



The Abdus Salam  
**International Centre  
for Theoretical Physics**



**2464-18**

**Earthquake Tectonics and Hazards on the Continents**

*17 - 28 June 2013*

**Mongolia**

R. Walker  
*University of Oxford, UK*

# Past earthquakes, slip-rates & mountain-building in Mongolia

Richard Walker  
Oxford University



**Oxford**

**Ed Nissen, Laura Gregory, Matt Fox, Conall MacNiocaill**

**MUST**

**Amgalan Bayasgalan, Erdenebat Molor, Gantulga  
Bayasgalan, Tsolmon Amгаа**

**UCL**

**Andy Carter**

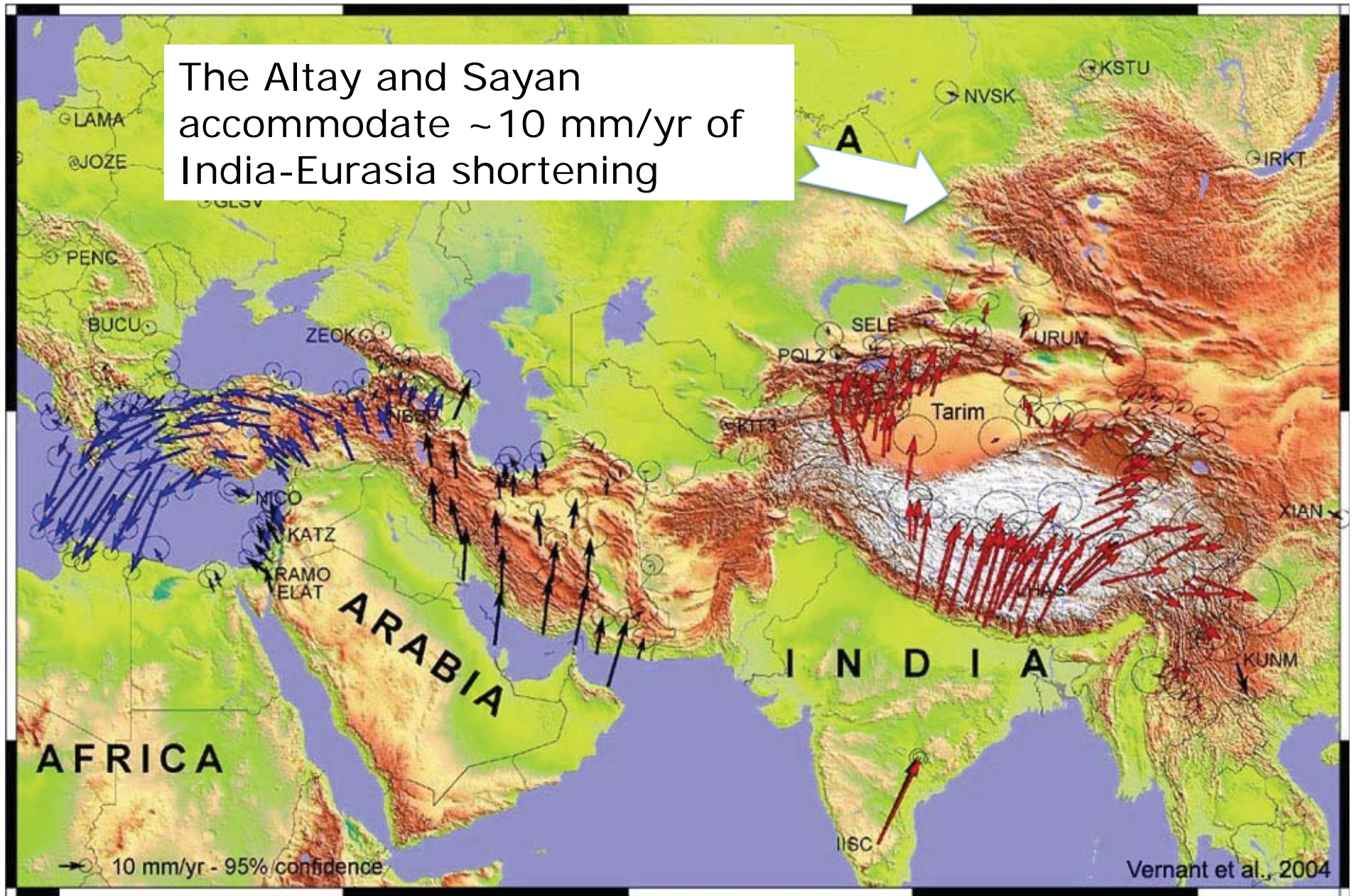
**USC**

**Josh West**



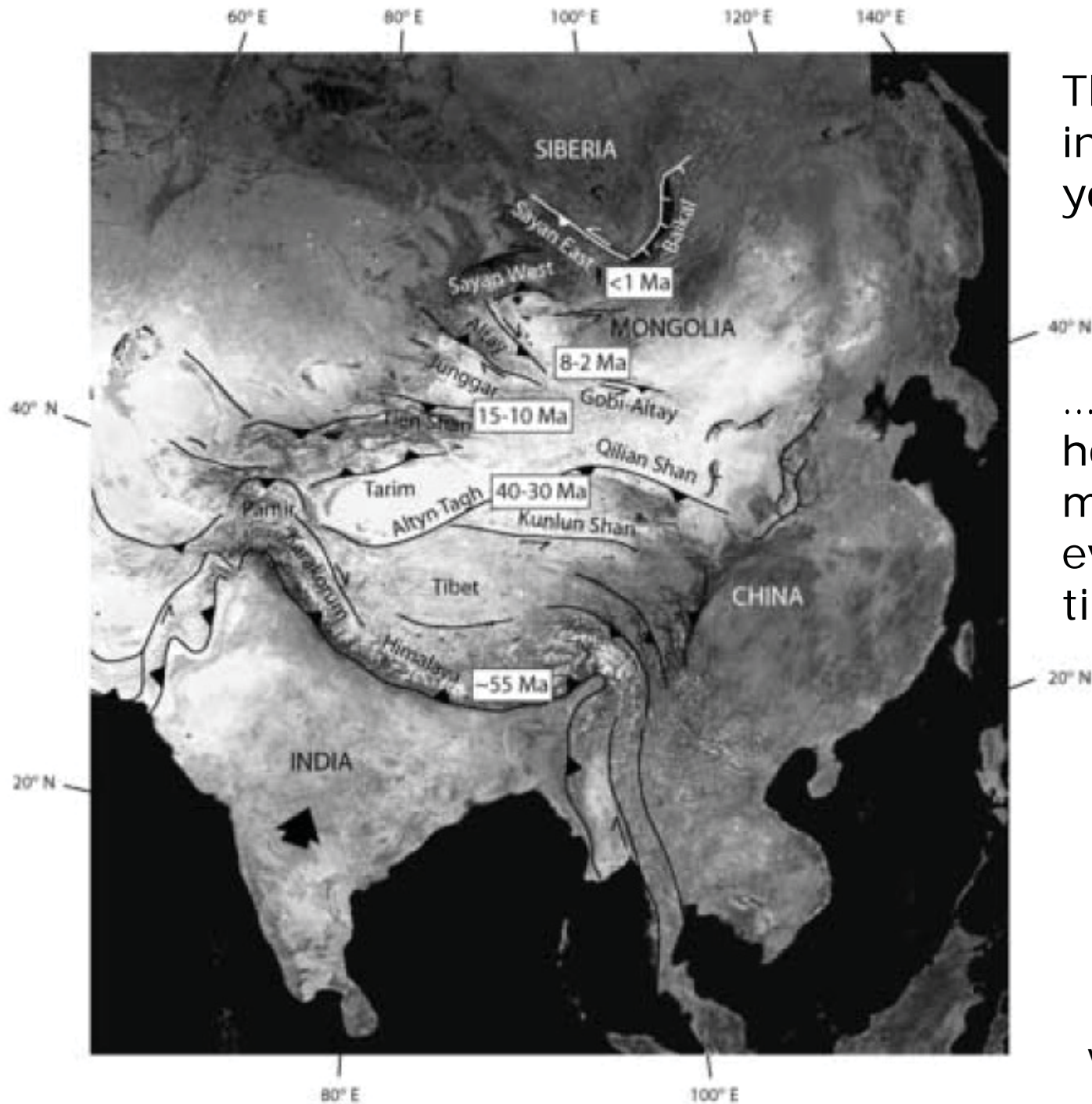


The Altay and Sayan  
accommodate ~10 mm/yr of  
India-Eurasia shortening



Philippe Vernant (<http://www-gpsg.mit.edu/~vernant/>)



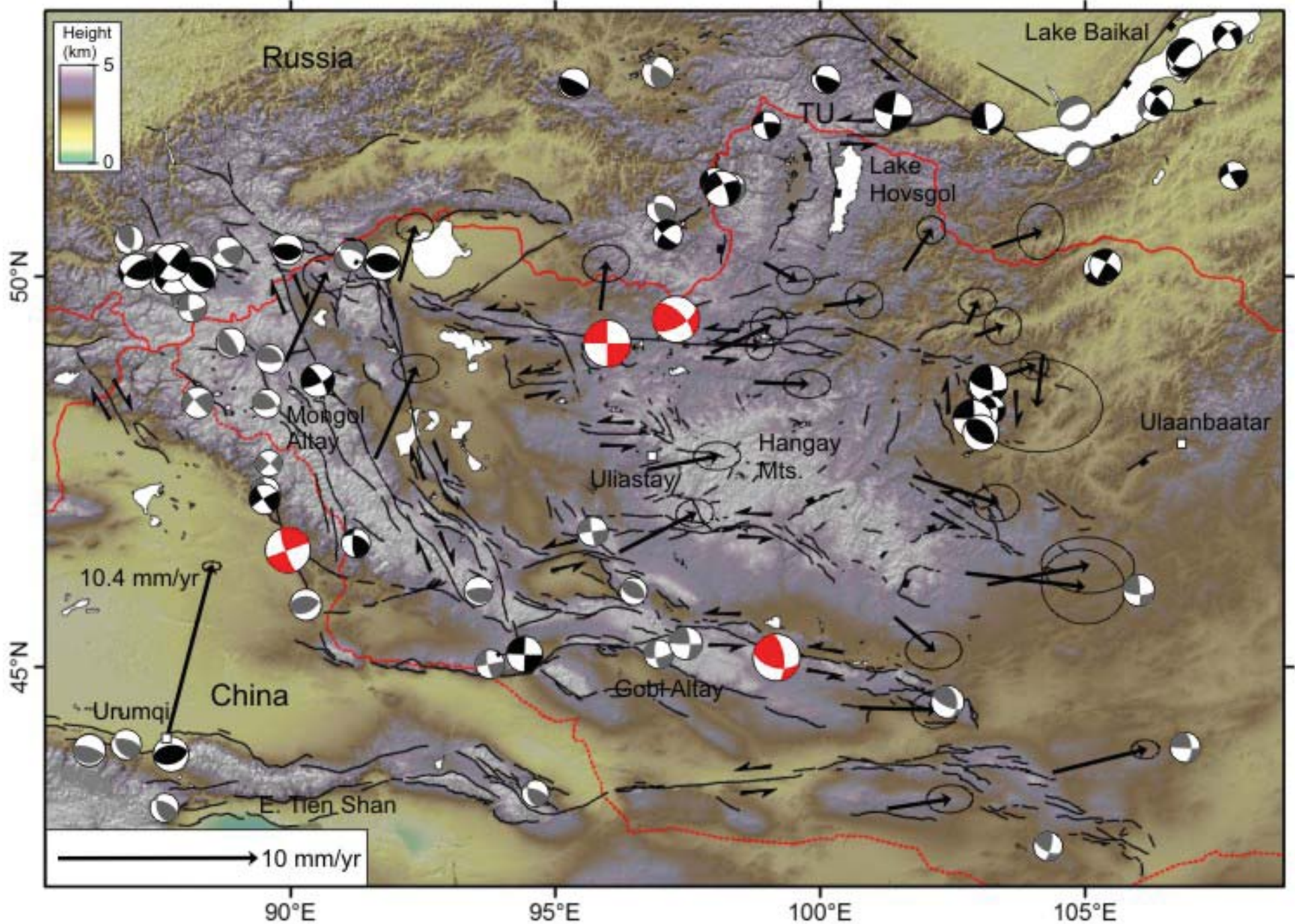


The active faulting in Mongolia is very young (~ 5Ma)

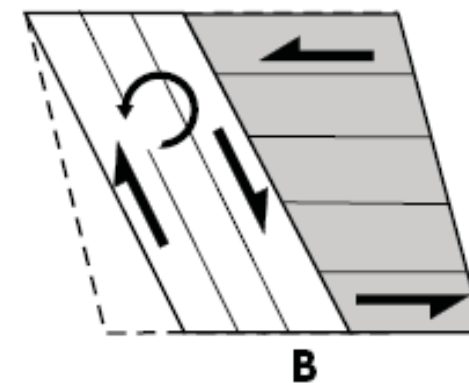
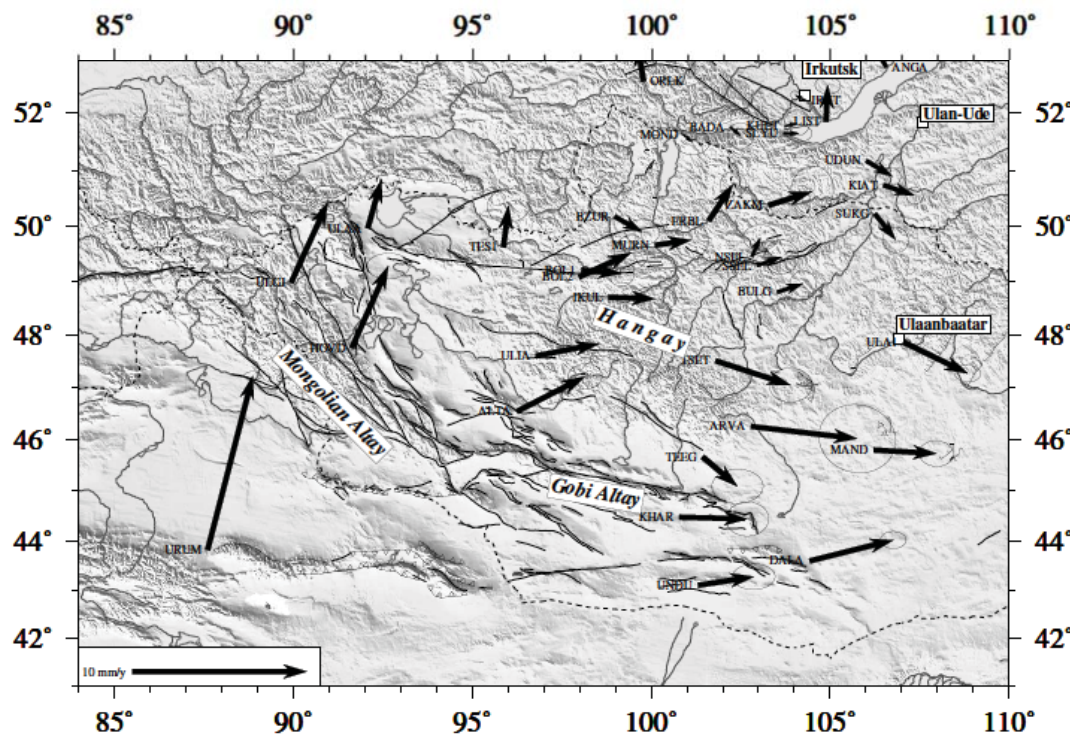
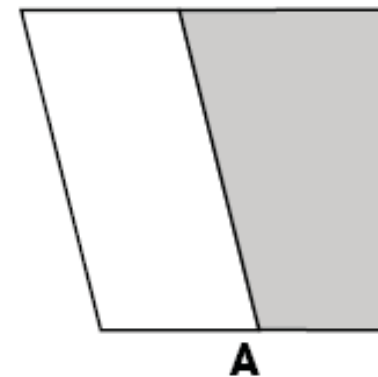
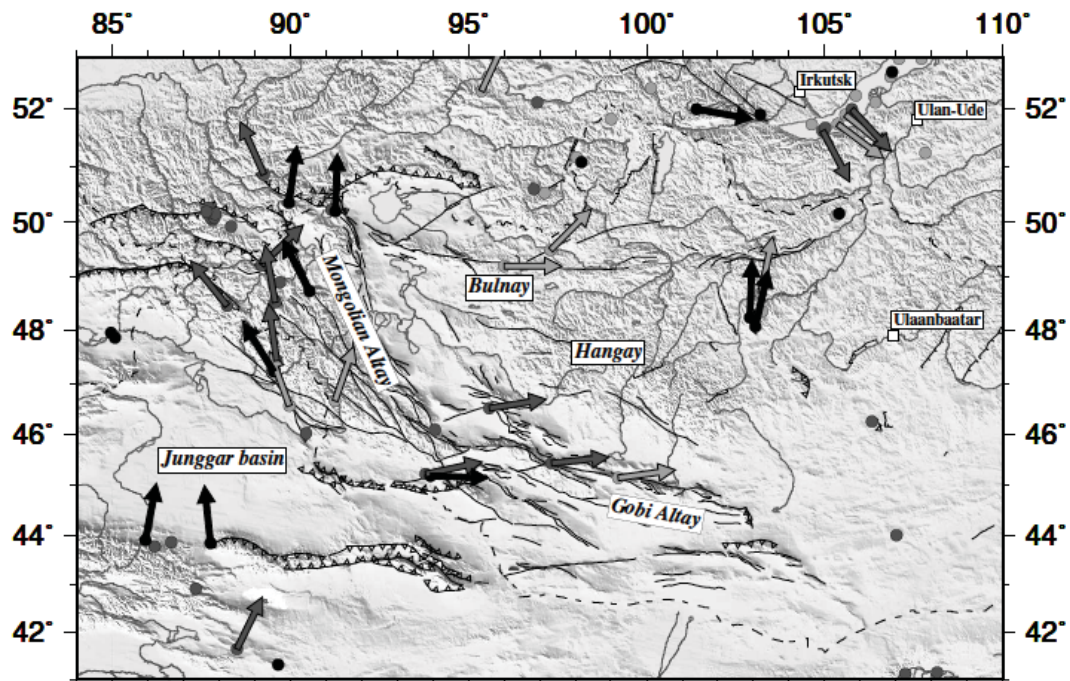
... so we can learn how the faults and mountains have evolved through time

Vassallo et.al. 2007

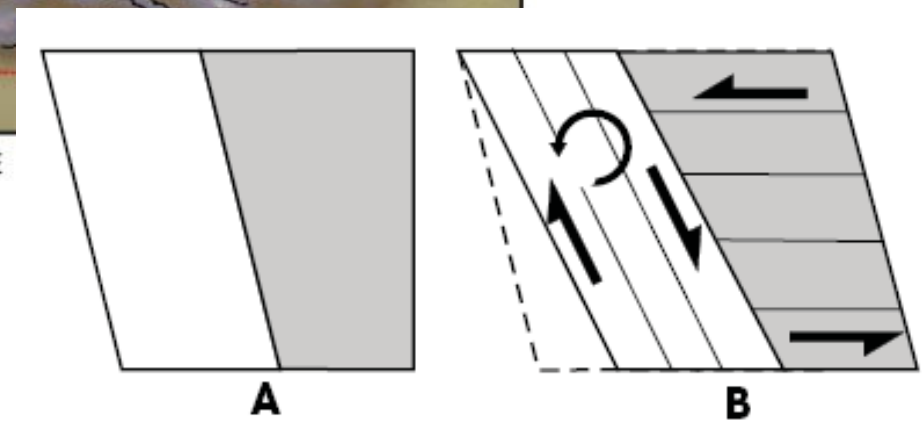
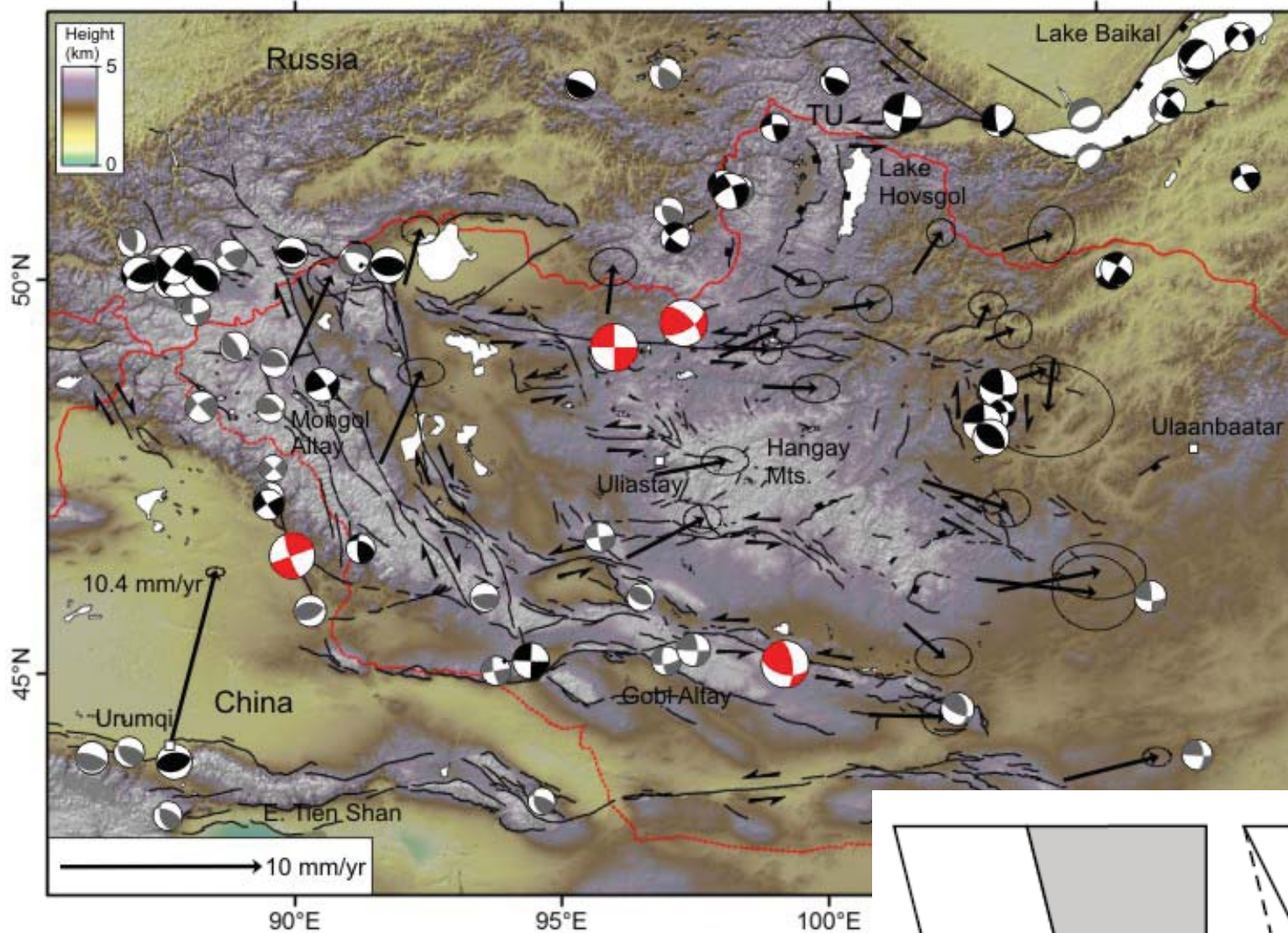












Very large historic and pre-historic earthquakes ...



1905 Bulnay Mw 8.3



2003 Chuya Mw 7.3

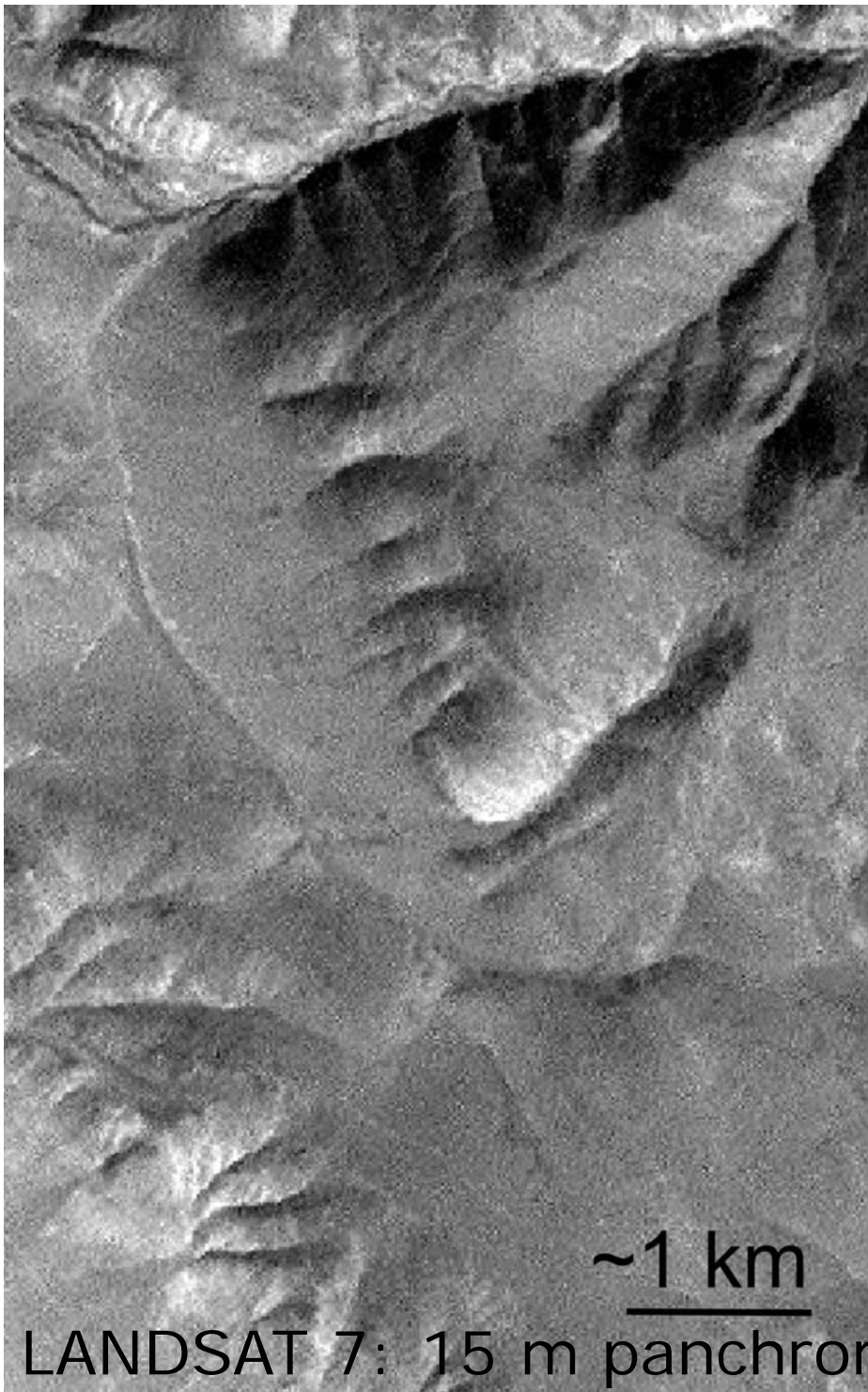


Jid palaeo-rupture  
850-950 years old  
(Walker et.al. 2006)

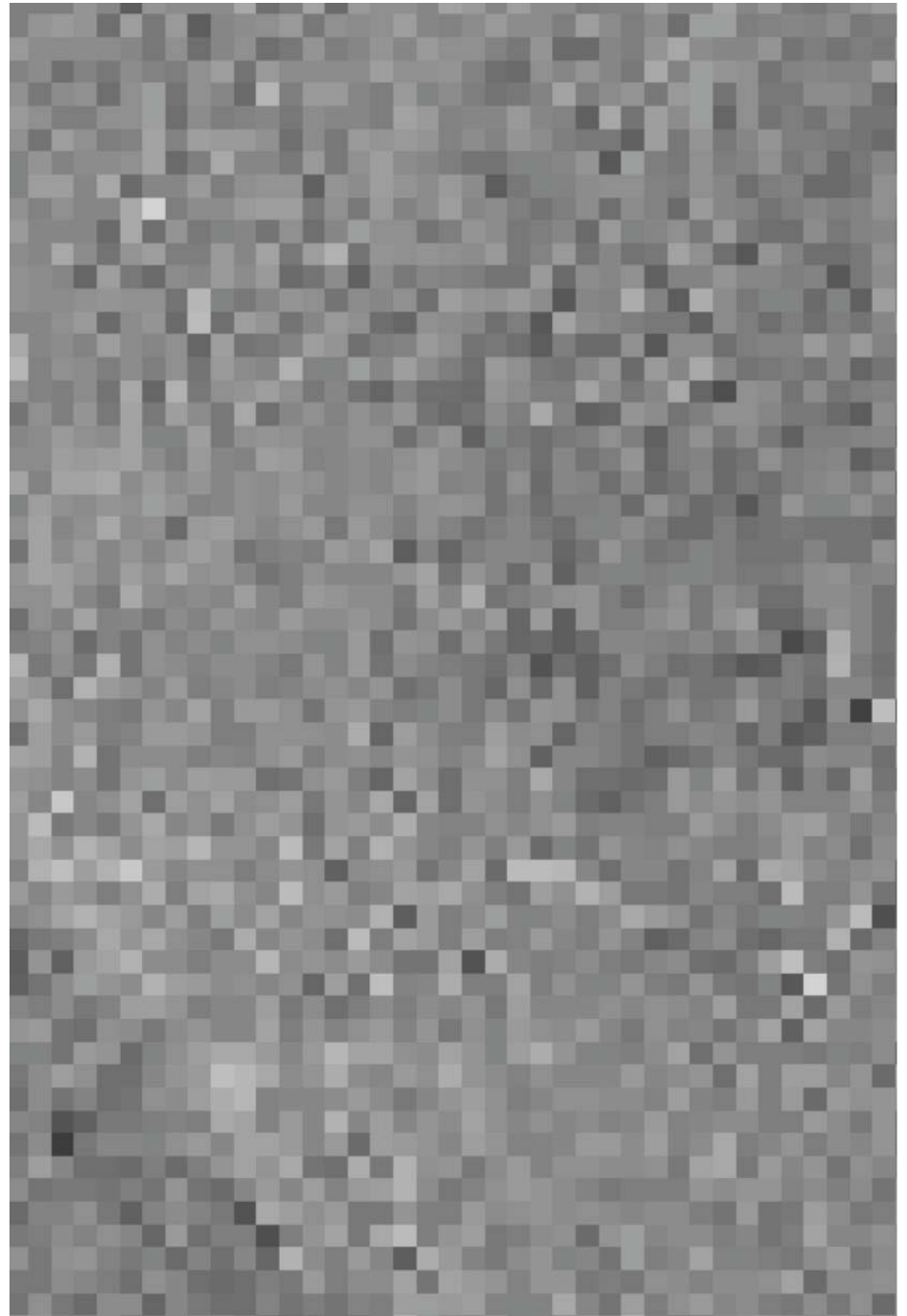
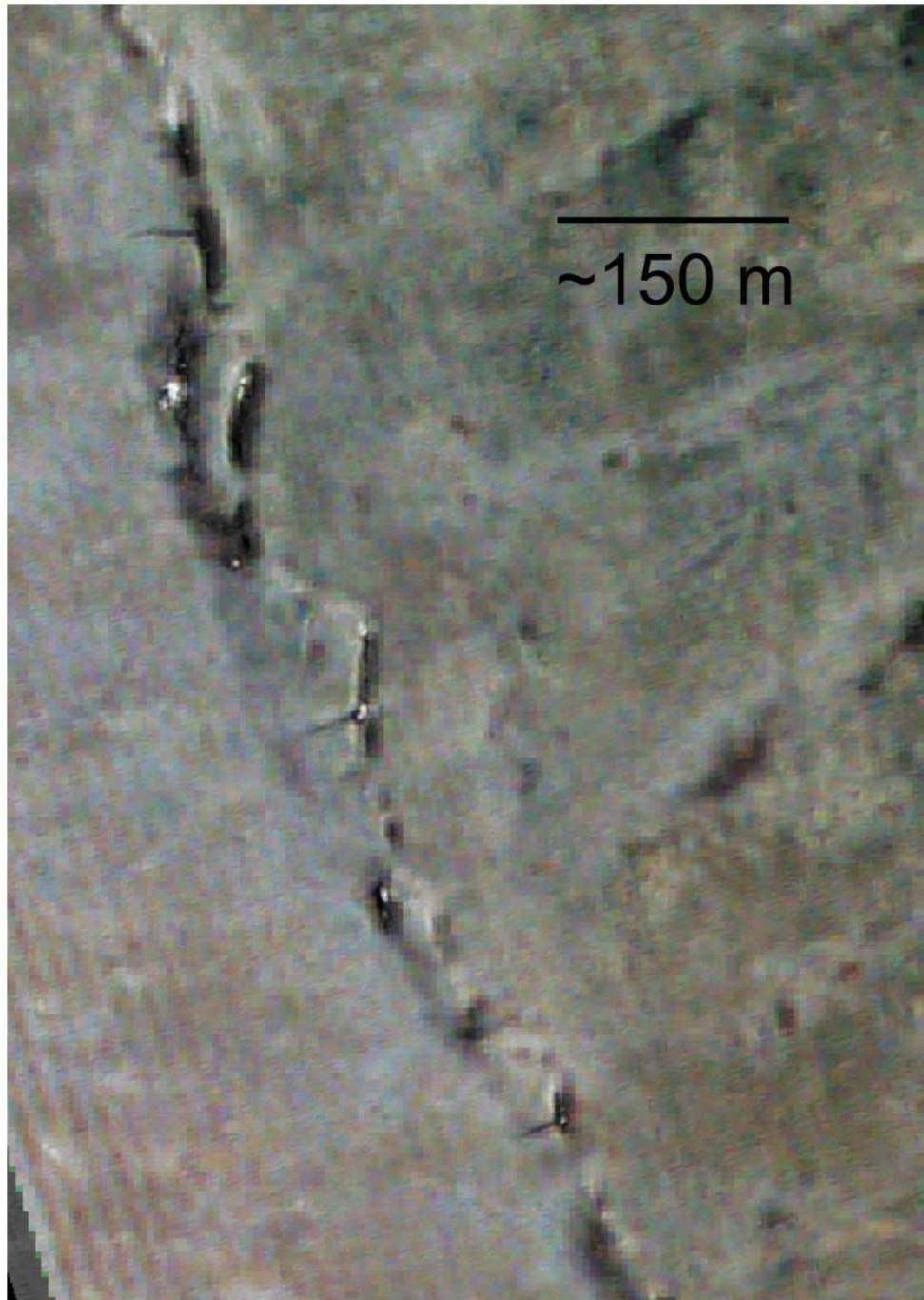


Ruptures are well preserved due to the arid environment



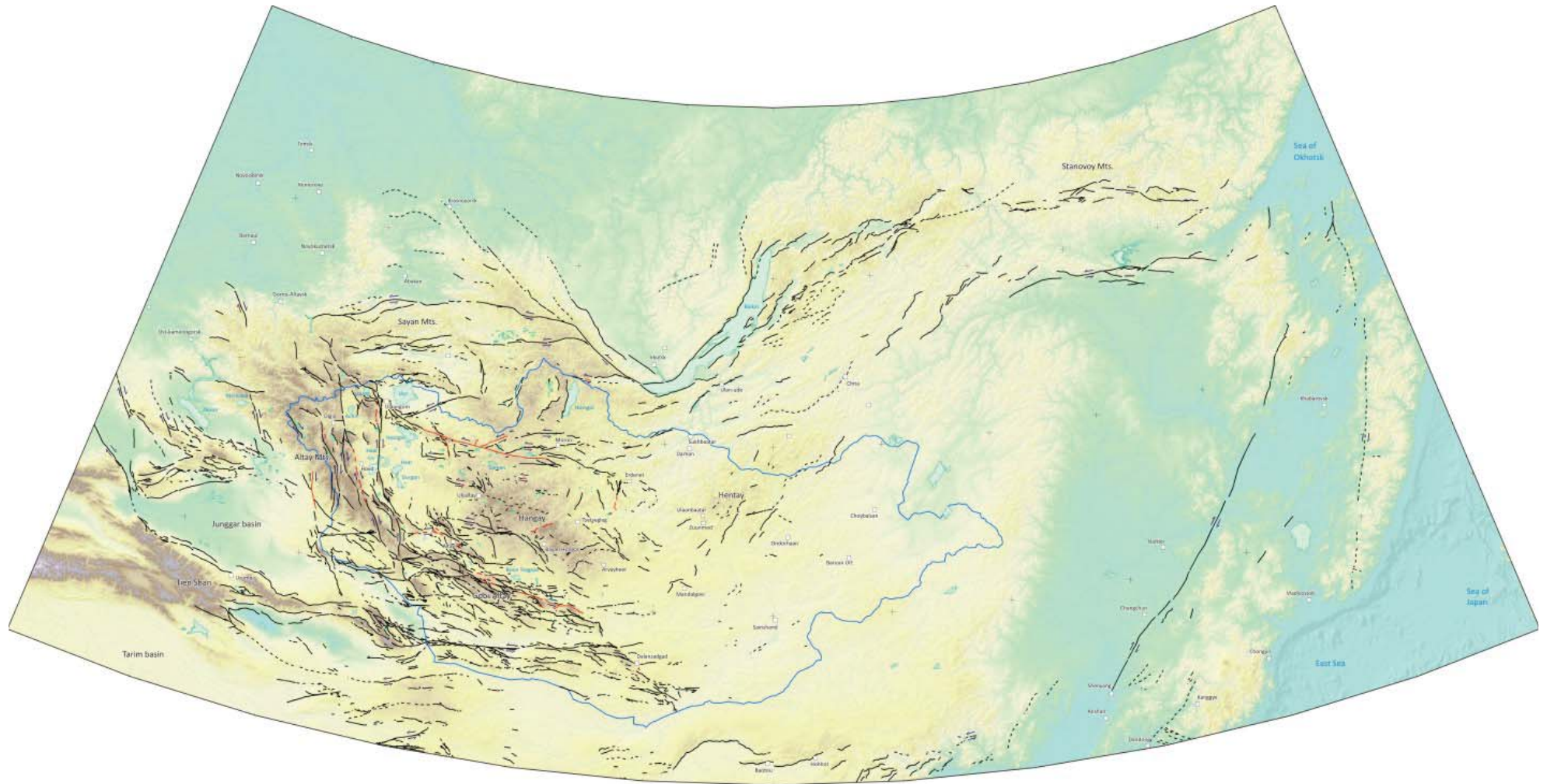








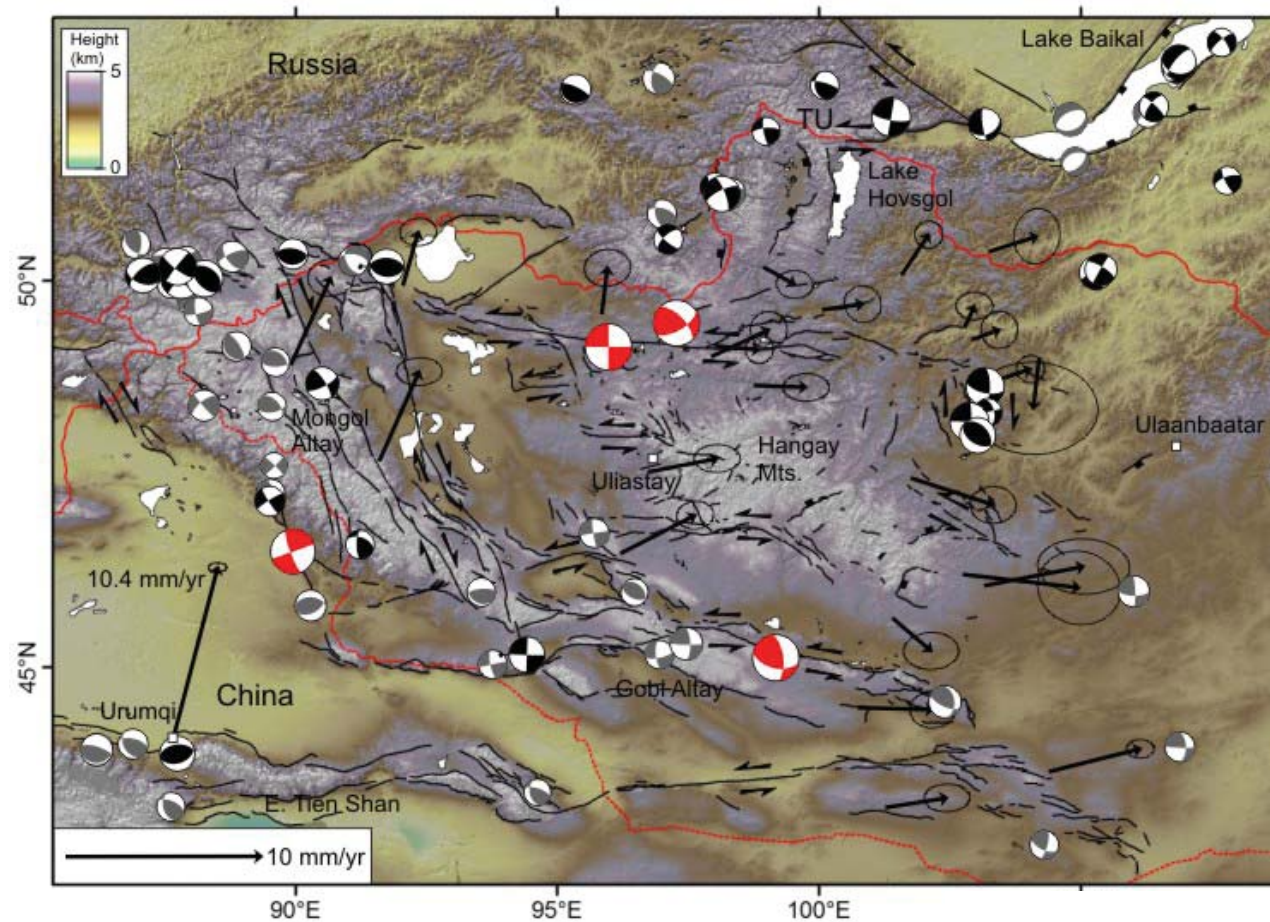
A map of active faults in NE Asia  
(with Y. Awata at the Geological Survey of Japan, and A. Bayasgalan  
at the Mongolian University of Science and Technology)



