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Managing Water in the West

Considerations for downdip extent of a Cascadia megathrust event

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Outline

- Want to estimate downdip extent of thrust zone earthquakes that will produce damaging ground motions.

- Evidence from seismicity vis a vis geodetic/thermal modeling.

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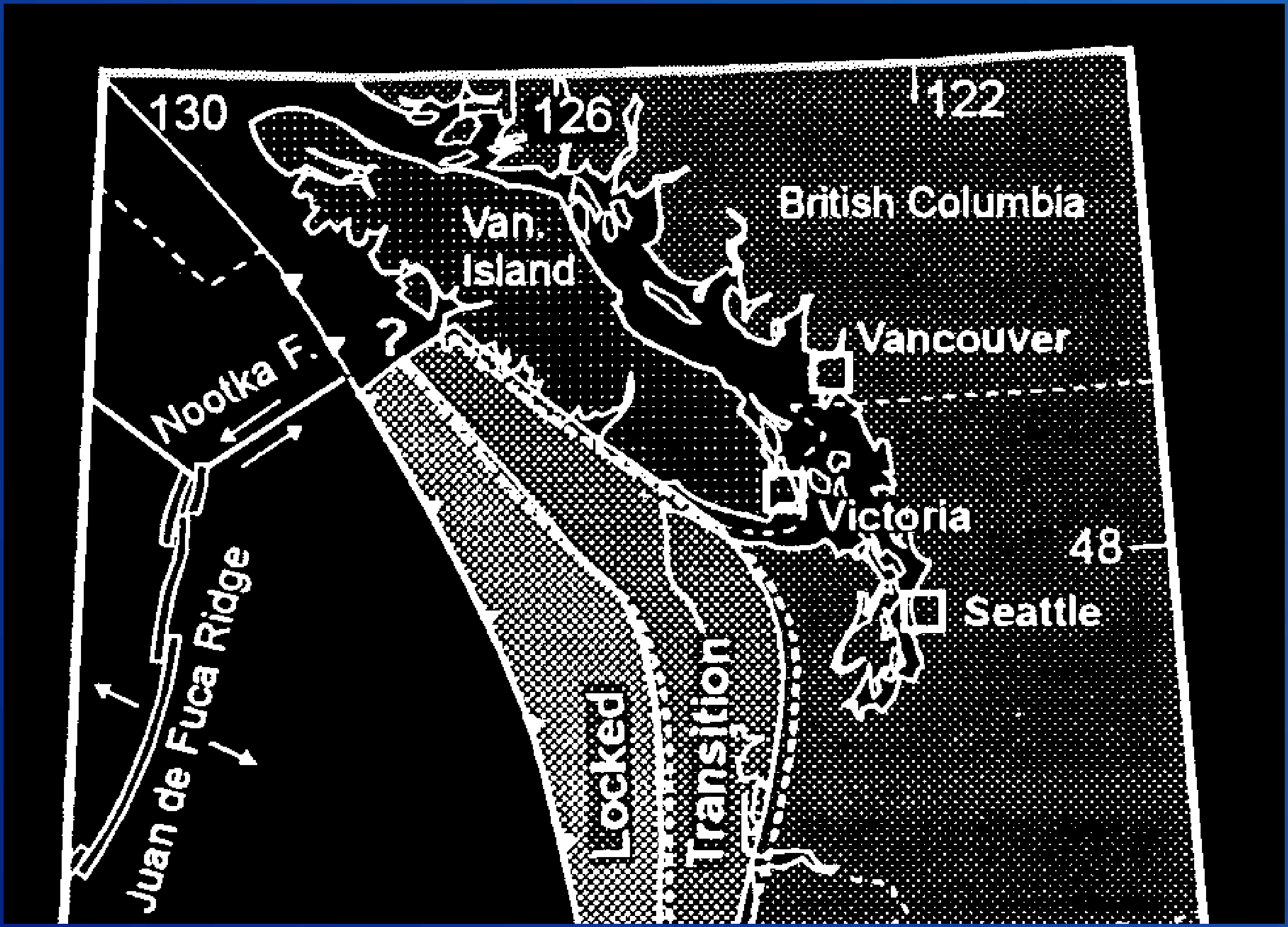
Fluck et al. (1997) Model



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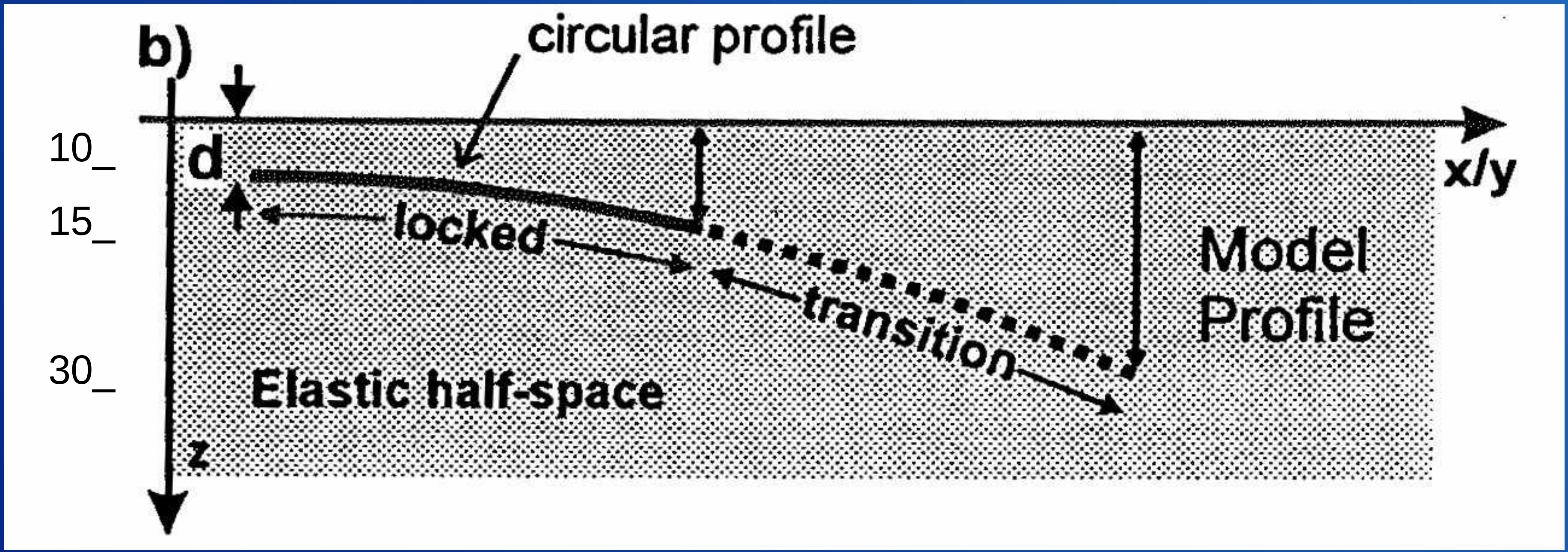
Fluck et al. (1997) Model



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- Hyndman, Wang, et al. (1995) use independent geodetic/tsunumi inversion from 1946 Nankaido event to compare thermal modeling-derived locations of “locked” and “transition” zones, and claim that most/some of transition zone does not produce seismic radiation.

