Subduction zone parameters: Observational constraints on slab dip and the maximum moment earthquake

Carl Tape

Mike Gurnis, Hiroo Kanamori, Mark Simons

March 13, 2007

Thanks to Dietmar Mueller for the updated seafloor age grids.

Two influential papers:

Ruff and Kanamori (1980), “Seismicity and the subduction process” (WOS:166)

Jarrard (1986), “Relations among subduction parameters” (WOS:413)

Basic idea:

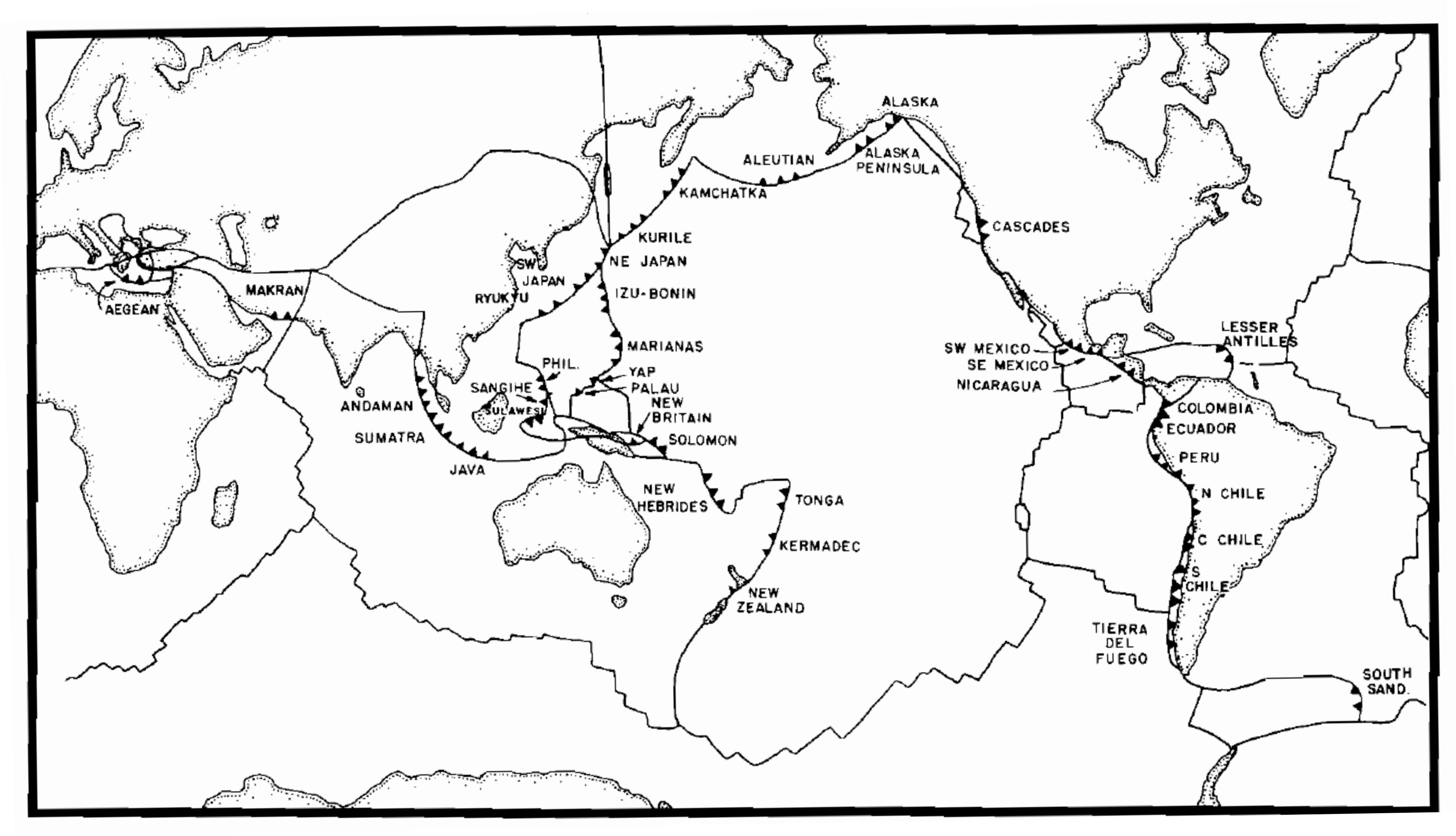
Choose a response variable (e.g., Mw-max or slap dip), choose a set of predictor variables, and determine whether a simple linear combination of predictors can estimate the response.

Why do we care:

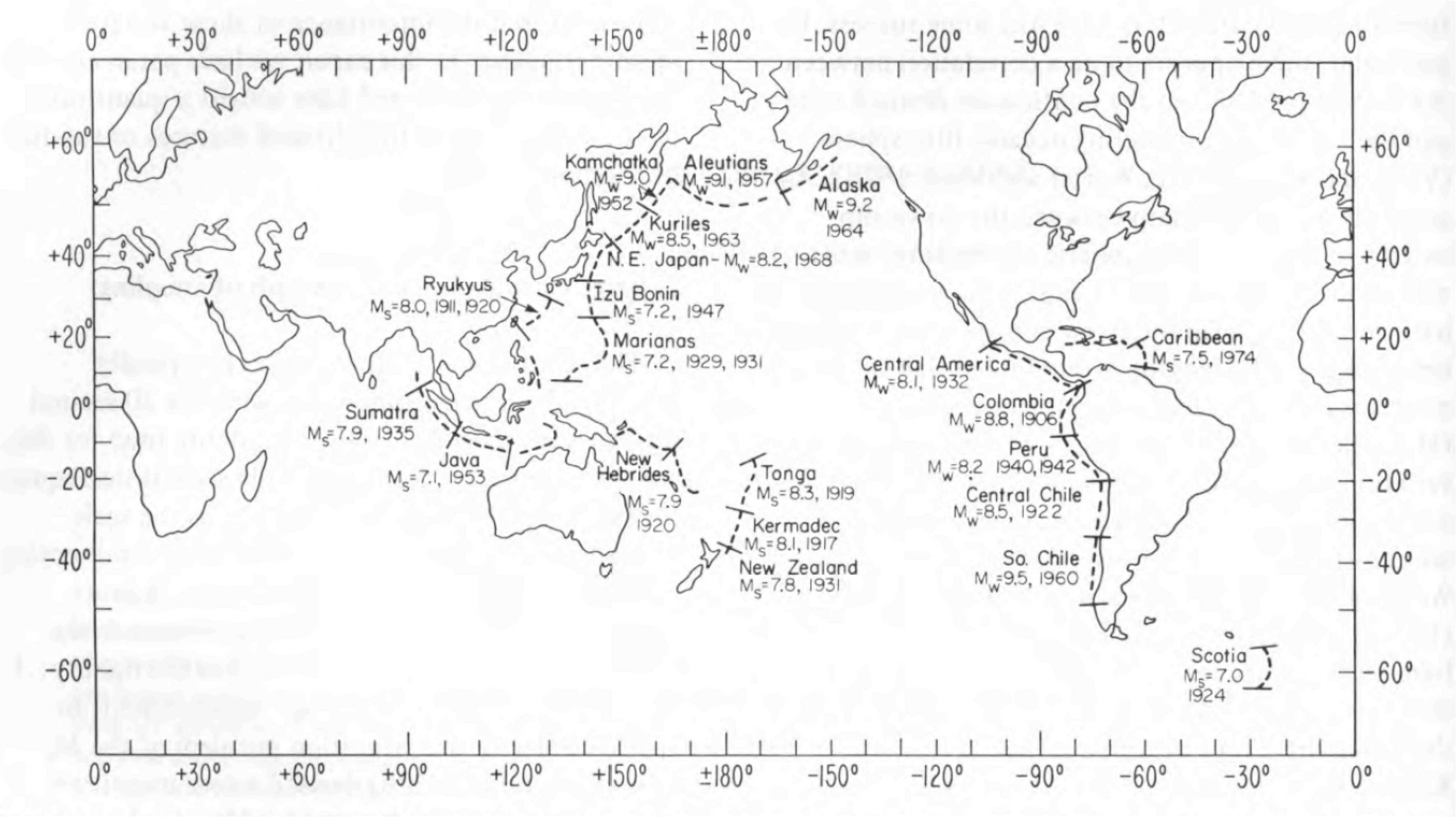
Physical intuition to get at the causal mechanism of a particular observation.

The intuition can guide modeling efforts.

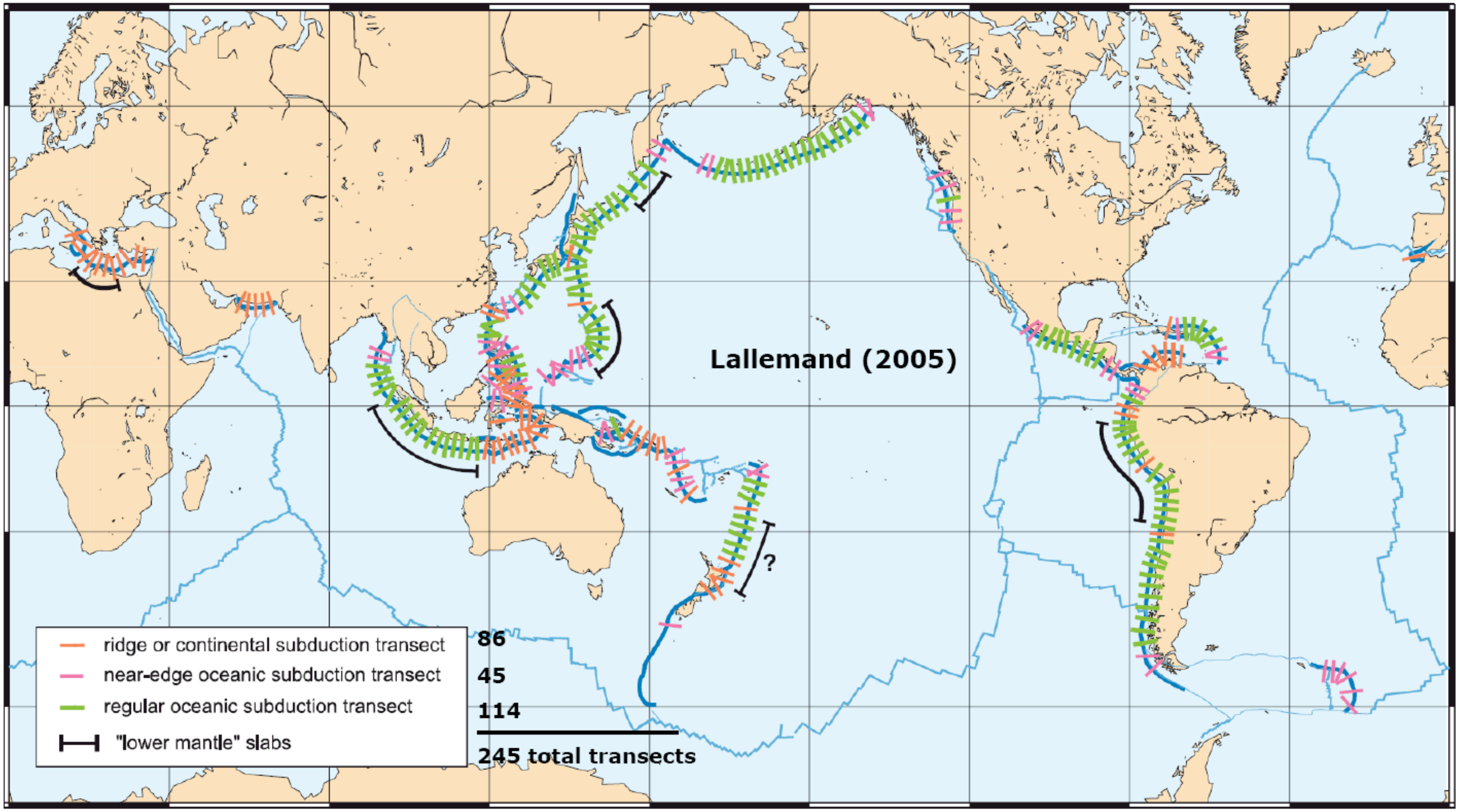
1. Select your subduction zones



Jarrard (1986)



Ruff and Kanamori (1980)


Lallemand (2005)
?
ridge or continental subduction transect 86
near-edge oceanic subduction transect 45
regular oceanic subduction transect 114
"lower mantle" slabs
245 total transects

2. Select a set of observable variables

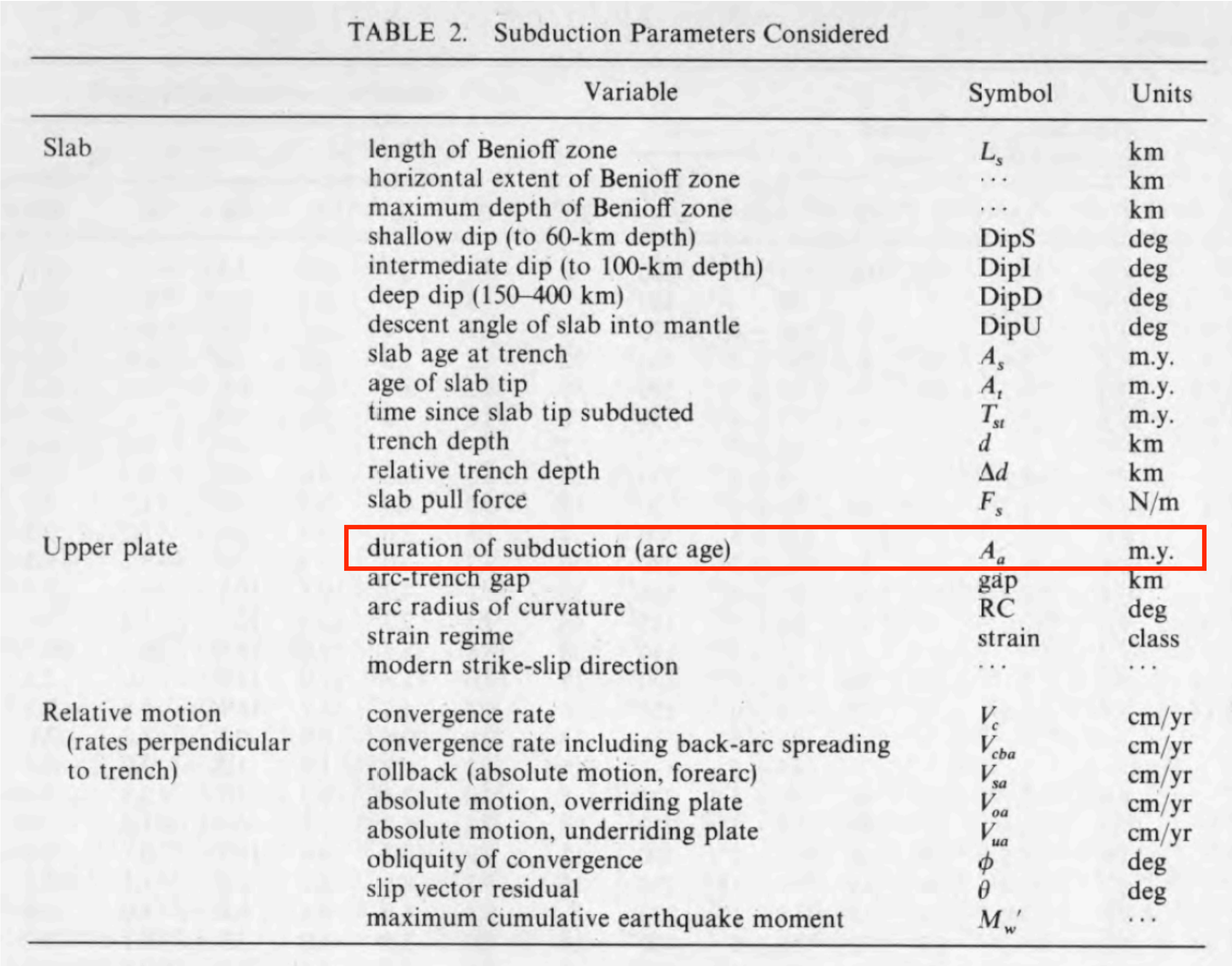


TABLE 2. Subduction Parameters Considered

	Variable	Symbol	Units
Slab	length of Benioff zone	L_s	km
	horizontal extent of Benioff zone	...	km
	maximum depth of Benioff zone	...	km
	shallow dip (to 60-km depth)	DipS	deg
	intermediate dip (to 100-km depth)	DipI	deg
	deep dip (150–400 km)	DipD	deg
	descent angle of slab into mantle	DipU	deg
	slab age at trench	A_s	m.y.
	age of slab tip	A_t	m.y.
	time since slab tip subducted	T_{st}	m.y.
	trench depth	d	km
	relative trench depth	Δd	km
	slab pull force	F_s	N/m
Upper plate	duration of subduction (arc age)	A_a	m.y.
	arc-trench gap	gap	km
	arc radius of curvature	RC	deg
	strain regime	strain	class
	modern strike-slip direction	...	...
Relative motion (rates perpendicular to trench)	convergence rate	V_c	cm/yr
	convergence rate including back-arc spreading	V_{cba}	cm/yr
	rollback (absolute motion, forearc)	V_{sa}	cm/yr
	absolute motion, overriding plate	V_{oa}	cm/yr
	absolute motion, underriding plate	V_{ua}	cm/yr
	obliquity of convergence	ϕ	deg
	slip vector residual	θ	deg
	maximum cumulative earthquake moment	M_w'	...