Japan Society for the Promotion of  
Science



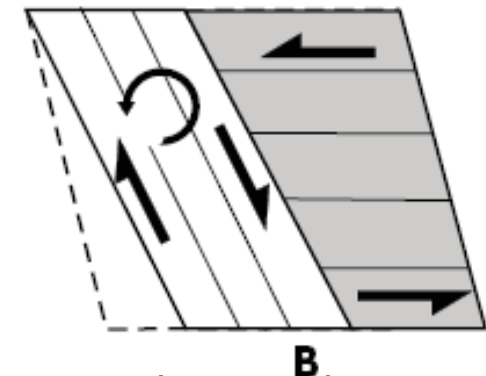
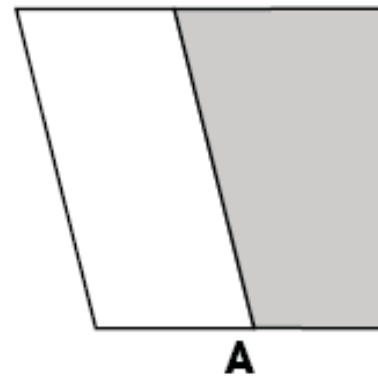
# The Altay



Compare distribution and rates of deformation over timescales from:

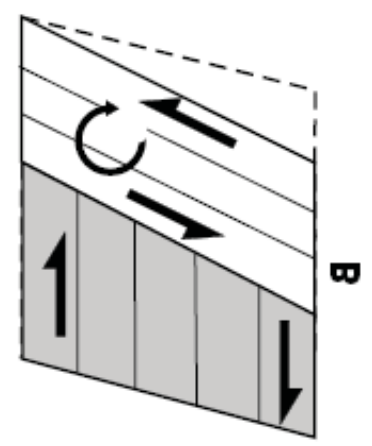
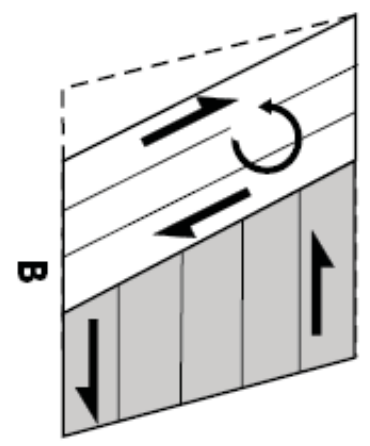
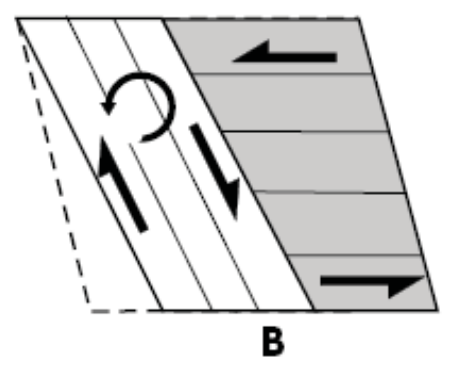
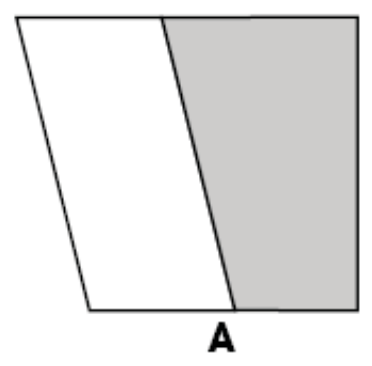
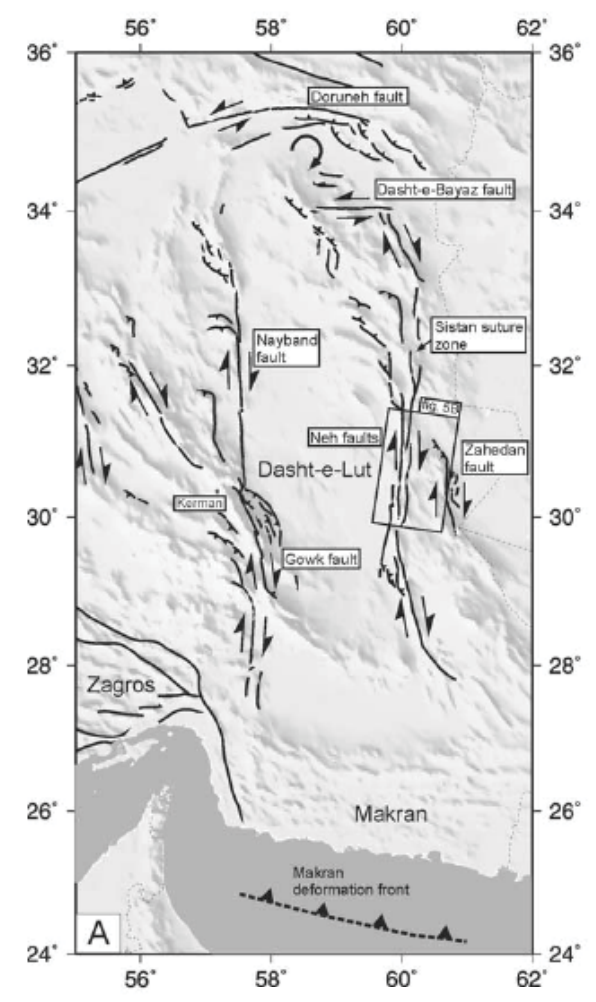
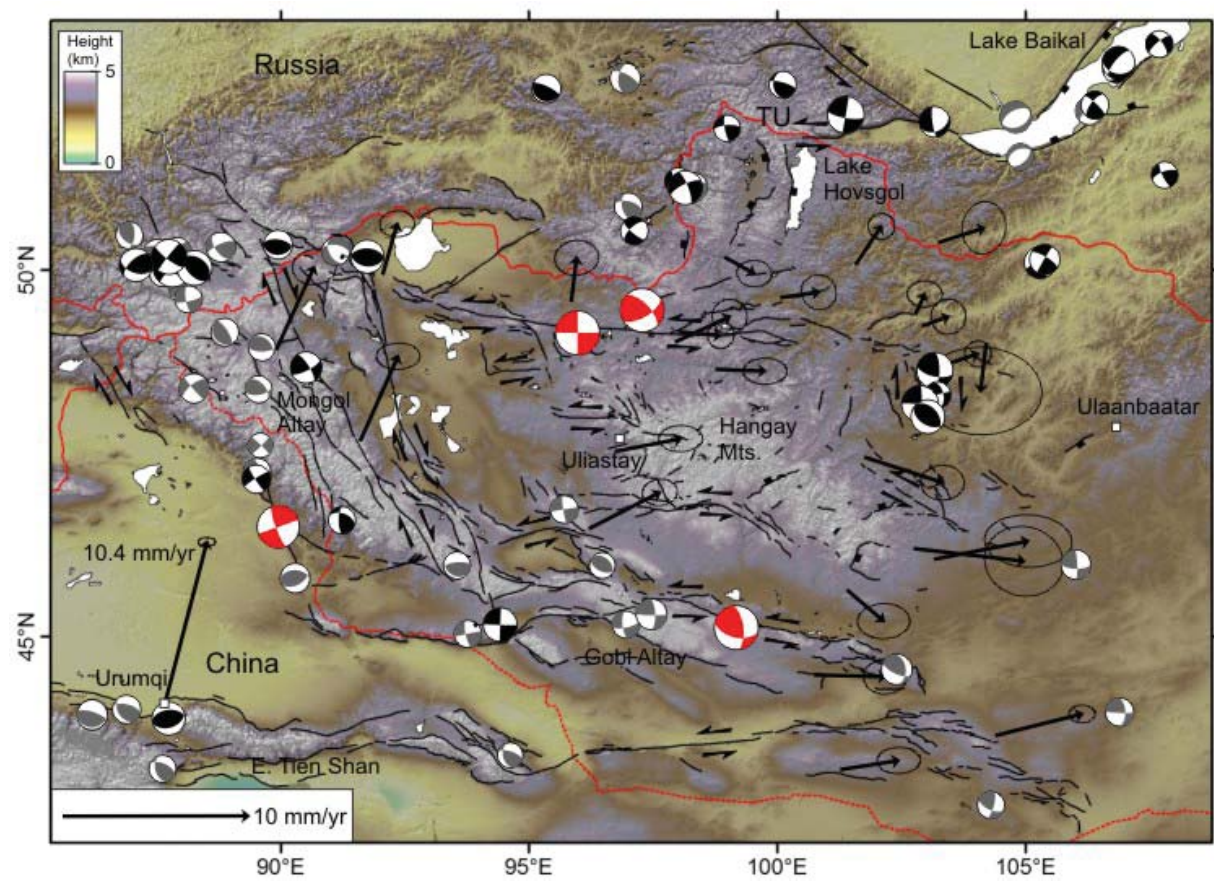
- 1) present-day (GPS)
- 2) 100 year (earthquakes)
- 3) 1000 year (palaeo-ruptures)
- 4) 10-100 ka (landscape)
- 5) >1 Ma (AFT, palaeomag, large-scale topography and river displacements)

How does this sketch work? How does it evolve through time?

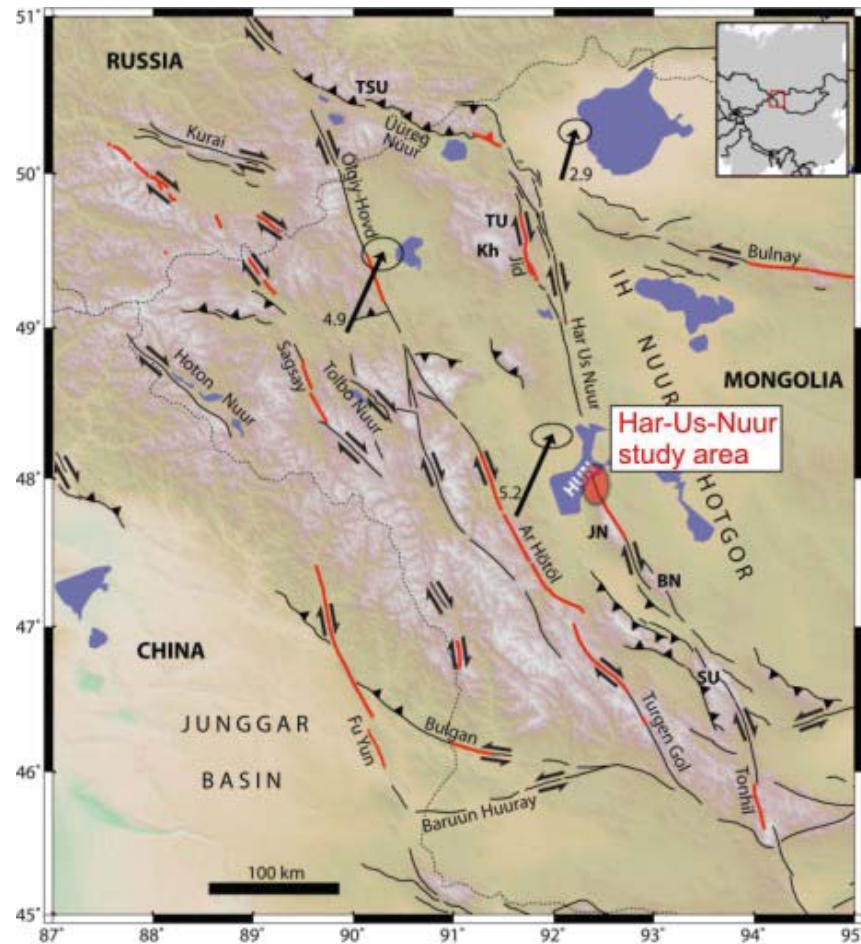


Bayasgalan et.al. 2005

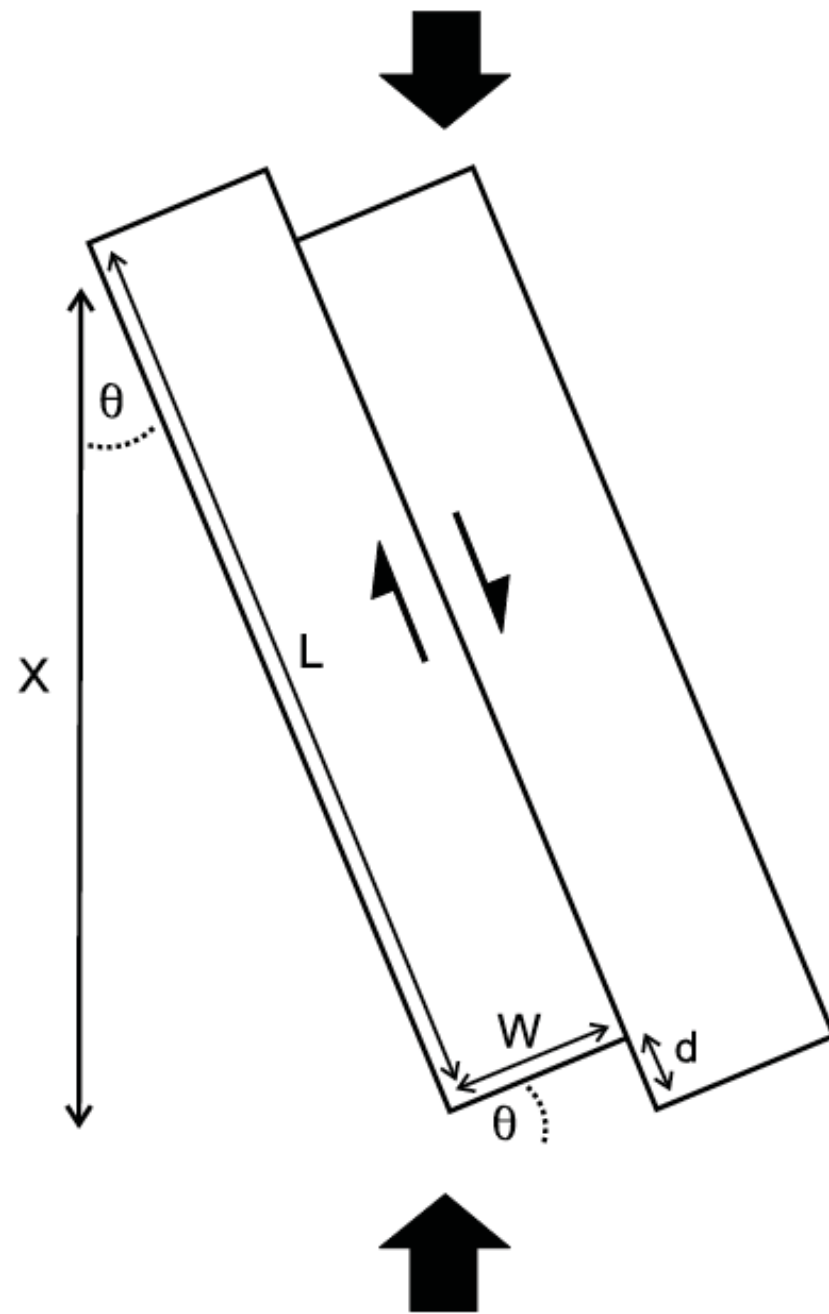




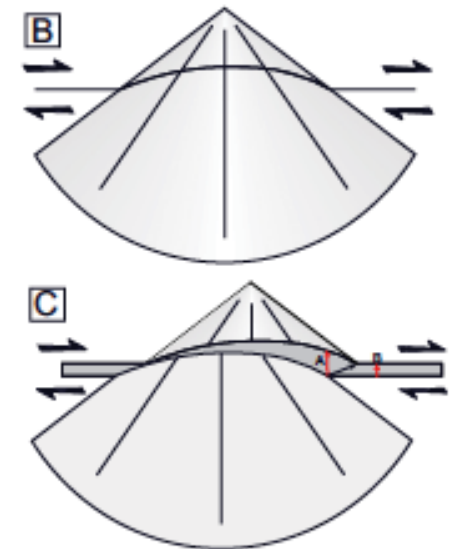
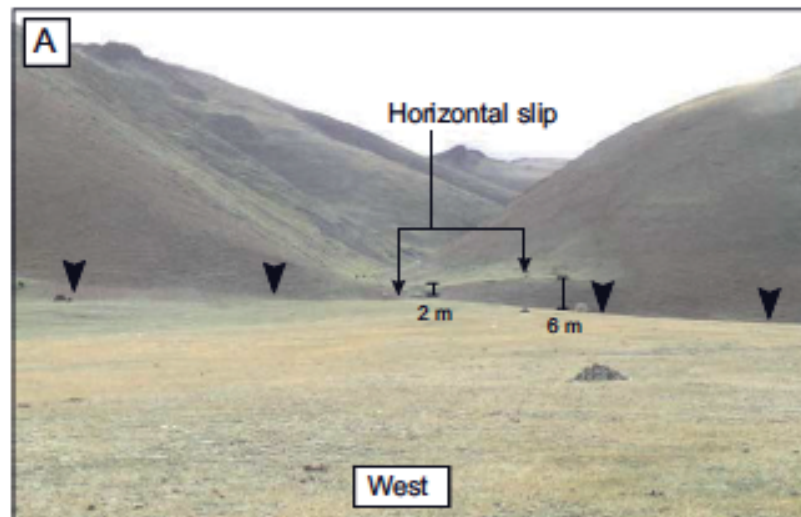
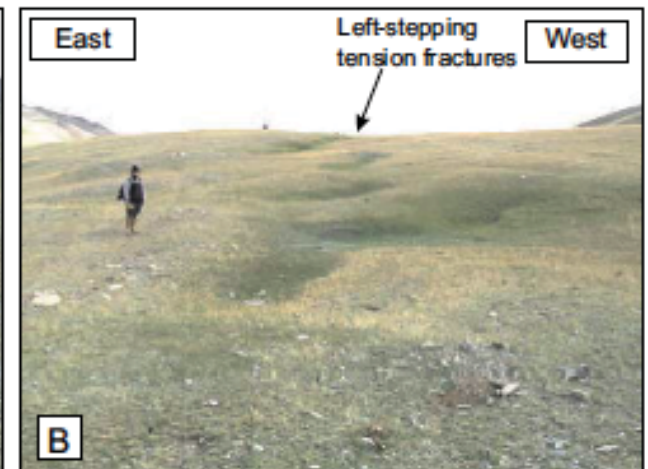
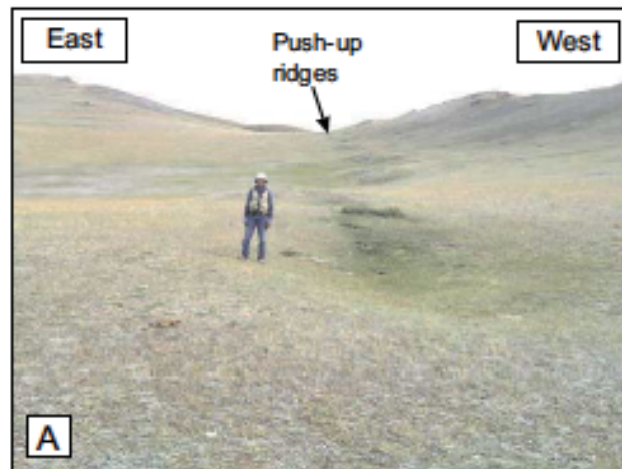
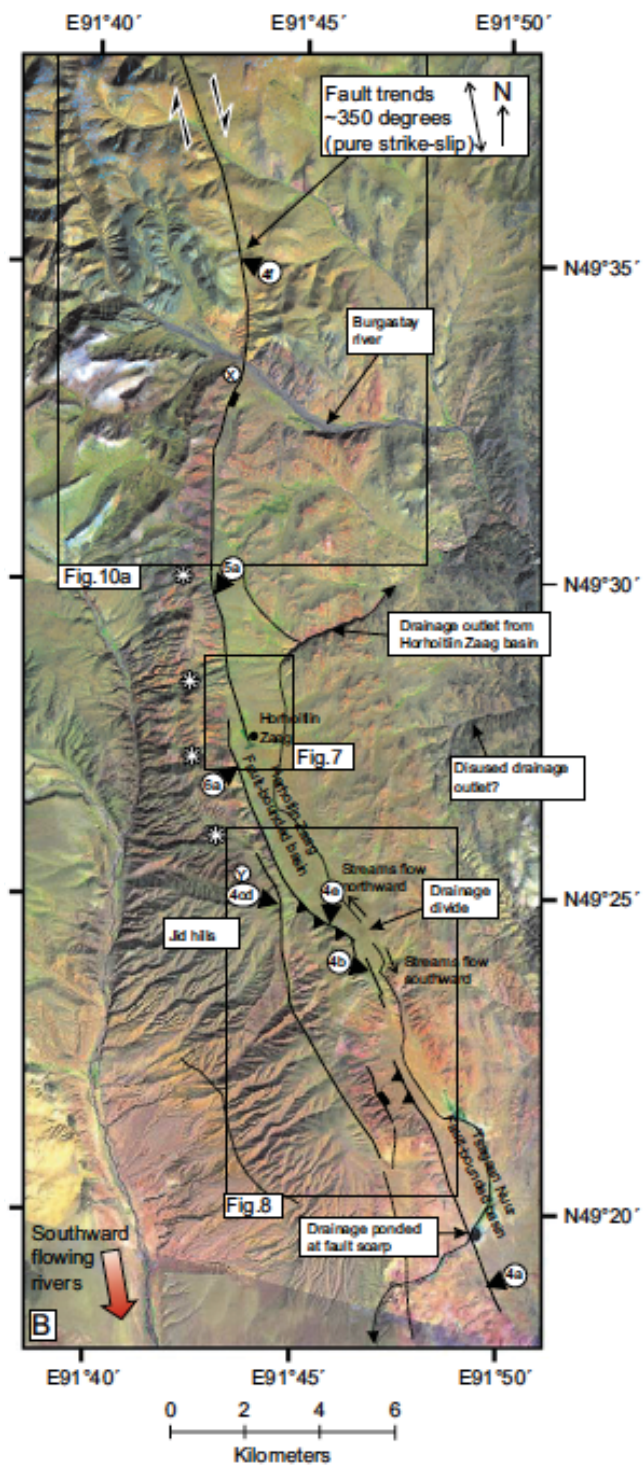




Red lines = earthquake ruptures  
 Baljinnyam et al. 1993  
 Walker et al. 2006  
 Nissen et al. 2009  
 Laura Gregory (next talk)

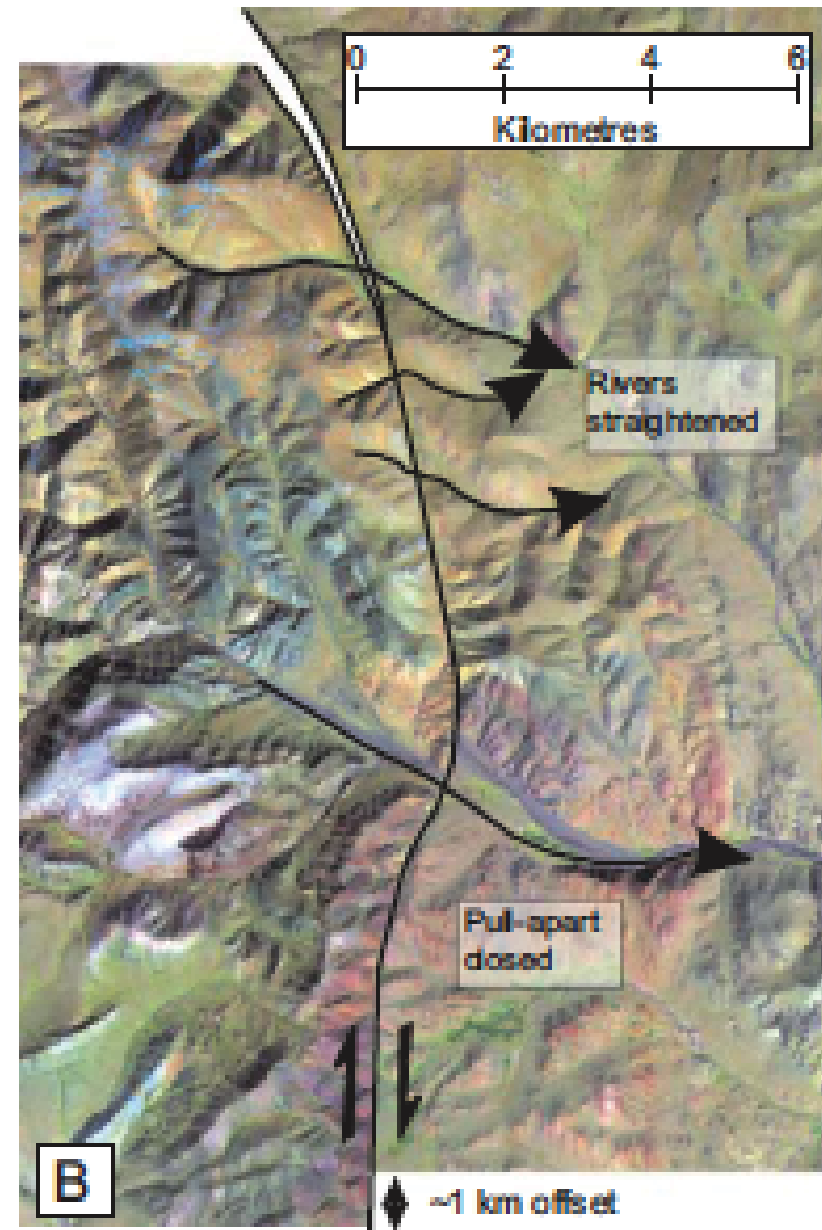
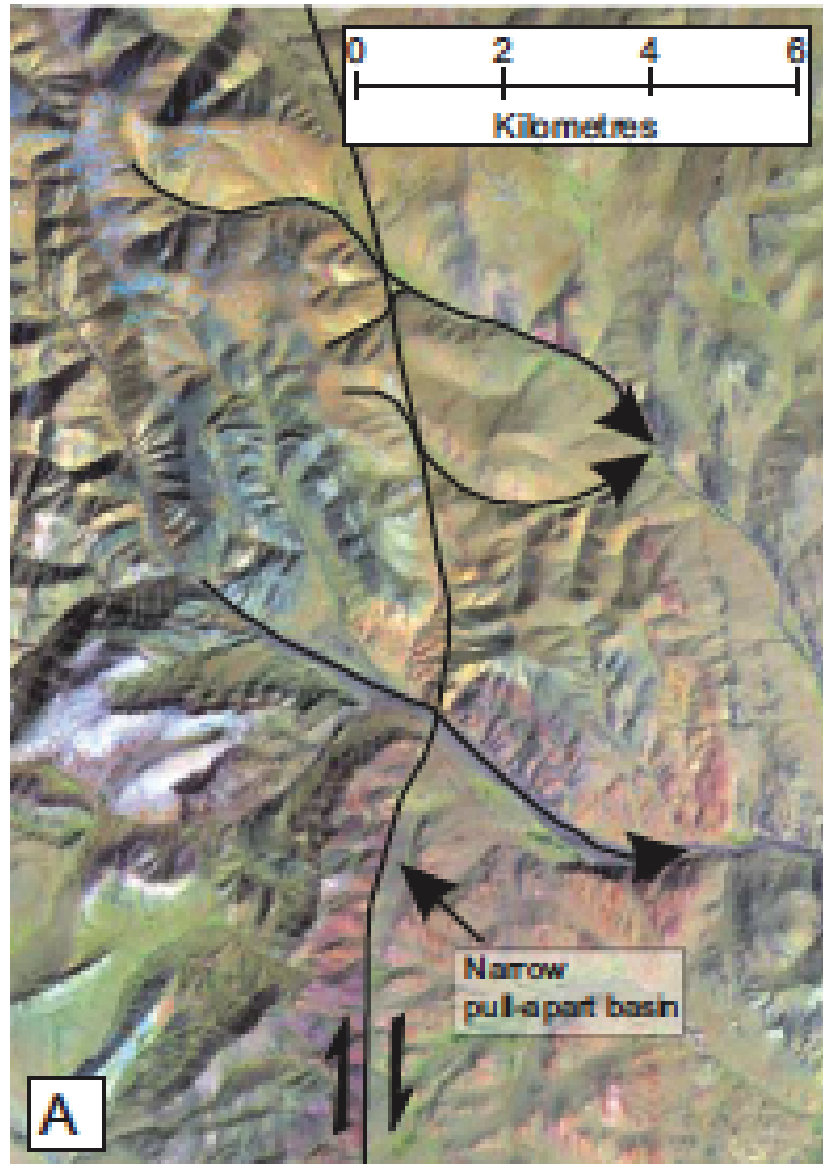




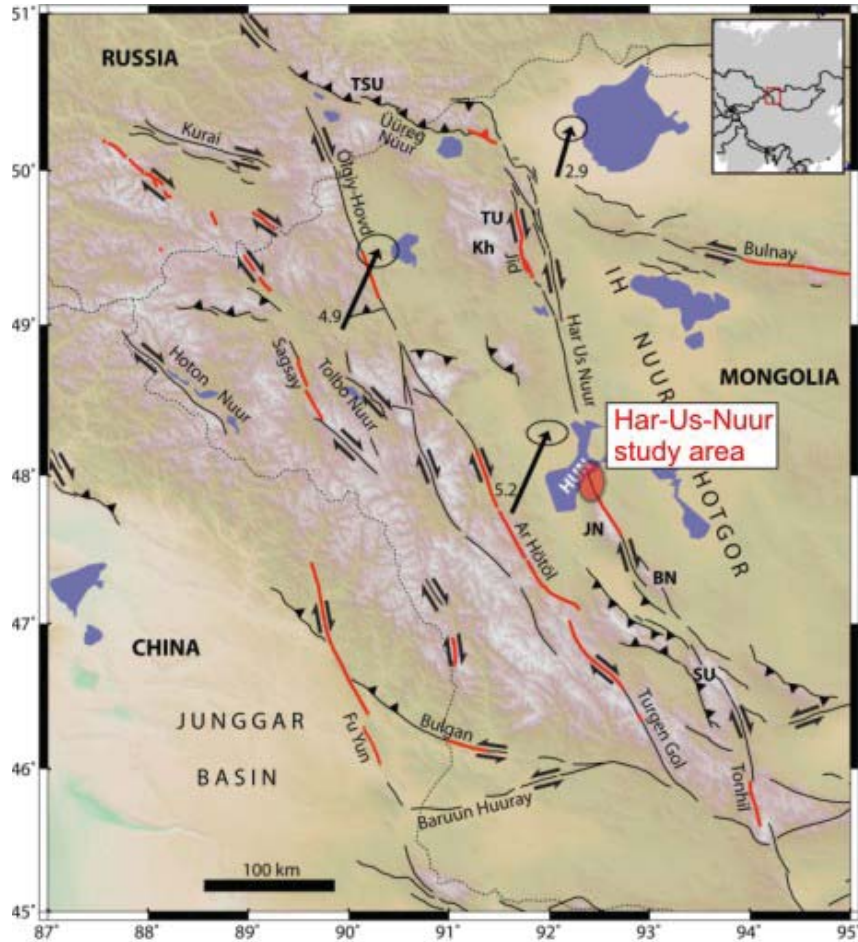


Walker et.al. 2006





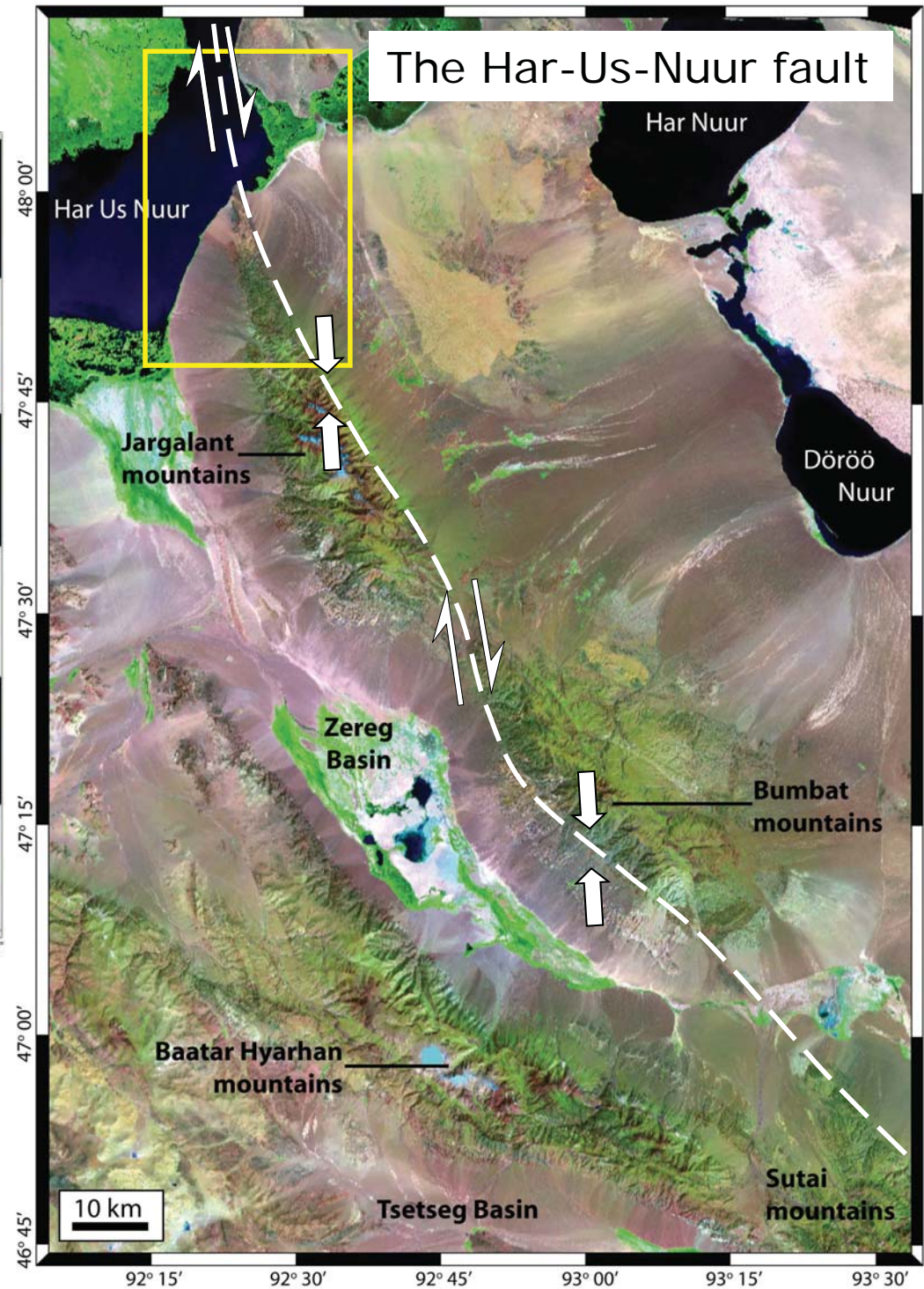




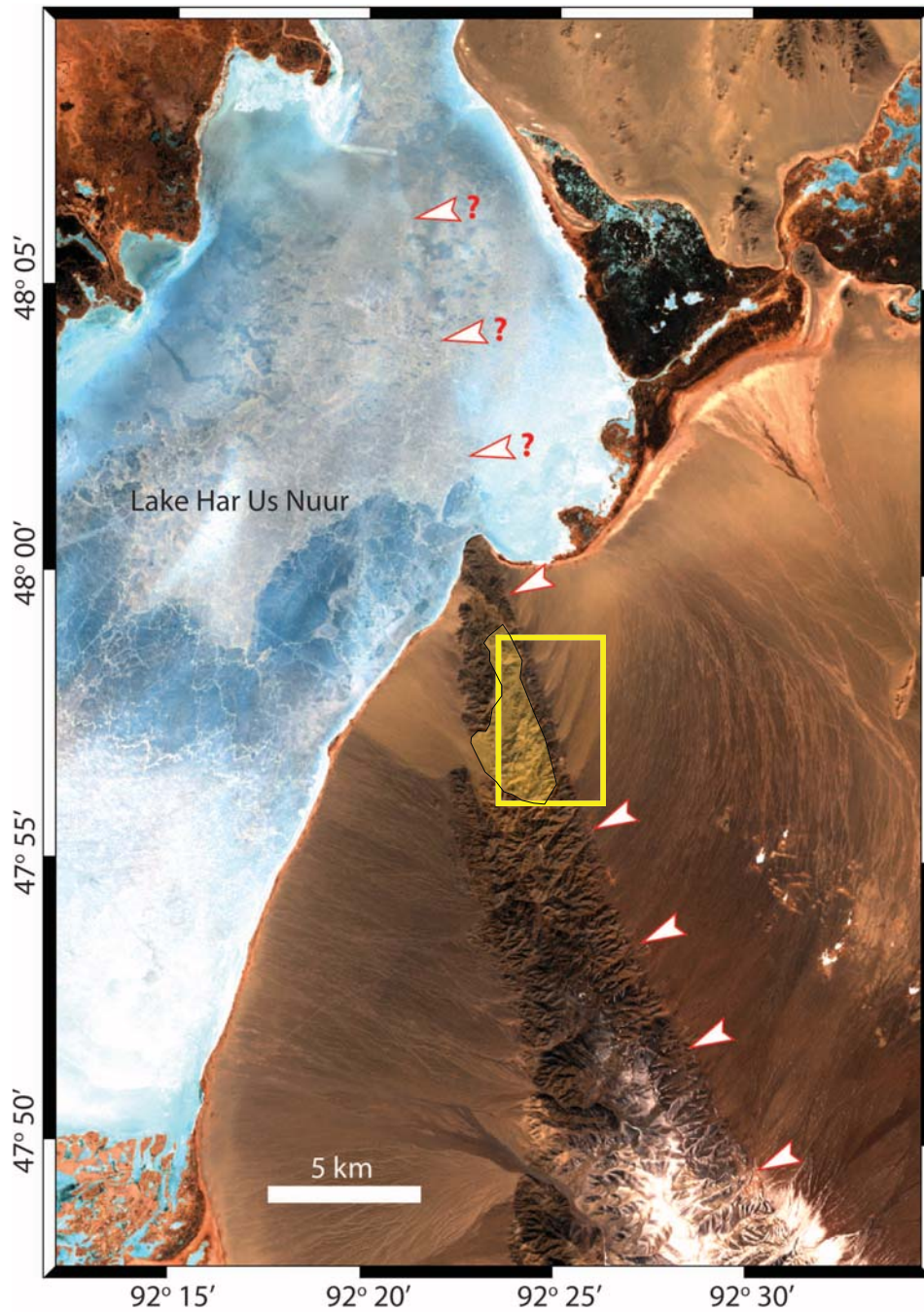
Red lines = earthquake ruptures

Question: what is the present-day distribution of fault slip in the Altay?