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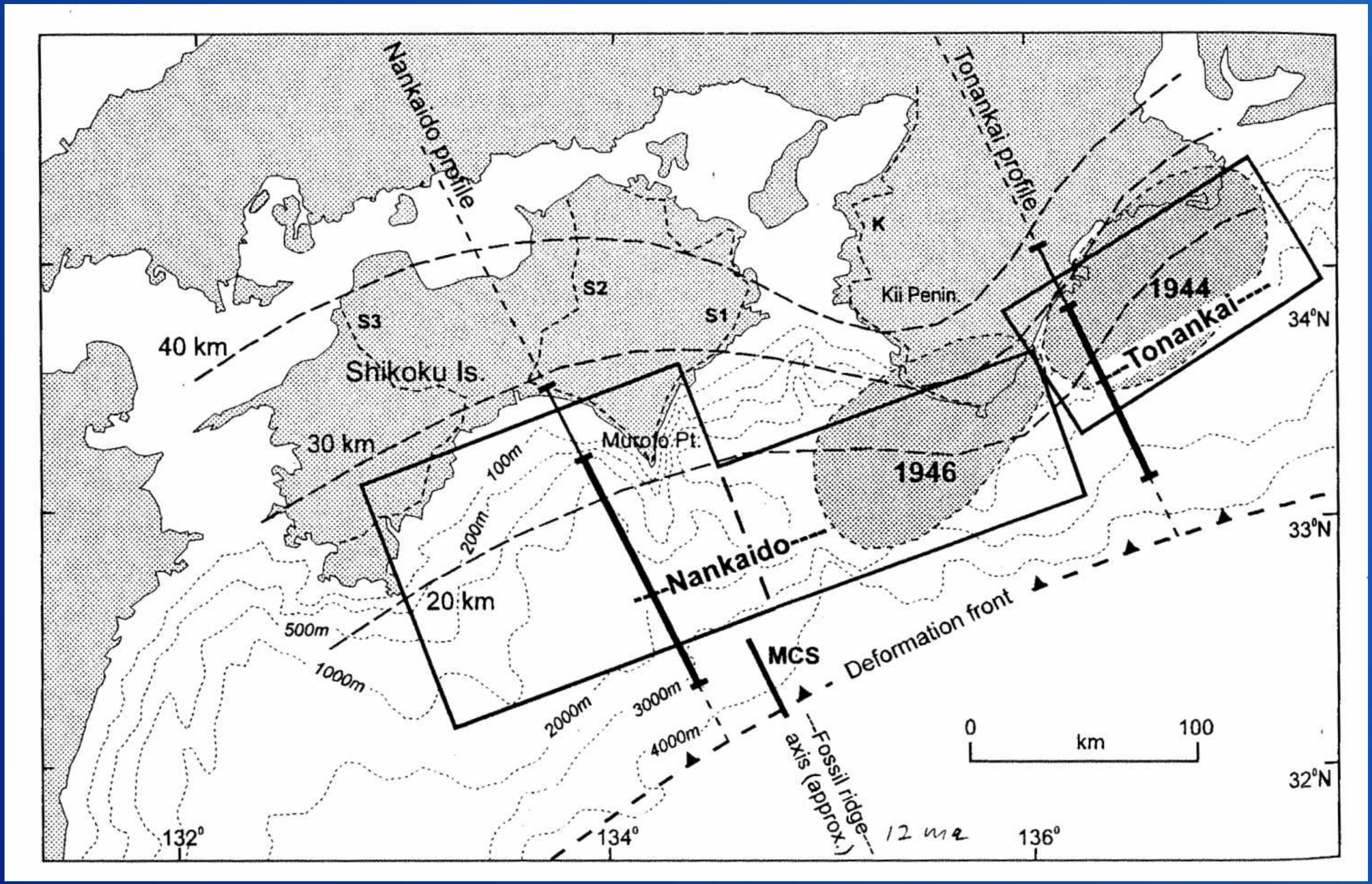
Hyndman et al. (1995)



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SATAKE: DEPTH DISTRIBUTION OF COSEISMIC SLIP ALONG NANKAI TROUGH

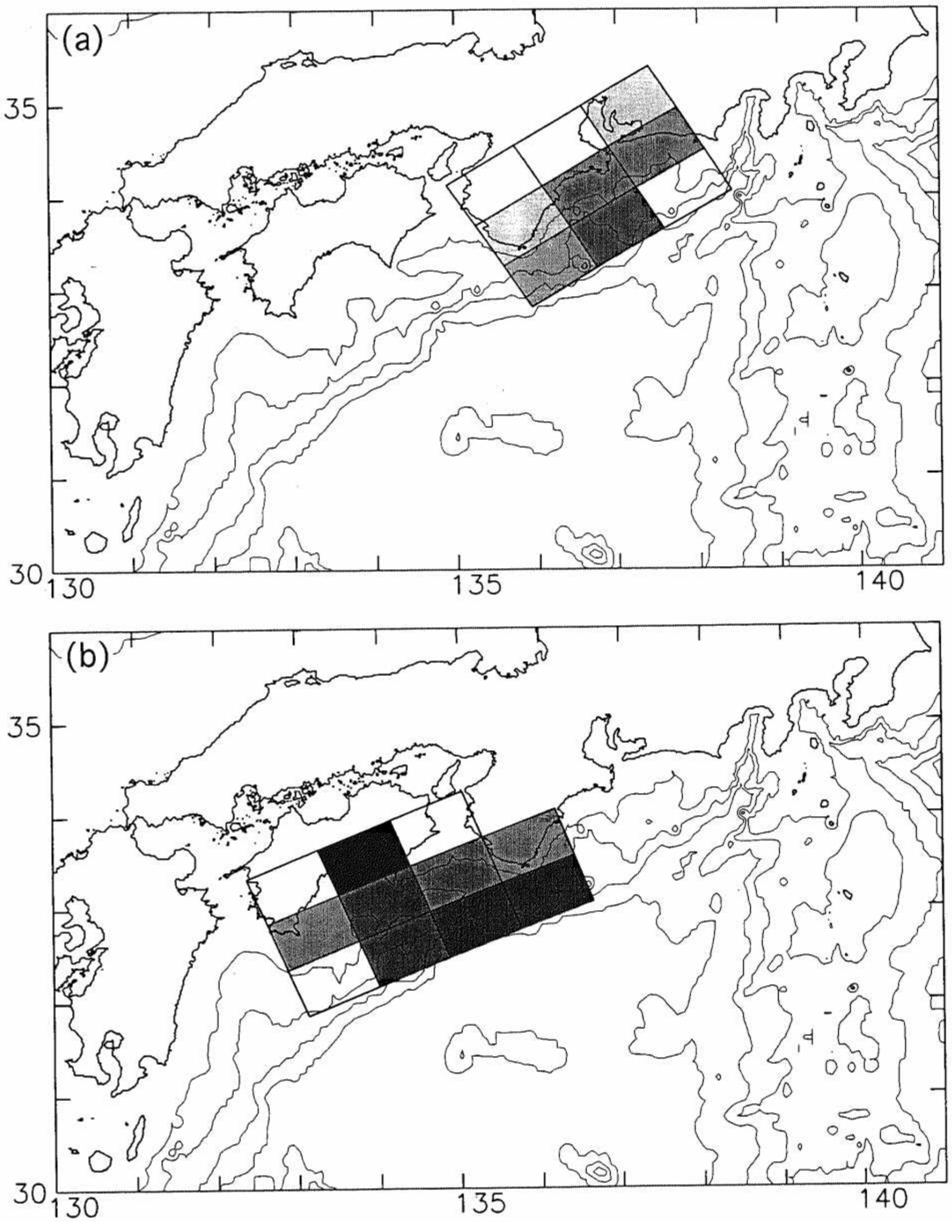

Fig. 12. (*a*) The slip distribution of each subfault for the 1944 Tonankai earthquake superimposed on bathymetry map. (*b*) The same map for the 1946 Nankaido earthquake. The darker the shade, the larger the slip. The shading scale is common for the both events.

Satake (1993)

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Tsunami and Geodetic Data

1946 Nankaido

35

0.48 +/- 0.13	2.41 +/- 0.11	-0.46 +/- 0.15	
1.35 +/- 0.17	1.77 +/- 0.17	1.47 +/- 0.18	1.31 +/- 0.21
0.01 +/- 0.16	1.74 +/- 0.38	1.95 +/- 0.27	2.01 +/- 0.27

25
15
5

1944 Tonankai

50

-0.74 +/- 0.15	0.29 +/- 0.12	0.62 +/- 0.14
0.66 +/- 0.15	1.54 +/- 0.18	1.49 +/- 0.15
1.15 +/- 0.20	1.63 +/- 0.22	0.19 +/- 0.14

35
20
5

Satake (1993)

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Yabuki and Matsu'ura (1993)

