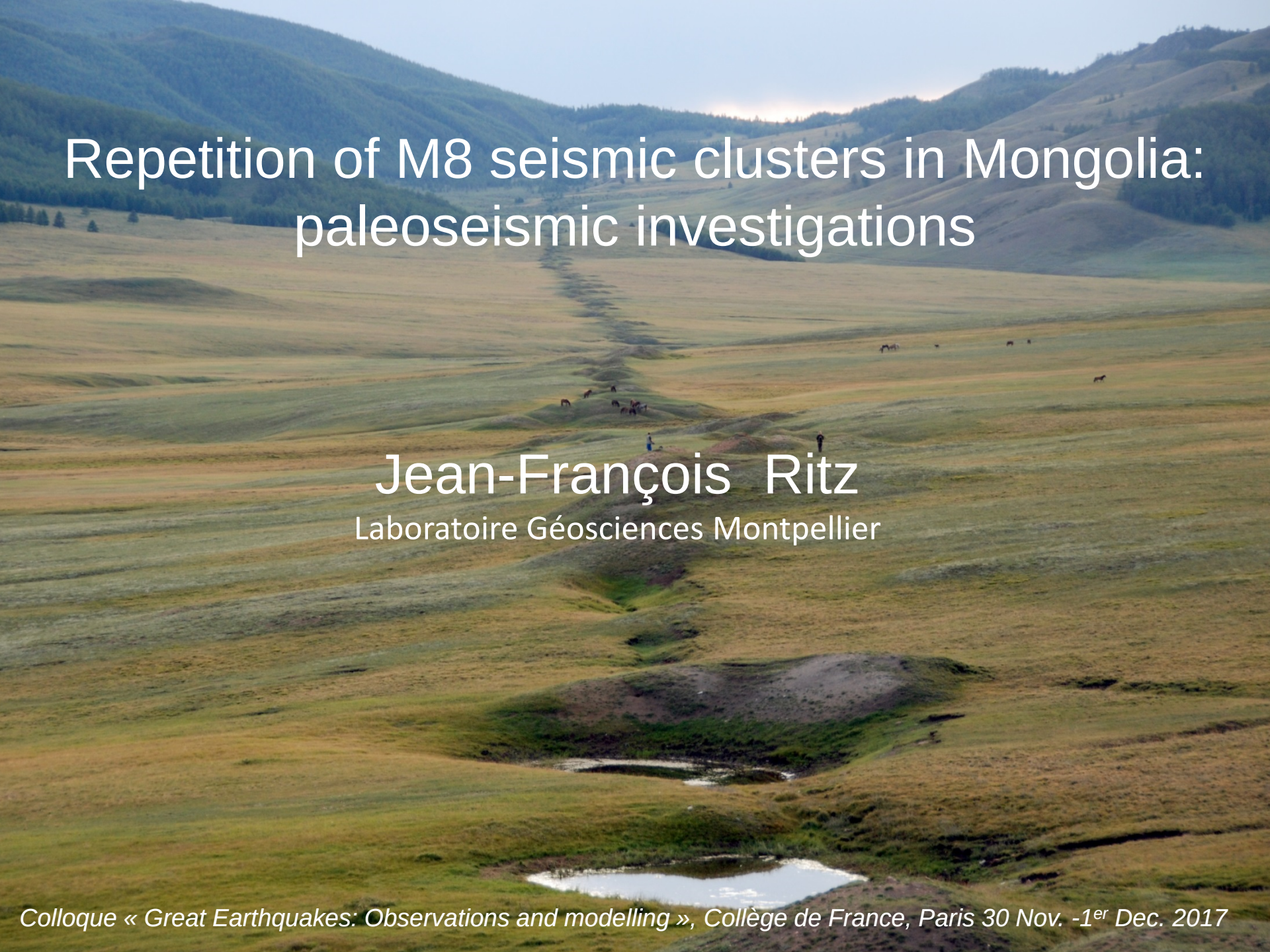


Repetition of M8 seismic clusters in Mongolia: paleoseismic investigations

Jean-François Ritz
Laboratoire Géosciences Montpellier

Colloque « Great Earthquakes: Observations and modelling », Collège de France, Paris 30 Nov. -1er Dec. 2017

with collaborators :

S. Carretier *[1], R. Vassallo *[2], M. Rizza *[3], R. Kurtz *[4], T. Battogtokh *[5] (PhDs at Geosciences Montpellier)

A. Chauvet, J. Chéry, M. Jolivet, M. Ferry , P. Vernant (Geosciences Montpellier)

M. Todbileg, S. Demberel (Geol. Soc. Mongolia and Mongolian Academy of Sciences, Ulan Bator)

C. Larroque (Géosciences Azur, Sophia-Antipolis)

Y. Klinger, J. Choi *[6] (IPG Paris)

L. Bollinger (CEA / LRSG, Bruyeres le Chatel)

R. Braucher, D. Bourlès (CEREGE, Aix-en-Provence)

C. Prentice, S. Mahan, D. Schwartz (USGS)

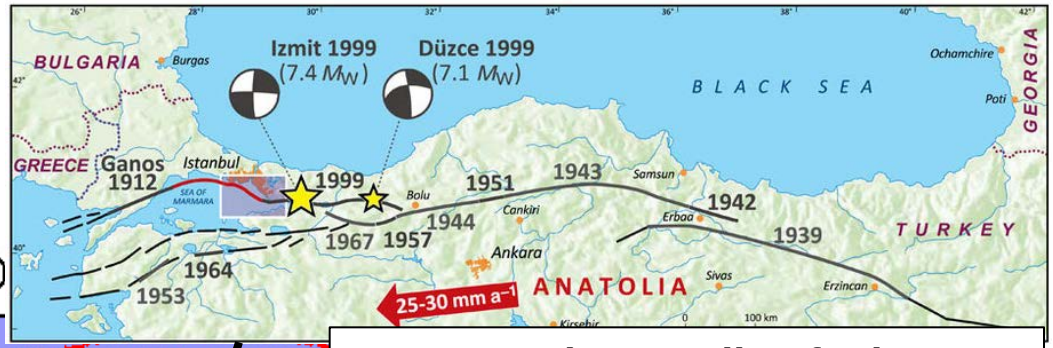
S. McGill (California State University)

A. & S. Arzhannikov (Russian Academy of Sciences, Irkutzk)

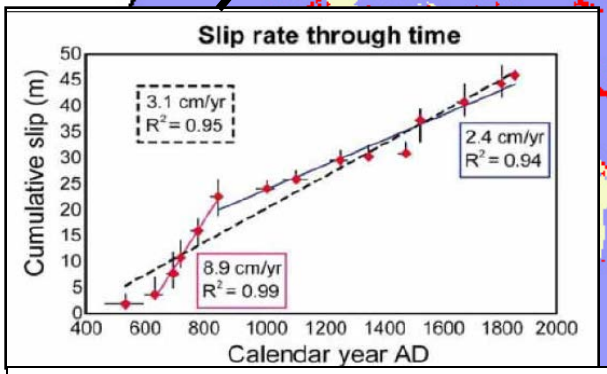
(*):

- 1: PhD 2000, now at Geosciences Environnement Toulouse (GET)
- 2 PhD 2006, now at Isterre - Université Savoie Mont Blanc Chambéry
- 3: PhD 2010, now at CEREGE - University Aix-Marseille
- 4: PhD 2017
- 5: in progress
- 6: Post-doc, now at Korea Institute of Geoscience and Mineral Resources

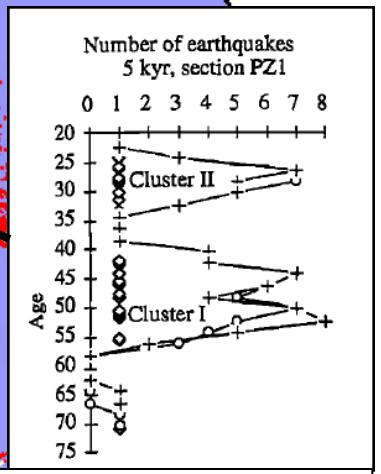
Seismic clustering along fault zones



North Anatolian fault
Stein et al., 1997
(and also Relinger et al. 2000,
Bonhoff et al., 2013,...)



San Andreas fault
Weldon et al., 2004.
(and also Sieh et al., 1989;
Grant et Sieh, 1994, ..],



Dead Sea fault
Marco, Stein & Agnon, JGR 1996
(and also Ferry et al., 2007, ..)

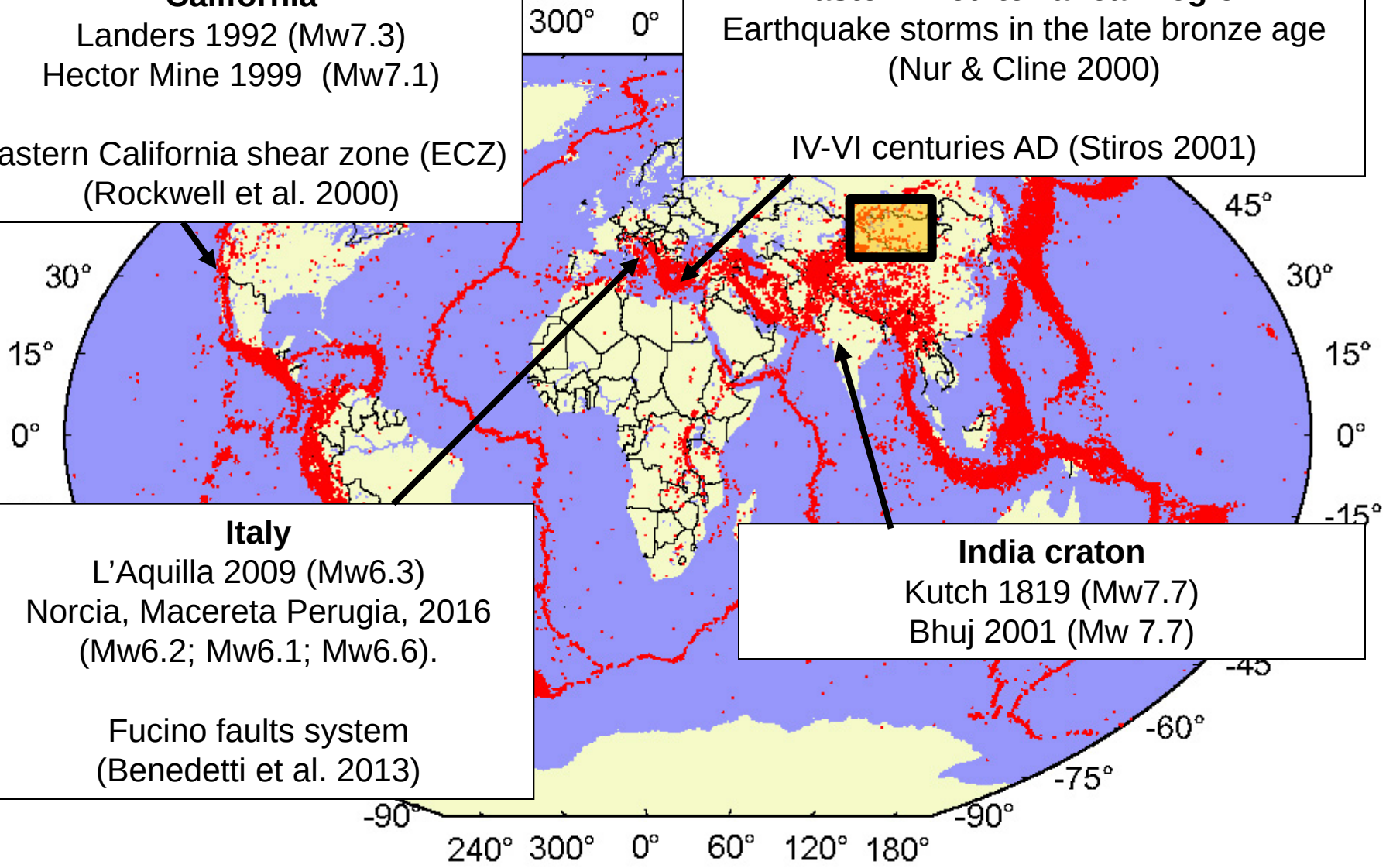
Regional seismic clusters (several faults)

California
Landers 1992 (Mw7.3)
Hector Mine 1999 (Mw7.1)

Eastern California shear zone (ECZ)
(Rockwell et al. 2000)

Eastern Mediterranean region
Earthquake storms in the late bronze age
(Nur & Cline 2000)

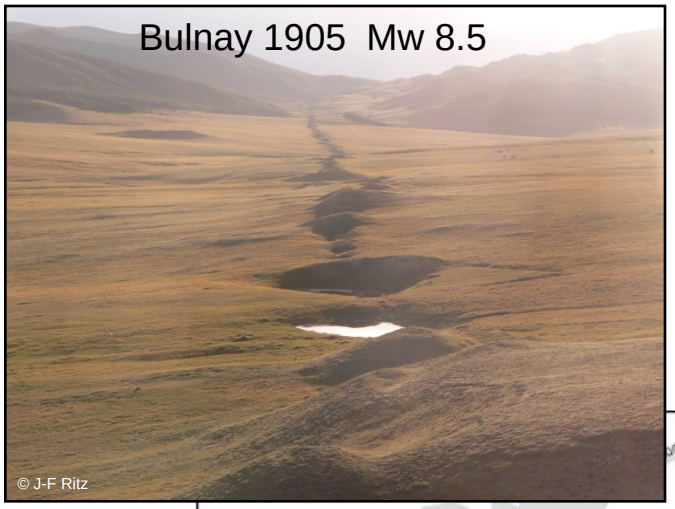
IV-VI centuries AD (Stiros 2001)

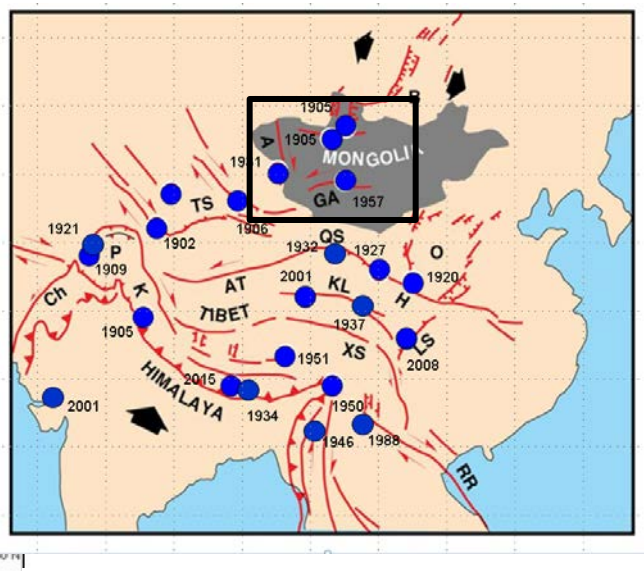


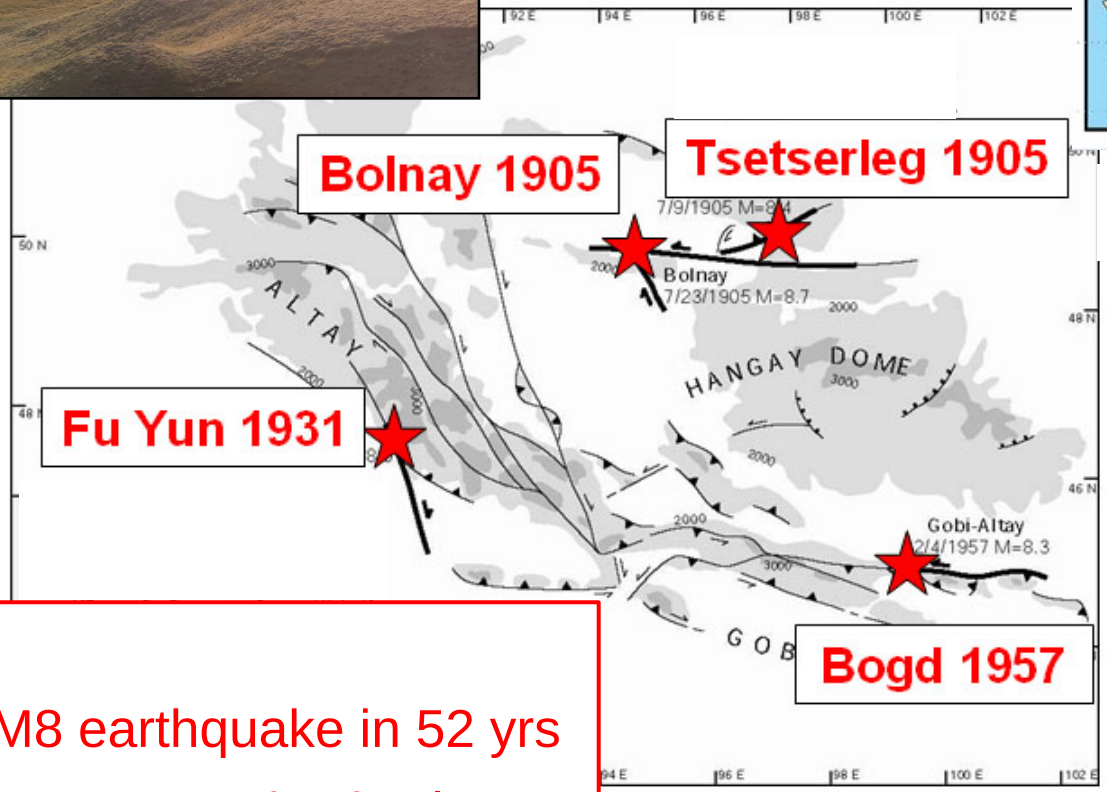
Italy
L'Aquilla 2009 (Mw6.3)
Norcia, Macereta Perugia, 2016
(Mw6.2; Mw6.1; Mw6.6).

Fucino faults system
(Benedetti et al. 2013)

India craton
Kutch 1819 (Mw7.7)
Bhuj 2001 (Mw 7.7)