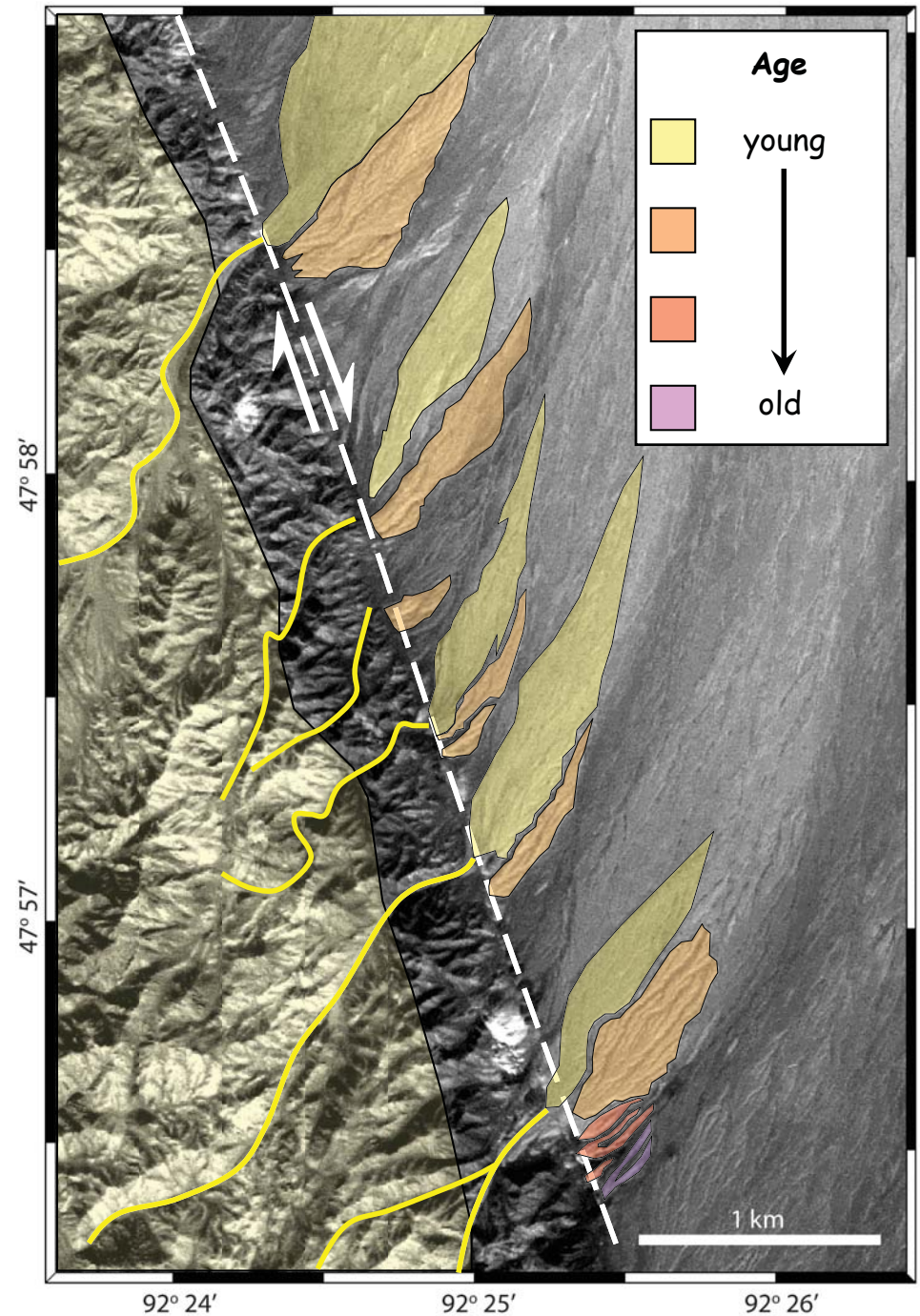
E. Nissen et.al., 2009





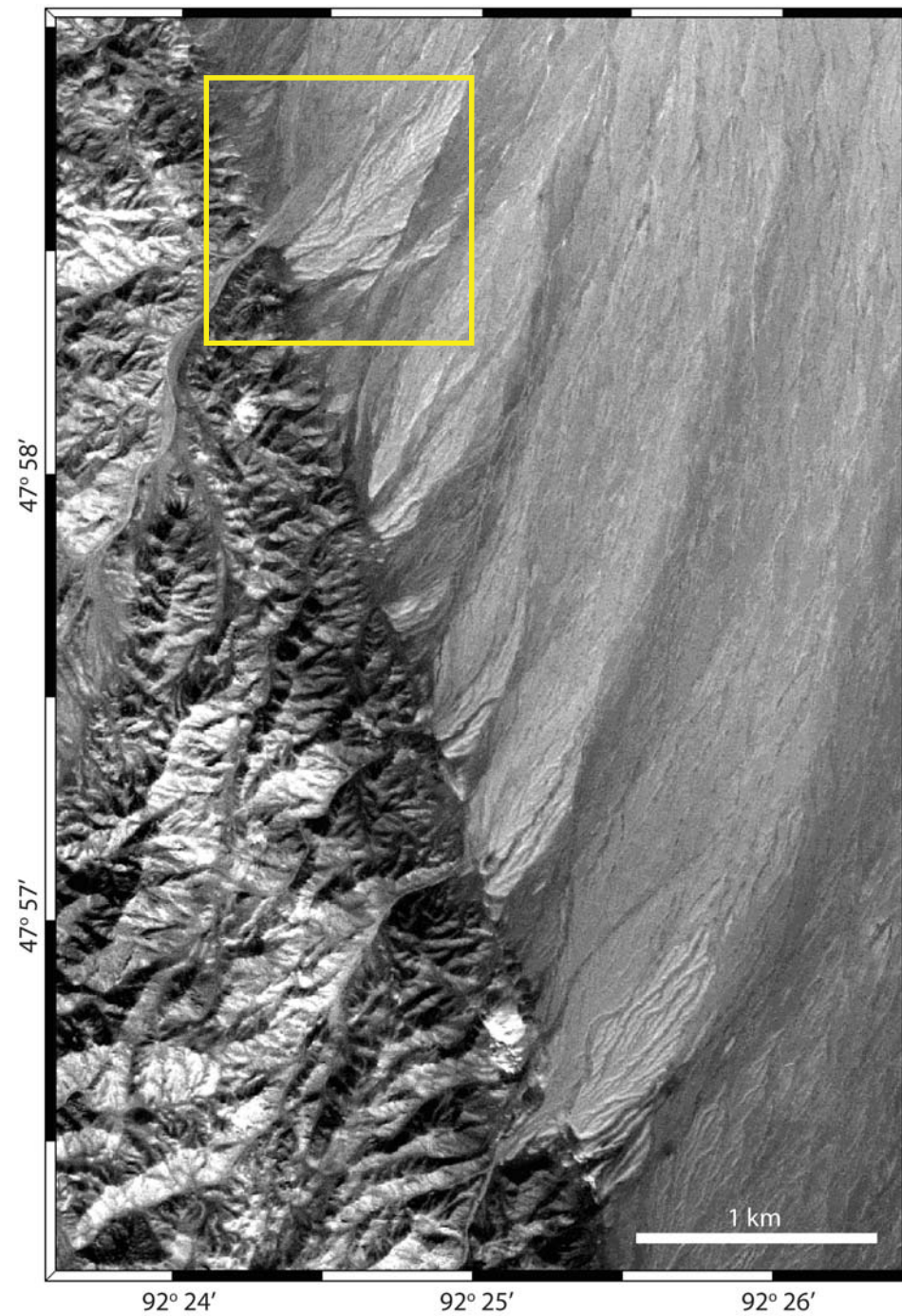
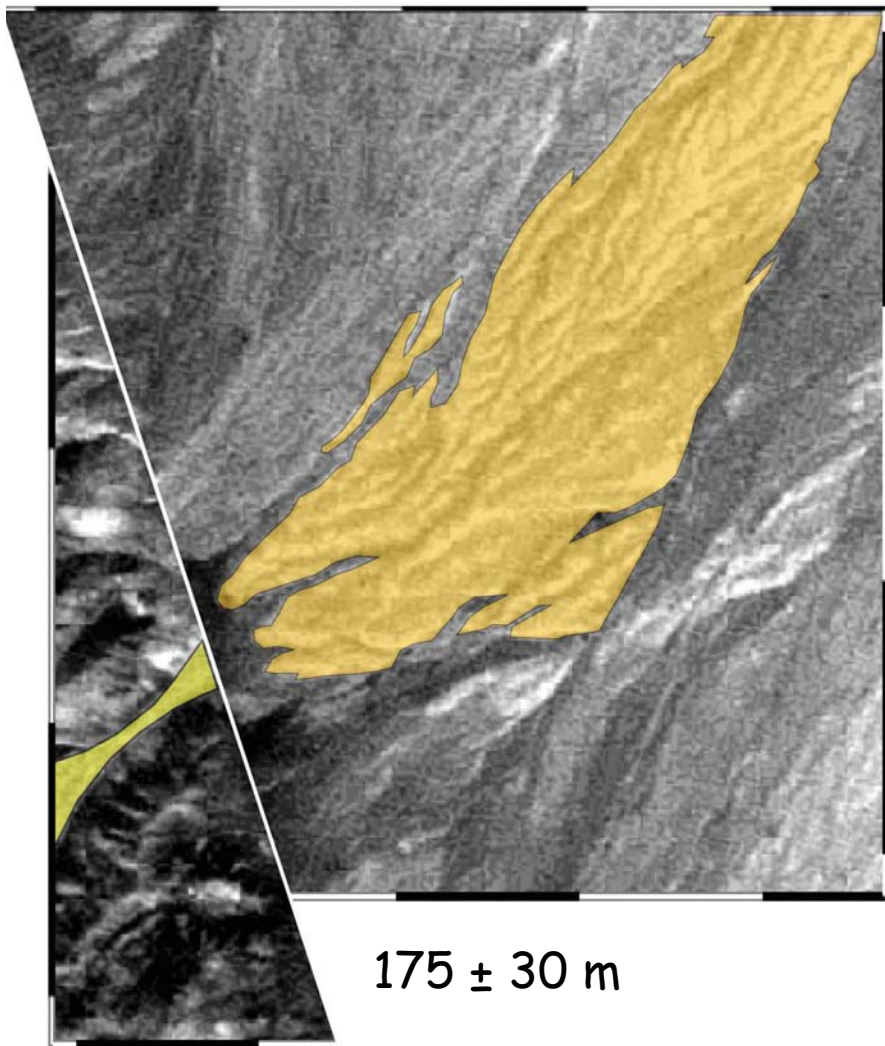


ASTER image (15 m pixels)

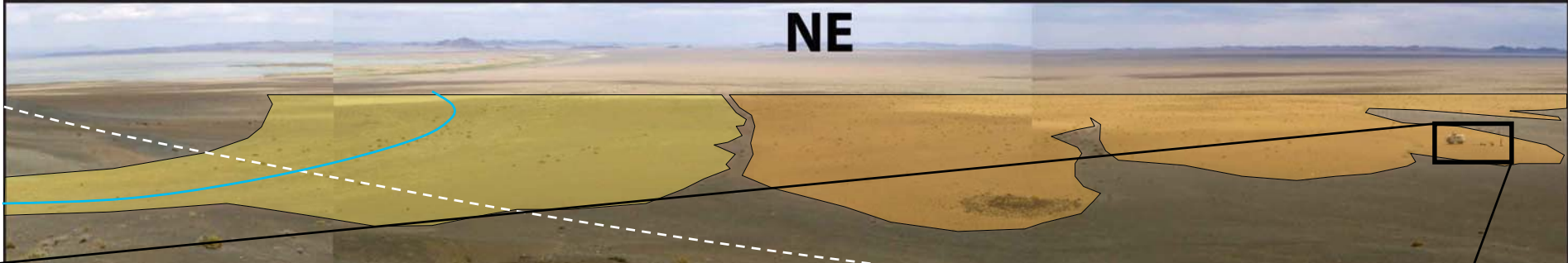


SPOT5 image (2.5 m pixels)





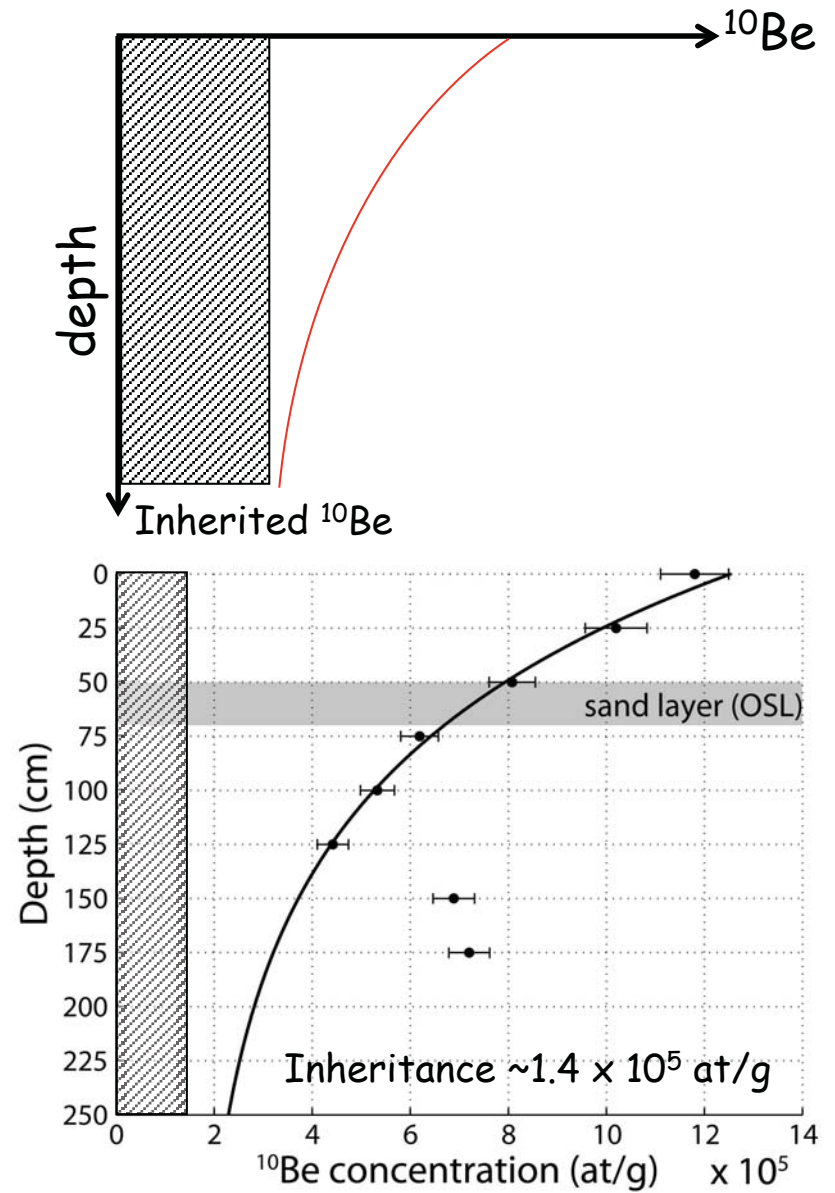








## In-situ cosmogenic $^{10}\text{Be}$ dating



Minimum age  $\sim 75,000$  years

Maximum slip-rate  $\sim 2.4 \pm 0.4$  mm/yr



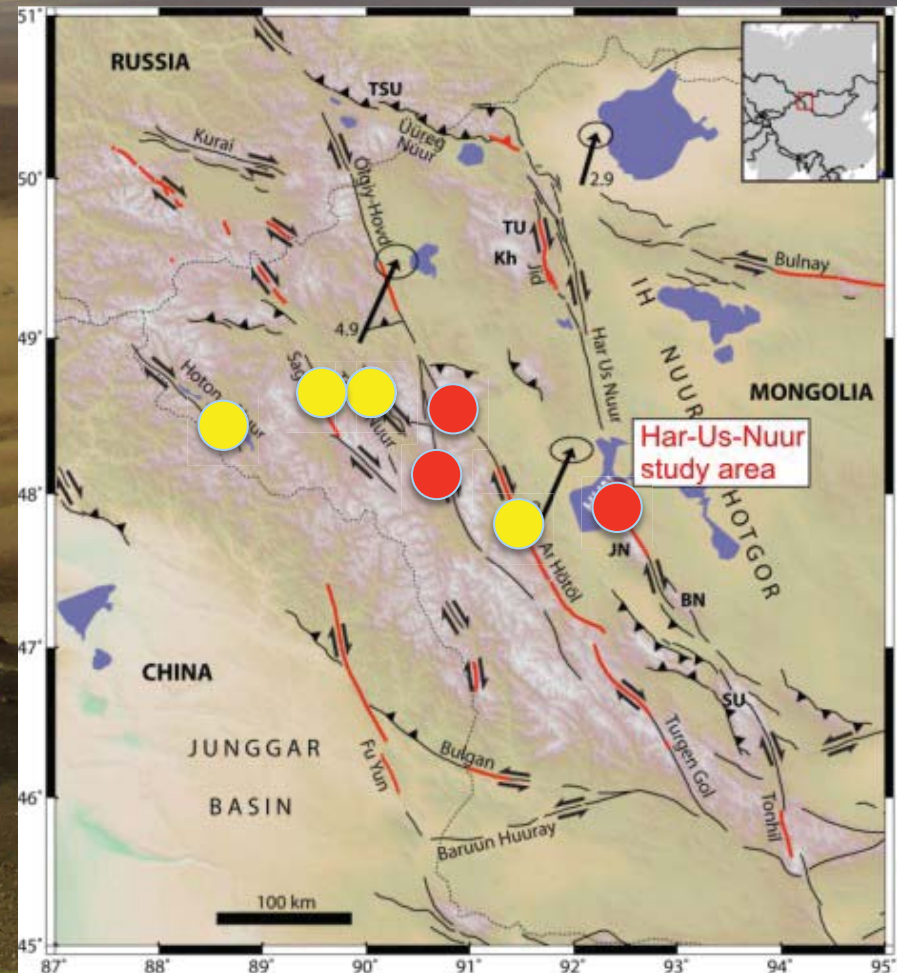


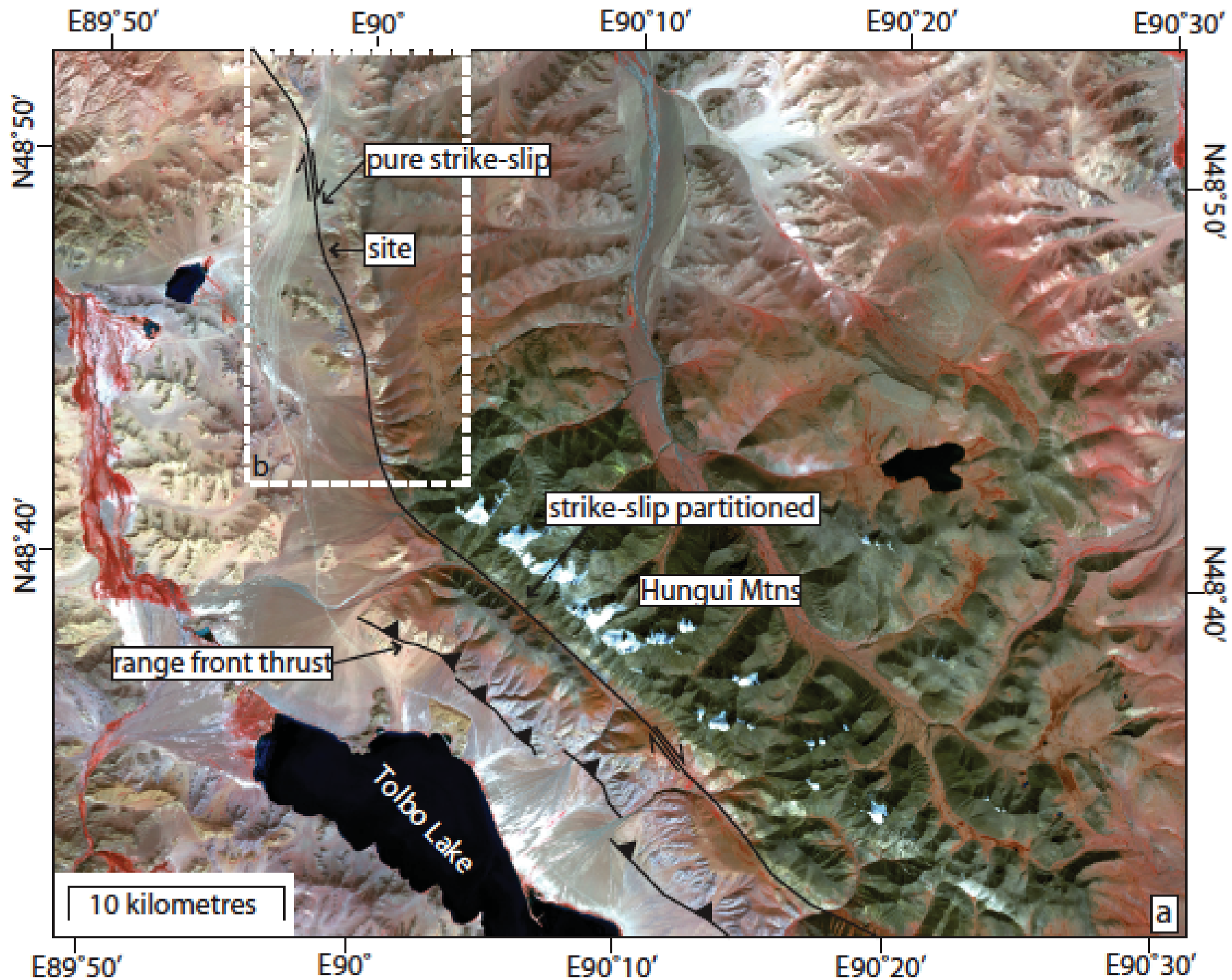
Palaeo-earthquake ruptures  
Length ~ 30 km  
Slip ~ 2.5 m  
Magnitude ~ 7



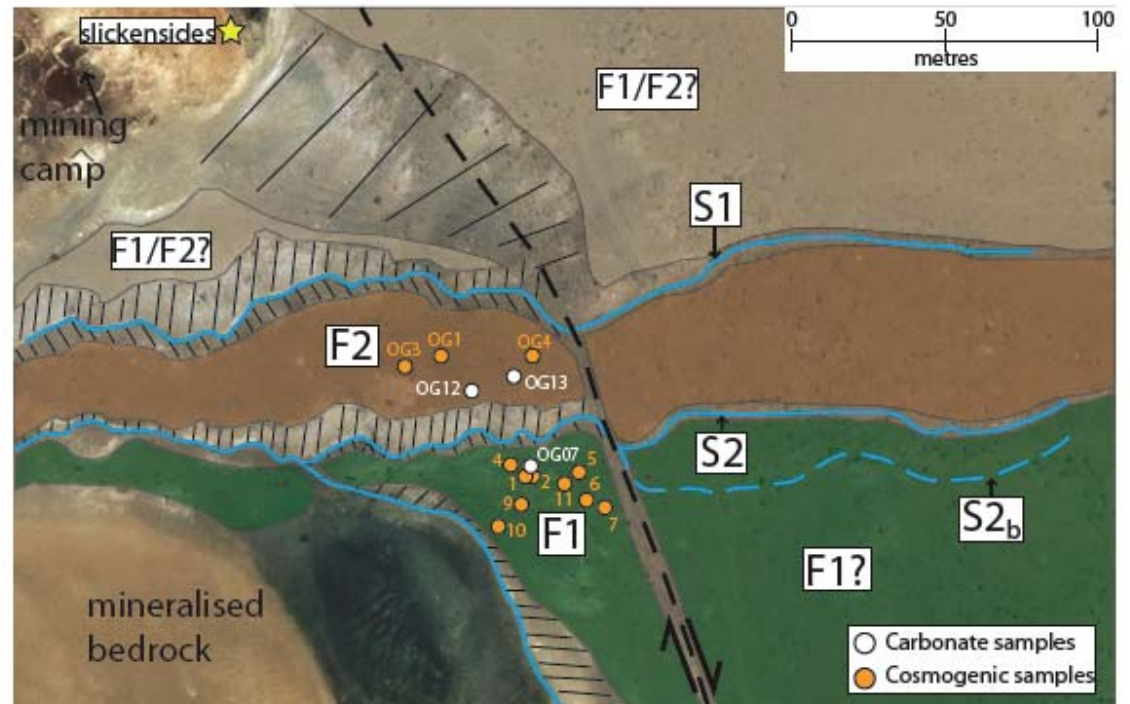
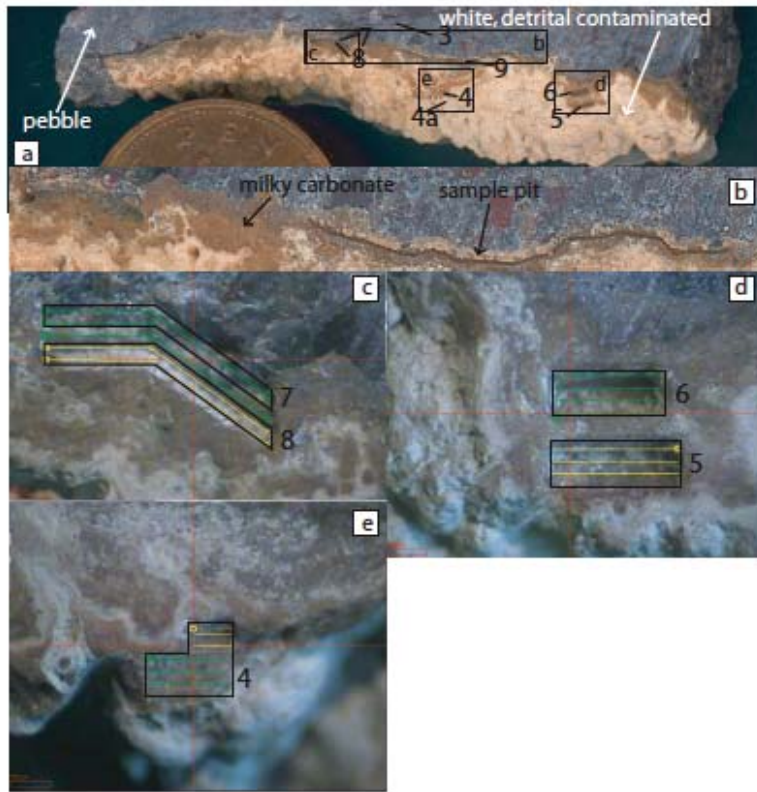
Har-Us-Nuur fault slip-rate is  $\sim 2.4$  mm/yr  
Evidence for paleo-earthquake of  $M_w \sim 7$   
Average earthquake repeat interval  $\sim 1,000$  yr

In these examples we are using  
 $^{10}\text{Be}$  exposure dating  
Optical (OSL) dating  
U-series dating









Quickbird imagery



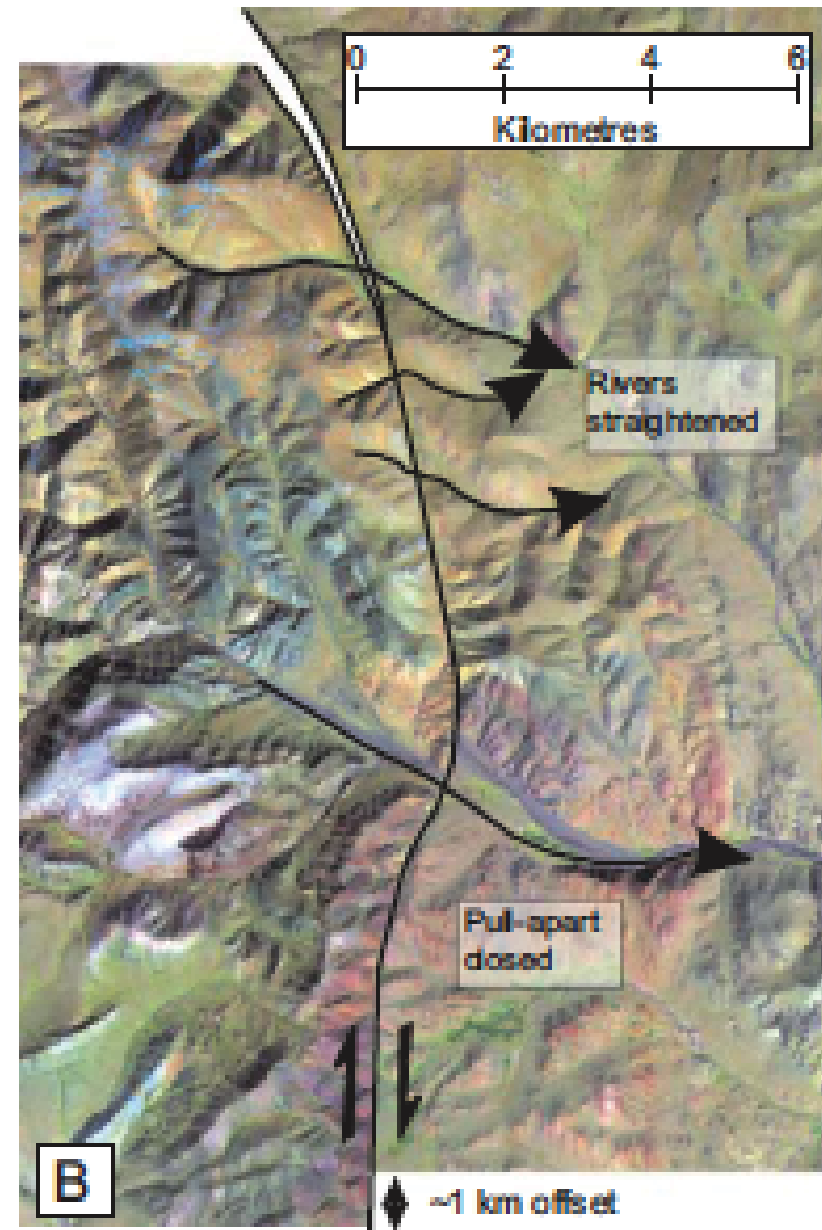
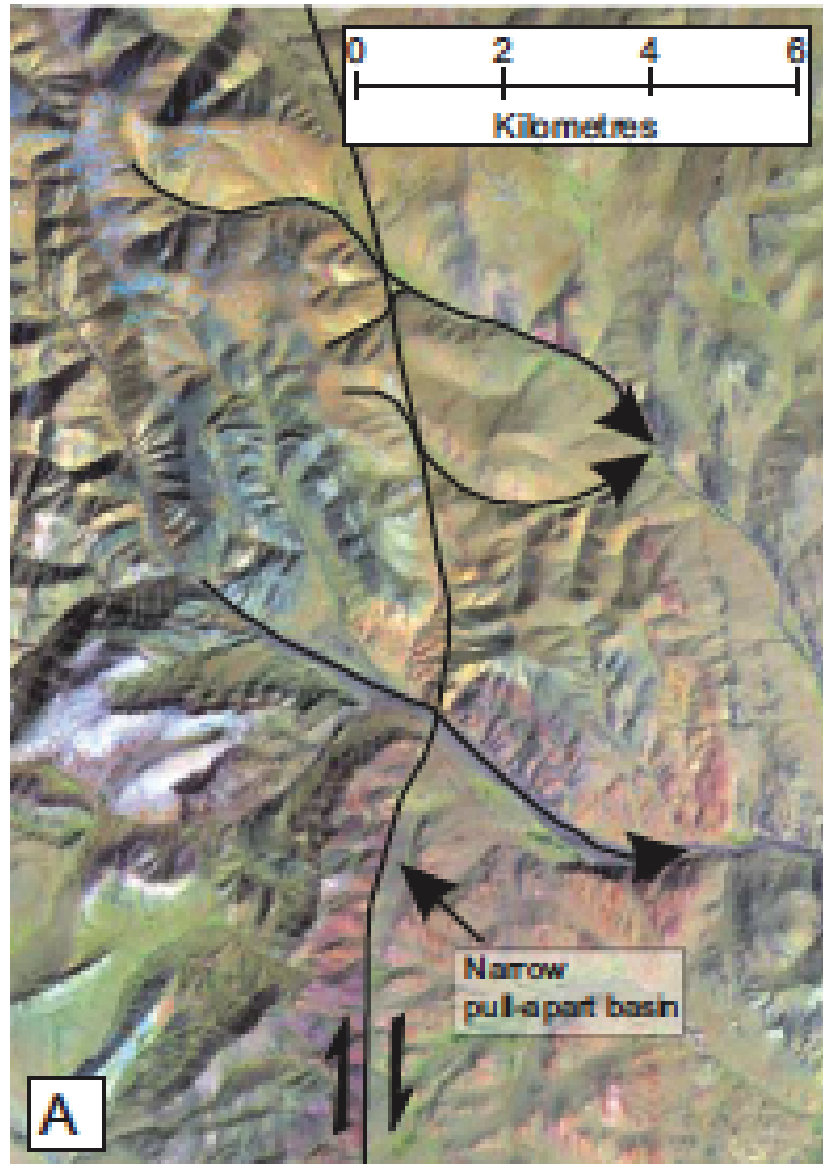




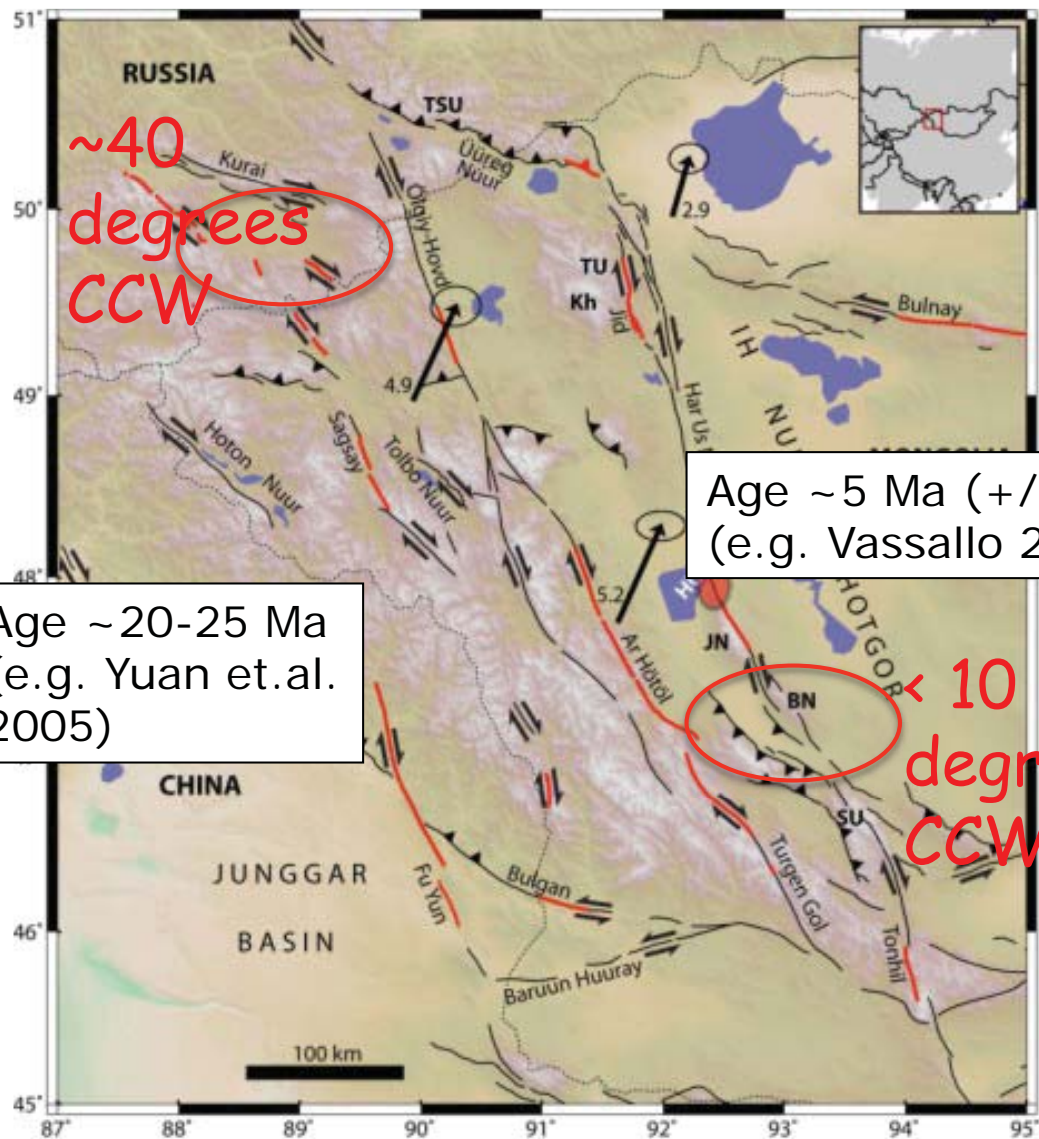
# Geological records of faulting











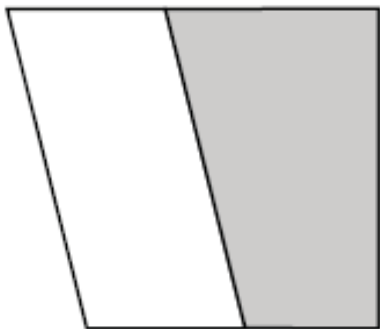
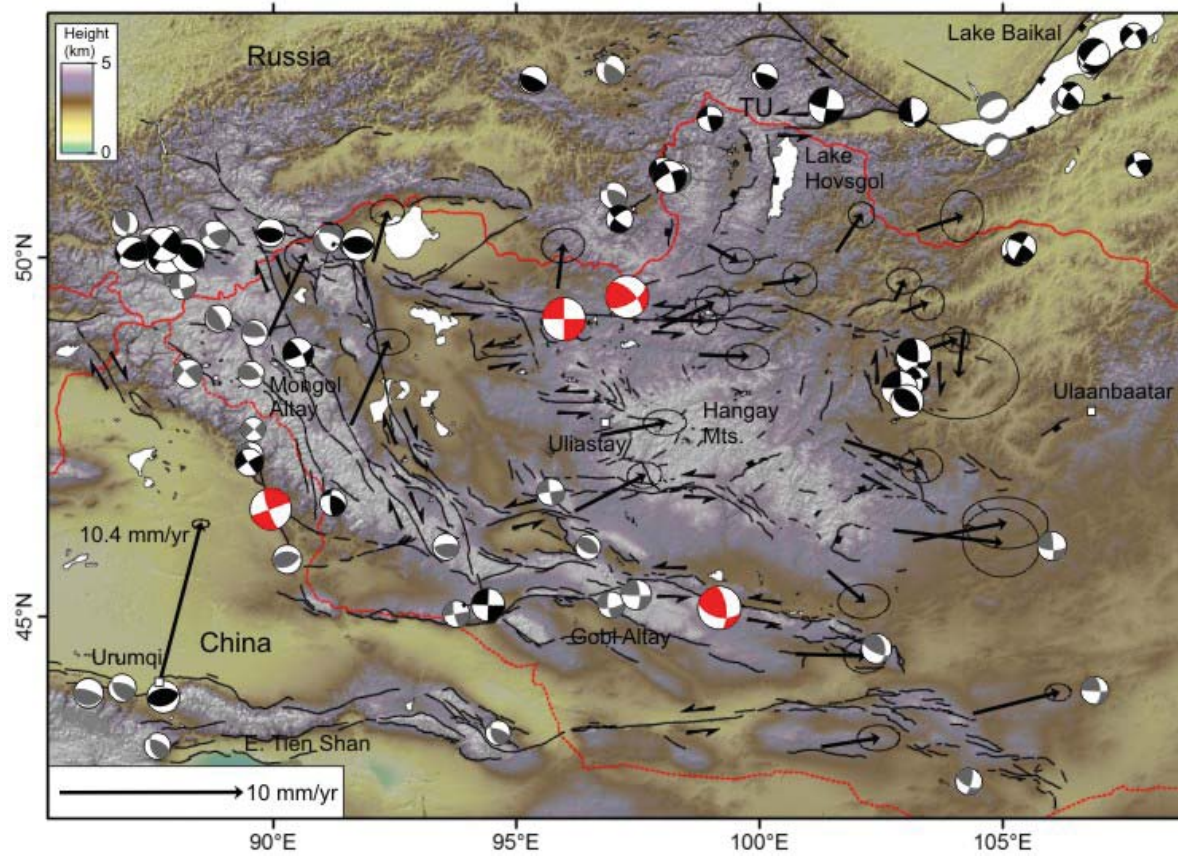
~40  
degrees  
CCW

Age ~20-25 Ma  
(e.g. Yuan et.al.  
2005)

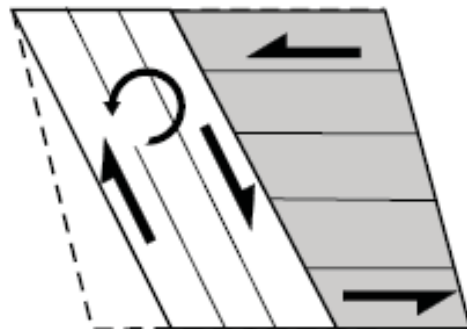
Age ~5 Ma (+/- 3 Ma)  
(e.g. Vassallo 2006)