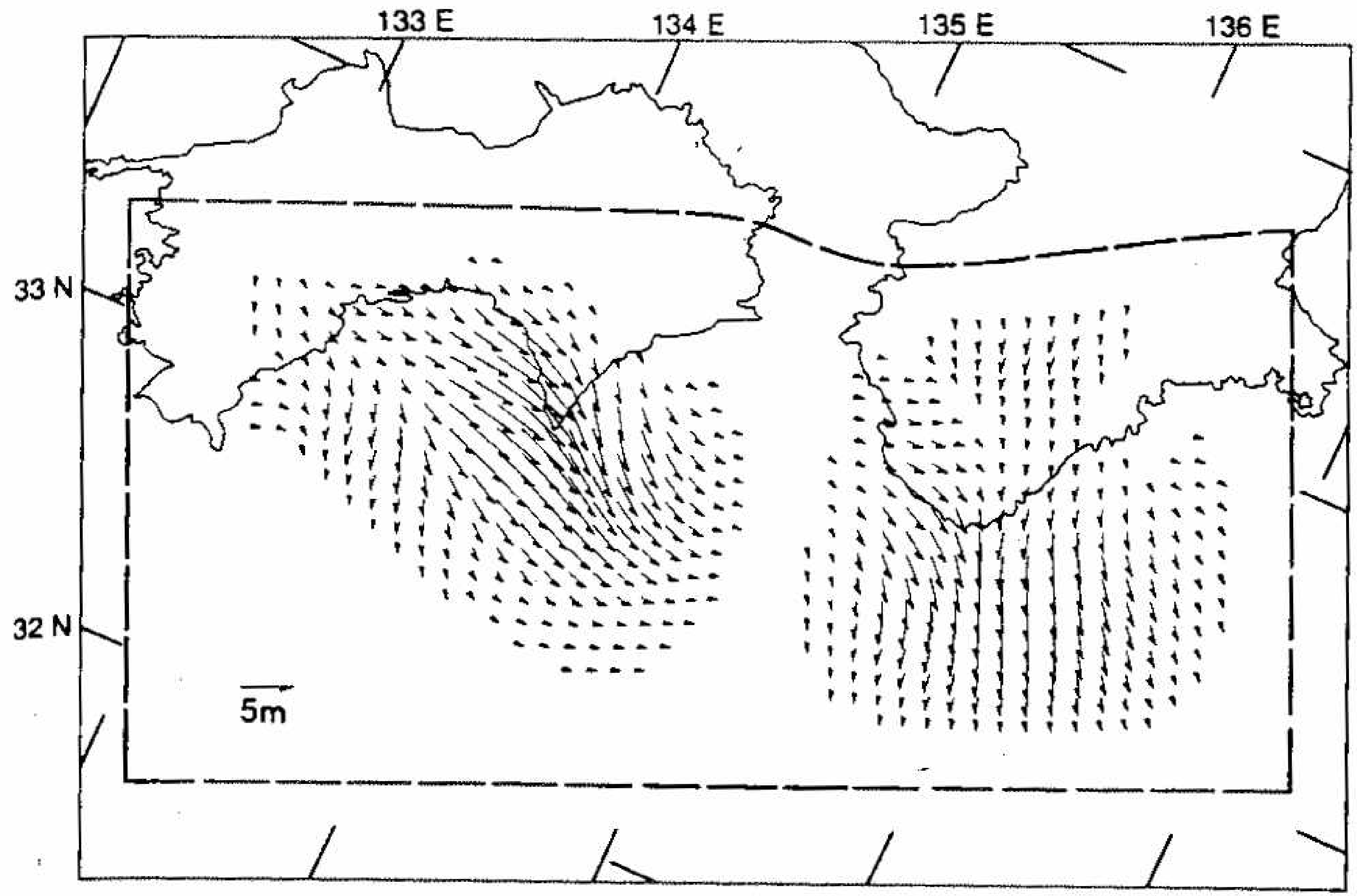
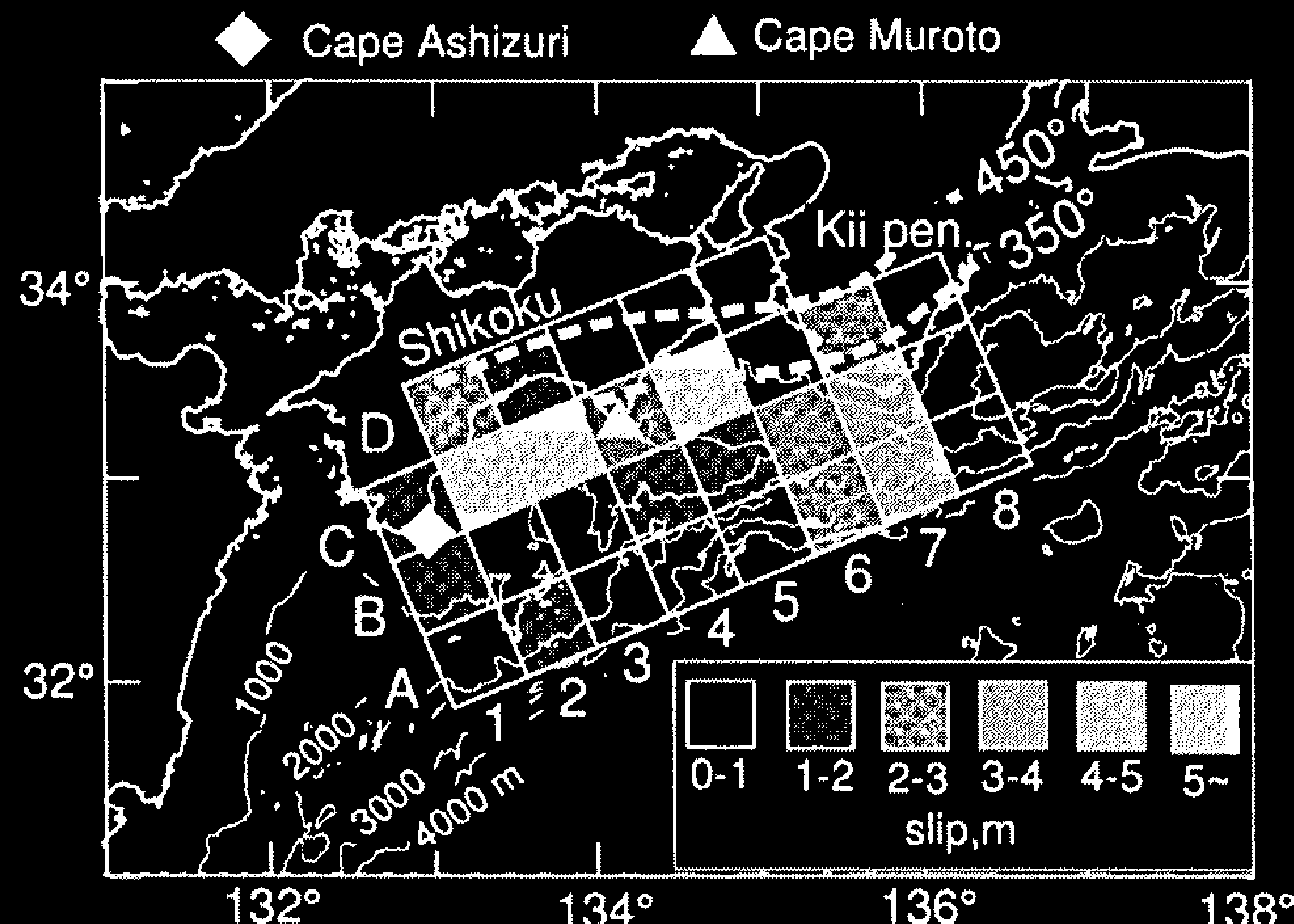


Figure 13. The distribution of slip vectors inverted from the observed surface displacement data. The area enclosed by the broken lines indicates the model fault region.

Y. TANIOKA AND K. SATAKE: THE 1946 NANKAI EARTHQUAKE



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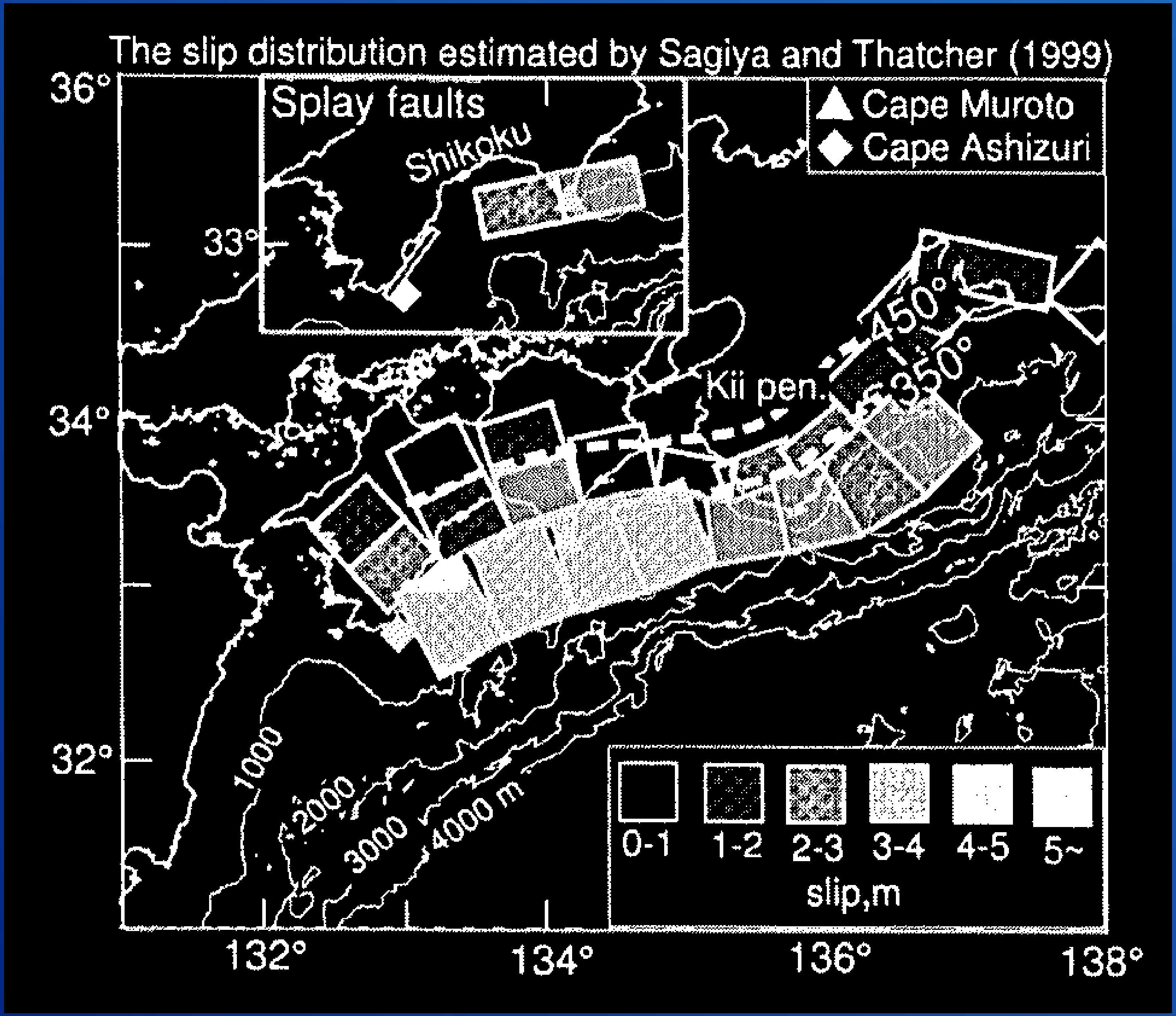