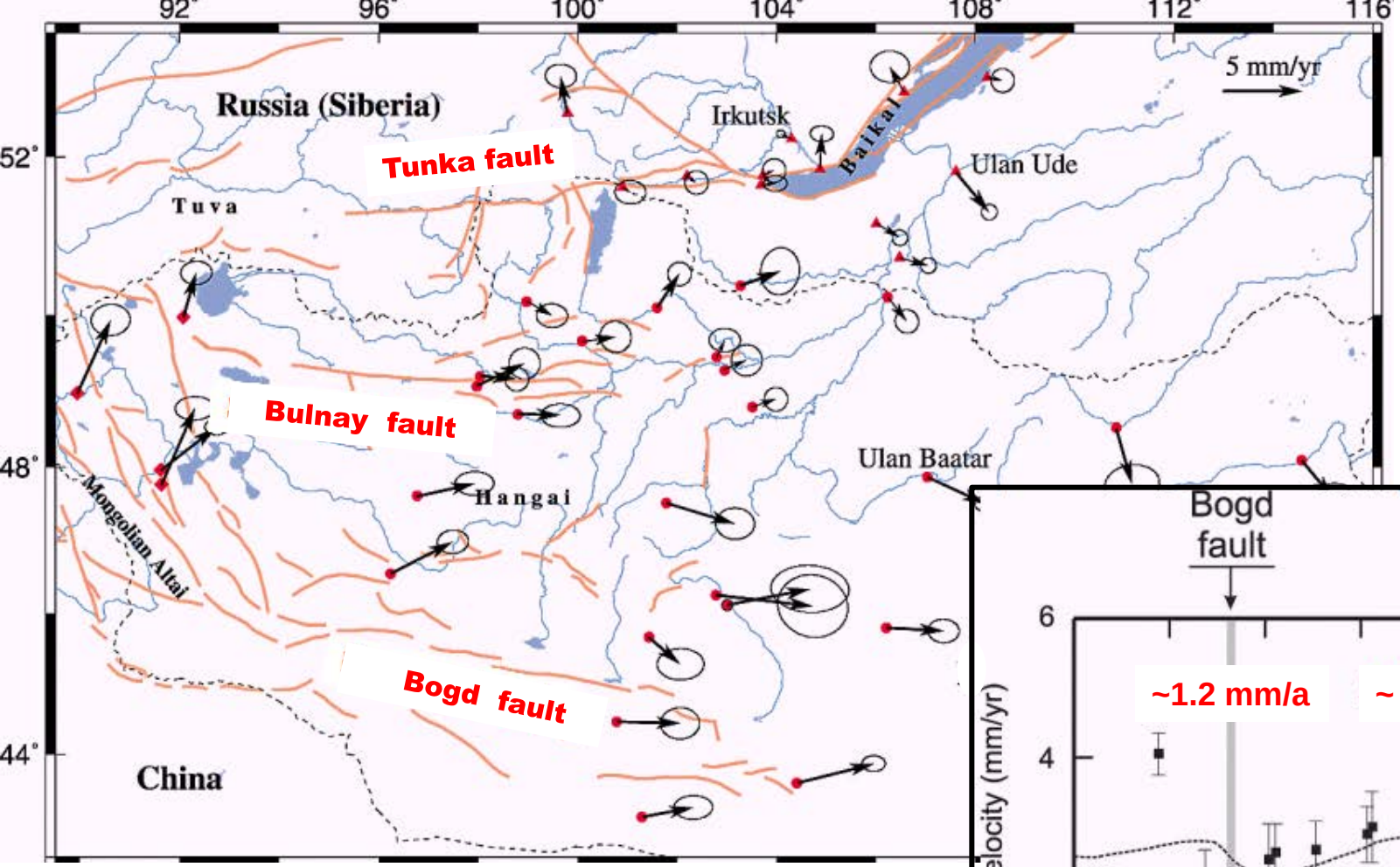


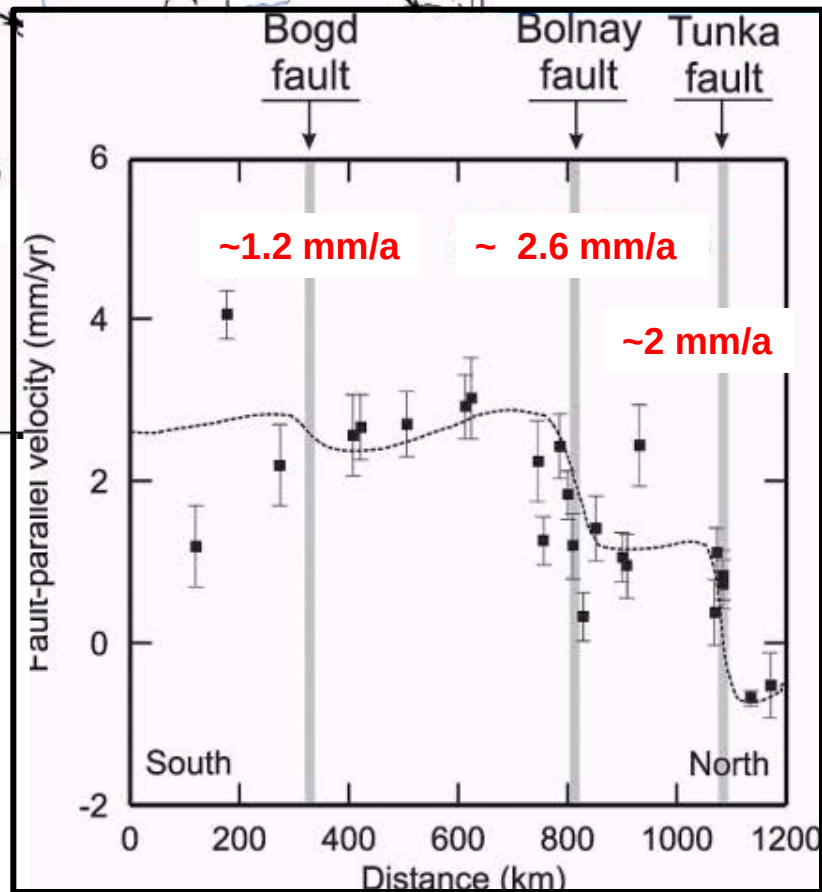


Asie Centrale: séismes de M7.8+ depuis 1900 AD

Four M8 earthquake in 52 yrs

⇒ XX century seismic cluster

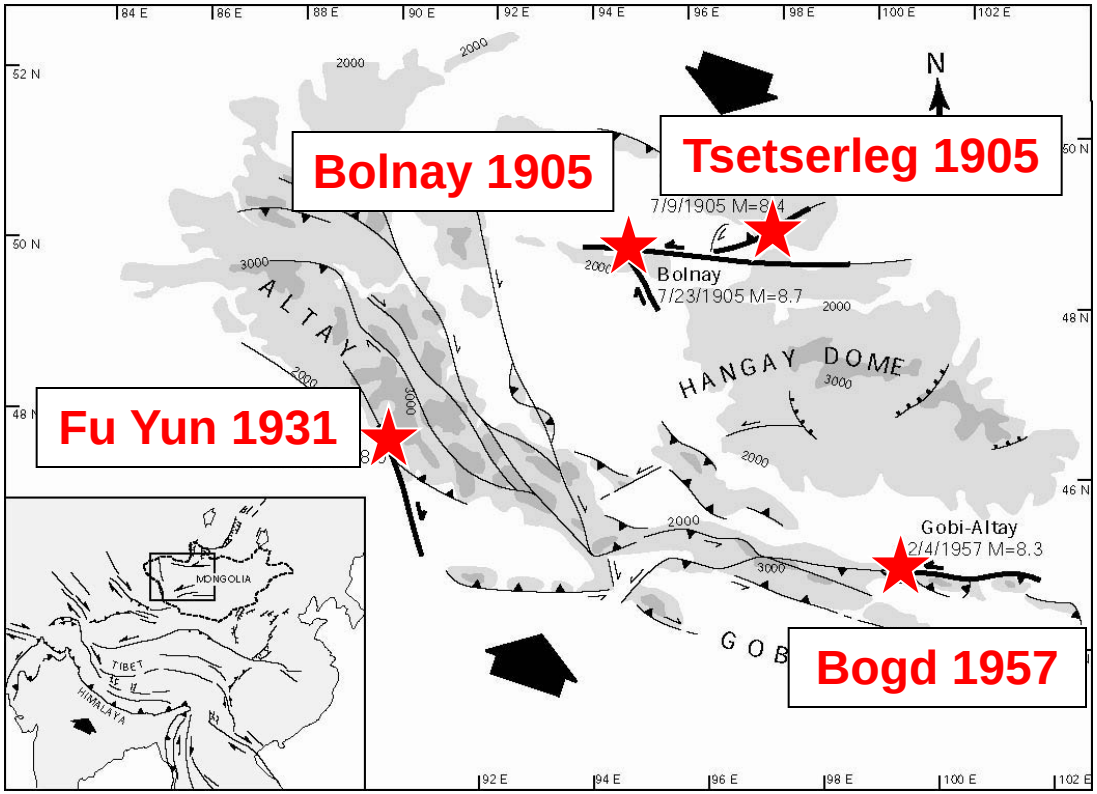




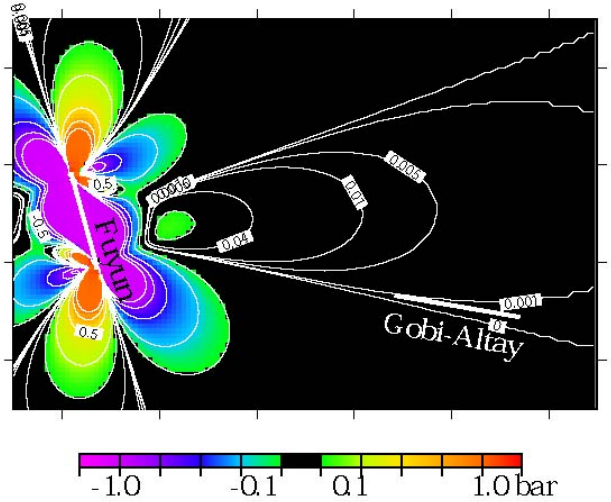
GPS measurements (mm/yr) in Mongolia

Calais et al. (2003); Vergnolle et al., (2003)

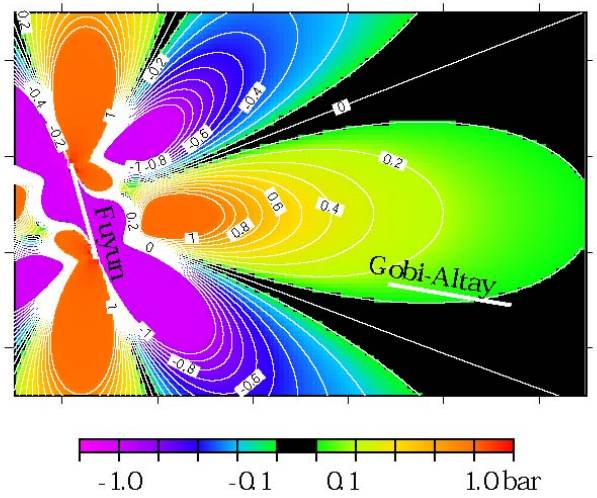
4 major events (M8) in 52 years, slow faults (~1mm/a)



Chéry, Carretier, Ritz (2001)

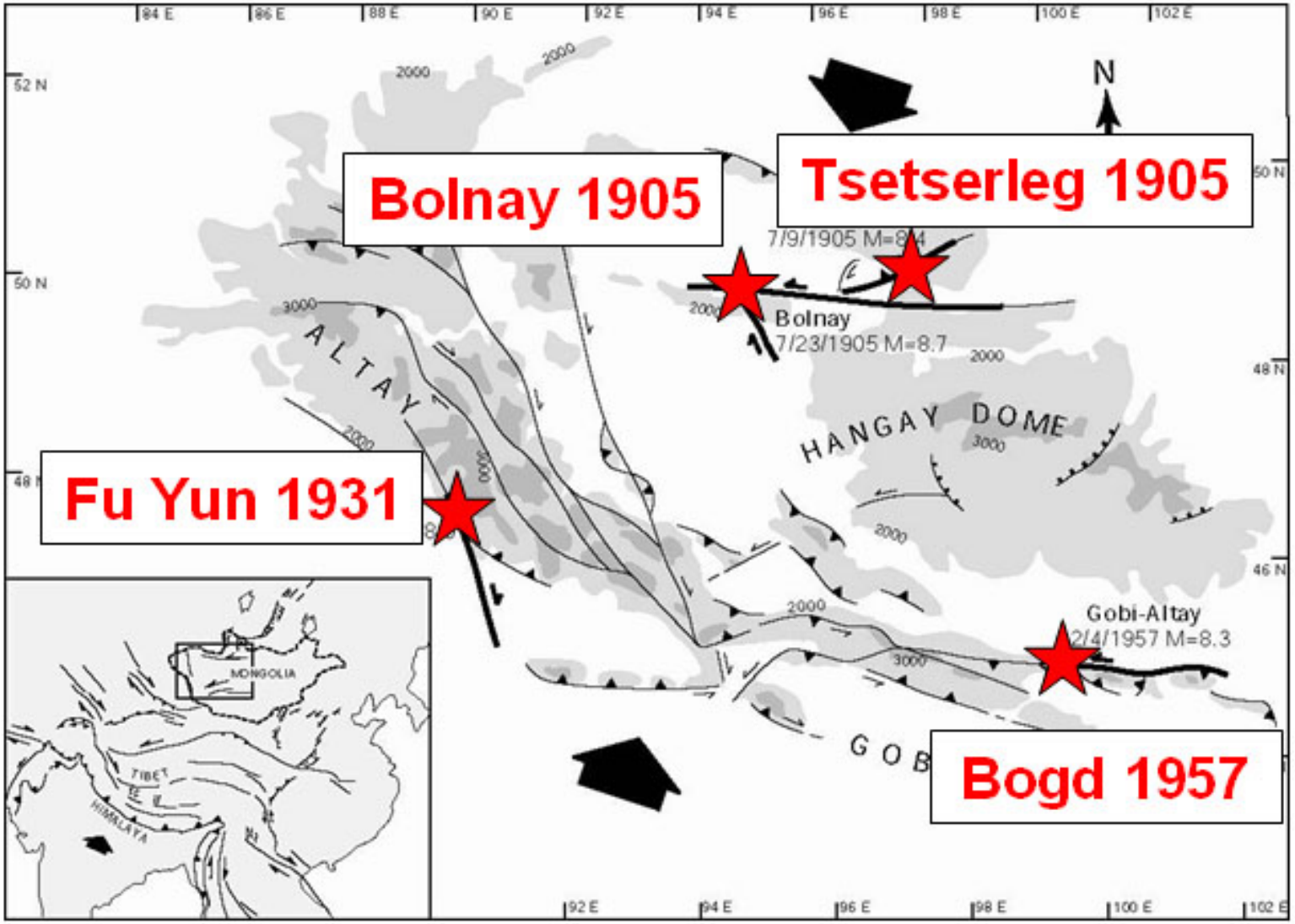


Co-seismic stress transfert
(upper elastic crust)



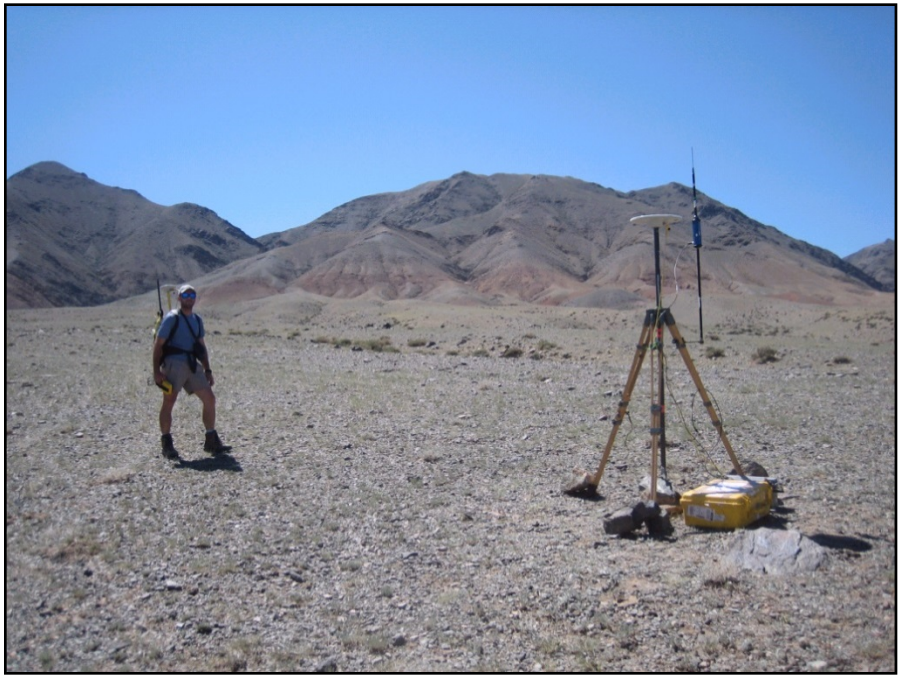
Post-seismic stress transfert
(visco-elastic lower crust)

Model: post-seismic visco-elastic stress transfert would explain this regional seismic clustering



Can we see the repetition of this M8 seismic cluster in paleoseismic records ?

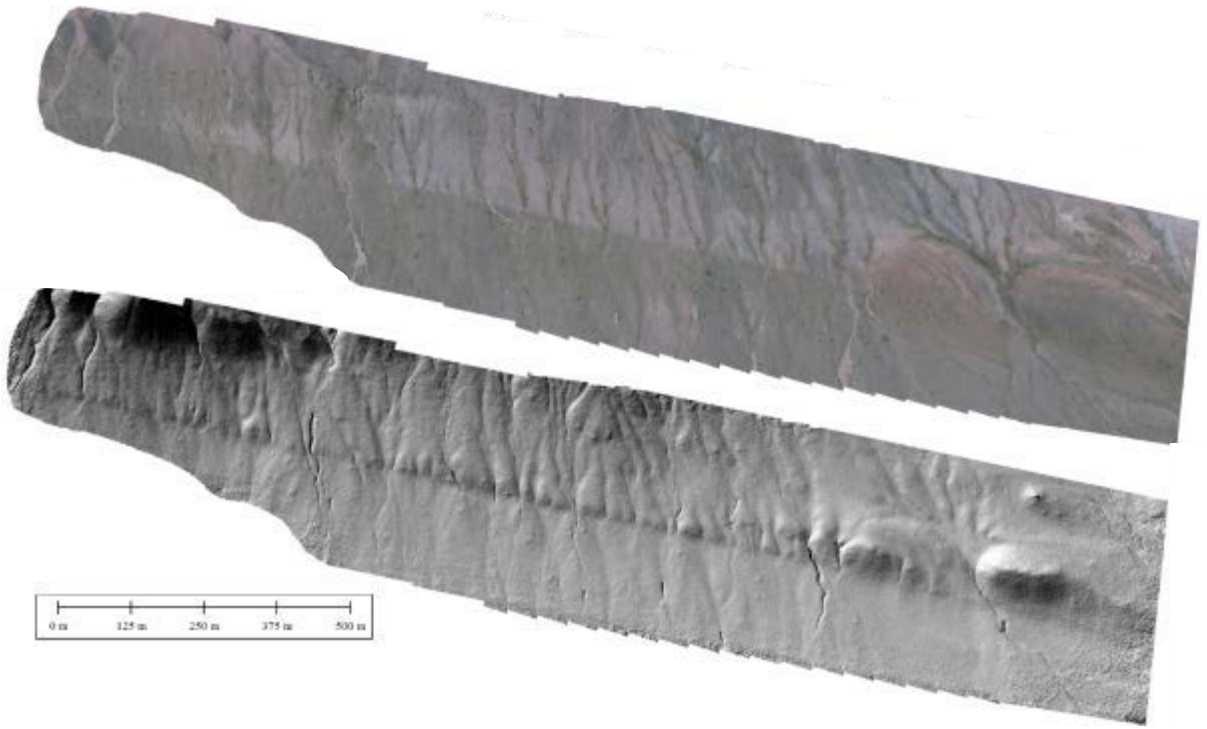
⇒ Paleoseismologic investigations along the Bogd and the Bulnay faults



Morphotectonic analysis

Slip rate: cumulative D / cumulative T
(SR = Dc / Tc) mm/yr

If unit coseismic Du is constant
SR = Du / Tu ⇒ (Tu = Du / SR) years



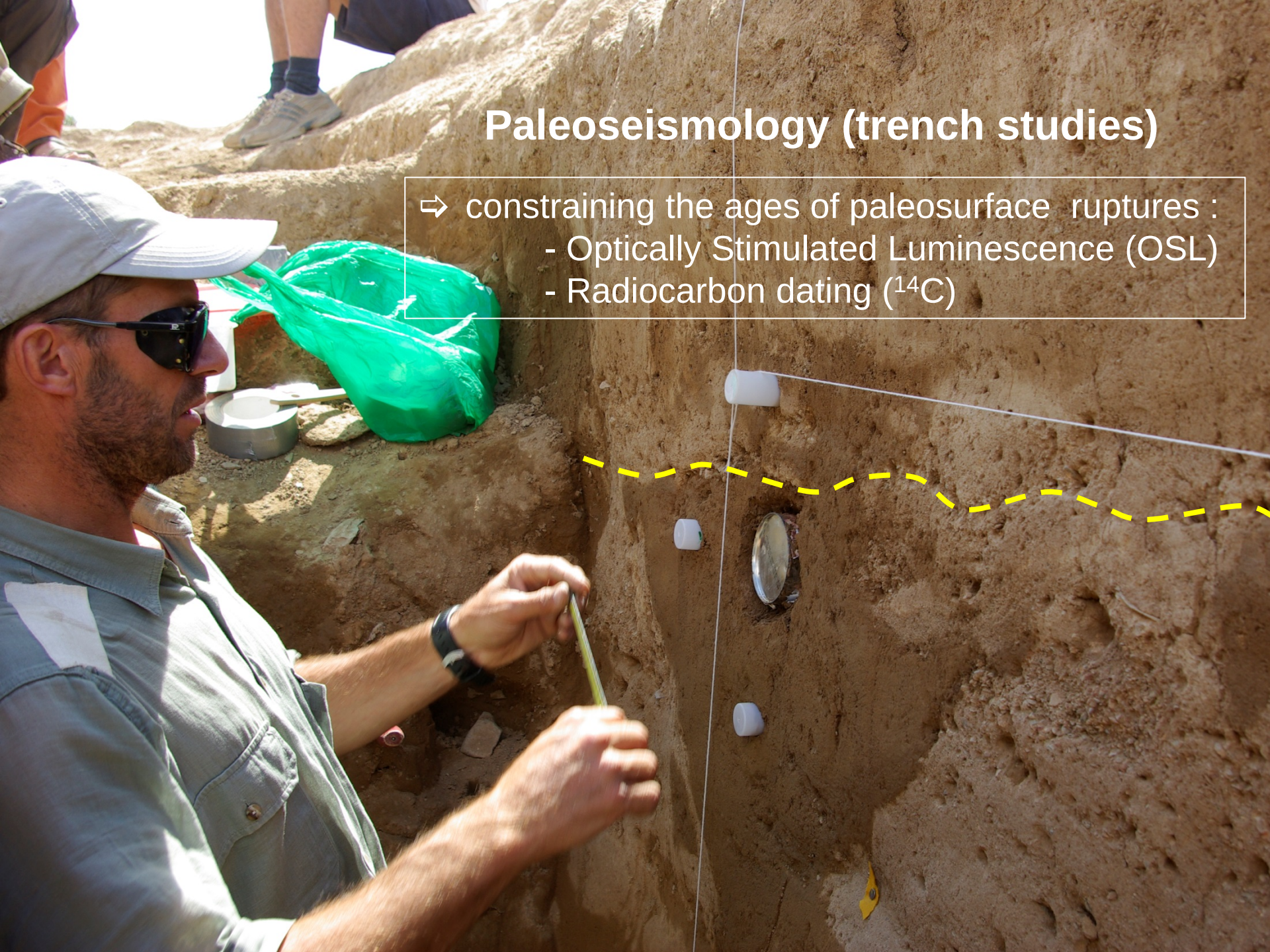
Measuring offsets (Dc, Du)
Analysing the slip distribution

⇨ Mapping Quaternary geomorphology
- Satellite imagery
- Aerial photographs
- Field: microtopography (DEM):
  GPS RTK, KAP, Scanner, Drone

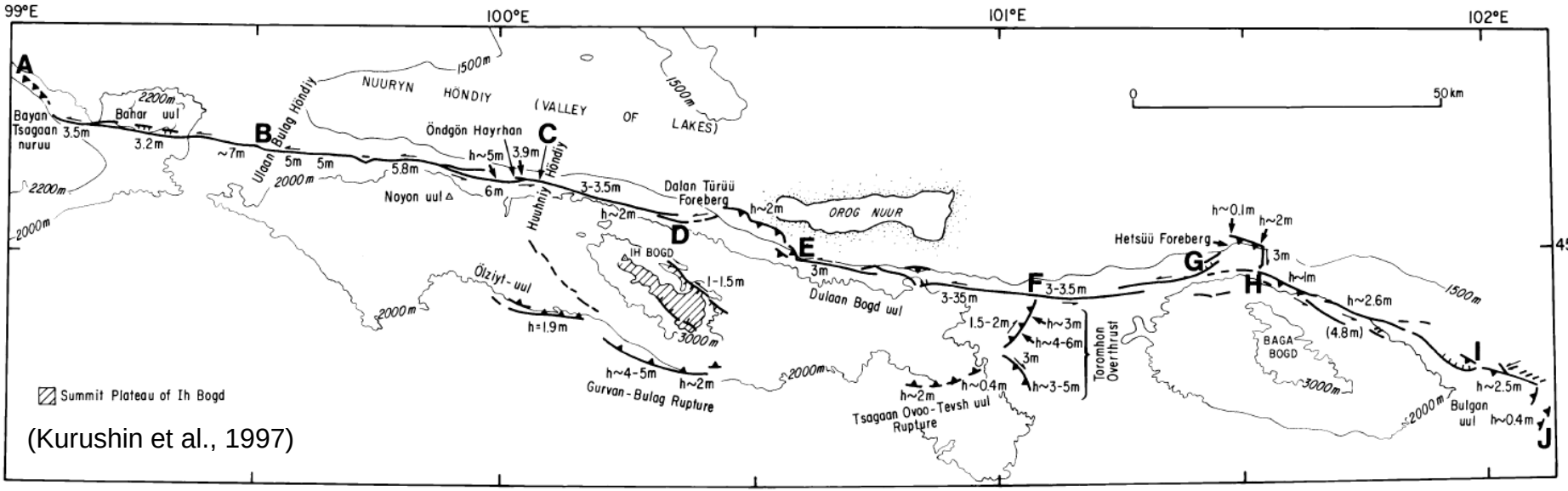
Surface age exposure dating (in situ produced ^{10}Be) sampling quartz-rich rocks: i.e. granit boulders exposed to cosmic-rays

⇒ **Ages of the displaced markers (Tc)**

Combining cumlative offsets (Dc) and ages (Tc) allows determining slip rates (SR= Dc/Tc) along faults


Paleoseismology (trench studies)
⇨ constraining the ages of paleosurface ruptures :
- Optically Stimulated Luminescence (OSL)
- Radiocarbon dating (^{14}C)

