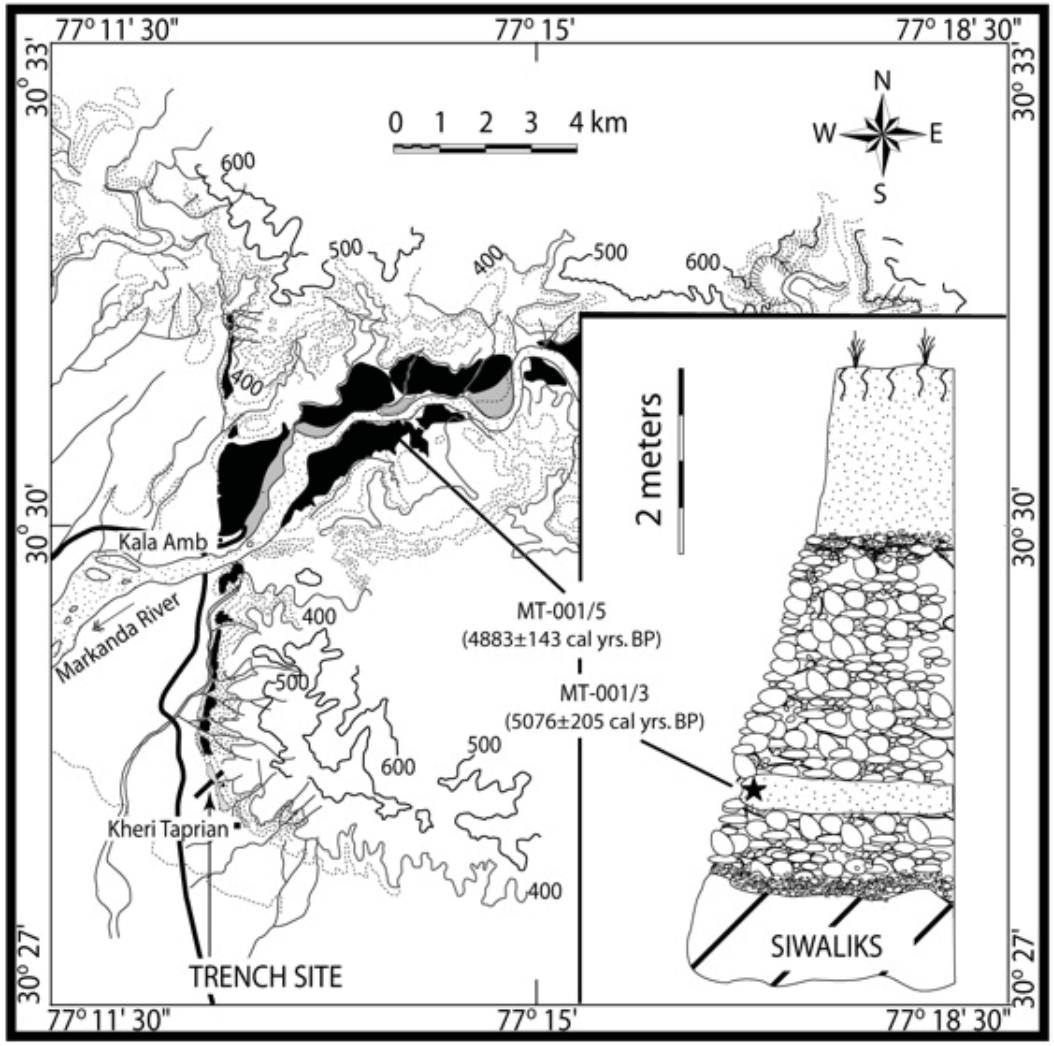
Site 2 - *near Kala Amb (Black Mango) and Markanda River - a tear fault along the HFT*