Jarrard (1986)

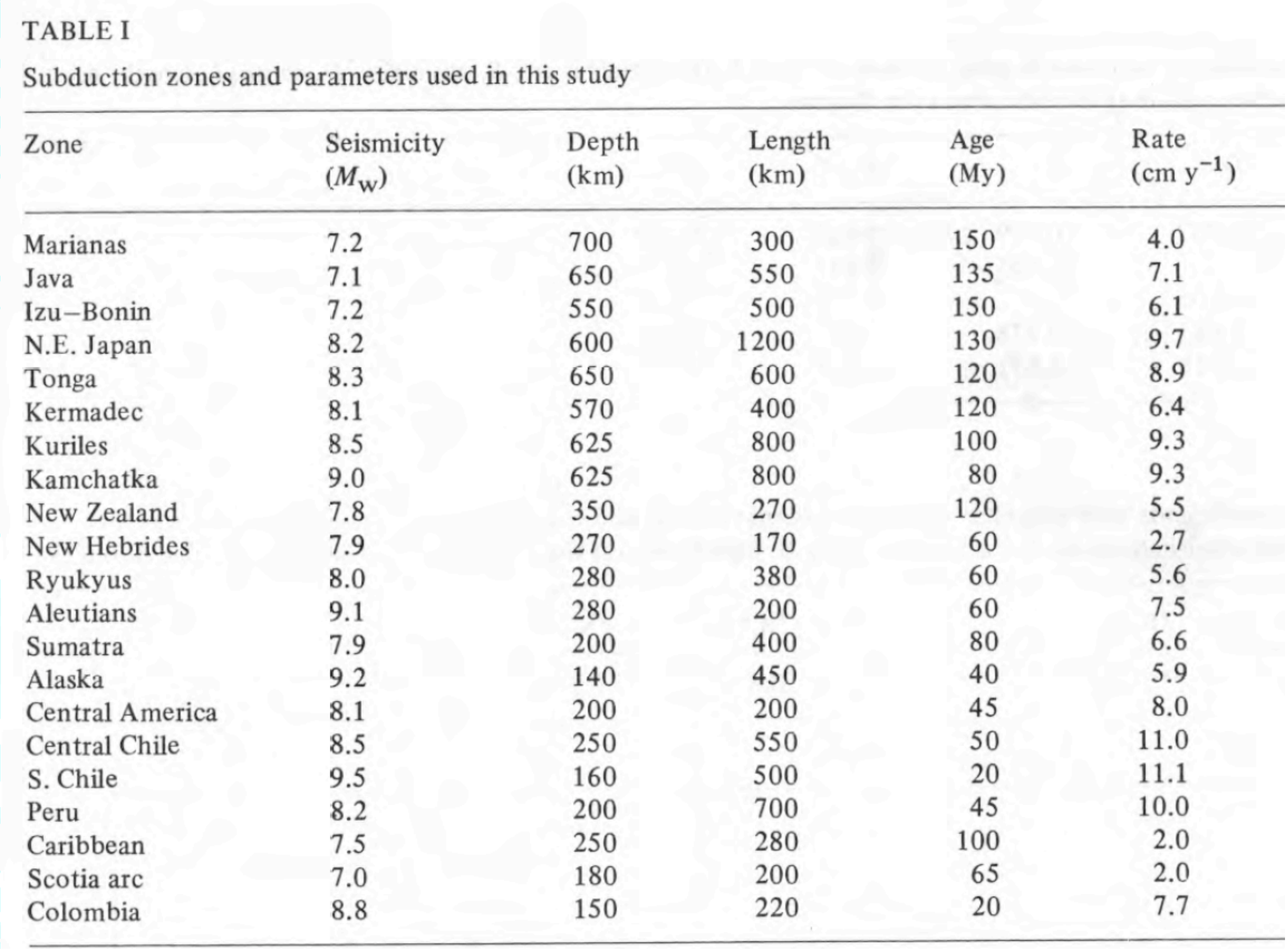


TABLE I

Subduction zones and parameters used in this study

Zone	Seismicity (M_W)	Depth (km)	Length (km)	Age (My)	Rate (cm y^{-1})
Marianas	7.2	700	300	150	4.0
Java	7.1	650	550	135	7.1
Izu–Bonin	7.2	550	500	150	6.1
N.E. Japan	8.2	600	1200	130	9.7
Tonga	8.3	650	600	120	8.9
Kermadec	8.1	570	400	120	6.4
Kuriles	8.5	625	800	100	9.3
Kamchatka	9.0	625	800	80	9.3
New Zealand	7.8	350	270	120	5.5
New Hebrides	7.9	270	170	60	2.7
Ryukyus	8.0	280	380	60	5.6
Aleutians	9.1	280	200	60	7.5
Sumatra	7.9	200	400	80	6.6
Alaska	9.2	140	450	40	5.9
Central America	8.1	200	200	45	8.0
Central Chile	8.5	250	550	50	11.0
S. Chile	9.5	160	500	20	11.1
Peru	8.2	200	700	45	10.0
Caribbean	7.5	250	280	100	2.0
Scotia arc	7.0	180	200	65	2.0
Colombia	8.8	150	220	20	7.7

Ruff and Kanamori (1980)

3. Make some scatterplots

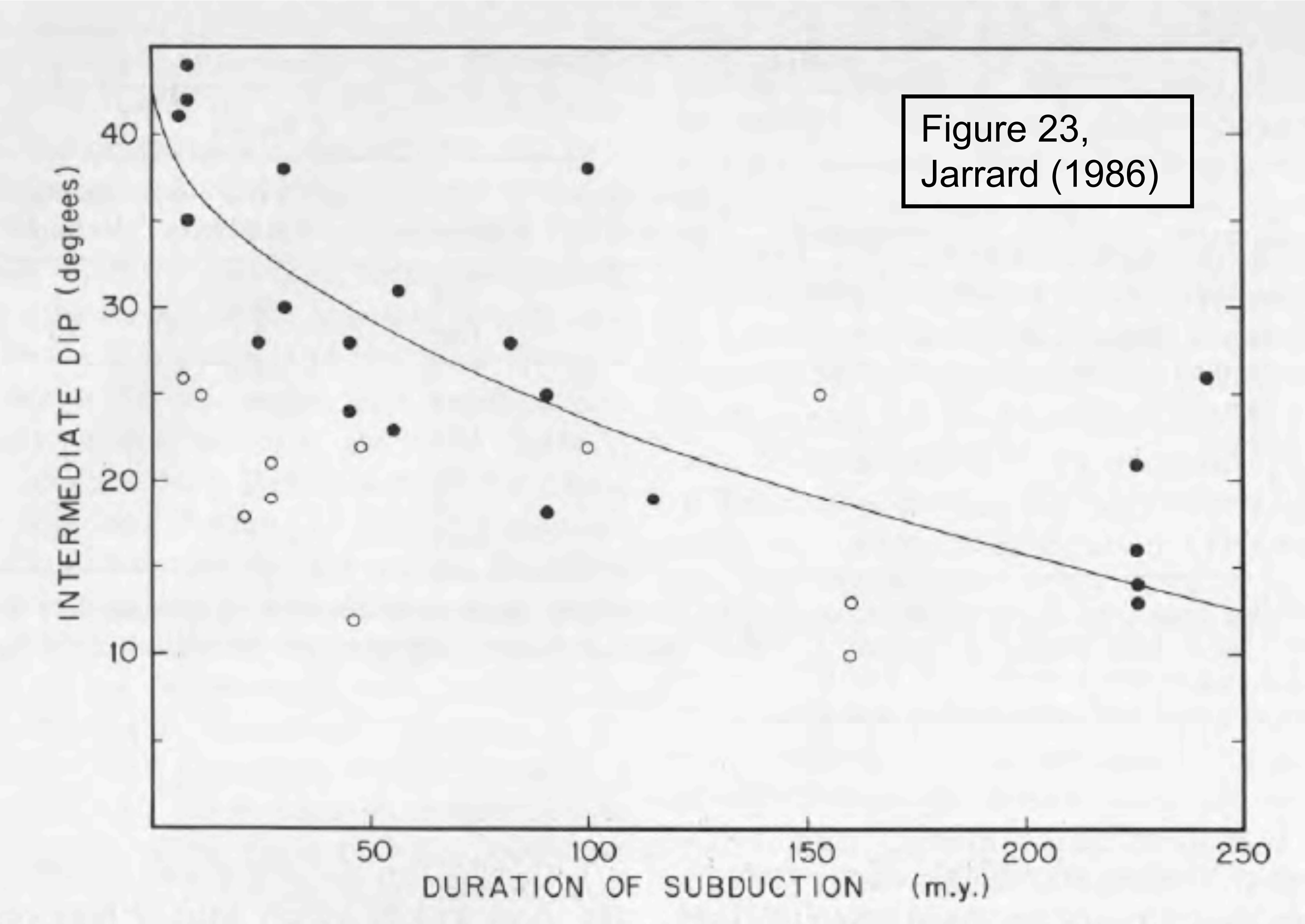
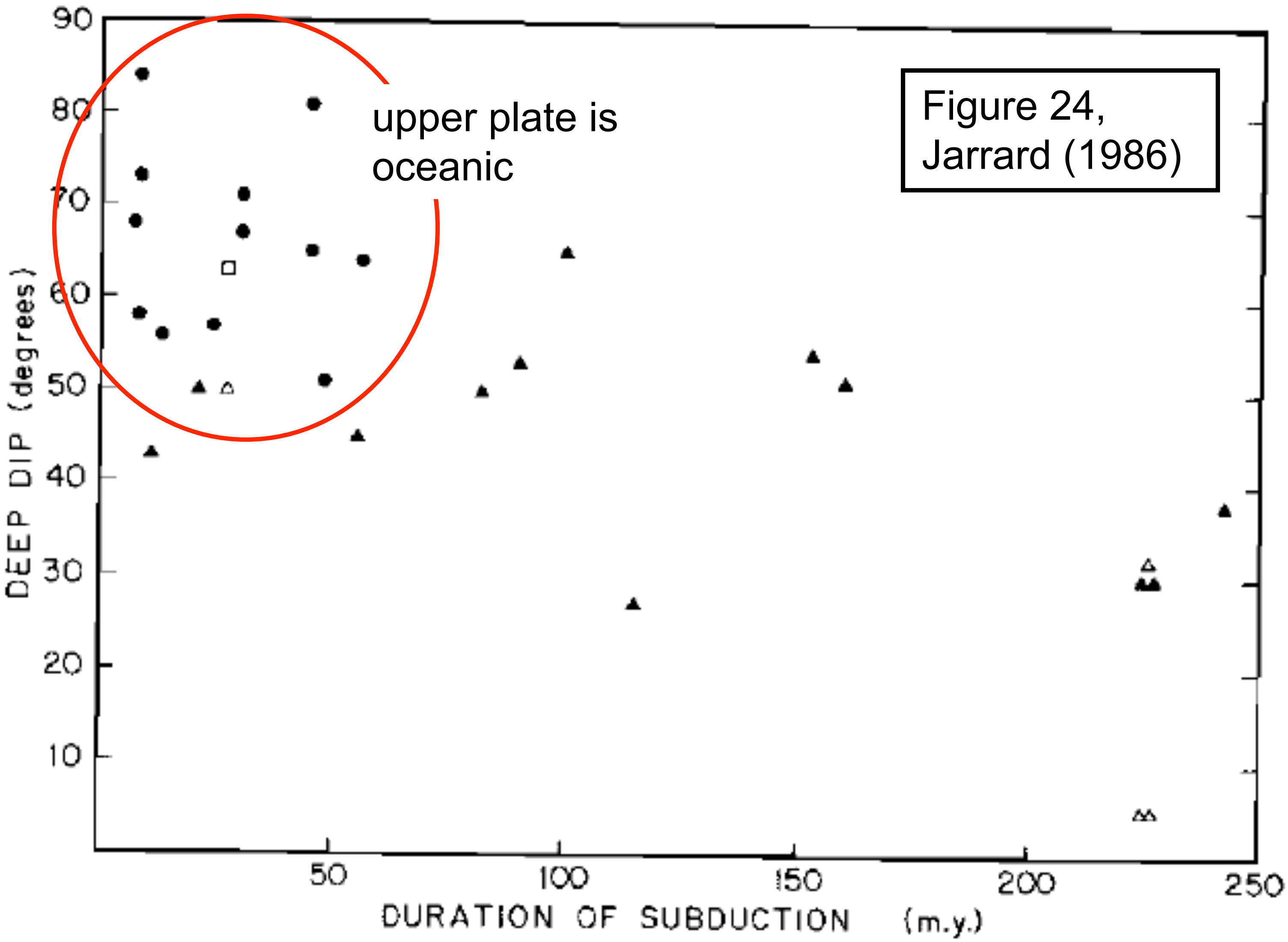
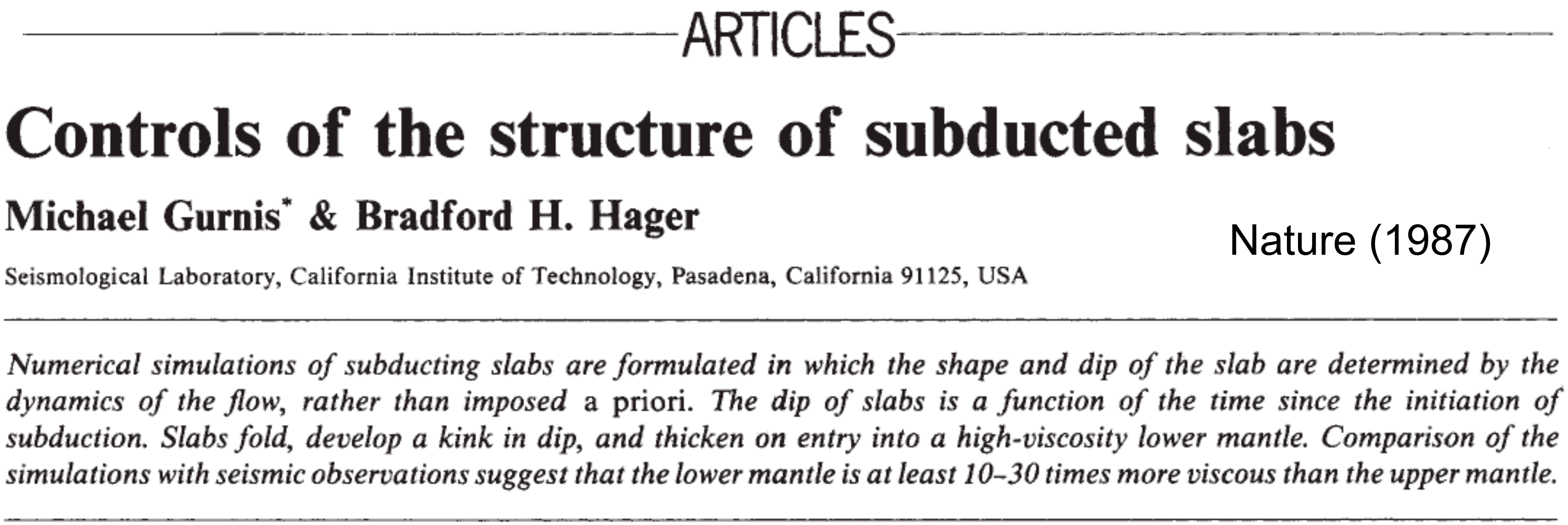


Figure 23,
Jarrard (1986)



upper plate is oceanic

Figure 24, Jarrard (1986)



ARTICLES

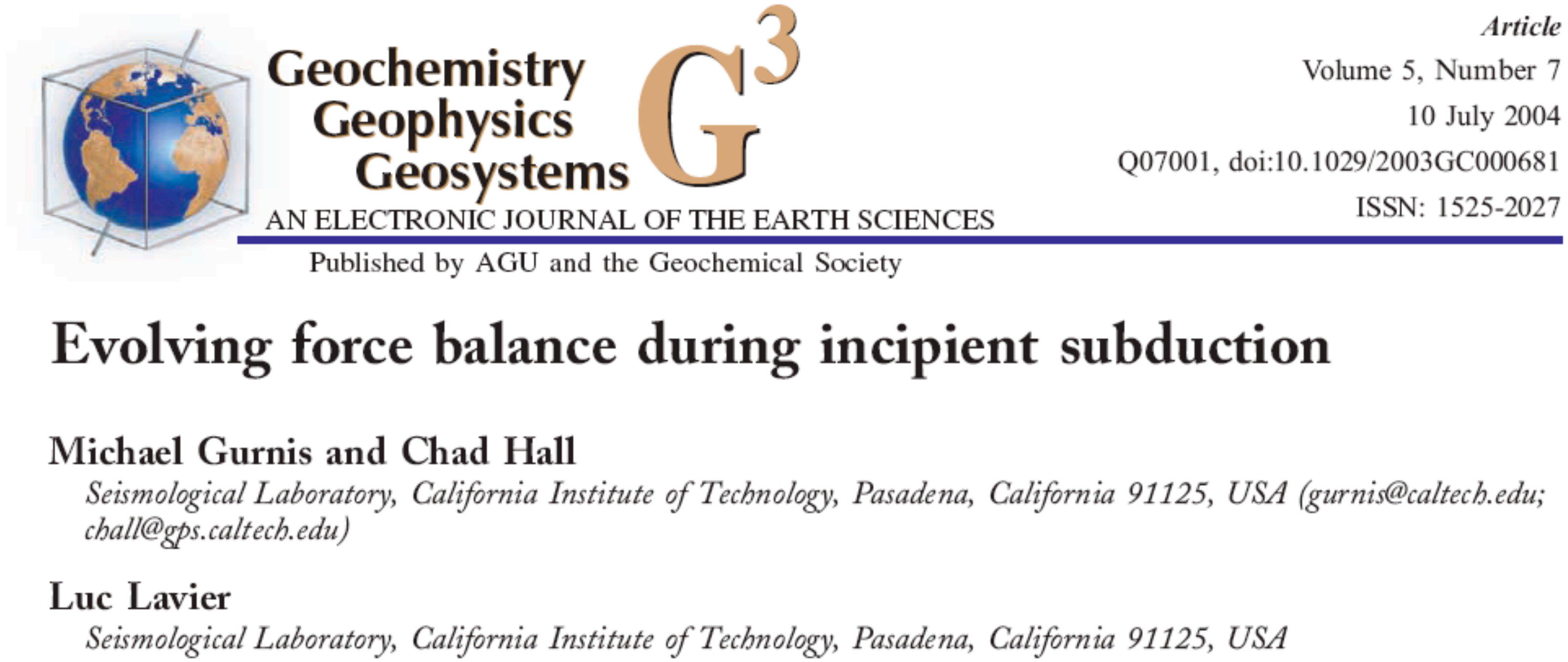
Controls of the structure of subducted slabs

Michael Gurnis* & **Bradford H. Hager**

Nature (1987)

Seismological Laboratory, California Institute of Technology, Pasadena, California 91125, USA

Numerical simulations of subducting slabs are formulated in which the shape and dip of the slab are determined by the dynamics of the flow, rather than imposed a priori. *The dip of slabs is a function of the time since the initiation of subduction. Slabs fold, develop a kink in dip, and thicken on entry into a high-viscosity lower mantle. Comparison of the simulations with seismic observations suggest that the lower mantle is at least 10–30 times more viscous than the upper mantle.*



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Evolving force balance during incipient subduction

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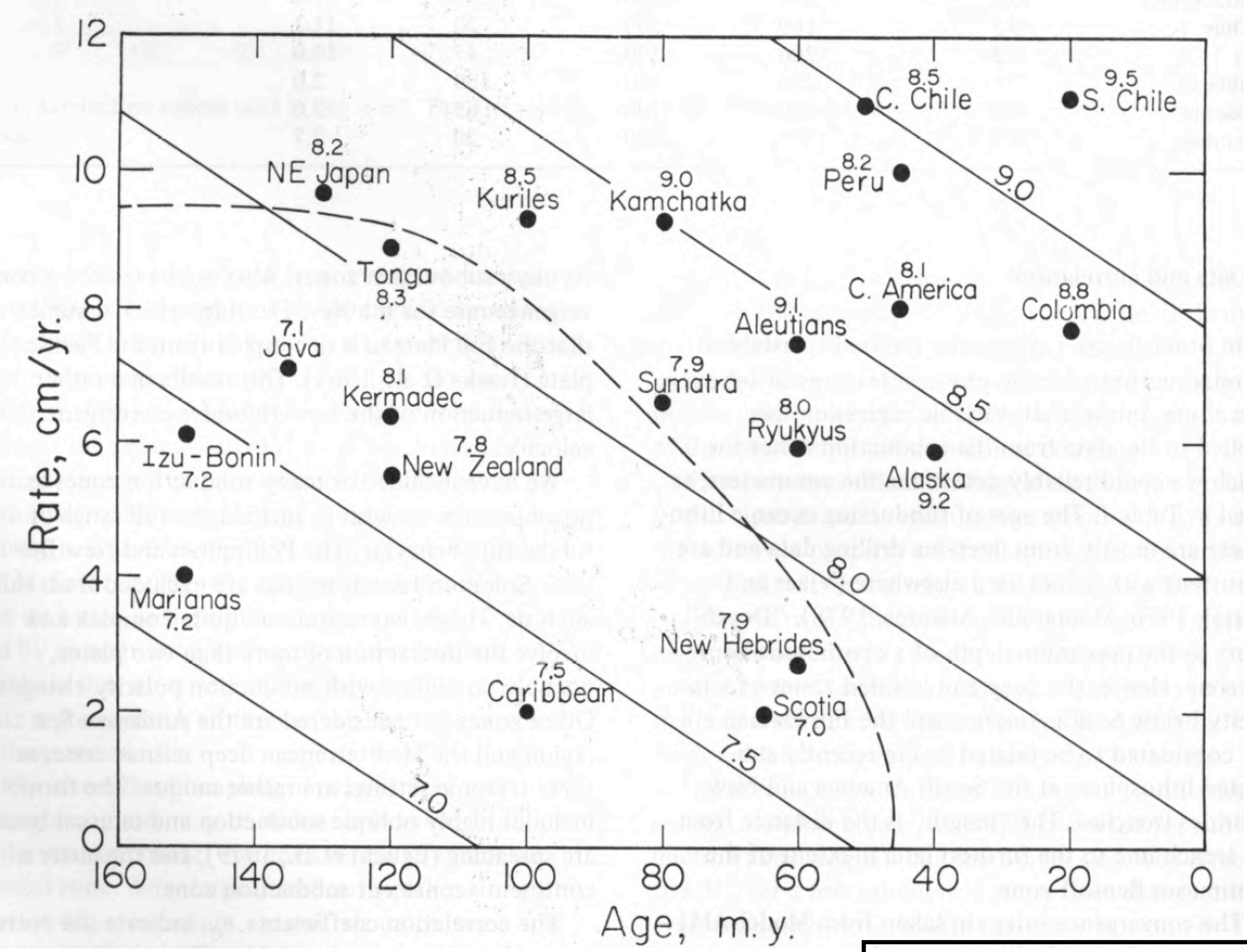
3. Make multiple linear regression (MLR) models



Ruff and Kanamori (1980)

3. Make multiple linear regression (MLR) models

(And don't just stop with scatterplots!)