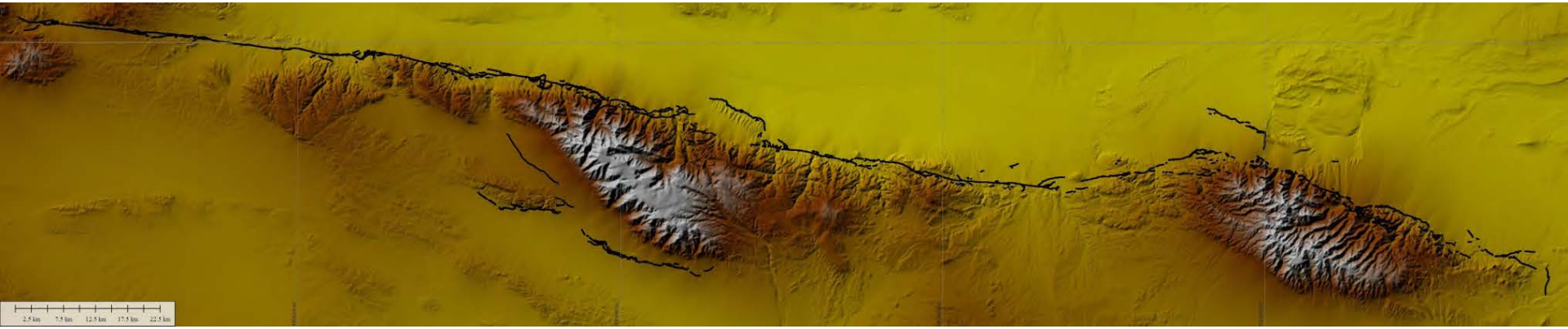
1957 M8 Gobi-Altay earthquake surface rupture

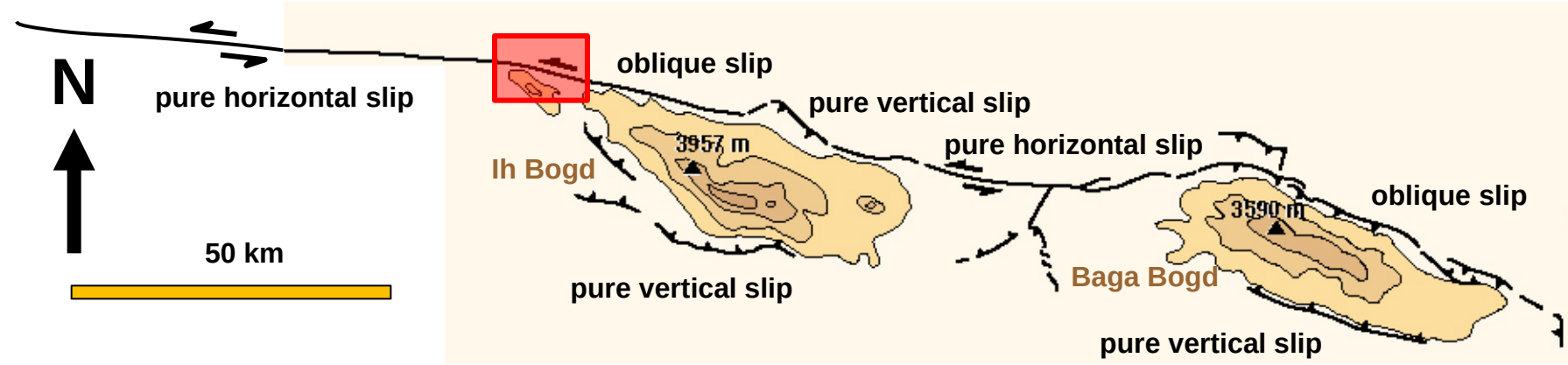


(Kurushin et al., 1997)

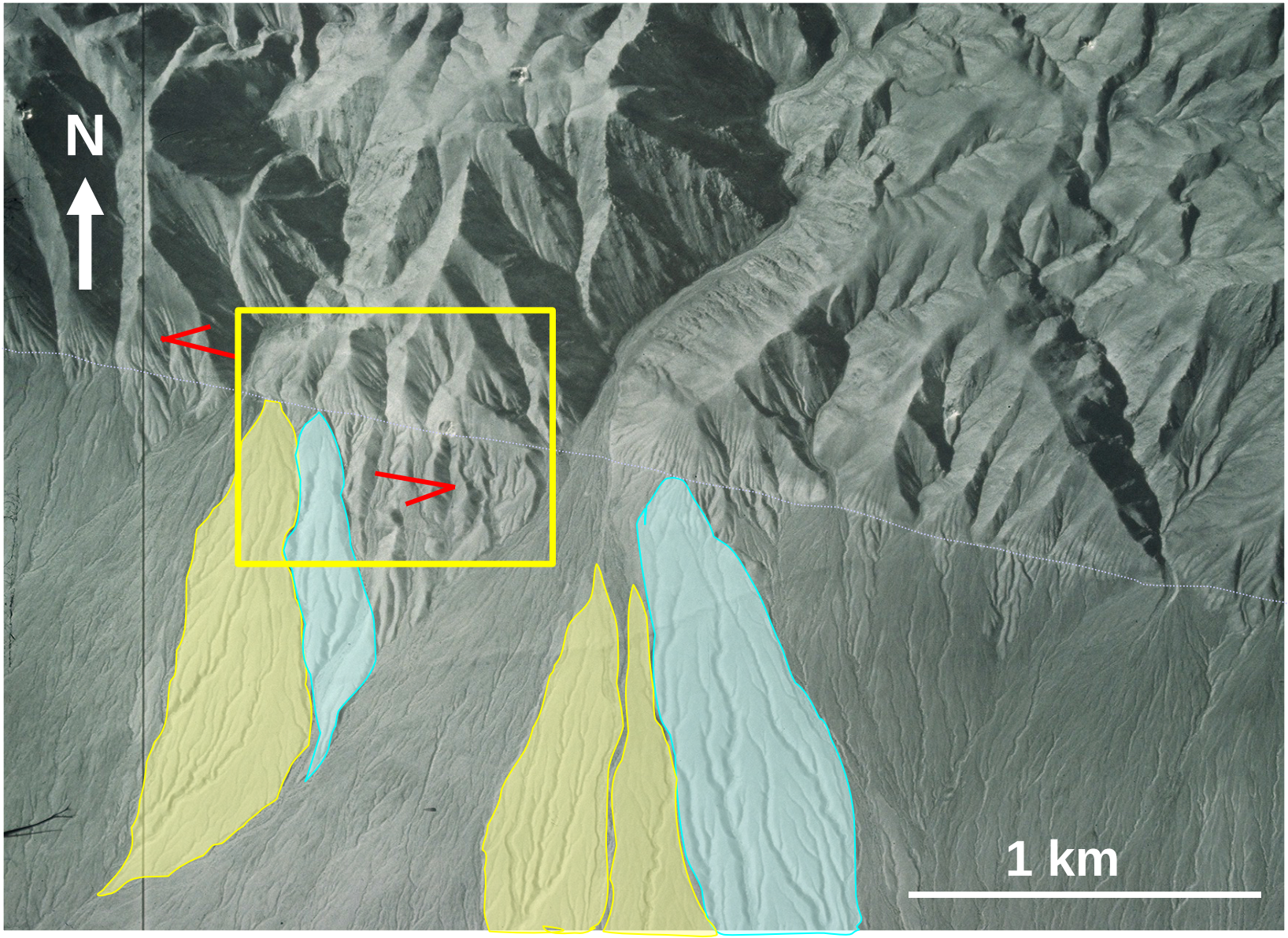
260 km long strike-slip fault with horizontal slip 3-6 m, (+ 100km “secondary” reverse faulting)

Close correlation between the geometry and the kinematics of 1957 rupture, and the topography

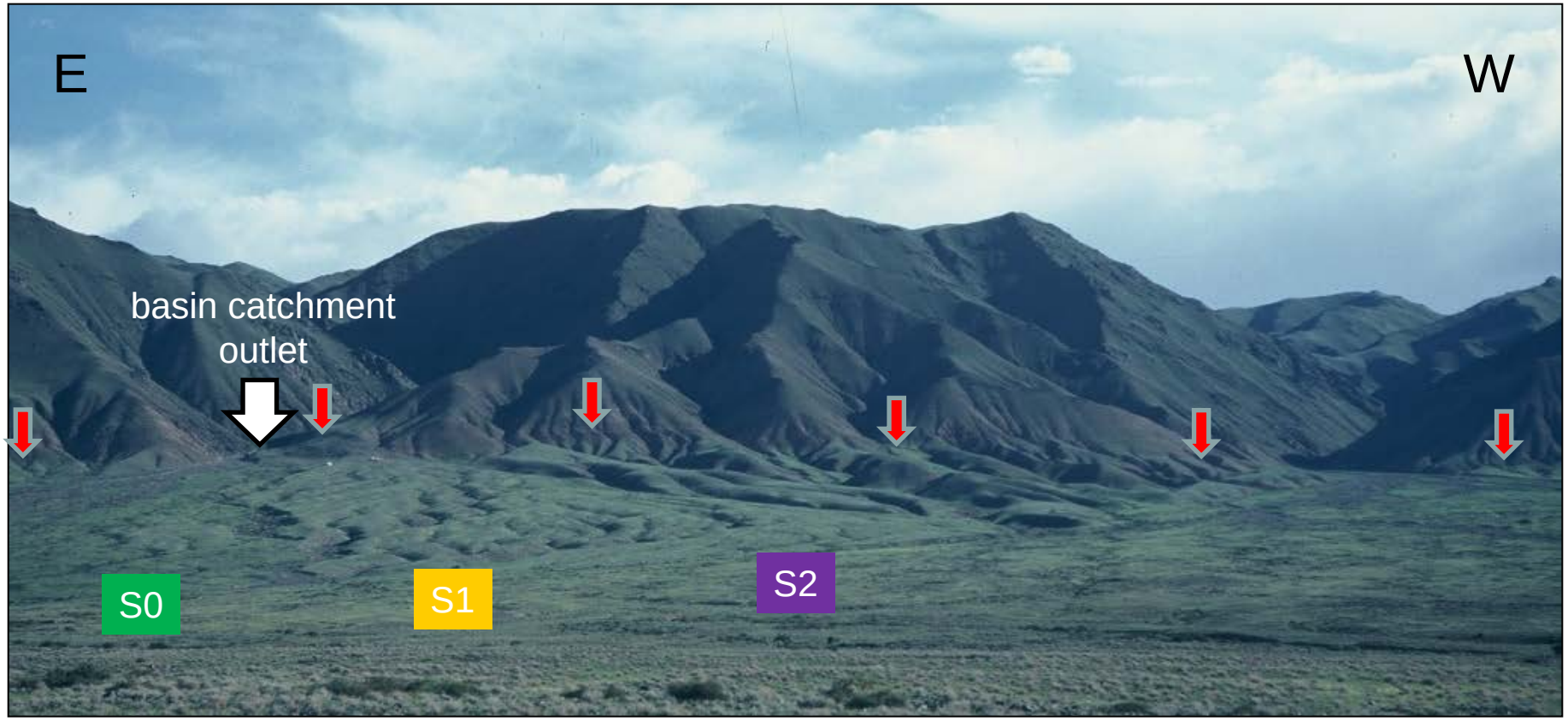


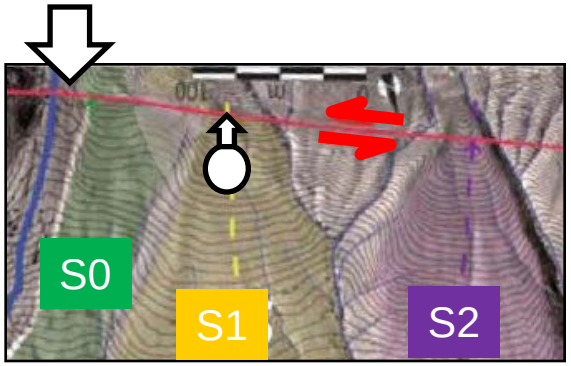


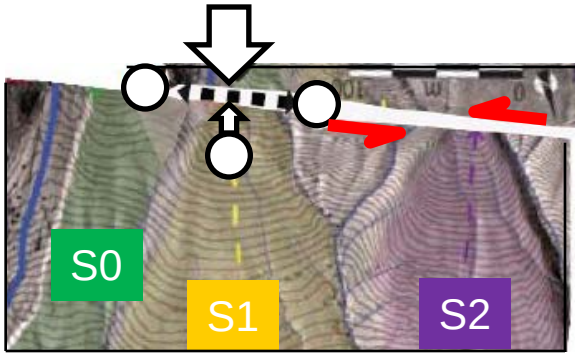
Bogd fault (Noyan Uul): aerial picture (USSR 1958)



Cumulative left-lateral displacements of alluvial fans





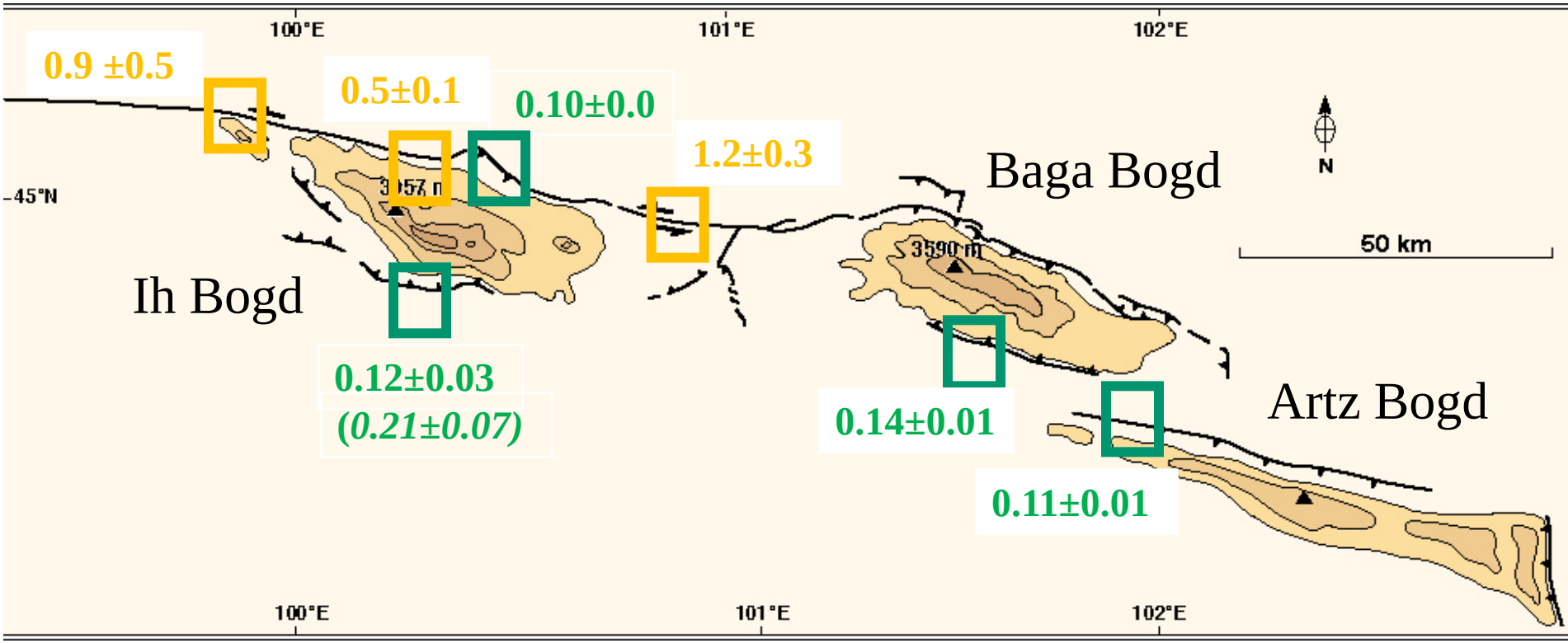


Dc = 46 m – 139 m

Tc (S1) = 108 ka

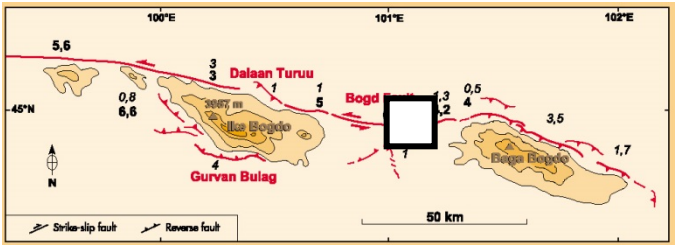
Horizontal slip rate (SR) : 0.9 ± 0.4 mm/yr

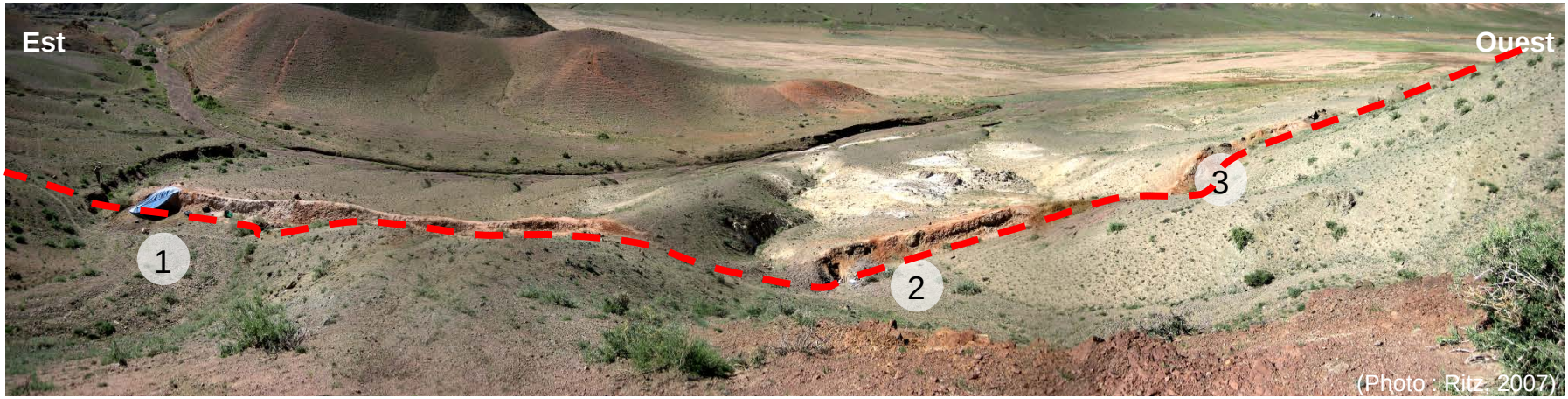
Horizontal and vertical slip rates along the Gurvan Bogd fault system (mm/yr)

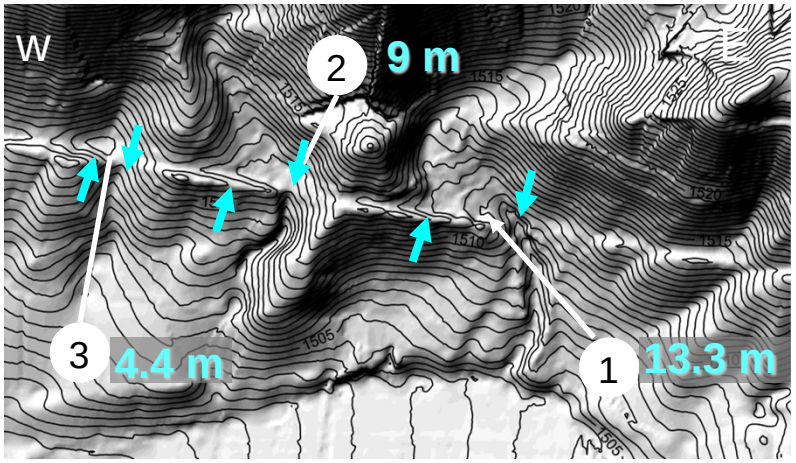


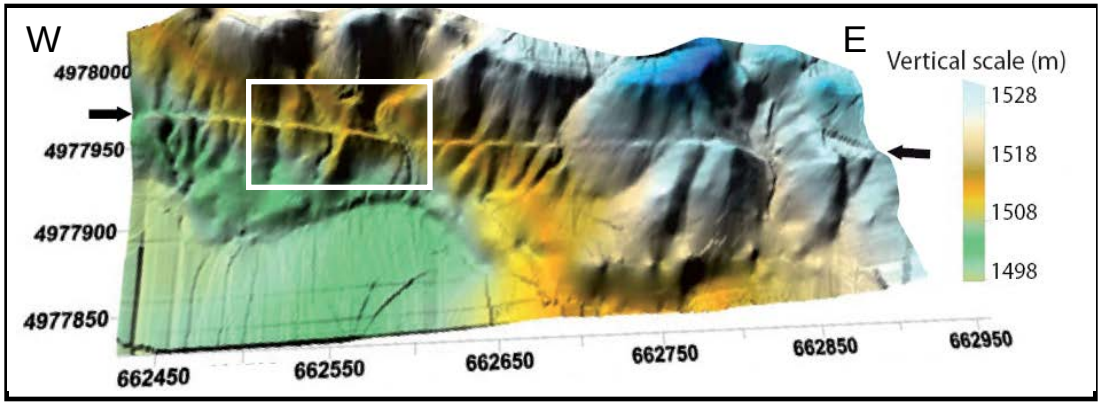
Ritz et al., 1995, 2003; Vassallo et al., 2005; 2007; Rizza et al., 2011

