Delineating Block Boundaries of the Earth's Crust in the Pacific Northwest from GPS

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Bob W. King,
Ray Wells
and a cast of tens

PNW GPS velocity field

Campaign data (1991 - 2004):

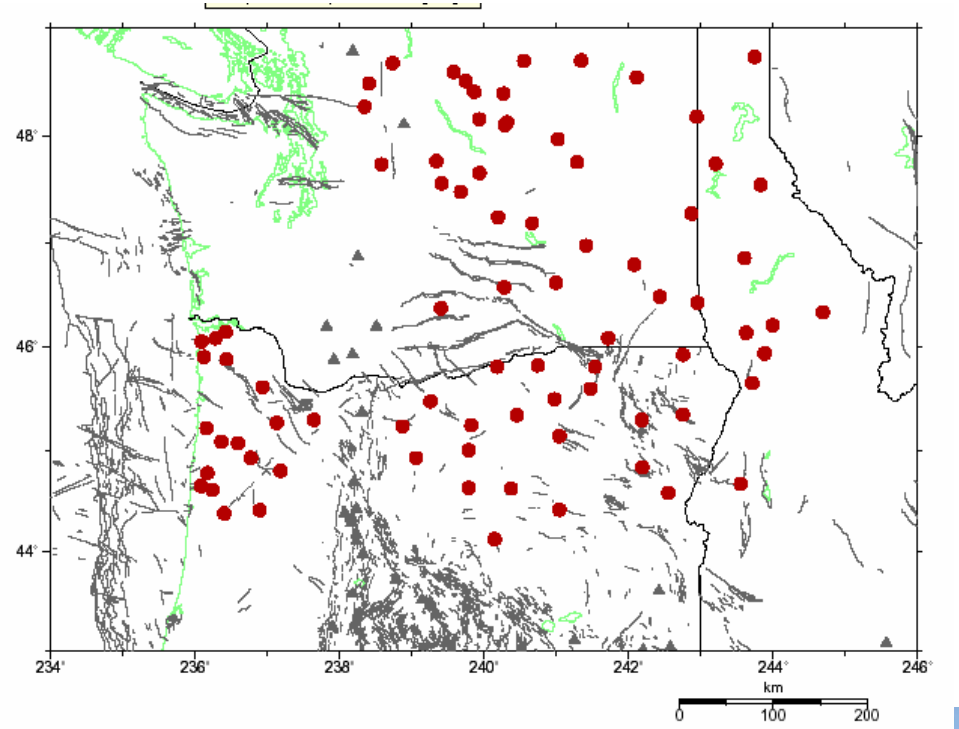
- University of Washington,
- Rensselaer Polytechnic Institute,
- US Geological Survey,
- Cascades Volcano Observatory,
- National Geodetic Survey,
- Geological Survey of Canada,
- others

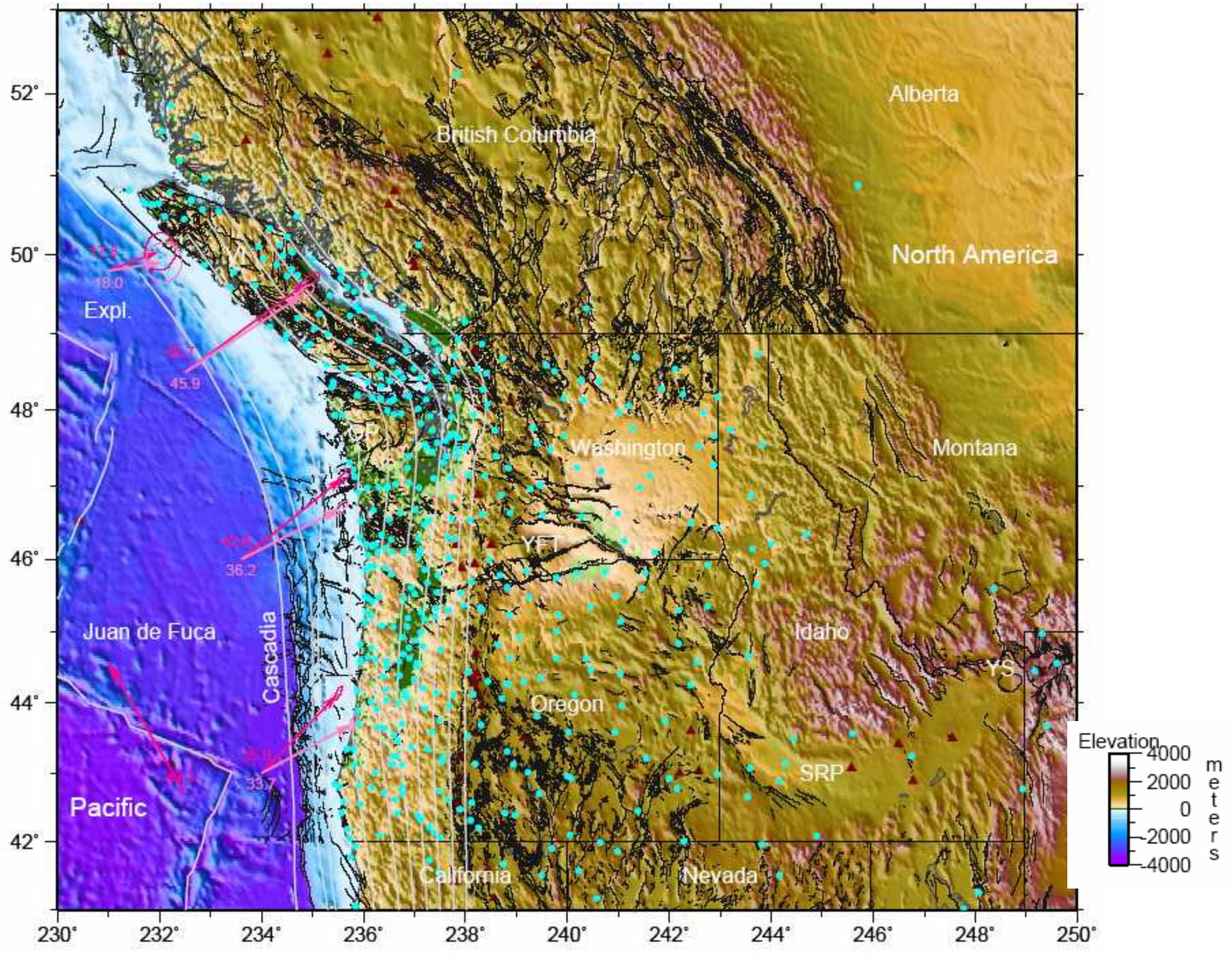
Continuous data (1991-2004):

- Geological Survey of Canada (Western Canada Deformation Array),
- Continuously Operating Reference Sites,
- Pacific Northwest Geodetic Array,

Processing with GAMIT at MIT.