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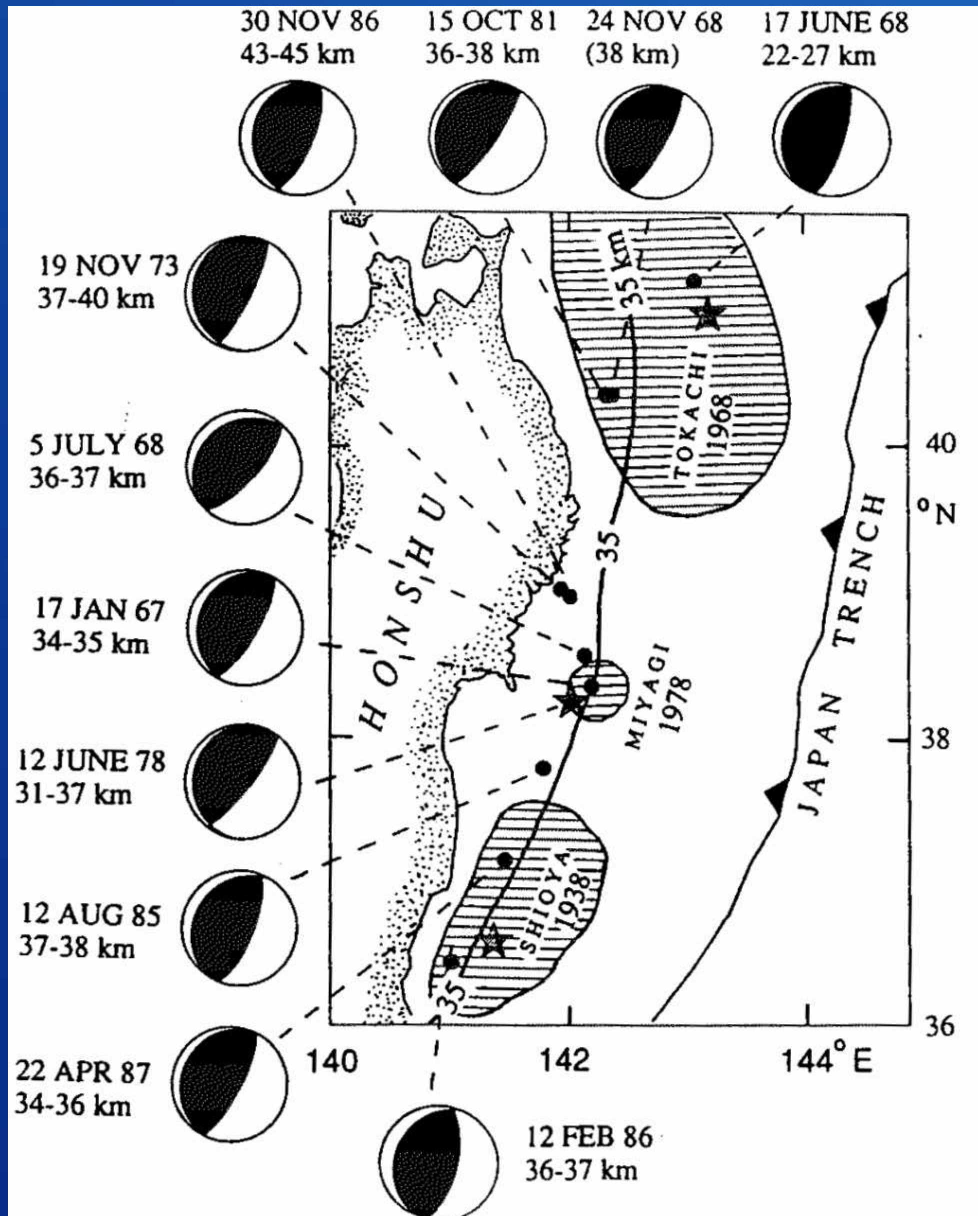
Seismological Evidence

Tichelaar & Ruff (1993) -
Used body wave inversion to find downdip limit to thrust zone (good depth resolution)

Dislocation modeling of large events with geodetic and tsunami data (Nankaido, Alaska, Sumatra)

Microseismic data (good correlation with the above)



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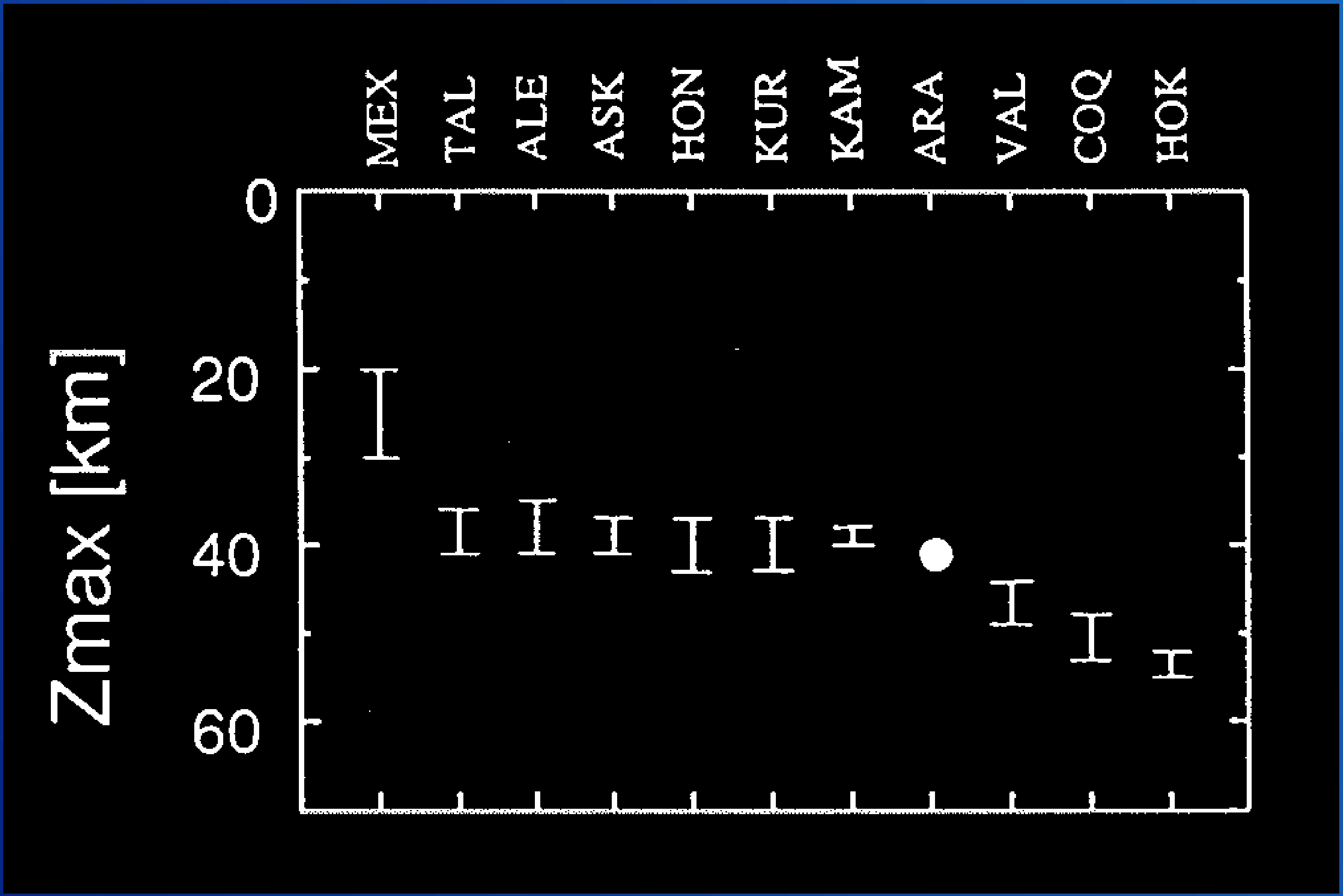