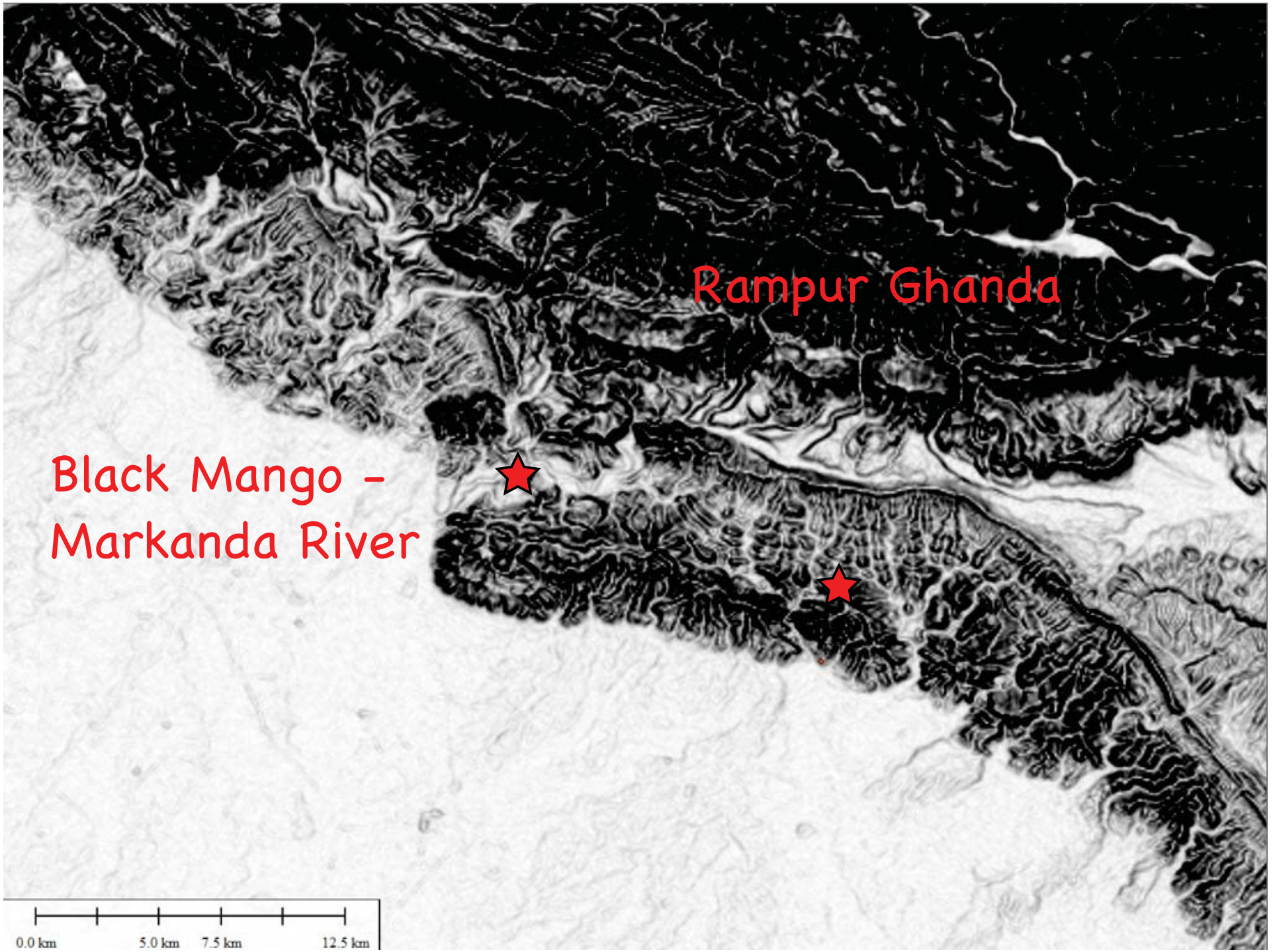
Black Mango - Markanda River