2004 survey of NE Oregon, E Washington and N Idaho

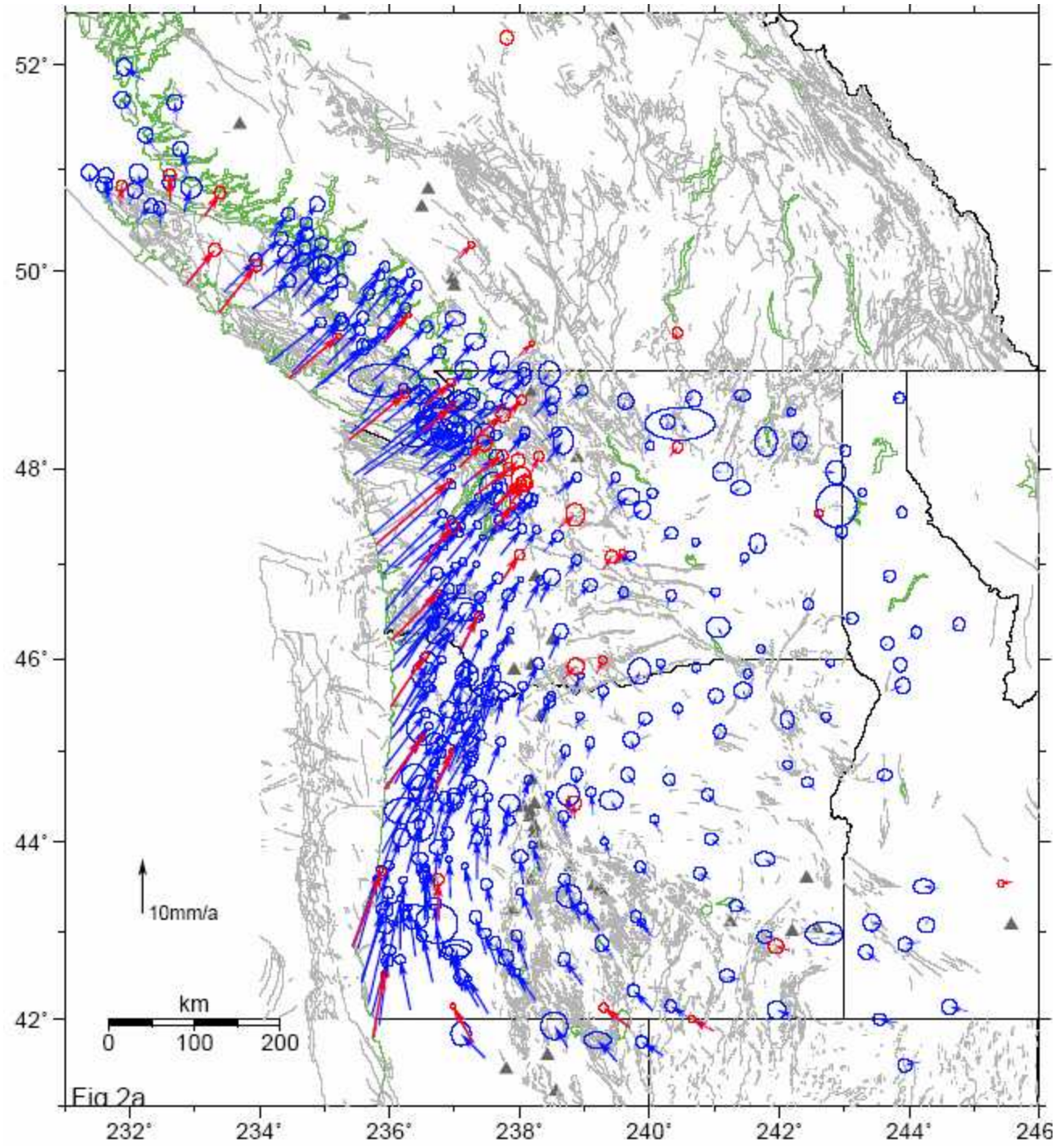


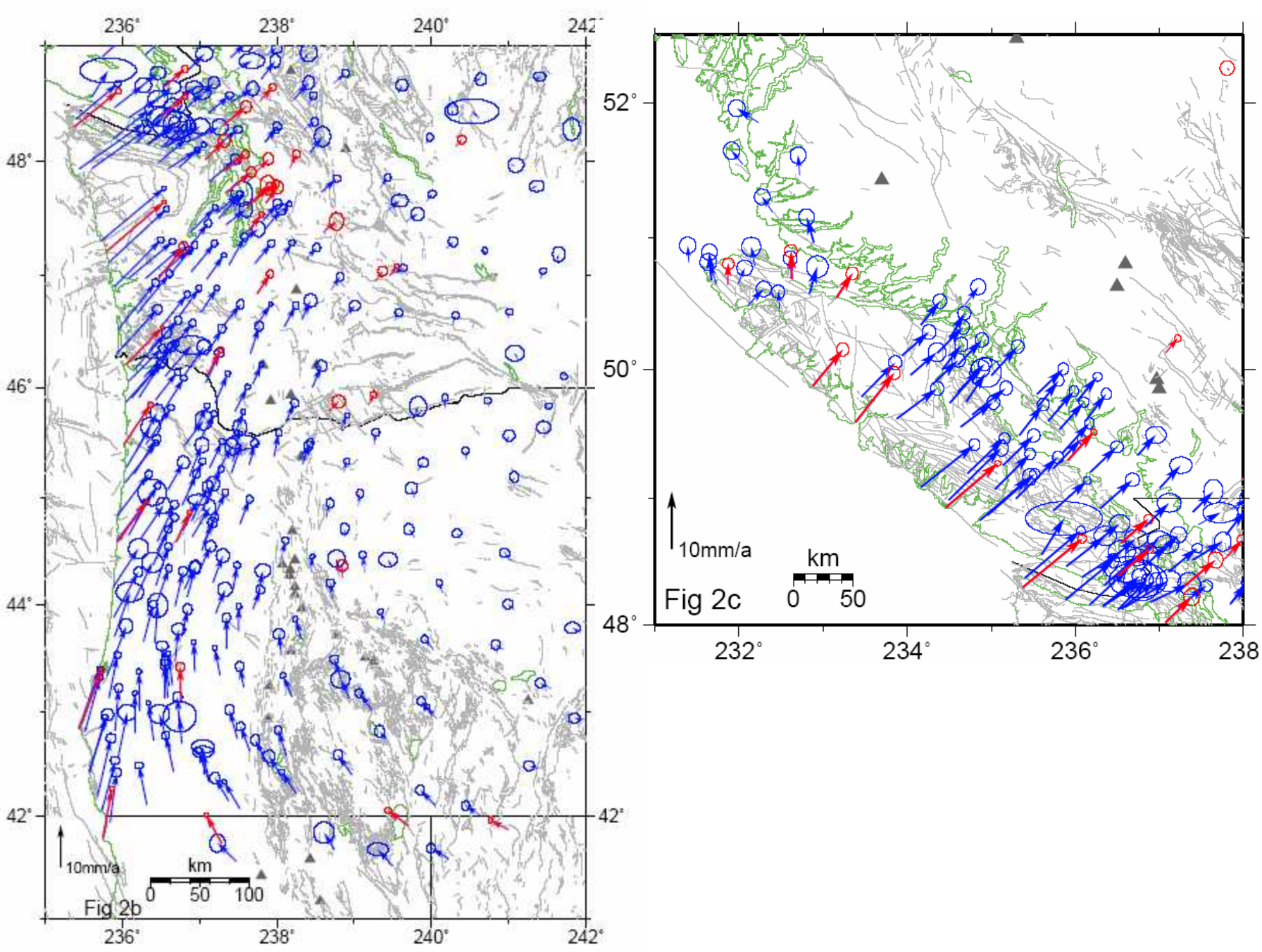

Alberta
British Columbia
North America
Expl.
Washington
Montana
Idaho
Oregon
YS
SRP
Juan de Fuca
Cascadia
Pacific
California
Nevada
17.1
18.0
45.9
36.2
33.7
52°
50°
48°
46°
44°
42°
230°
232°
234°
236°
238°
240°
242°
244°
246°
248°
250°
Elevation
4000
2000
0
-2000
-4000
meters

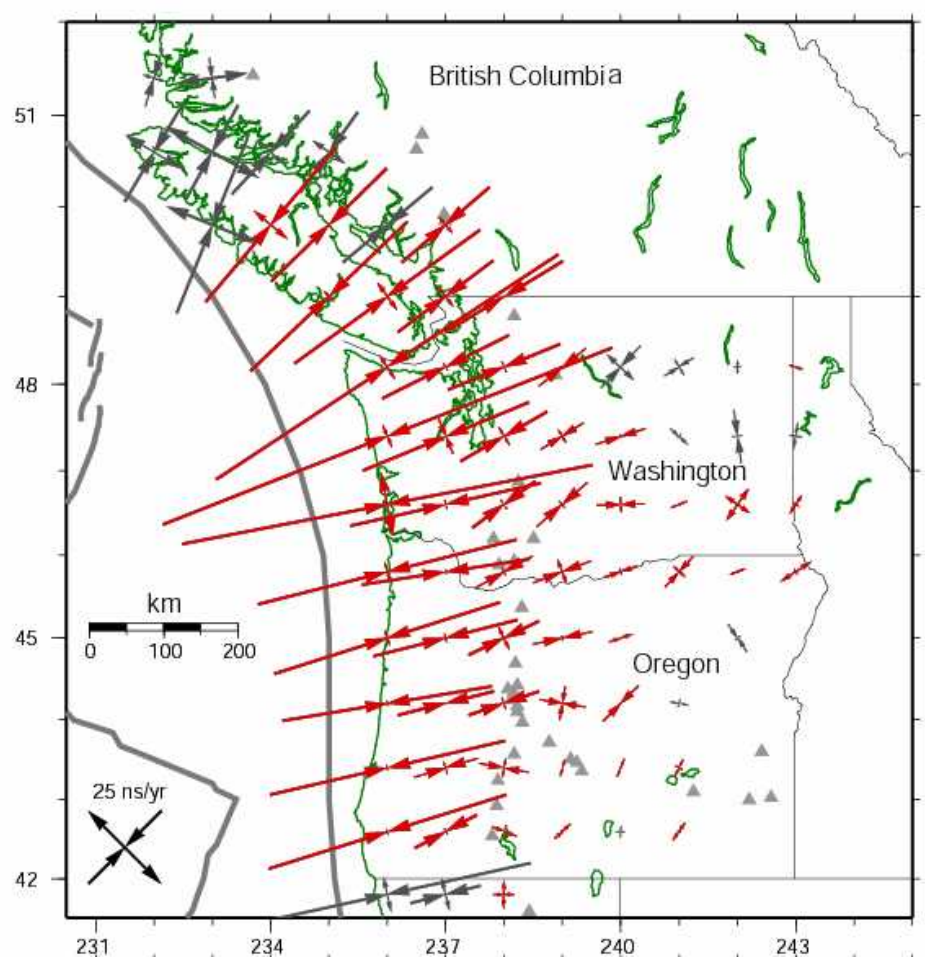
New velocity field for Pacific Northwest derived from campaign (blue) and continuous sites (red).

Reference frame is North America and ellipses are 70% confidence.

Vancouver Island data from Geological Survey of Canada (Herb Dragert et al.)

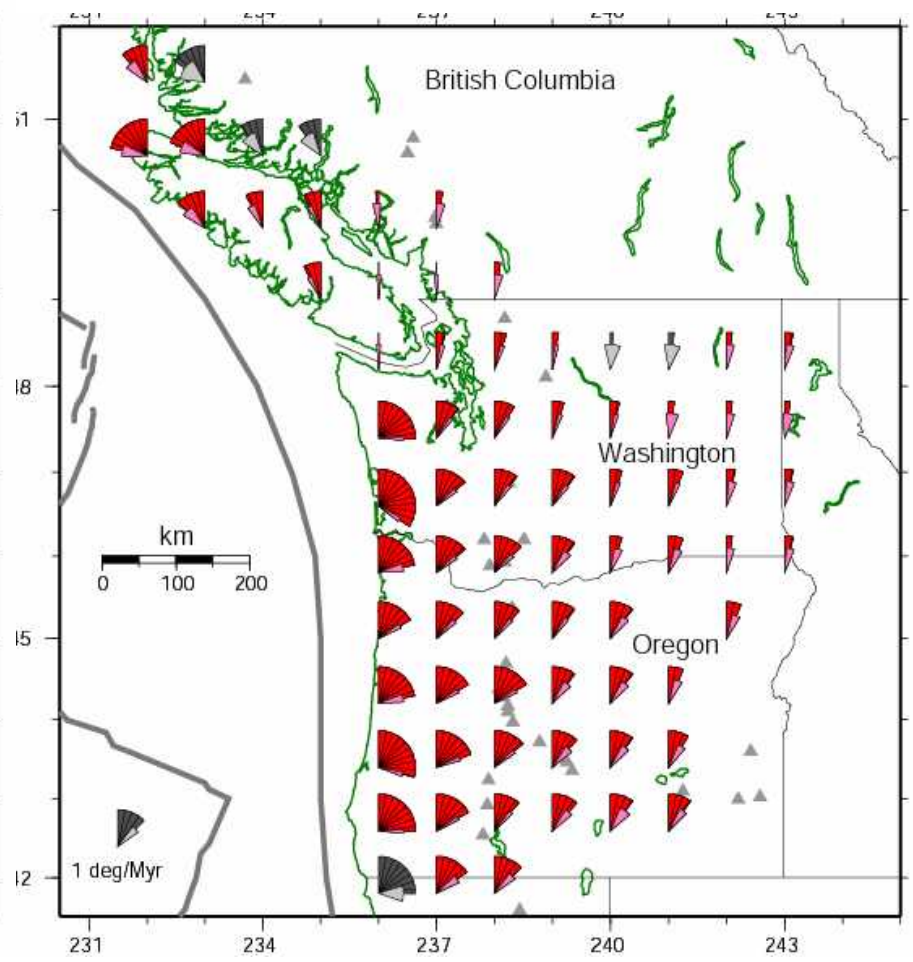



236°
238°
240°
242°
48°
46°
44°
42°
10mm/a
km
0 50 100
Fig 2b
52°
50°
48°
232°
234°
236°
238
10mm/a
km
0 50
Fig 2c



Strain rates

10 mm/yr over 500 km = 20 ns/yr



Rotation rates

10 mm/yr over 500 km = 20 nanoradians/yr
= 1.2 deg/Myr

Data

GPS velocities
- Our solution

Slip vectors
- CMT, NUVEL-1, C. DeMets
- Braunmiller & Nabelek
- Pezzopane & Weldon
- PNSN, OSU

Transform azimuths
- C. DeMets

Spreading/slip rates
- NUVEL-1, C. DeMets
- Pezzopane & Weldon
- Wells unpublished
- Hazards compilation