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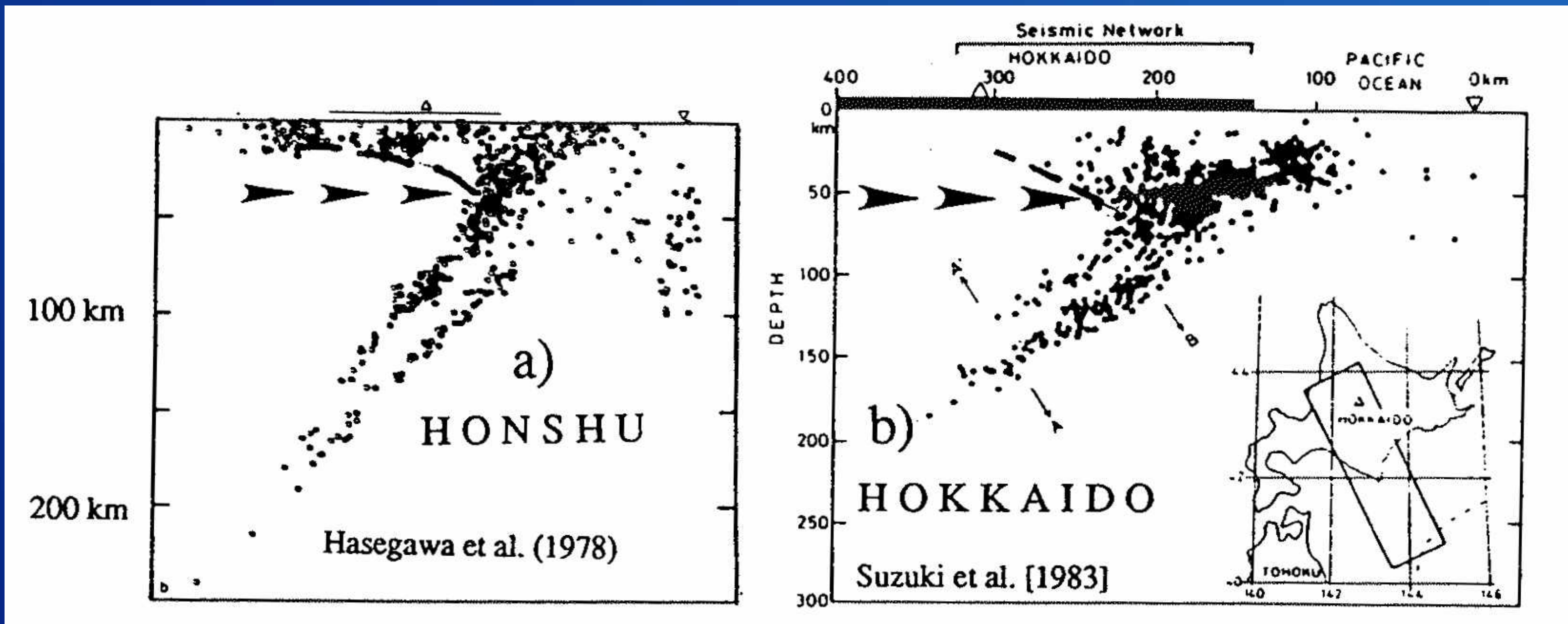

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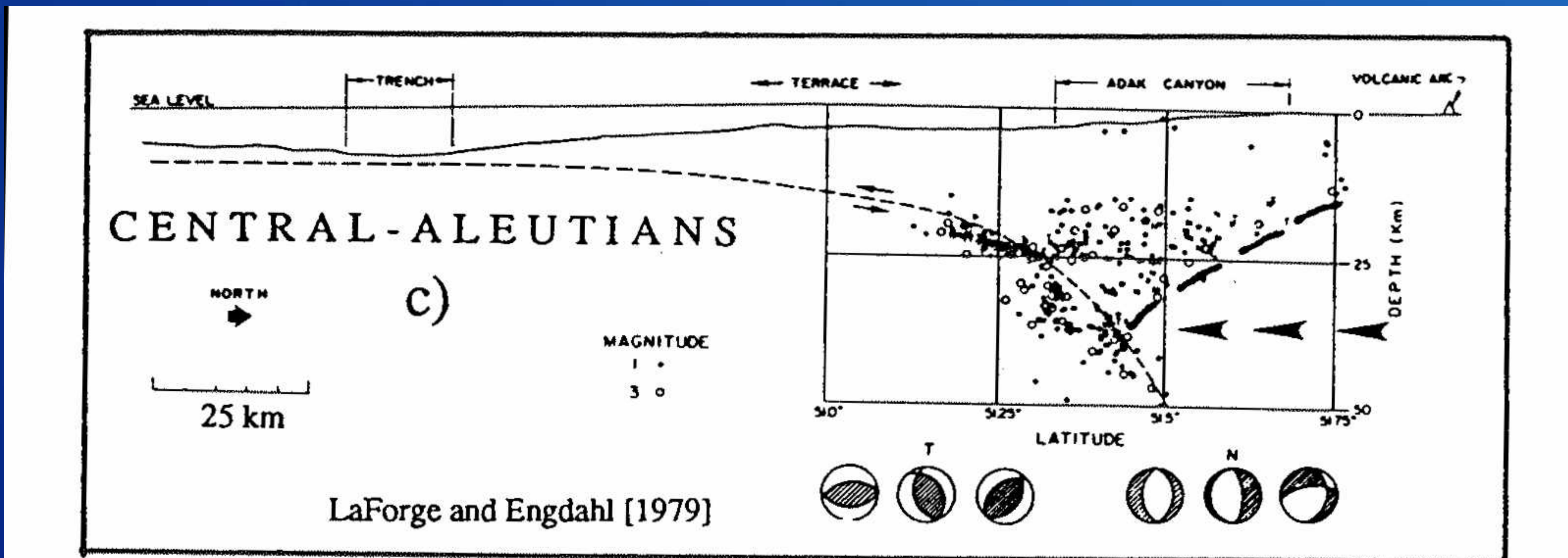

LaForge and Engdahl [1979]

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1986 M8 Aleutians event
Engdahl & Ekstrom (1989)

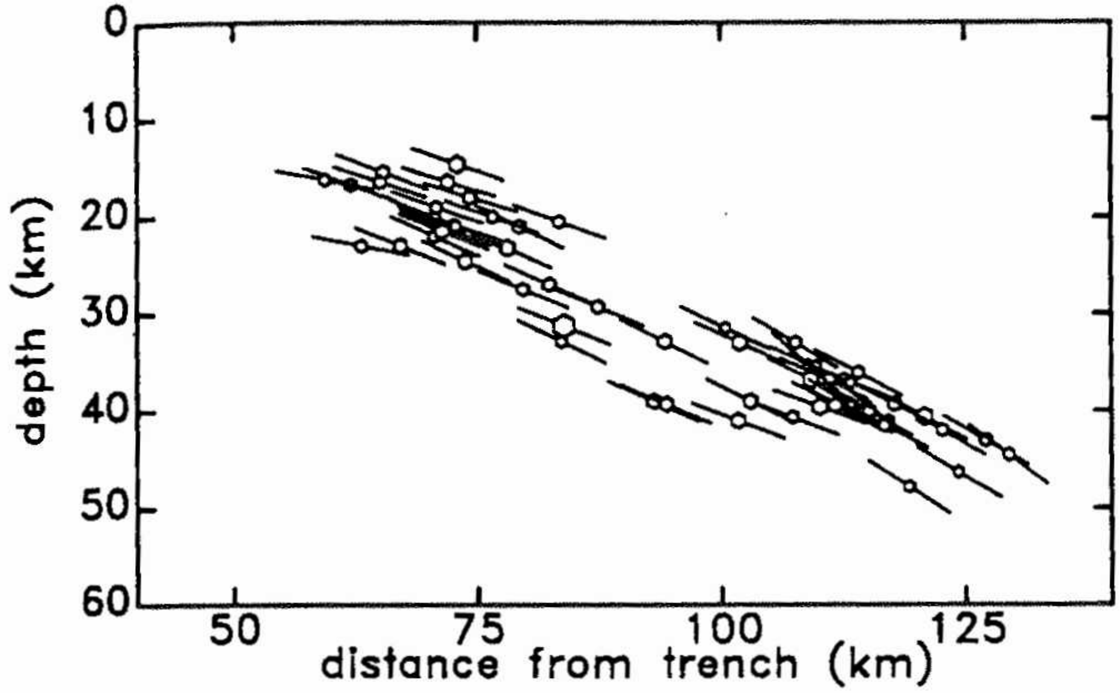
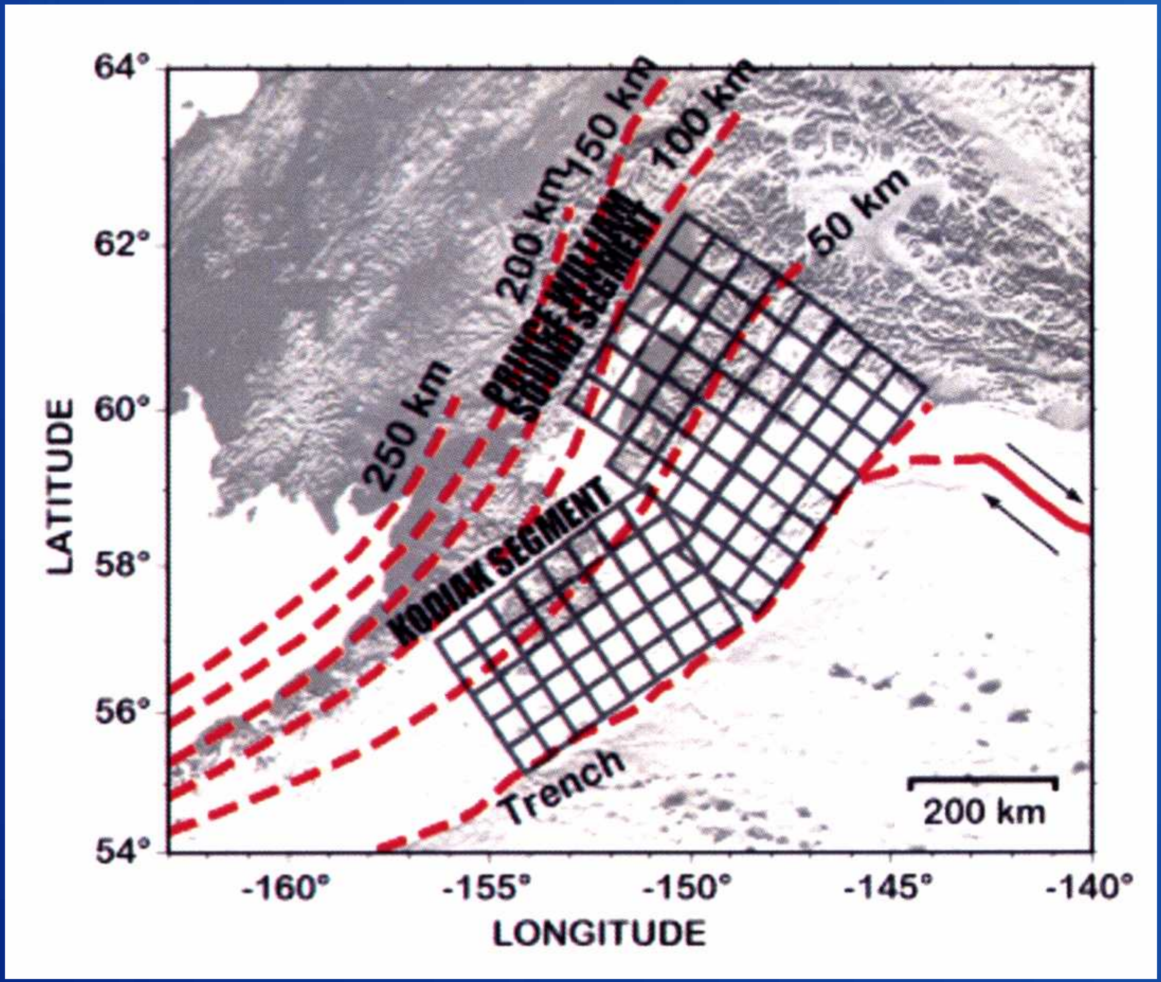