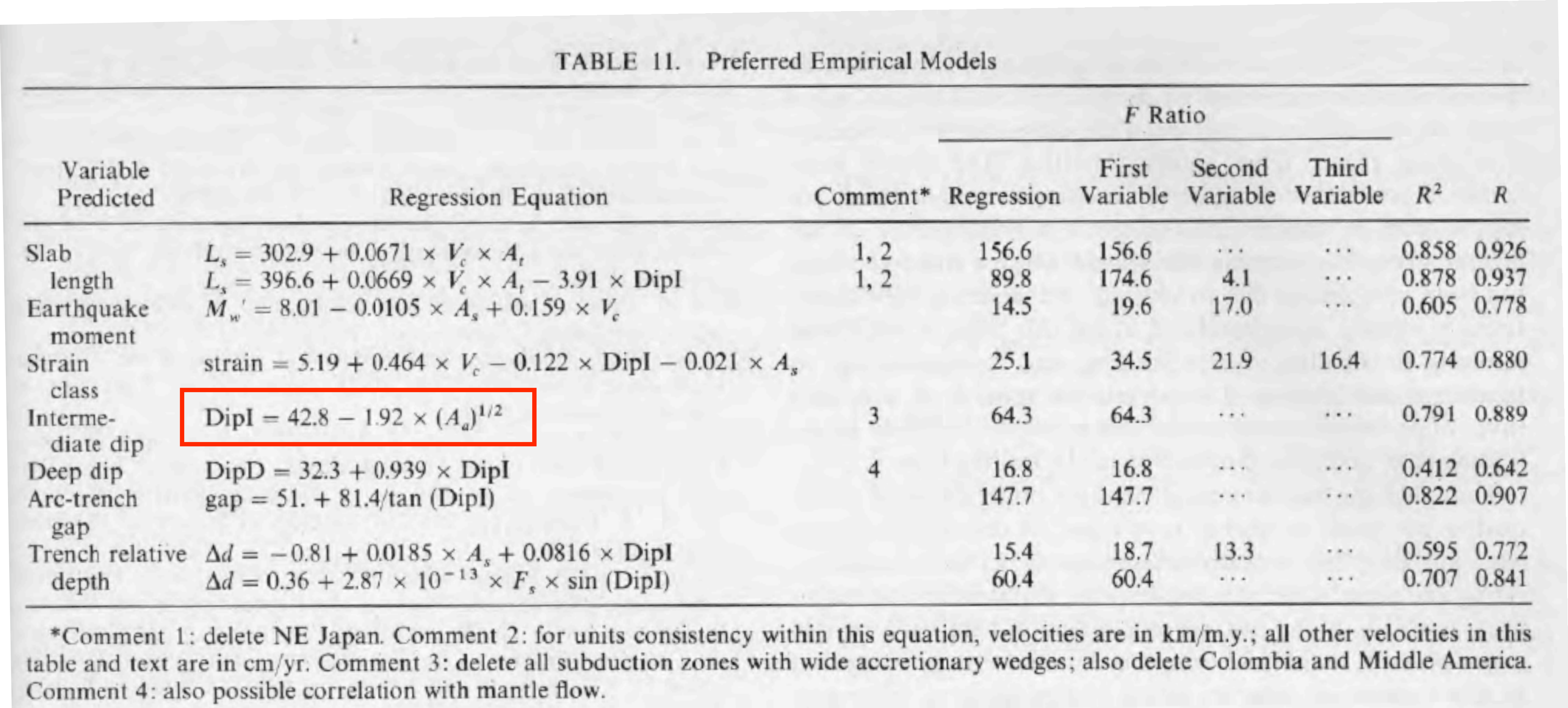


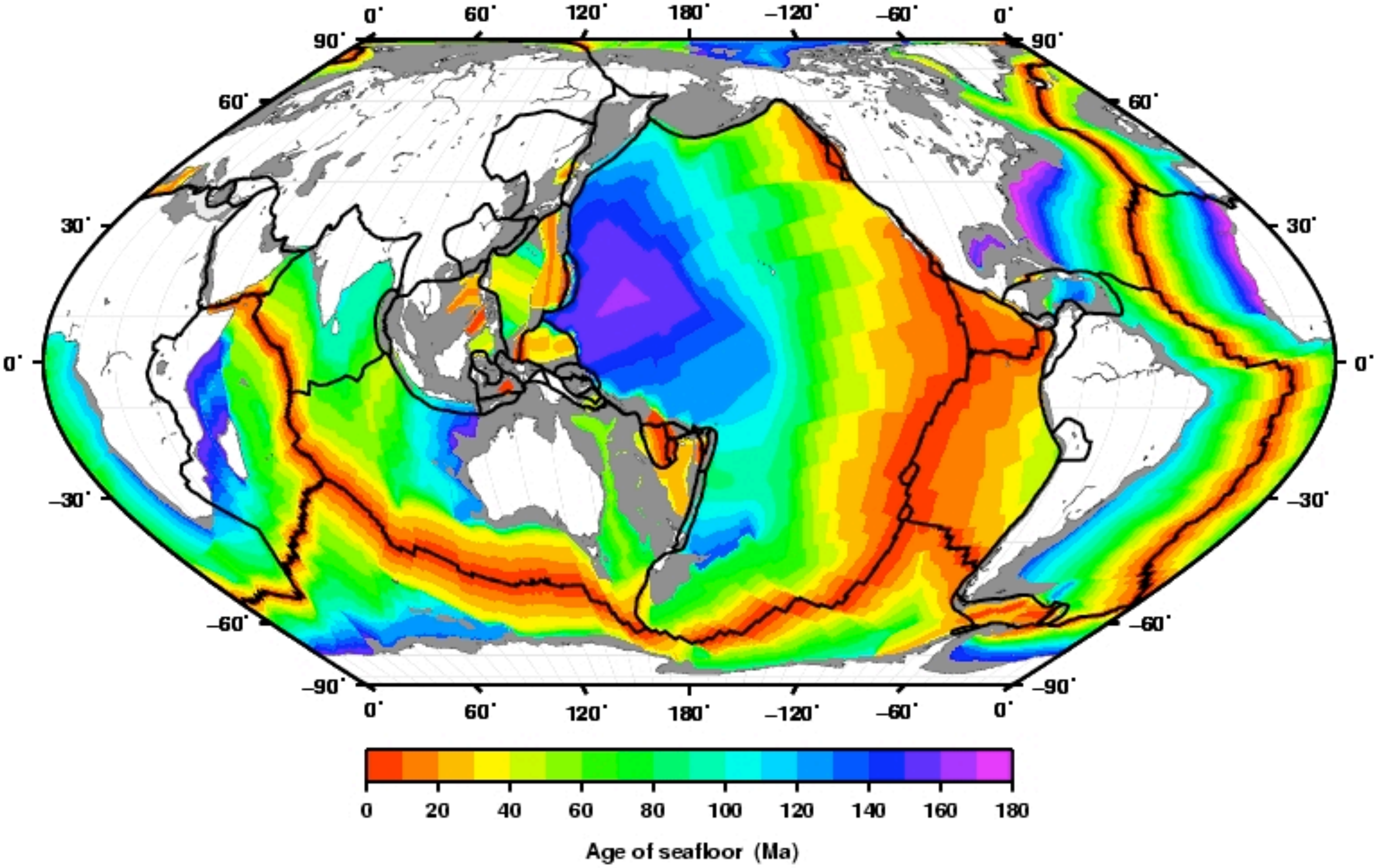
TABLE 11. Preferred Empirical Models

Variable Predicted	Regression Equation	Comment*	F Ratio					
			Regression	First Variable	Second Variable	Third Variable	R^2	R
Slab length	$L_s = 302.9 + 0.0671 \times V_c \times A_t$	1, 2	156.6	156.6	···	···	0.858	0.926
	$L_s = 396.6 + 0.0669 \times V_c \times A_t - 3.91 \times \text{DipI}$	1, 2	89.8	174.6	4.1	···	0.878	0.937
Earthquake moment	$M_w' = 8.01 - 0.0105 \times A_s + 0.159 \times V_c$		14.5	19.6	17.0	···	0.605	0.778
Strain class	$\text{strain} = 5.19 + 0.464 \times V_c - 0.122 \times \text{DipI} - 0.021 \times A_s$		25.1	34.5	21.9	16.4	0.774	0.880
Intermediate dip	$\text{DipI} = 42.8 - 1.92 \times (A_a)^{1/2}$	3	64.3	64.3	···	···	0.791	0.889
Deep dip	$\text{DipD} = 32.3 + 0.939 \times \text{DipI}$	4	16.8	16.8	···	···	0.412	0.642
Arc-trench gap	$\text{gap} = 51. + 81.4/\tan(\text{DipI})$		147.7	147.7	···	···	0.822	0.907
Trench relative depth	$\Delta d = -0.81 + 0.0185 \times A_s + 0.0816 \times \text{DipI}$		15.4	18.7	13.3	···	0.595	0.772
	$\Delta d = 0.36 + 2.87 \times 10^{-13} \times F_s \times \sin(\text{DipI})$		60.4	60.4	···	···	0.707	0.841

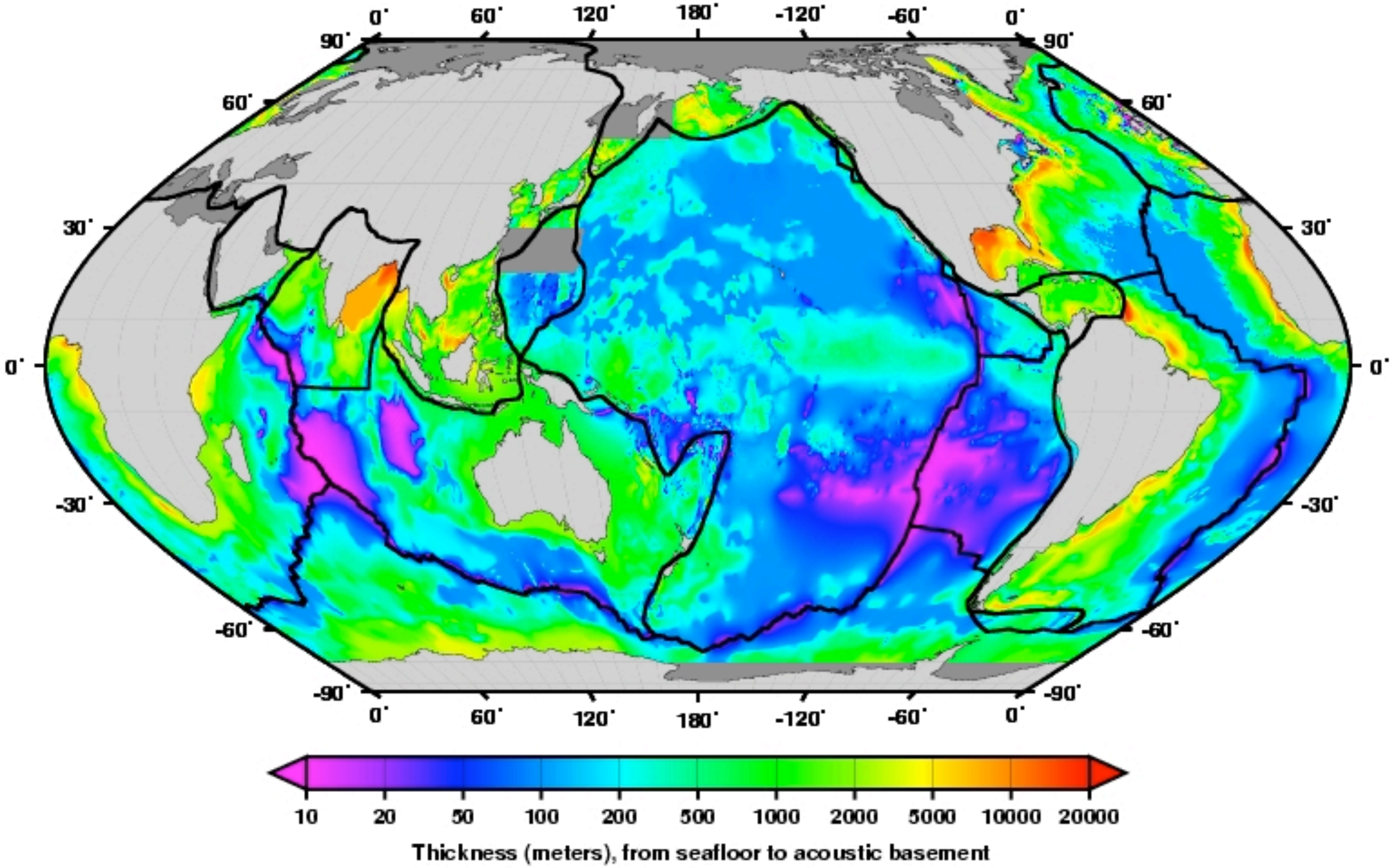
*Comment 1: delete NE Japan. Comment 2: for units consistency within this equation, velocities are in km/m.y.; all other velocities in this table and text are in cm/yr. Comment 3: delete all subduction zones with wide accretionary wedges; also delete Colombia and Middle America. Comment 4: also possible correlation with mantle flow.

Jarrard (1986)

Age of the Seafloor



Sediment Thickness

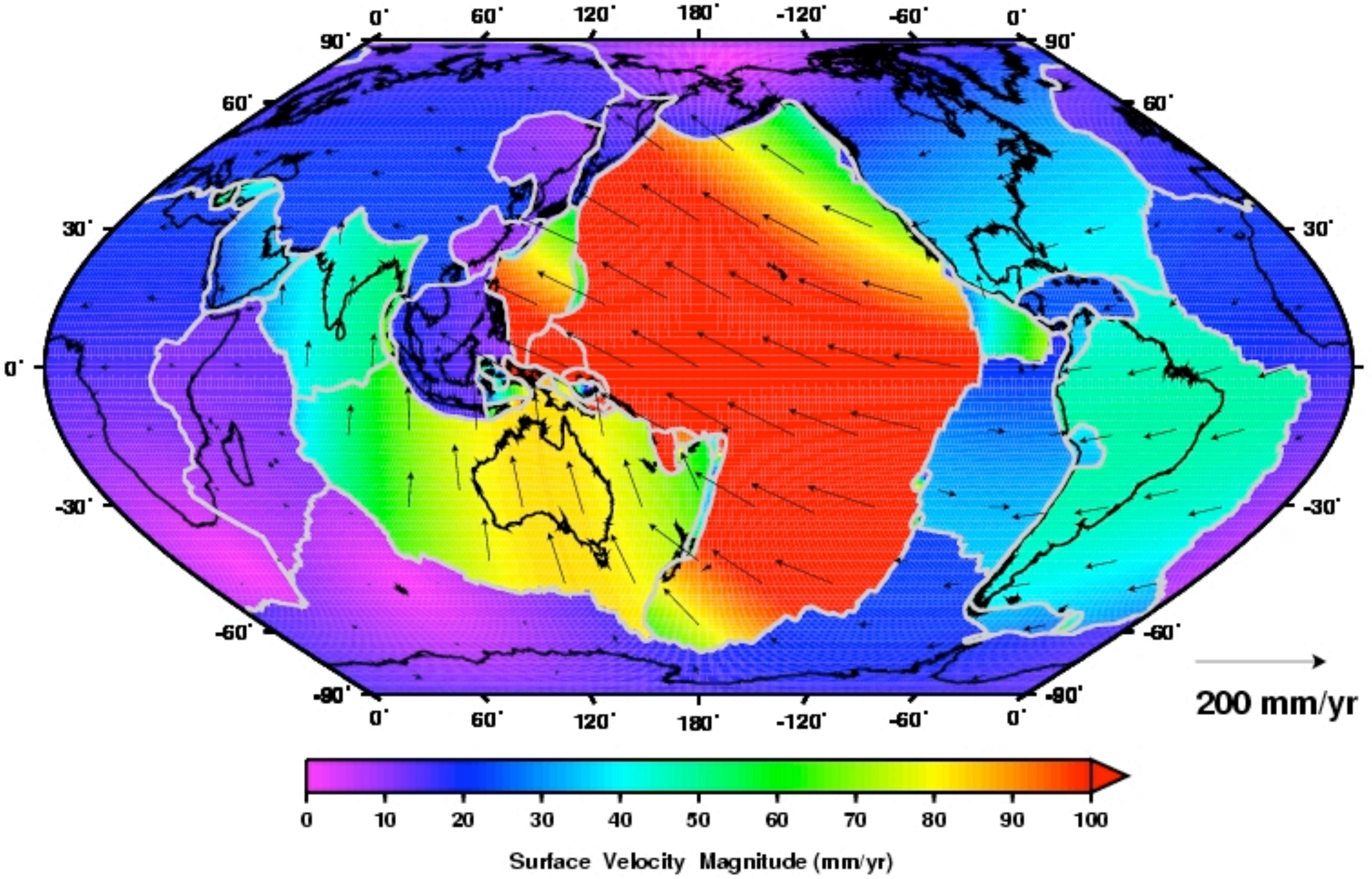


Computing surface velocities

1. Description of plate boundaries.
2. Euler vectors for each plate.
3. Reference frame choice (e.g., “hot spot reference frame”)?

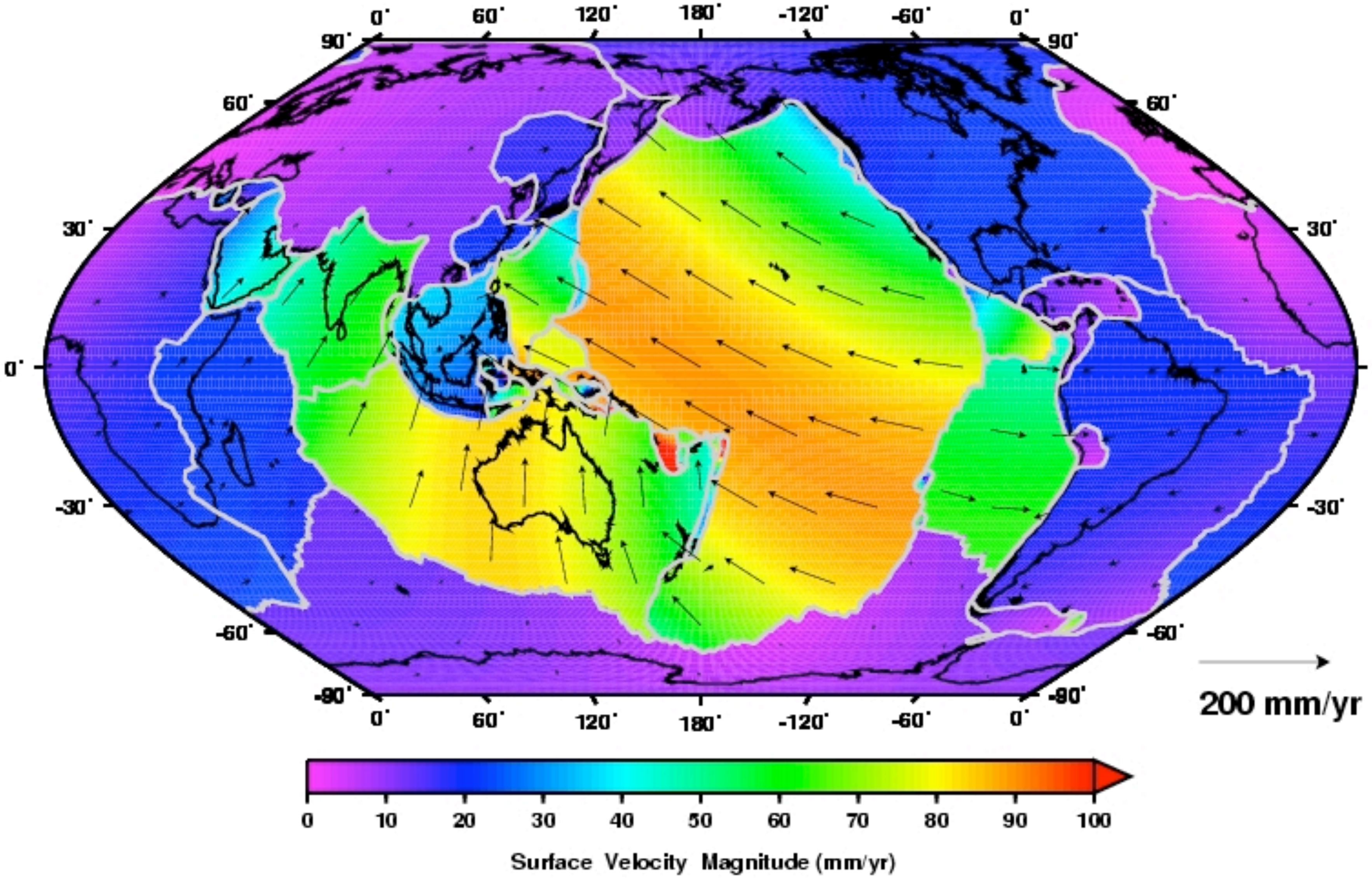
Global Plate Velocities

bird_gripp model



Global Plate Velocities

bird_morgan model



Computing the convergence velocity, the trench-normal convergence velocity, and the obliquity.