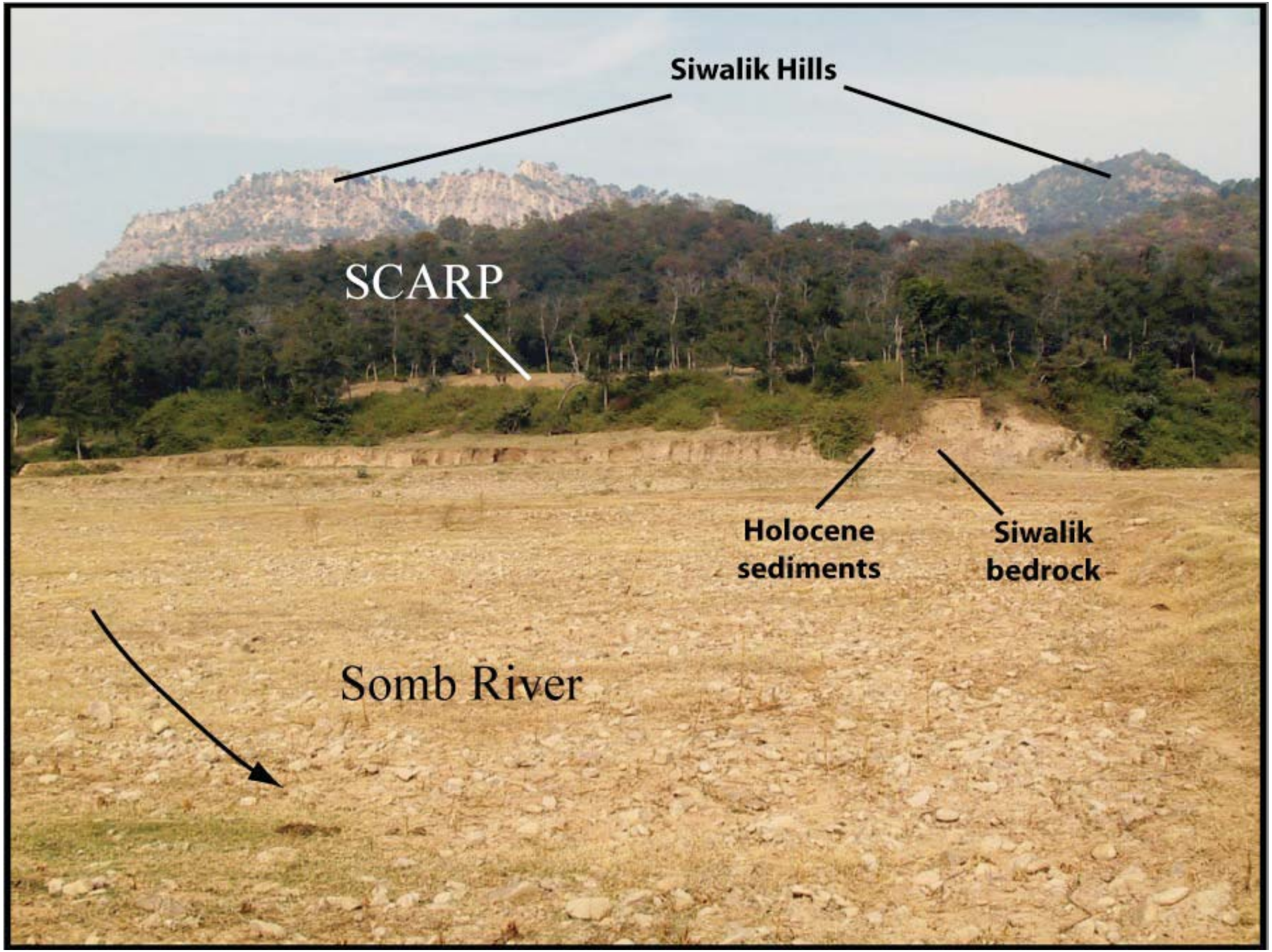
Truncated - Uplifted Terraces along tear fault