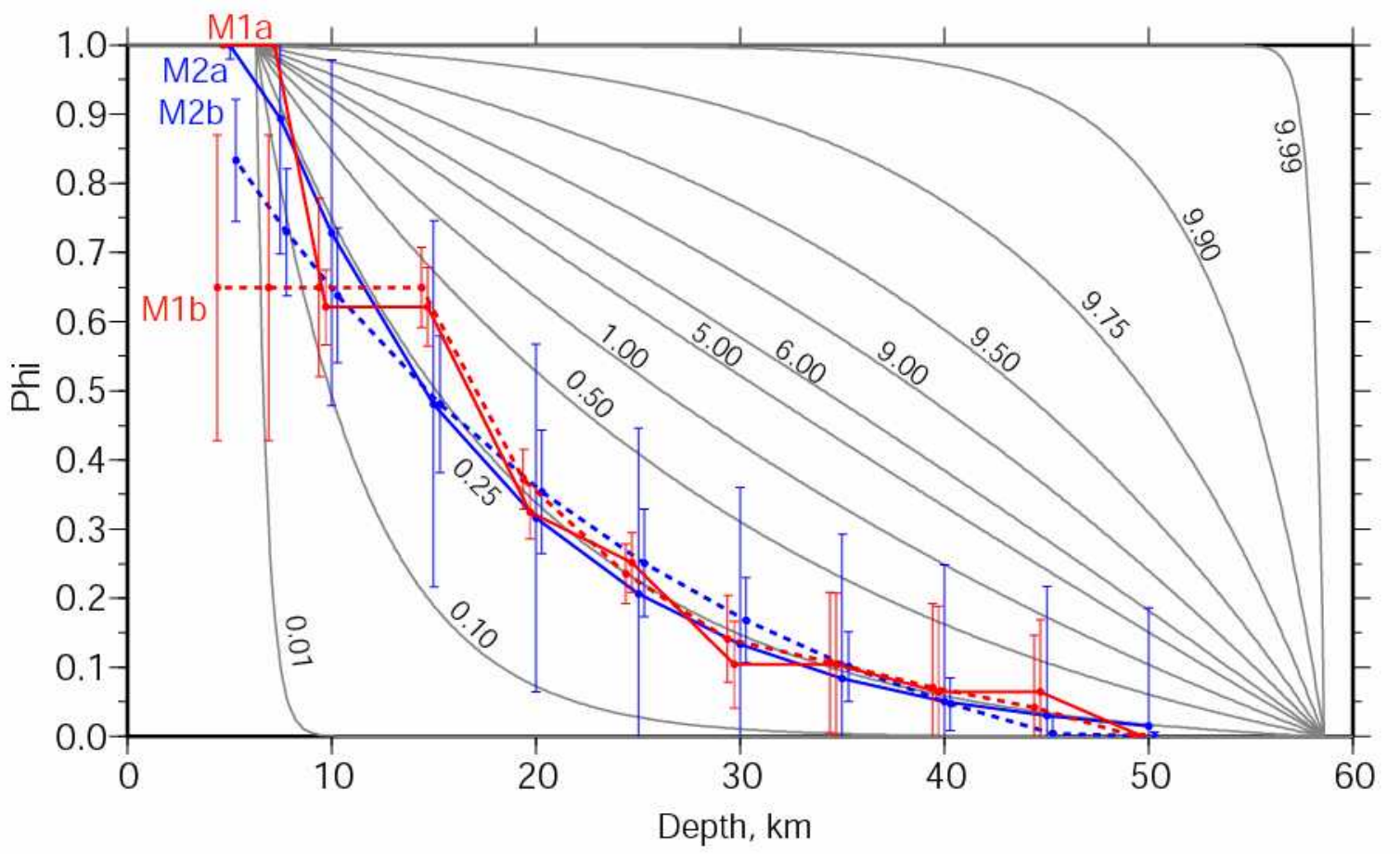
Parameters

Block rotations relative to North America
- Pacific (fixed)
- Juan de Fuca, Explorer
- Crustal block(s)

Reference frame
- North America (fixed)

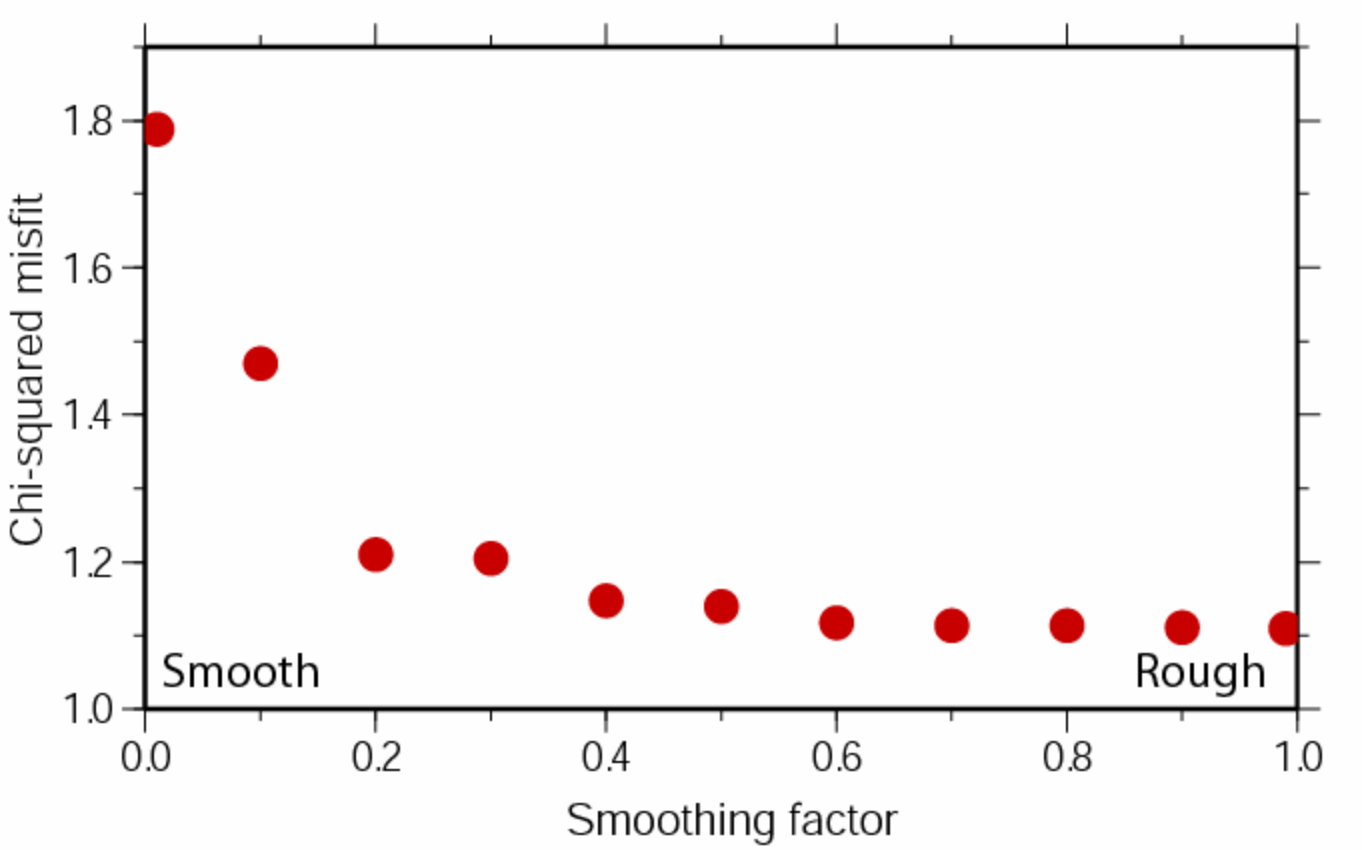
Fault locking
- Cascadia thrust
- Crustal faults

One-dimensional locking solution (variation with depth only)

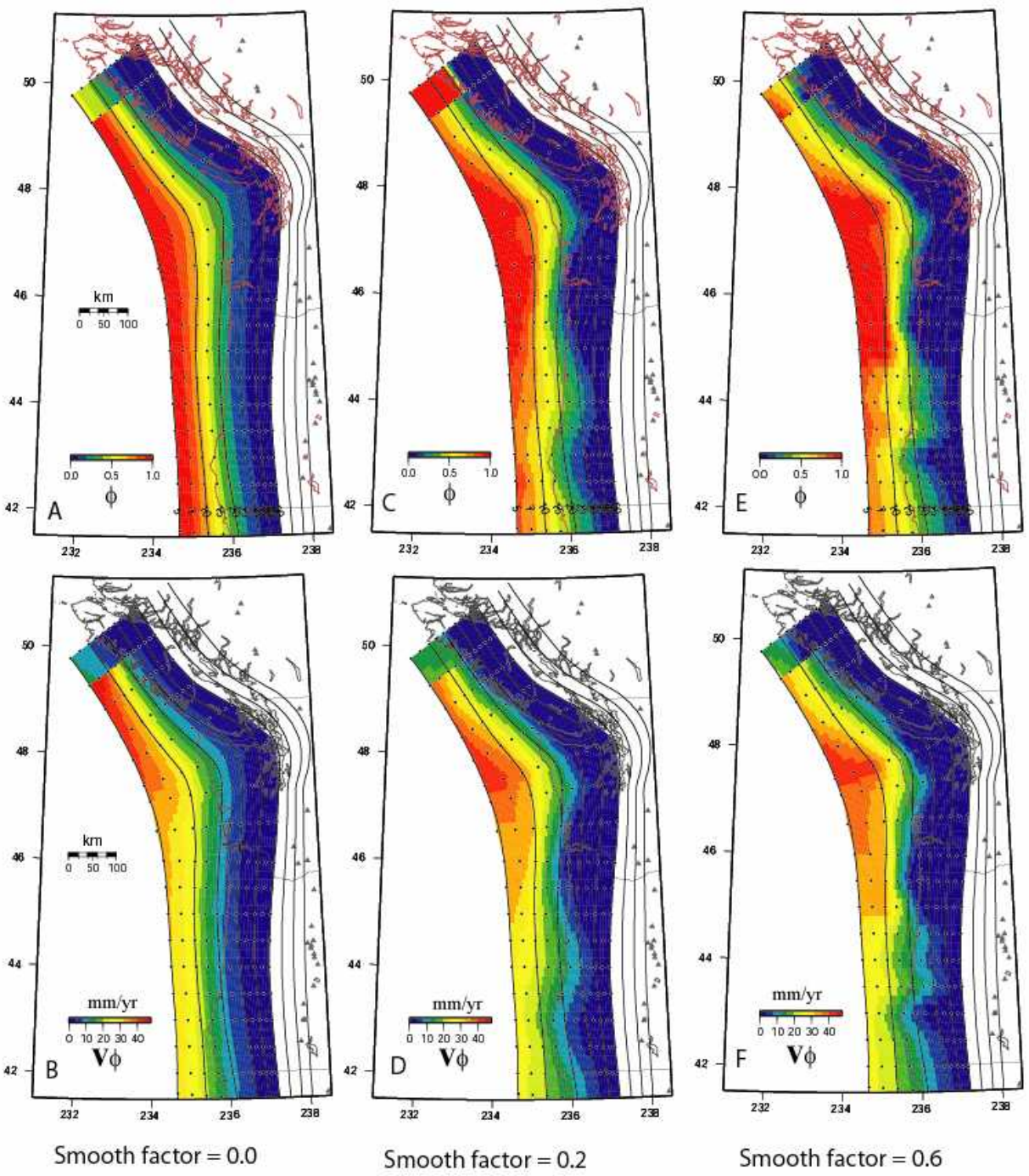


Wang modified Downdip decrease

Coupling along strike varies fairly smoothly; no more than 40% to 60% every 100 km along strike.