Should we only consider the major plates (NUVEL)?

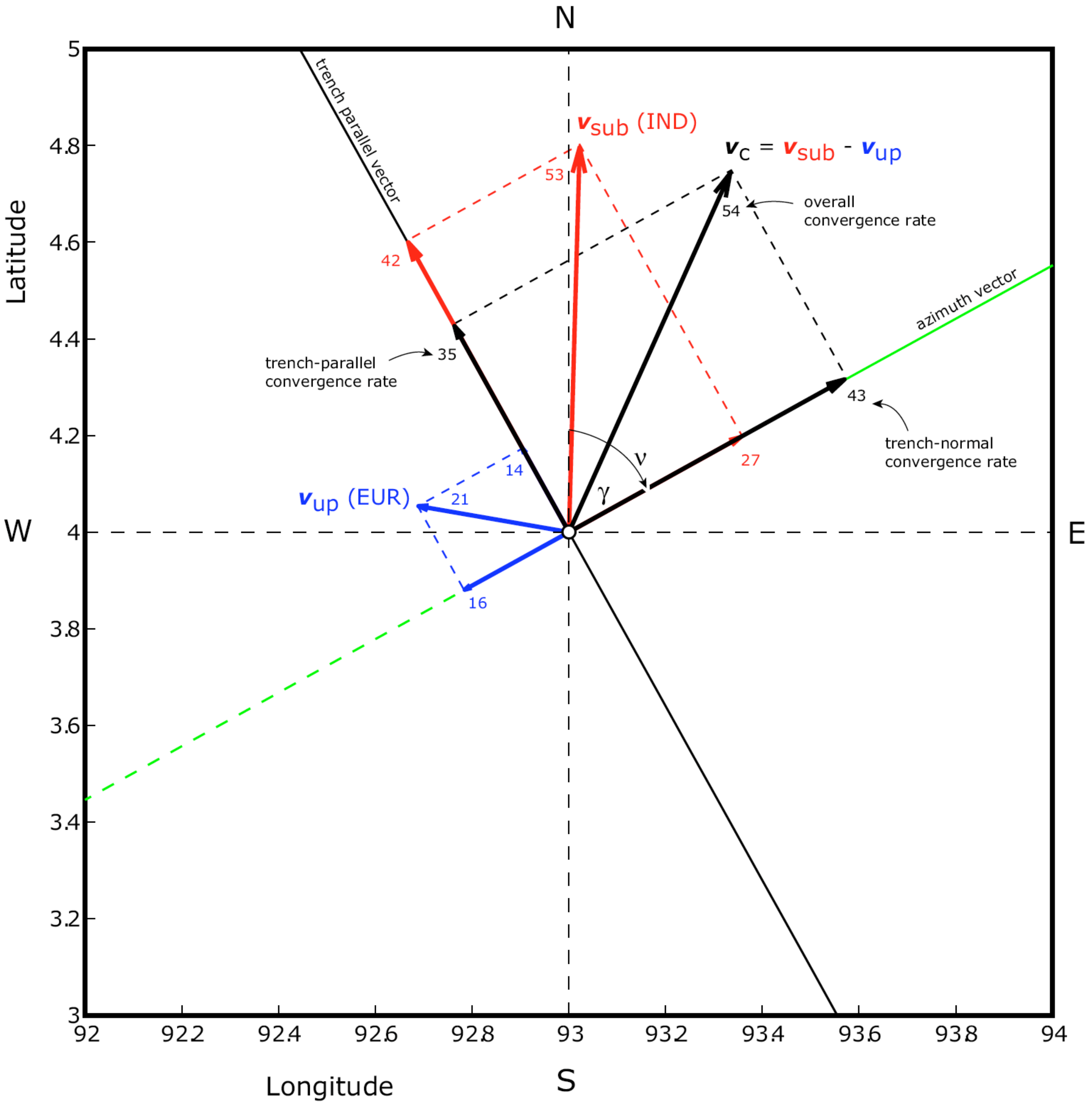
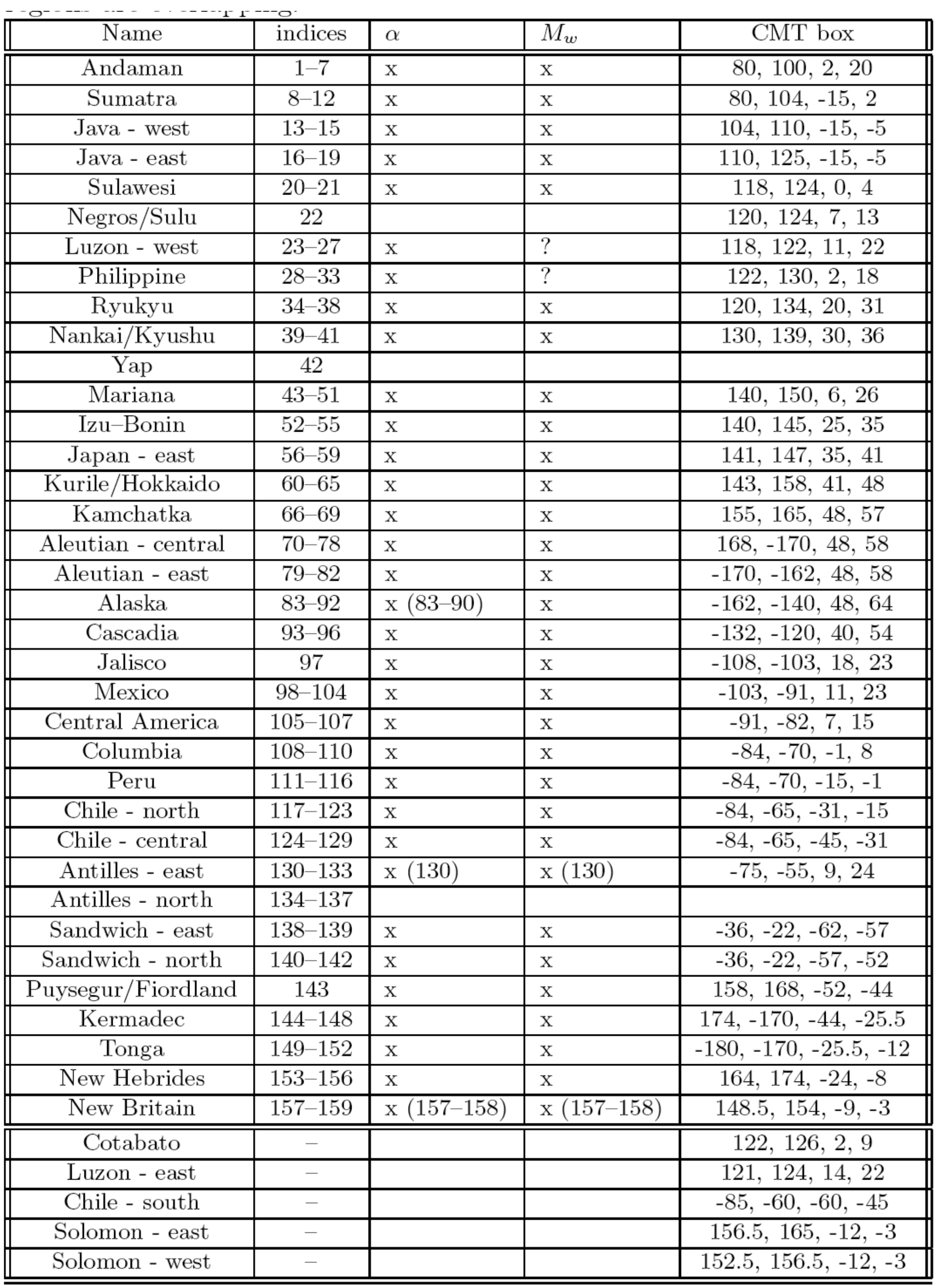


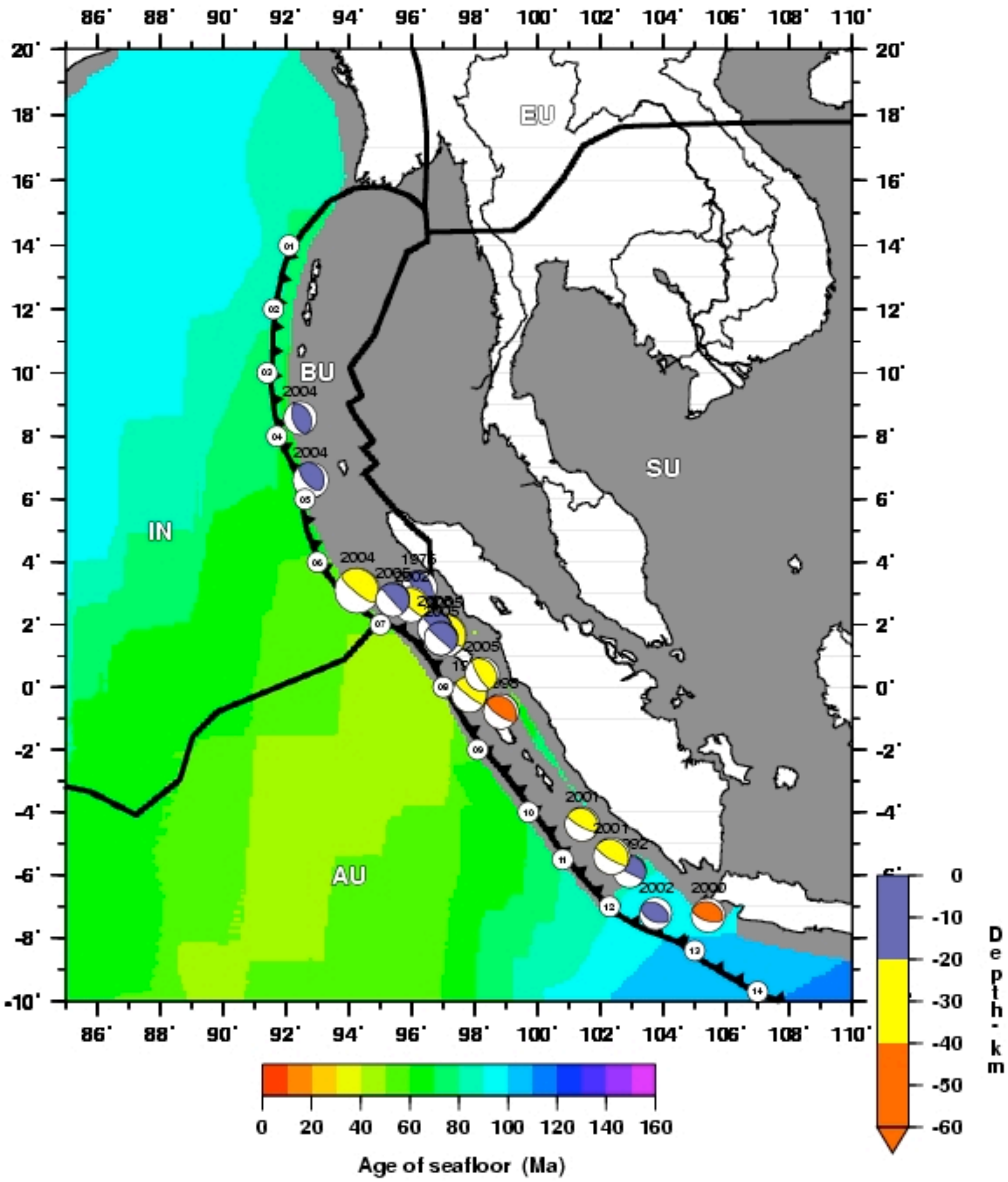
Table 1: Slab dip angle conventions used in this study, in *Jarrard* (1986), and in *Lallemand et al.* (2005).

Name		N_α	definition here	definition of *Jarrard* (1986)
shallow dip	α_0	159	dip in zone of interplate thrust event	dip from trench to 60 km depth
intermediate dip	α_i	159	dip in the depth region 0 to 125 km (*Lallemand et al.*, 2005)	dip from trench to 100 km depth
deep dip	α_d	117	dip in the depth region below 125 km (*Lallemand et al.*, 2005)	dip over part or all of the interval 100 to 400 km depth