Slip distribution along the Bogd fault



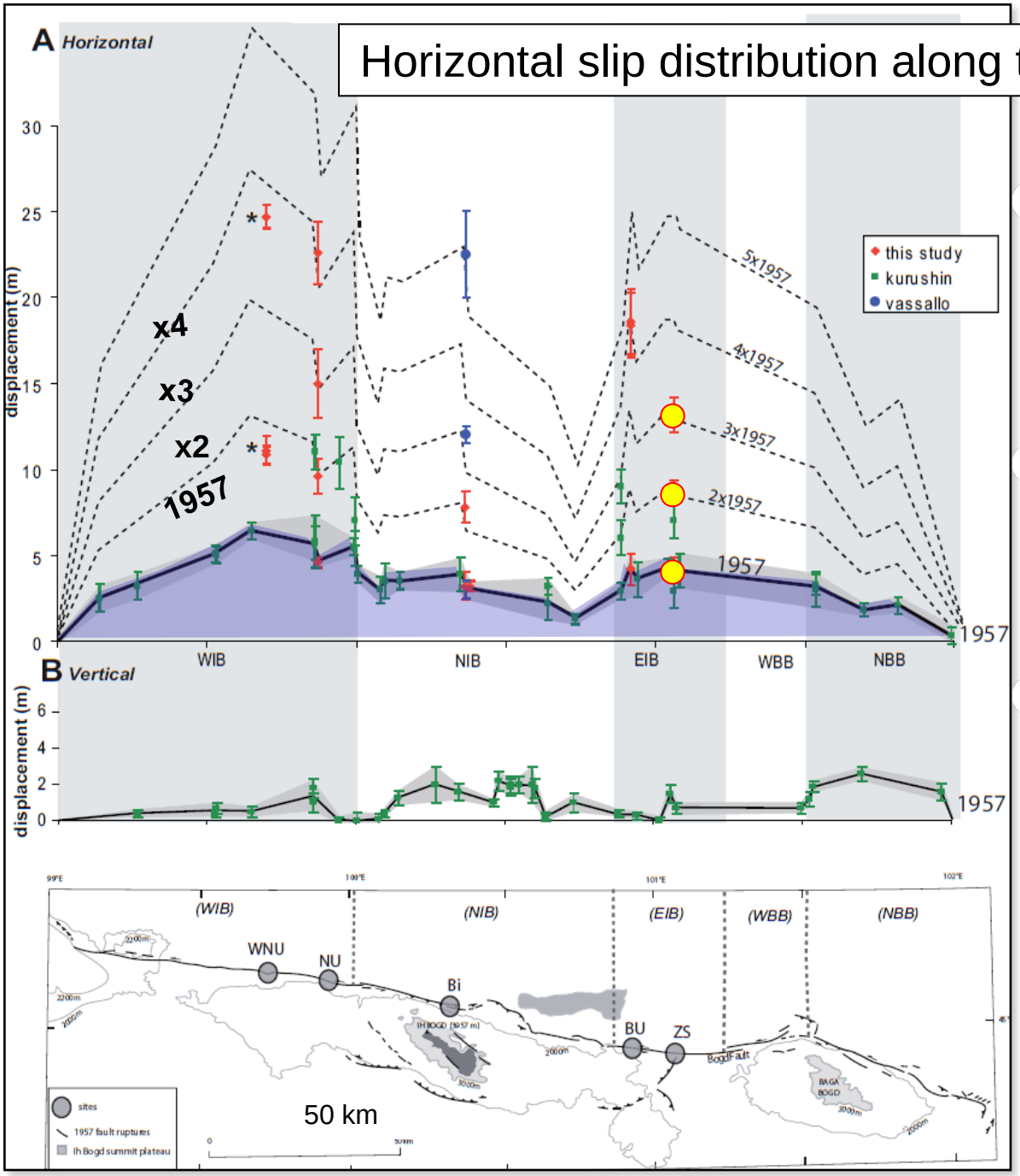






M. Rizza et al., GJI 2011

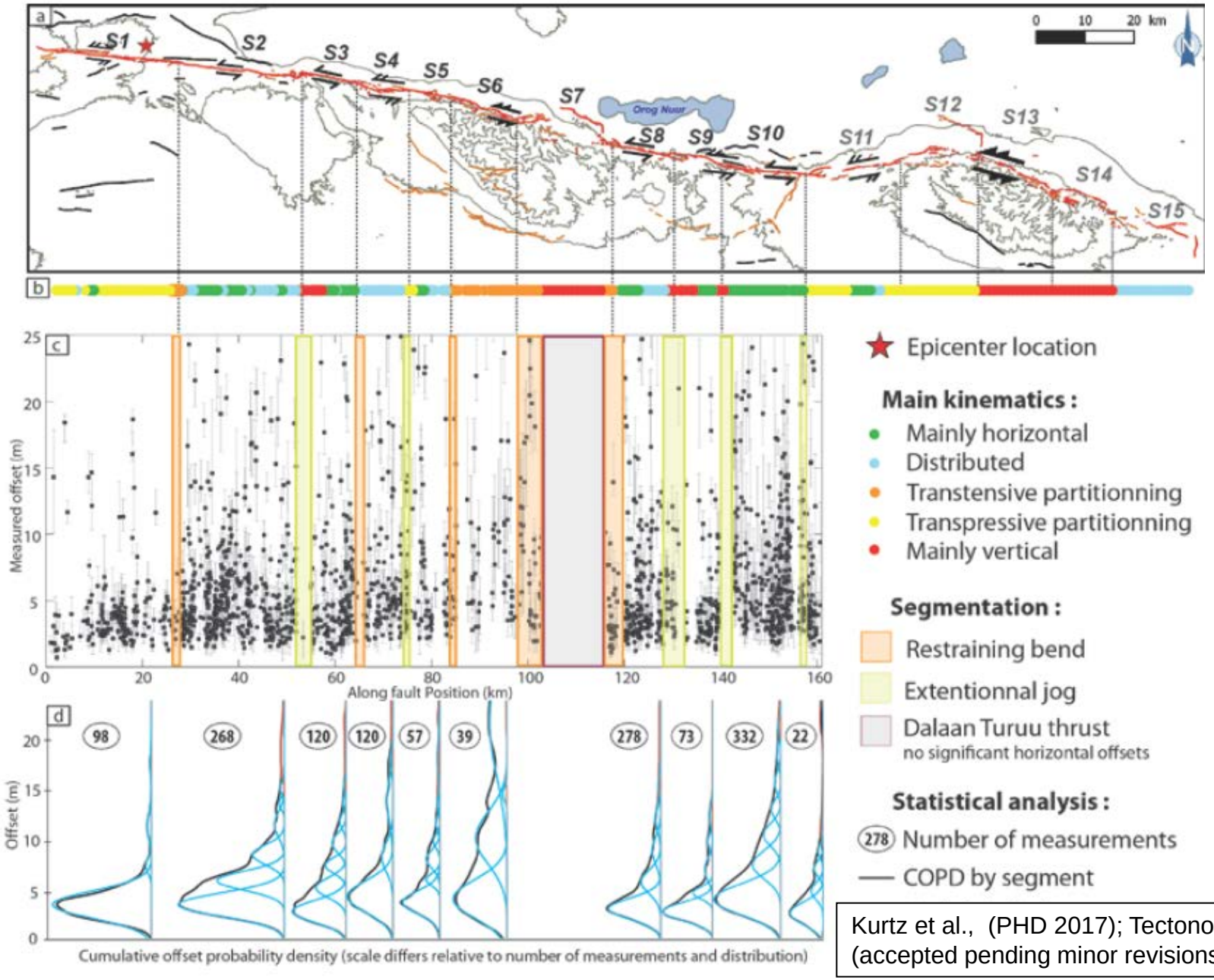
Horizontal slip distribution along the Bogd fault



- 90 measurements
- slip distribution of cumulative offsets multiple of the 1957 slip distribution
- «characteristic» slip distribution suggested

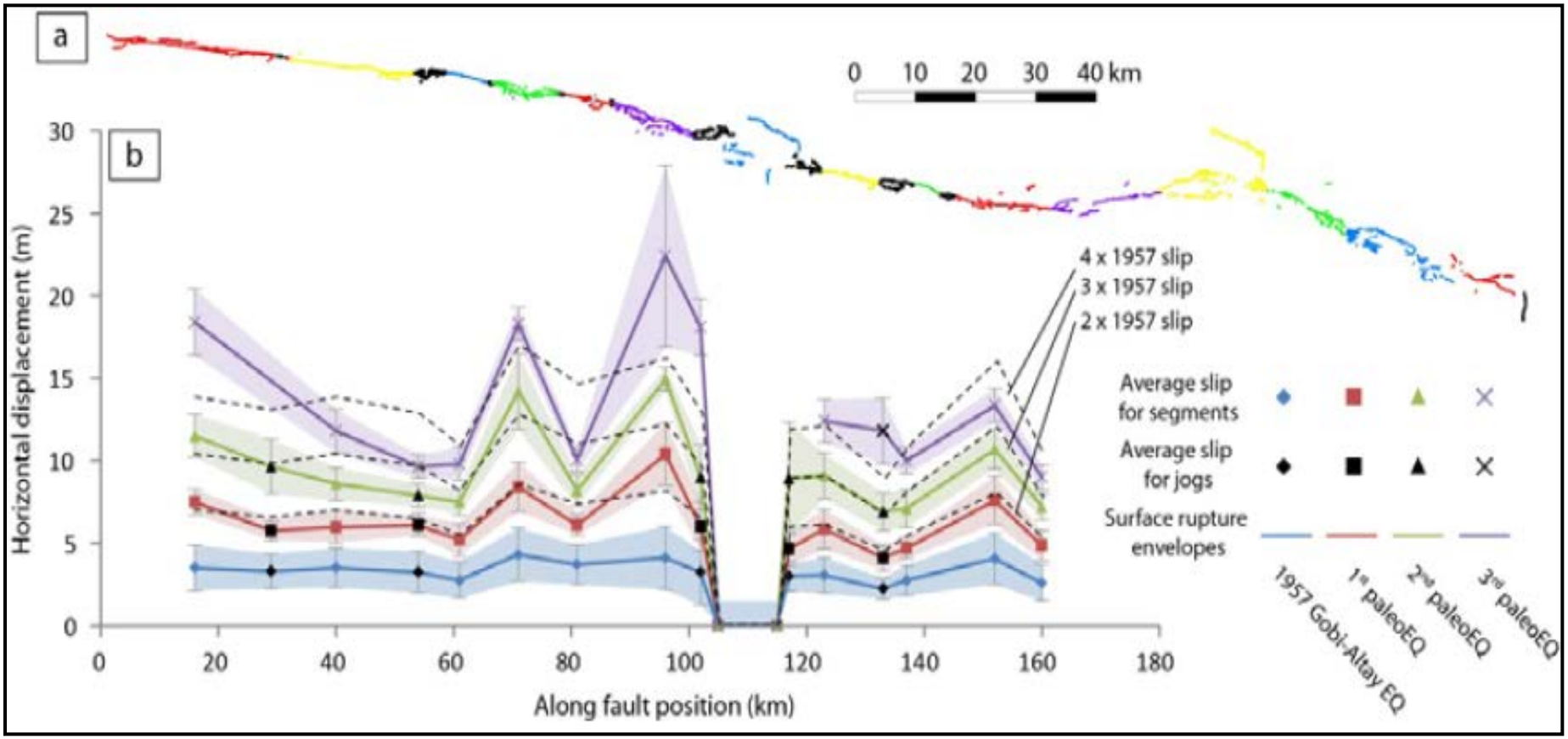
Rizza et al., GJI 2011

Statistics: Cumulative Offset Probability Densities (COPD) analysis of the horizontal slip distribution from aerial photographs (~1500 measurements)



Kurtz et al., (PHD 2017); Tectonophysics, (accepted pending minor revisions)

Mean horizontal offset / segment from COPD analysis



Kurtz et al., (PHD 2017); Tectonophysics (accepted pending minor revisions)

⇒ Characteristic slip distribution confirmed

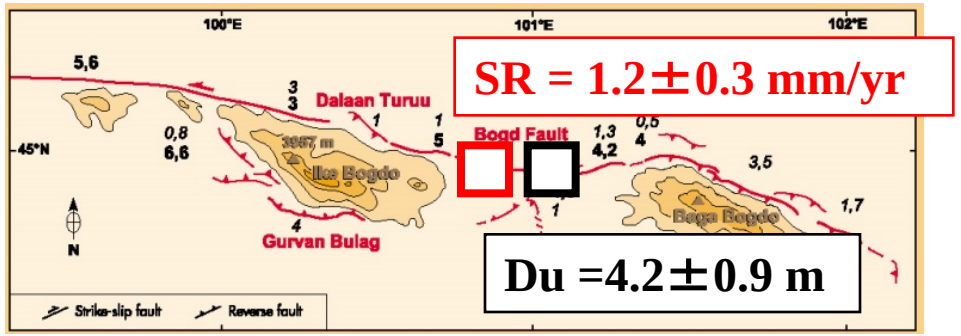
Timing of past events along the Bogd fault

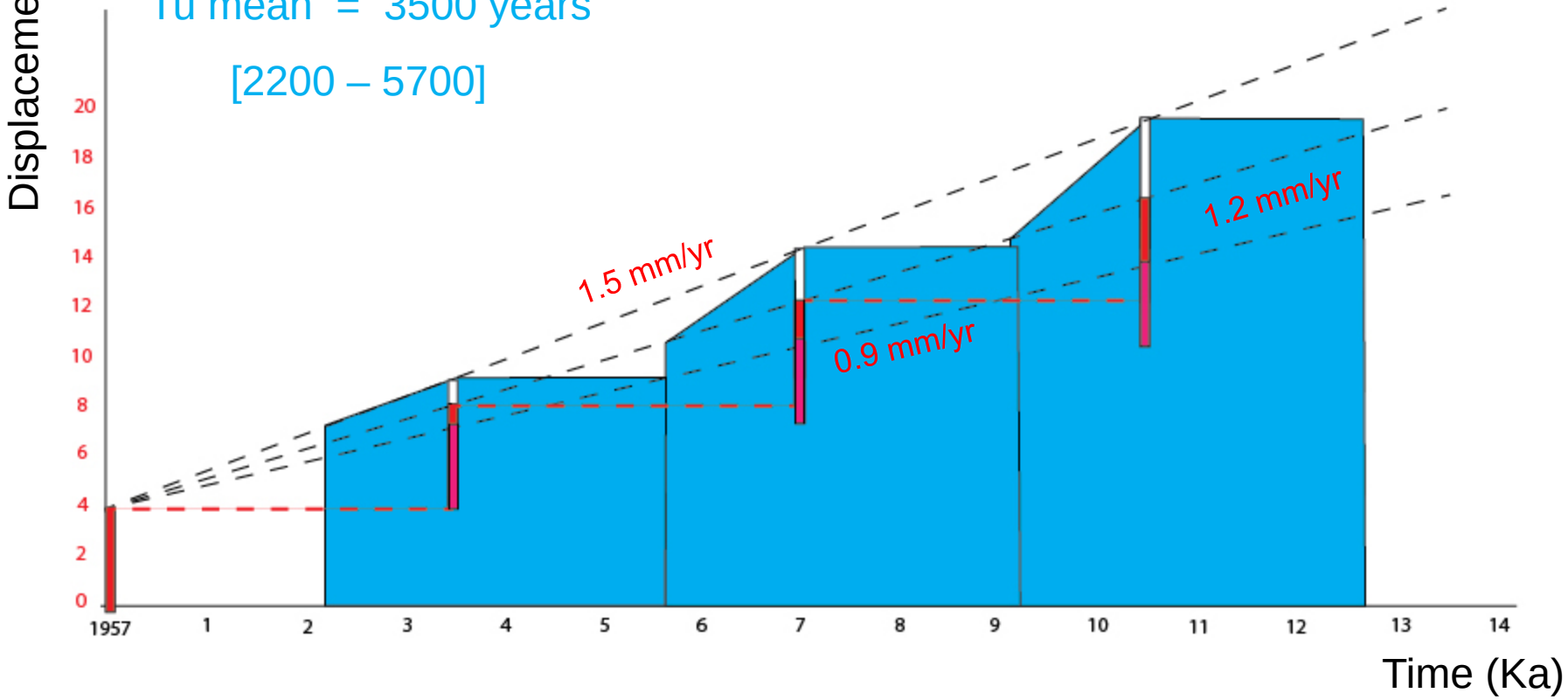
SR = Du / T ⇨ Tu = Du / SR

Tu = 4.2±0.9 / 1.2 ±0.3

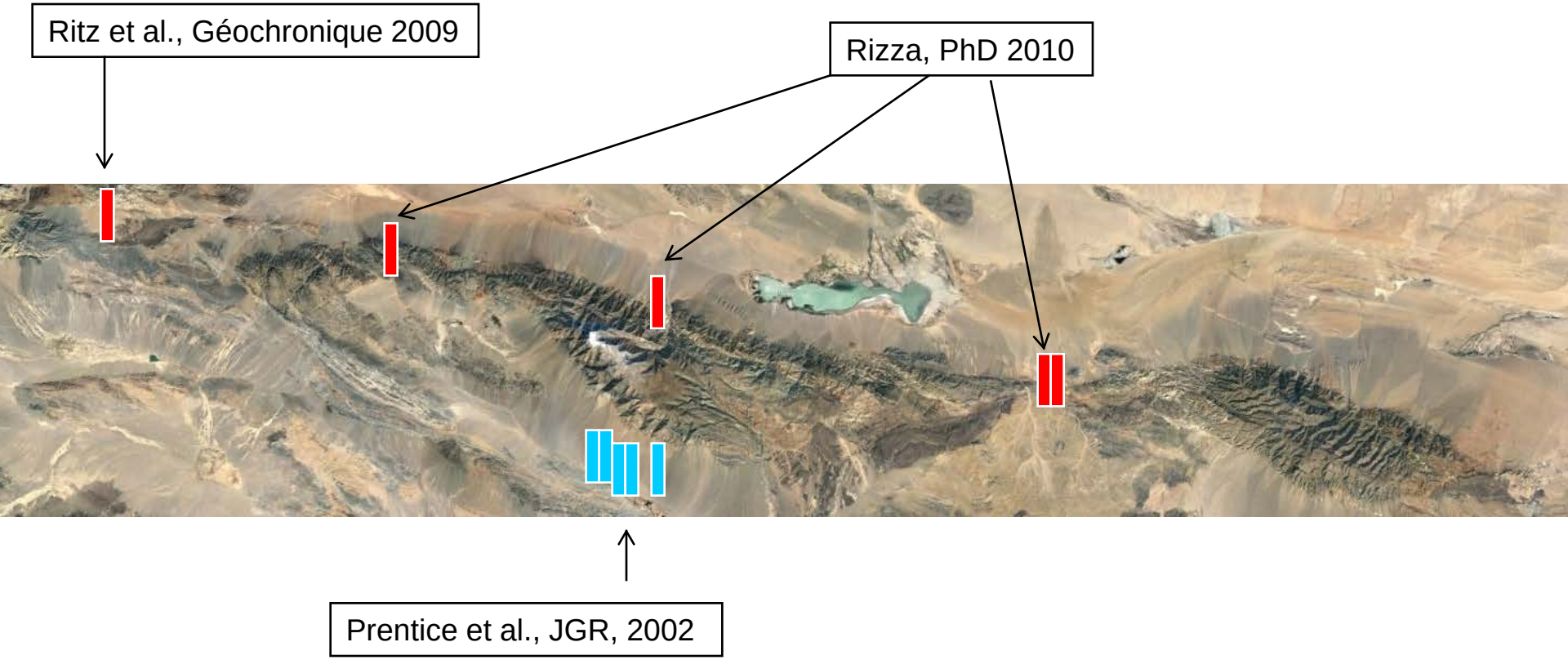
Tu mean = 3500 years

[2200 – 5700]

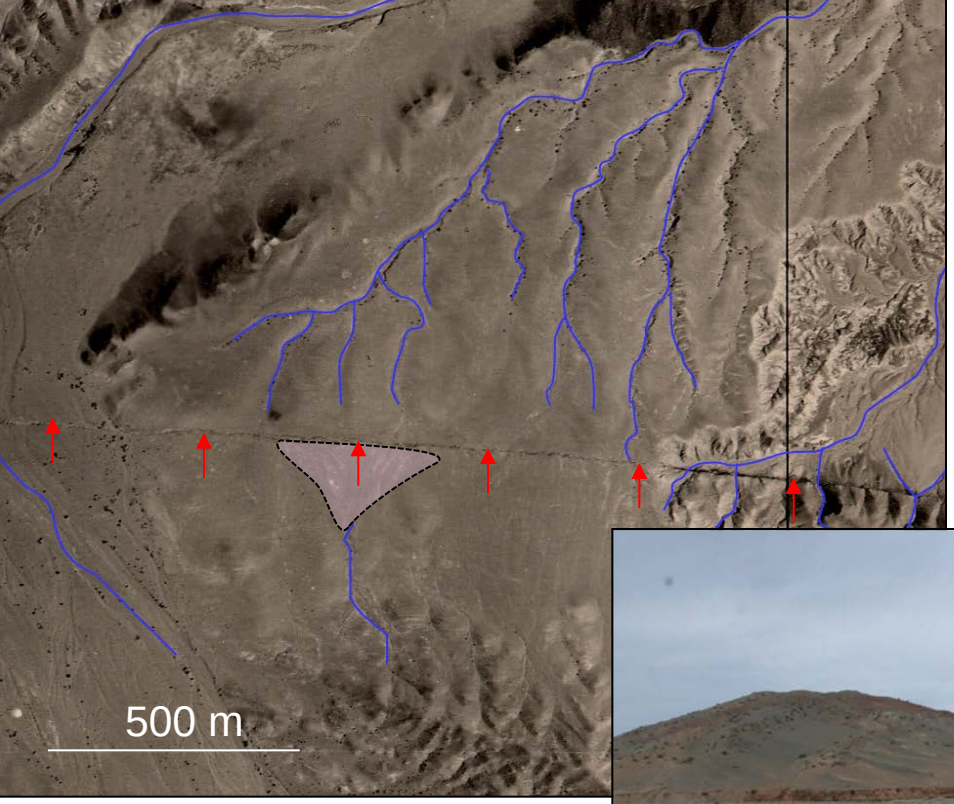


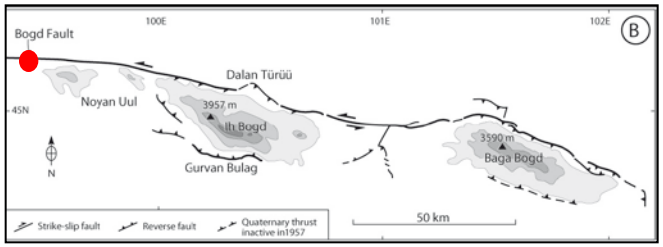


Paleoseismology (trench studies)