Fig. 5. Cross-sectional view showing the hypocentral locations of the events in the main thrust zone as well as projections of the nodal planes which dip to the North. Events with nonstandard mechanisms were excluded from the plot.

1964 Alaska
Ichinose et al. (2006)



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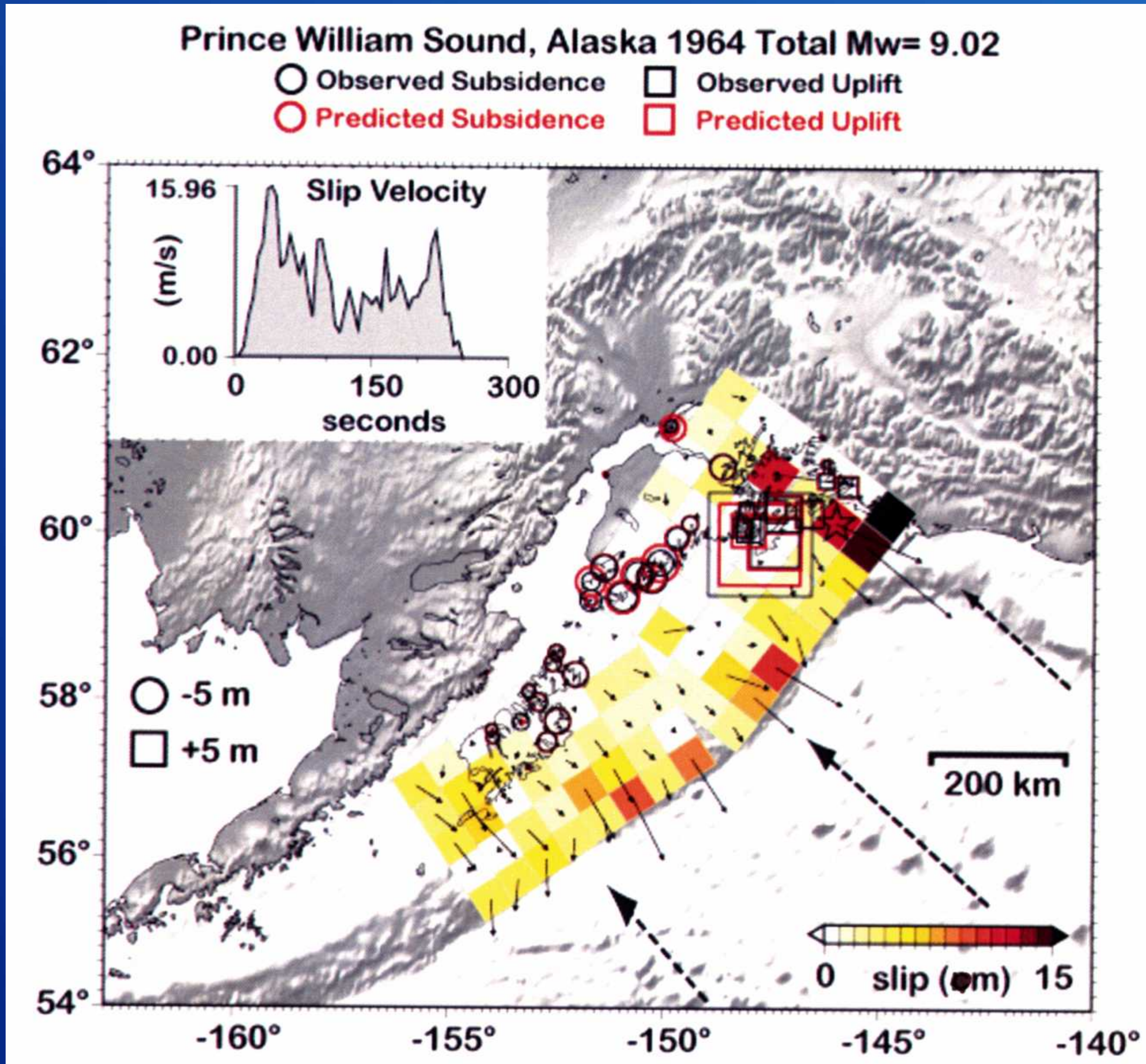

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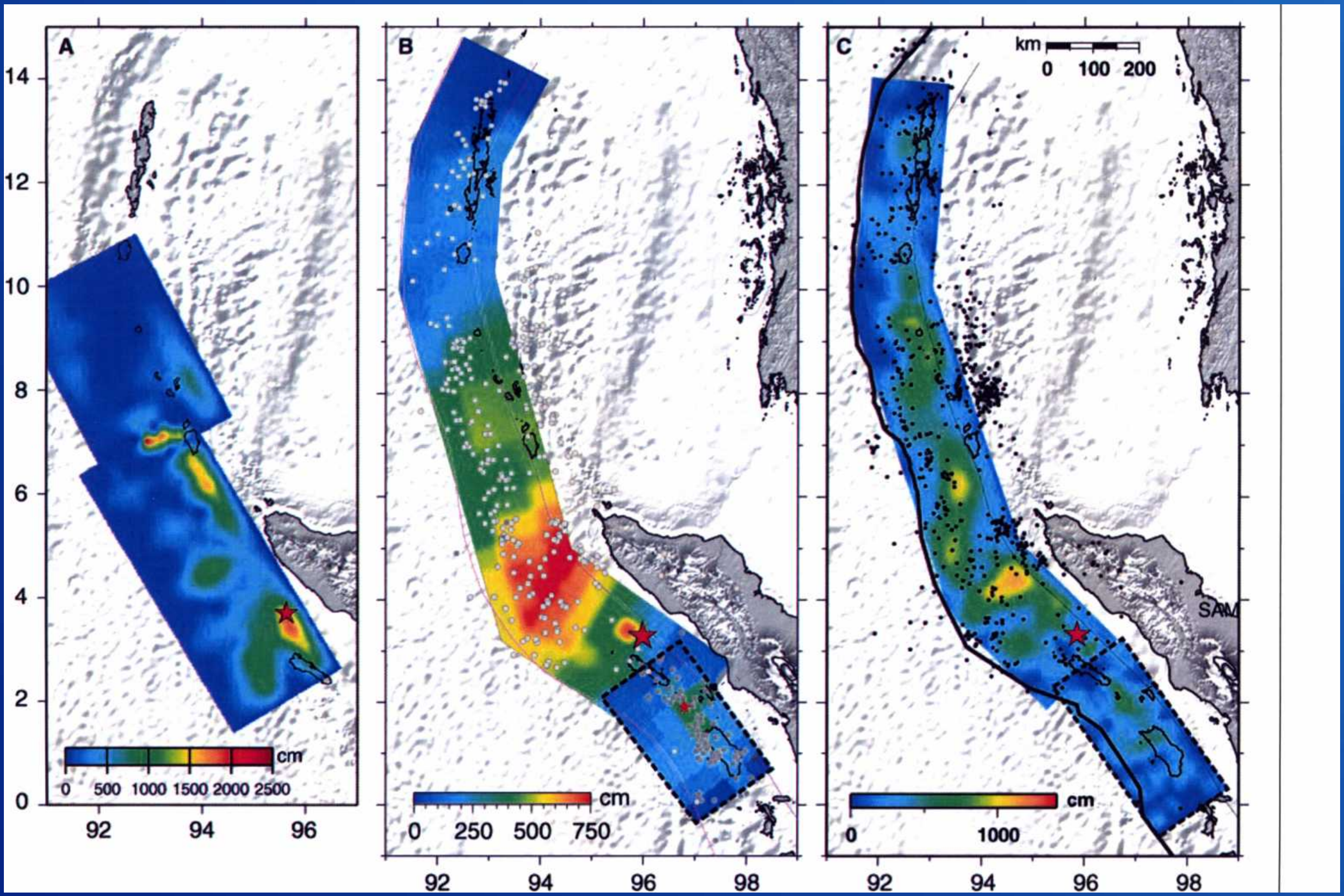
Sumatra 2004