< 10  
degrees  
CCW





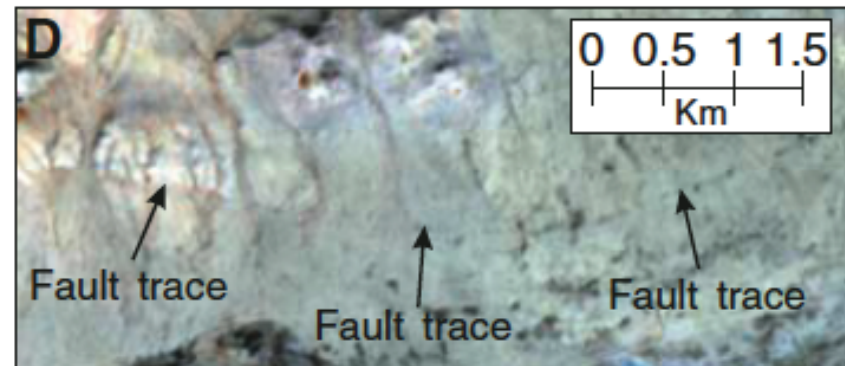
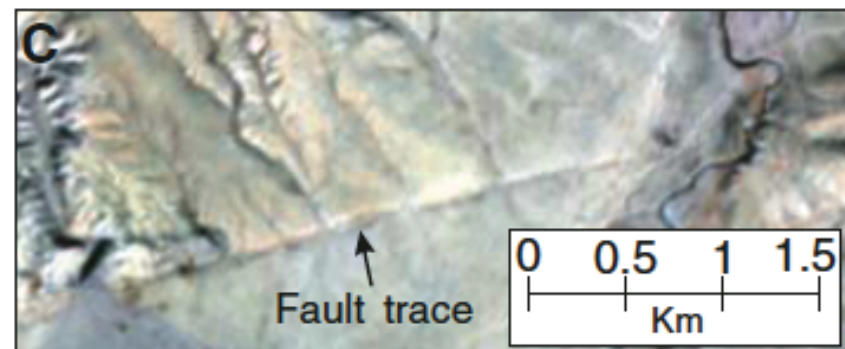
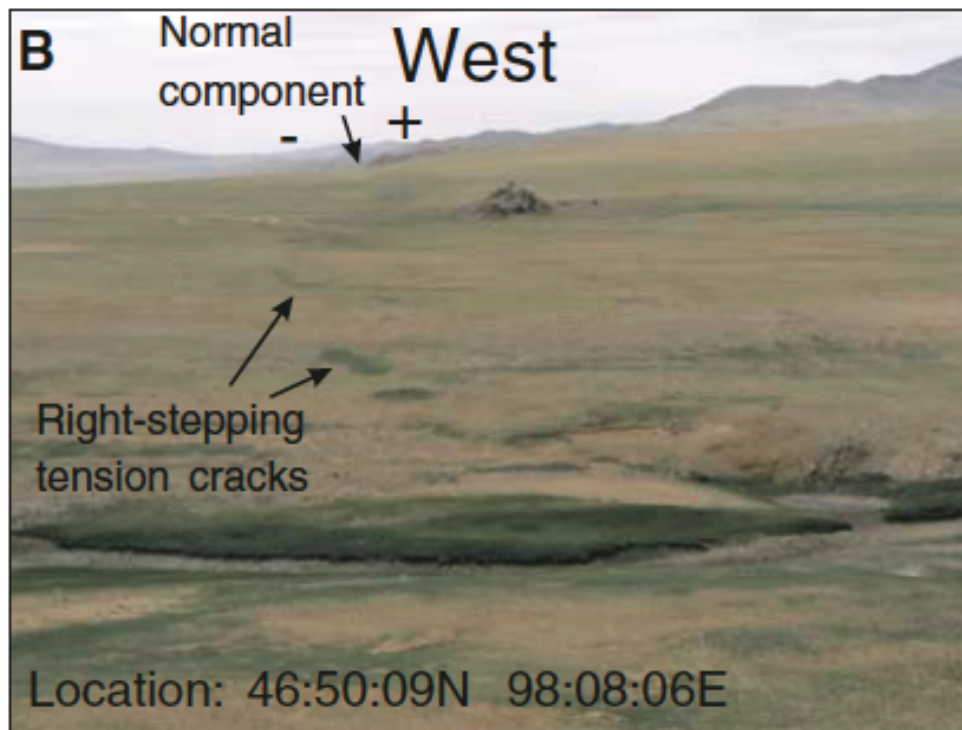
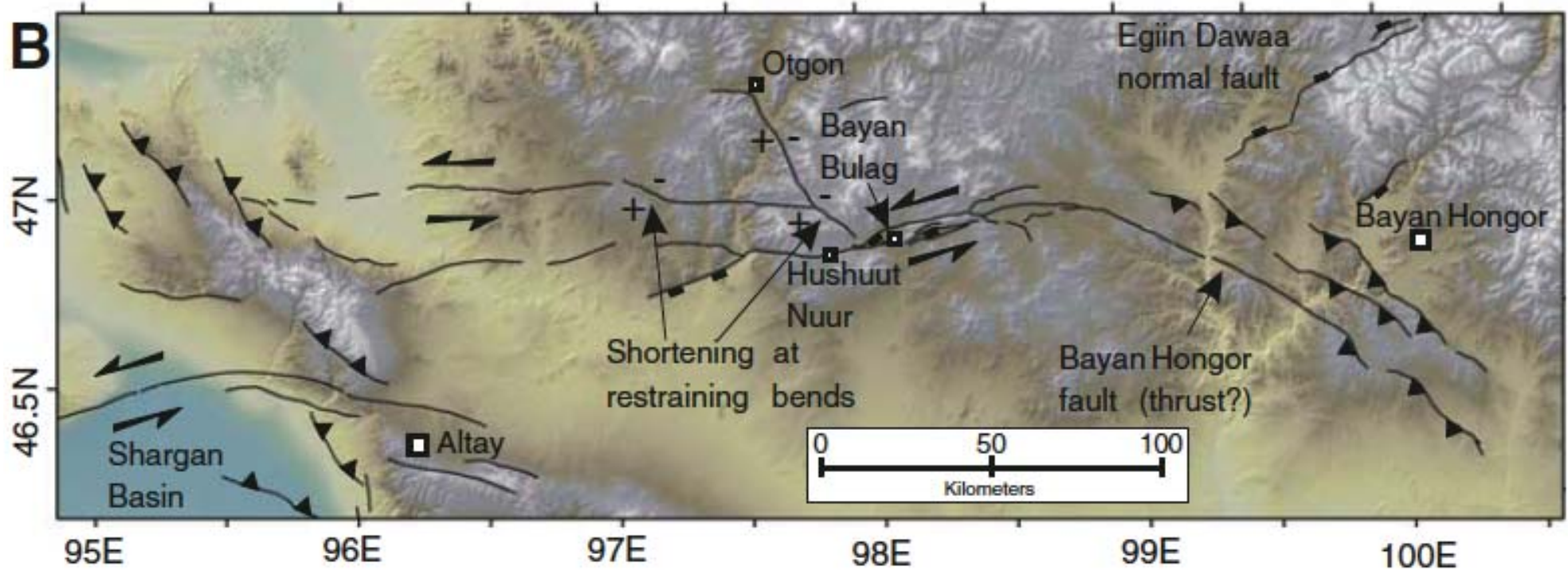
**A**



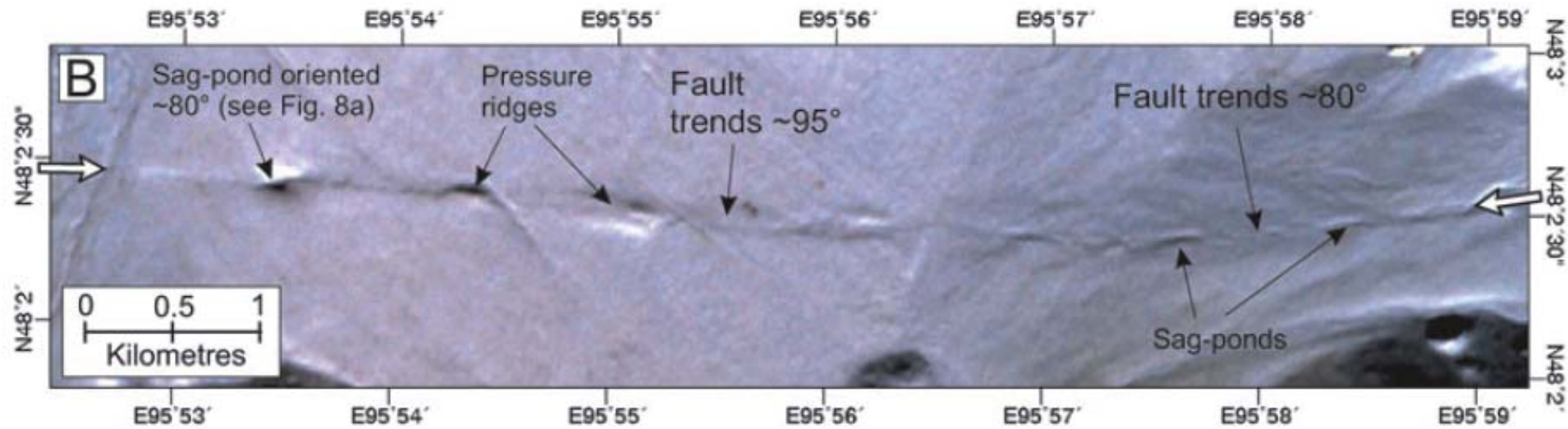
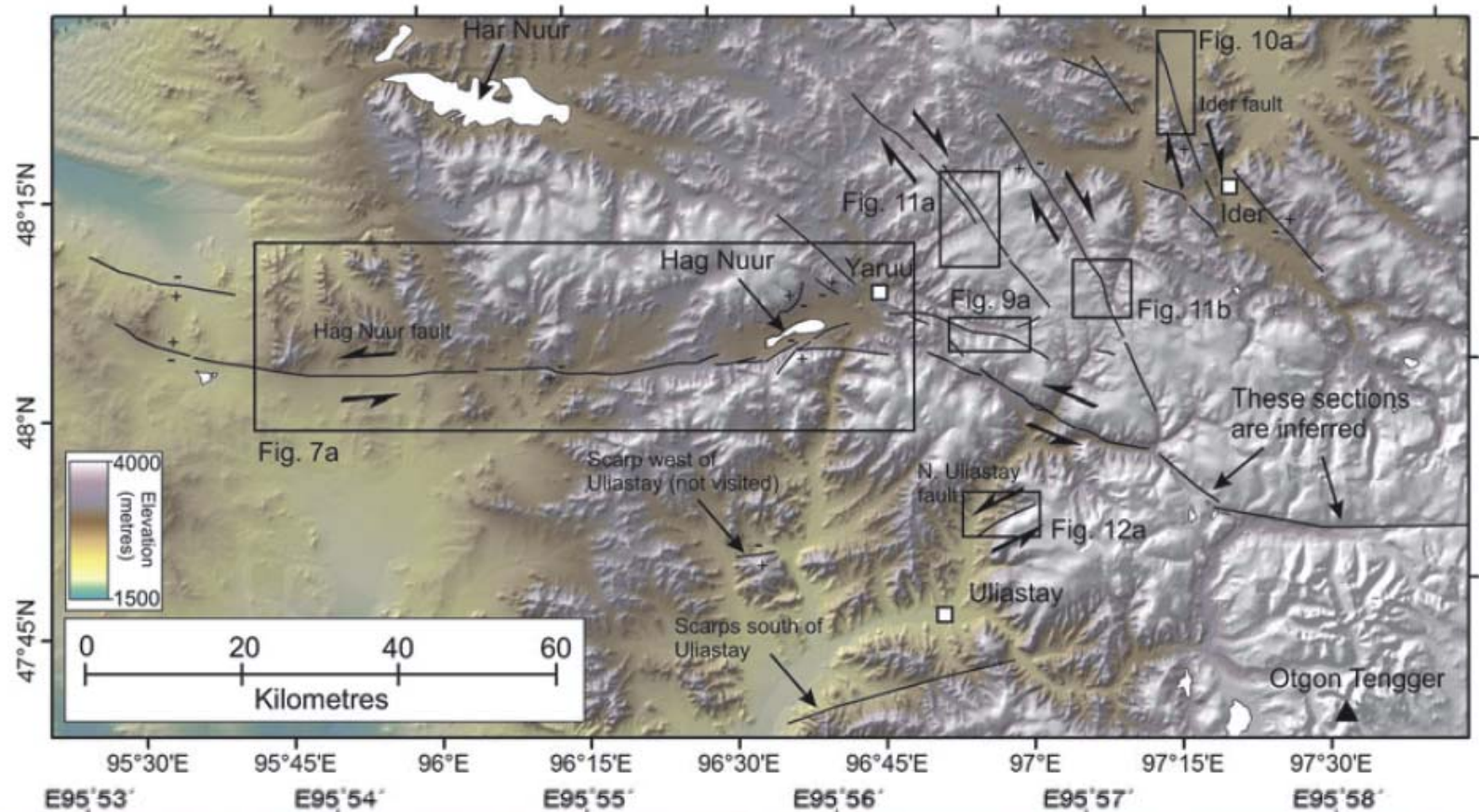
**B**

Bayasgalan et.al. 2005





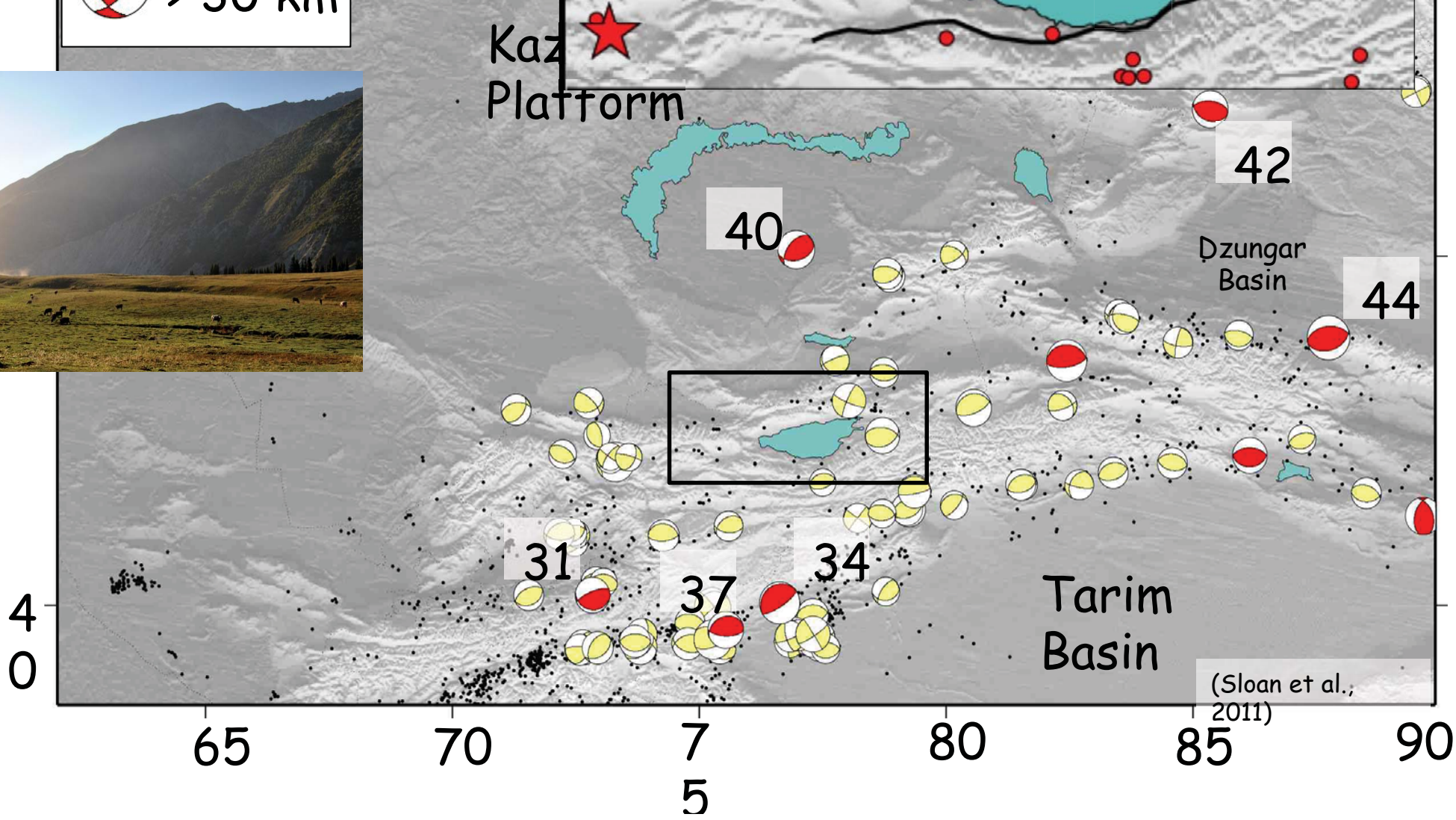
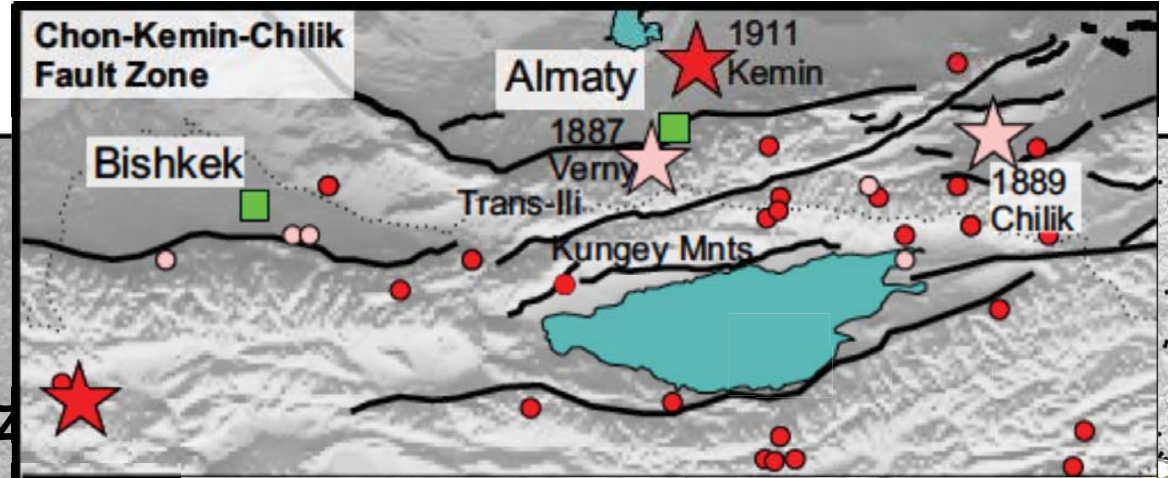
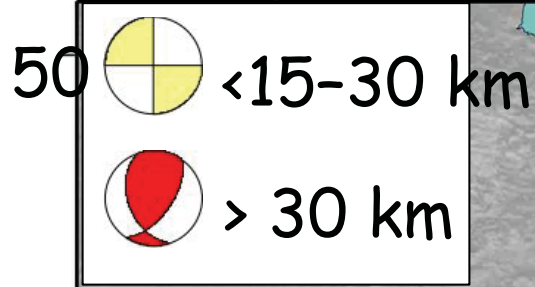




Walker et.al. 2008



# Northern Tien Shan

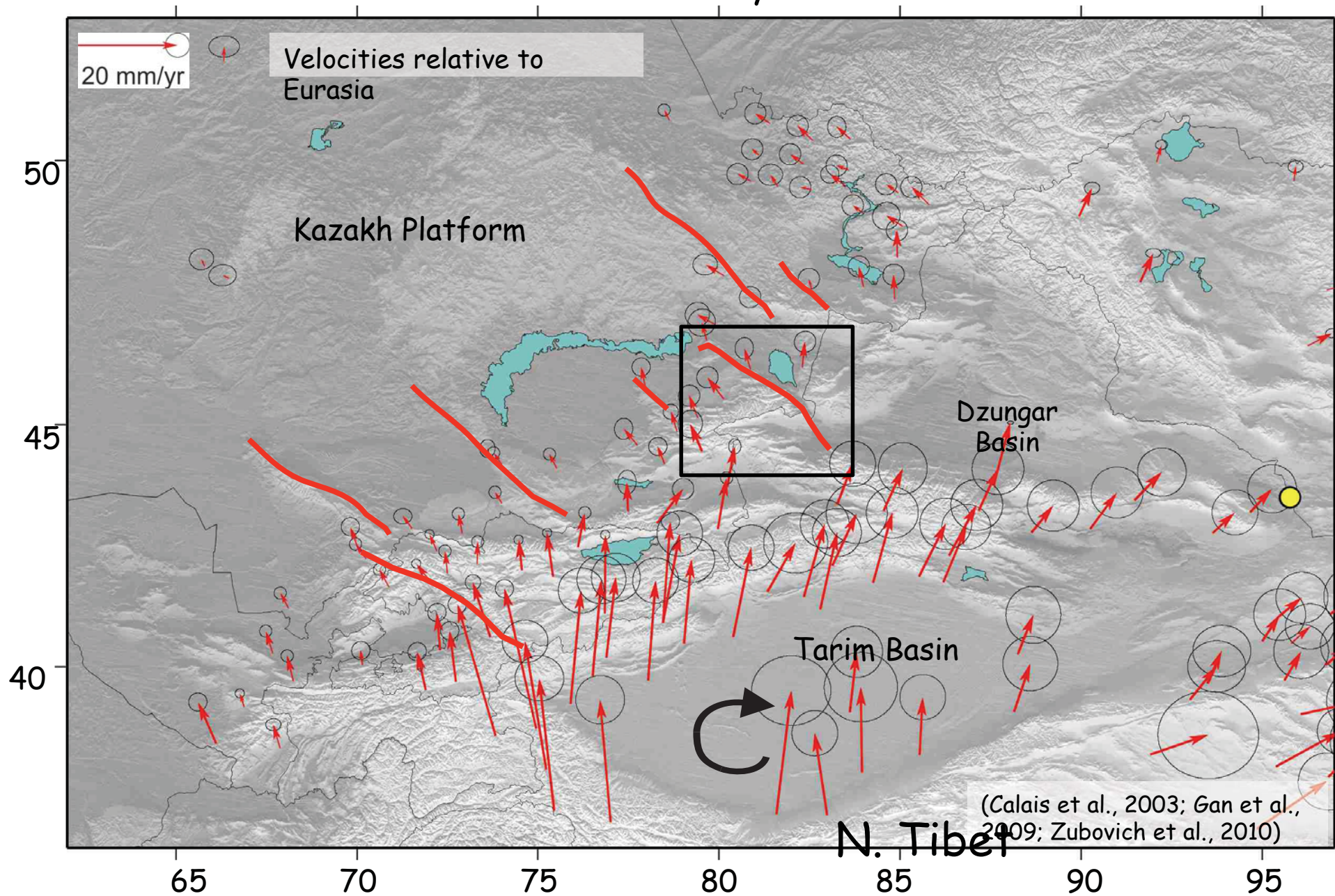






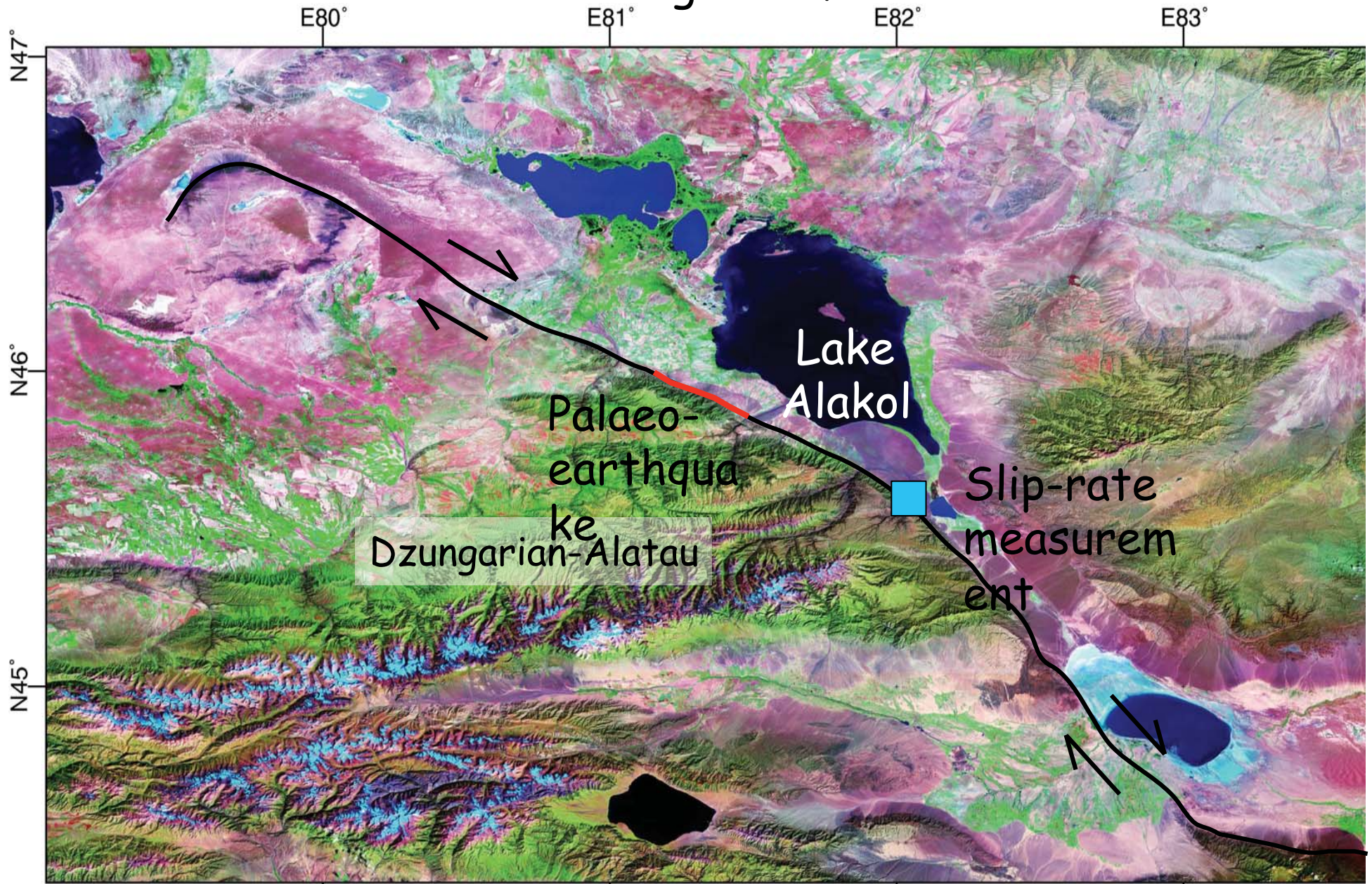


# GPS velocity field



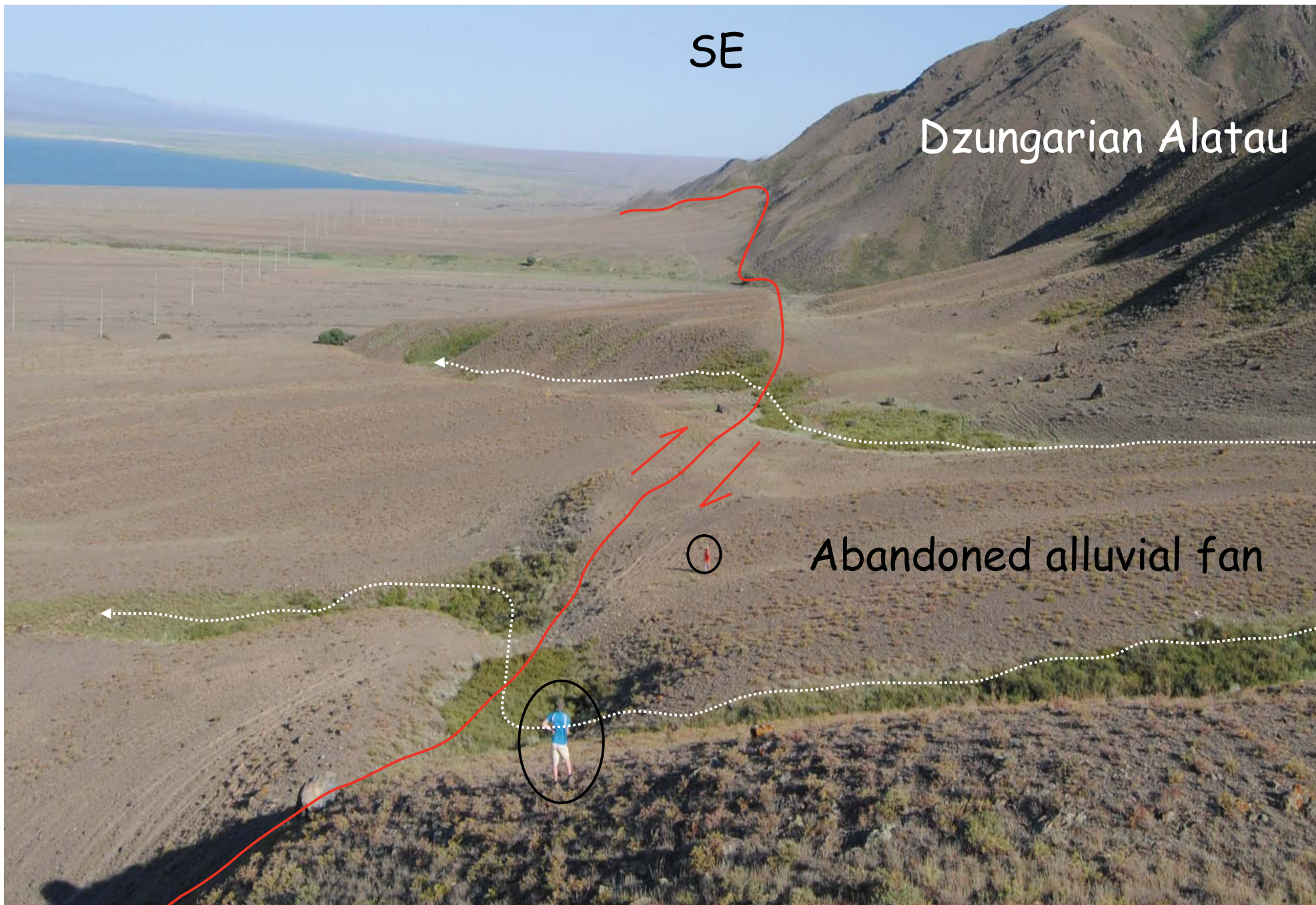


# Dzungarian fault



Campbell et al., *in preparation*



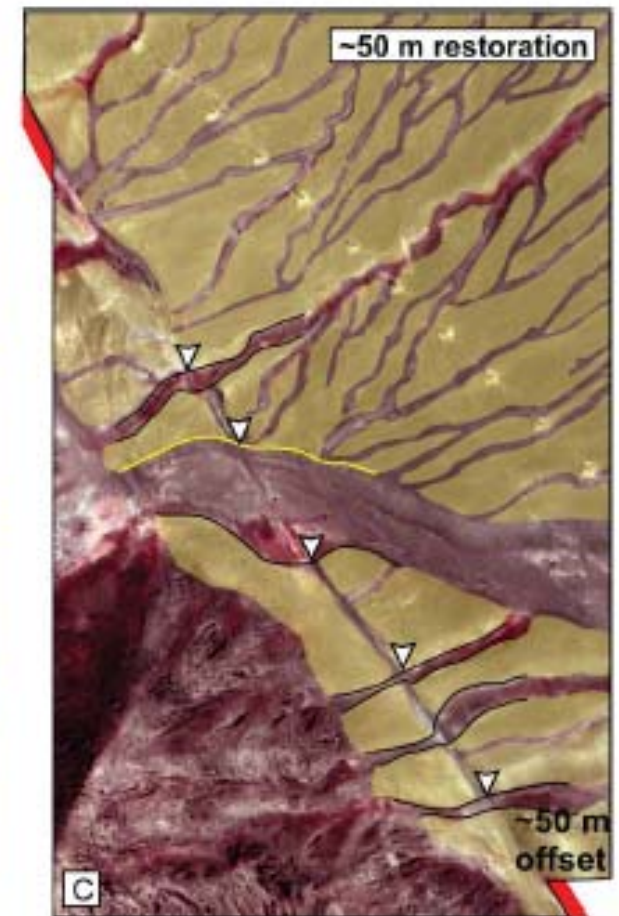
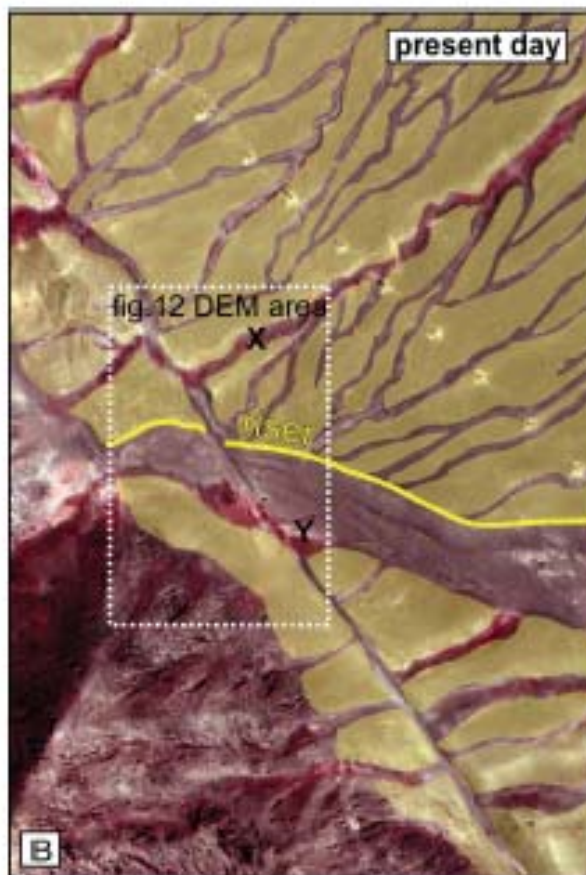
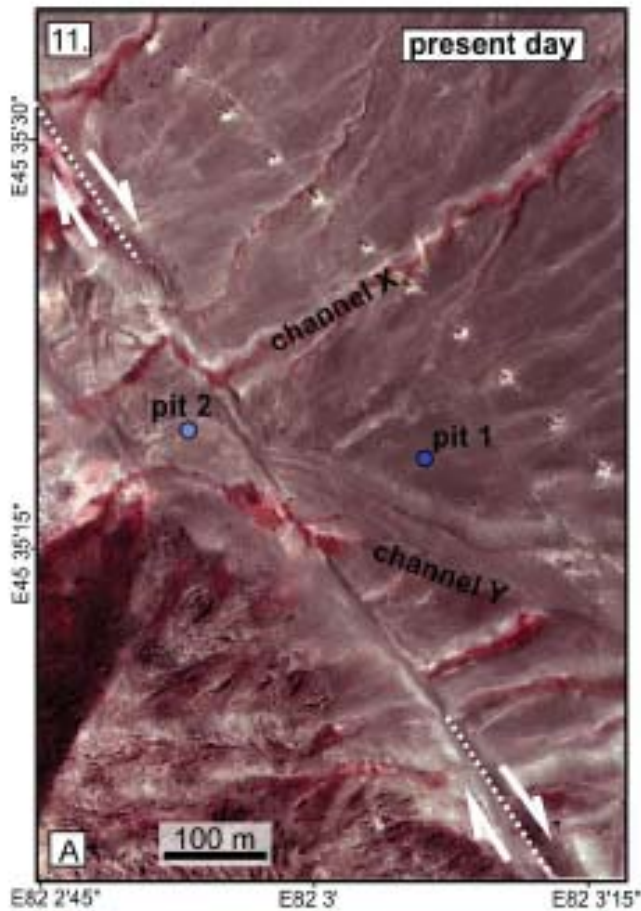


SE

Dzungarian Alatau

Abandoned alluvial fan





50 +/- 5 m displacement

Pit 1 OSL dating: 25.7 +/- 5.8 ka

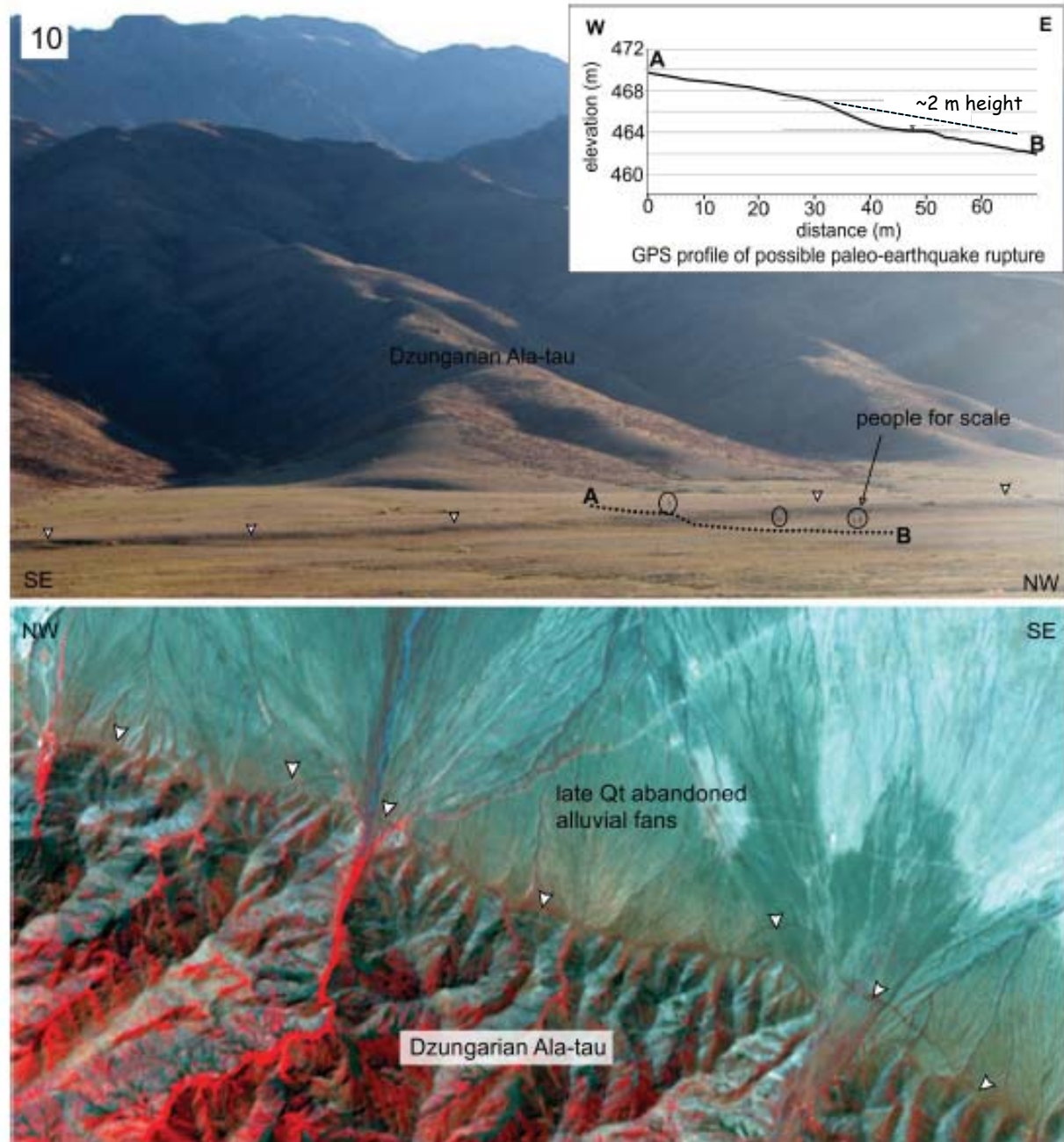
Average slip-rate: 1.4-2.75 mm/yr

KOMPSAT-2 (1 m imagery)

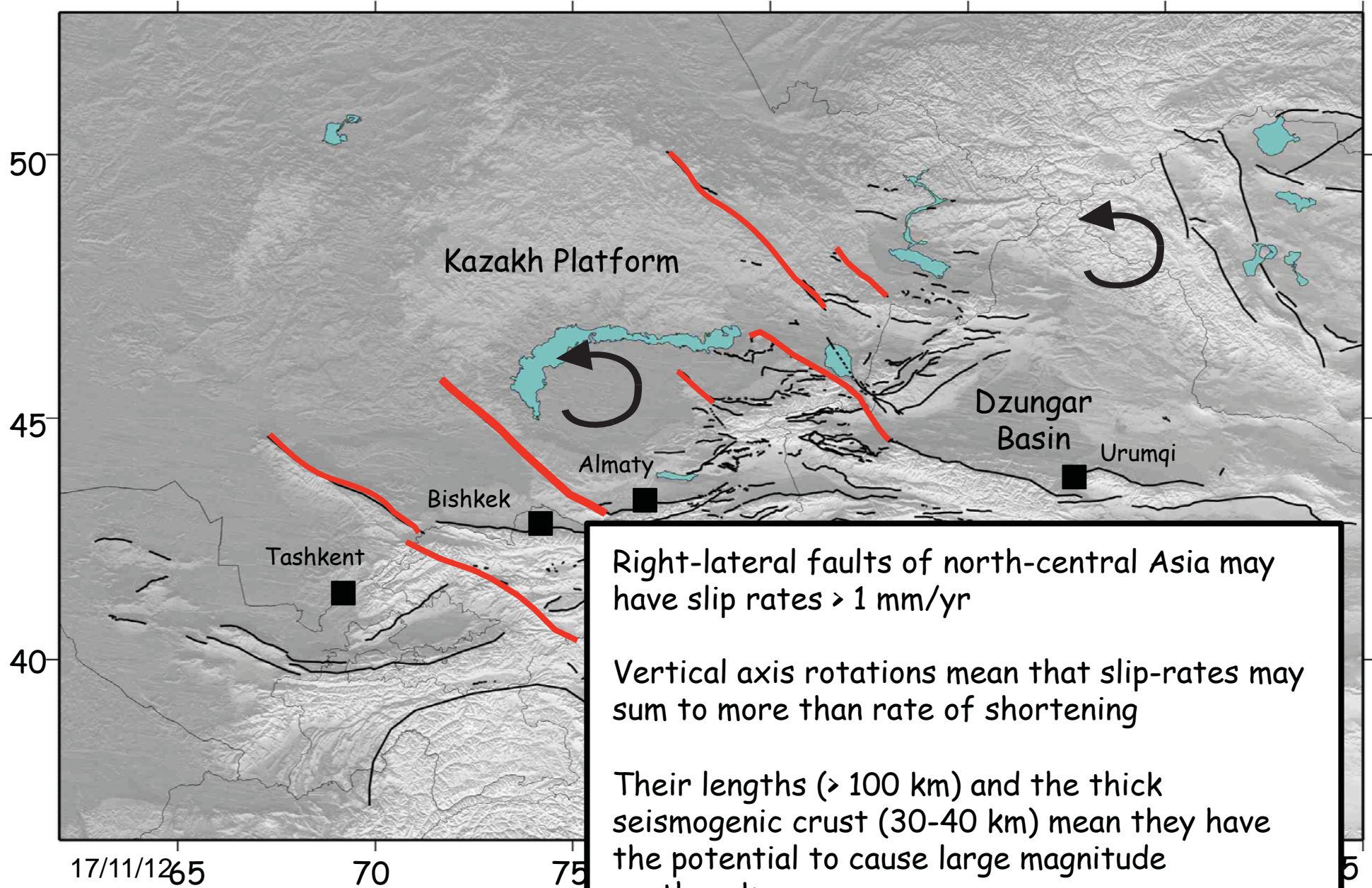


Only one  $M_w \sim 7$   
palaeo-  
earthquake  
rupture visible in  
the landscape

Potential for  
large earthquakes  
( $M_w 7.5+$ ) on  
remaining fault  
segments?