Choice of subduction zones



Name	indices	α	M_w	CMT box
Andaman	1–7	x	x	80, 100, 2, 20
Sumatra	8–12	x	x	80, 104, -15, 2
Java - west	13–15	x	x	104, 110, -15, -5
Java - east	16–19	x	x	110, 125, -15, -5
Sulawesi	20–21	x	x	118, 124, 0, 4
Negros/Sulu	22			120, 124, 7, 13
Luzon - west	23–27	x	?	118, 122, 11, 22
Philippine	28–33	x	?	122, 130, 2, 18
Ryukyu	34–38	x	x	120, 134, 20, 31
Nankai/Kyushu	39–41	x	x	130, 139, 30, 36
Yap	42			
Mariana	43–51	x	x	140, 150, 6, 26
Izu–Bonin	52–55	x	x	140, 145, 25, 35
Japan - east	56–59	x	x	141, 147, 35, 41
Kurile/Hokkaido	60–65	x	x	143, 158, 41, 48
Kamchatka	66–69	x	x	155, 165, 48, 57
Aleutian - central	70–78	x	x	168, -170, 48, 58
Aleutian - east	79–82	x	x	-170, -162, 48, 58
Alaska	83–92	x (83–90)	x	-162, -140, 48, 64
Cascadia	93–96	x	x	-132, -120, 40, 54
Jalisco	97	x	x	-108, -103, 18, 23
Mexico	98–104	x	x	-103, -91, 11, 23
Central America	105–107	x	x	-91, -82, 7, 15
Columbia	108–110	x	x	-84, -70, -1, 8
Peru	111–116	x	x	-84, -70, -15, -1
Chile - north	117–123	x	x	-84, -65, -31, -15
Chile - central	124–129	x	x	-84, -65, -45, -31
Antilles - east	130–133	x (130)	x (130)	-75, -55, 9, 24
Antilles - north	134–137			
Sandwich - east	138–139	x	x	-36, -22, -62, -57
Sandwich - north	140–142	x	x	-36, -22, -57, -52
Puysegur/Fiordland	143	x	x	158, 168, -52, -44
Kermadec	144–148	x	x	174, -170, -44, -25.5
Tonga	149–152	x	x	-180, -170, -25.5, -12
New Hebrides	153–156	x	x	164, 174, -24, -8
New Britain	157–159	x (157–158)	x (157–158)	148.5, 154, -9, -3
Cotabato	–			122, 126, 2, 9
Luzon - east	–			121, 124, 14, 22
Chile - south	–			-85, -60, -60, -45
Solomon - east	–			156.5, 165, -12, -3
Solomon - west	–			152.5, 156.5, -12, -3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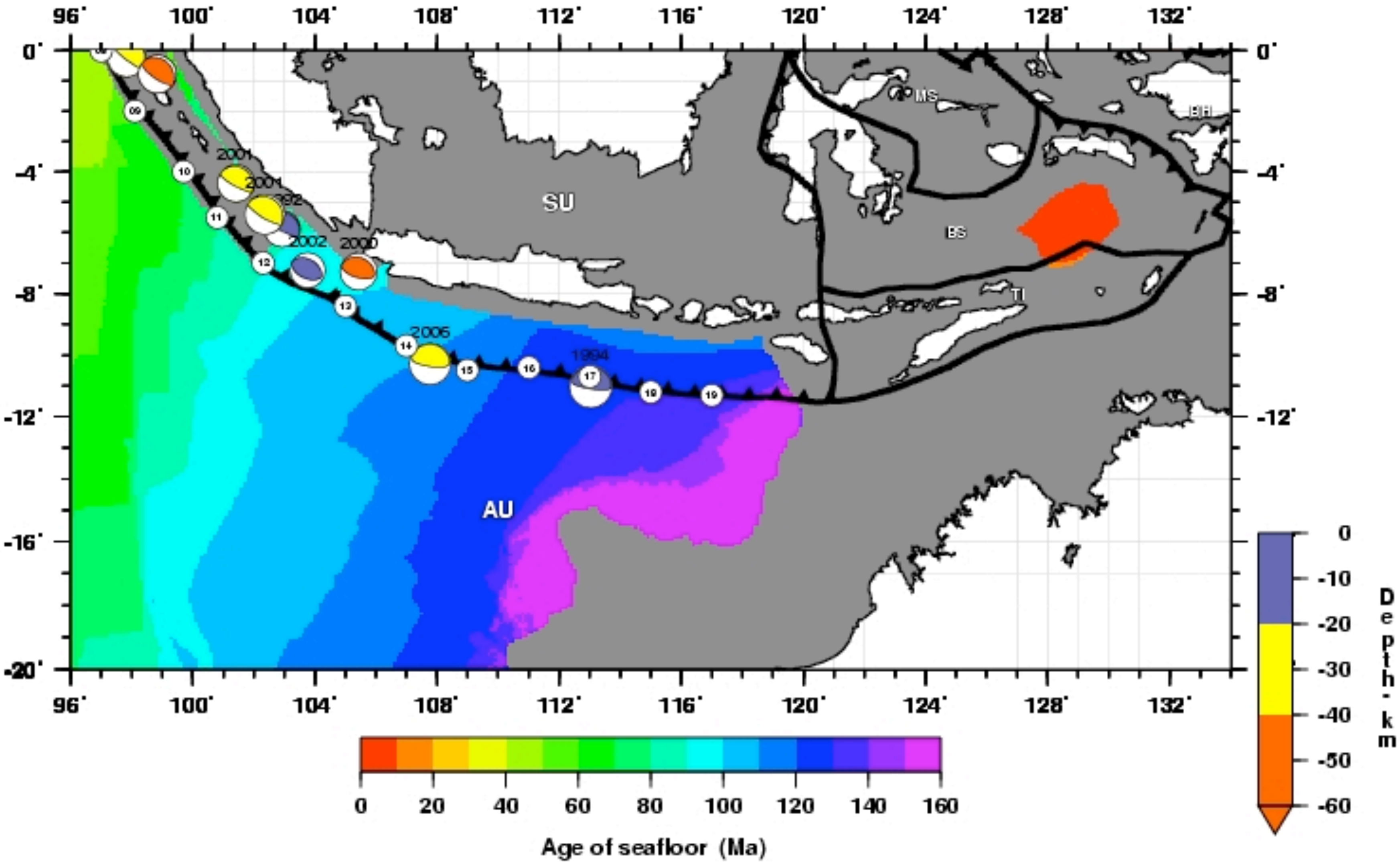
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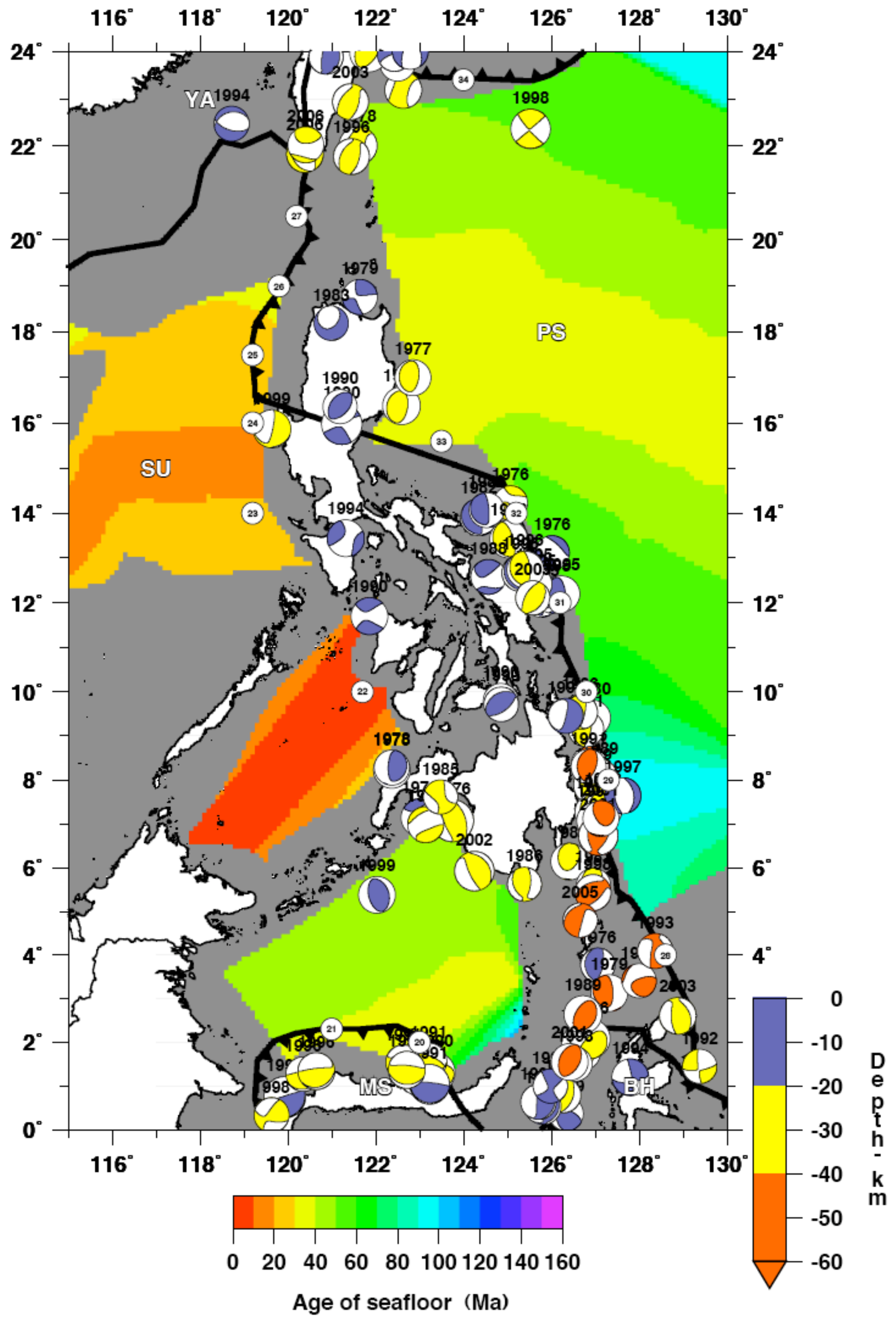
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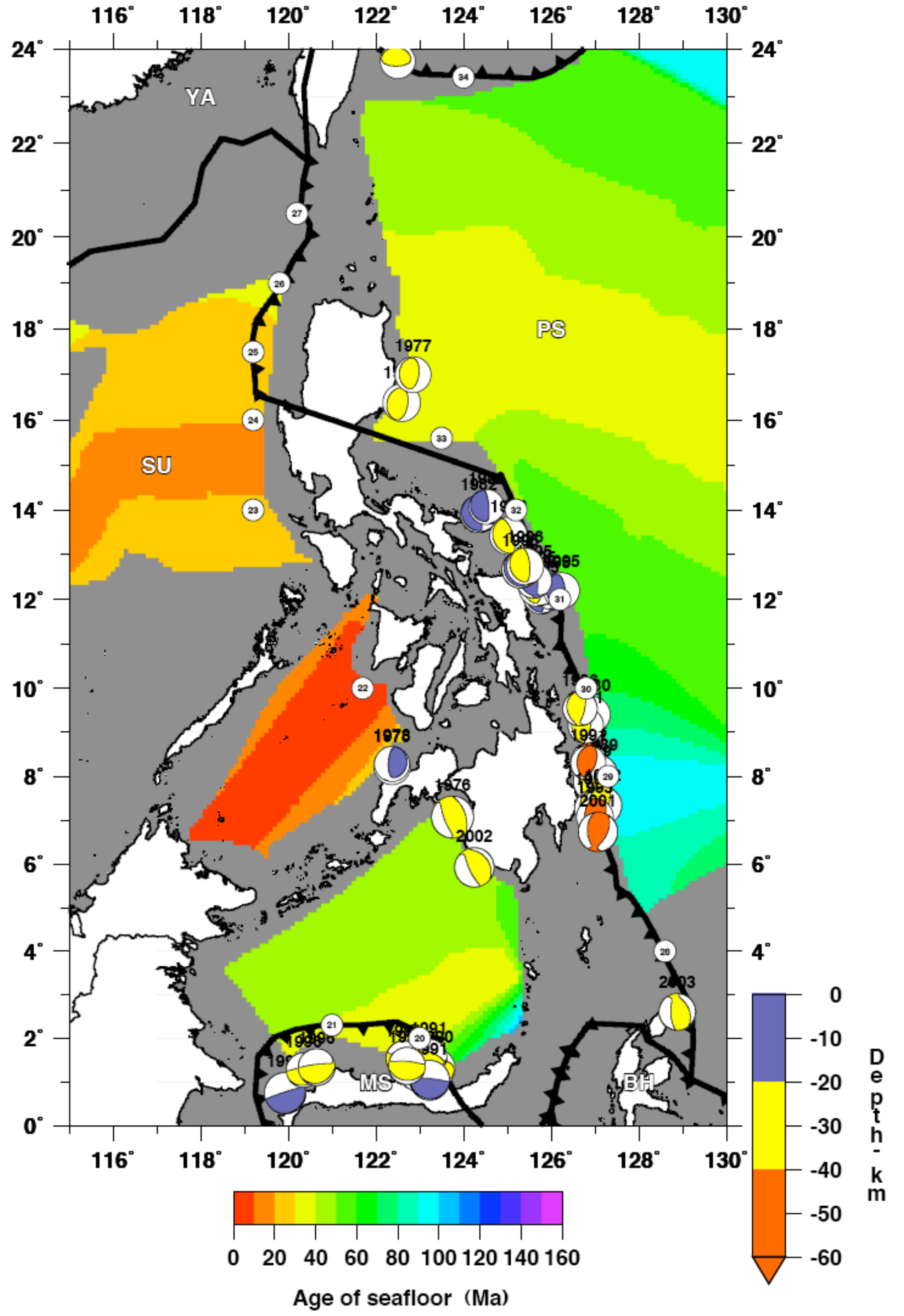
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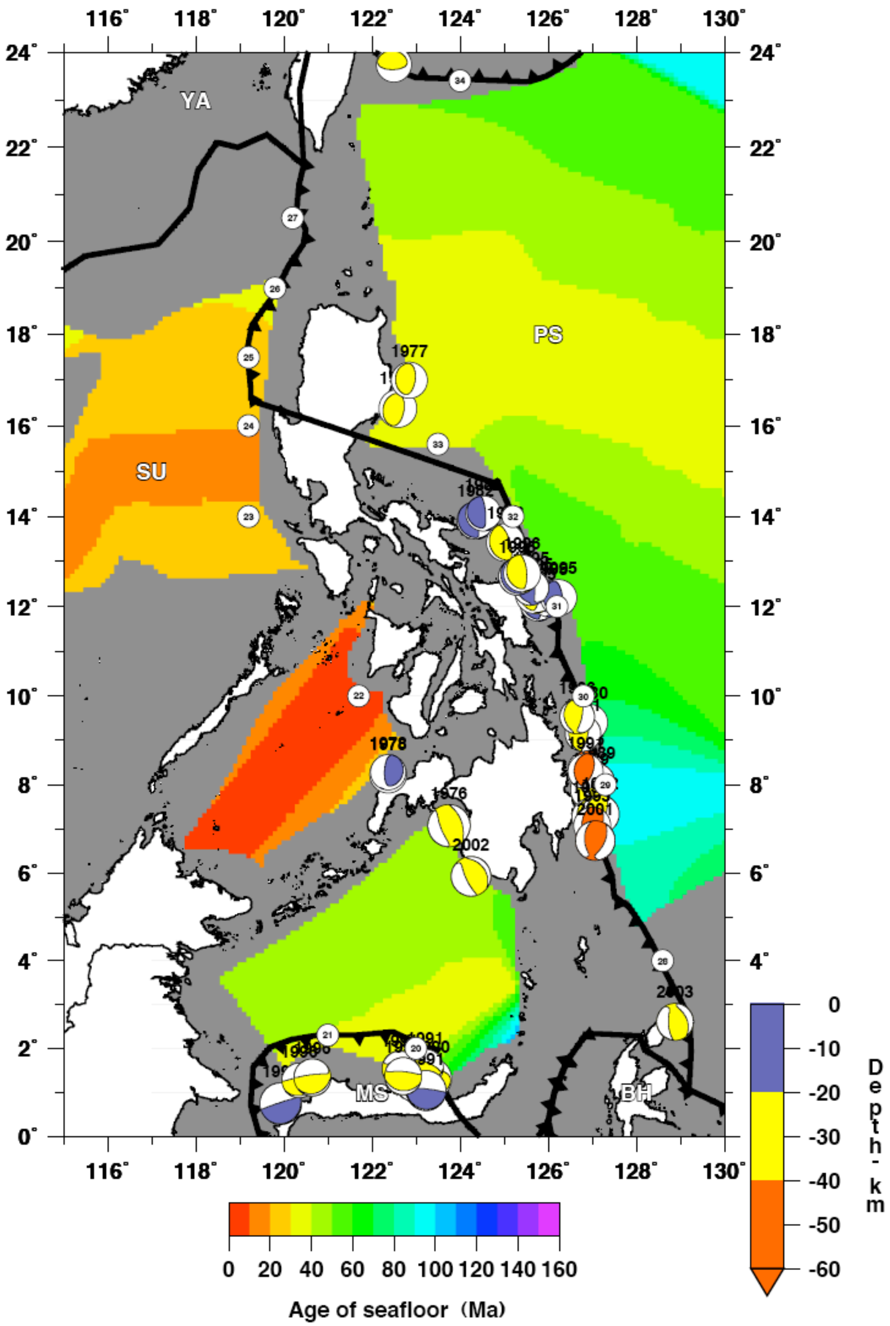

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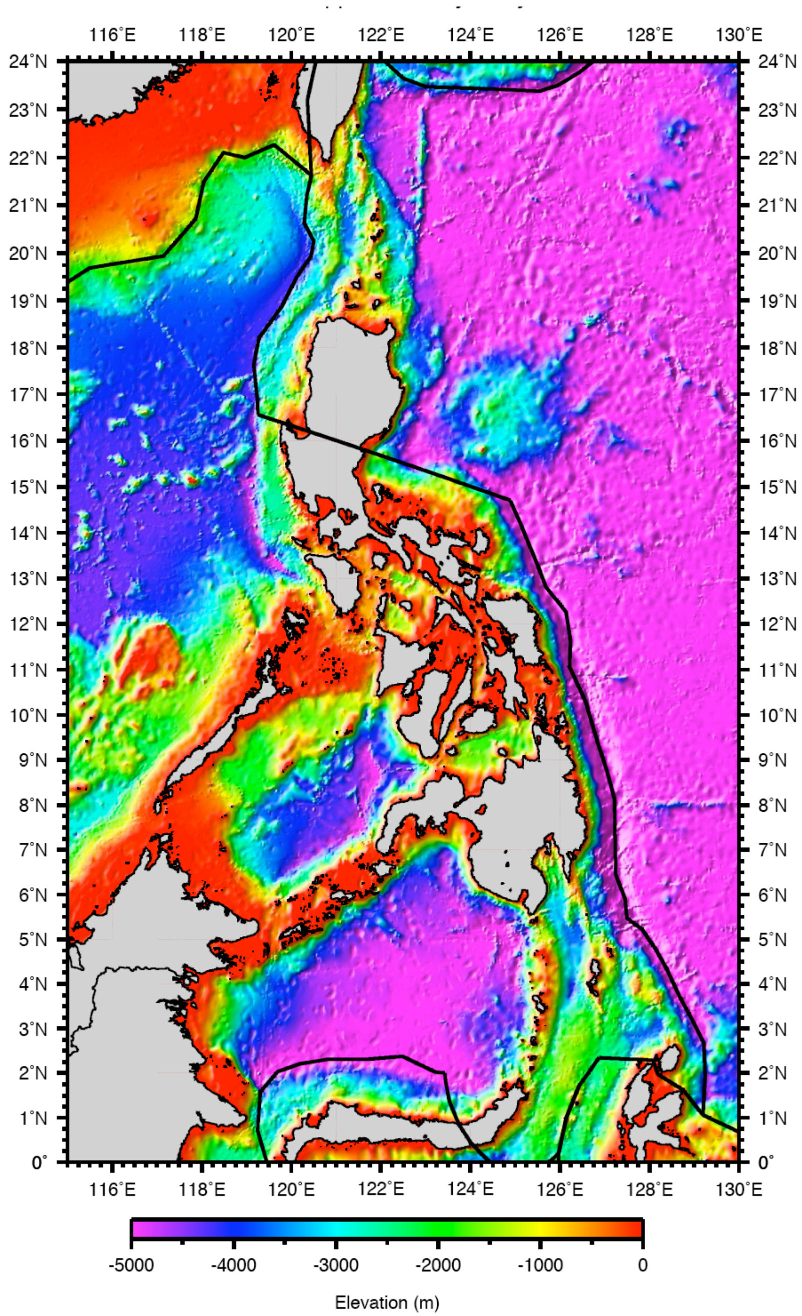

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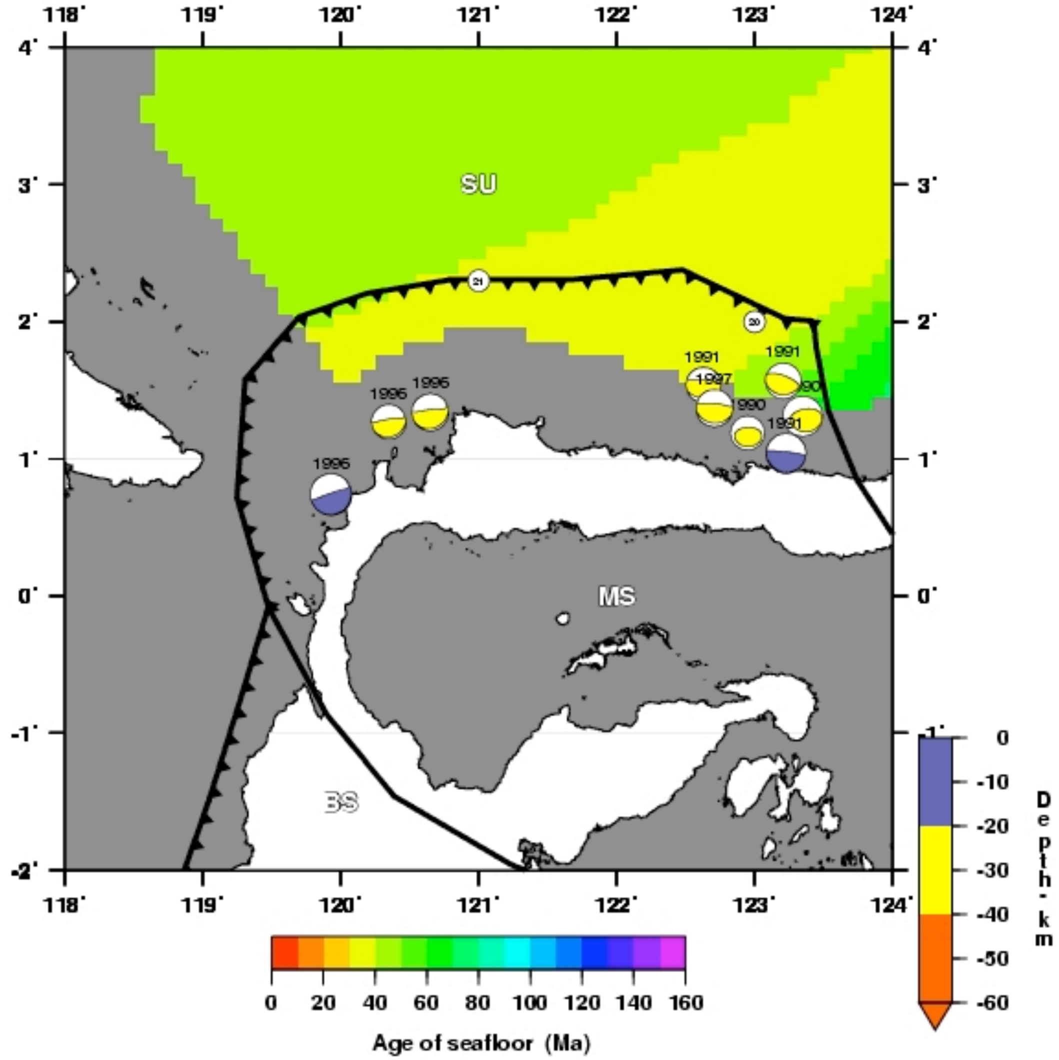
Elevation (m)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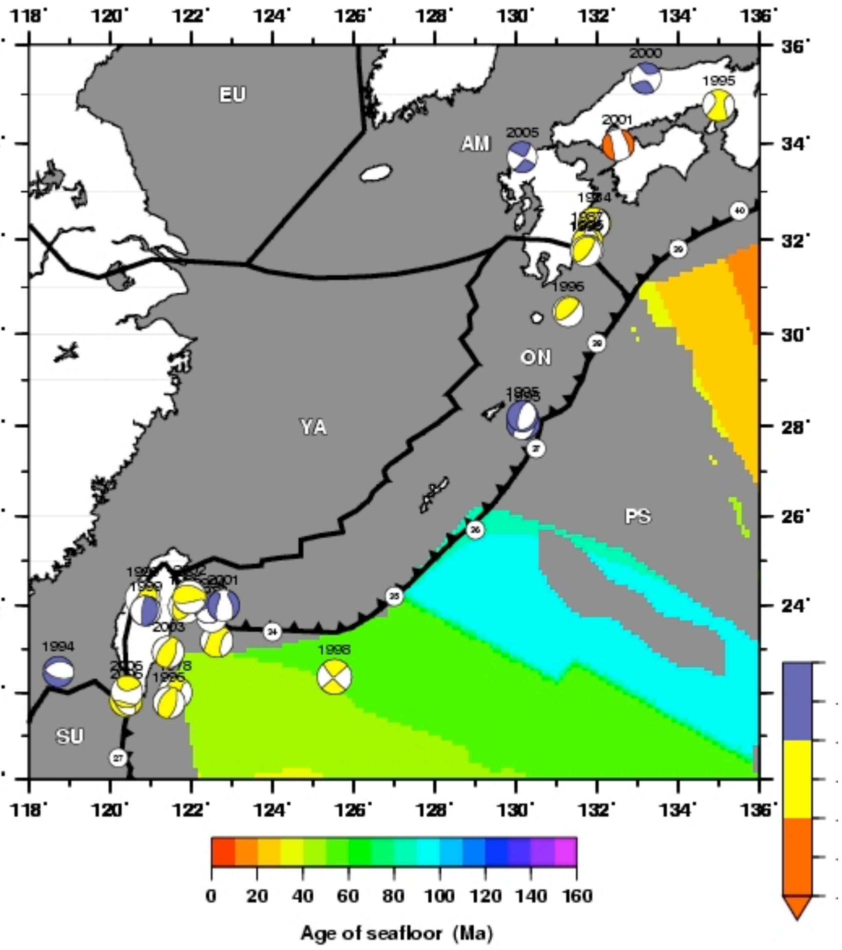