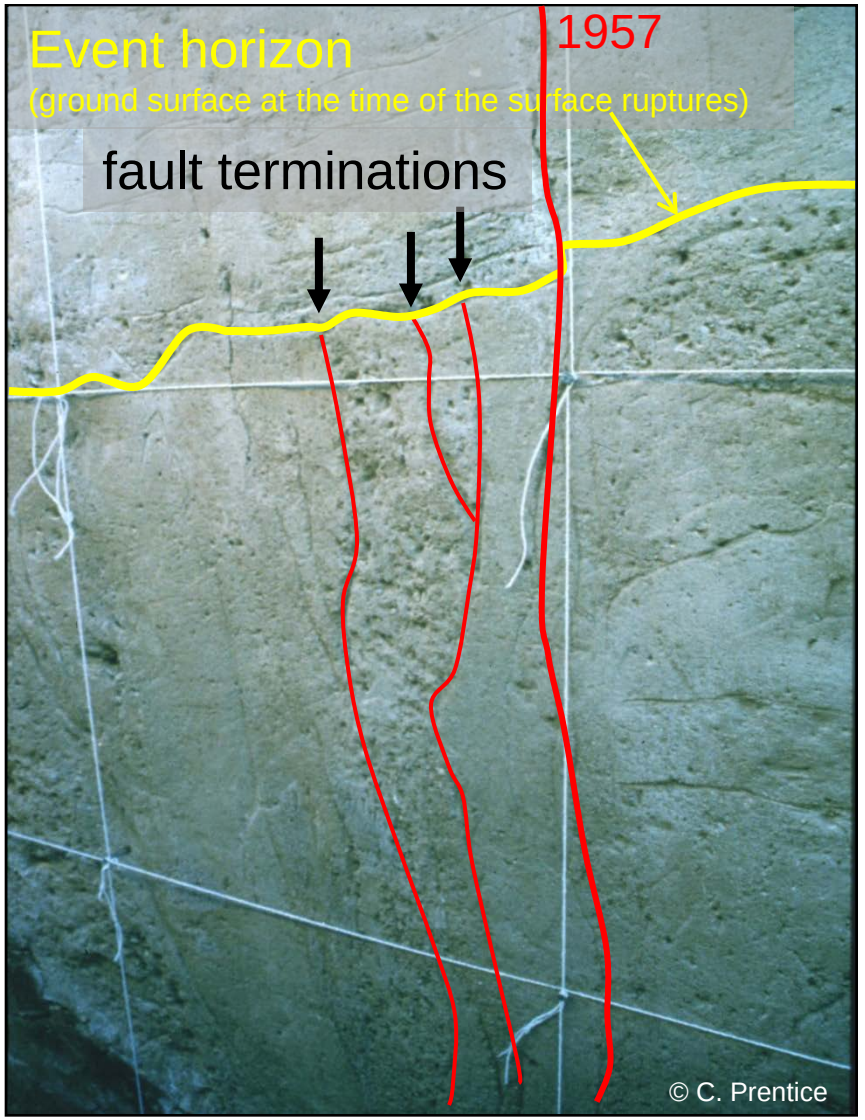


Bogd fault (Ulan Bulag)

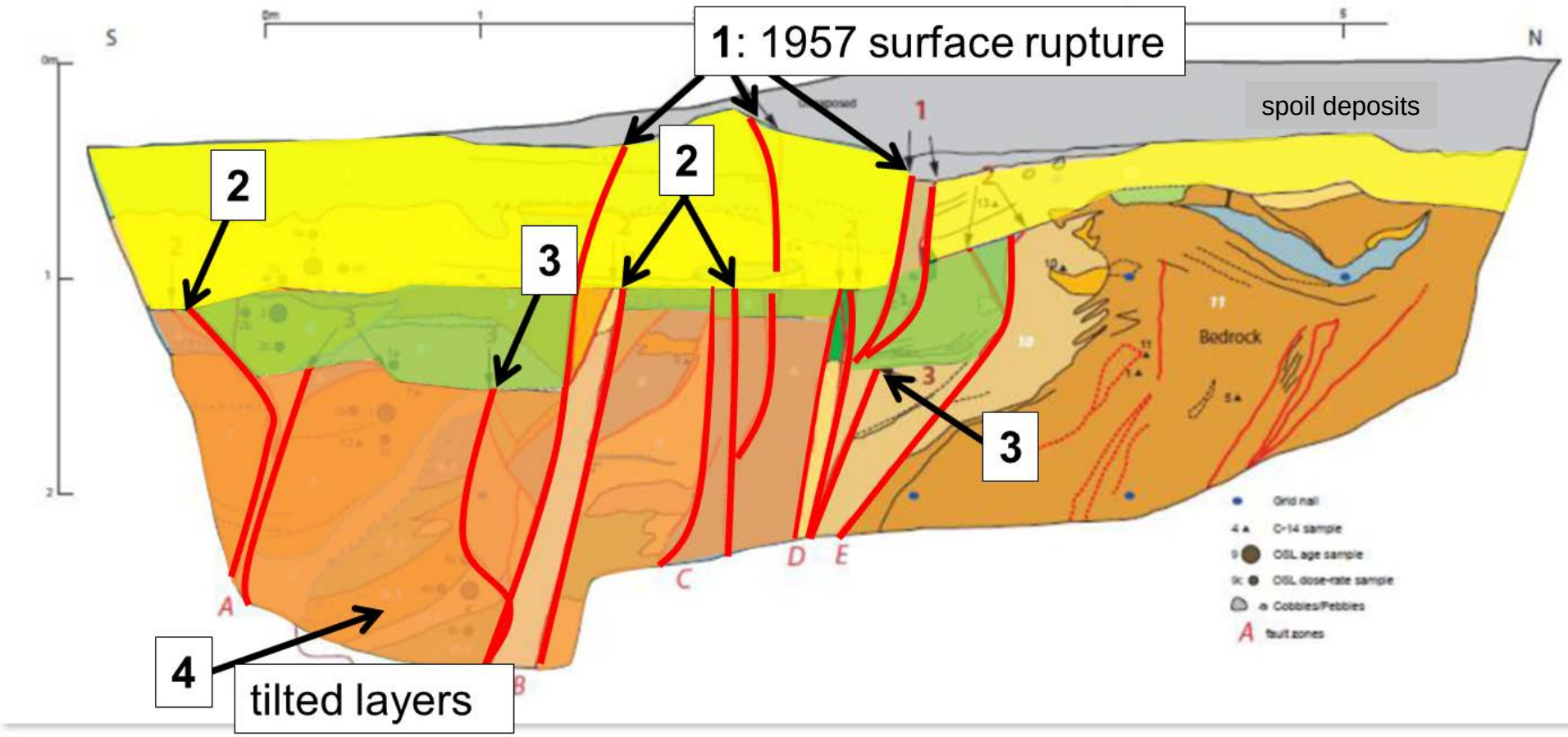




Logging young quaternary deposits and their deformations

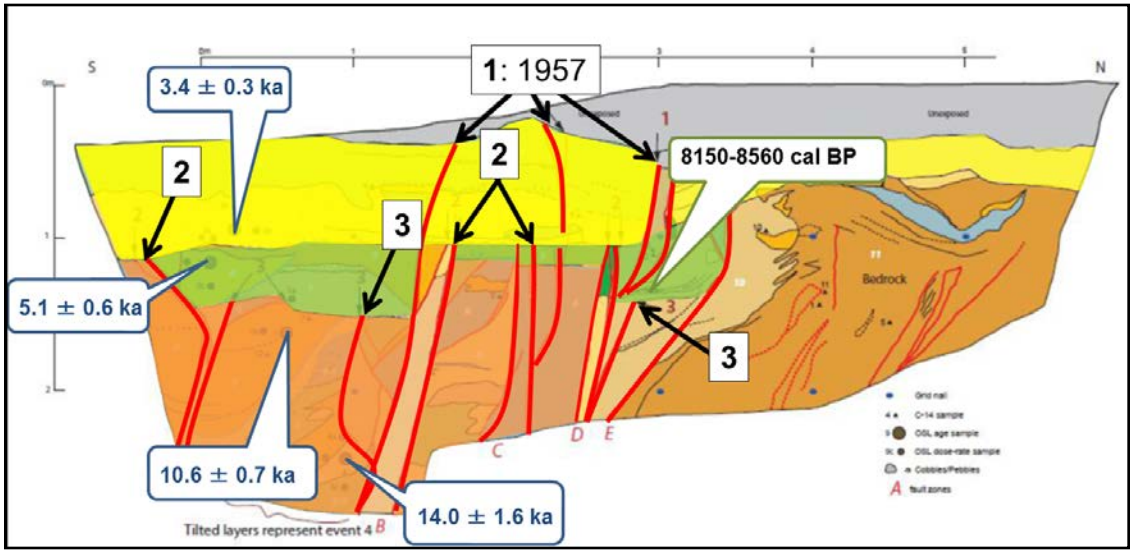


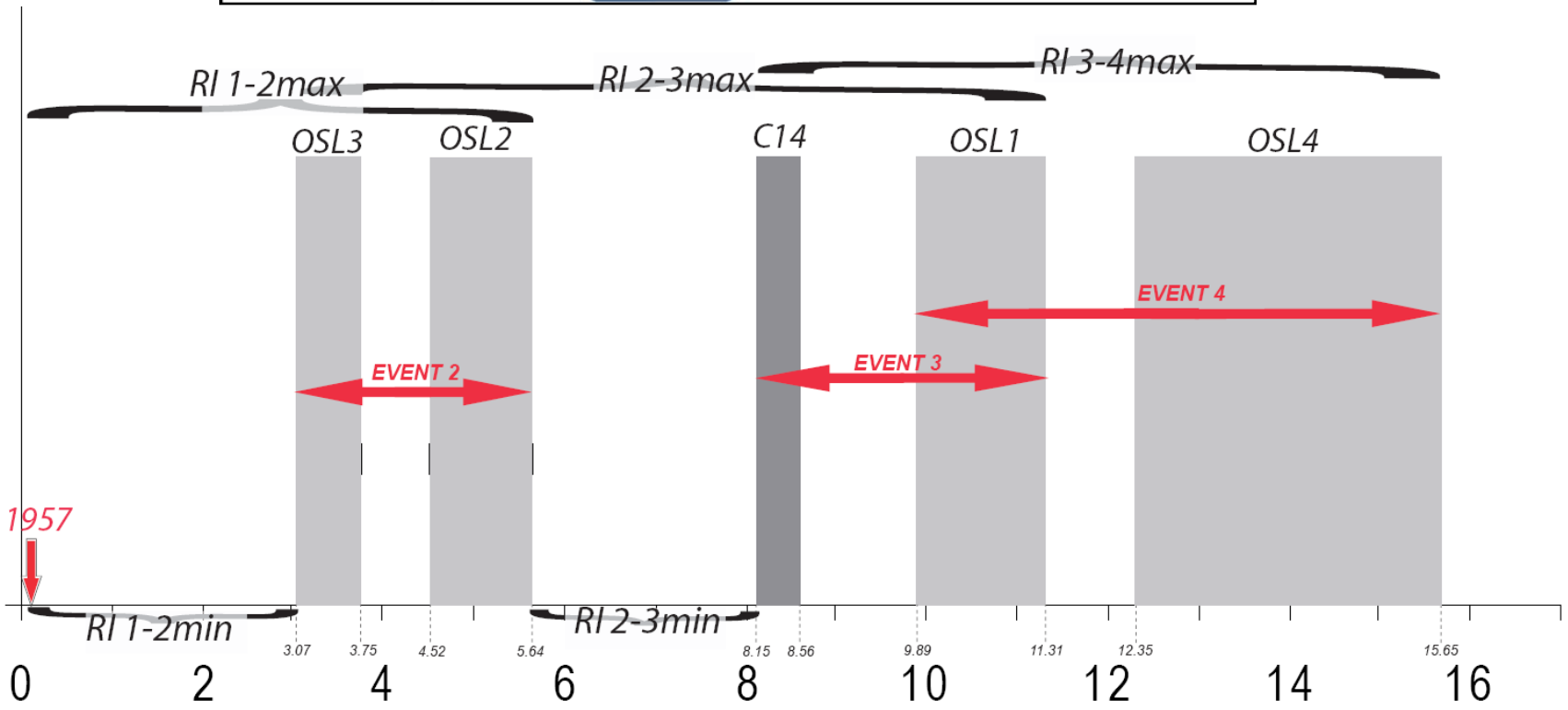
Trench Log



- 4 events

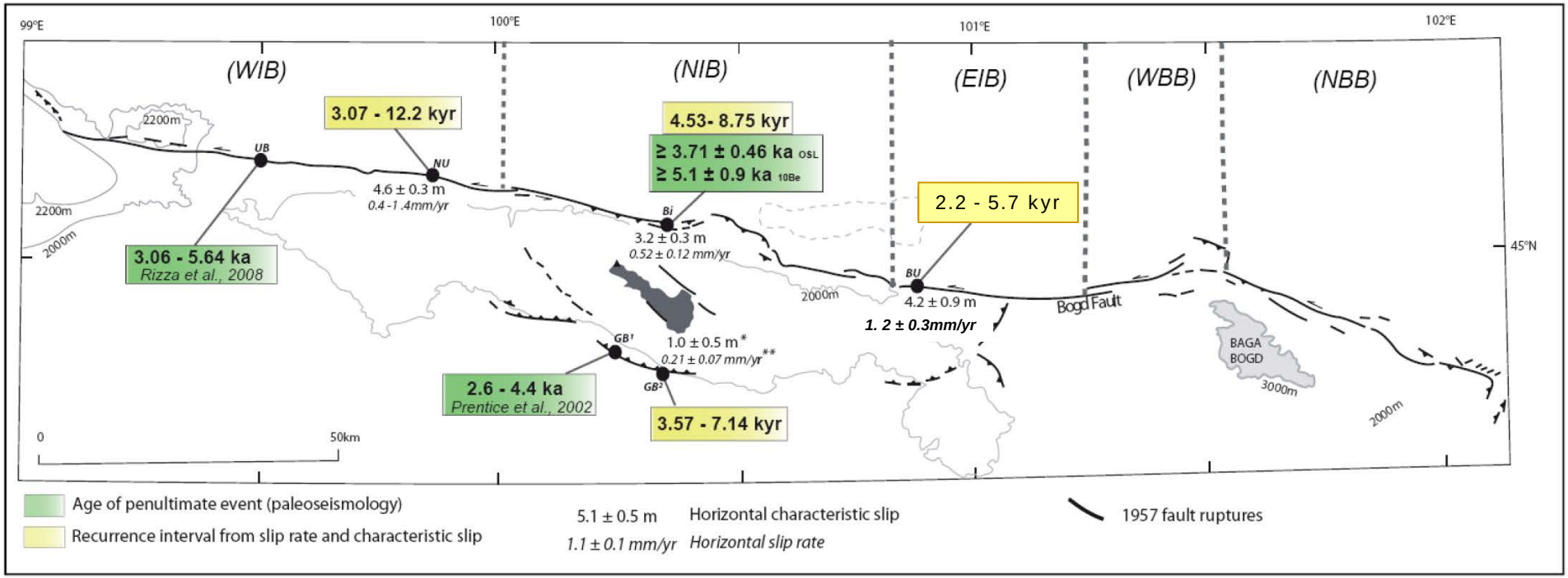
Ritz et al., Géochronique 2009





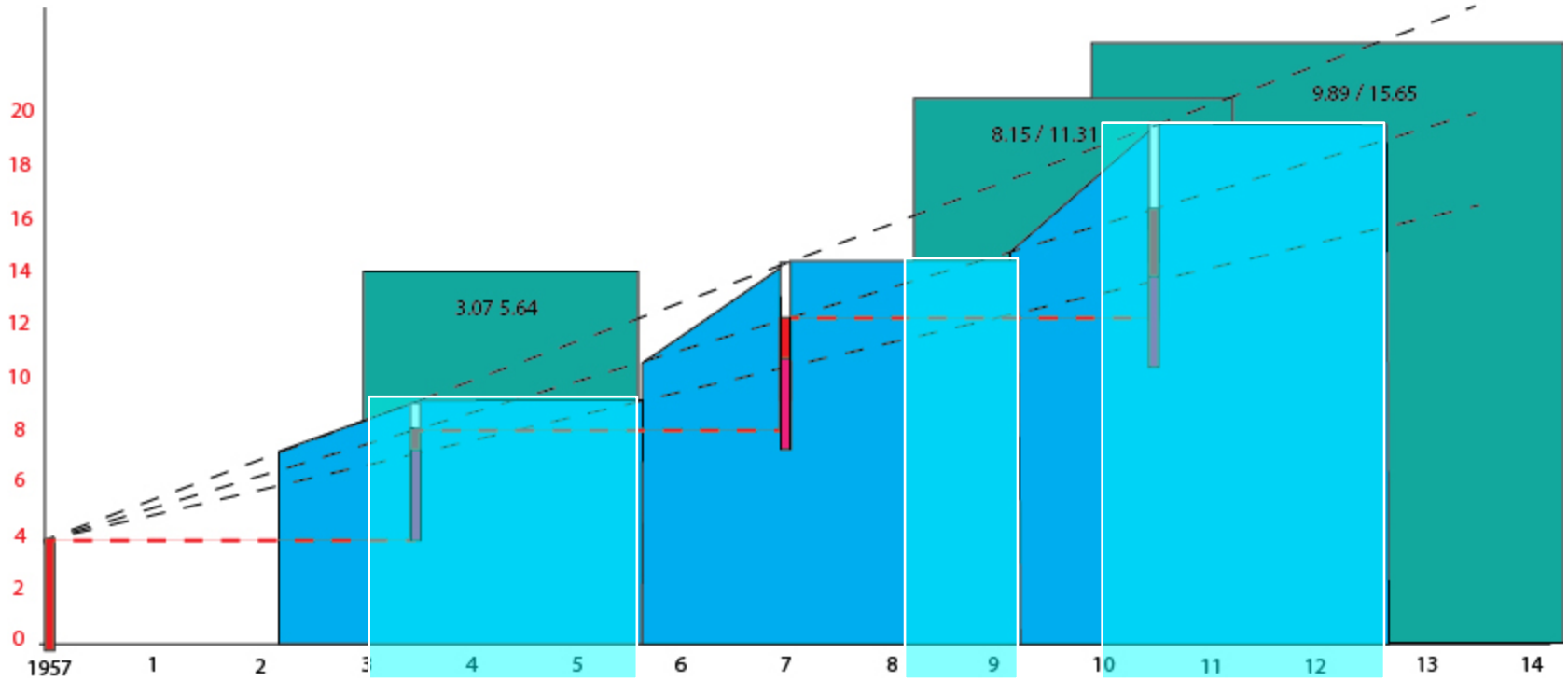
Mean recurrence interval : 4500 ± 1400 years [3100 – 5900]

Timing of past events along the Bogd fault

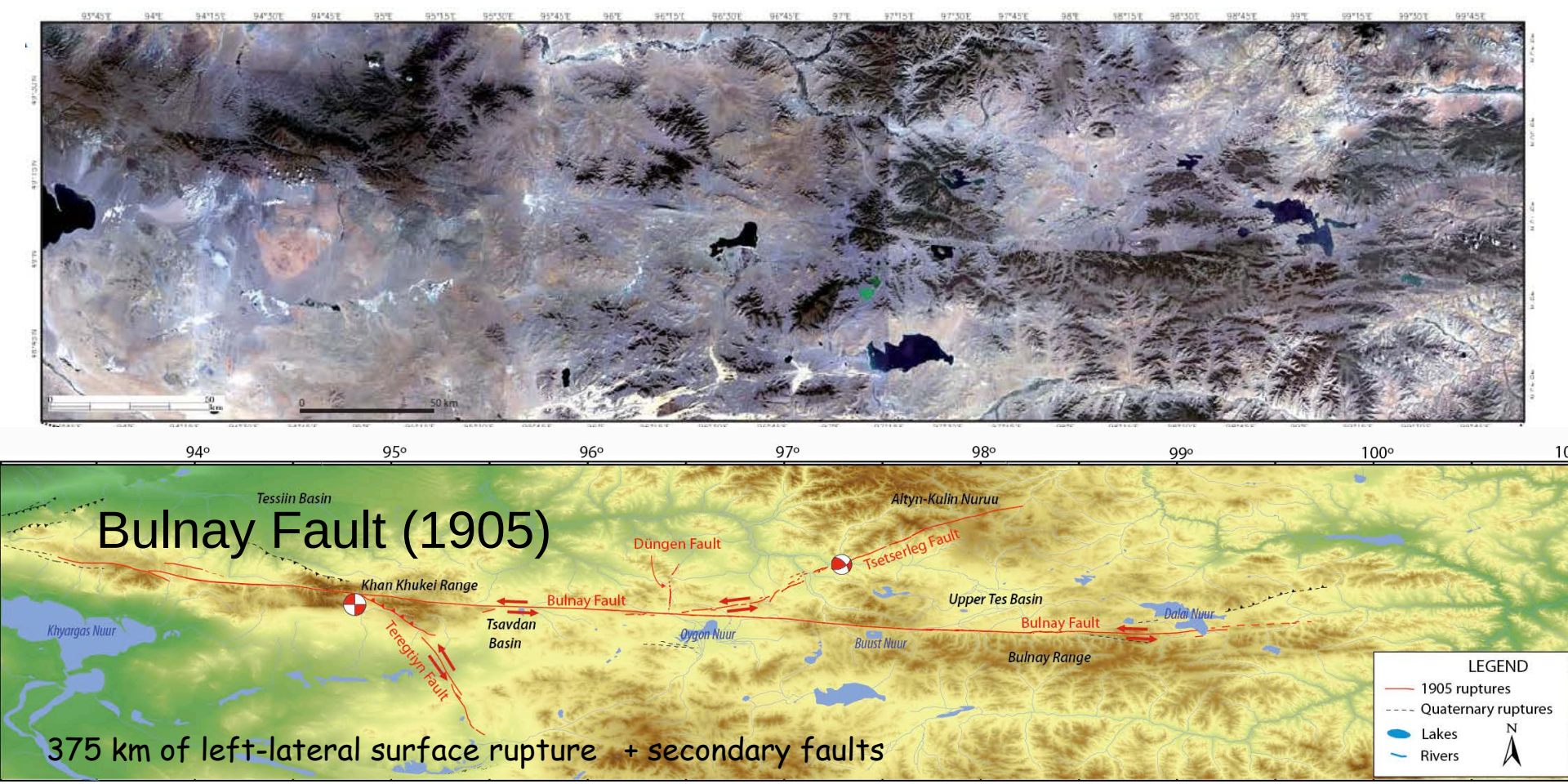


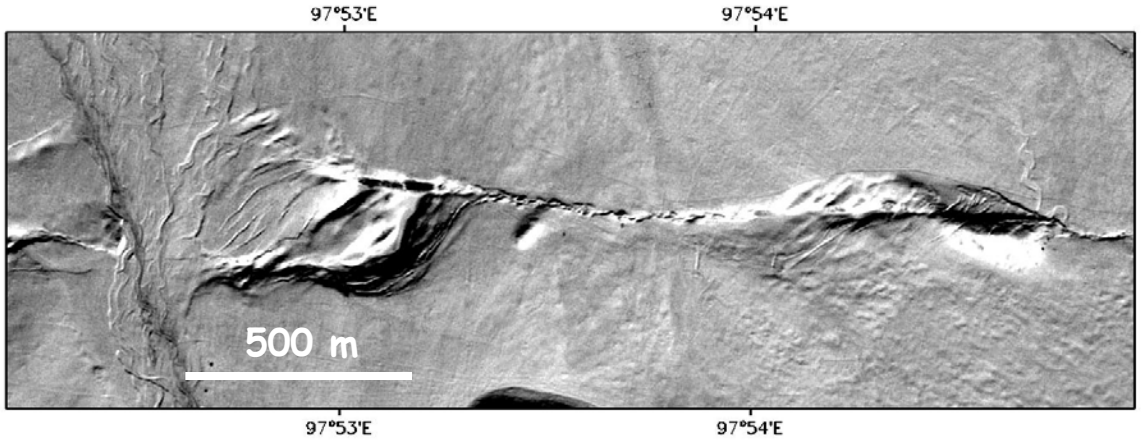
Timing of past events along the Bogd fault

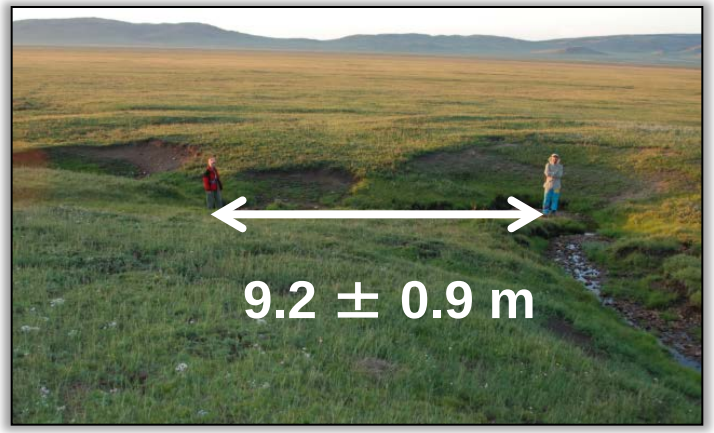
morphotectonic and paleoseismic results



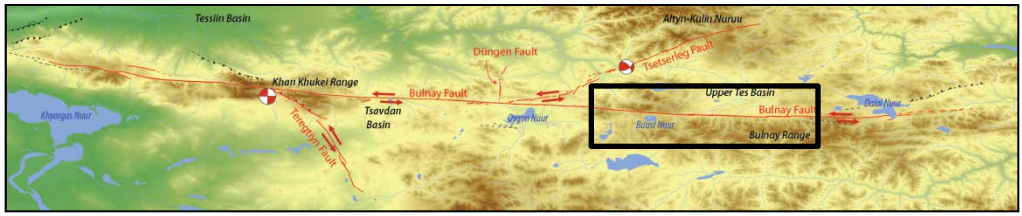

What about the Bulnay Fault ?