Right-lateral faults of north-central Asia may have slip rates  $> 1$  mm/yr

Vertical axis rotations mean that slip-rates may sum to more than rate of shortening

Their lengths ( $> 100$  km) and the thick seismogenic crust (30-40 km) mean they have the potential to cause large magnitude earthquakes

Thank you



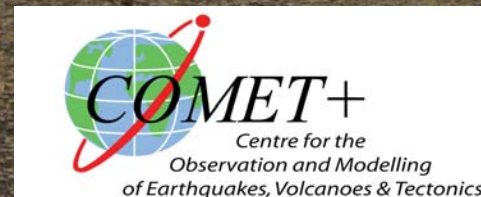


**Thank you**



# Past earthquakes, slip-rates & mountain-building in Mongolia

Richard Walker  
Oxford University





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**Ed Nissen, Laura Gregory, Matt Fox, Conall MacNiocaill**

**MUST**

**Amgalan Bayasgalan, Erdenebat Molor, Gantulga  
Bayasgalan, Tsolmon Amгаа**

**UCL**

**Andy Carter**

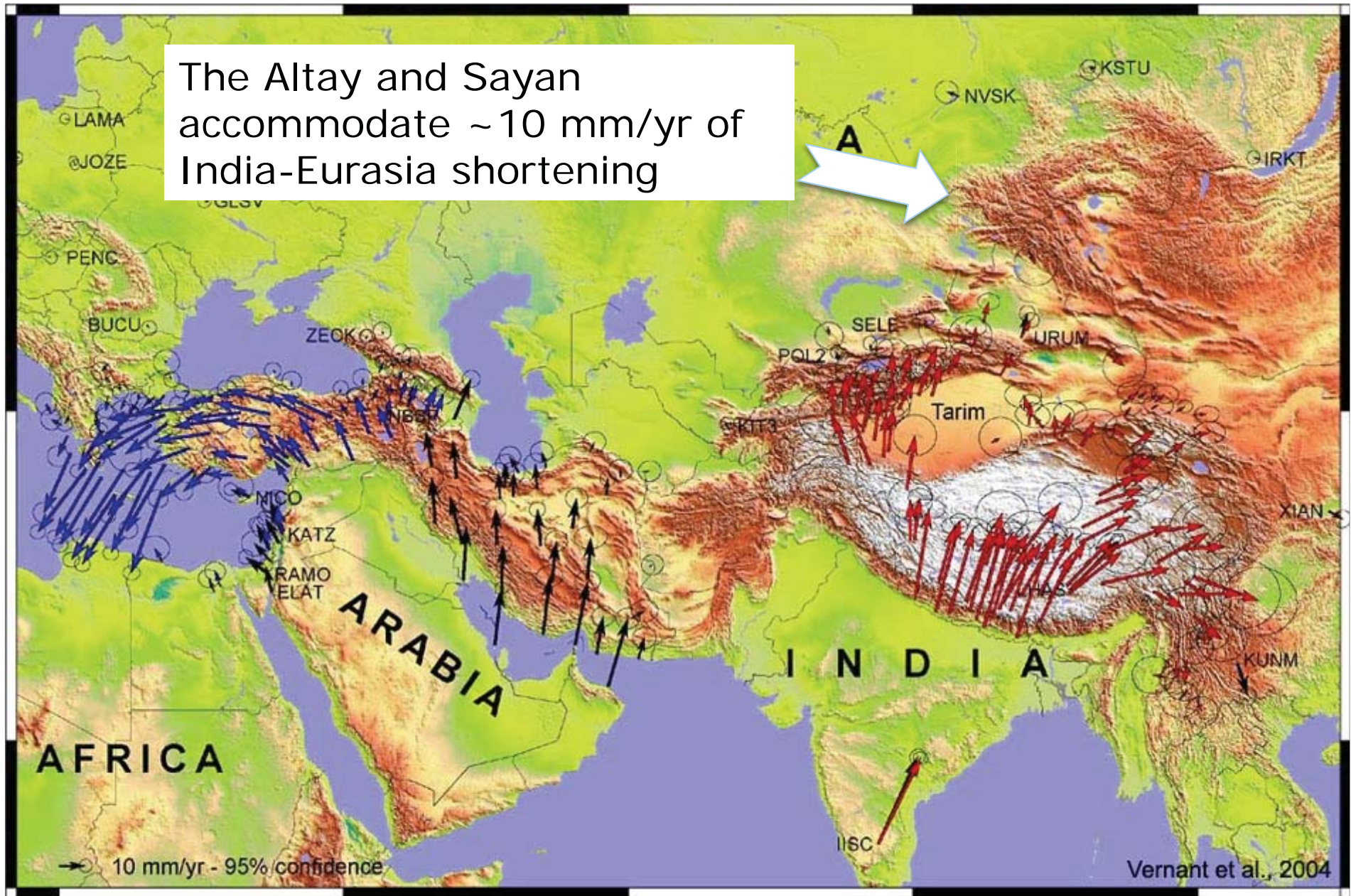
**USC**

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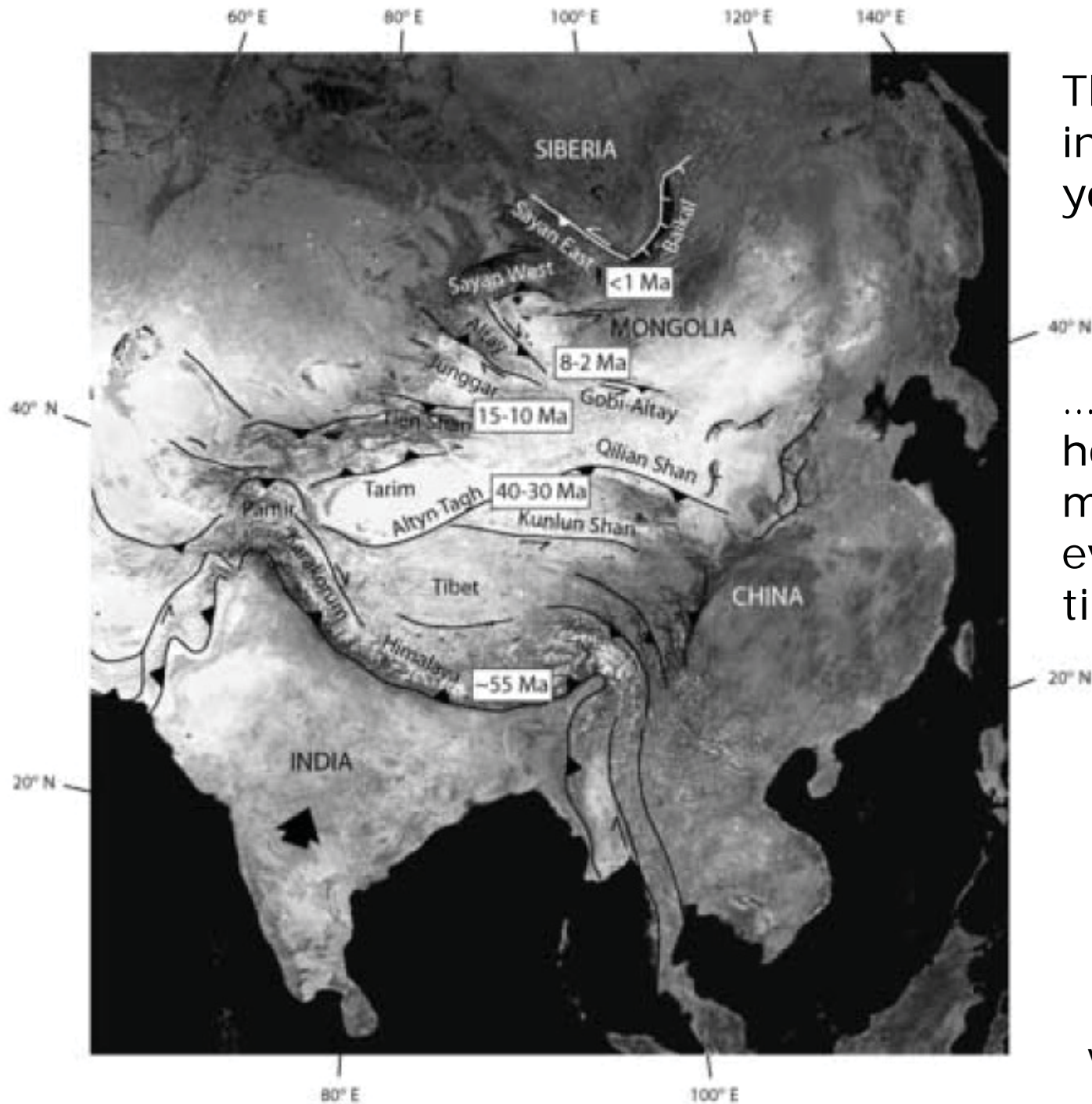




The Altay and Sayan  
accommodate ~10 mm/yr of  
India-Eurasia shortening





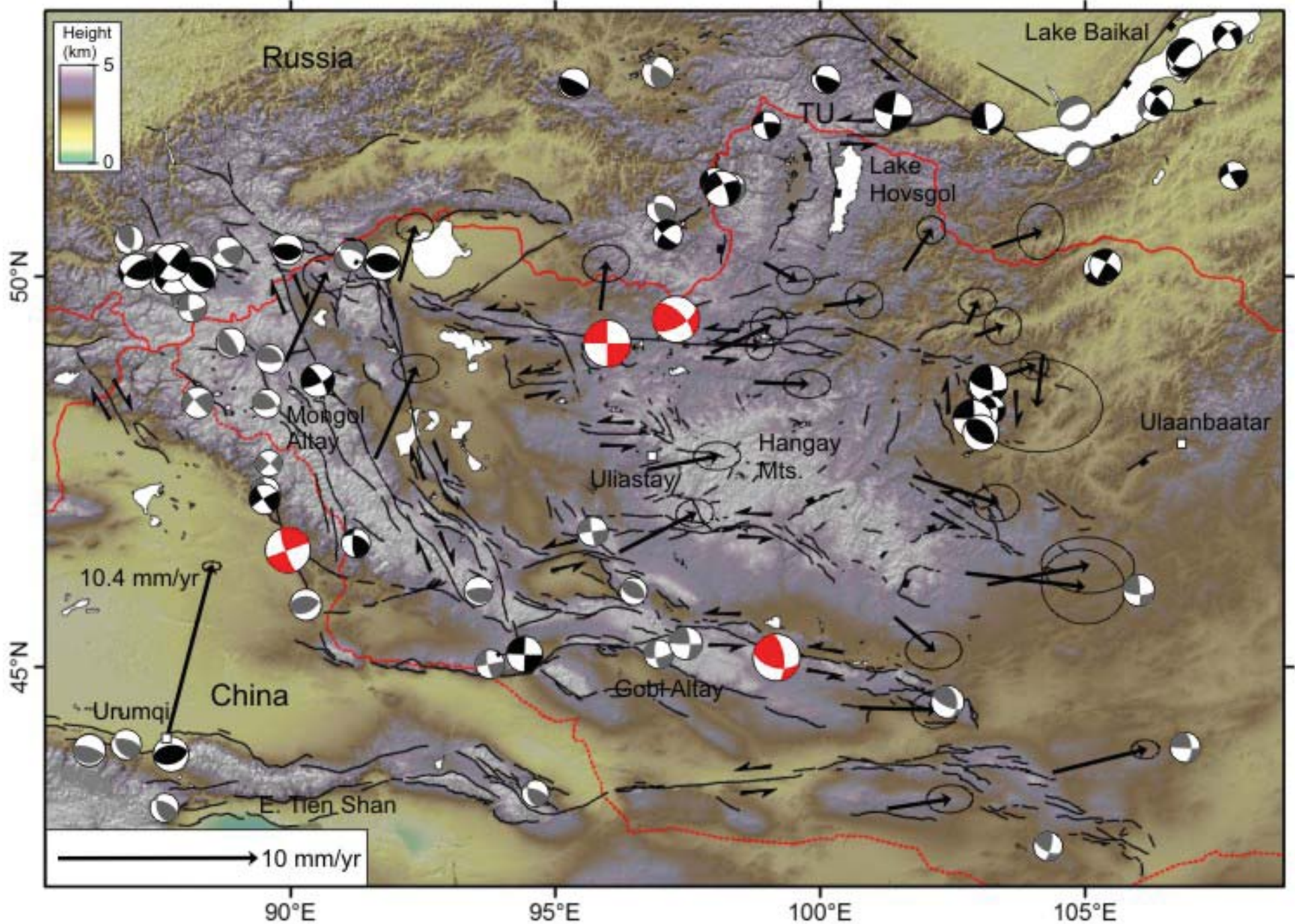


The active faulting in Mongolia is very young (~ 5Ma)

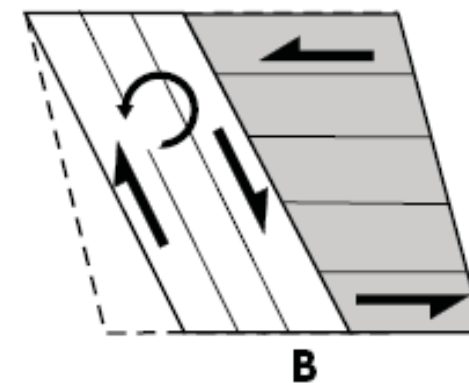
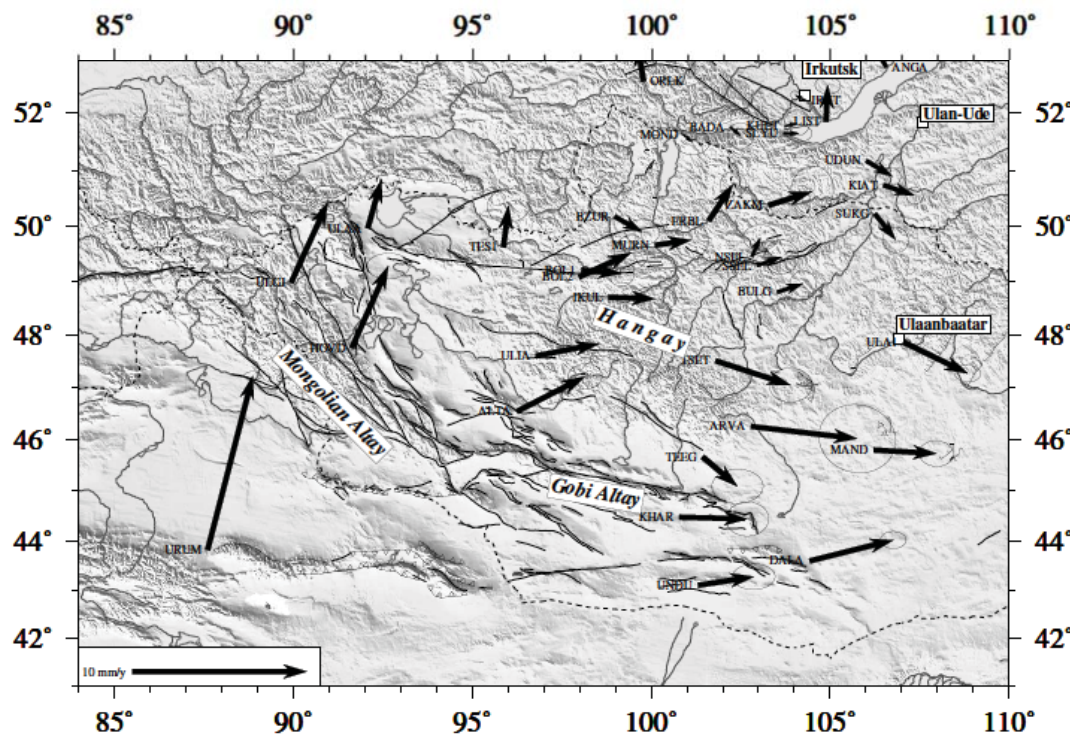
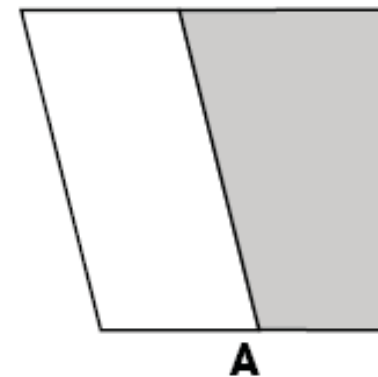
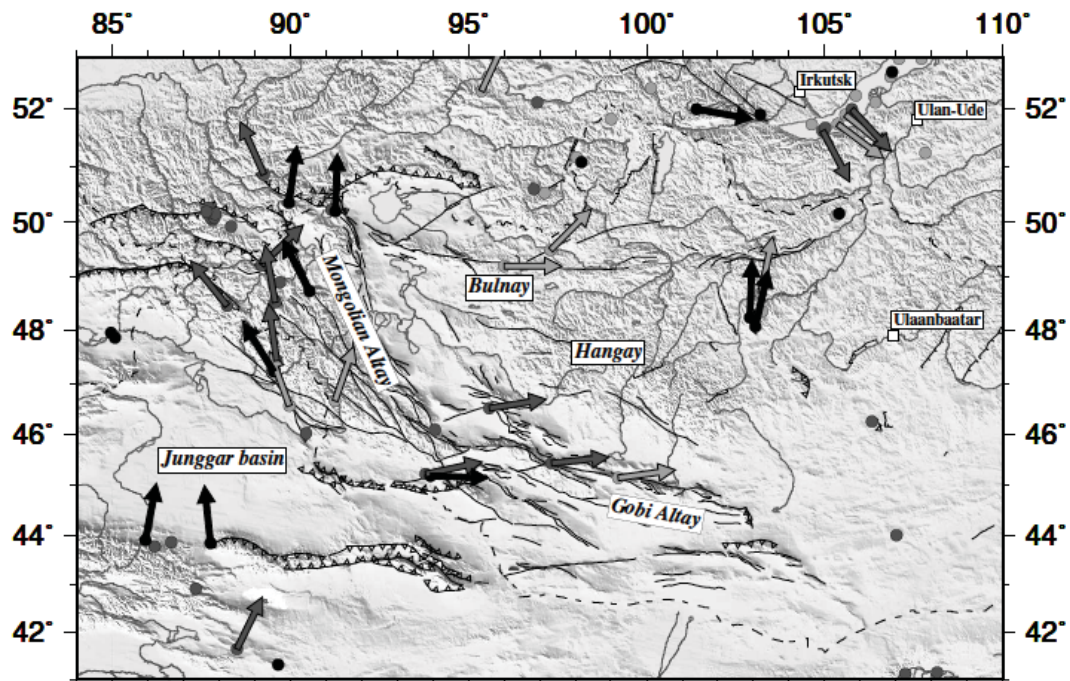
... so we can learn how the faults and mountains have evolved through time

Vassallo et.al. 2007

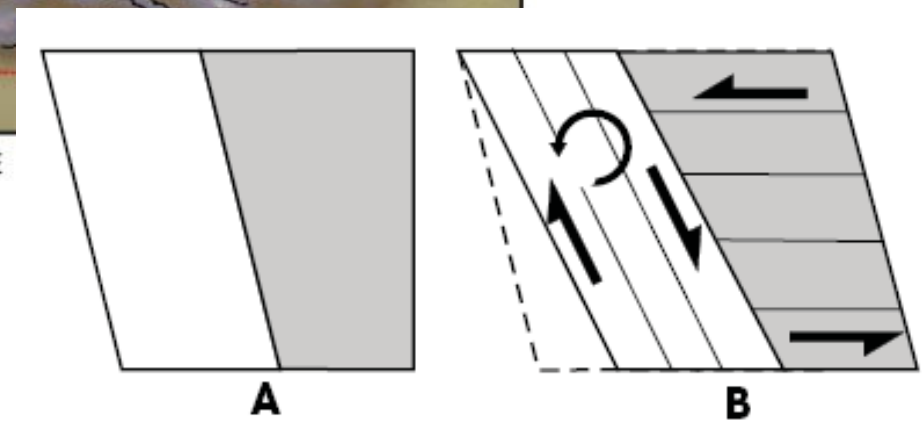
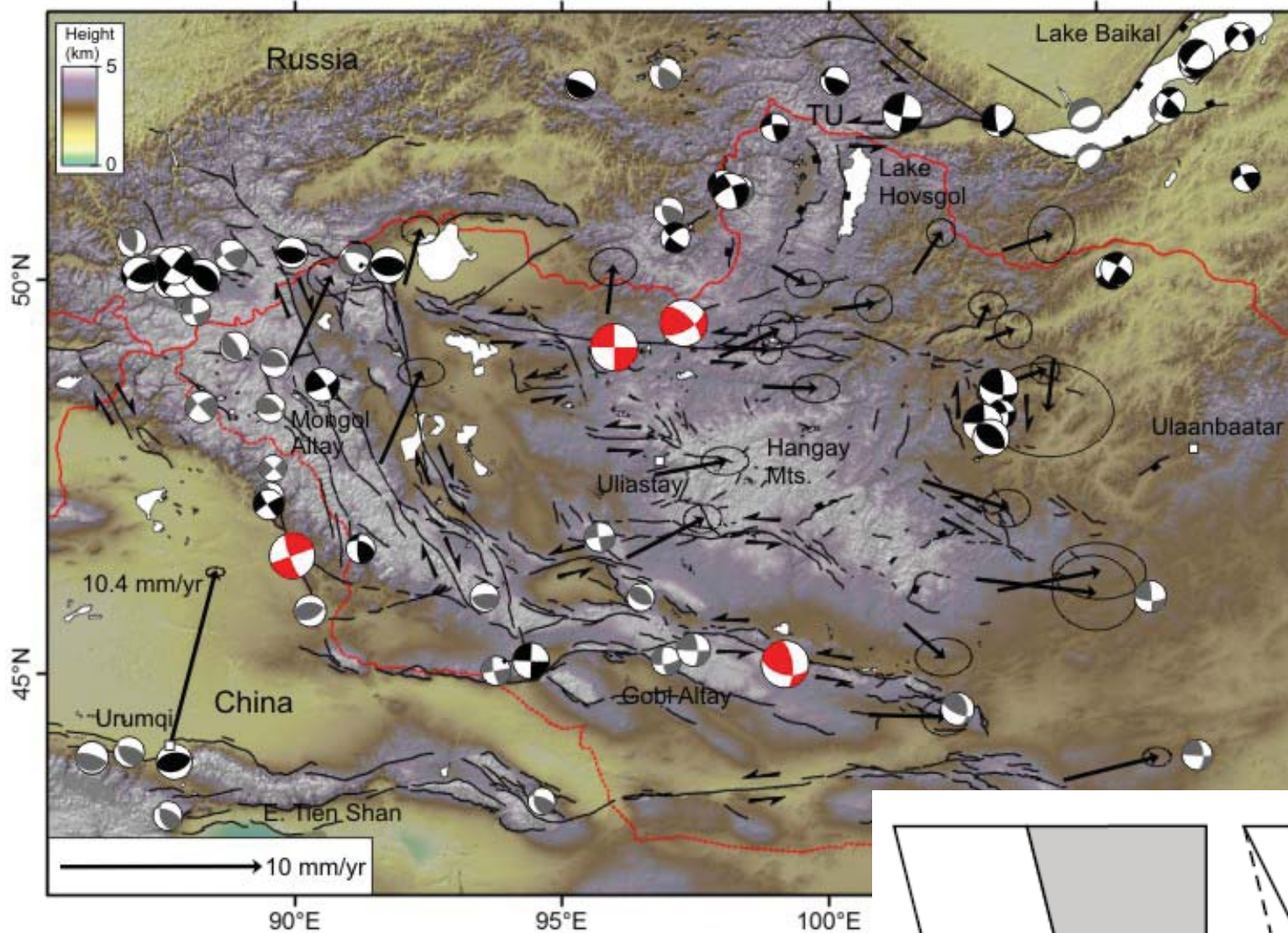












Very large historic and pre-historic earthquakes ...



1905 Bulnay Mw 8.3



2003 Chuya Mw 7.3

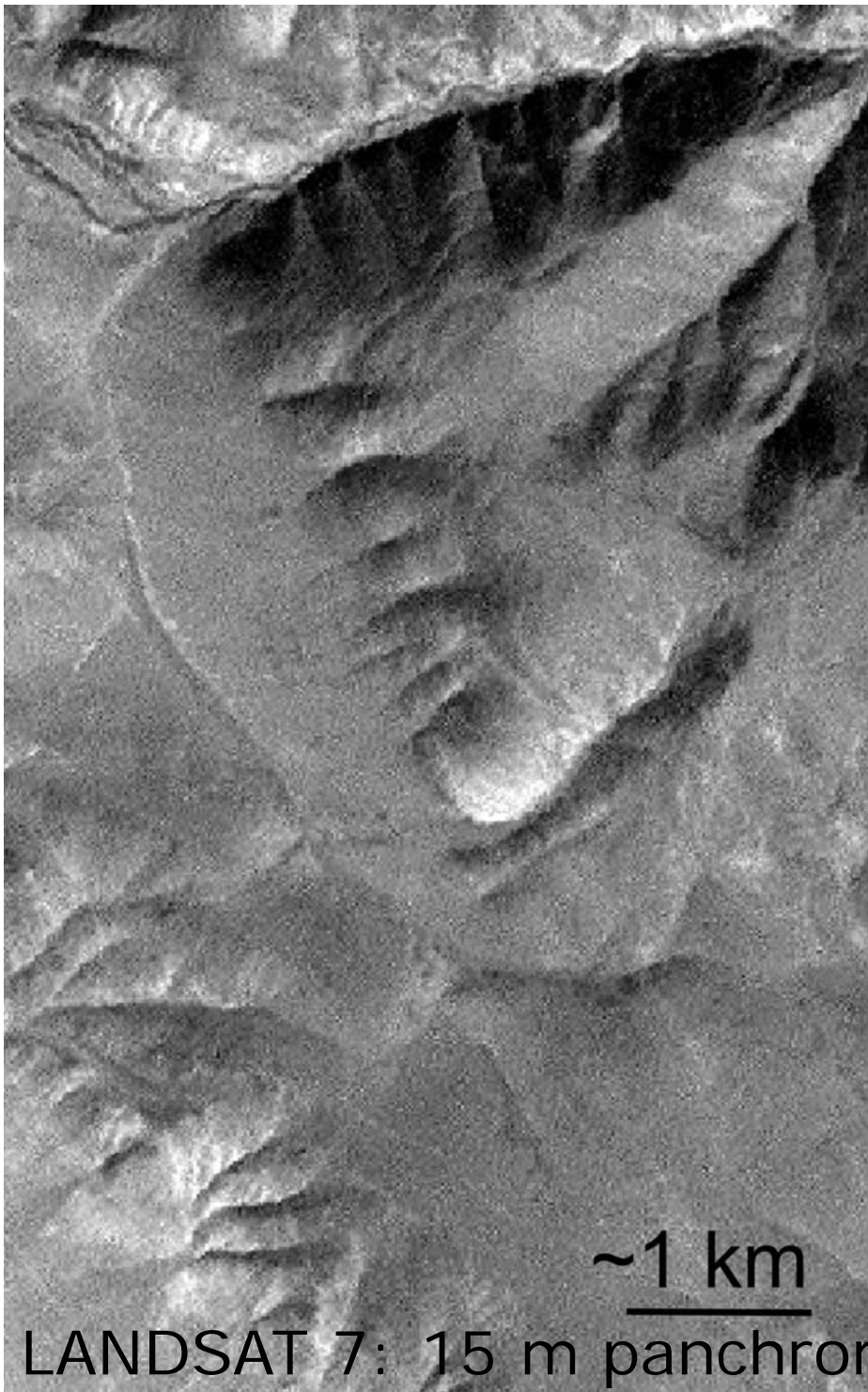


Jid palaeo-rupture  
850-950 years old  
(Walker et.al. 2006)

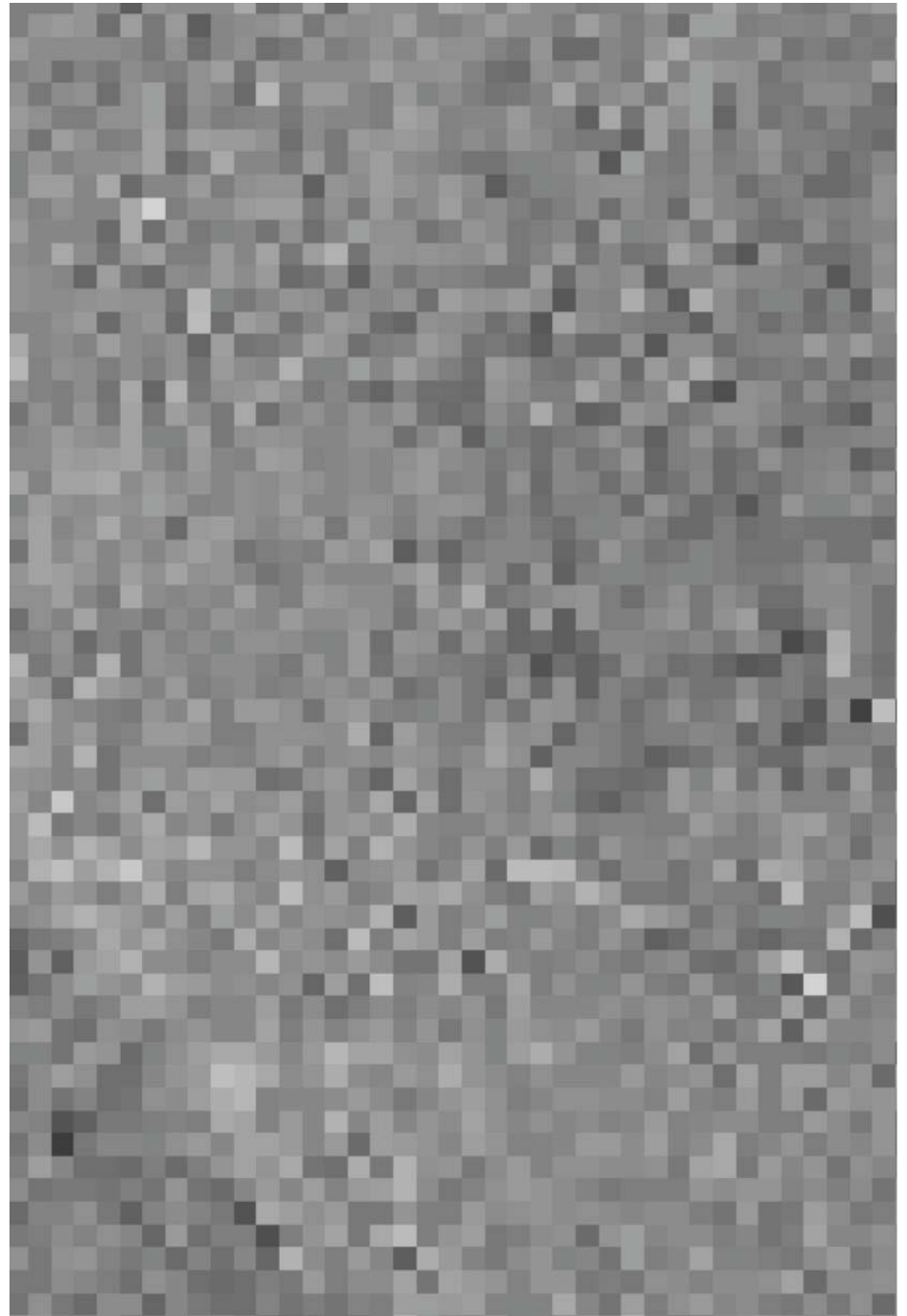
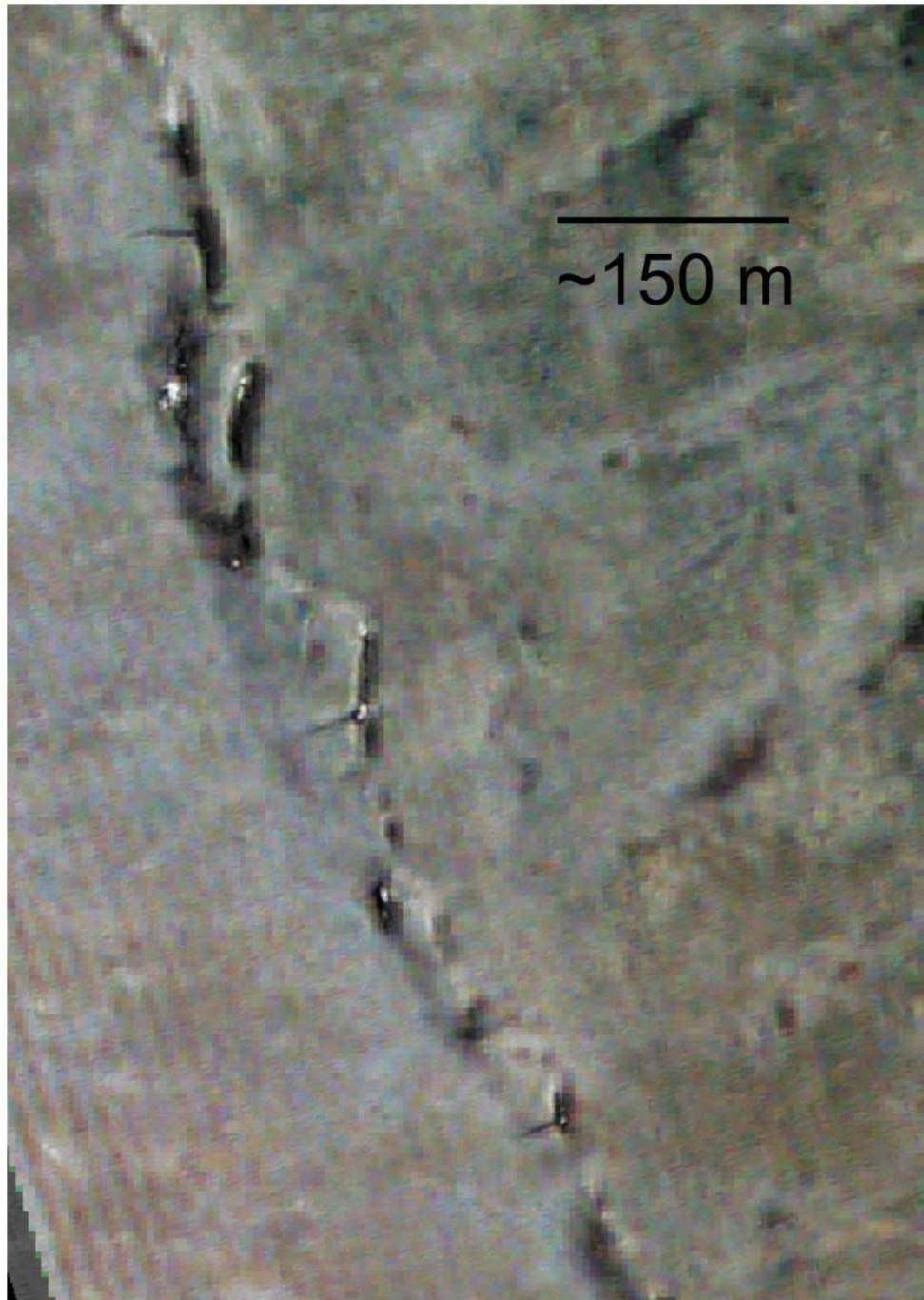


Ruptures are well preserved due to the arid environment



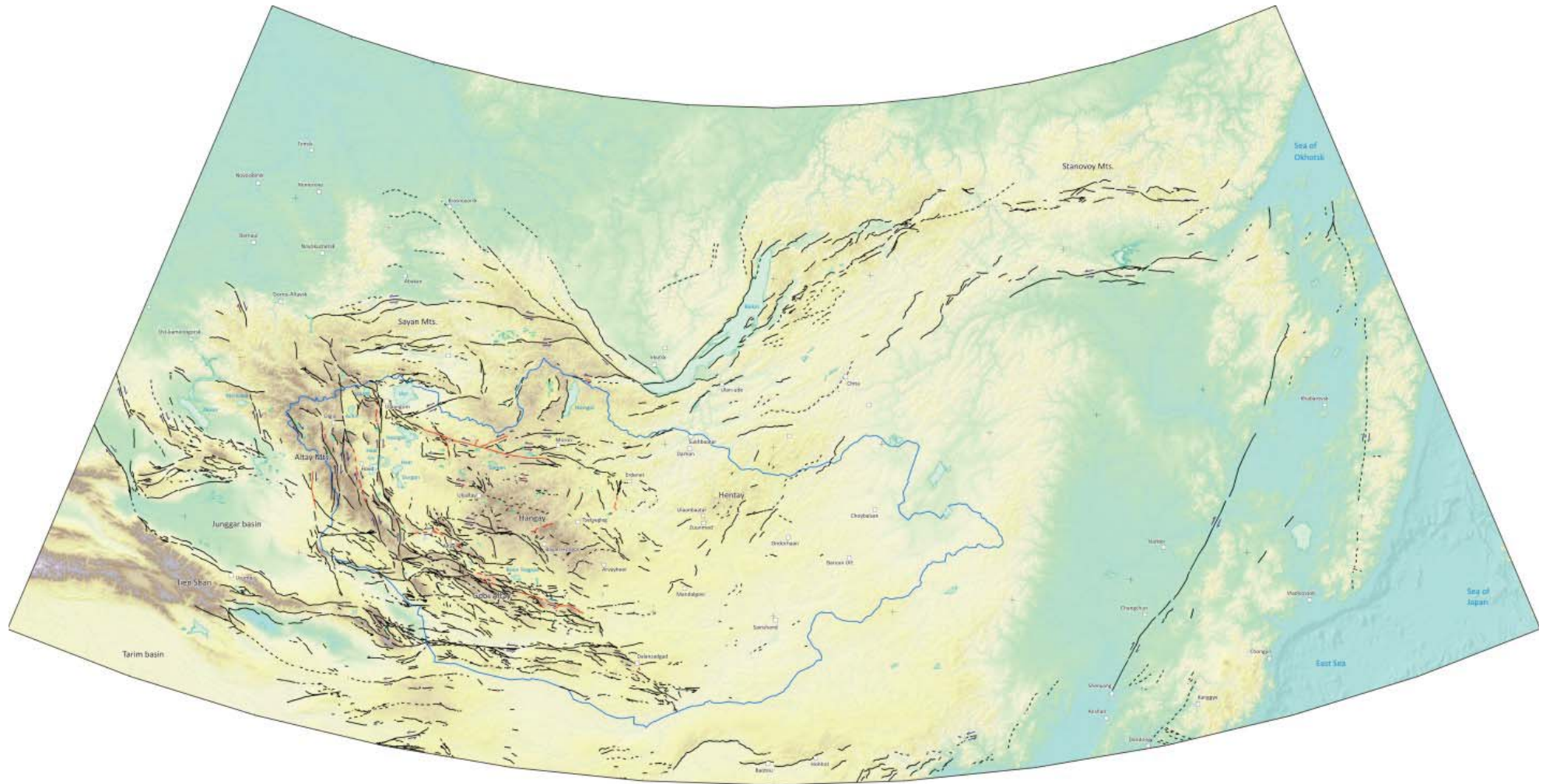








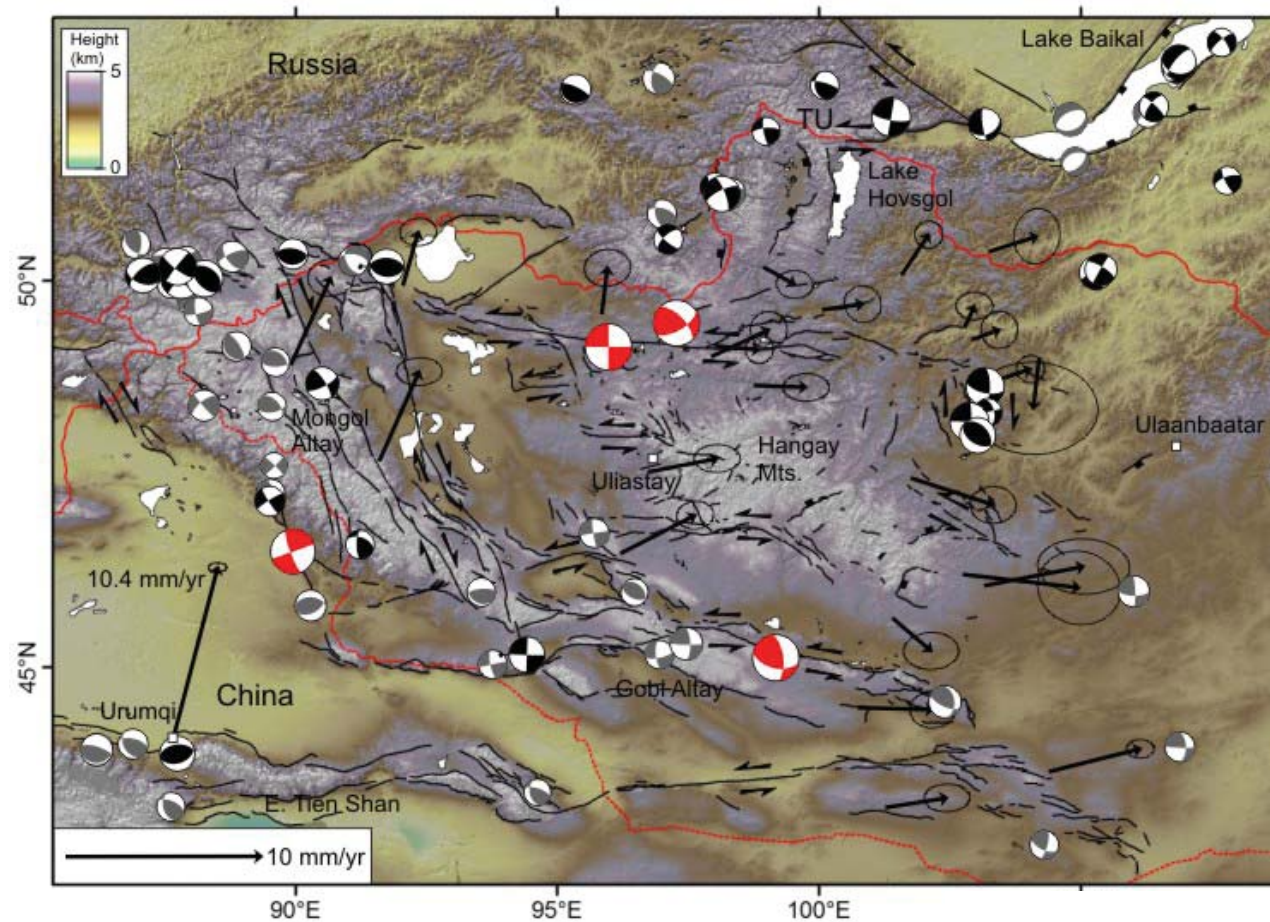
A map of active faults in NE Asia  
(with Y. Awata at the Geological Survey of Japan, and A. Bayasgalan  
at the Mongolian University of Science and Technology)