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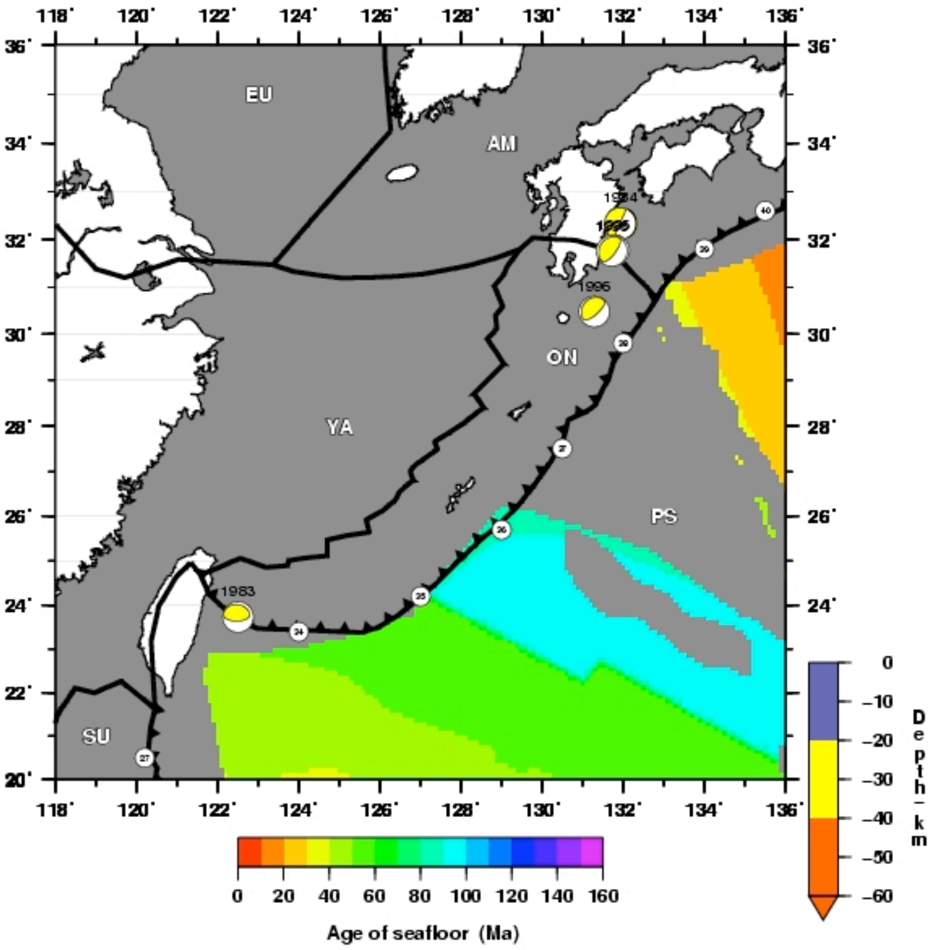

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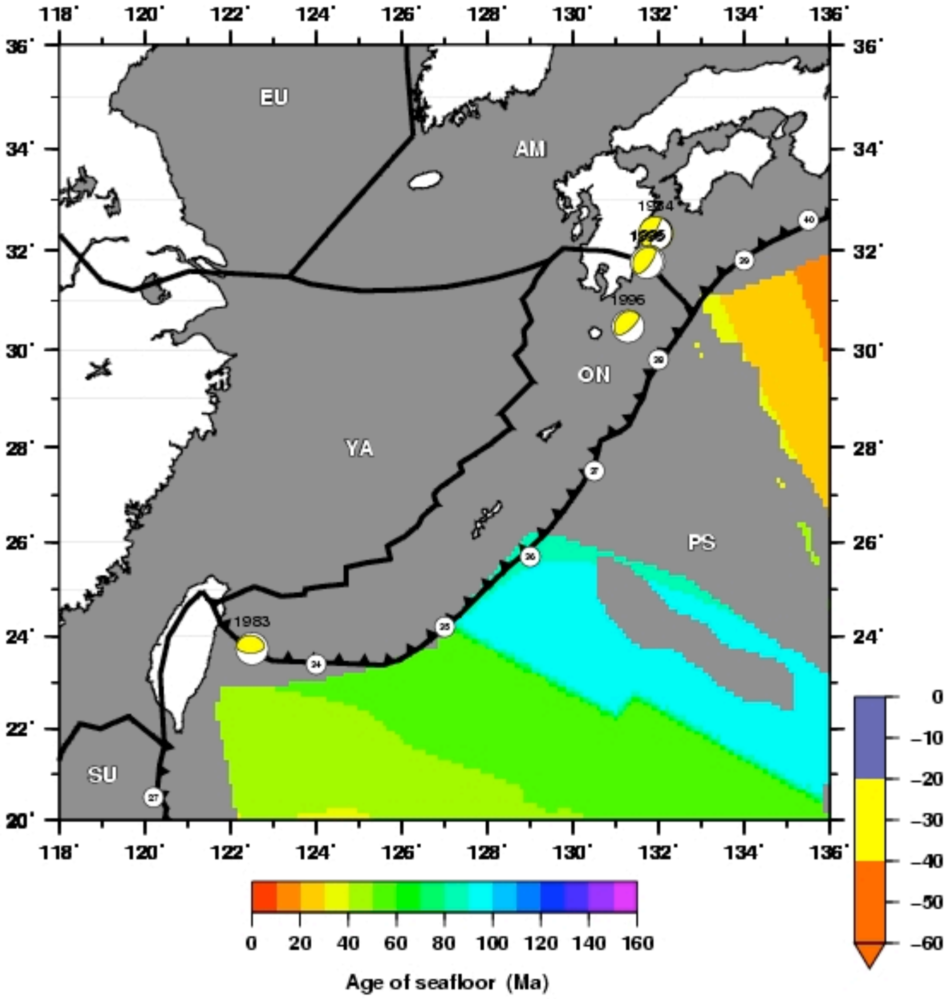

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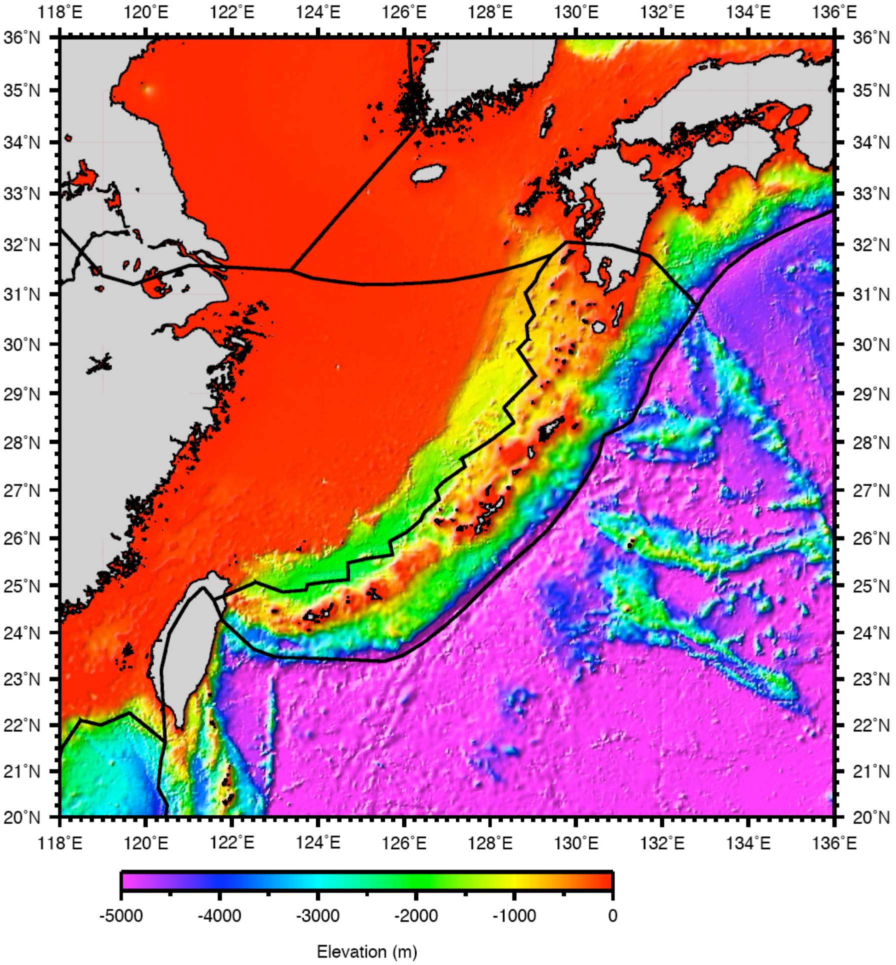
140
160
Age of seafloor (Ma)



118˚E
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124˚E
126˚E
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130˚E
132˚E
134˚E
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36˚N
35˚N
34˚N
33˚N
32˚N
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23˚N
22˚N
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20˚N
-5000
-4000
-3000
-2000
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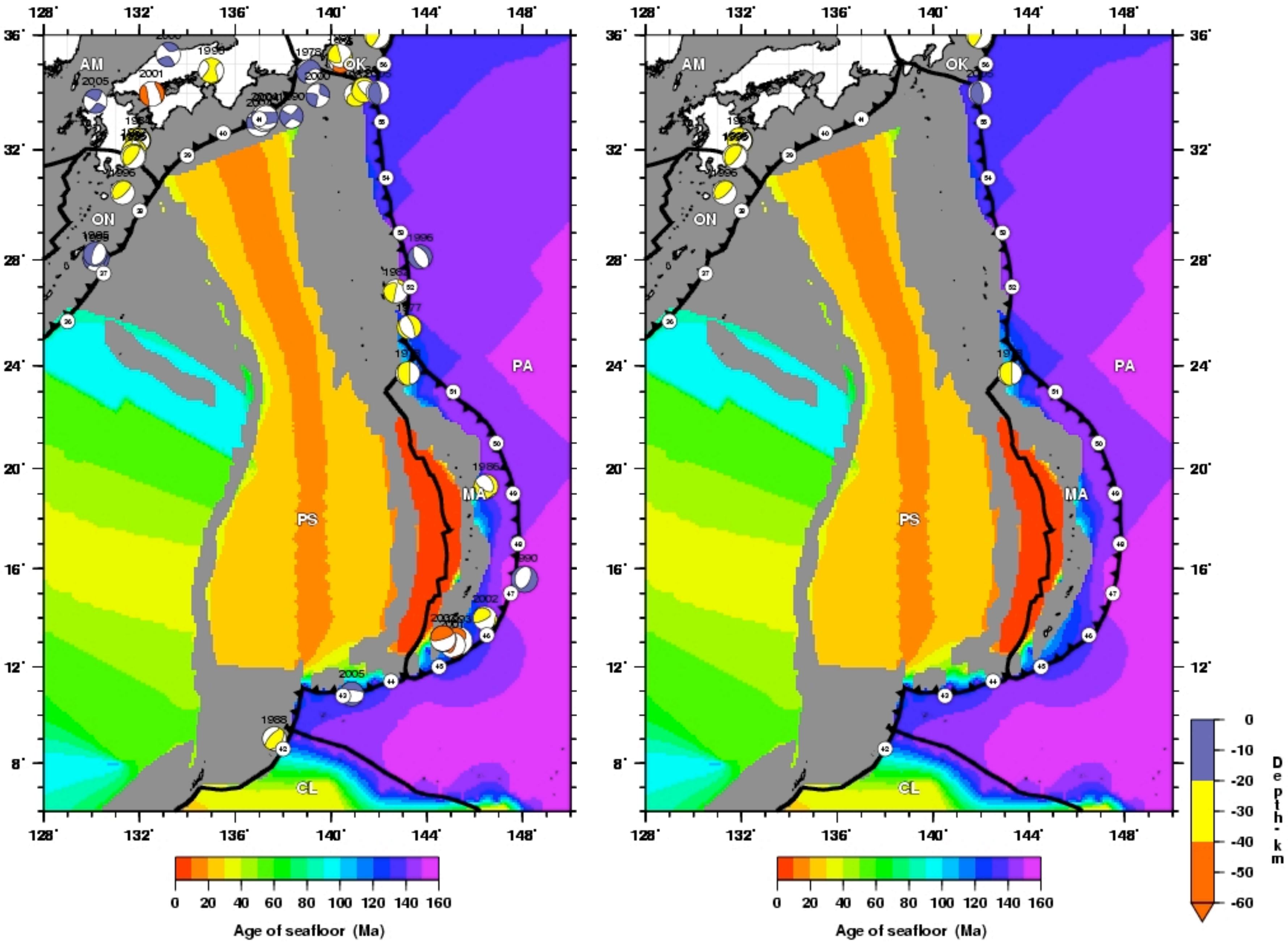
0
Elevation (m)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Age of seafloor (Ma)
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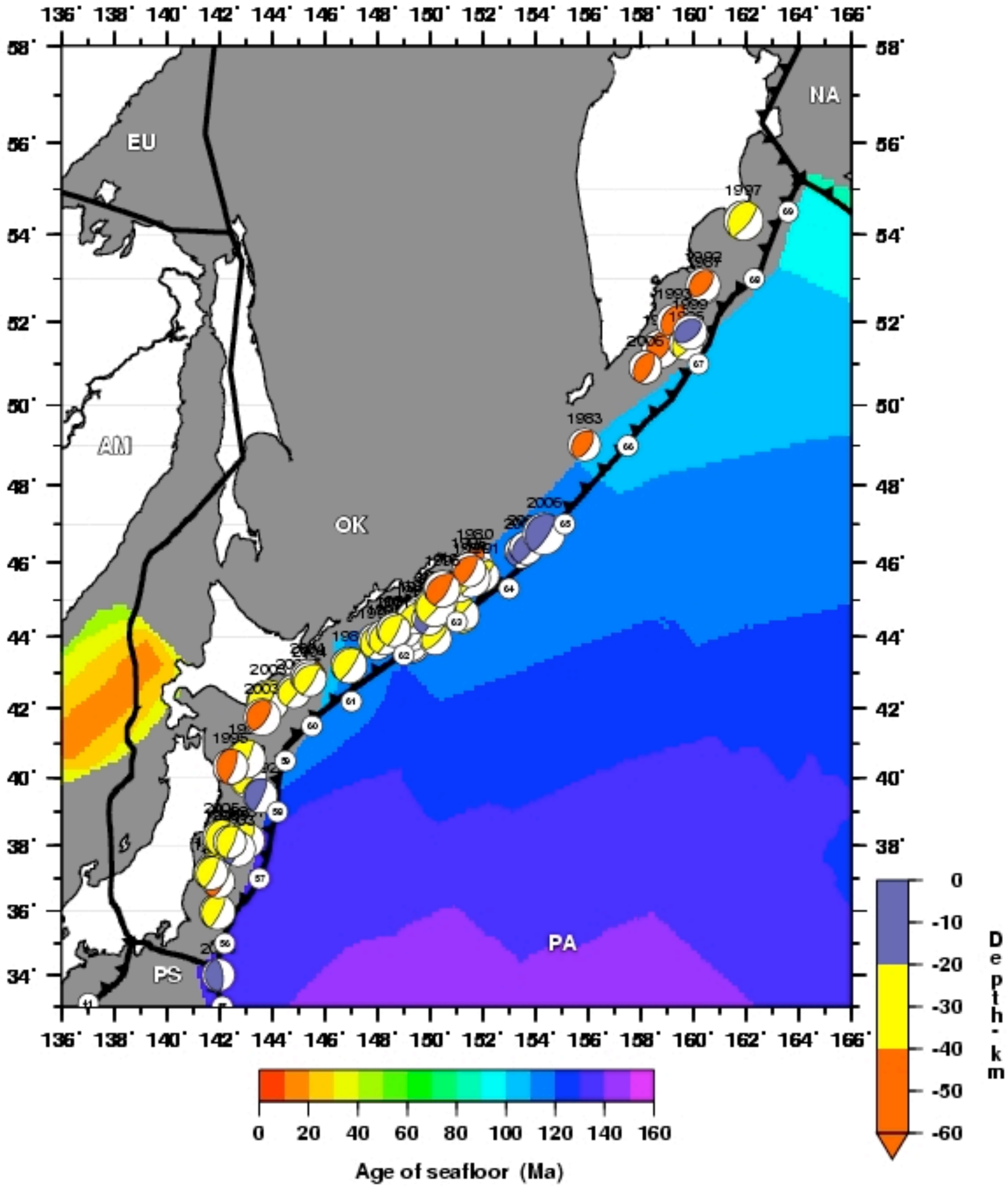
-40
-50
-60
Depth - km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58˚ 56˚ 54˚ 52˚ 50˚ 48˚ 46˚ 44˚ 42˚ 40˚ 38˚ 36˚ 34˚
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OK
NA
PA
PS
1997
1992
1993
1999
2006
1963
2005
1960
2003
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-10
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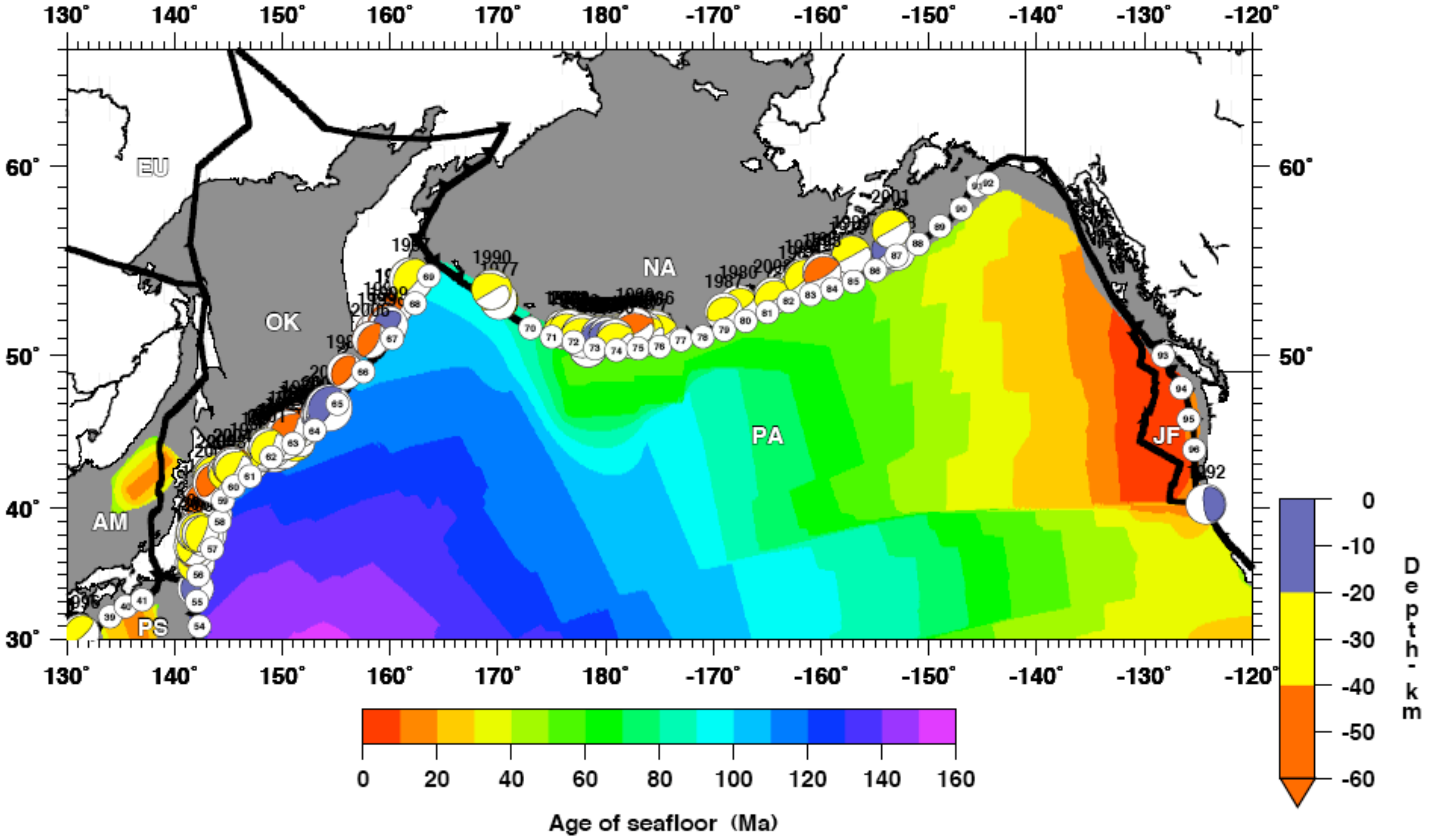
-60
Depth - km
0 20 40 60 80 100 120 140 160
Age of seafloor (Ma)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Age of seafloor (Ma)
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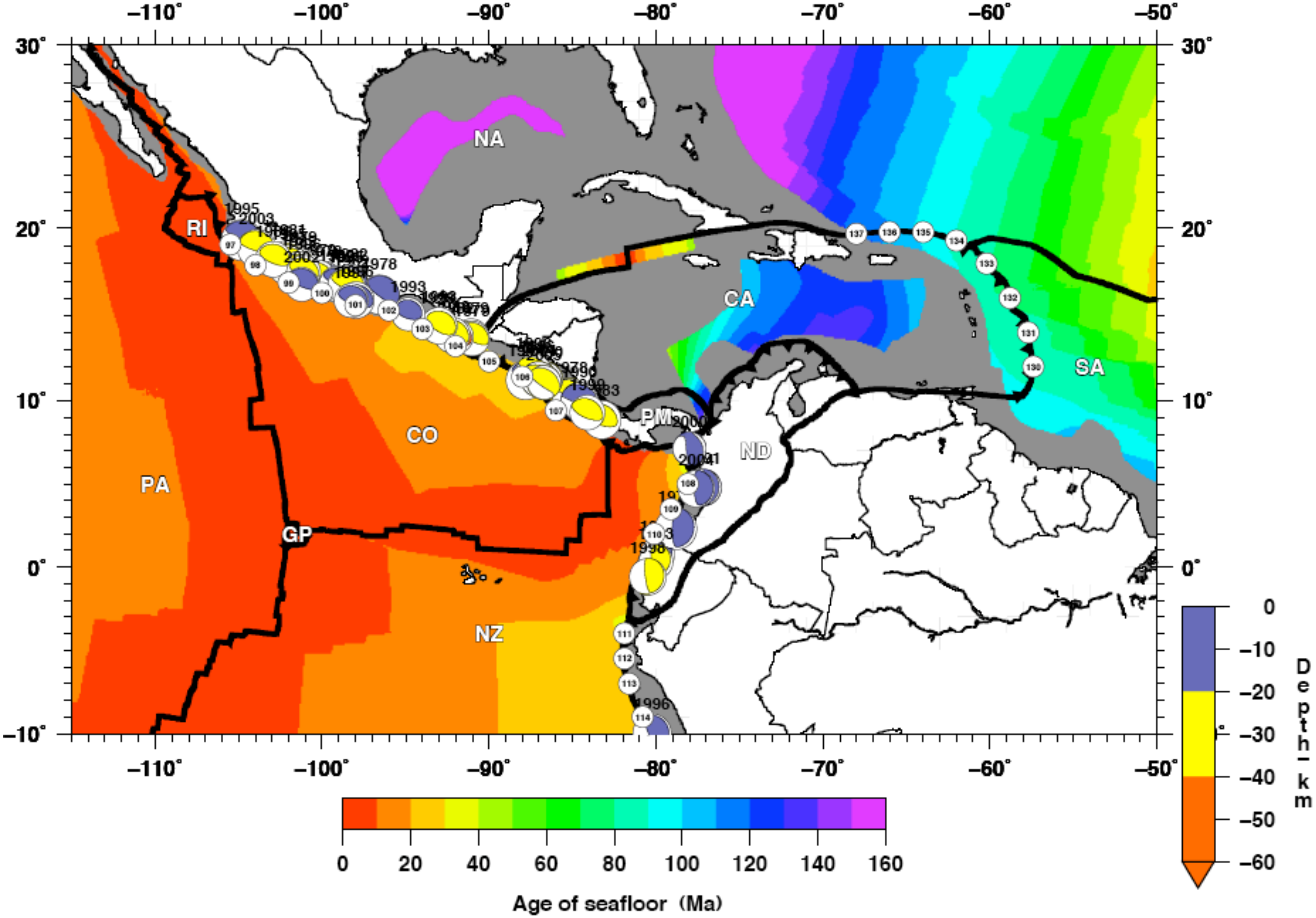
Depth - km