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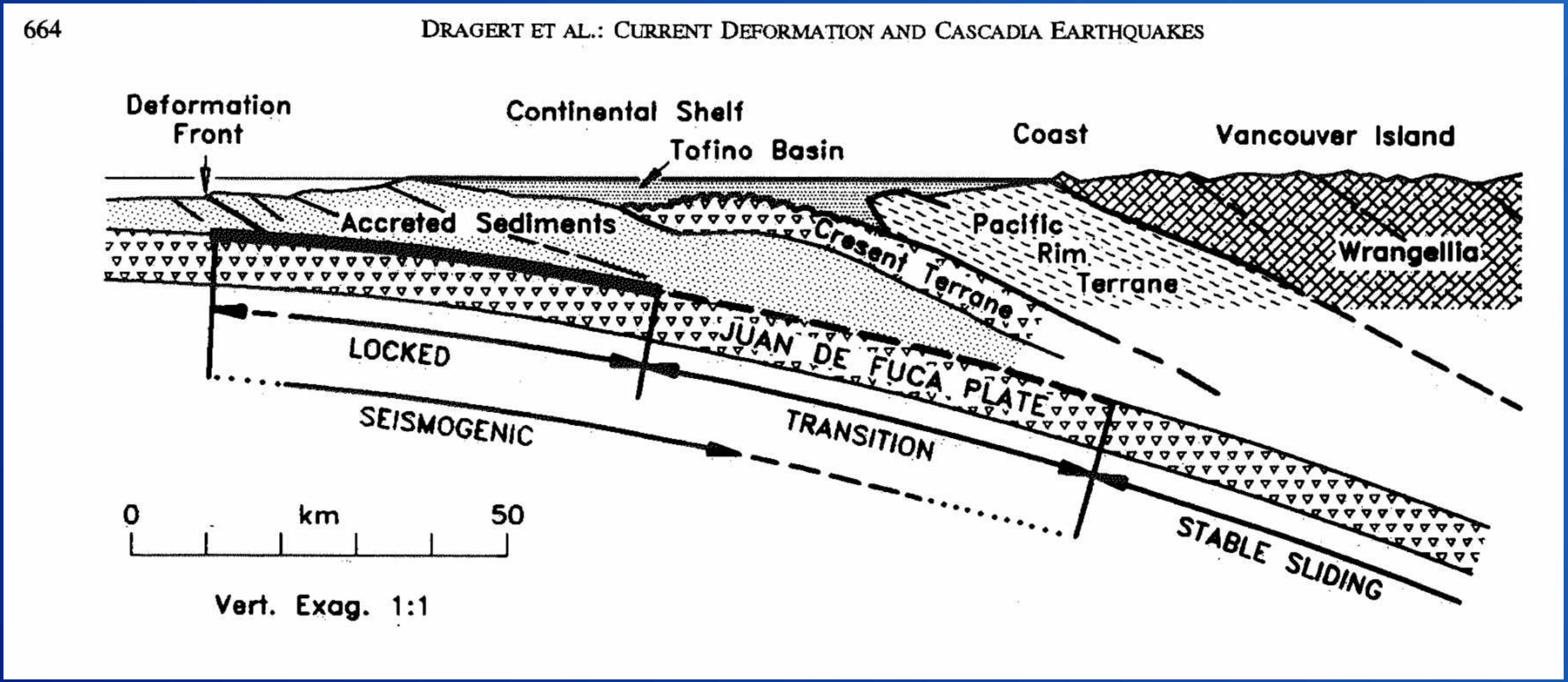
Dragert et al. 1994



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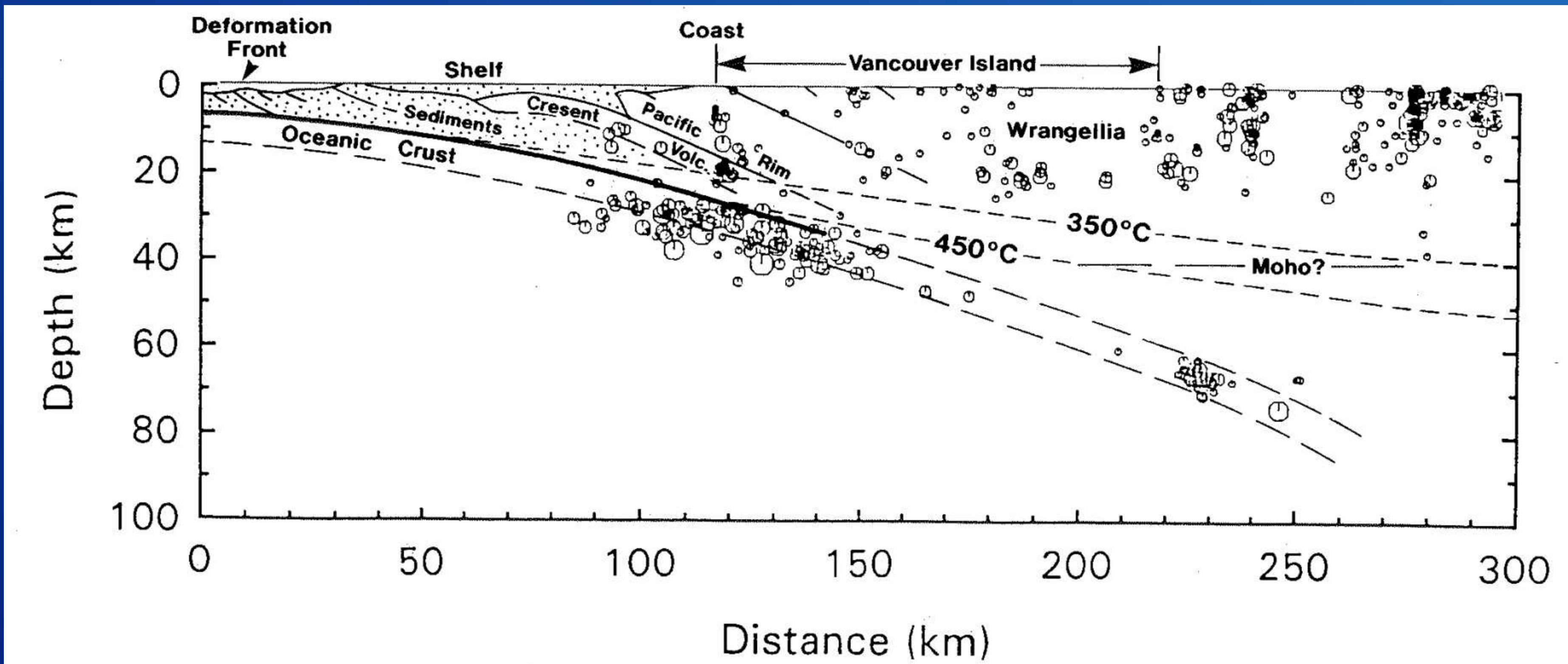