Japan Society for the Promotion of  
Science



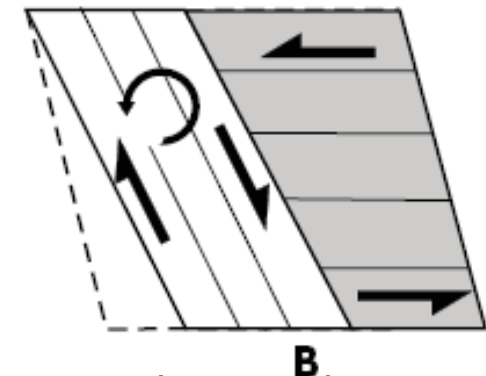
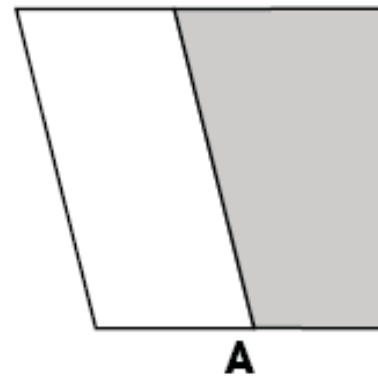
# The Altay



Compare distribution and rates of deformation over timescales from:

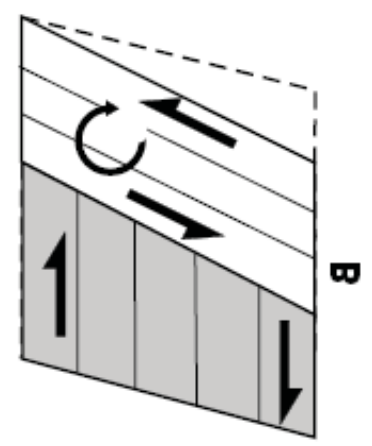
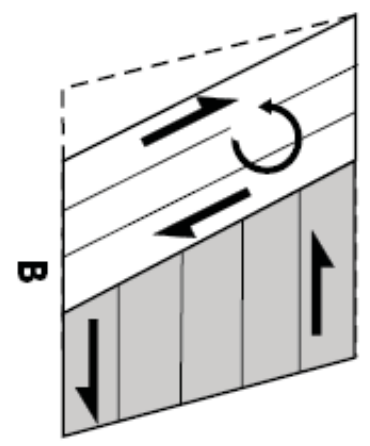
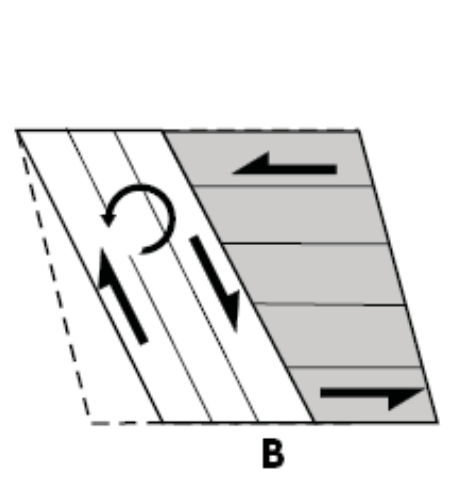
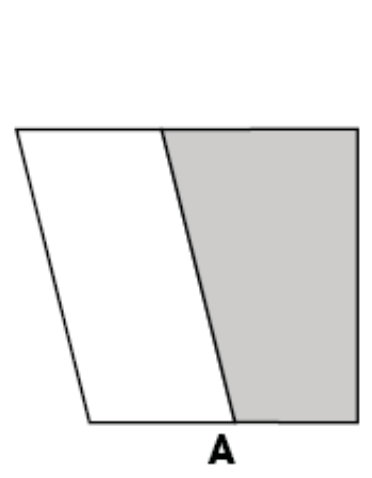
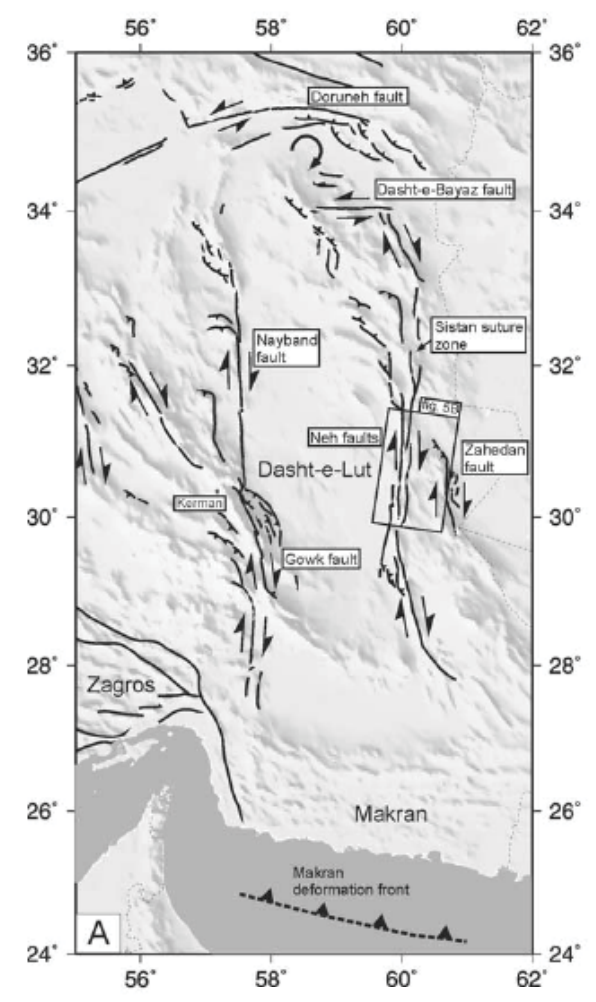
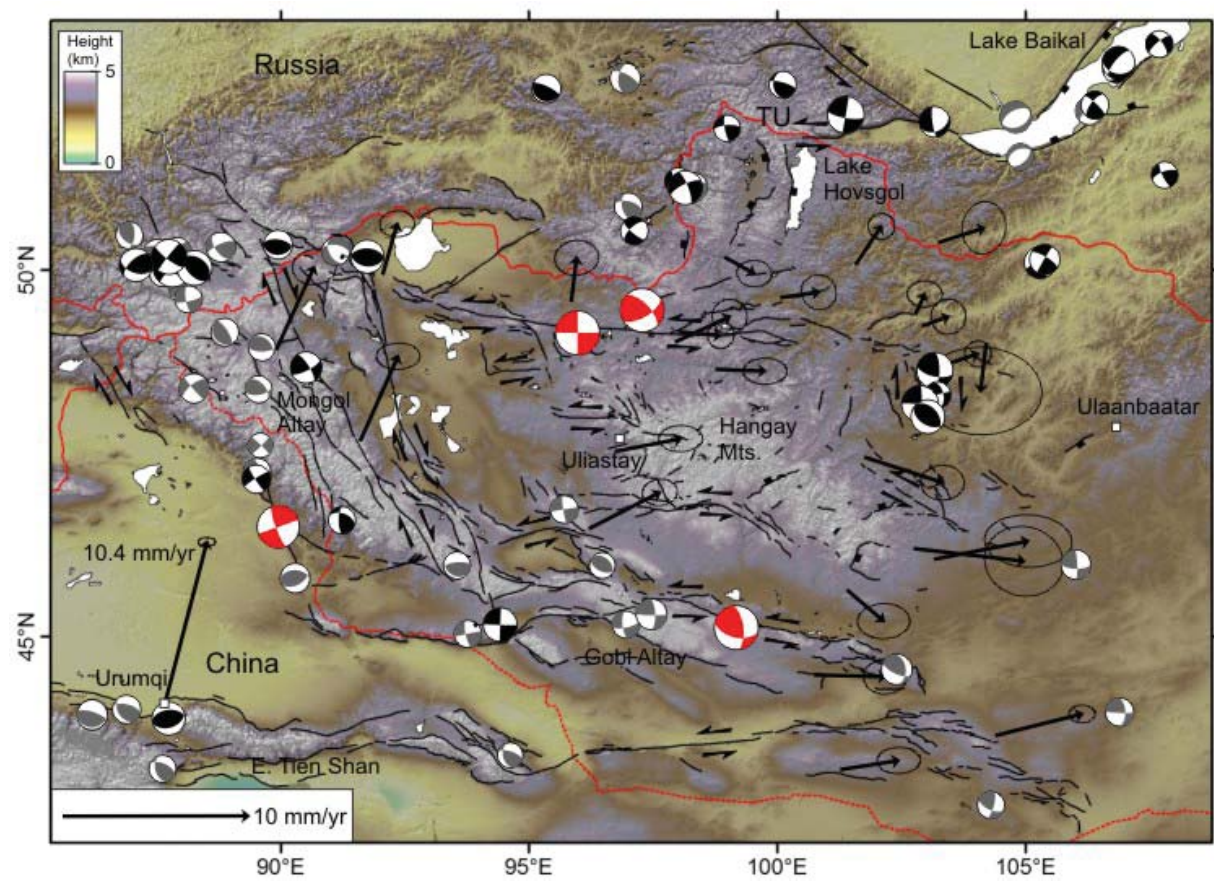
- 1) present-day (GPS)
- 2) 100 year (earthquakes)
- 3) 1000 year (palaeo-ruptures)
- 4) 10-100 ka (landscape)
- 5) >1 Ma (AFT, palaeomag, large-scale topography and river displacements)

How does this sketch work? How does it evolve through time?

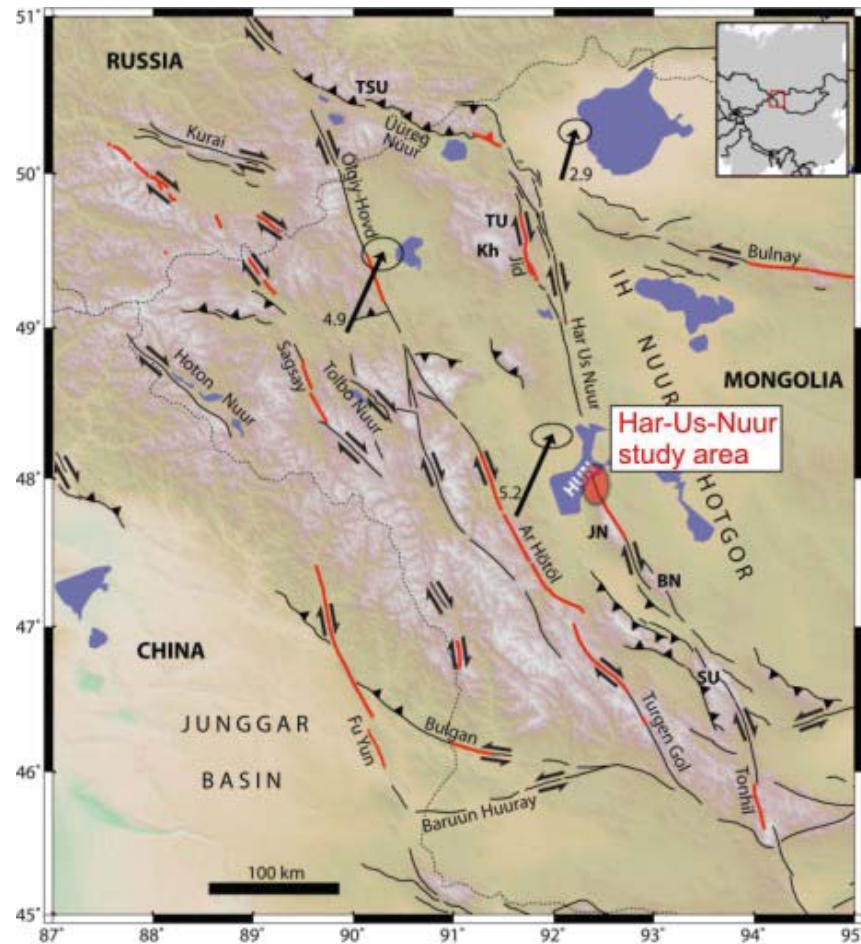


Bayasgalan et.al. 2005

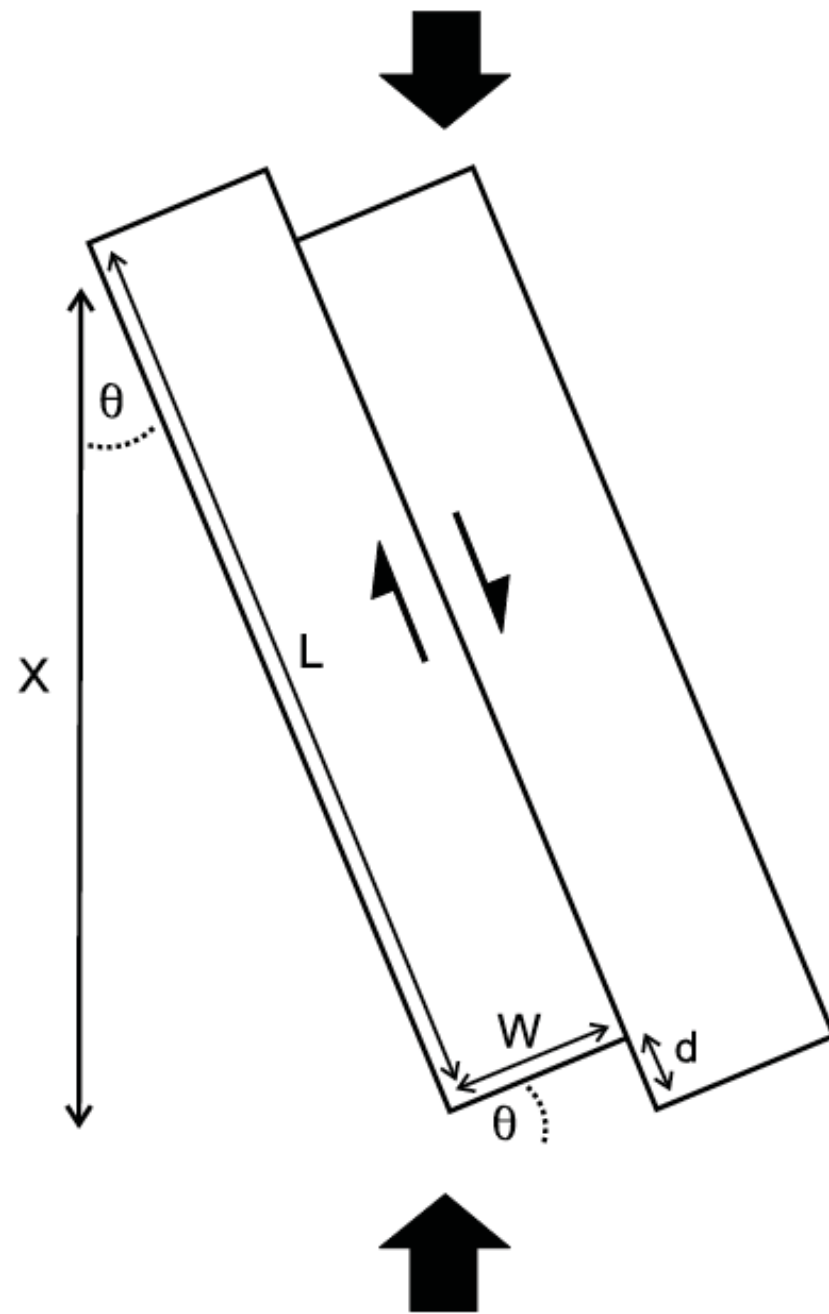




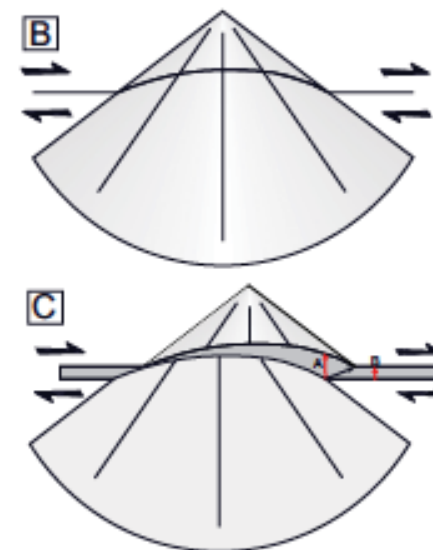
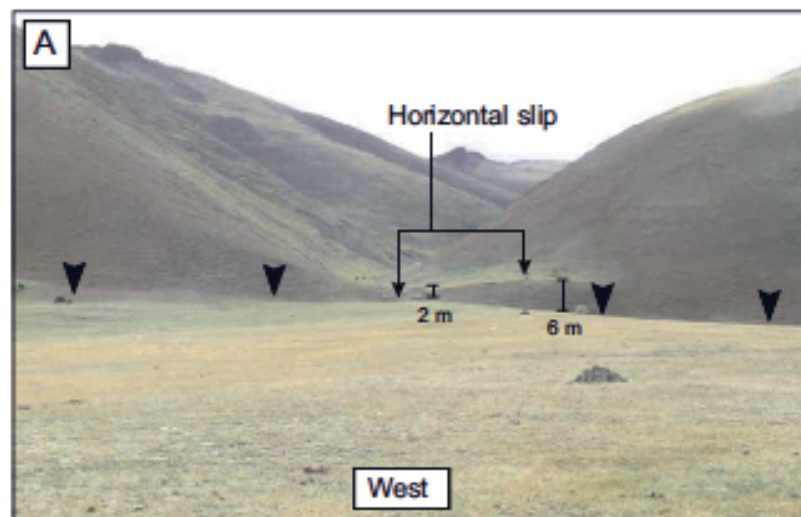
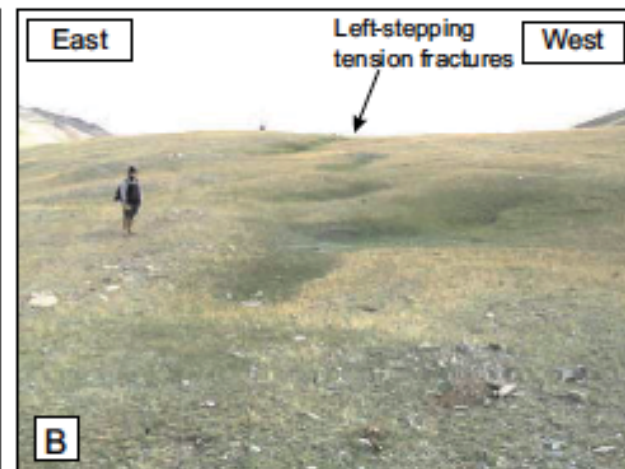
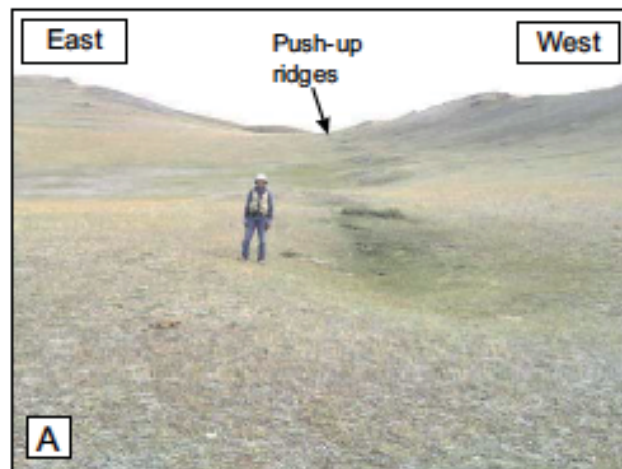
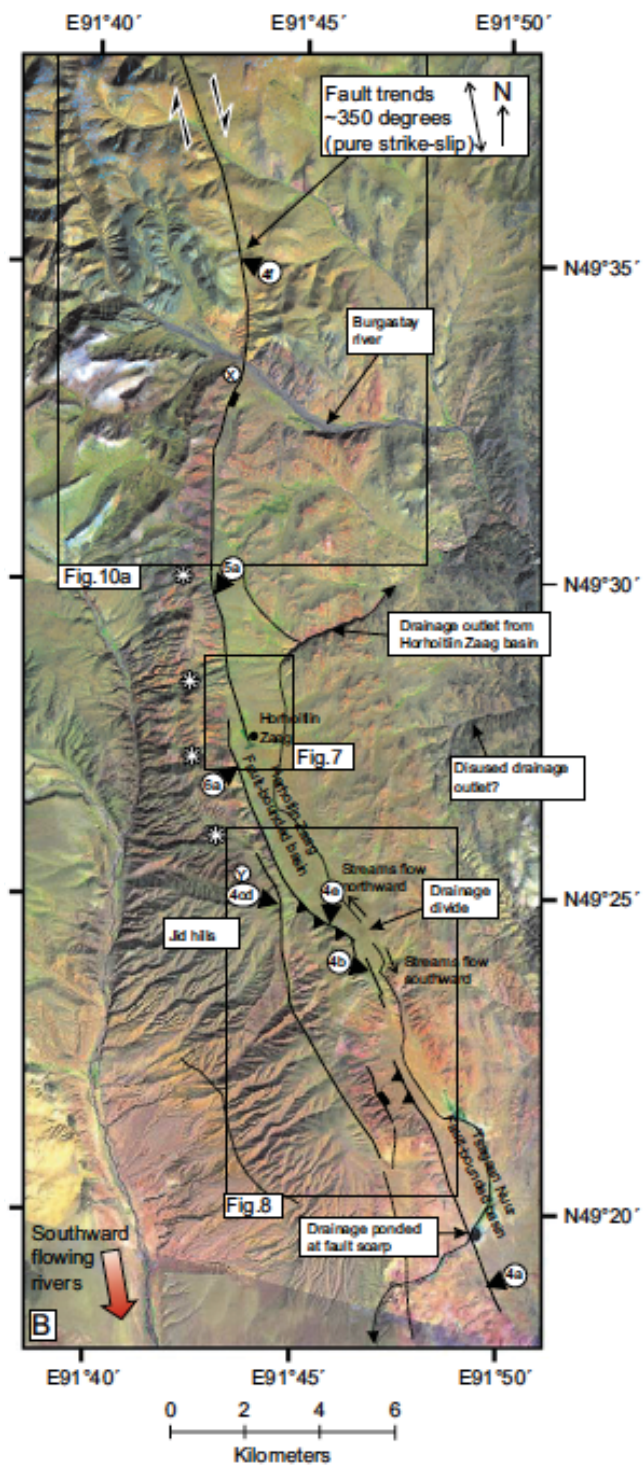




Red lines = earthquake ruptures  
 Baljinnyam et al. 1993  
 Walker et al. 2006  
 Nissen et al. 2009  
 Laura Gregory (next talk)

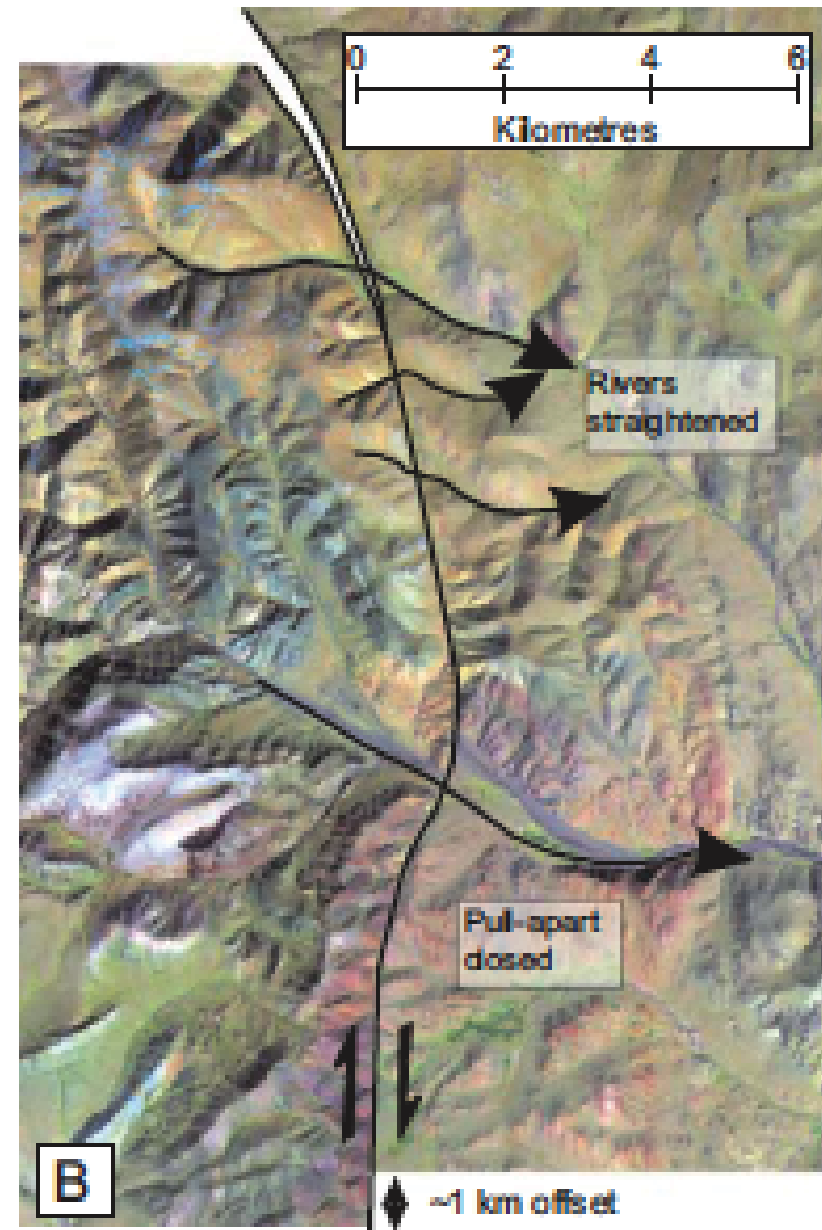
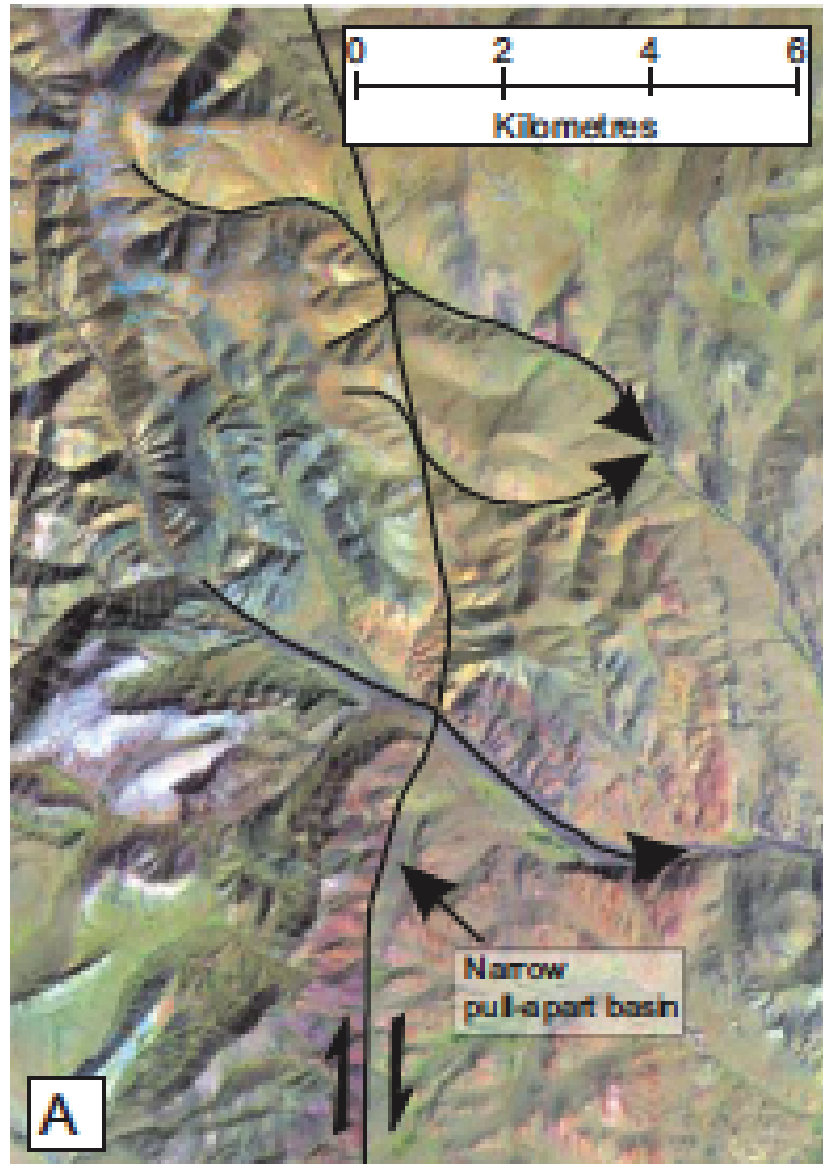




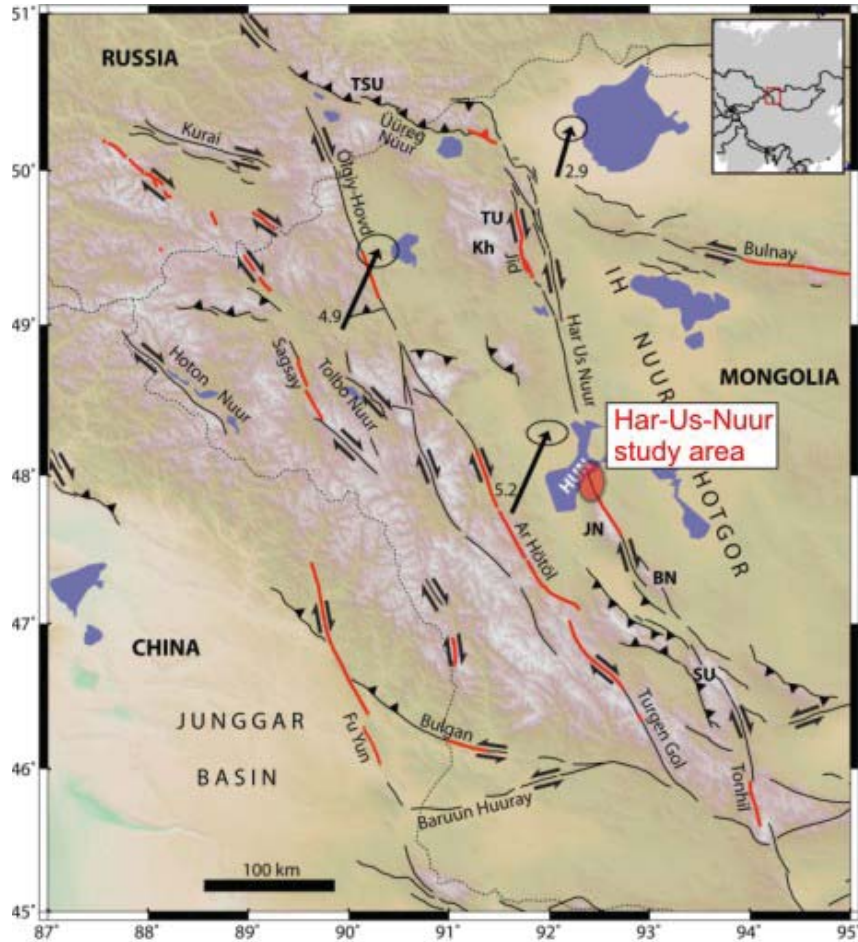


Walker et.al. 2006





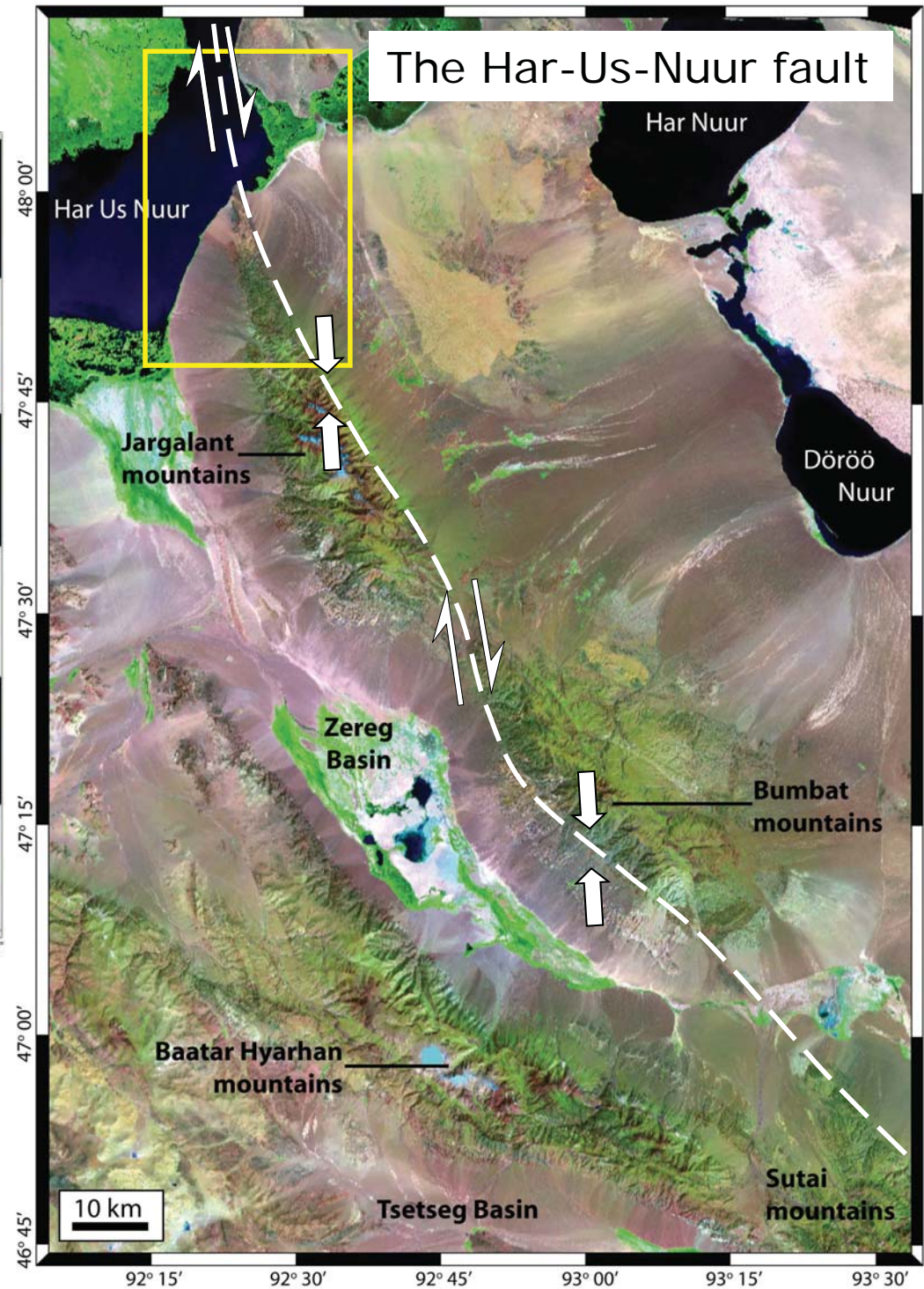




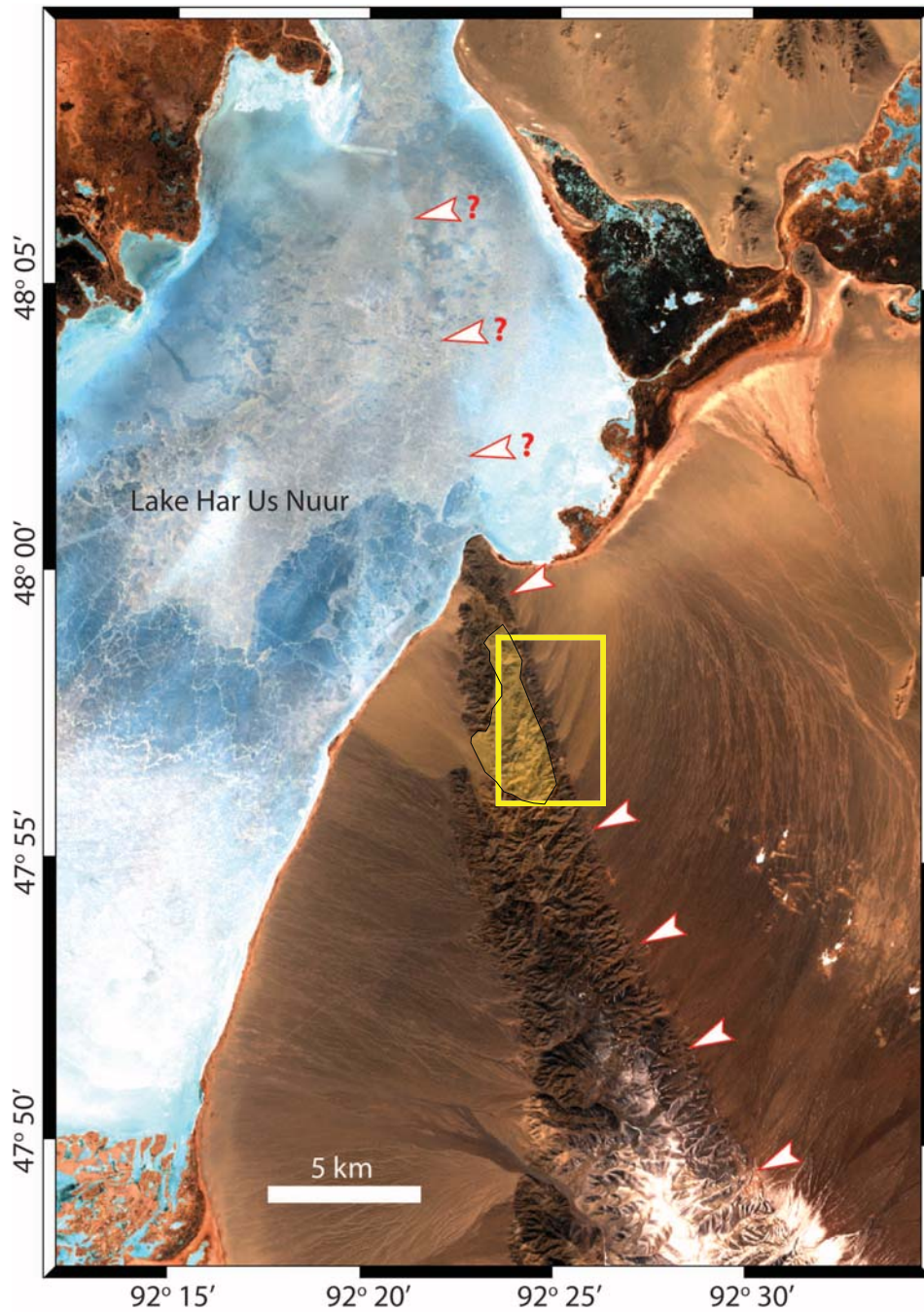
Red lines = earthquake ruptures

Question: what is the present-day distribution of fault slip in the Altay?