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Age of seafloor (Ma)
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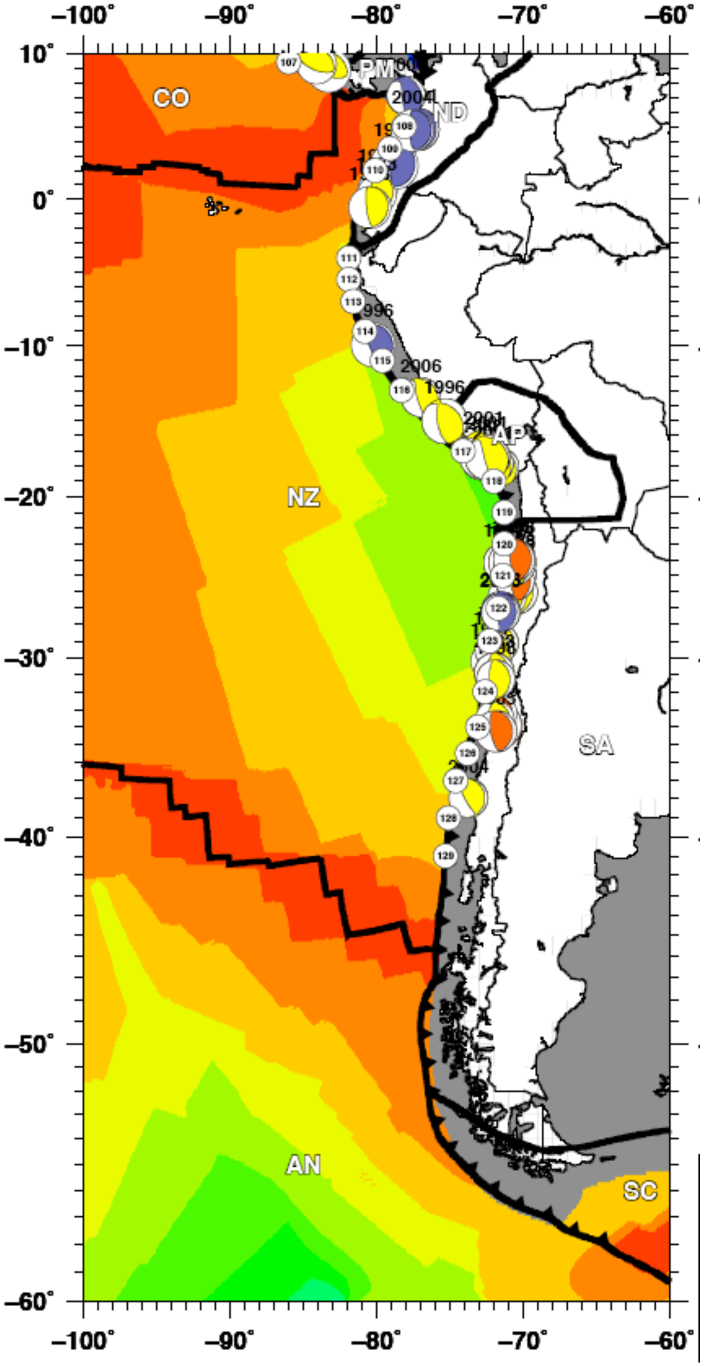
Depth − km



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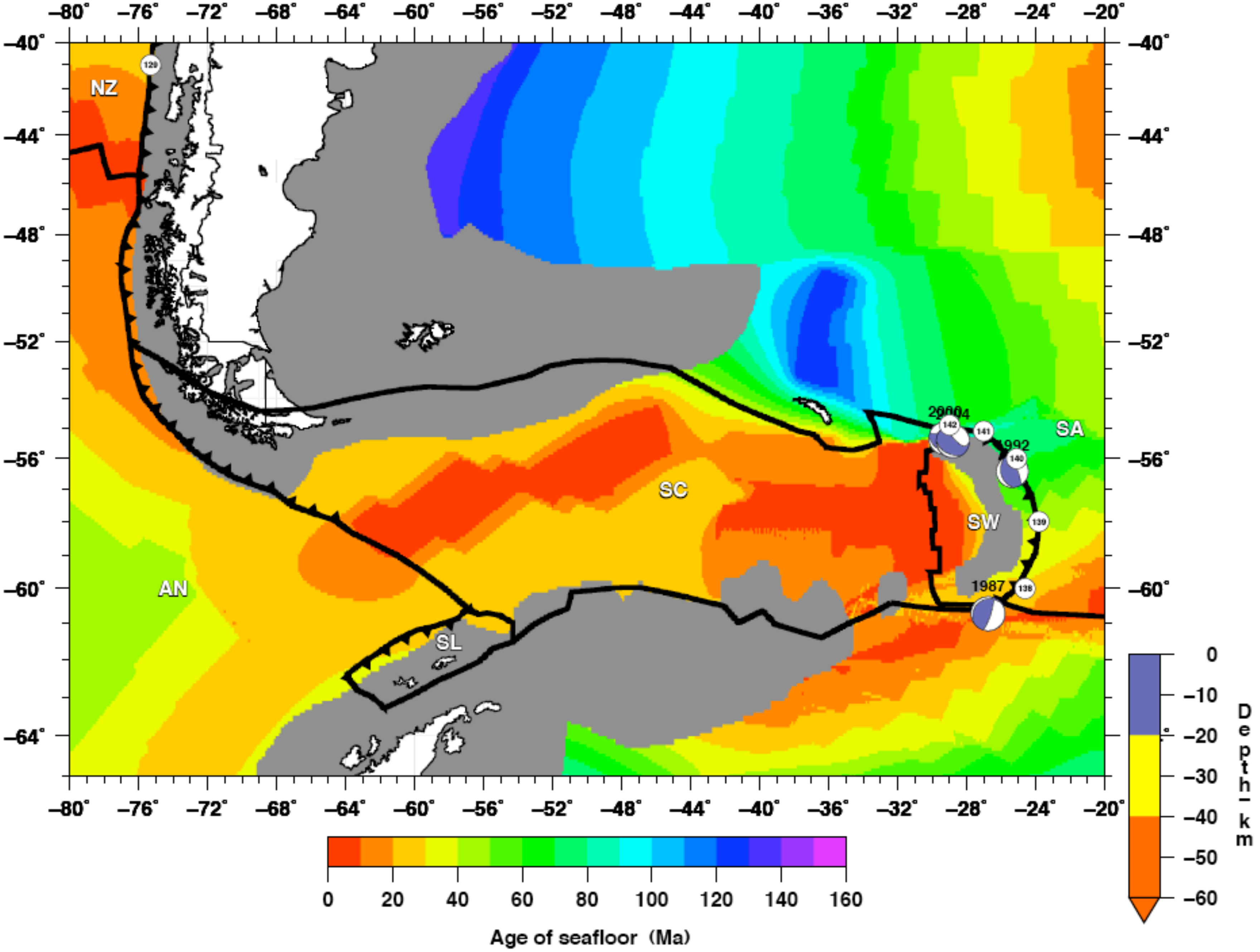–80˚
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Age of seafloor (Ma)
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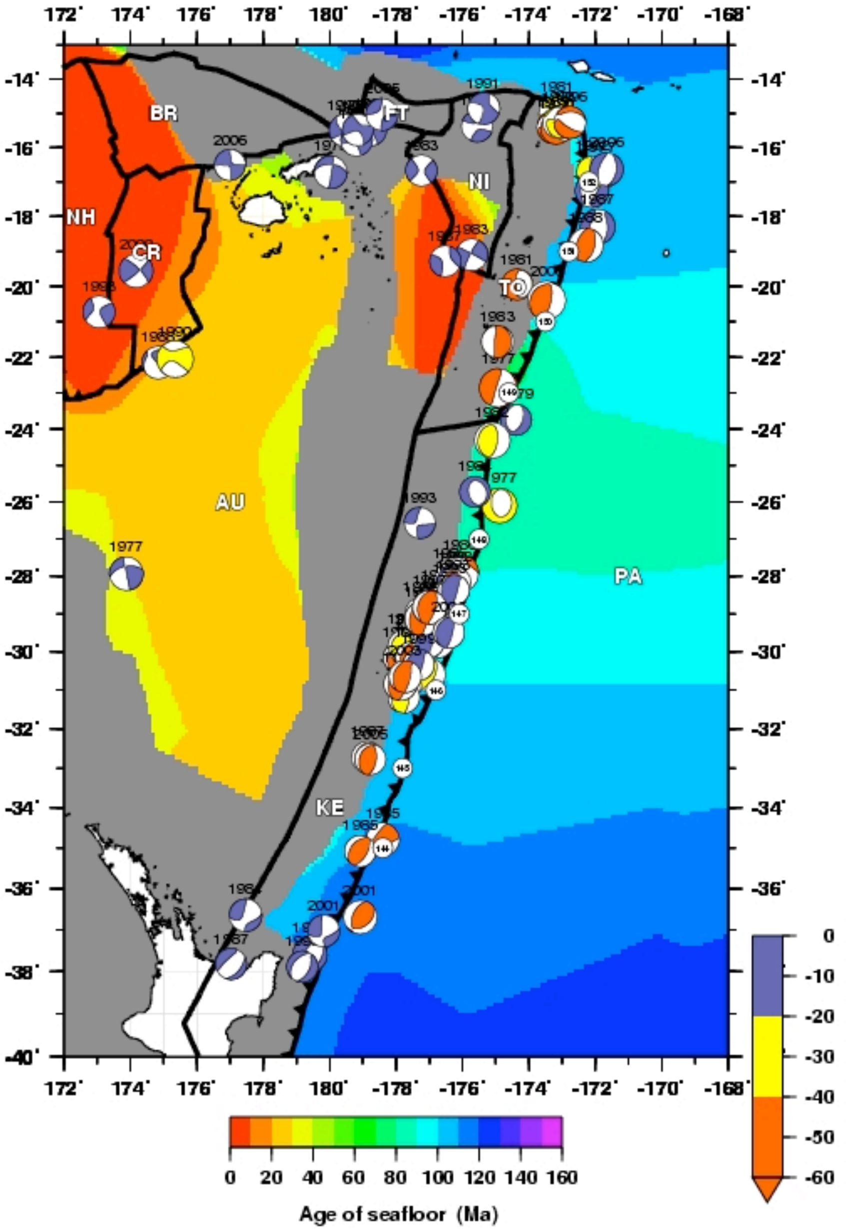
Depth – km



172˚ 174˚ 176˚ 178˚ 180˚ -178˚ -176˚ -174˚ -172˚ -170˚ -168˚
-14˚ -16˚ -18˚ -20˚ -22˚ -24˚ -26˚ -28˚ -30˚ -32˚ -34˚ -36˚ -38˚ -40˚
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Age of seafloor (Ma)
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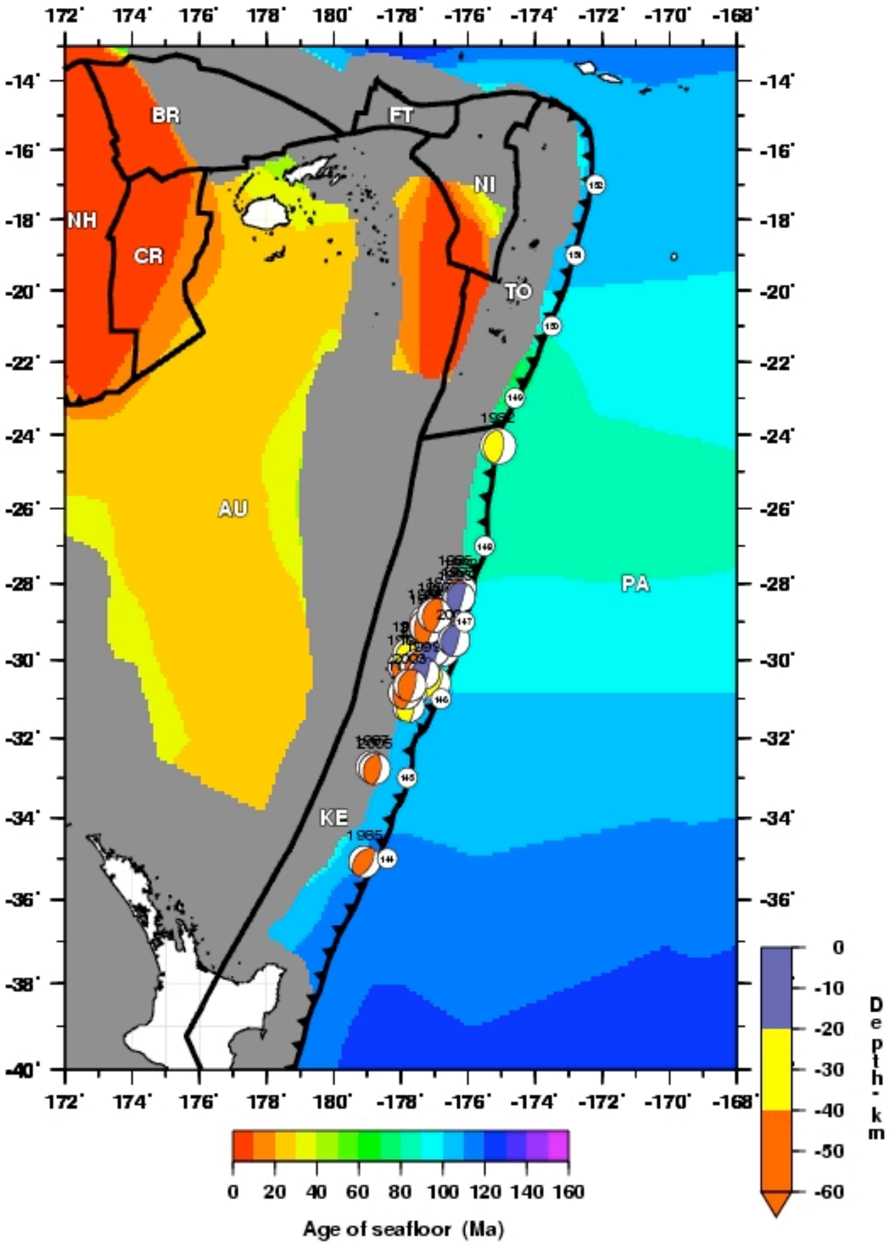

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Age of seafloor (Ma)
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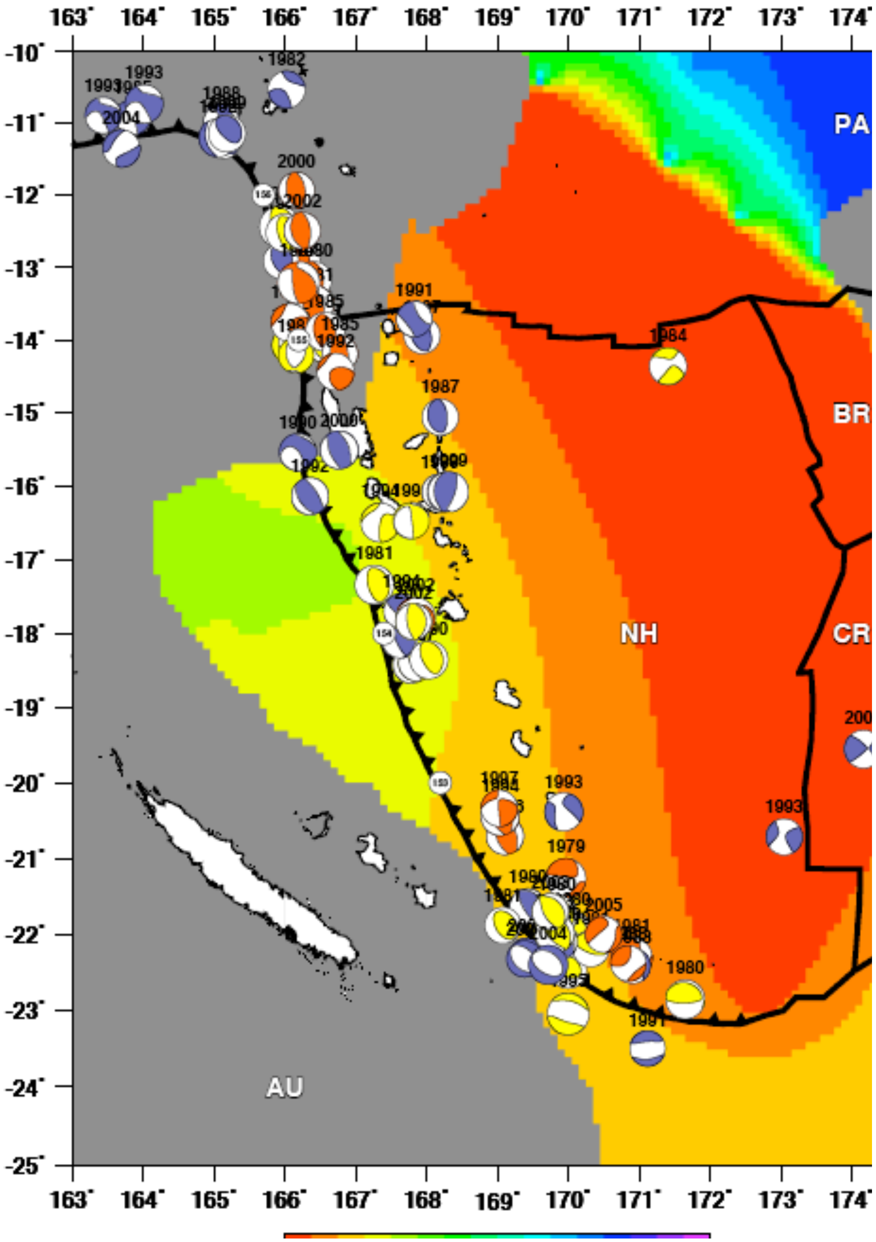
Depth - km