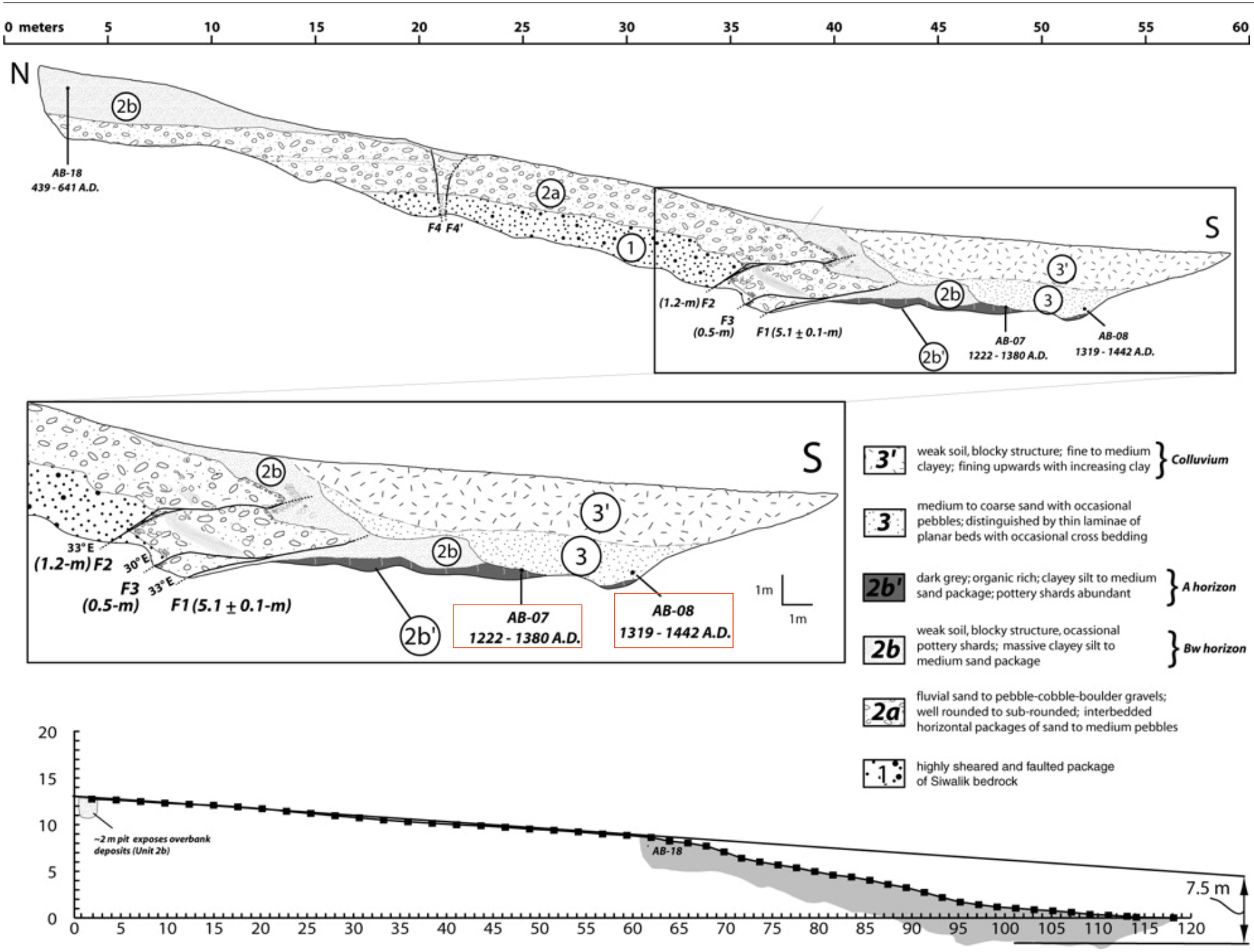


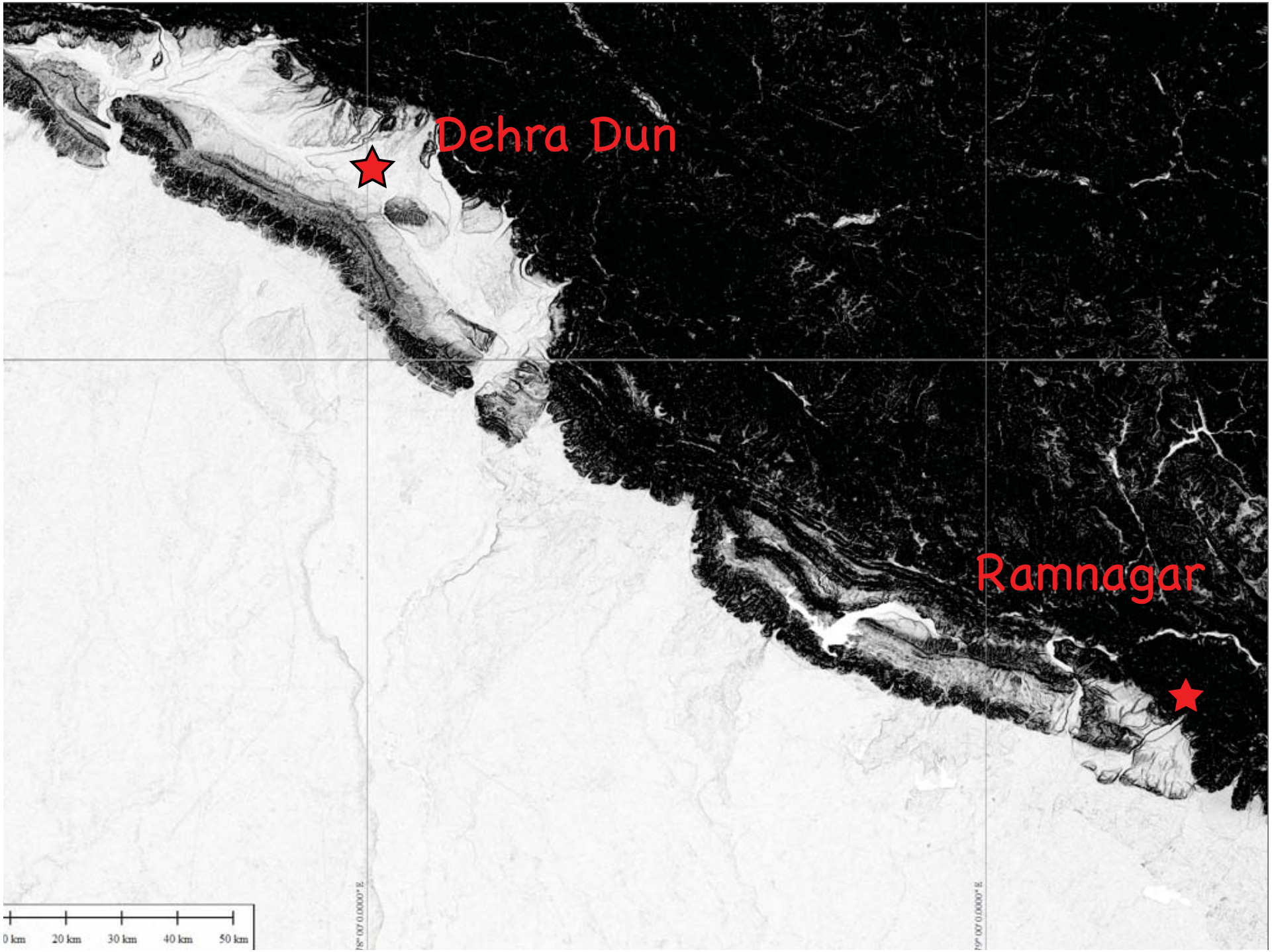