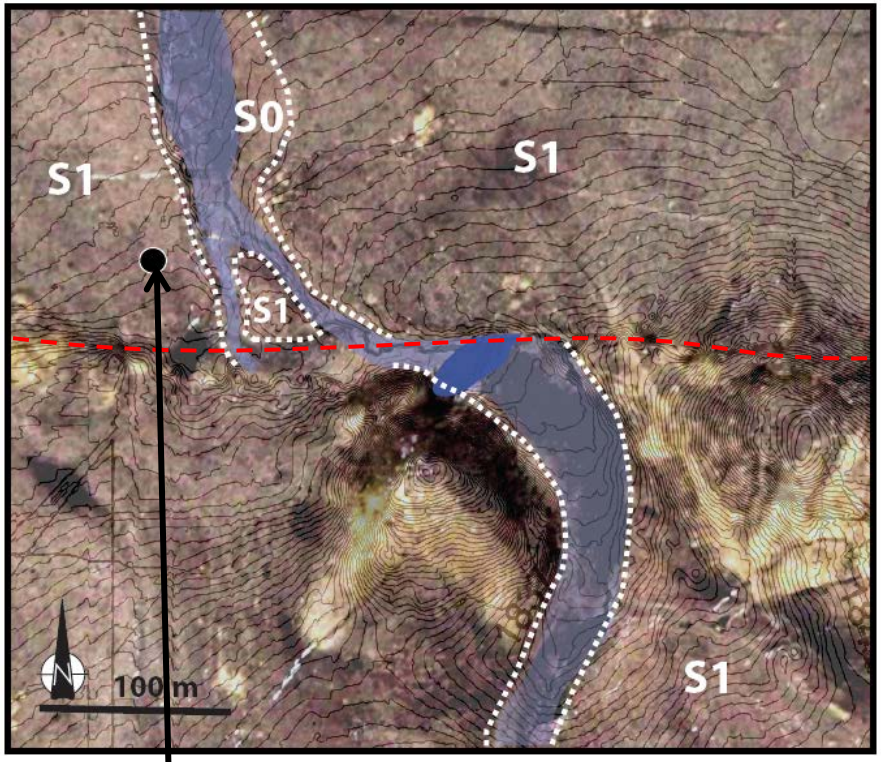

94°
95°
96°
97°
98°
99°
100°
Bulnay Fault (1905)
Tessiin Basin
Altyn-Kulin Nuruu
Düngen Fault
Tsetserleg Fault
Khan Khukei Range
Bulnay Fault
Upper Tes Basin
Dalai Nuur
Khyargas Nuur
Tsavdan Basin
Teregtiyn Fault
Oygon Nuur
Buust Nuur
Bulnay Fault
Bulnay Range
LEGEND
1905 ruptures
Quaternary ruptures
Lakes
Rivers
N
375 km of left-lateral surface rupture + secondary faults

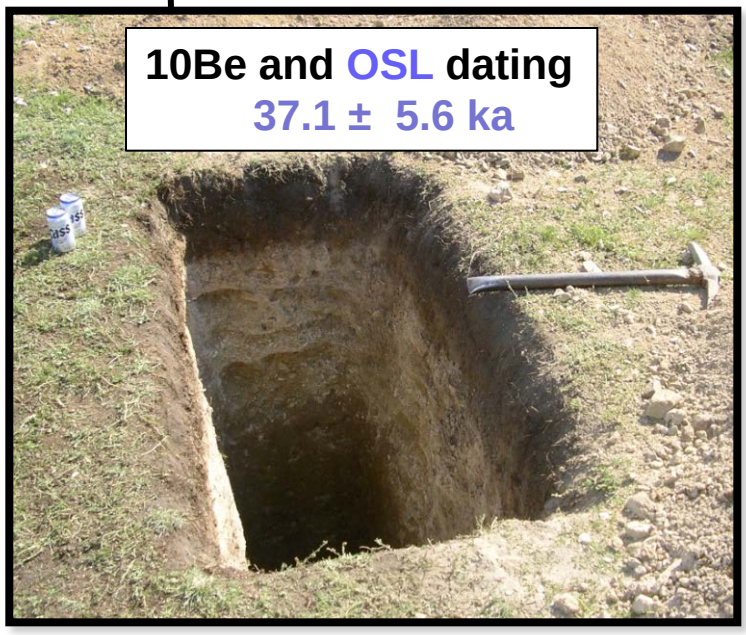

97°53'E
97°54'E
500 m
97°53'E
97°54'E


9.2 ± 0.9 m

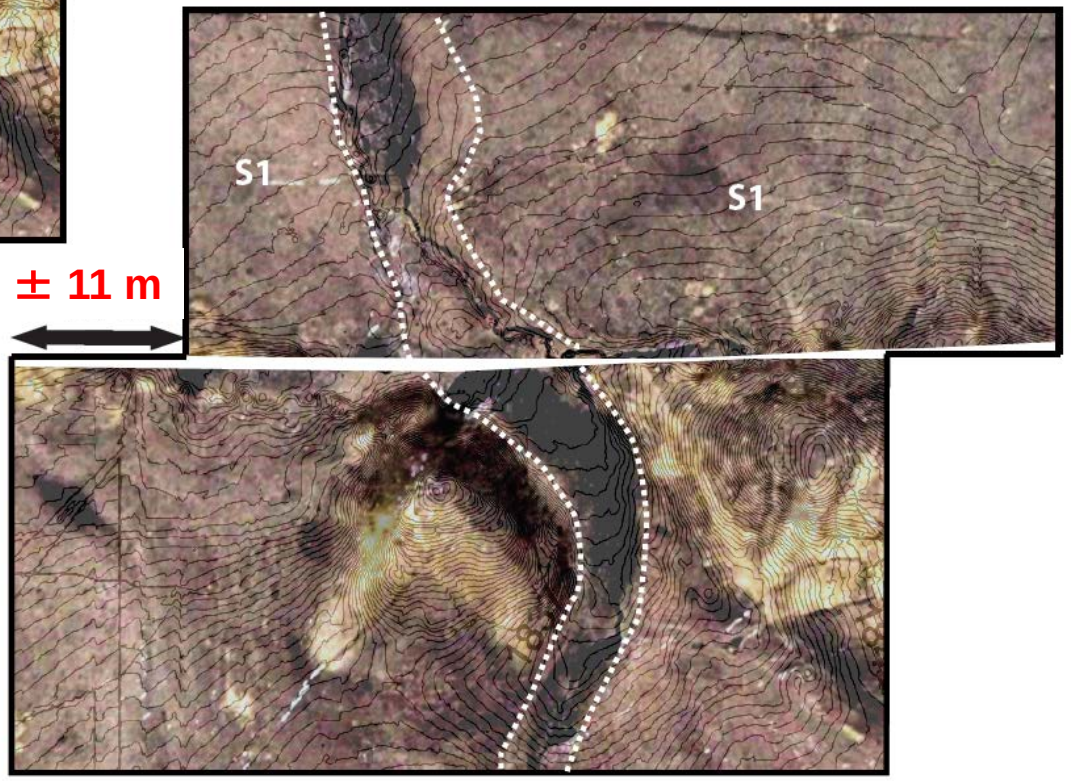
Slip rate along the Bulnay Fault



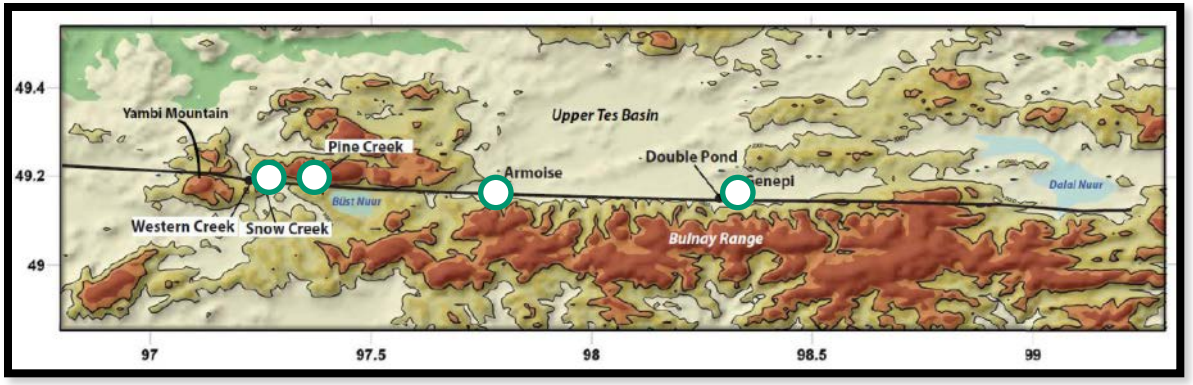


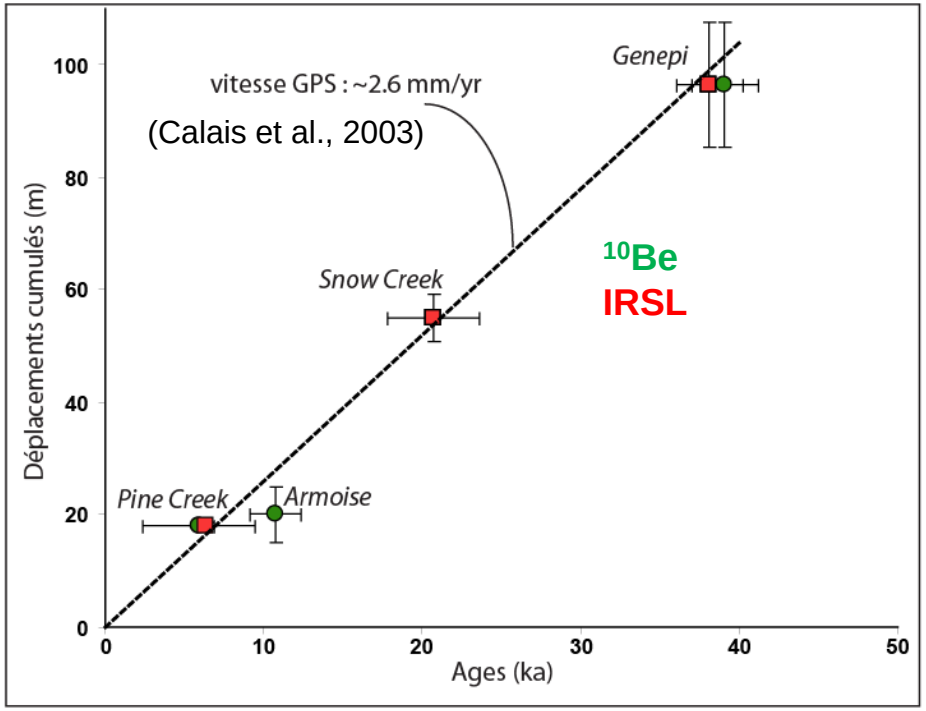


96 ± 11 m



SR = 2.6 ± 0.8 mm/yr



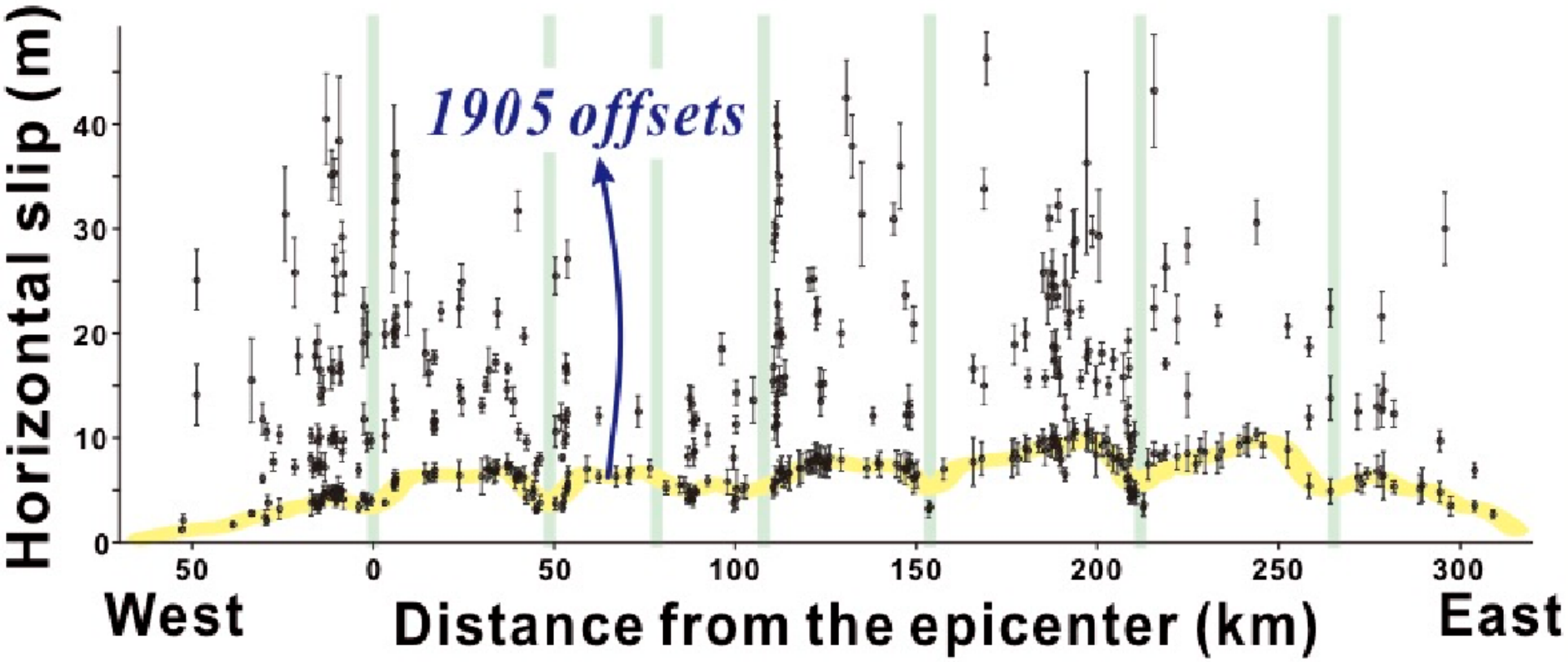


Rizza et al., BSSA 2015

Slip rate: 3.1 ± 1.7 mm/yr (Genepi site: 2.6 ± 0.8 mm/yr)

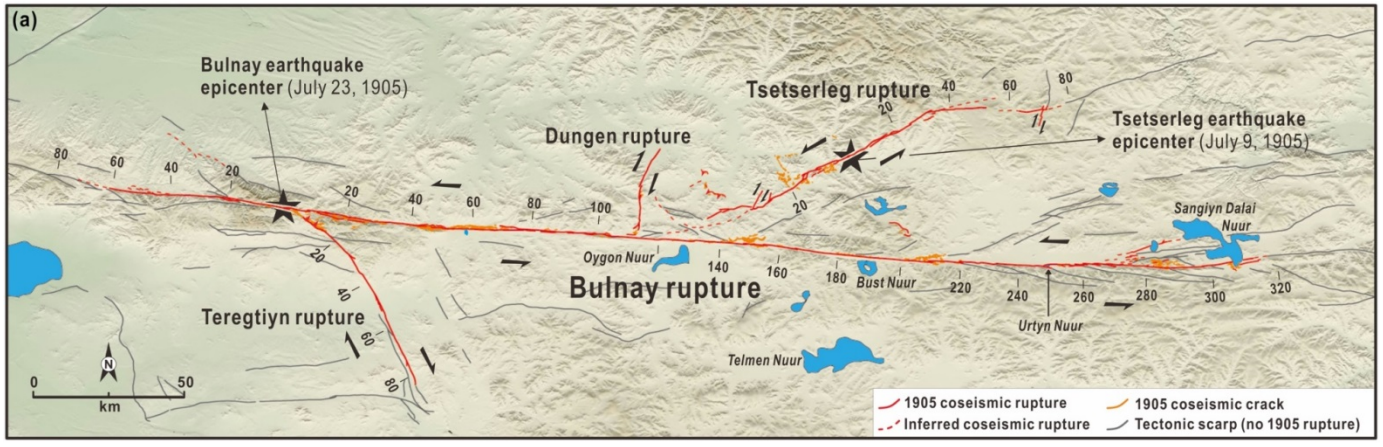
Slip distribution analysis along the Bulnay fault

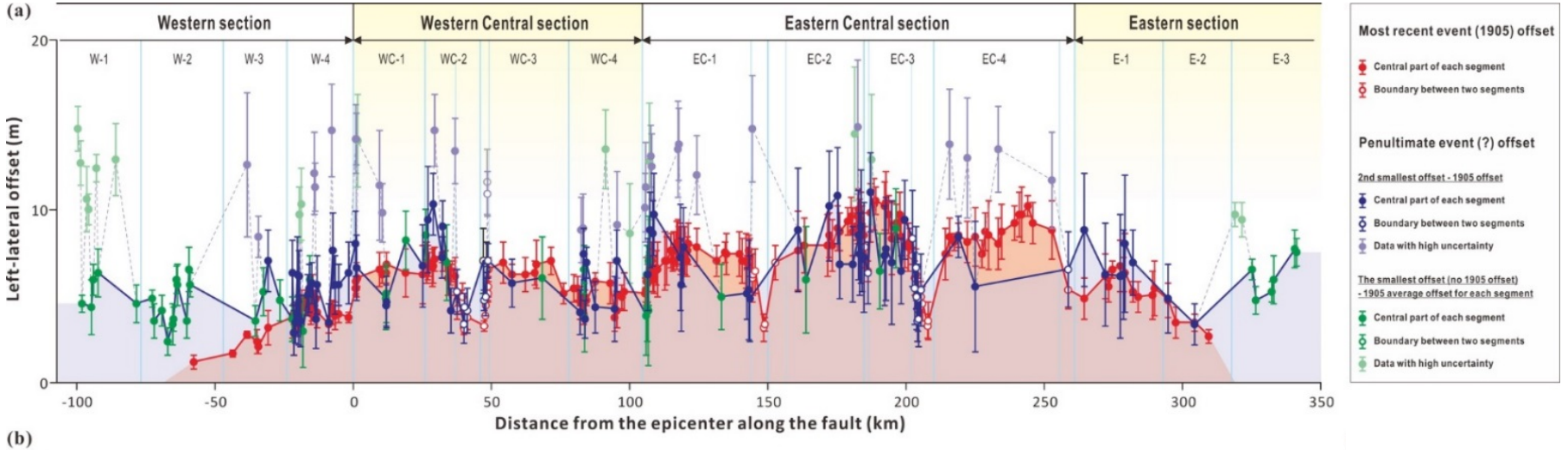
from Pleiades satellite images

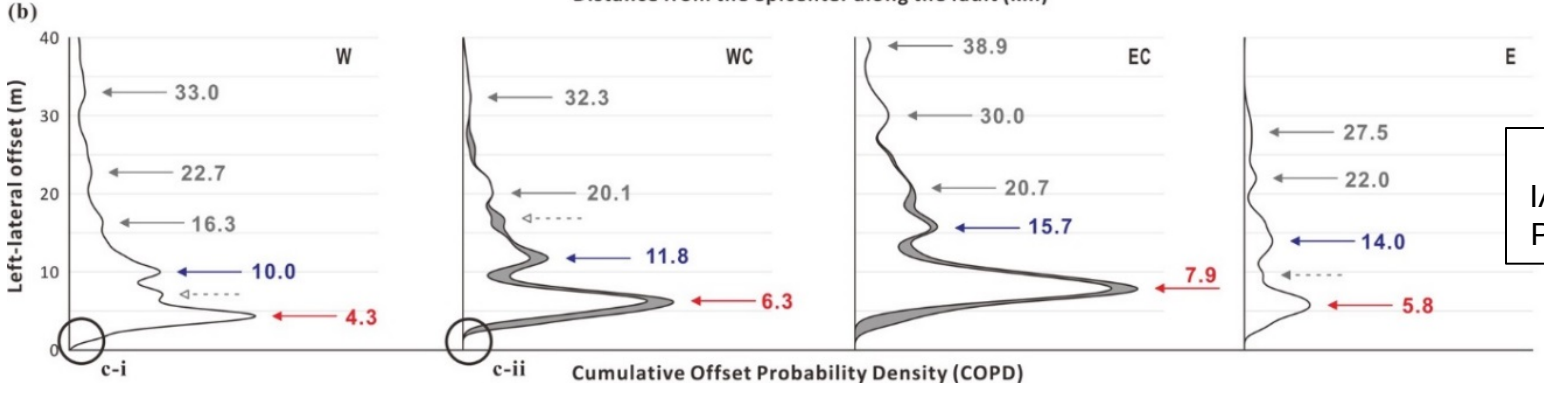


Choi et al., JGR, accepted

Penultimate event on the Bulnay fault (characteristic slip)