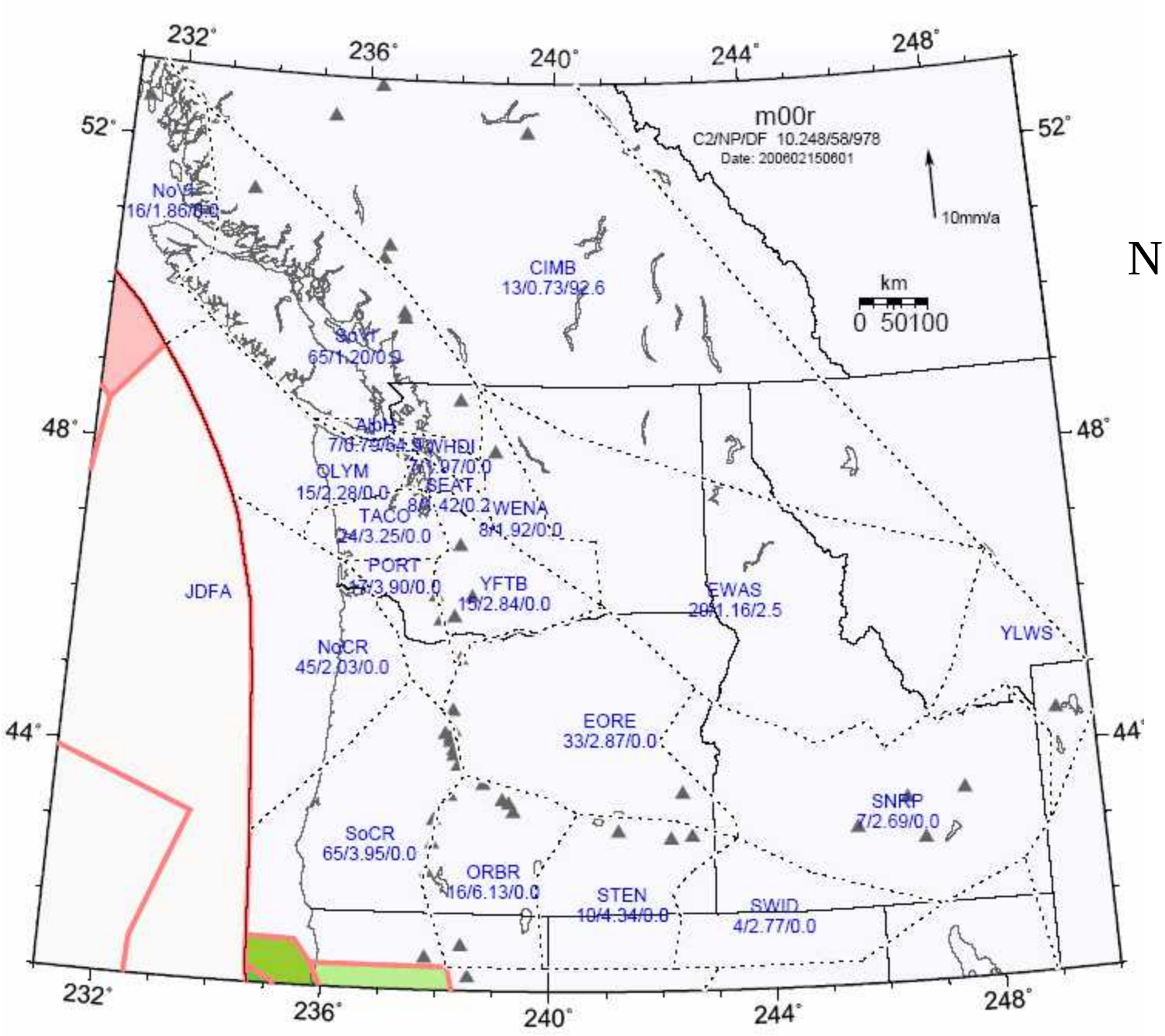


Along-strike smoothing



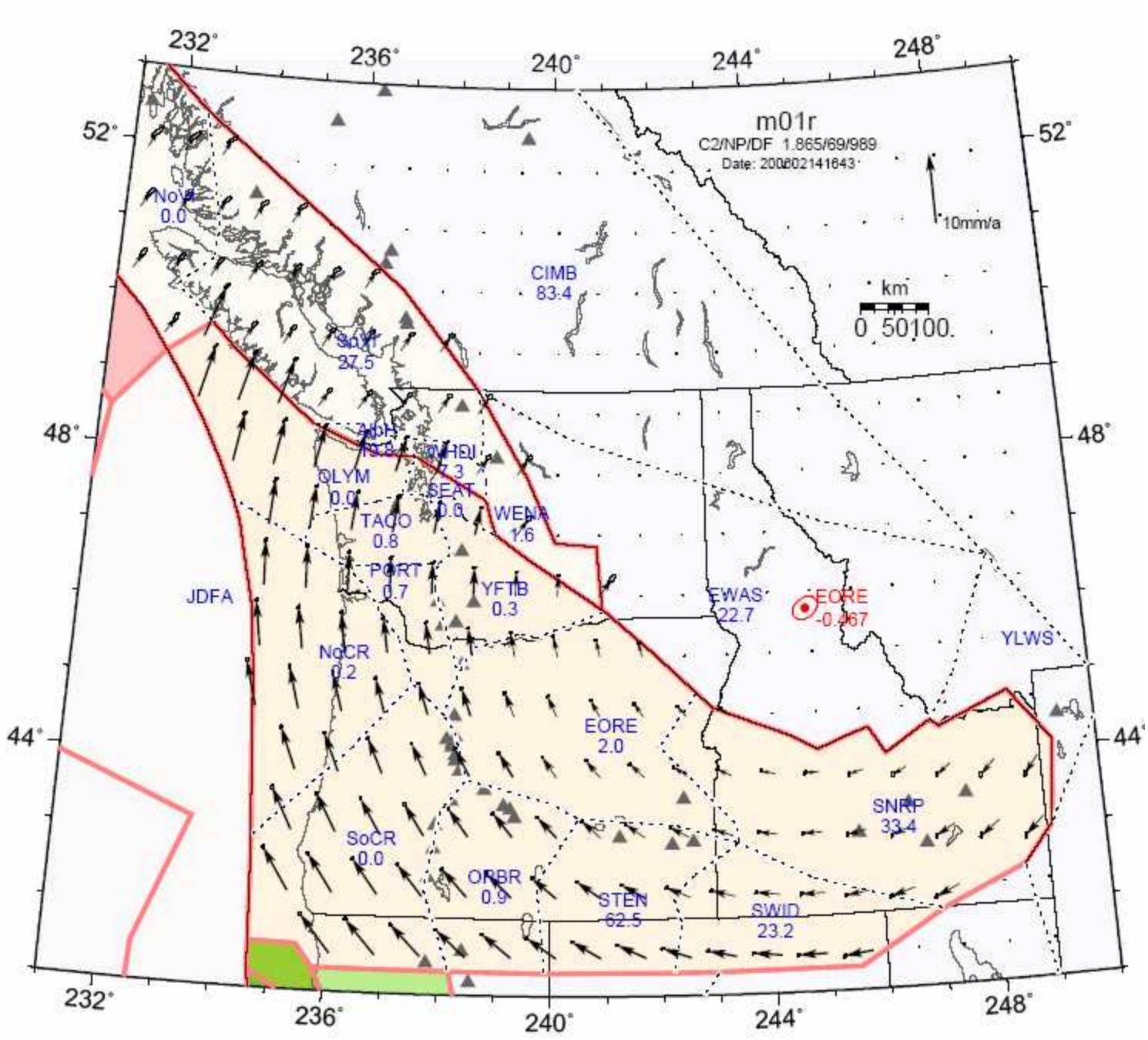
Moment rate
1.4E20 Nm/yr

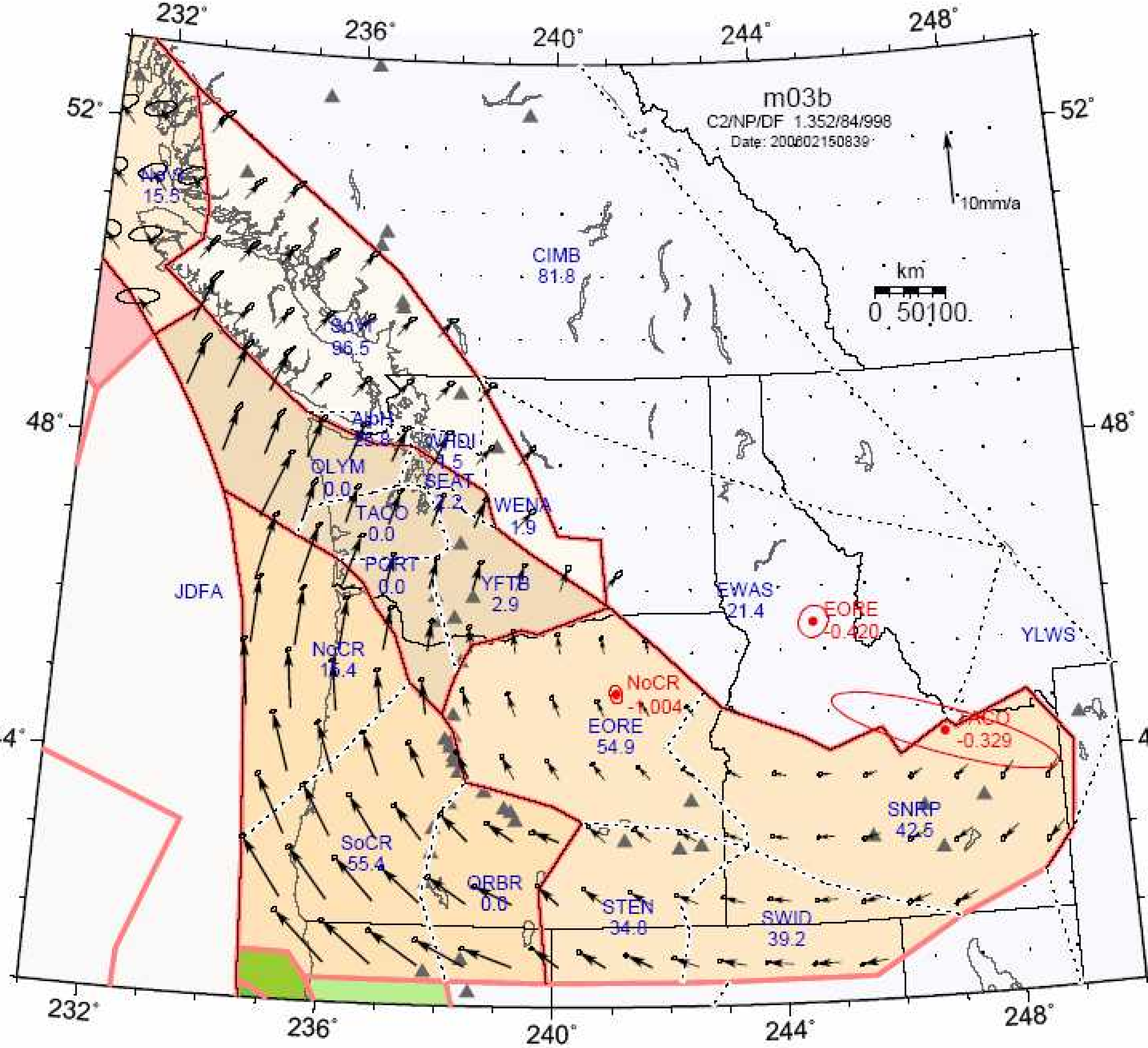
Mw 8.70 per 100 yrs
Mw 9.02 per 300 yrs
Mw 9.22 per 600 yrs