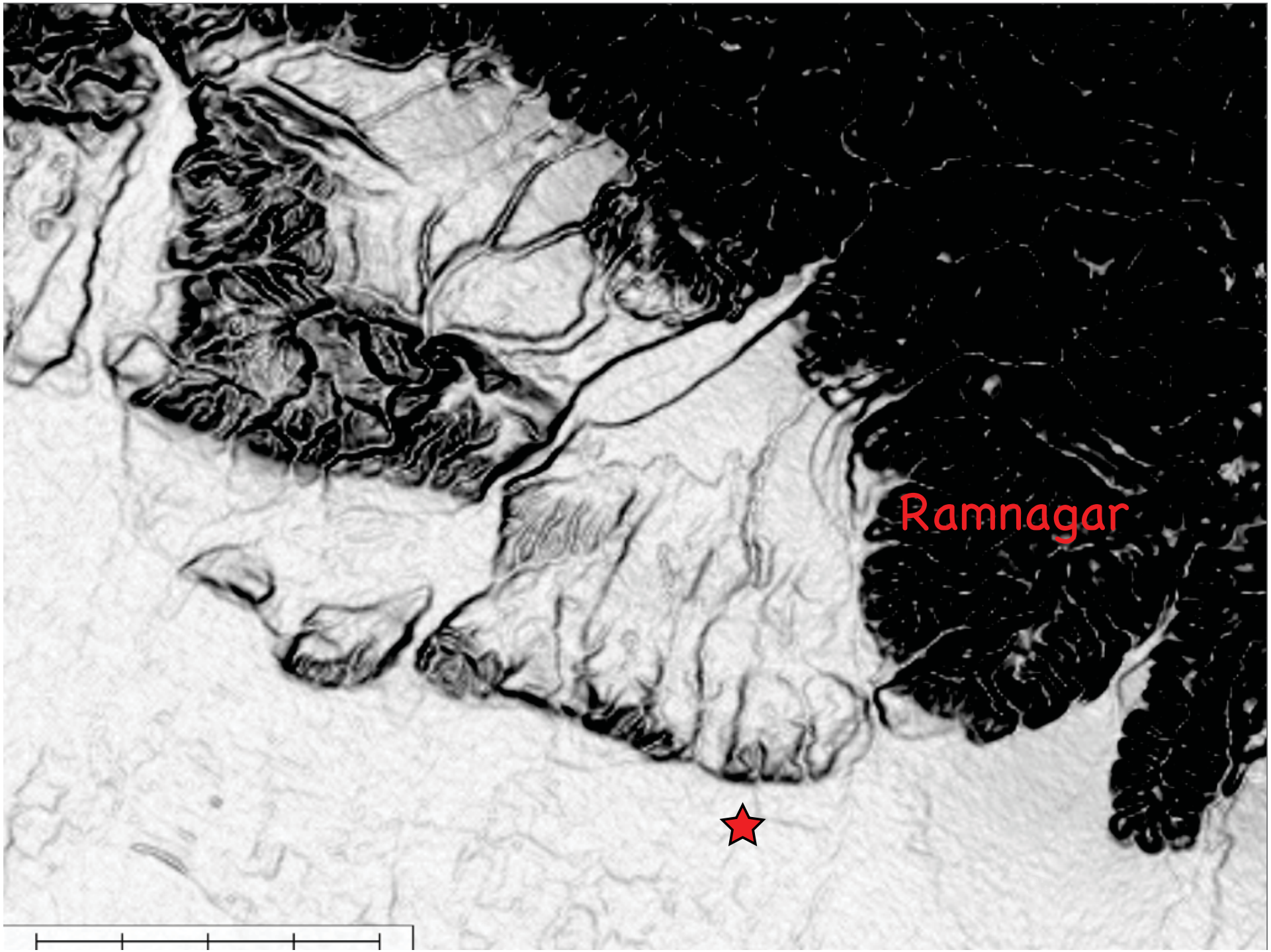
Dividing 27m uplift by
4883 ± 143
yields uplift rate of
<= 4.8 ± 0.9 mm/yr