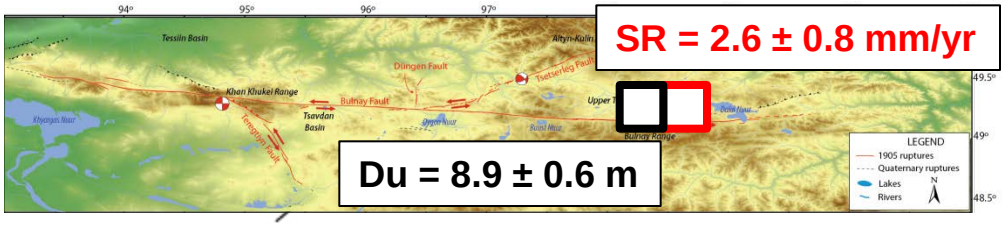






Choi & Klinger
IAG Ulan Bator 2017
PATA-days NZ 2017

Timing of past events along the Bulnay fault

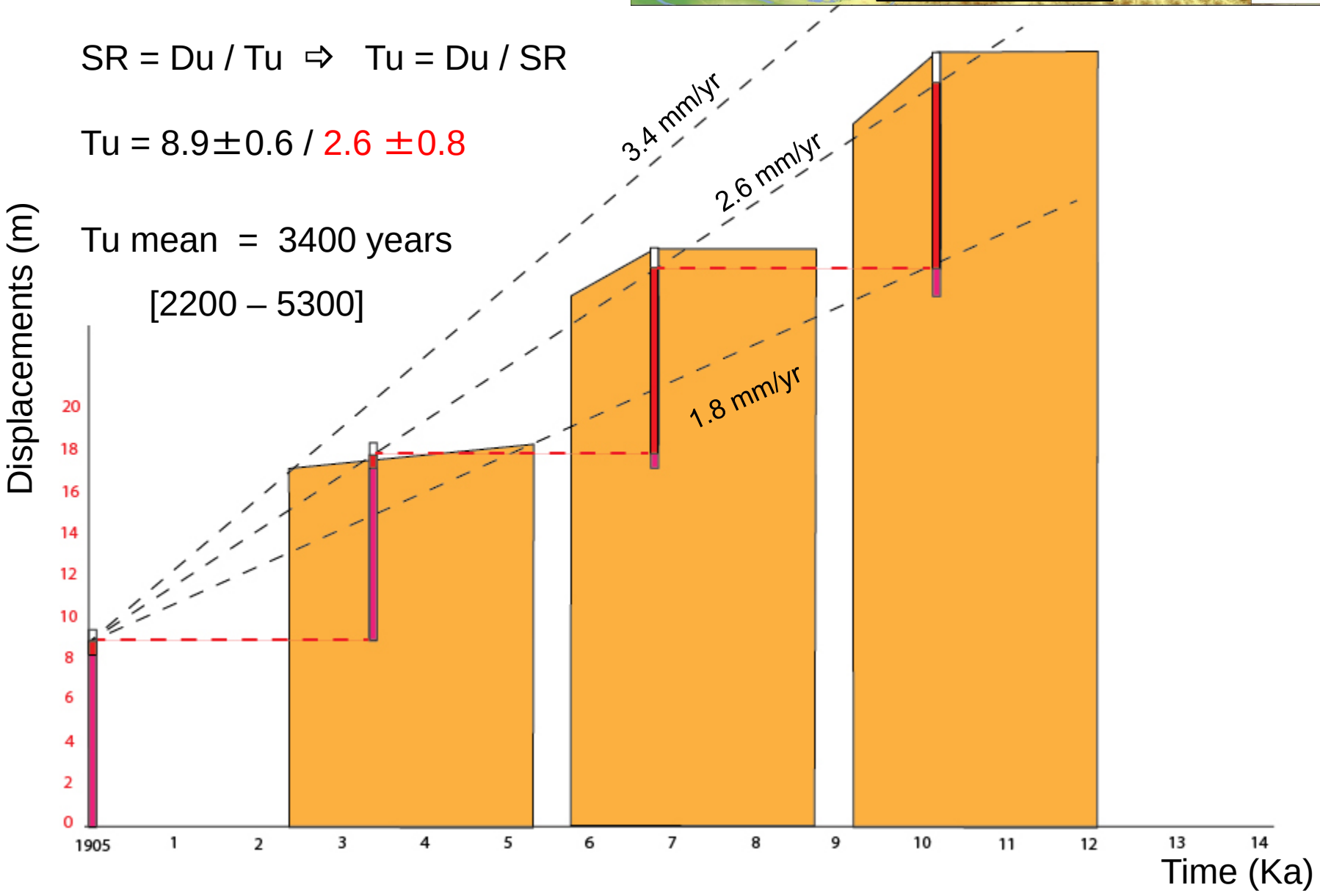


SR = Du / Tu ⇨ Tu = Du / SR

Tu = 8.9±0.6 / 2.6 ±0.8

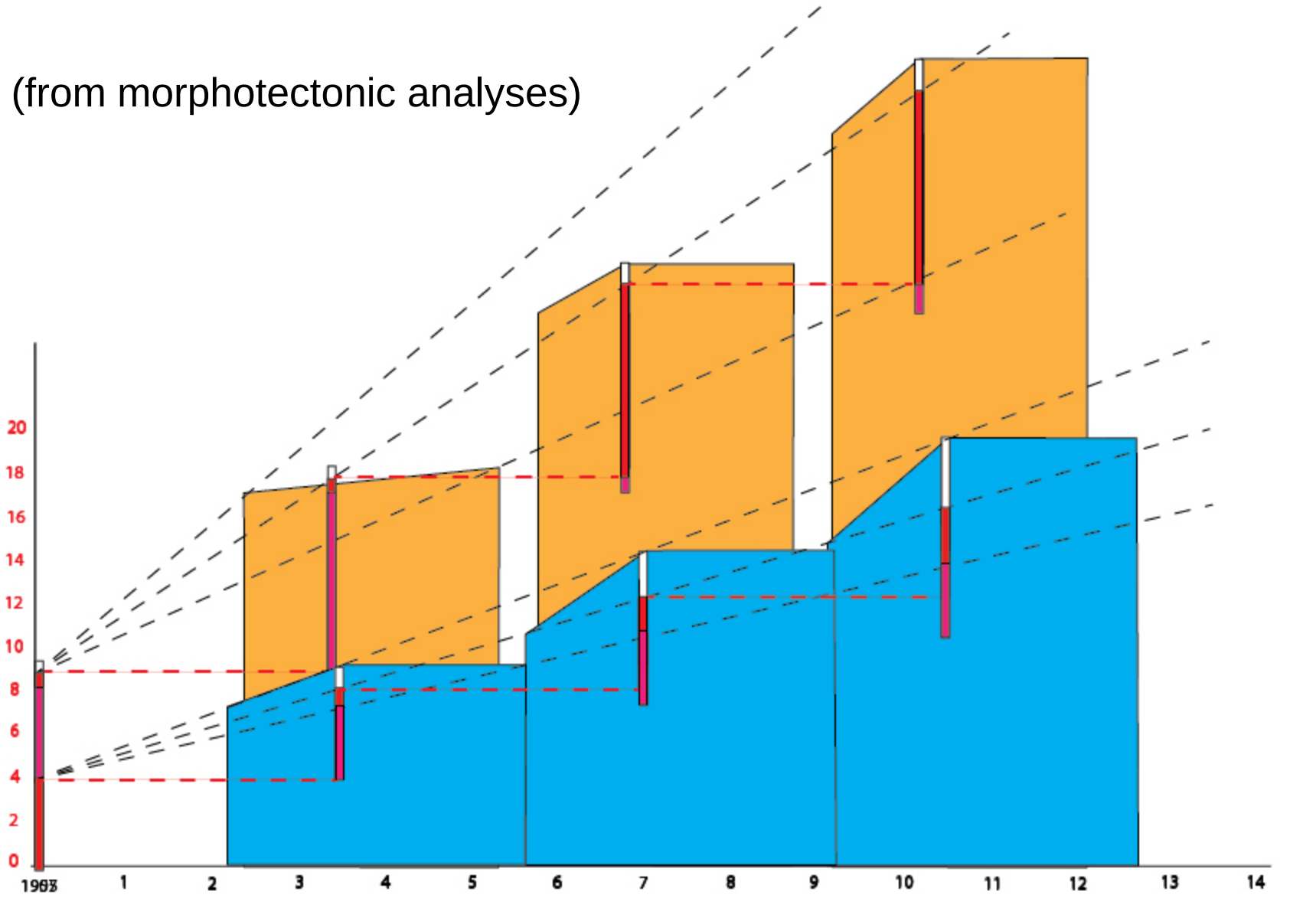
Tu mean = 3400 years

[2200 – 5300]

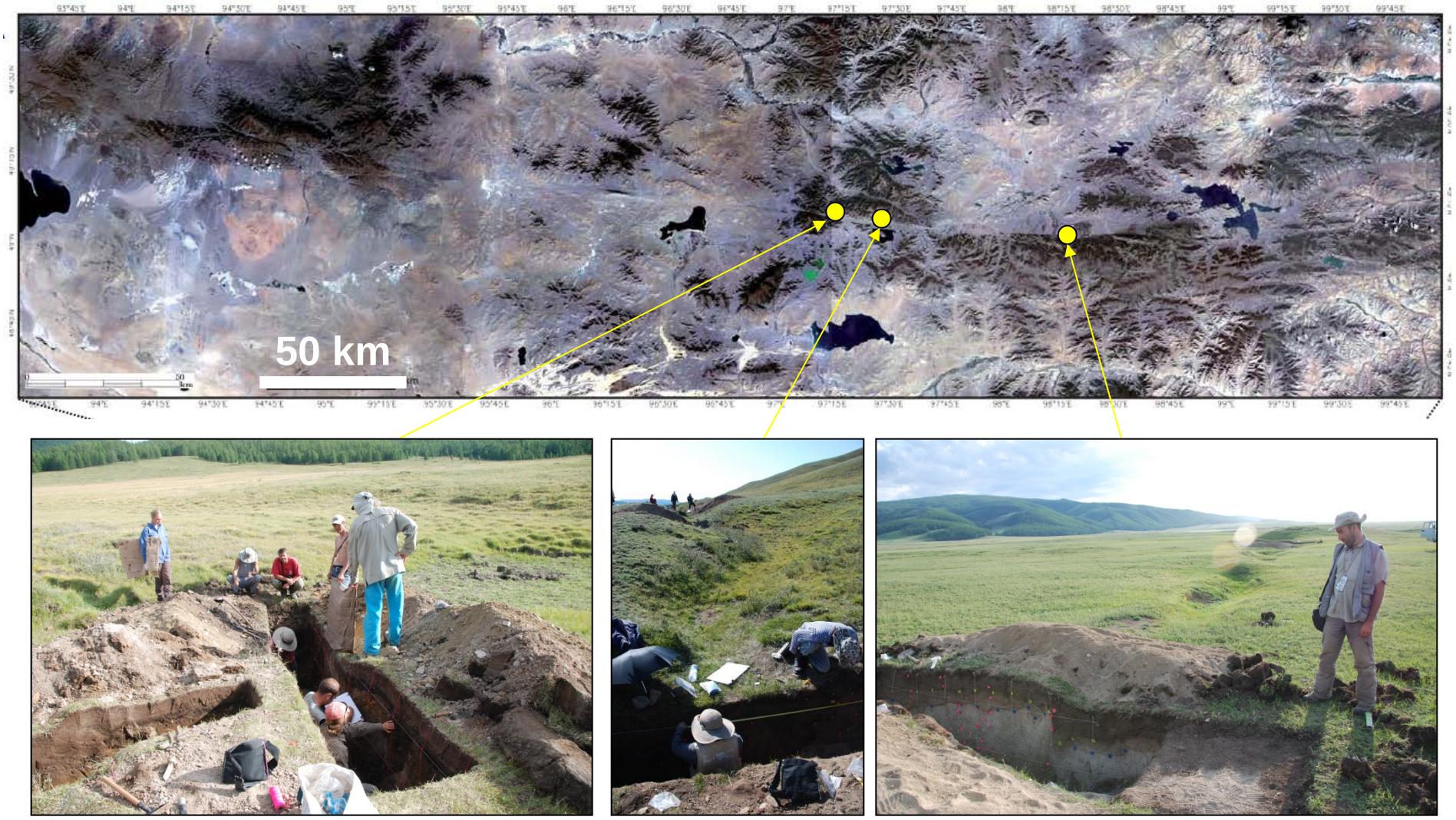


Timing of past events along the Bogd and Bulnay faults

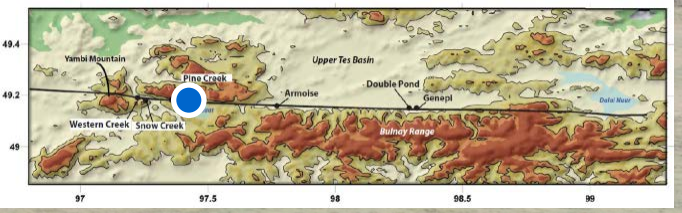
(from morphotectonic analyses)



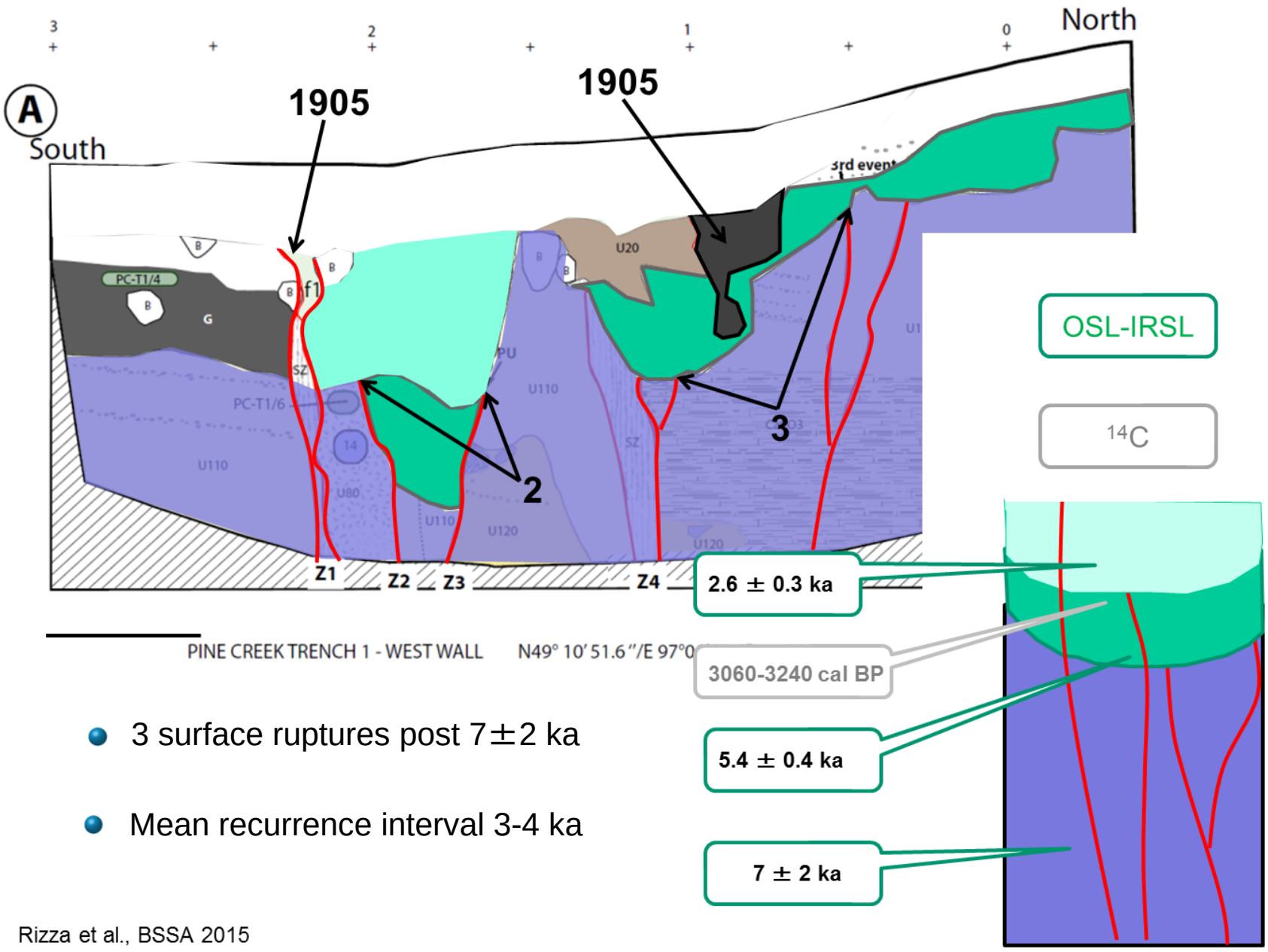
Paleoseismology



Trench study at « Pine creek » site



18.0 ± 0.5 m

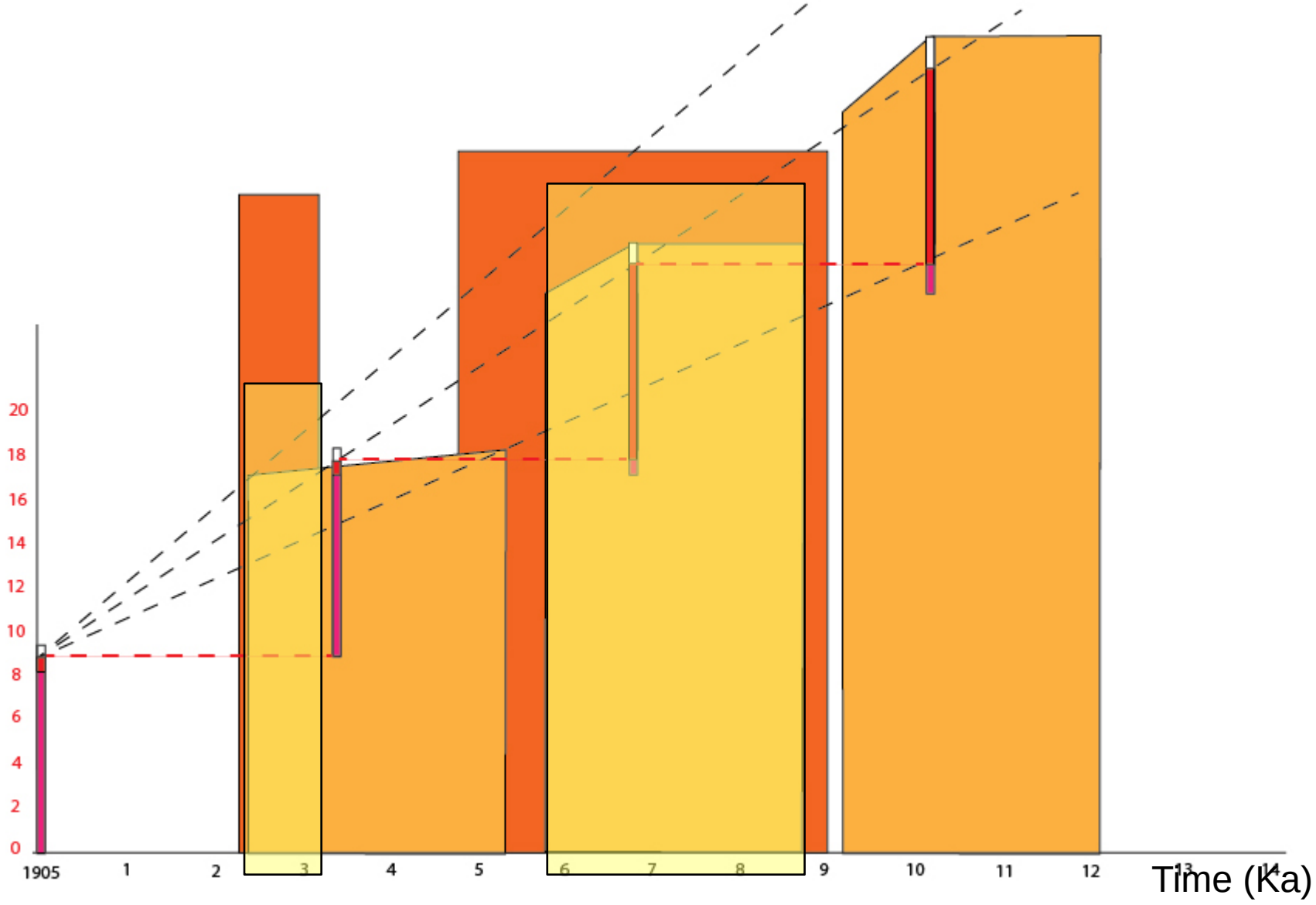


- 3 surface ruptures post 7±2 ka
- Mean recurrence interval 3-4 ka

Rizza et al., BSSA 2015

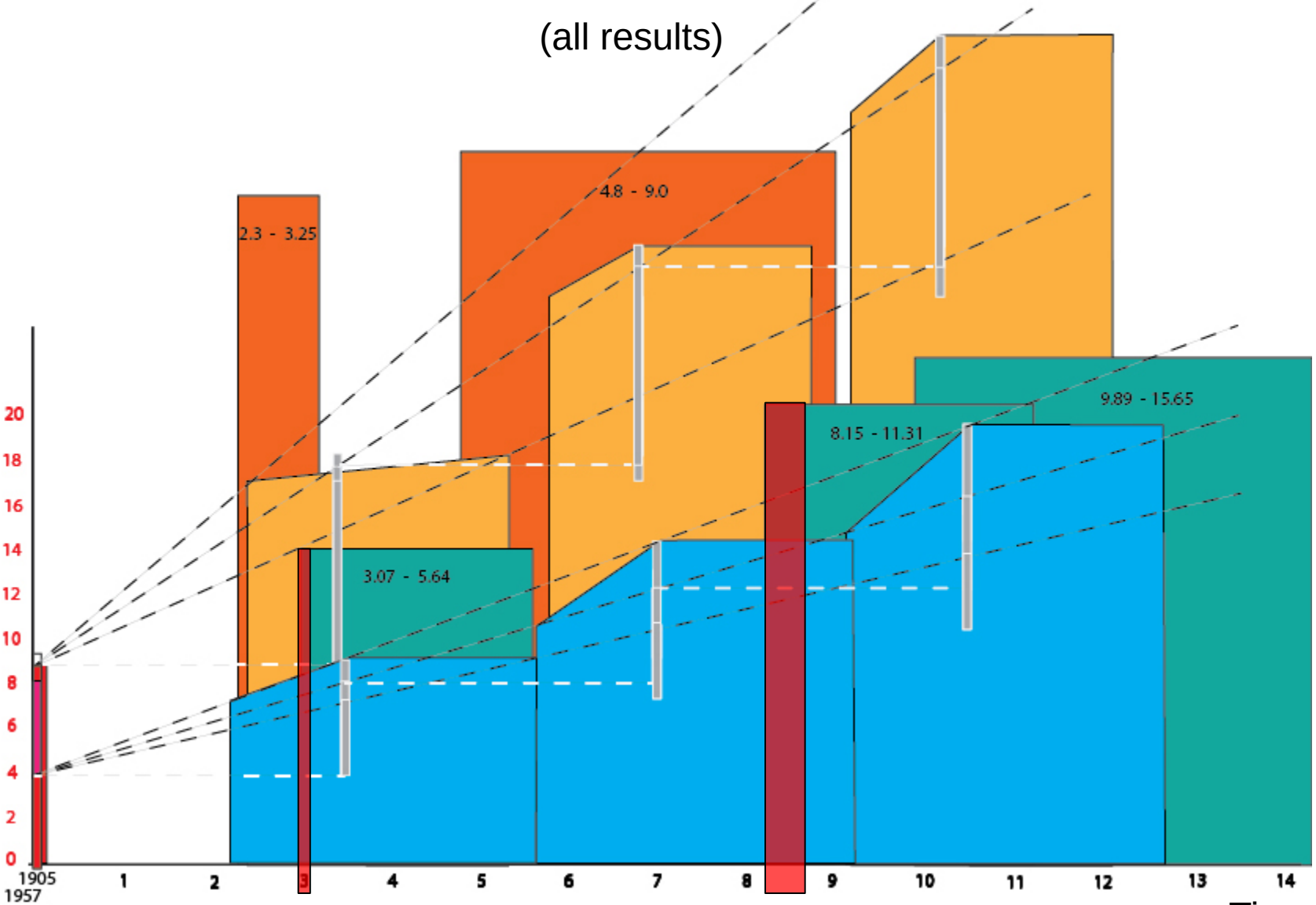
Timing of past events along the Bulnay fault