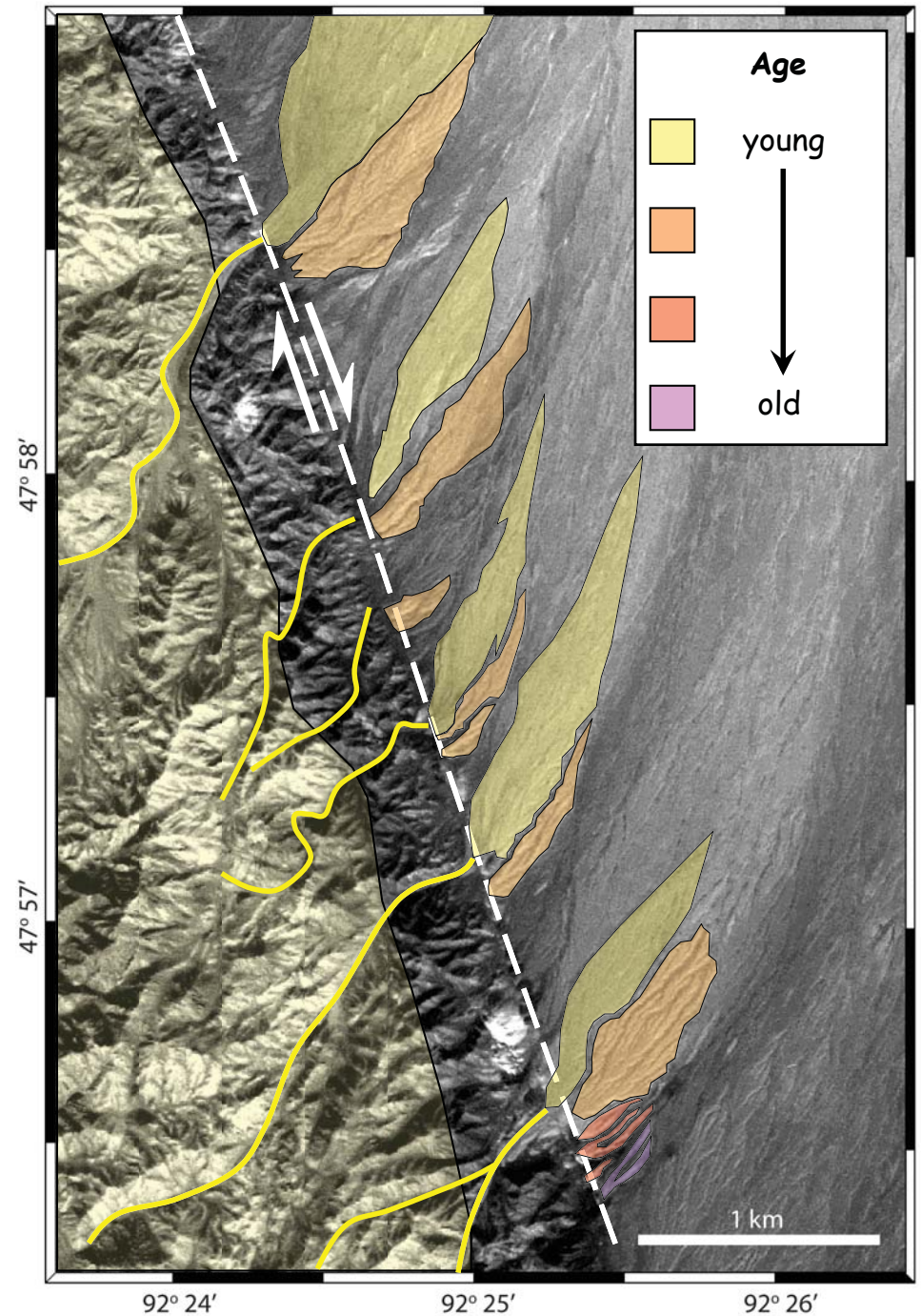
E. Nissen et.al., 2009





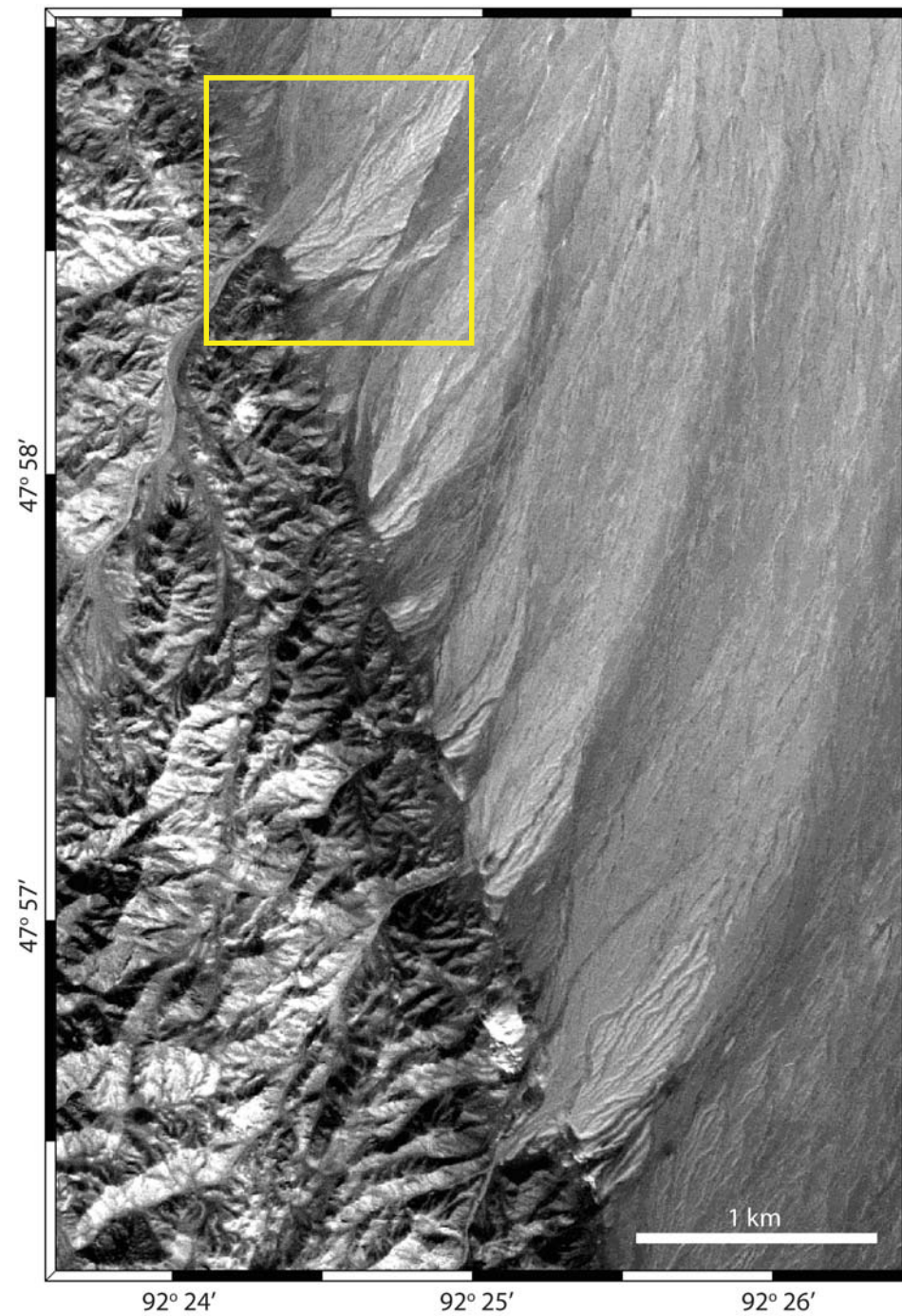
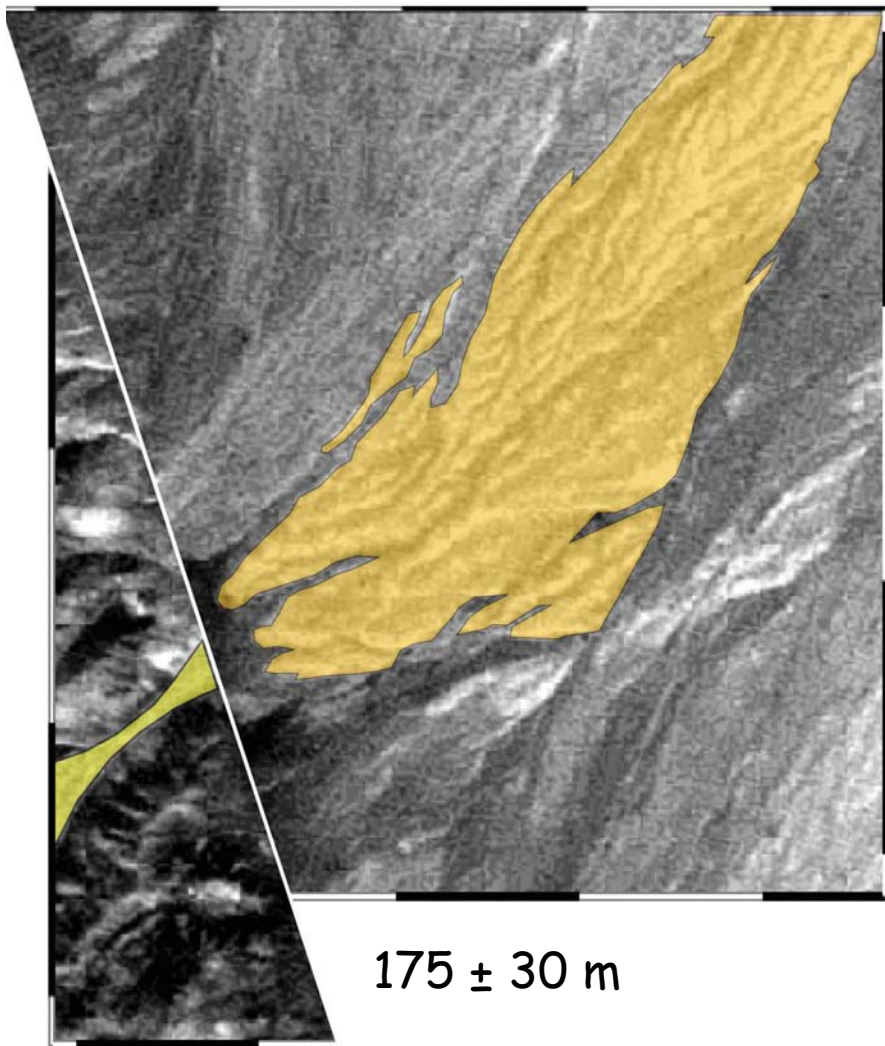


ASTER image (15 m pixels)

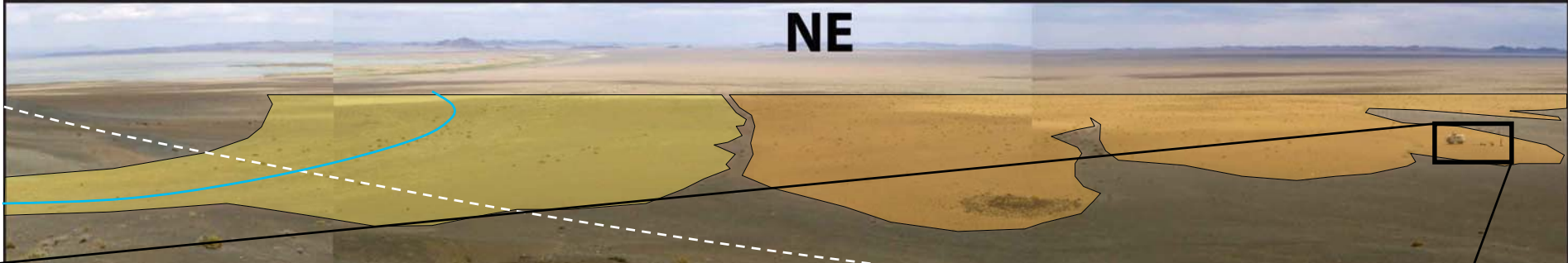


SPOT5 image (2.5 m pixels)





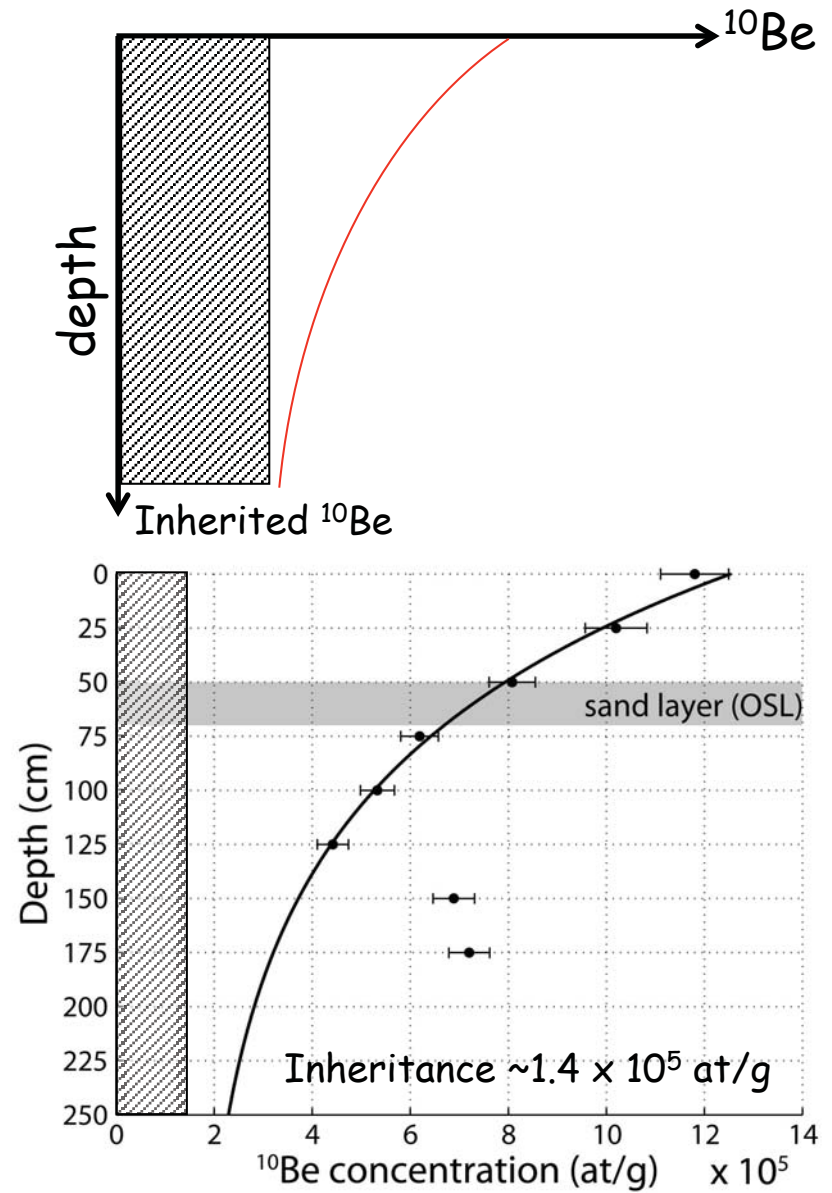








## In-situ cosmogenic $^{10}\text{Be}$ dating



Minimum age  $\sim 75,000$  years

Maximum slip-rate  $\sim 2.4 \pm 0.4$  mm/yr



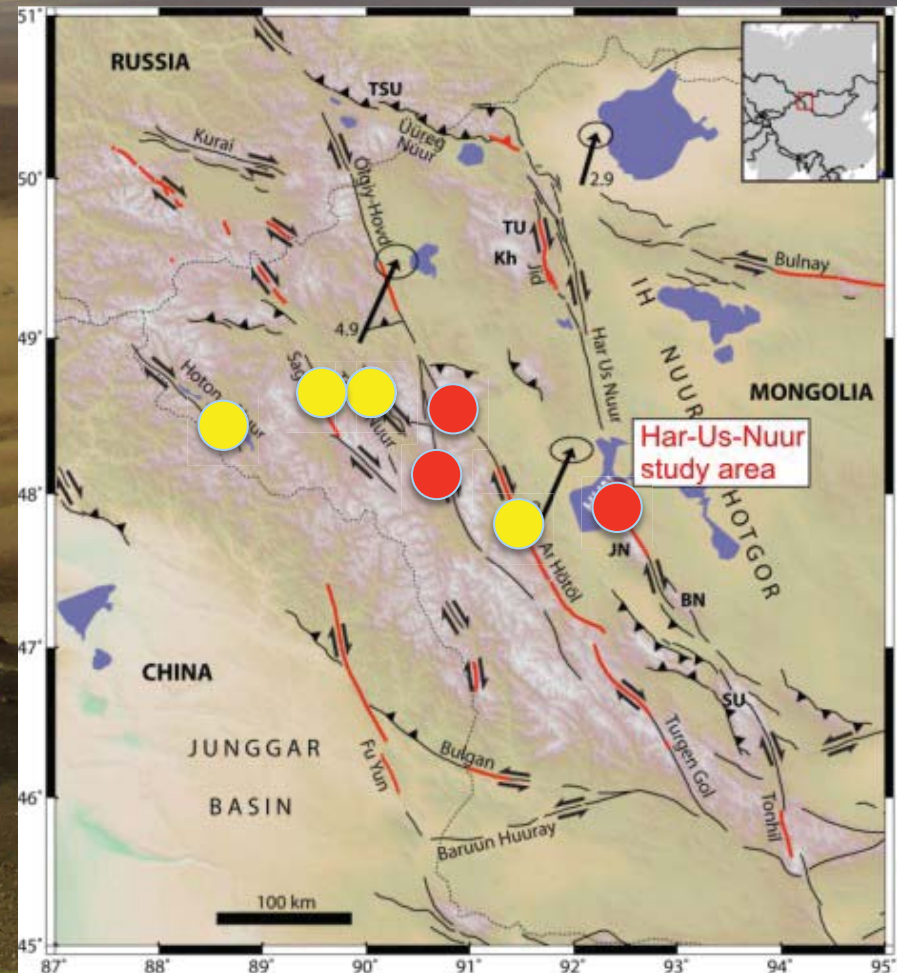


Palaeo-earthquake ruptures  
Length ~ 30 km  
Slip ~ 2.5 m  
Magnitude ~ 7

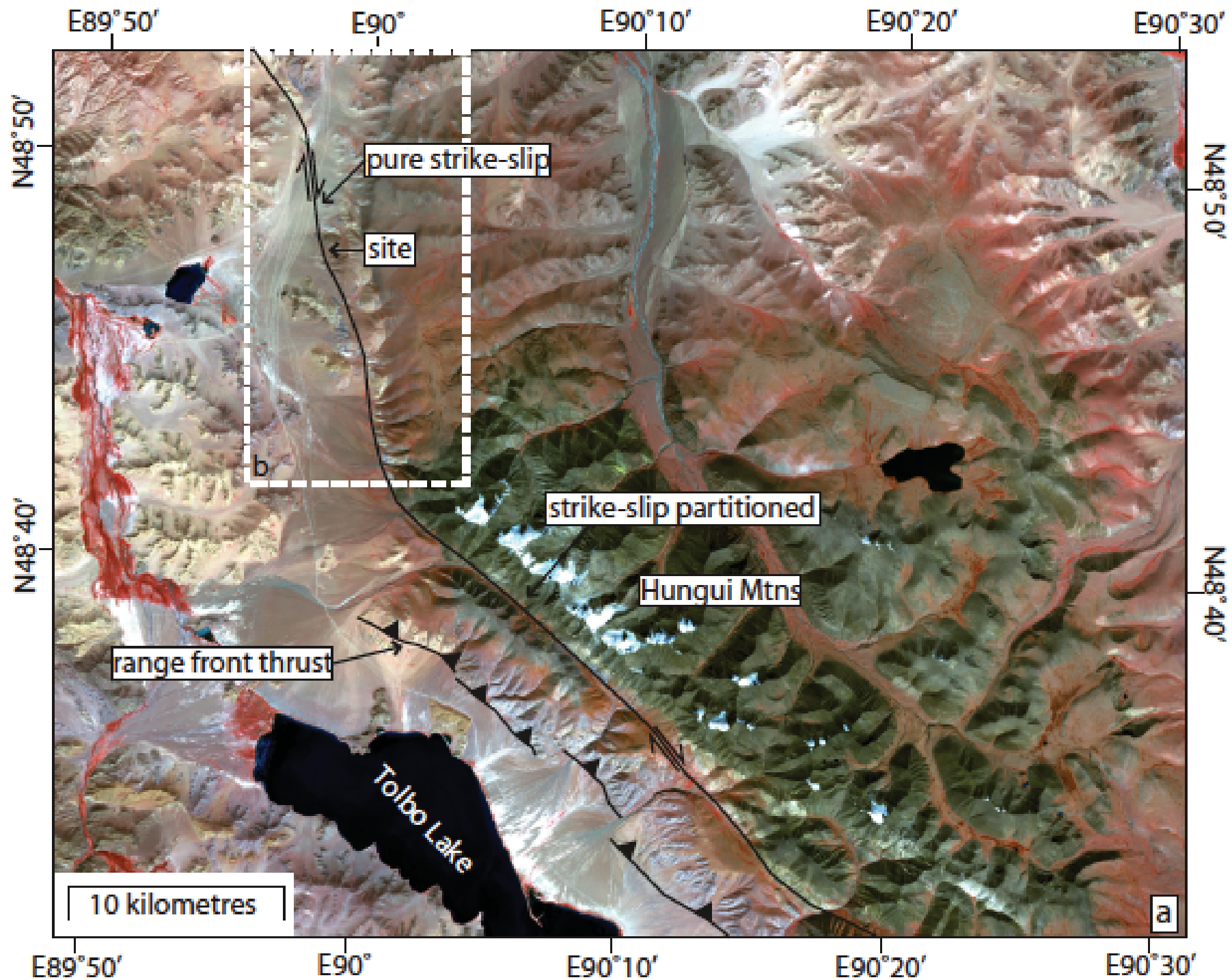


Har-Us-Nuur fault slip-rate is  $\sim 2.4$  mm/yr  
Evidence for paleo-earthquake of  $M_w \sim 7$   
Average earthquake repeat interval  $\sim 1,000$  yr

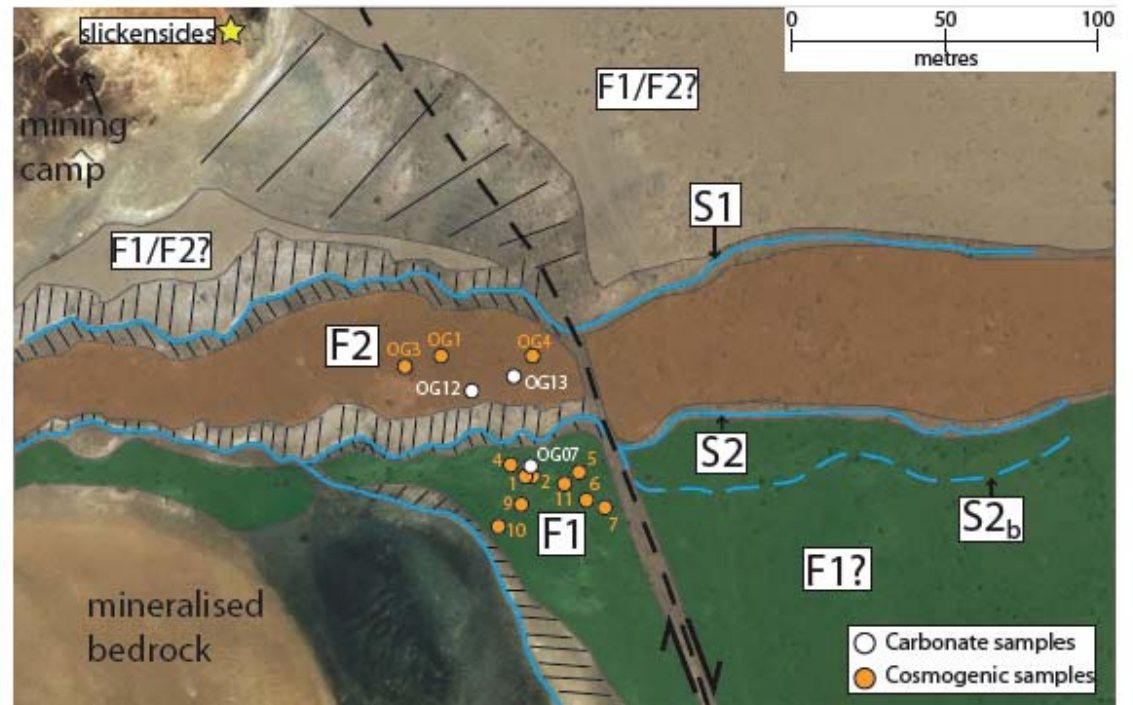
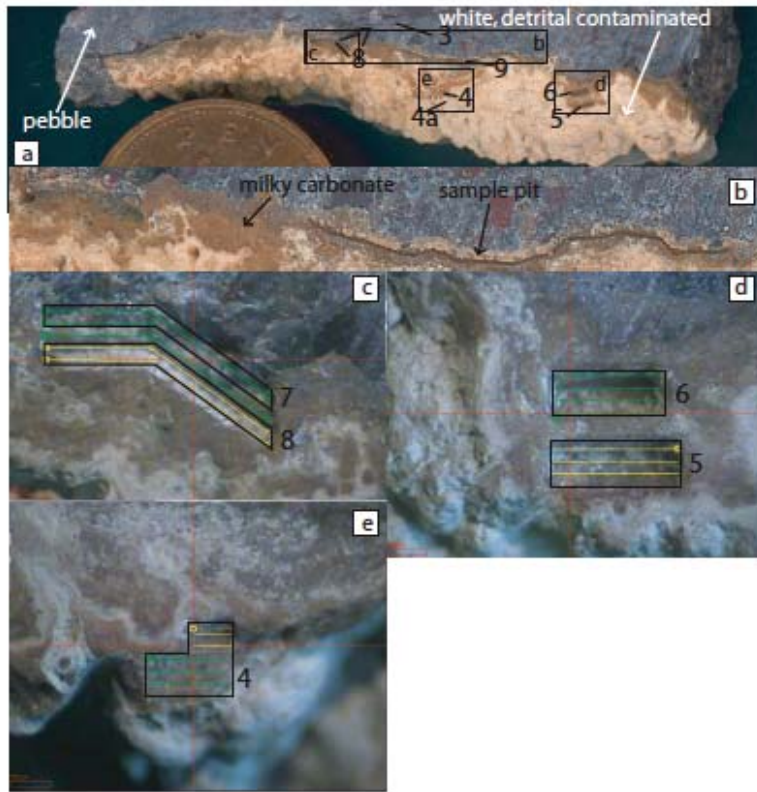
In these examples we are using  
 $^{10}\text{Be}$  exposure dating  
Optical (OSL) dating  
U-series dating











Quickbird imagery



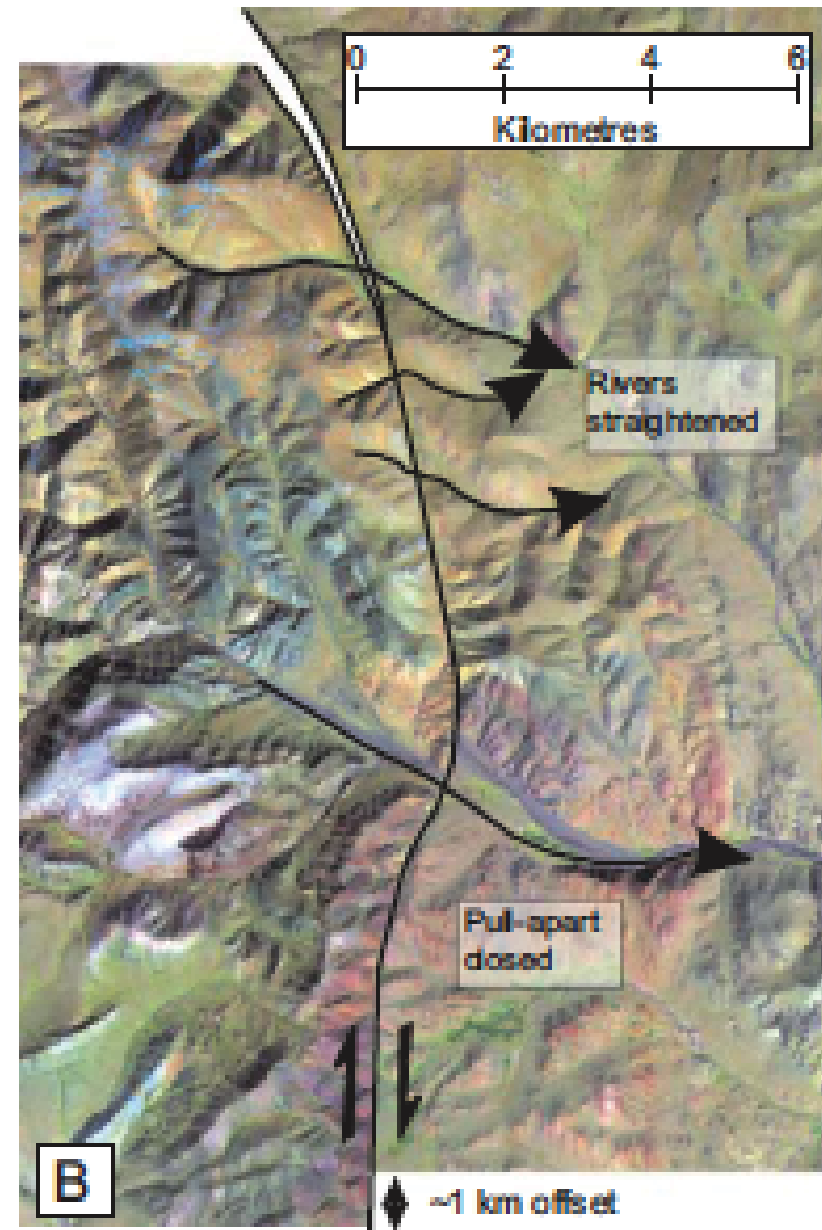
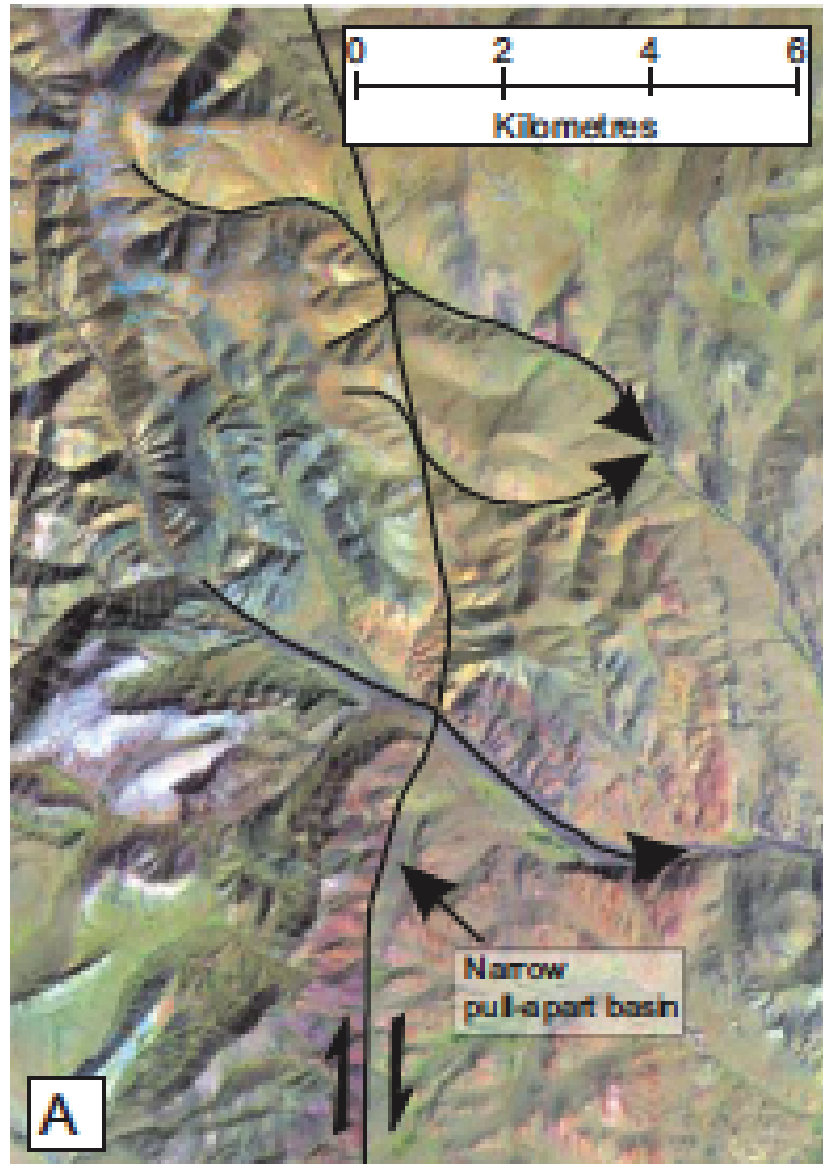




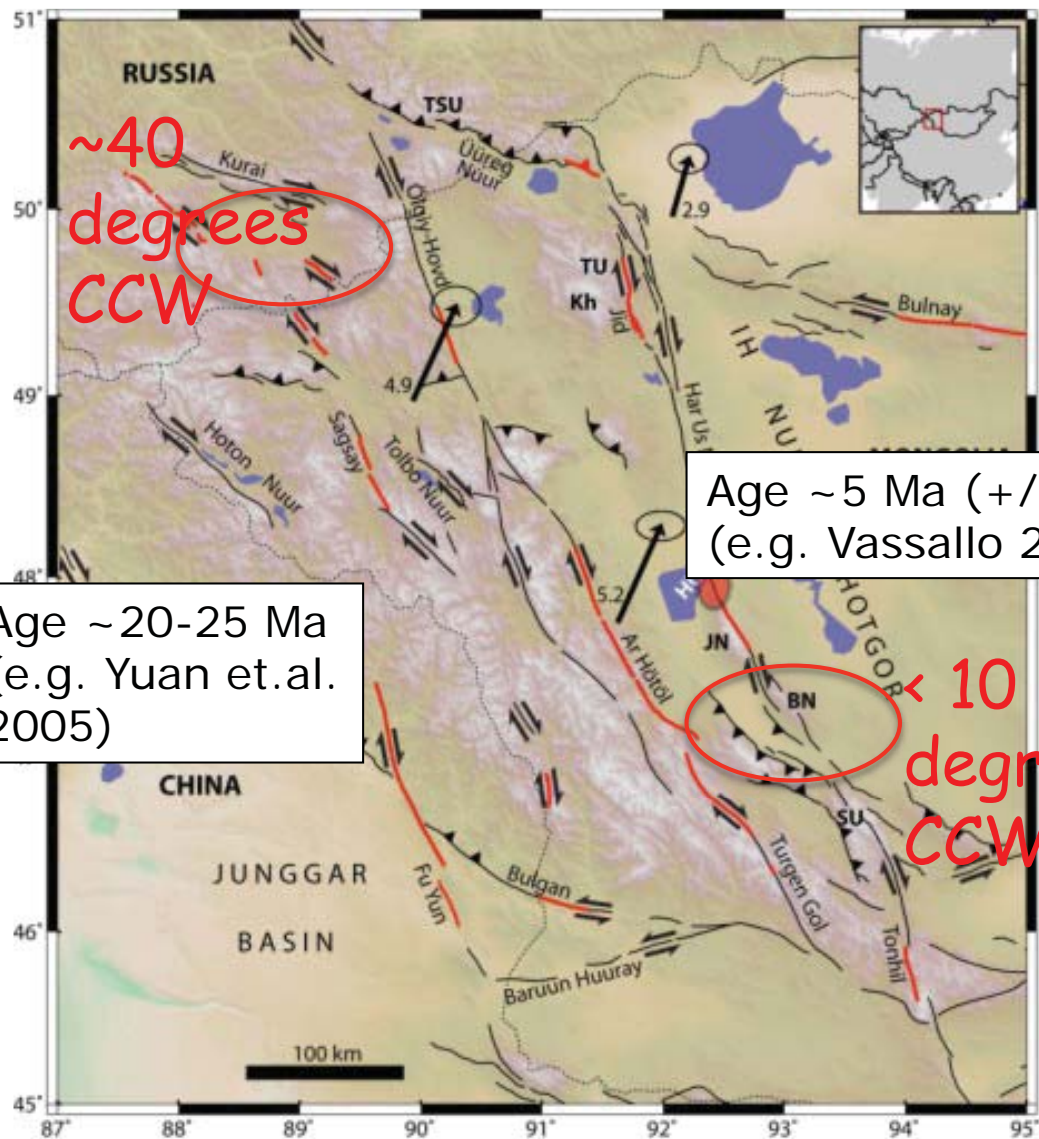
# Geological records of faulting









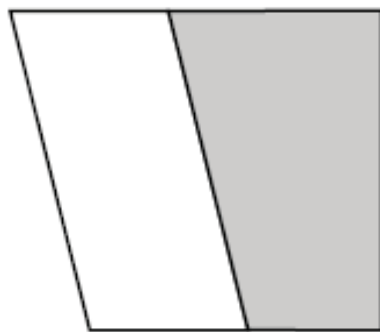
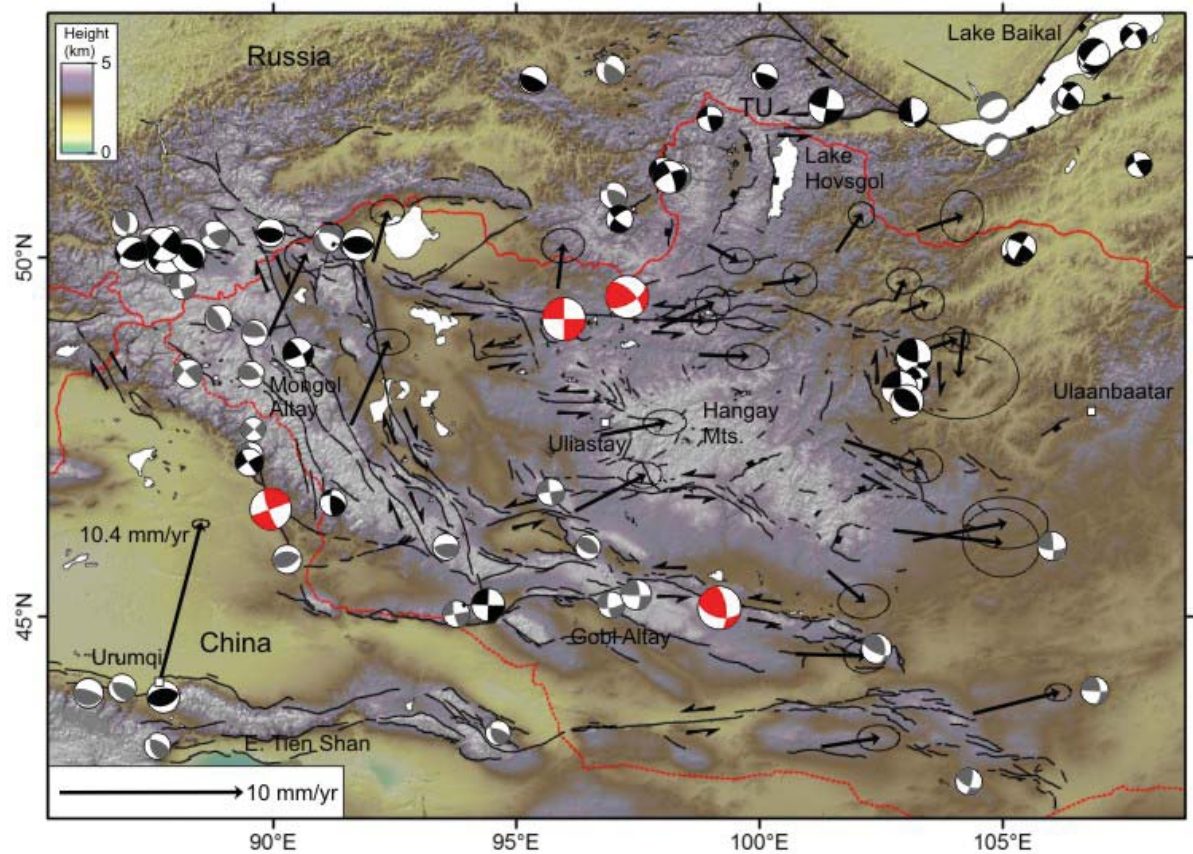


Age ~20-25 Ma  
(e.g. Yuan et.al. 2005)

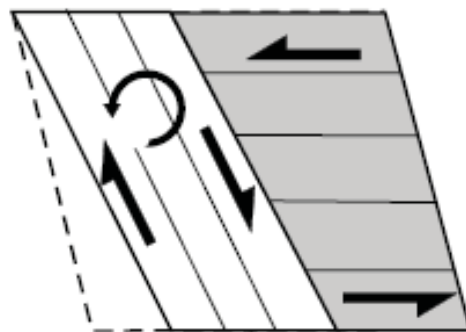
Age ~5 Ma (+/- 3 Ma)  
(e.g. Vassallo 2006)