Rampur Ghanda
Black Mango -
Markanda River
0.0 km
5.0 km
7.5 km
12.5 km

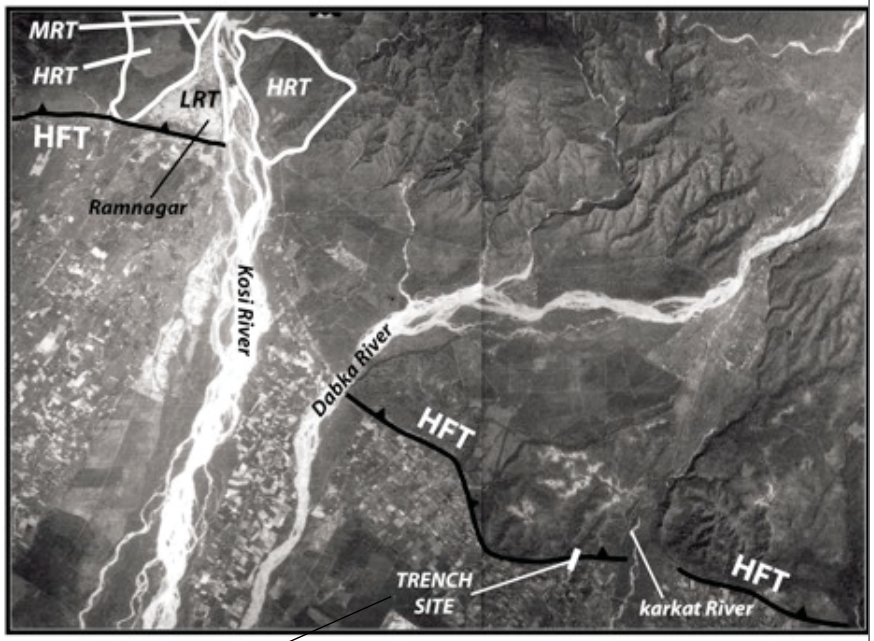

Siwalik Hills
SCARP
Holocene sediments
Siwalik bedrock
Somb River

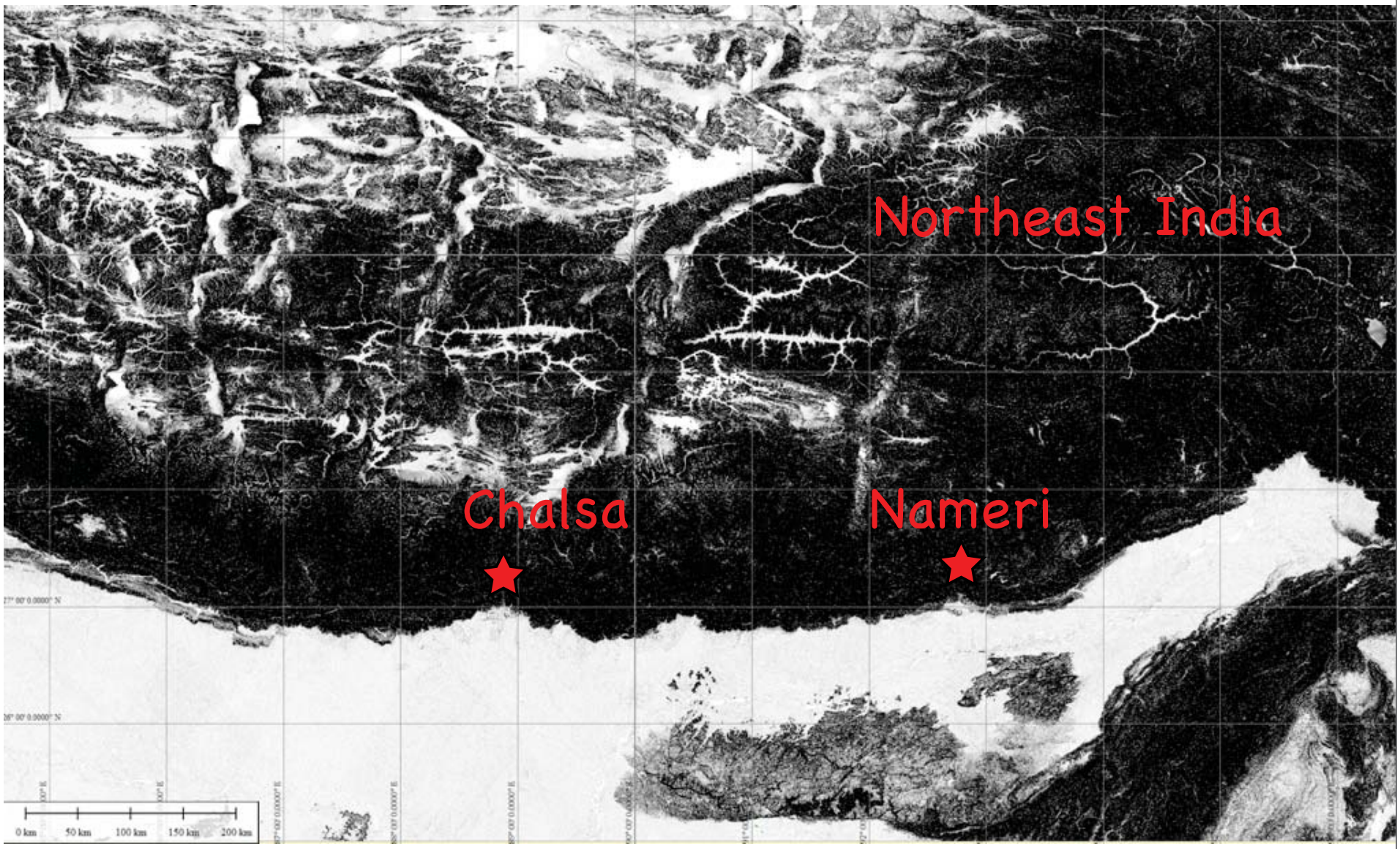

0 meters 5 10 15 20 25 30 35 40 45 50 55 60
N
2b
AB-18
439 - 641 A.D.
2a
F4 F4'
1
S
3'
2b
3
(1.2-m) F2
F3
(0.5-m)
F1 (5.1 ± 0.1-m)
2b'
AB-07
1222 - 1380 A.D.
AB-08
1319 - 1442 A.D.
S
2b
3'
3
33° E
30° E
33° E
(1.2-m) F2
F3
(0.5-m)
F1 (5.1 ± 0.1-m)
2b'
AB-07
1222 - 1380 A.D.
AB-08
1319 - 1442 A.D.
1m
1m
3' weak soil, blocky structure; fine to medium clayey; fining upwards with increasing clay } Colluvium
3 medium to coarse sand with occasional pebbles; distinguished by thin laminae of planar beds with occasional cross bedding
2b' dark grey; organic rich; clayey silt to medium sand package; pottery shards abundant } A horizon
2b weak soil, blocky structure, ocassional pottery shards; massive clayey silt to medium sand package } Bw horizon
2a fluvial sand to pebble-cobble-boulder gravels; well rounded to sub-rounded; interbedded horizontal packages of sand to medium pebbles
1 highly sheared and faulted package of Siwalik bedrock
20
15
10
5
0
~2 m pit exposes overbank deposits (Unit 2b)
AB-18
7.5 m
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