morphotectonic and paleoseismic results

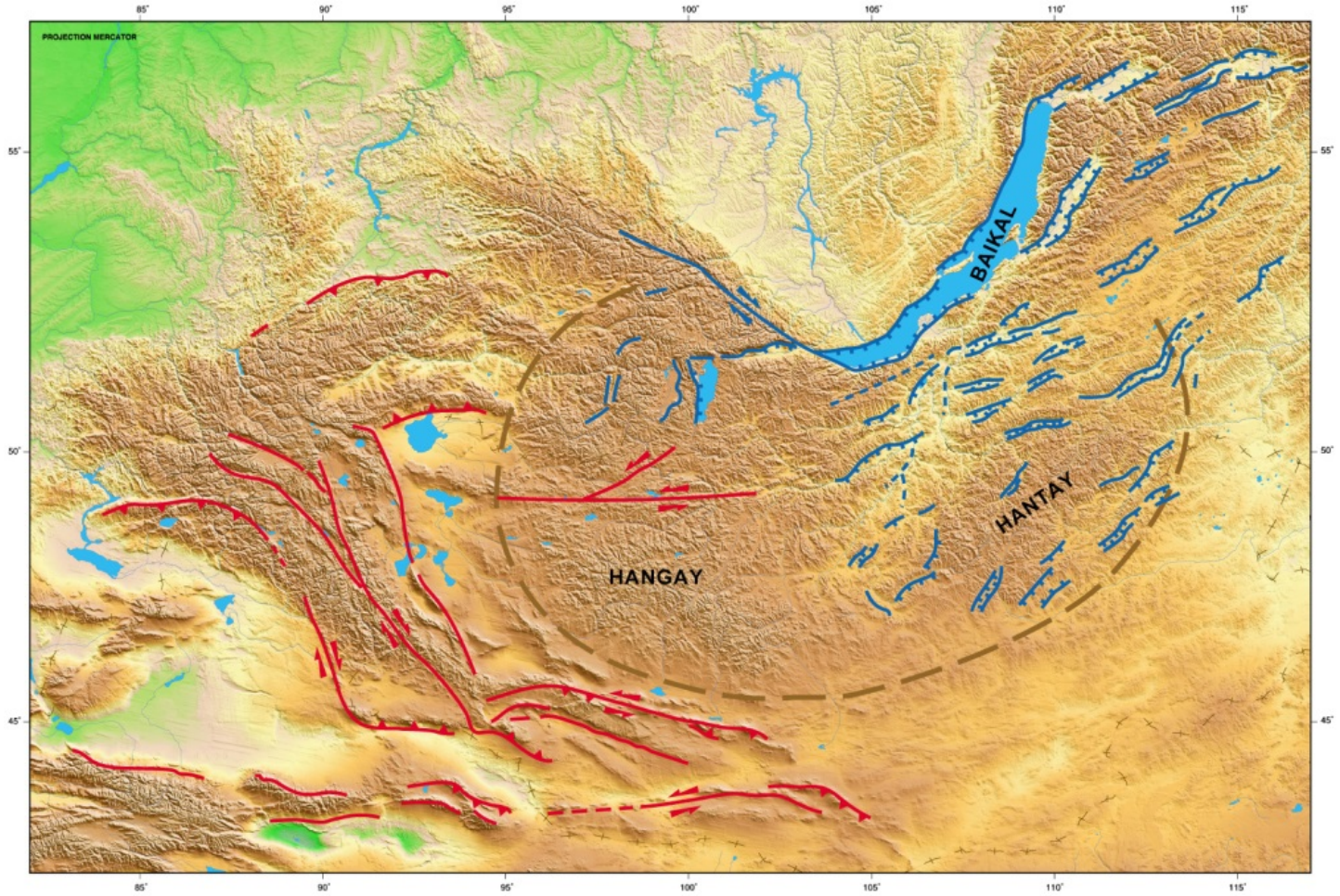


Timing of past events along the **Bogd** and **Bulnay faults**

(all results)



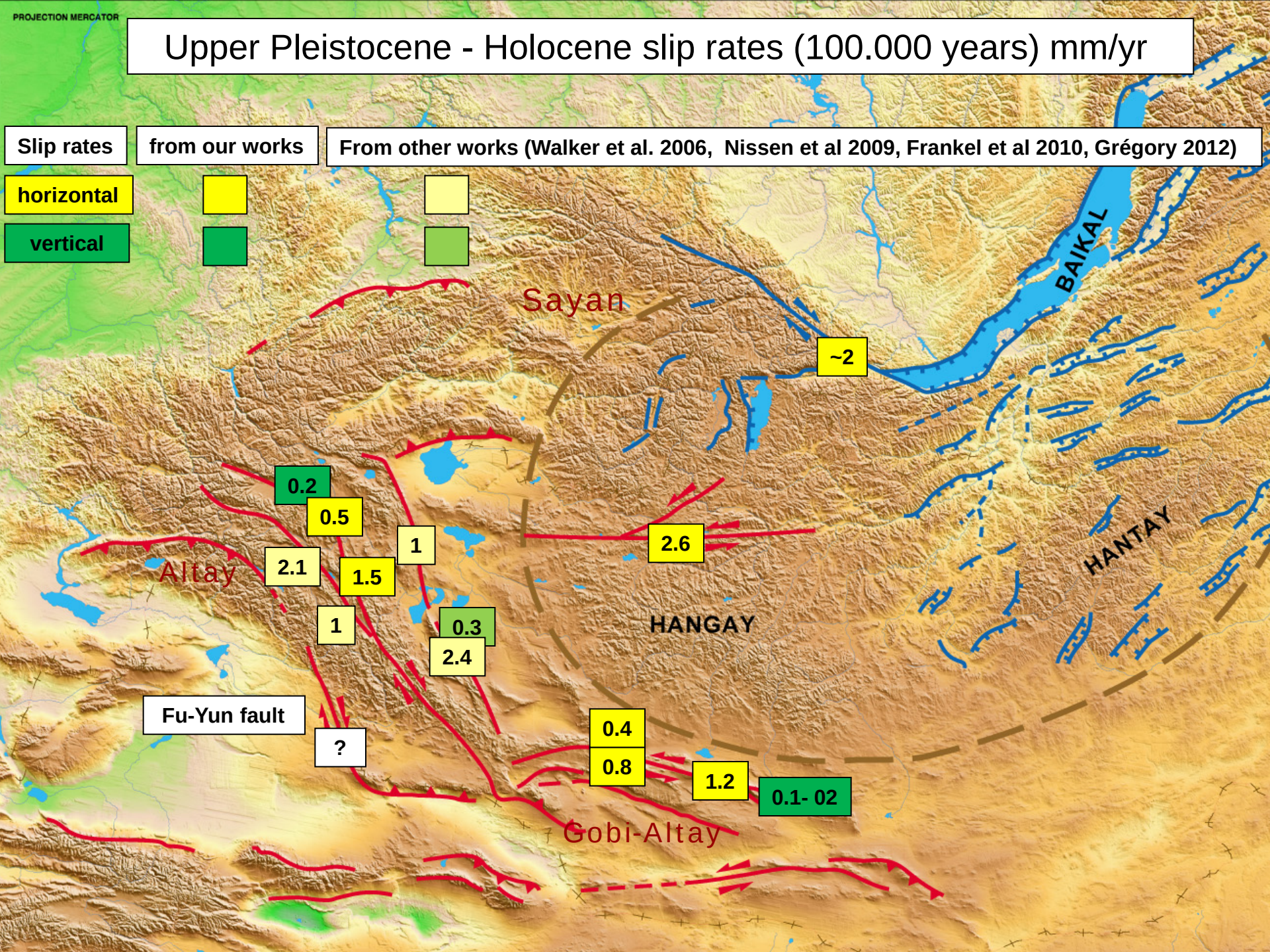
Previous M8 seismic clusters associating Bogd and Bulnay faults may have occurred in the past



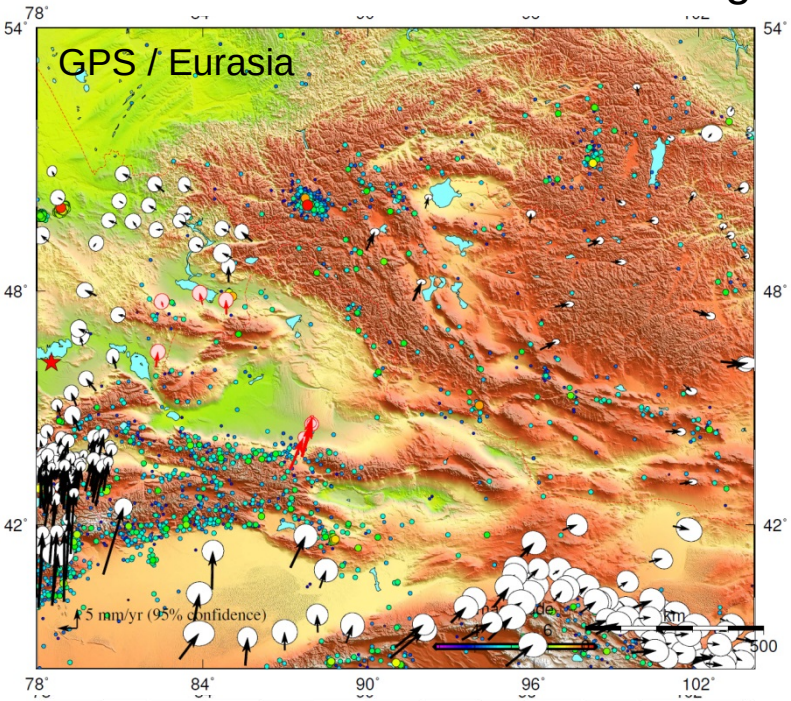
What about the timing of other large ruptures in western Mongolia ?

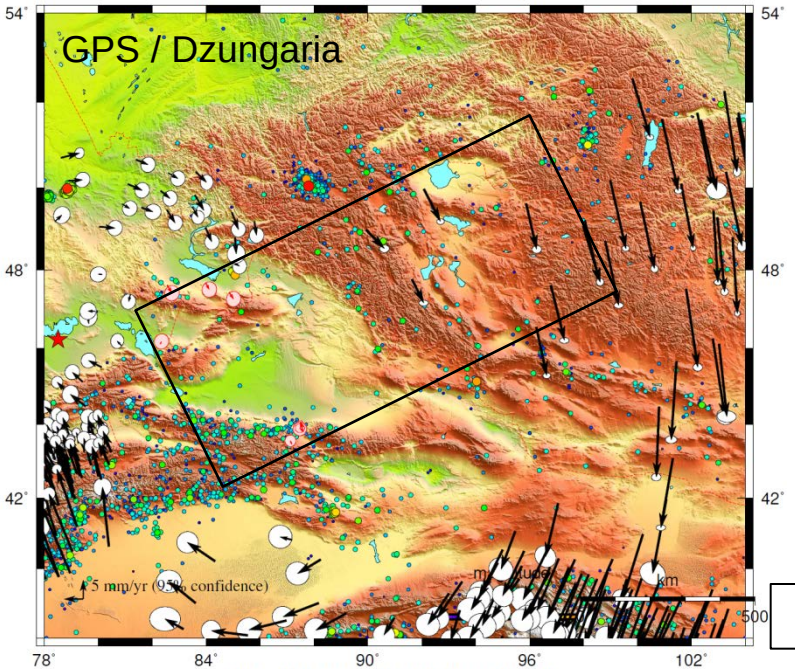
Do the other faults break also during seismic clusters ? Or “randomly” ?

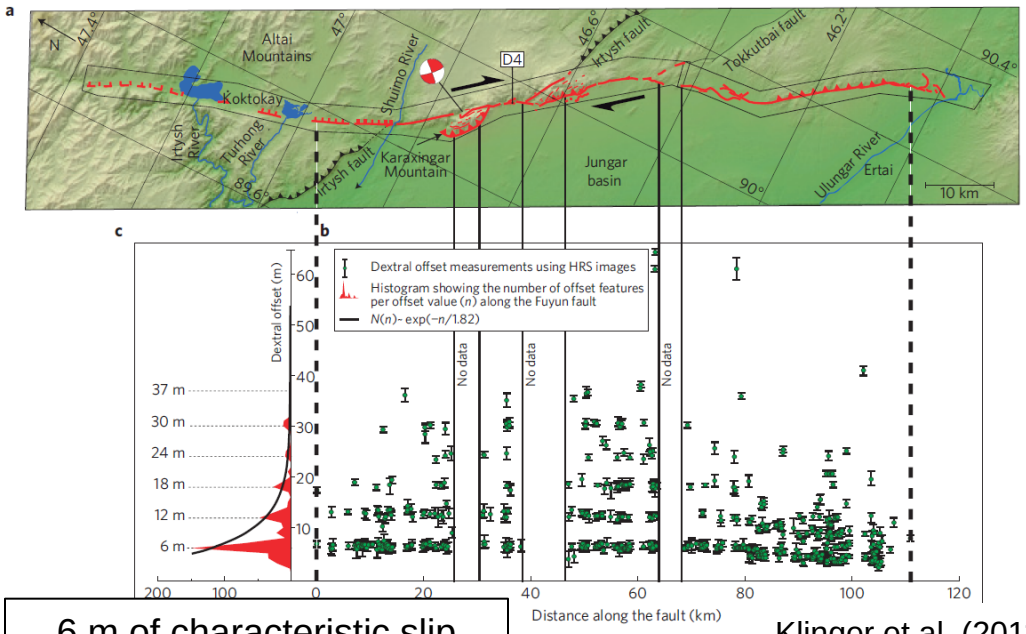
What is the distribution in space and in time of seismic ruptures in western Mongolia ?


PROJECTION MERCATOR
Upper Pleistocene - Holocene slip rates (100.000 years) mm/yr
Slip rates
from our works
From other works (Walker et al. 2006, Nissen et al 2009, Frankel et al 2010, Grégory 2012)
horizontal
vertical
Sayan
BAIKAL
~2
HANTAY
HANGAY
Altay
Gobi-Altay
0.2
0.5
1
2.1
1.5
2.6
1
0.3
2.4
Fu-Yun fault
?
0.4
0.8
1.2
0.1- 02

What about the timing of past events along the Fu-Yun fault ?



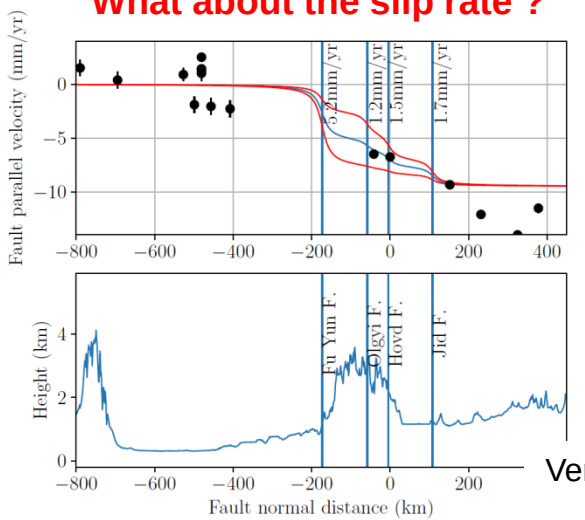




6 m of characteristic slip

Klinger et al. (2011)

What about the slip rate ?

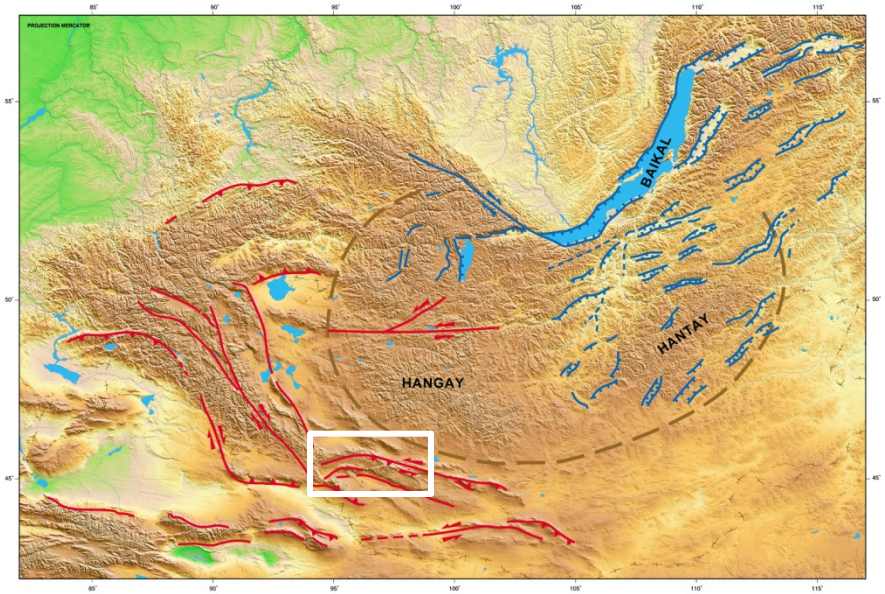


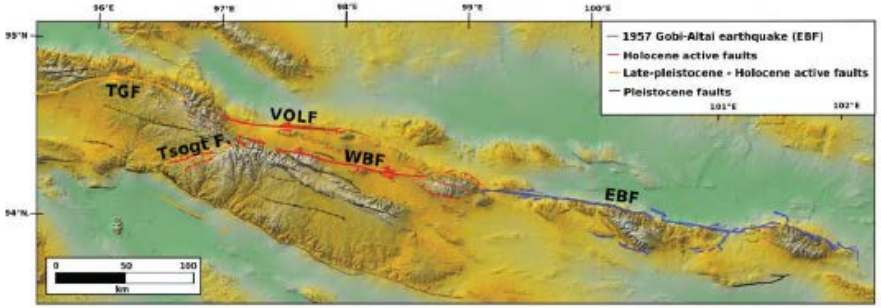
Vernant (pers. com.)

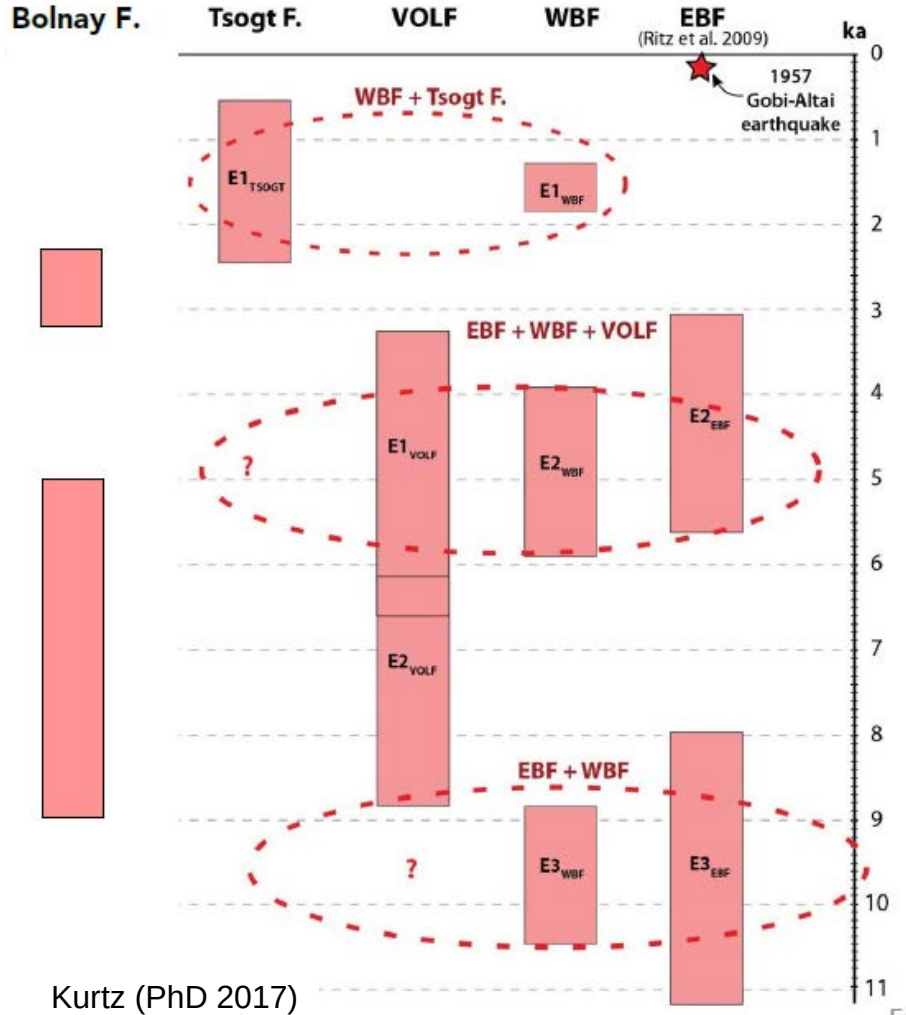
After GPS : between 1.5 and 7 mm/yr (max)

Paleoseismology:

Timing of past earthquakes in western Gobi-Altay







Kurtz (PhD 2017)


Thank you
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