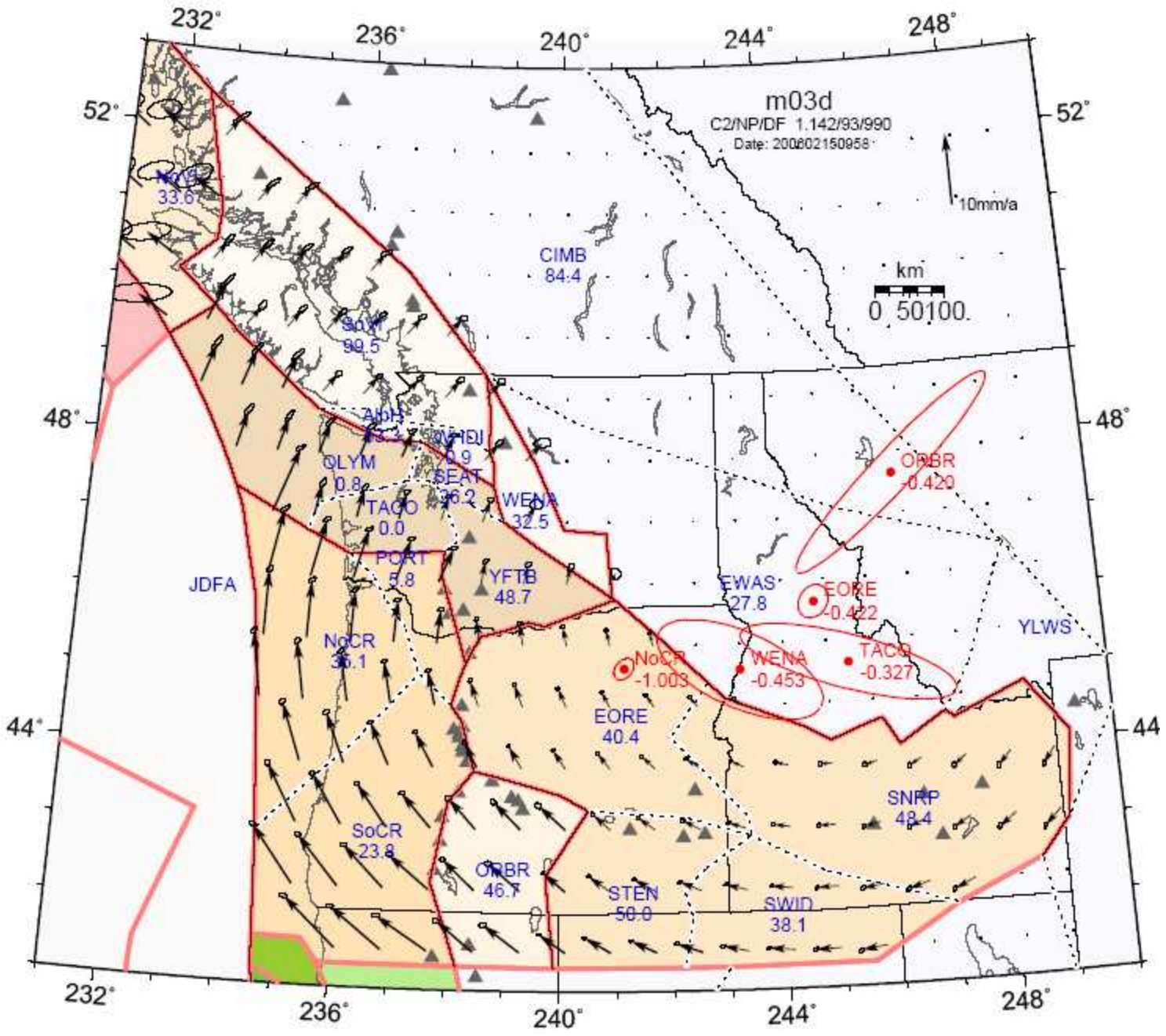
All part of NA

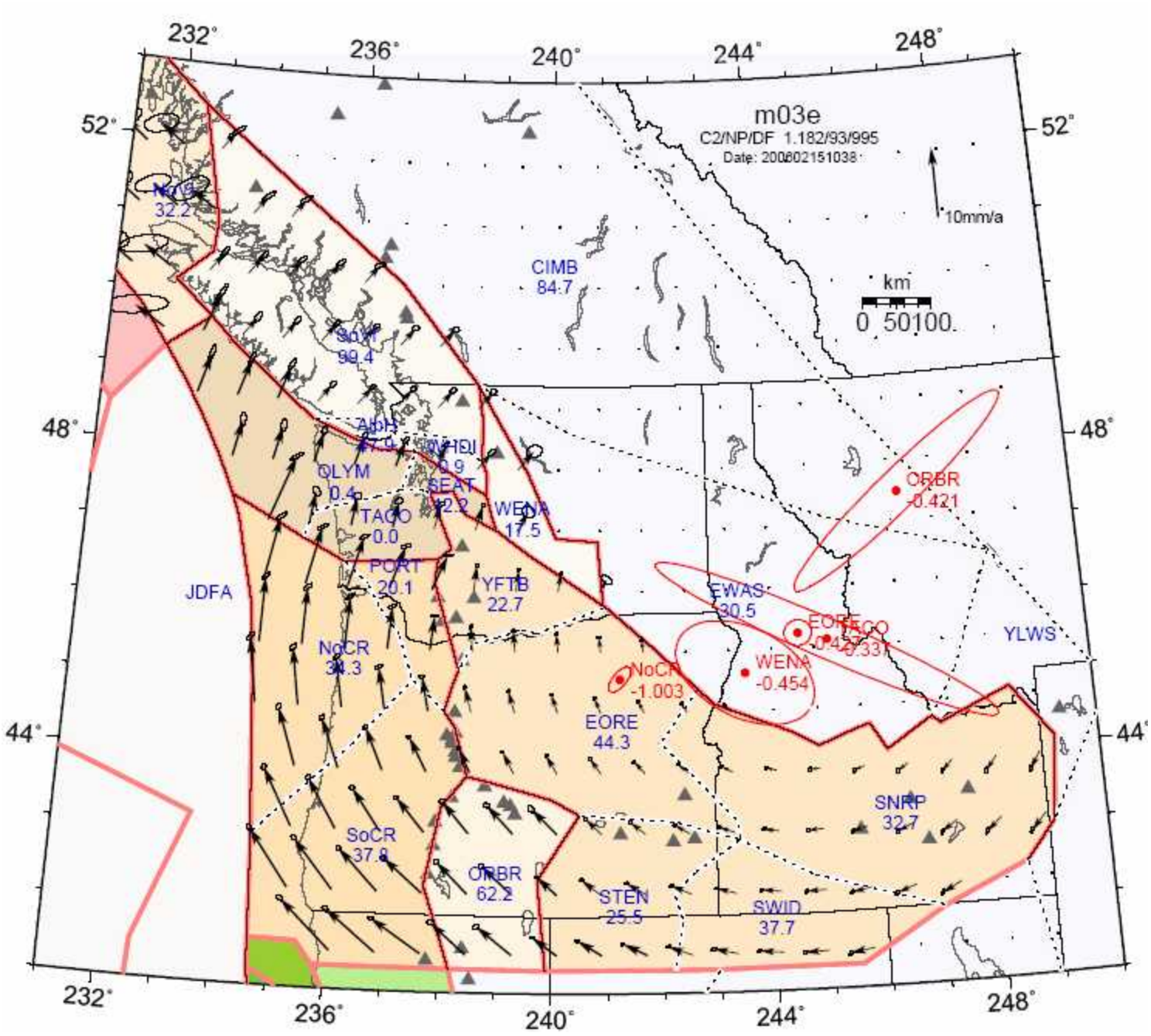
N / Nrms / Q

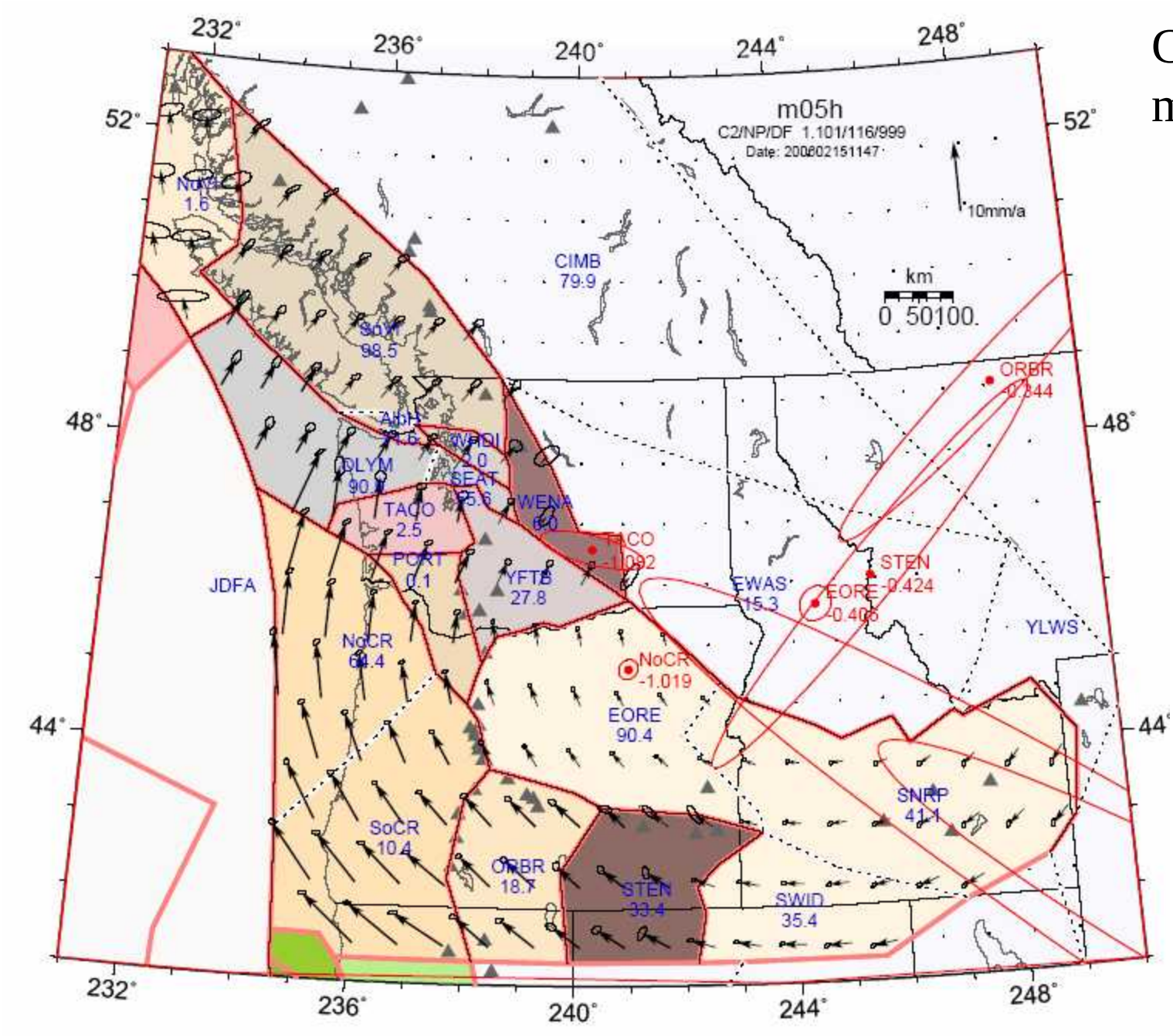

m01r
C2/NP/DF 1.865/69/989
Date: 2008/02/14 16:43
10mm/a
km
0 50100.
232°
236°
240°
244°
248°
52°
48°
44°
CIMB
83.4
NoVI
0.0
SoVI
27.5
NHDI
7.3
OLYM
0.0
SEAT
0.0
WENA
1.6
TACO
0.8
PORT
0.7
YFTB
0.3
JDFA
EWAS
22.7
EORE
-0.467
YLWS
NoCR
0.2
EORE
2.0
SNRP
33.4
SoCR
0.0
ORBR
0.9
STEN
62.5
SWID
23.2



m03b
C2/NP/DF 1.352/84/998
Date: 200802150839
10mm/a
km
0 50100
CIMB
81.8
NoVI
15.5
SoVI
96.5
OLYM
0.0
TACO
0.0
SEAT
WENA
1.9
PORT
0.0
YFTB
2.9
JDFA
NoCR
15.4
EWAS
21.4
EORE
-0.420
YLWS
NoCR
-1.004
EORE
54.9
-0.329
SNRP
42.5
SoCR
55.4
ORBR
0.0
STEN
34.8
SWID
39.2
232°
236°
240°
244°
248°