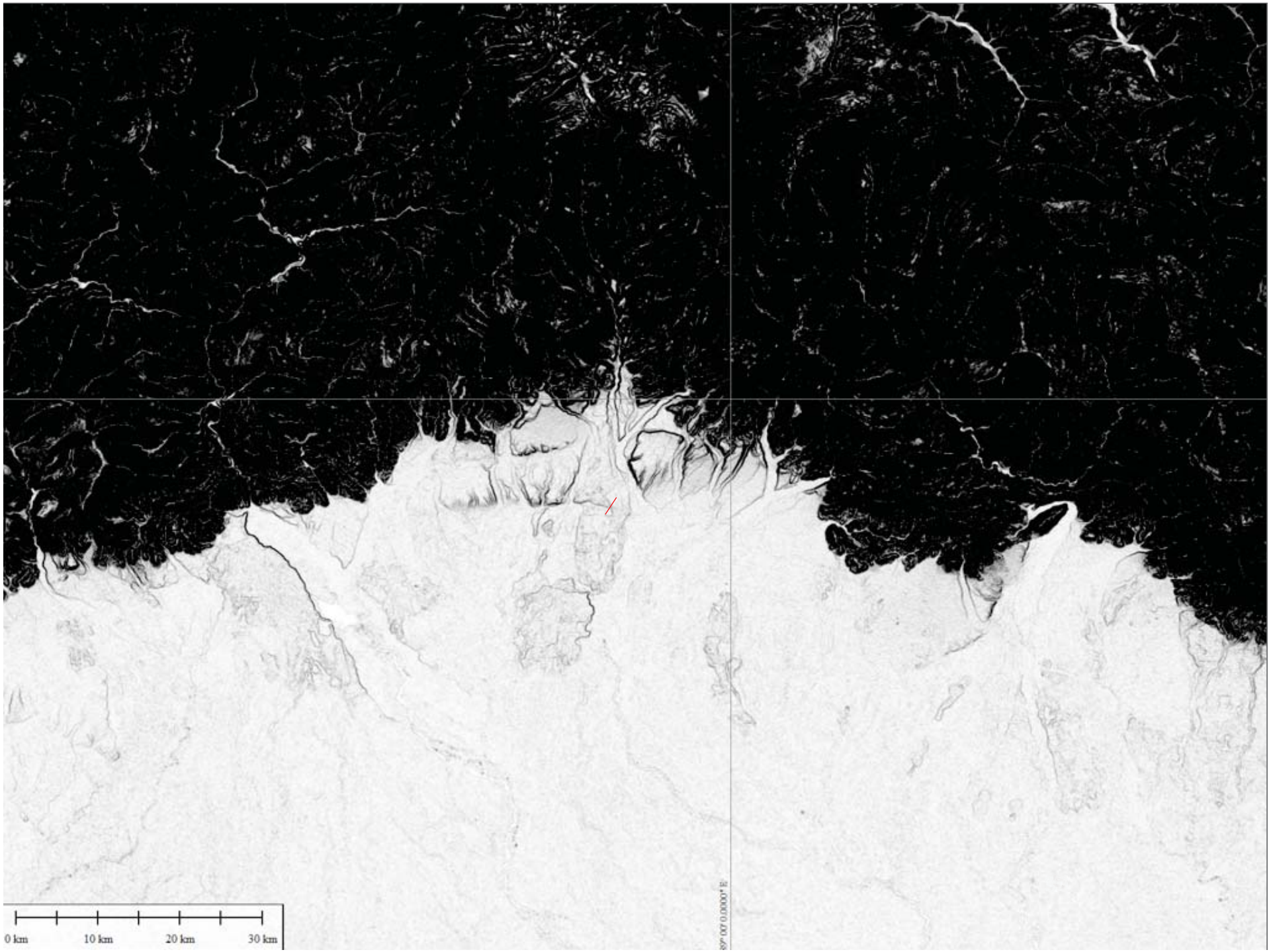

Dehra Dun
Ramnagar
0 km
20 km
30 km
40 km
50 km

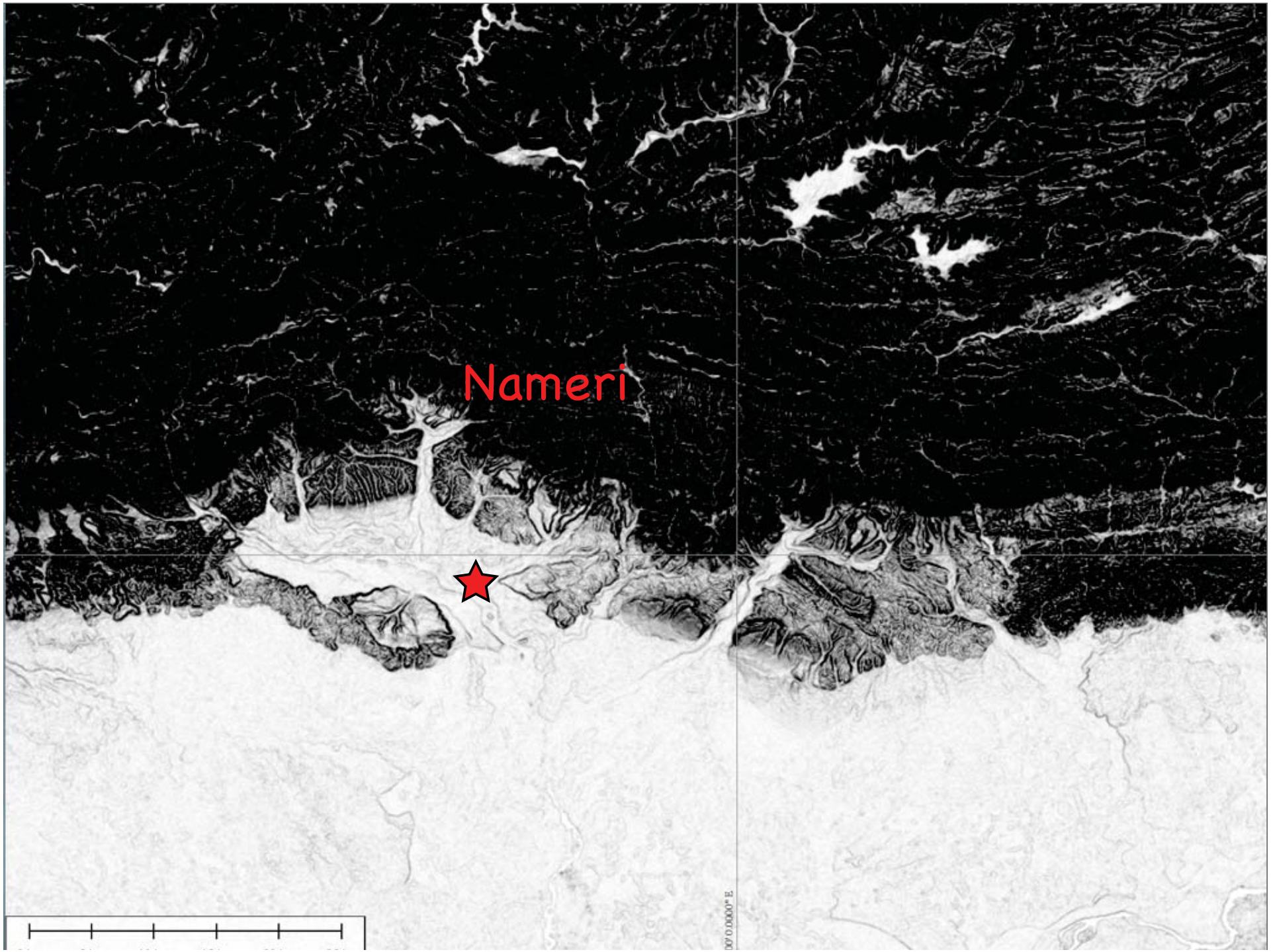

Ramnagar

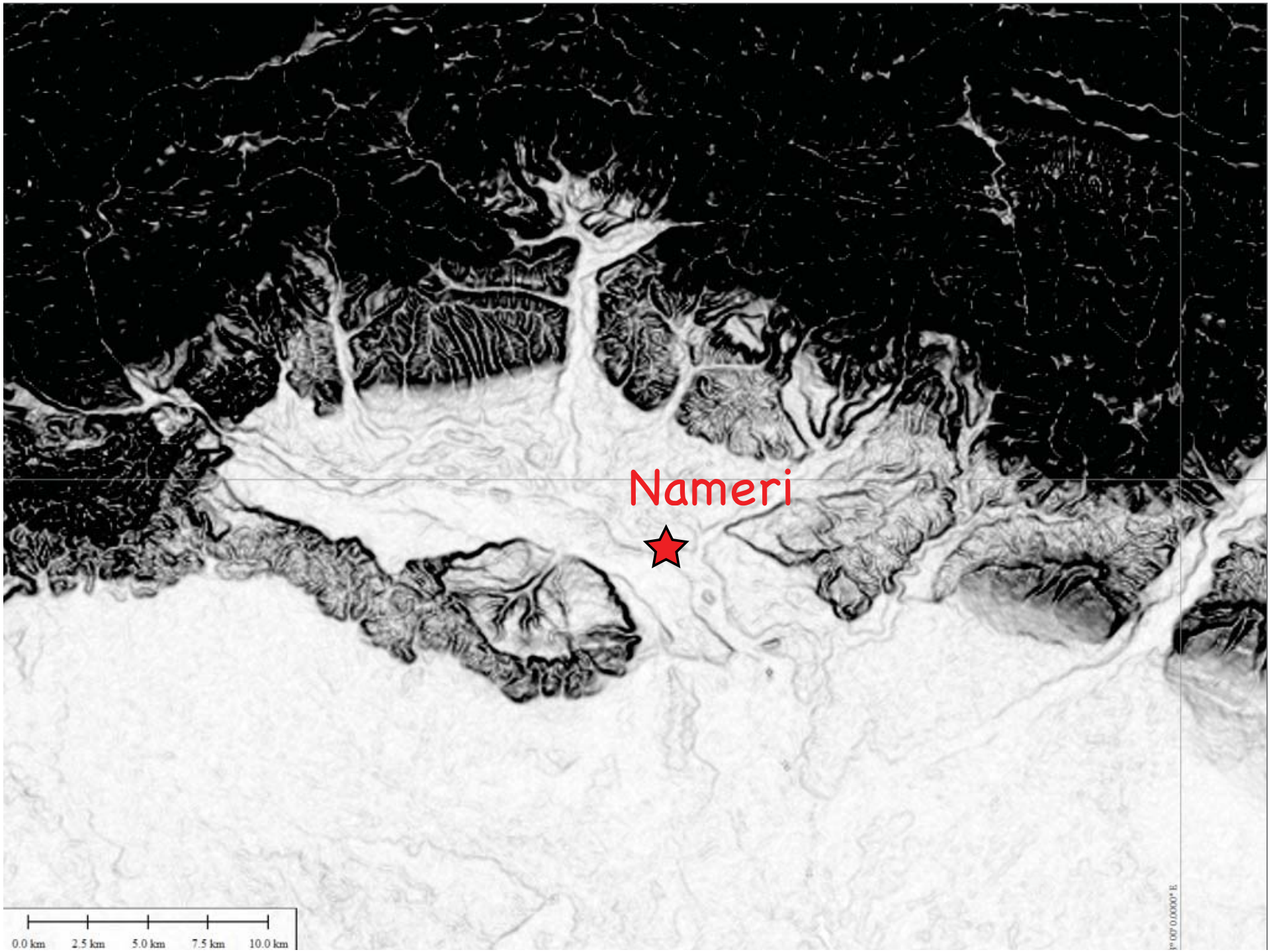
The scarp and trench…




Northeast India
Chalsa
Nameri
0 km
50 km
100 km
150 km
200 km


0 km
10 km
20 km
30 km


Nameri


Nameri
0.0 km
2.5 km
5.0 km
7.5 km
10.0 km

Nameri Tiger Preserve Trench Site - Site 7