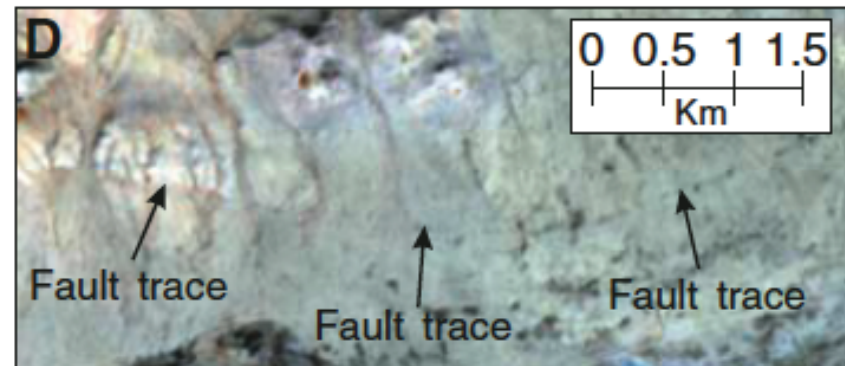
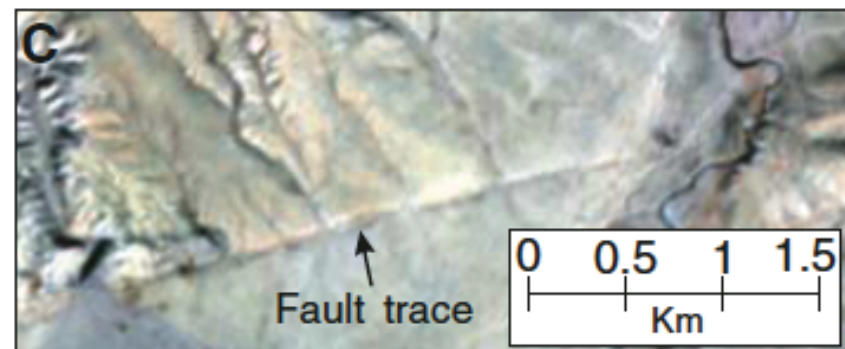
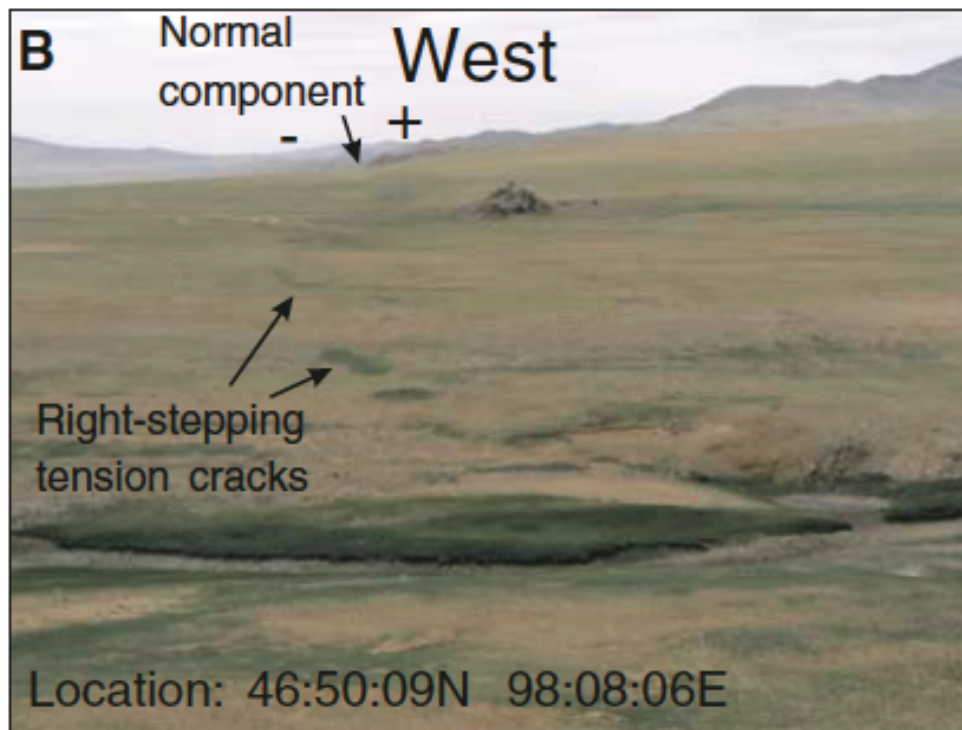
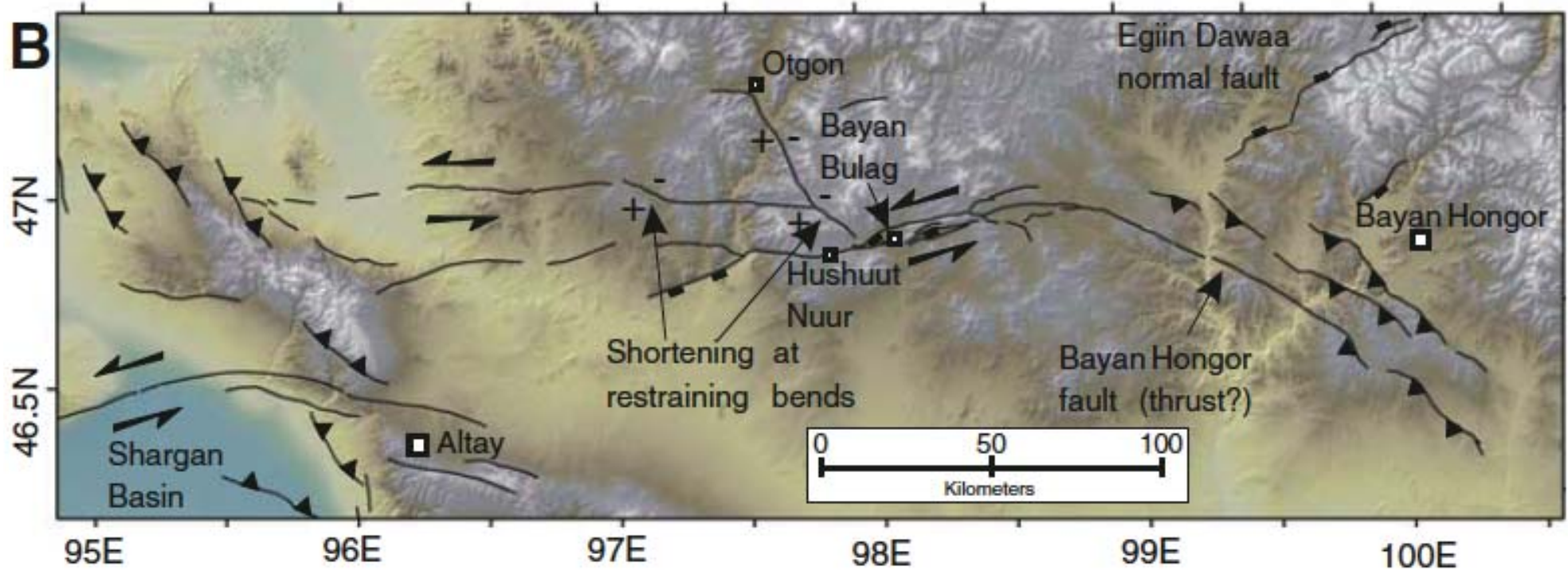
**A**



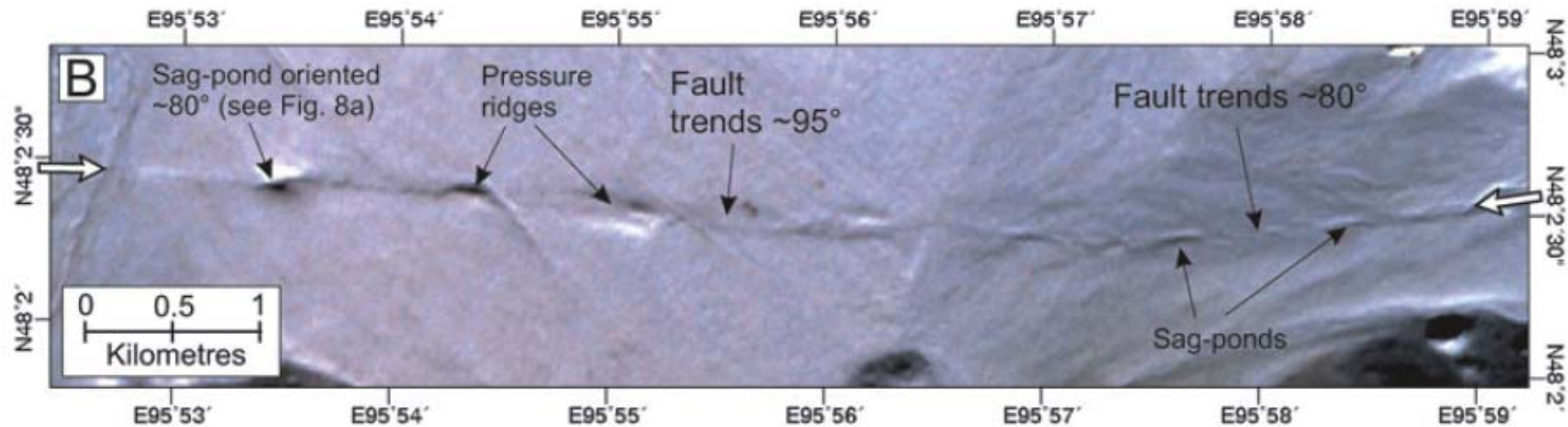
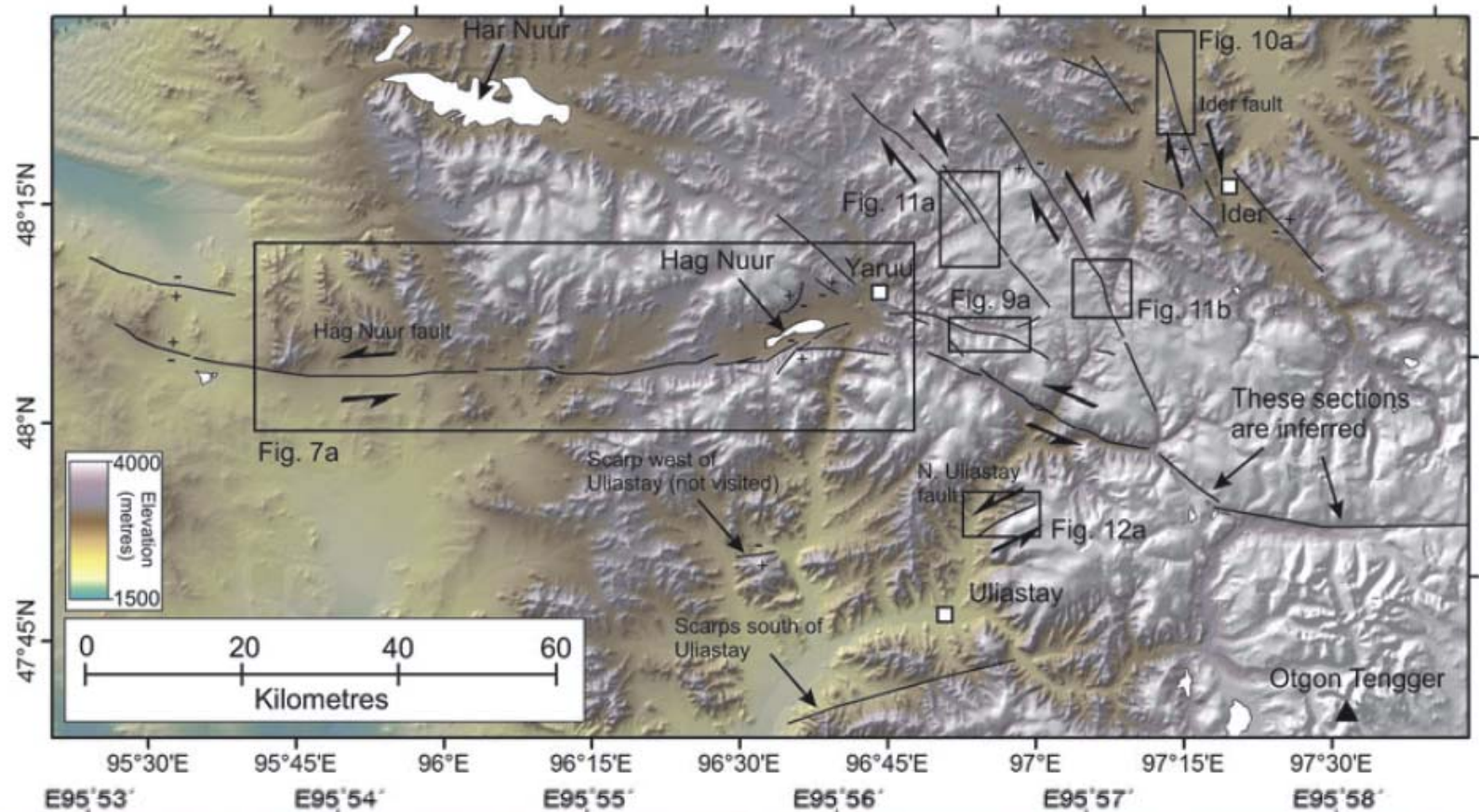
**B**

Bayasgalan et.al. 2005





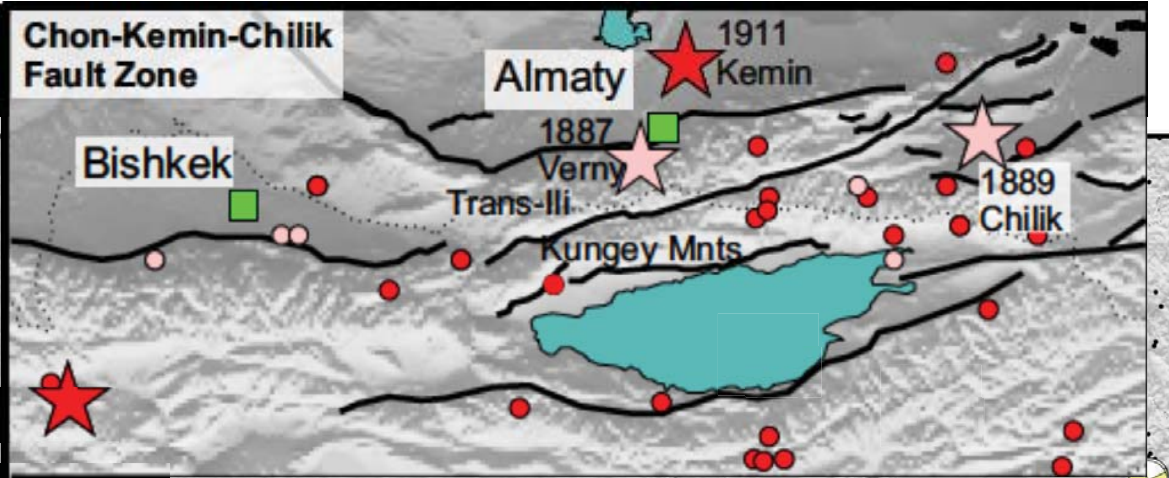
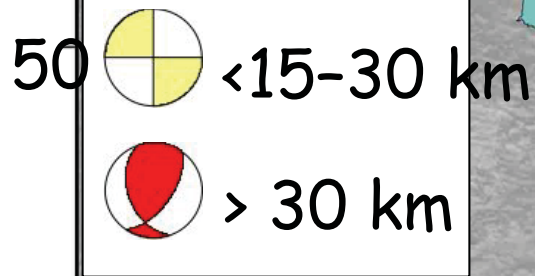




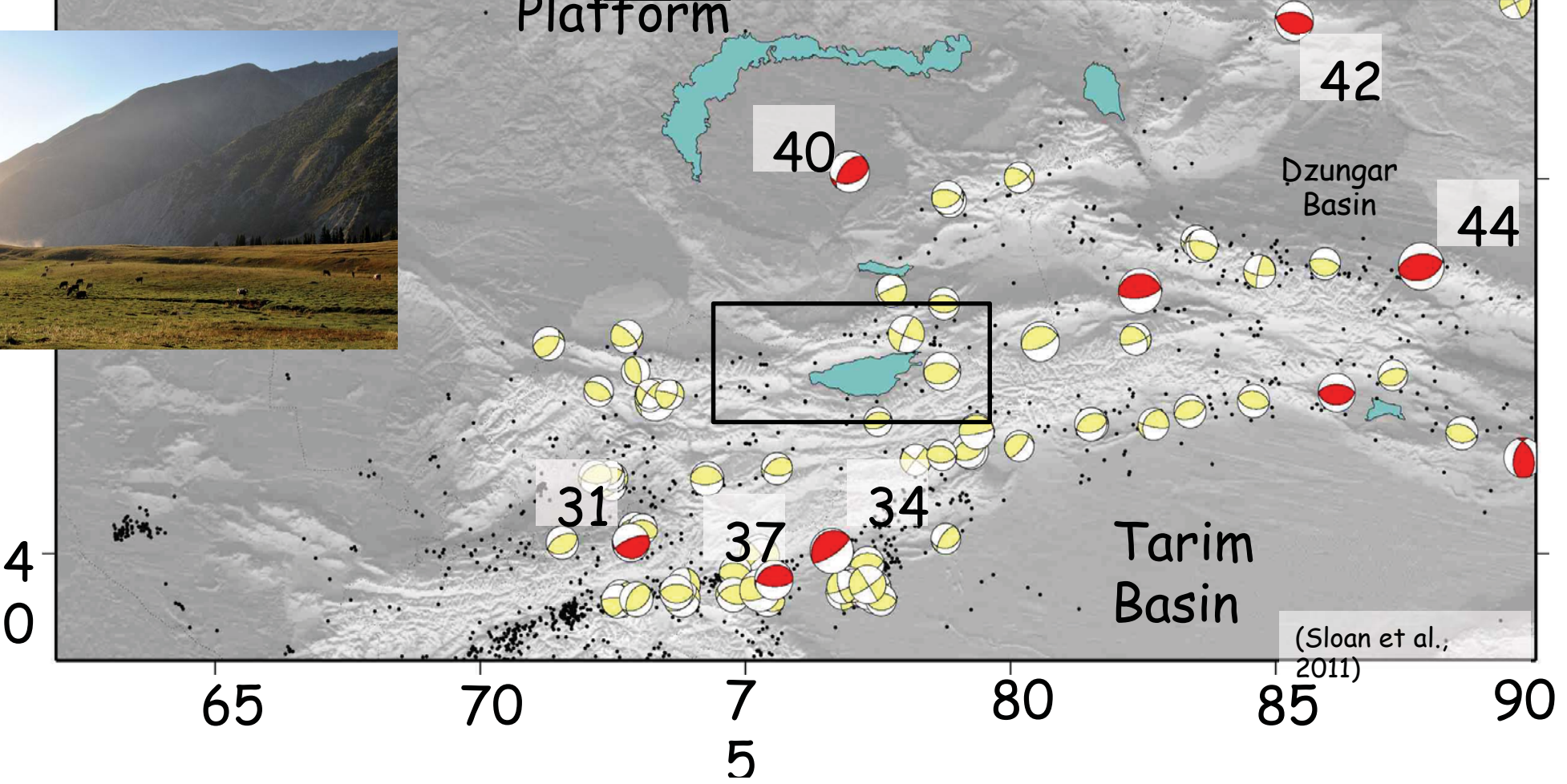
Walker et.al. 2008



# Northern Tien Shan



Kaz Platform



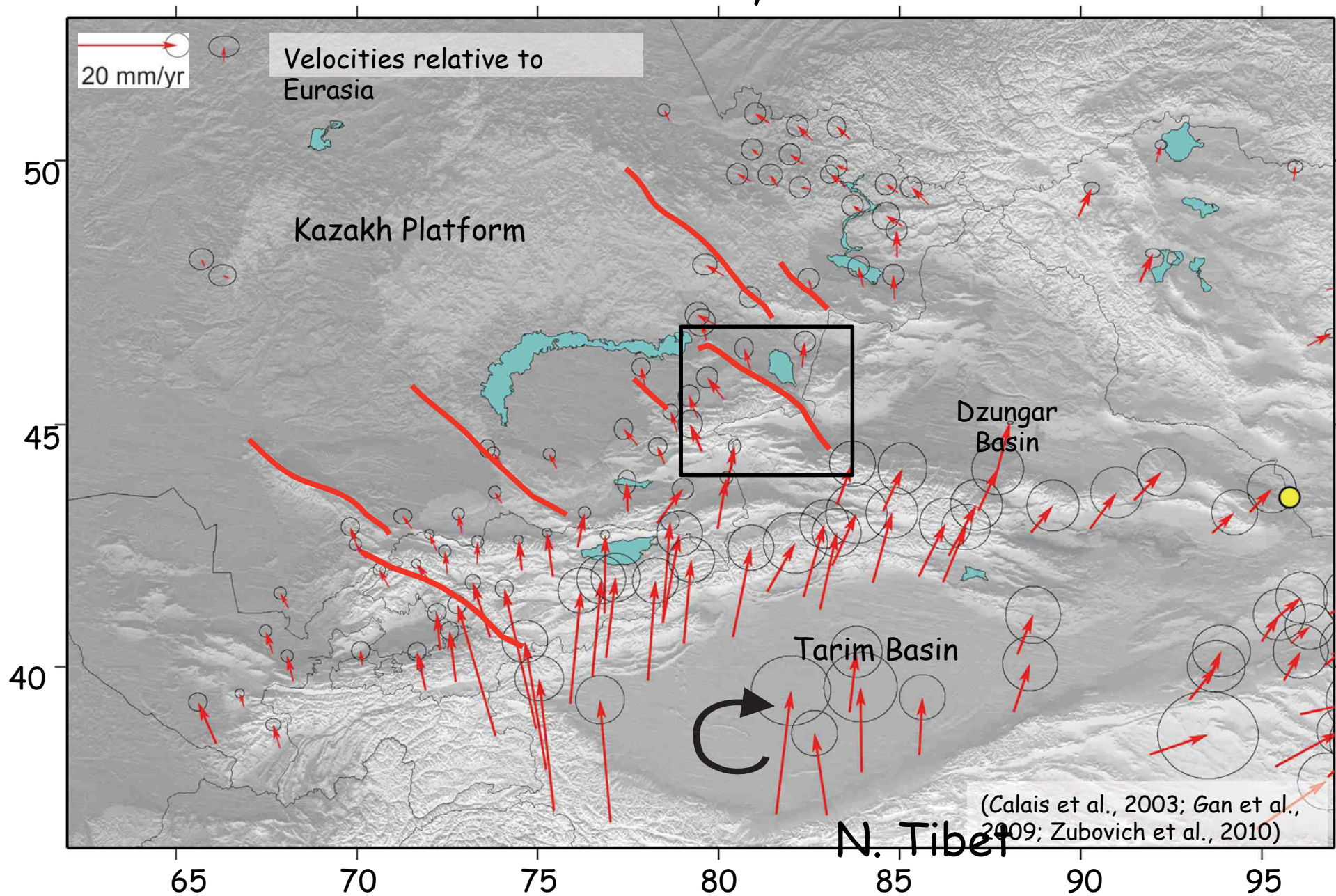




Walker, *Geoscientist* magazine, 2012

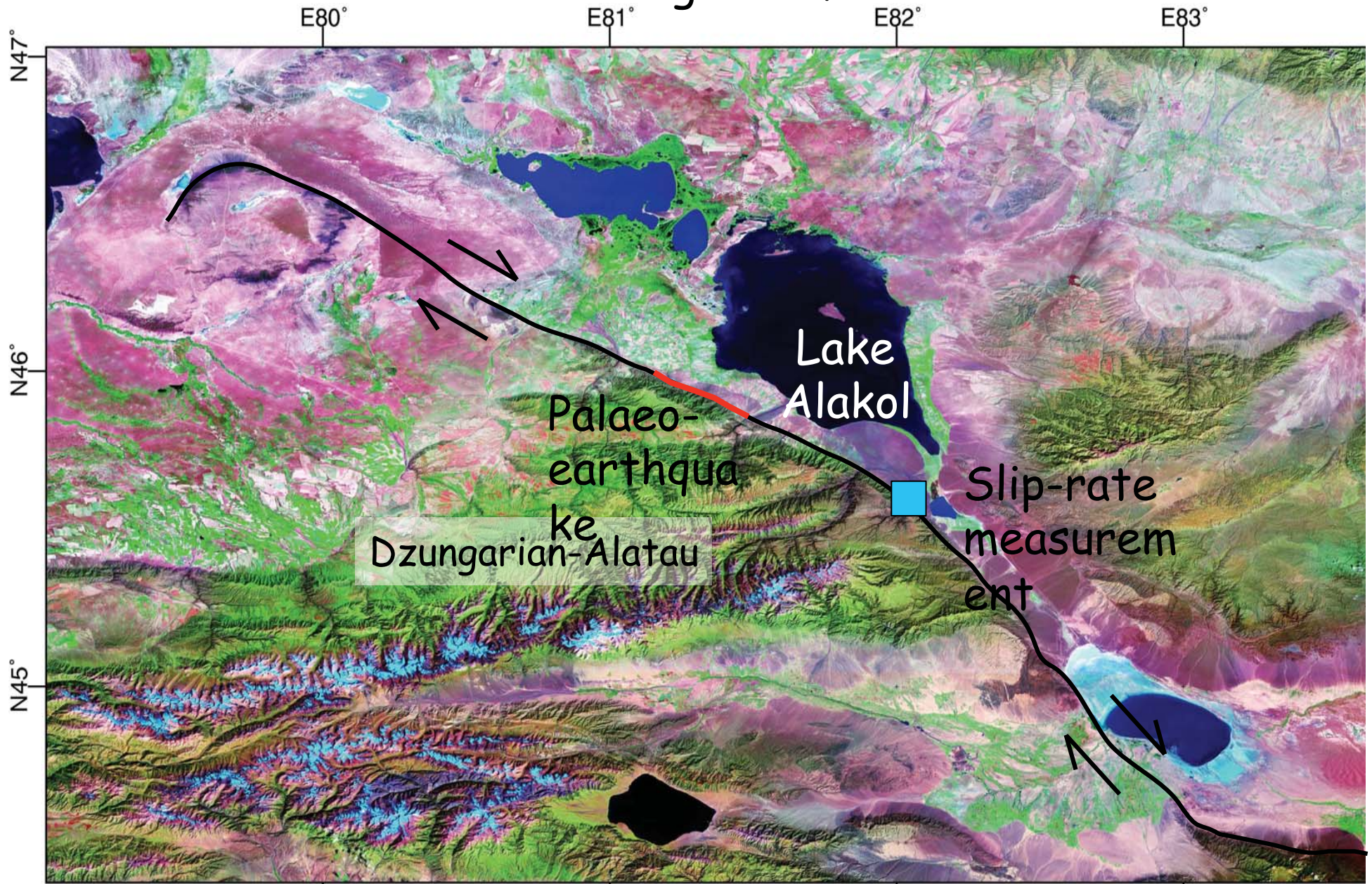


# GPS velocity field



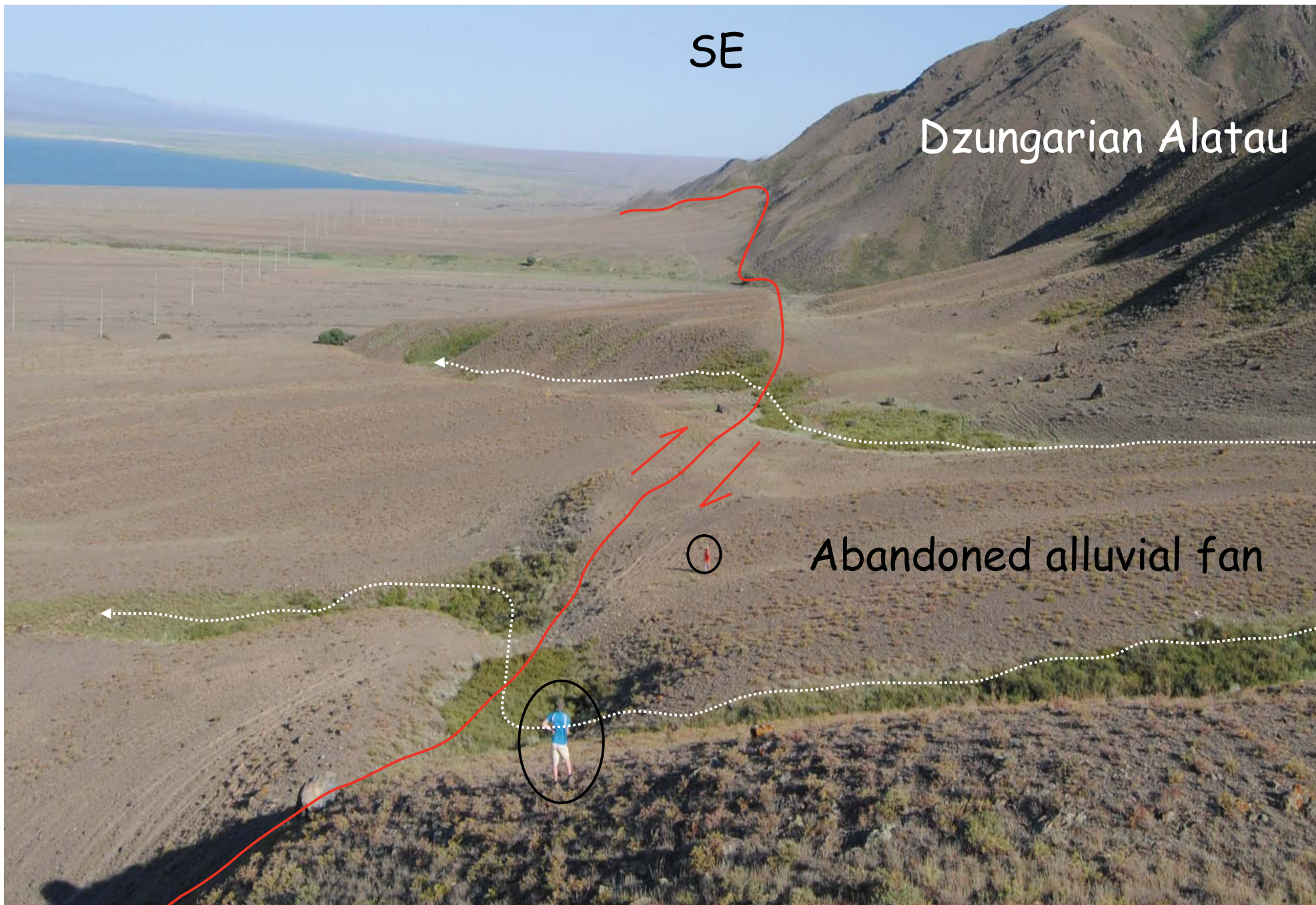


# Dzungarian fault



Campbell et al., *in preparation*



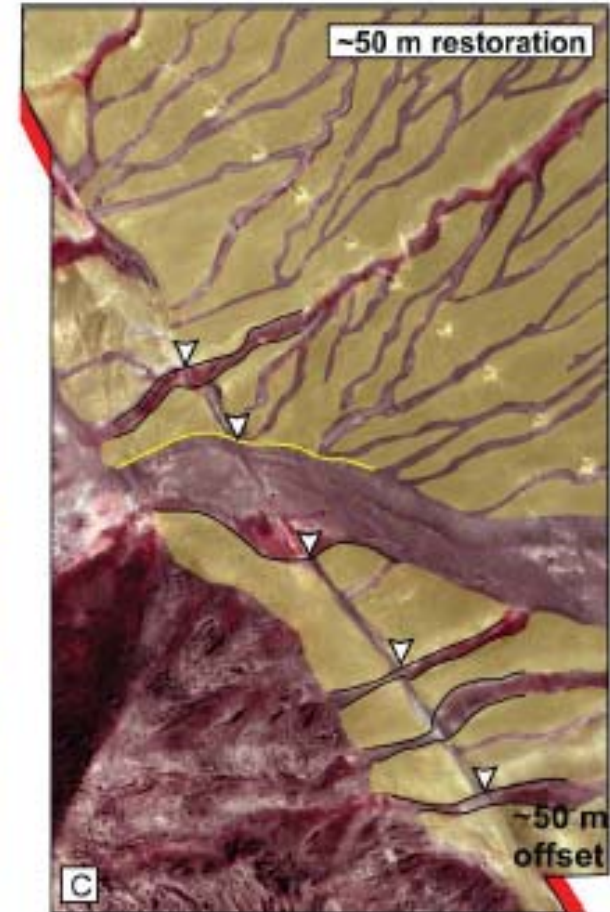
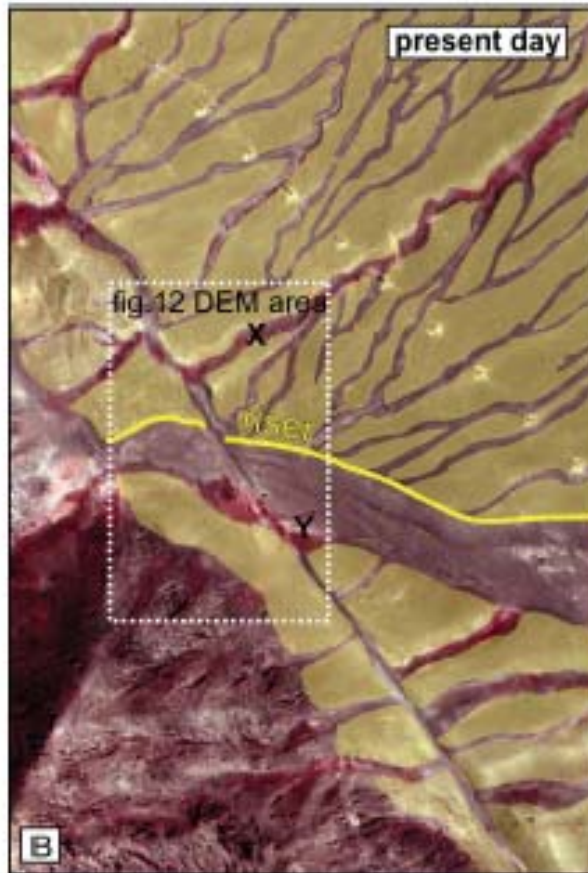
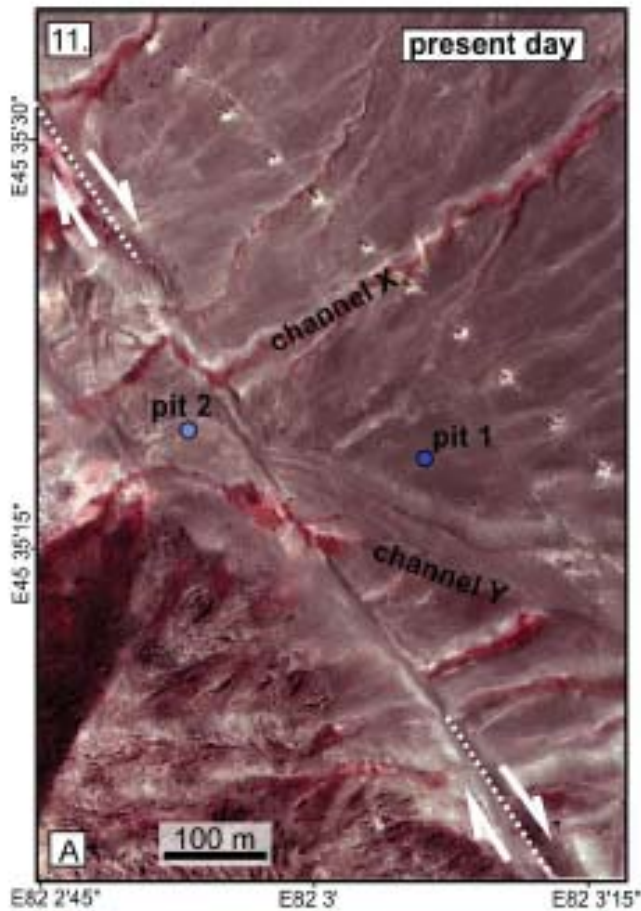


SE

Dzungarian Alatau

Abandoned alluvial fan





50 +/- 5 m displacement

Pit 1 OSL dating: 25.7 +/- 5.8 ka

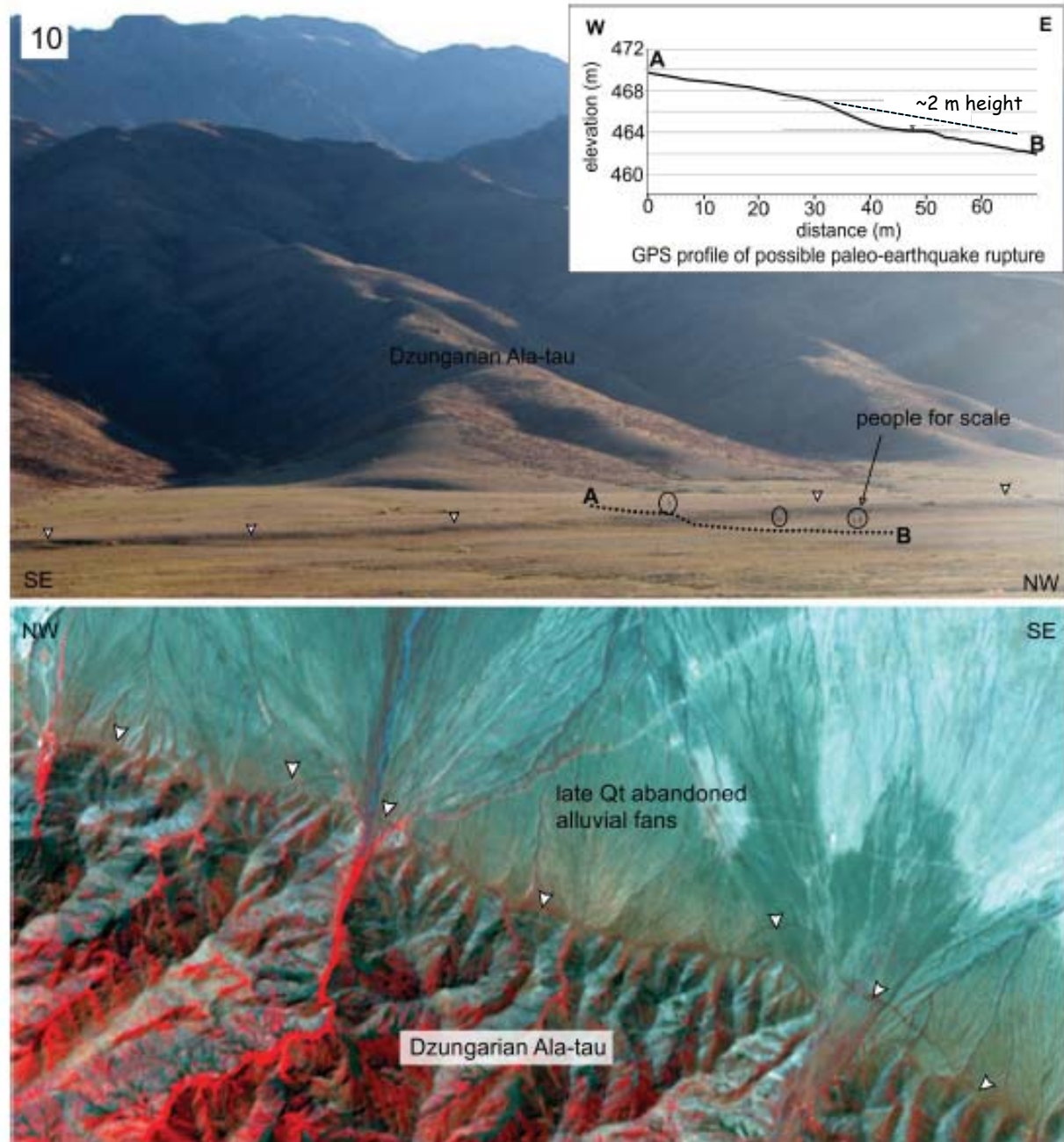
Average slip-rate: 1.4-2.75 mm/yr

KOMPSAT-2 (1 m imagery)

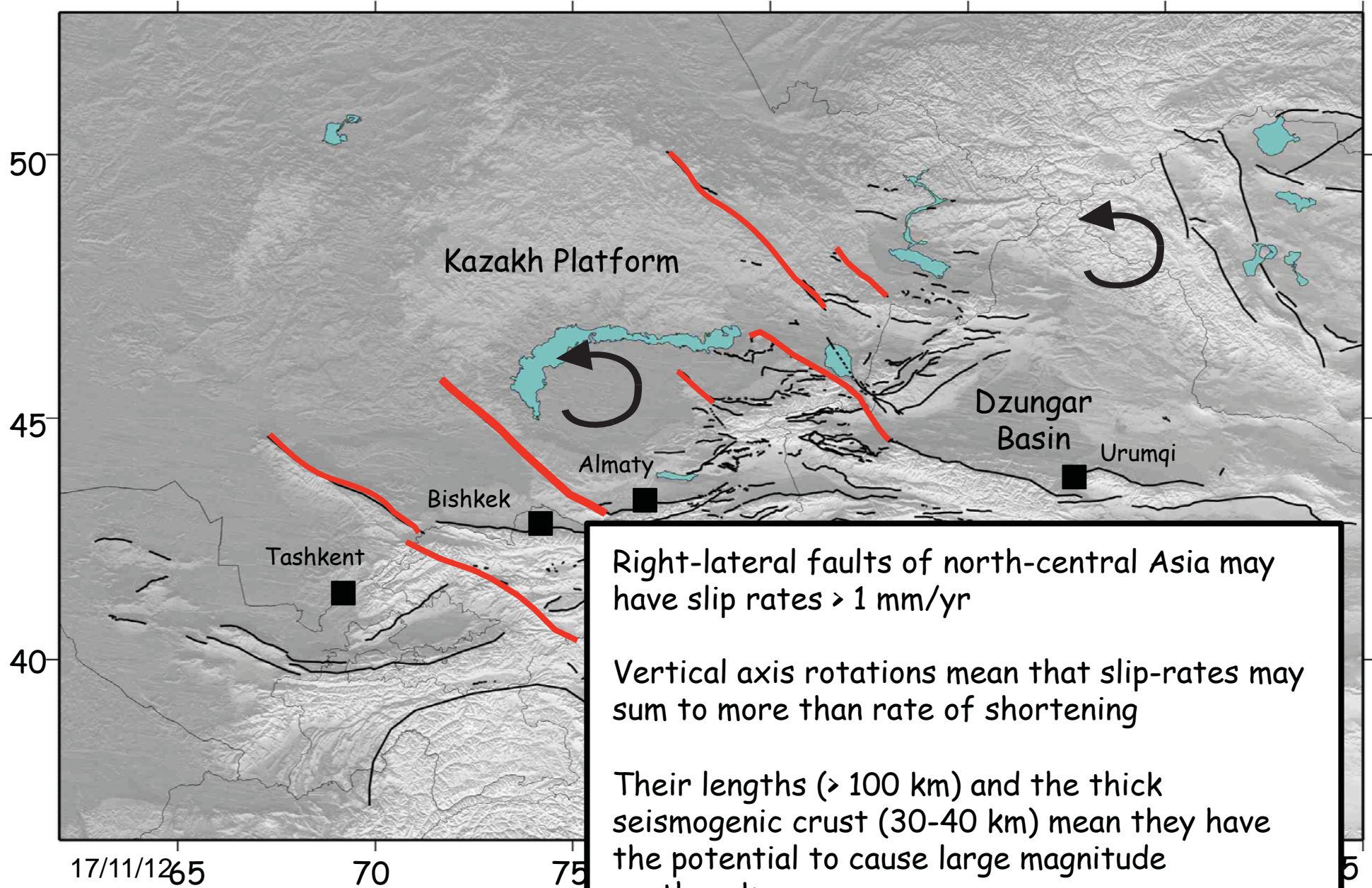


Only one  $M_w \sim 7$   
palaeo-  
earthquake  
rupture visible in  
the landscape

Potential for  
large earthquakes  
( $M_w 7.5+$ ) on  
remaining fault  
segments?







Right-lateral faults of north-central Asia may have slip rates  $> 1$  mm/yr

Vertical axis rotations mean that slip-rates may sum to more than rate of shortening

Their lengths ( $> 100$  km) and the thick seismogenic crust (30-40 km) mean they have the potential to cause large magnitude earthquakes

Thank you





**Thank you**