52°
48°
44°

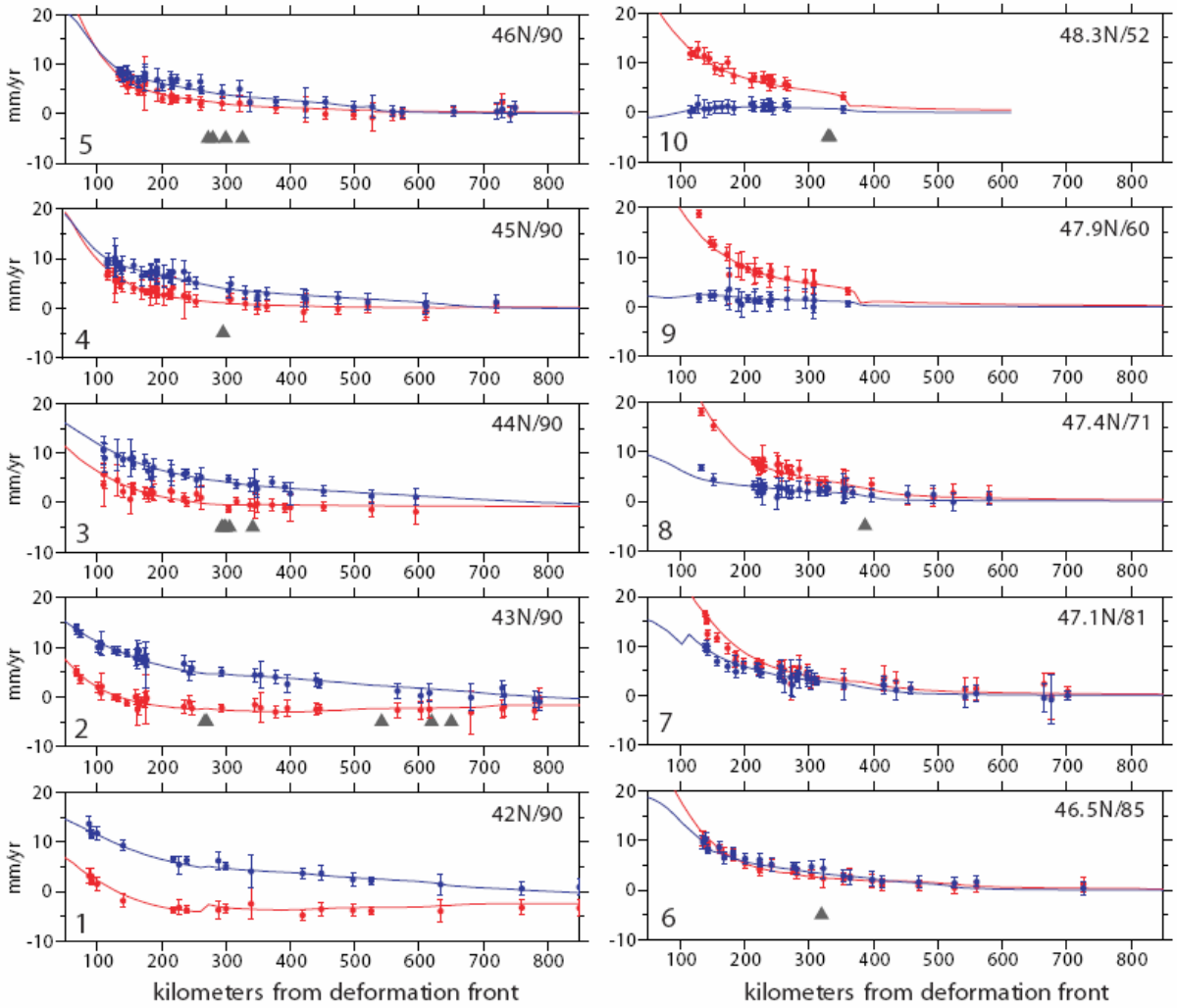

m03d
C2/NP/DF 1.142/93/990
Date: 20060215095
10mm/a
km
0 50100
232°
236°
240°
244°
248°
52°
48°
44°
CIMB
84.4
NOOR
33.6
SOVI
99.5
ALBH
OLYM
0.8
SEAT
36.2
TACO
0.0
PORT
5.8
WENA
32.5
YFTB
48.7
JDFA
NoCR
35.1
SoCR
23.8
ORBR
46.7
STEN
50.0
SWID
38.1
EORE
40.4
SNRP
48.4
EWAS
27.8
YLWS
ORBR
-0.420
EORE
-0.422
NoCR
-1.003
WENA
-0.453
TACO
-0.327


m03e
C2/NP/DF 1.182/93/995
Date: 20060215103
10mm/a
km
0 50100
232°
236°
240°
244°
248°
52°
48°
44°
CIMB
84.7
NoVI
32.2
SoVI
99.4
OLYM
0.4
SEAT
12.2
TACO
0.0
PORT
20.1
YFTB
22.7
WENA
17.5
JDFA
NoCR
34.3
SoCR
37.8
ORBR
62.2
EORE
44.3
STEN
25.5
SWID
37.7
SNRP
32.7
EWAS
30.5
YLWS
ORBR
-0.421
EORE
-0.447
TACO
-0.331
NoCR
-1.003
WENA
-0.454