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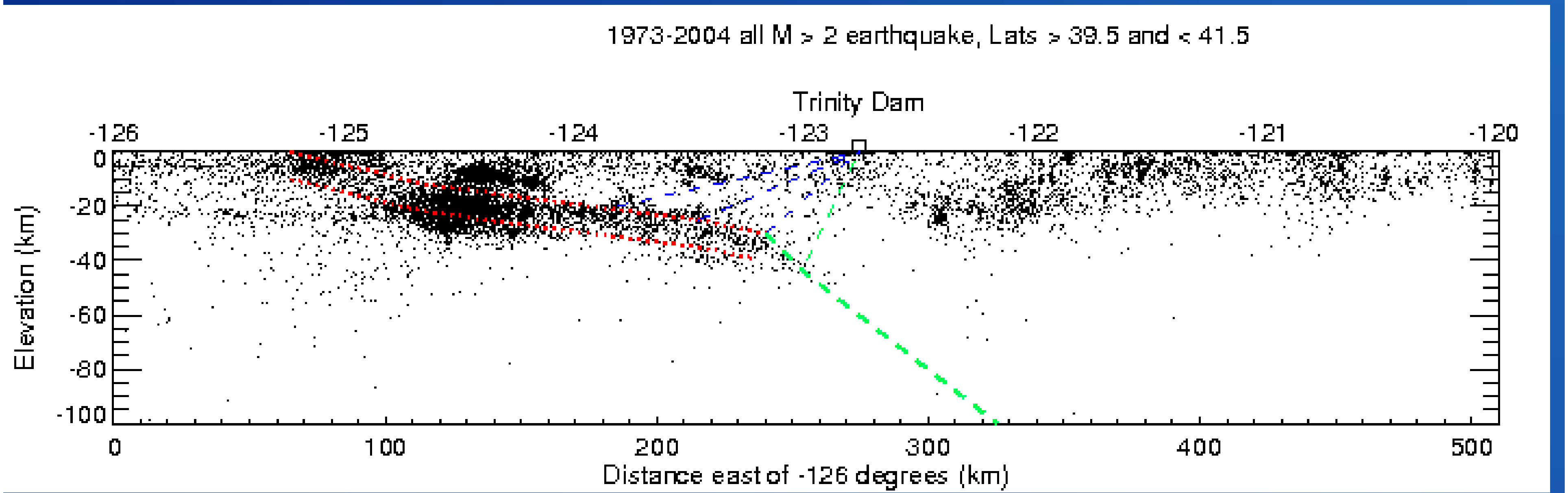
Gorda plate - Mendocino



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Correspondence of Episodic Slip and Tremor with Downdip Edge of Coseismic Slip

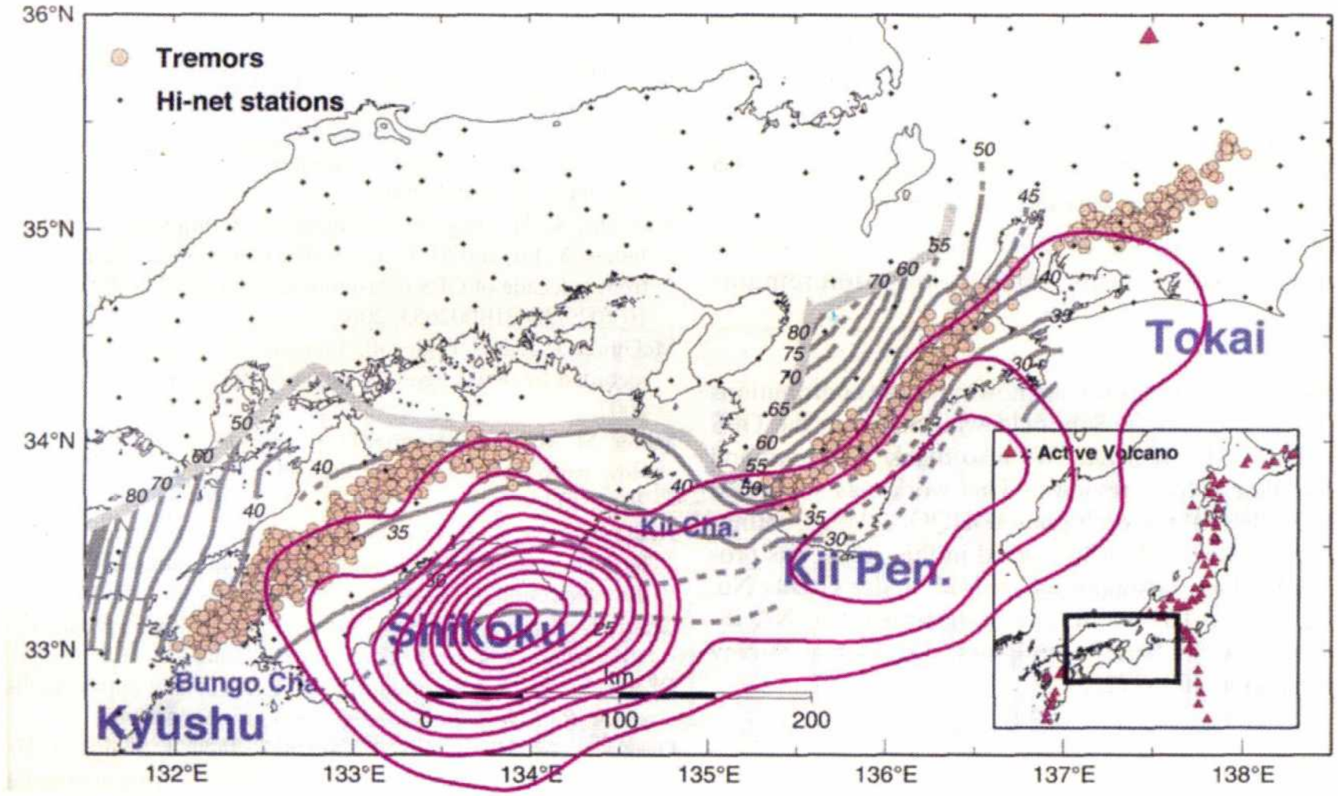

Fig. 9. Map of location of tremors and contours of coseismic slip for southern Japan. The coseismic slip distribution estimates (contours are 1 m; outer contour is the 1 m contour) derived by Sagiya and Thatcher (1999) for the Tonankai and Nankaido earthquakes have been overlain on a map of non-volcanic tremors published by Obara (2002). The tremors, having an average depth of 30 km, appear to delineate the downdip extent of coseismic rupture (and possible afterslip) along the strike of the subduction zone.

Conclusions (1)

- Existence of transition zone as a non-seismic radiation producing zone not well corroborated by microseismic data and dislocation inversions of large events.
- Dislocation inversions of geodetic, tsunami observations show significant seismic radiation emanates from within the transition zone, or deeper.

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Conclusions (2)

- Microseismic data show no gradation in seismic moment release along Benioff zone to base of transition zone, implying ~constant seismogenic frictional properties.
- Why can't transition zone produce seismic radiation during large events?
- It is now, for smaller events.
- It apparently has during large events.

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Conclusions (3)

- Based on maximum downdip depths of large events, 15 km would be unusually shallow. Large events typically emit seismic radiation at 30-40+ km. Intersection of crustal seismicity with Benioff zone seismicity corresponds well to these results.
- Cascadia possibly like Mexico (TR93), i.e., 20-30 km .

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Conclusions (4)

- Existence of an aseismic transition zone implies a gap between “locked zone” earthquakes and intraslab earthquakes. This has not been observed.
- Transition zone reflects <u>interseismic</u> behavior. We are concerned with <u>seismic</u> behavior.

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Conclusions (5)

- Use of both locked and transition zones to estimate downdip extent originally recommended by Fluck et al. (1993)……
- Location of Episodic Tremor and Slip events in Japan is consistent with these conclusions.

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Thus we take the downdip width of the locked zone (and the transition zone if one is included), determined from dislocation models of interseismic deformation data, to approximate the maximum downdip rupture width in great earthquakes.

Fluck et al. (1997)

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Wang et al. (2003)

[41] A conservative approach for Cascadia is to assume that full coseismic rupture takes place over the entire locked zone and the slip decreases linearly downdip halfway into the present ETZ. Assuming 500 years of slip deficit (about

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Conclusions (6)

- Detailed look at seismicity in Mendocino region (inversion for location and 3d velocity structure, focal mechanisms) needs to be done.
- Cursory look shows Benioff zone seismicity extends down to 30 km.

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TR93 Caveats on Thermal Modeling

temperature can explain coupling depth. The thermal regime in subduction zones can not be calculated with the same confidence as in other tectonic environments. Temperature estimation depends on the assumptions made about radiogenic heat generation in the overlying lithosphere and the depth dependence of shear stresses on the plate interface. Assuming radiogenic heat generation that exponentially depends on depth, and assuming a constant coefficient of friction, we find a bimodal distribution of temperatures at the maximum depth of the seismically coupled zone: while most subduction zones are uncoupled for temperatures exceeding 400° C, some remain coupled to temperatures of about 550° C. It is possible that the

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TR93 Comments on Thermal Modeling

one, are found. On the other hand, an arbitrary combination of mechanisms ranging from temperature to dehydration reactions could be invoked to explain the observations of coupling depth and its variability.

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TR93

coupling of 20–30 km. Detailed seismicity studies show that micro-earthquakes within the upper plate cease at the same depths at which plate interface coupling ceases. While many

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Recommendations

- Downdip extent for Cascadia should be ~30 km.

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