Geologic model

Profiles



Red = E or NE component

Blue = N or NW component

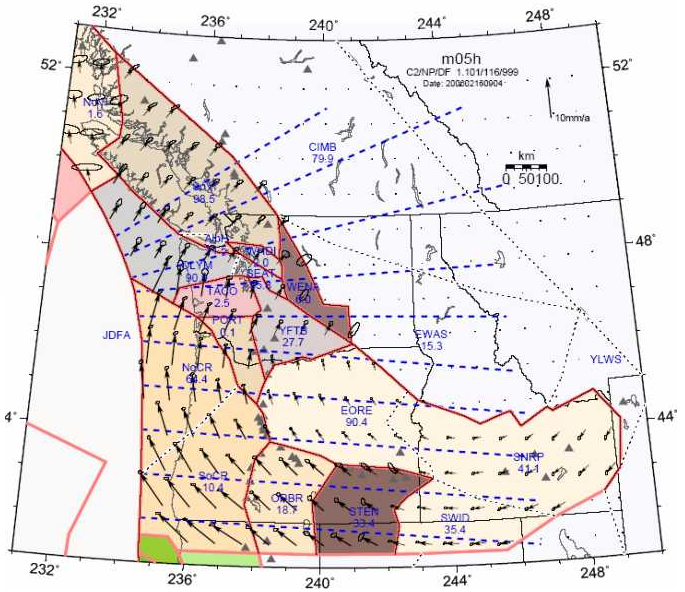
Triangles = volcanoes

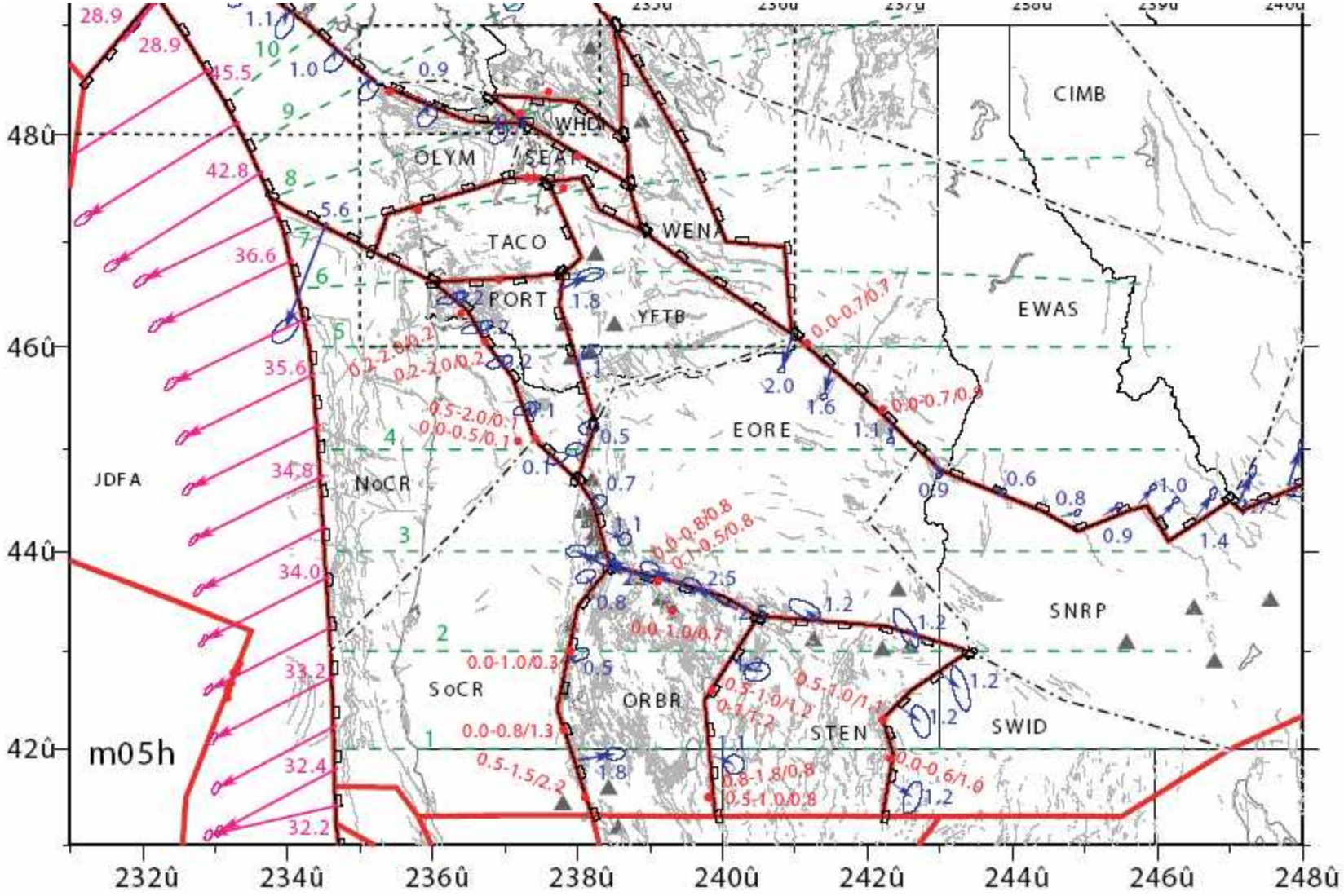
Very little offset at volcanic arc

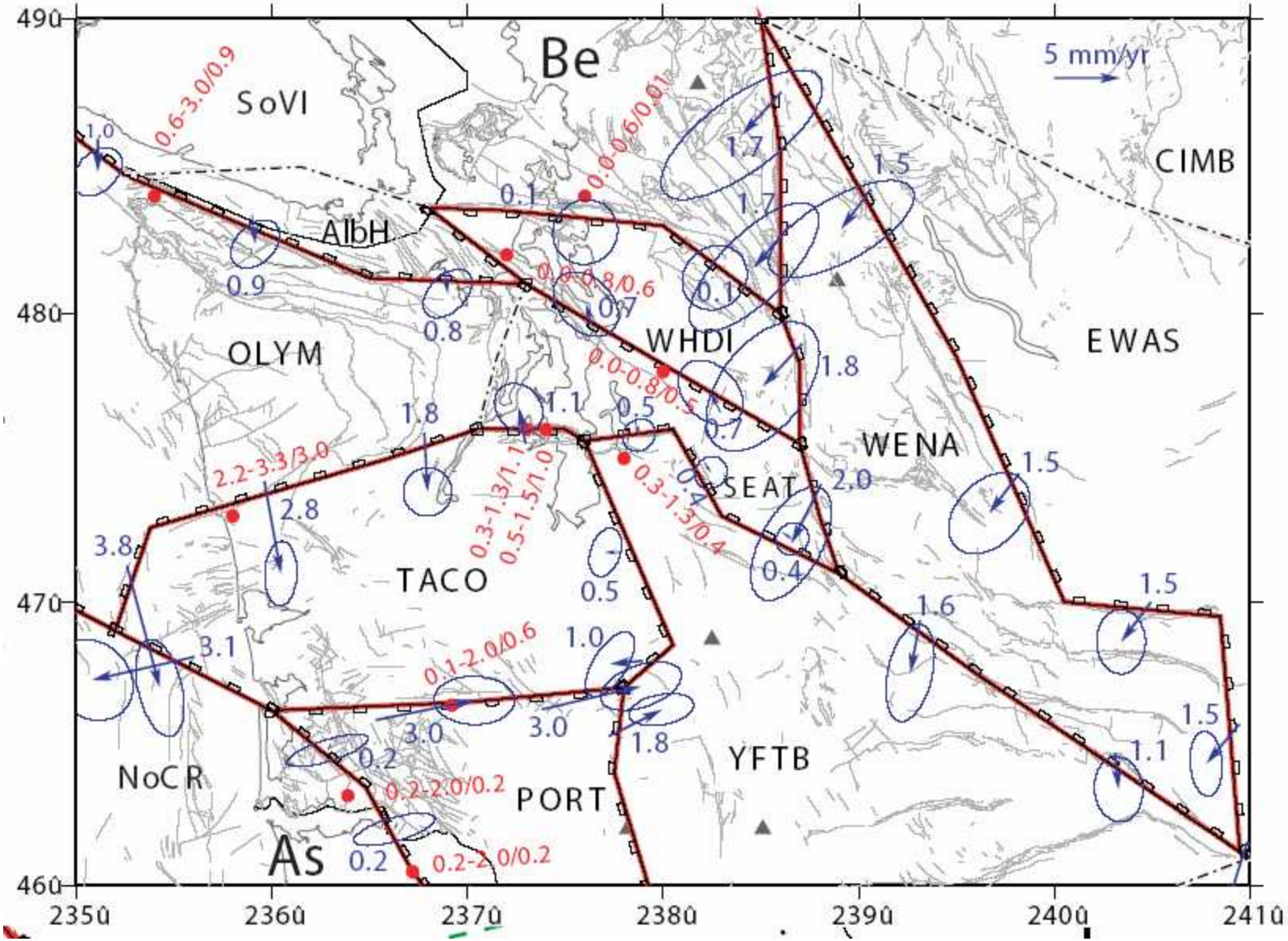
E-component flat in N OR backarc

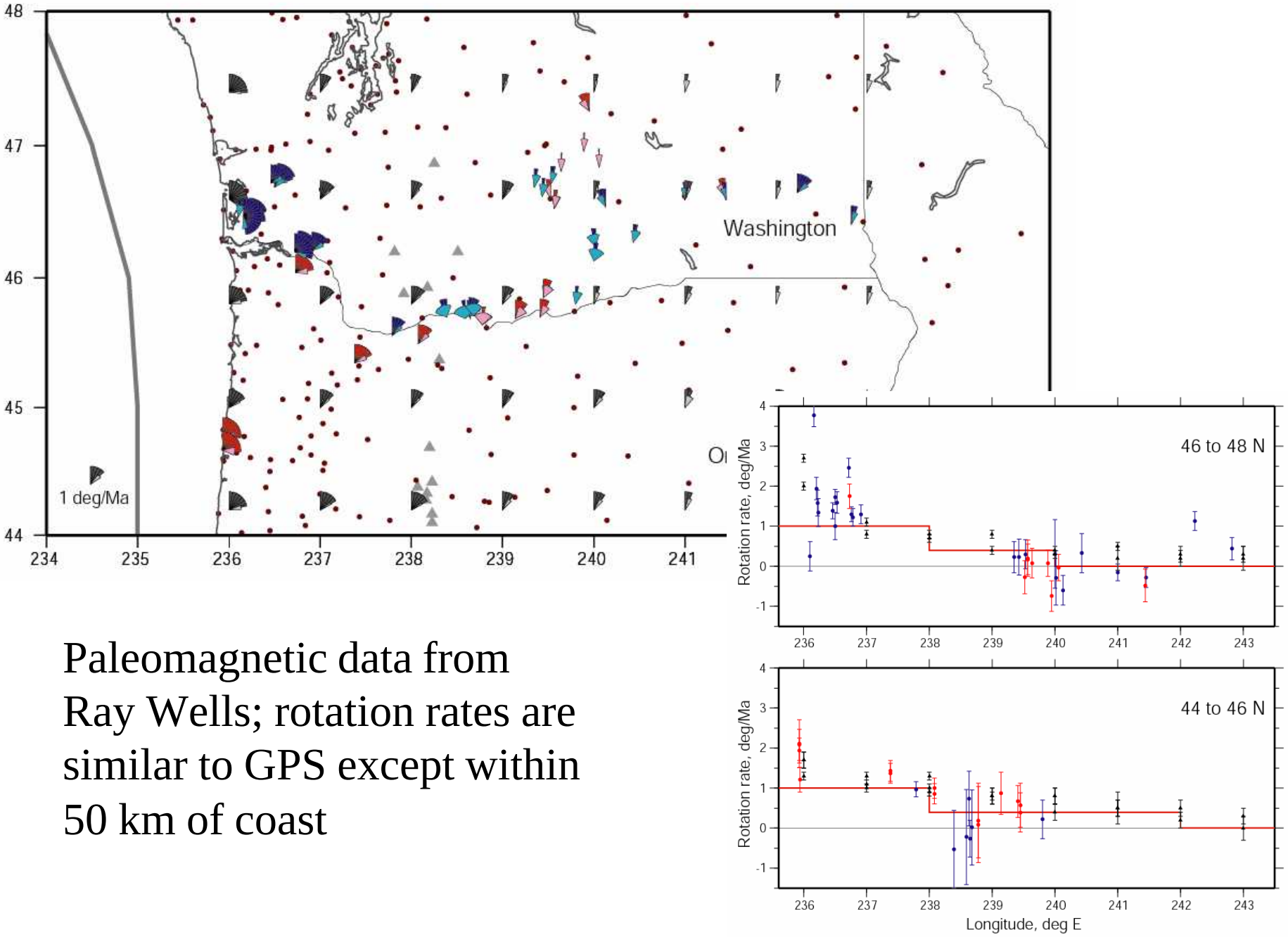
1 mm/yr extension in S OR backarc

Contraction across WA Cascades

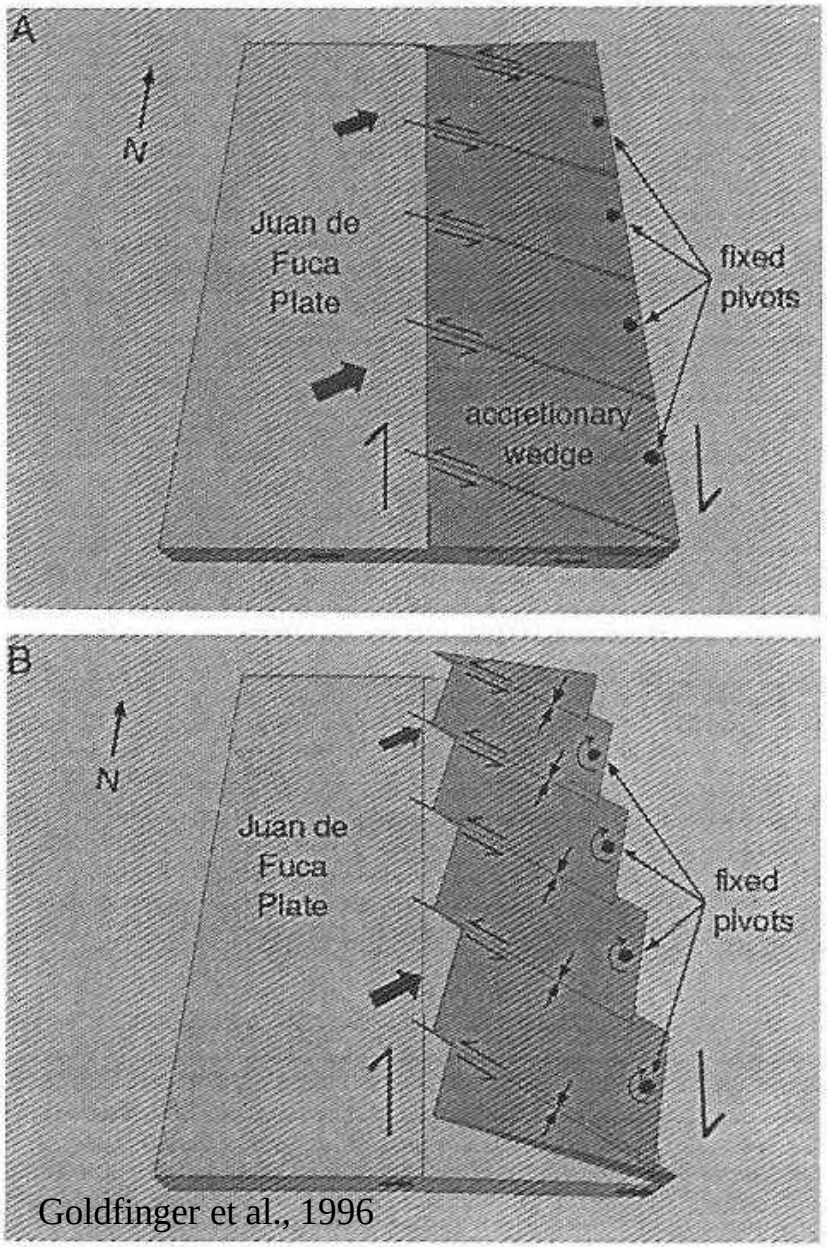



m05h
CIMB
EWAS
SNRP
SWID
EORE
WENA
TACO
OLYM
SEAT
WHDI
PORT
YFTB
JDFA
NoCR
SoCR
ORBR
STEN
48û
46û
44û
42û
232û
234û
236û
238û
240û
242û
244û
246û
248û


Be
As
SoVI
AlbH
OLYM
WHDI
CIMB
EWAS
WENA
SEAT
TACO
NoCR
PORT
YFTB
5 mm/yr
0.6-3.0/0.9
0.0-0.6/0.01
0.0-0.8/0.6
0.0-0.8/0.5
2.2-3.3/3.0
0.3-1.3/1.1
0.5-1.5/1.0
0.3-1.3/0.4
0.1-2.0/0.6
0.2-2.0/0.2
0.2-2.0/0.2
490
480
470
460
235
236
237
238
239
240
241



Paleomagnetic data from Ray Wells; rotation rates are similar to GPS except within 50 km of coast

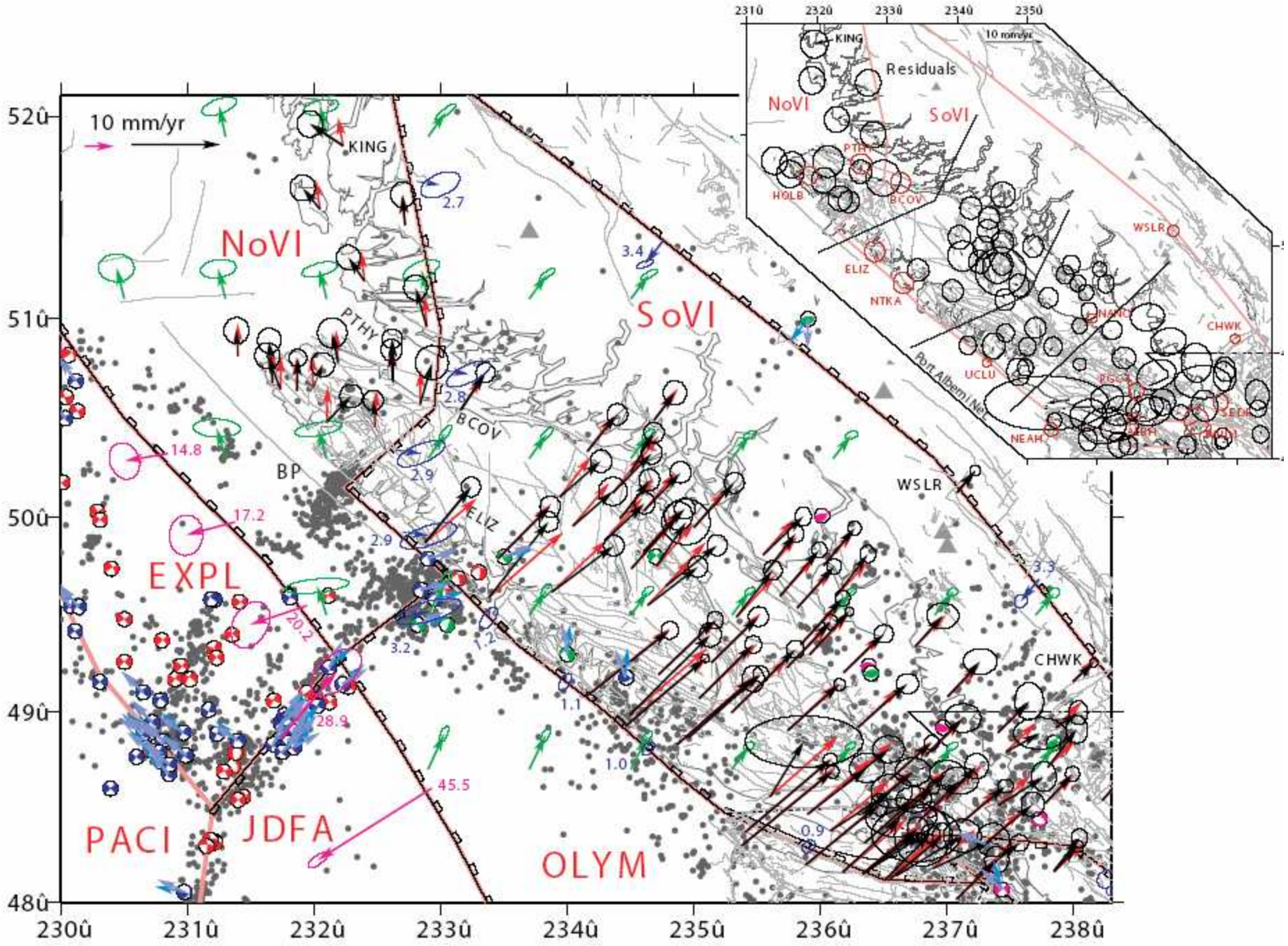


Goldfinger et al., 1996

BOE calculation:

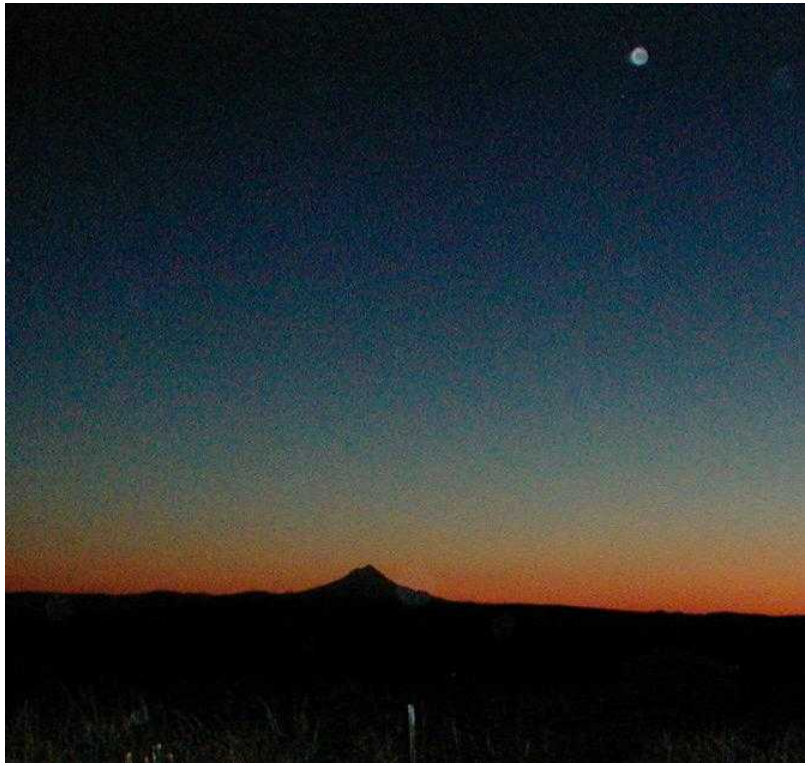
Strike-slip rate will be approximately ωh where h is the N-S spacing of faults and ω the rotation rate.

For h =40 km and v = 5 mm/yr, $\omega \approx 13$ nanoradians/yr, slightly less than 1 deg/Myr.


10 mm/yr
KING
NoVI
SoVI
EXPL
PACI
JDFA
OLYM
BP
PTHY
BCOV
ELIZ
WSLR
CHWK
2.7
3.4
2.8
2.9
14.8
17.2
20.2
28.9
45.5
3.2
1.2
1.1
1.0
0.9
3.3
Residuals
10 mm/yr
PTH
HOLB
NTKA
NEAH
UCLU
Port Alberni Net
231û
232û
233û
234û
235û
52û
51û
50û
49û
48û
230û
231û
232û
233û
234û
235û
236û
237û
238û

Summary

- Oregon, including volcanic arc, rotates clockwise as nearly rigid block relative to North America
- About 1 mm/yr extension at volcanic arc is possible, but no significant strike-slip
- Westward motion of Oregon probably driven by opening of the Basin and Range
- Long-term shortening rate near Seattle is 4 to 5 mm/yr
- Vancouver Island moving 2 to 3 mm/yr to NNE.



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