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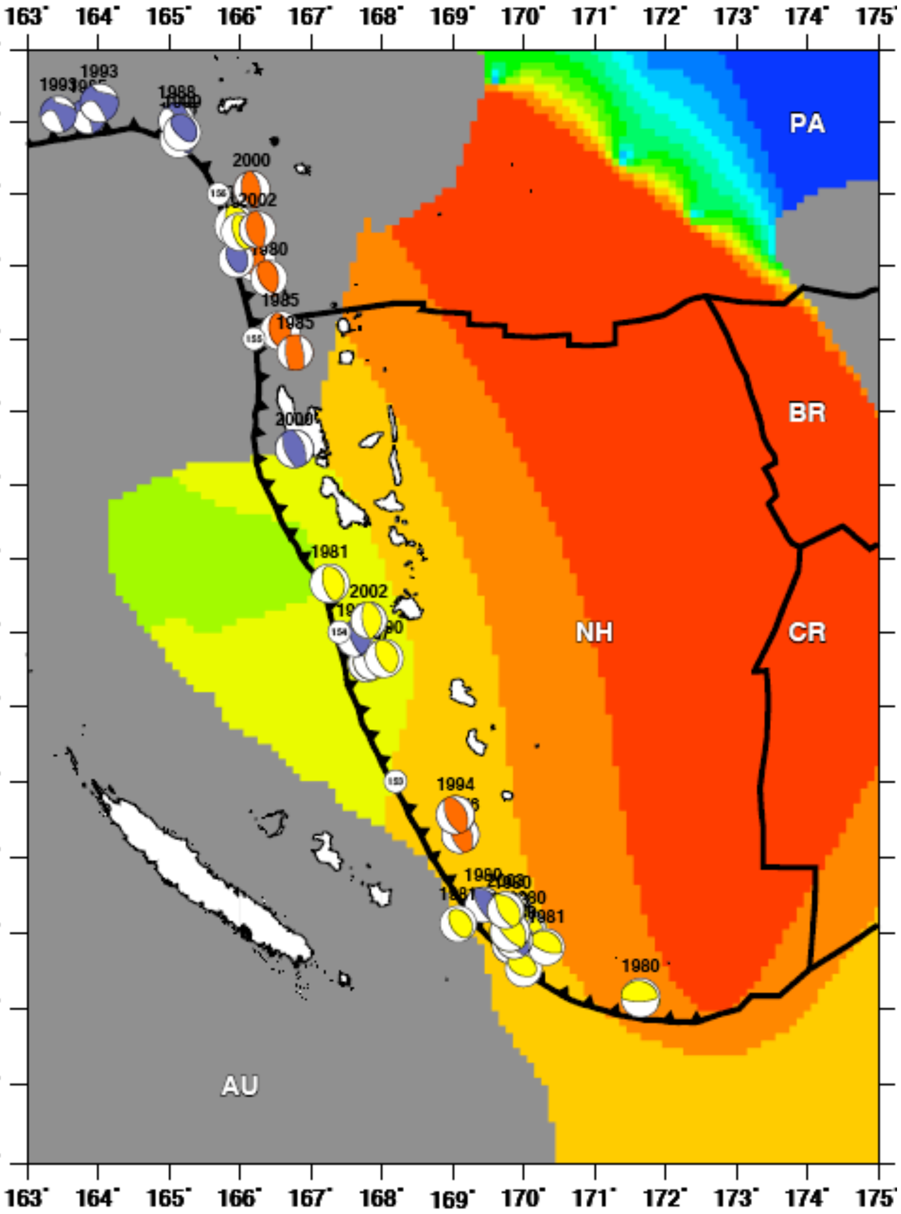

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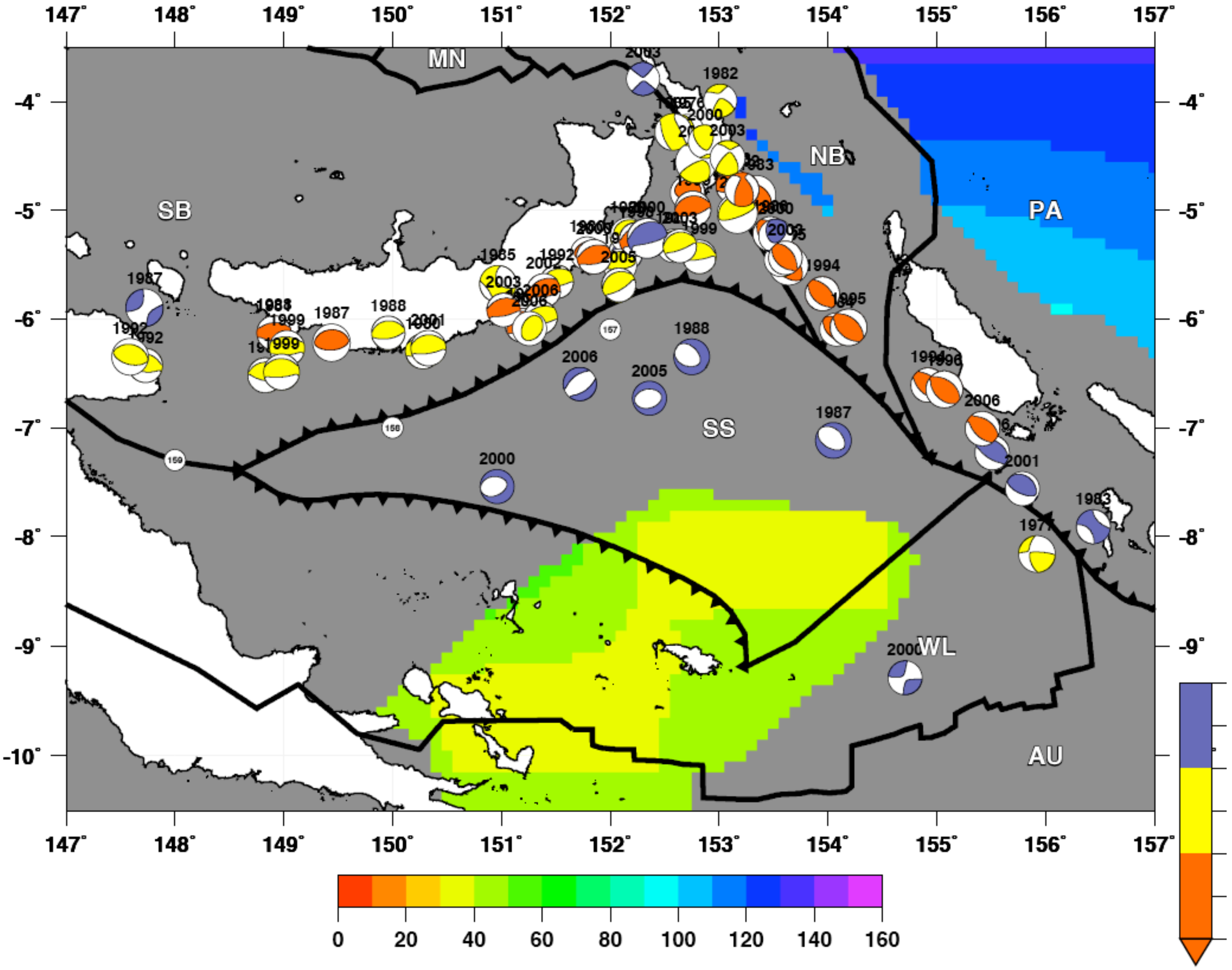

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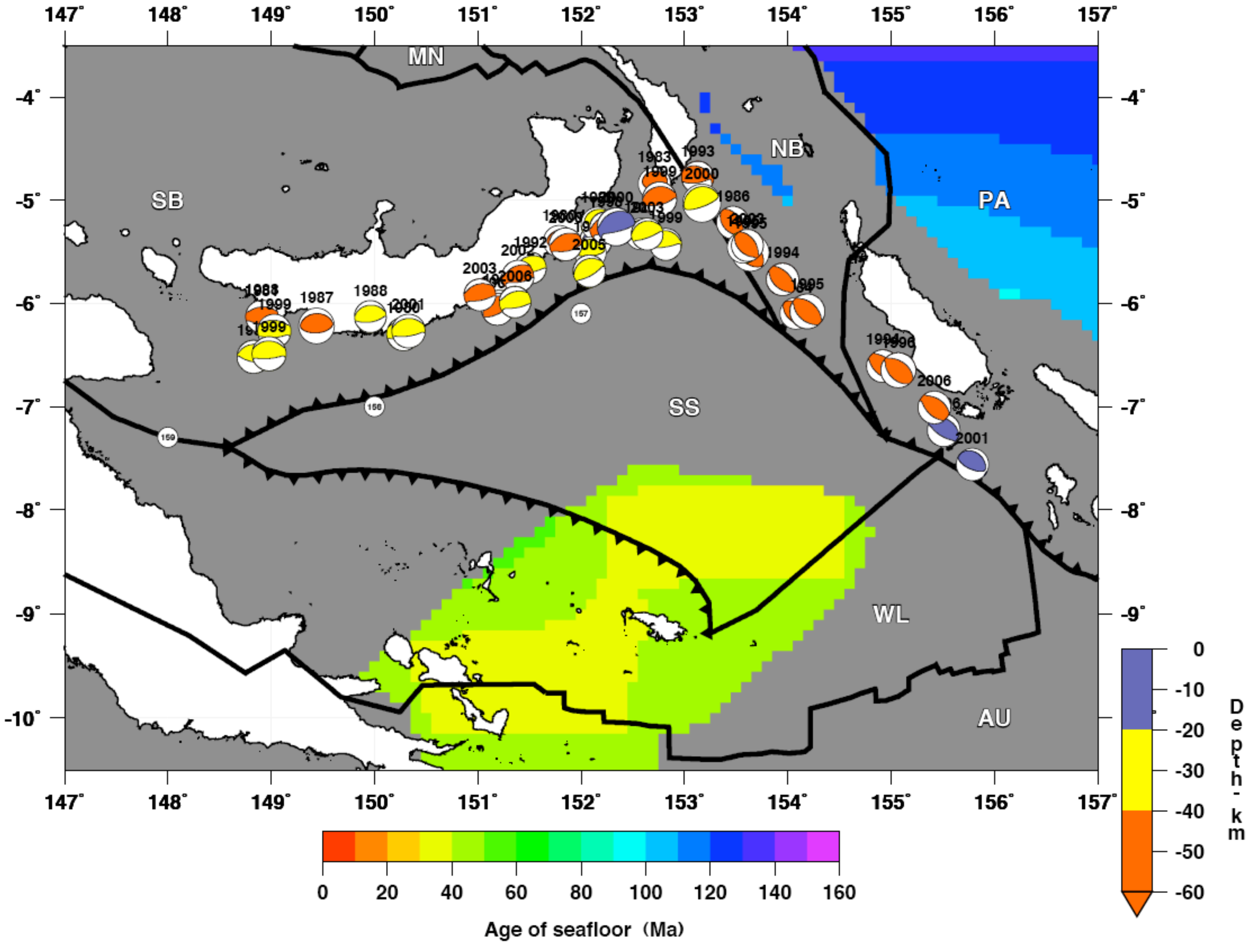
Age of seafloor (Ma)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Age of seafloor (Ma)
0
-10
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-40
-50
-60
Depth - km

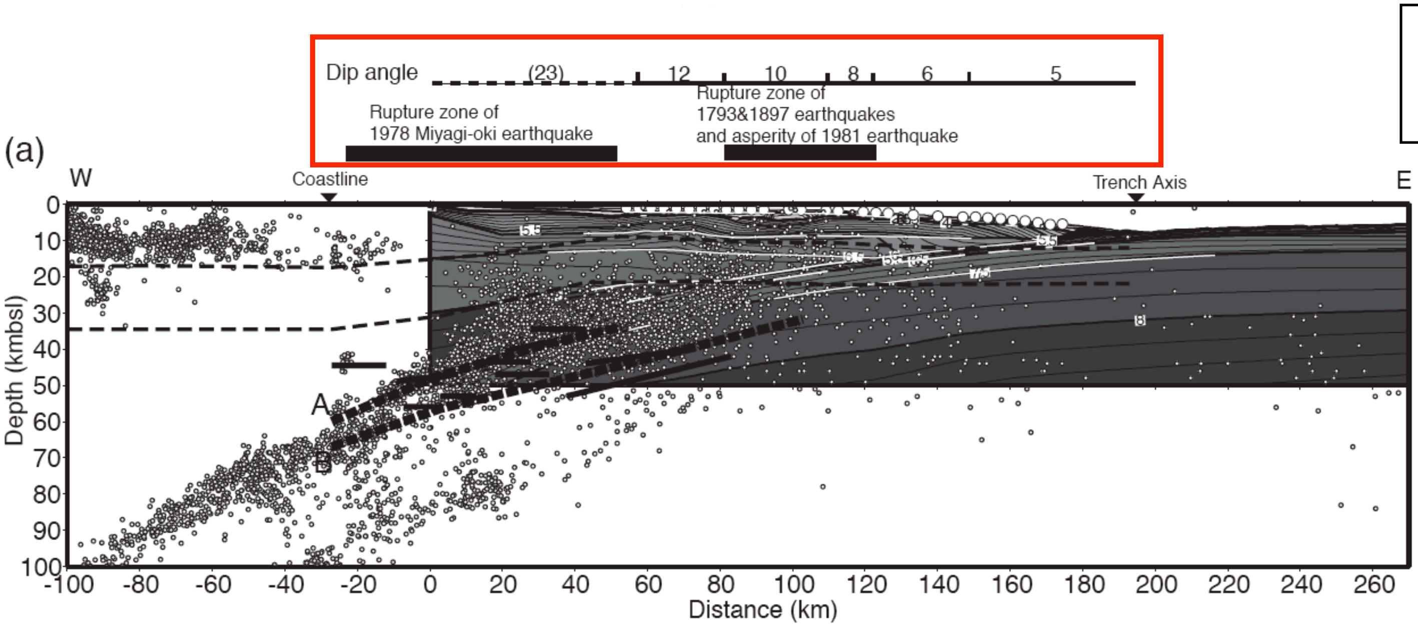
The age of subduction zone (SA)

Subduction zone	SA, Age Estimate (Ma)		Reference
	J86	here	
Andaman	100 ± 40	100	*Jarrard* (1986)
Sumatra	27 ± 3	200	*Hamilton* (1979)
Java - west	27 ± 3	27	*Jarrard* (1986)
Java - east	27 ± 3	27	*Jarrard* (1986)
Sulawesi	7 ± 4	7	*Jarrard* (1986)
Luzon - west	–	23	*Yumul Jr. et al.* (2003)
Philippine	6 ± 4	6	*Ozawa et al.* (2004); *Yumul Jr. et al.* (2003)
Ryukyu	55 ± 5	55	*Jarrard* (1986)
Nankai/Kyushu	175 ± 5	17	*Kimura et al.* (2005)
Mariana	45 ± 5	45	*Stern and Bloomer* (1992)
Izu–Bonin	45 ± 5	45	*Stern and Bloomer* (1992)
Japan - east	115 ± 5	$120 \pm 7^{\dagger}$	*Minoura and Hasegawa* (1992)
Kurile–Hokkaido	82 ± 16	82	*Jarrard* (1986)
Kamchatka	153 ± 10	153	*Jarrard* (1986)
Aleutian - central	56 ± 6	55	*Scholl et al.* (1986)
Aleutian - east	160 ± 10	160	*Jarrard* (1986)
Alaska	160 ± 10	160	*Jarrard* (1986)
Cascadia	175 ± 10	175	*Jarrard* (1986)
Jalisco	90 ± 3	90	*Jarrard* (1986)
Mexico	90 ± 3	90	*Jarrard* (1986)
Central America	100 ± 10	100	*Jarrard* (1986)
Columbia	242 ± 5	242	*Jarrard* (1986)
Peru	226 ± 19	226	*Jarrard* (1986)
Chile - north	226 ± 19	226	*Jarrard* (1986)
Chile - central	226 ± 19	226	*Jarrard* (1986)
Antilles - east	48 ± 4	48	*Jarrard* (1986)
Sandwich - east	30	45	*Barker* (2001)
Sandwich - north	30	45	*Barker* (2001)
Puysegur/Fiordland	–	12 ± 4	*Sutherland et al.* (2006)
Kermadec	30 ± 2	28	*Ballance et al.* (1999)
Tonga	24 ± 7	48	*McDougall* (1994)
New Hebrides	8 ± 3	11 ± 1	*Greene et al.* (1994)
New Britain	8 ± 3	8	*Petterson et al.* (1999)
Cotabato	–	4	
Negros/Sulu	–	4	
Luzon - east	–		
Chile - south	150 ± 6		*Jarrard* (1986)
Antilles - north	48 ± 4		*Jarrard* (1986)
Solomon - east	–	8	*Petterson et al.* (1999)
Solomon - west	8 ± 3	8	*Petterson et al.* (1999)

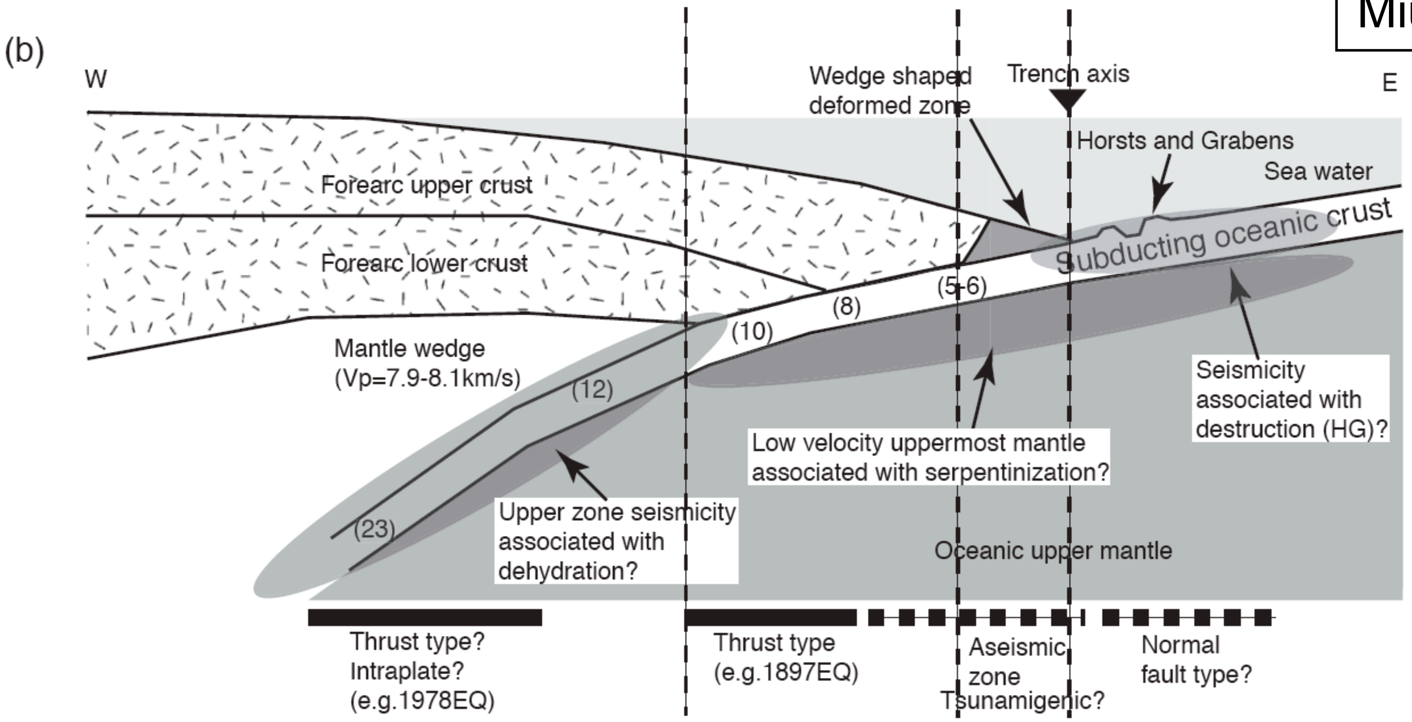
The seismogenic dip angle

index	name	CMT ($M_w \geq 6.5$)			J86	here	Reference
		#	depth	α_0	α_0	α_0	
1	Andaman	6	18 ± 7	21 ± 13	19	15	*Engdahl et al.* (2007)
2	Sumatra	10	23 ± 10	16 ± 10	16	7	(multiple options)
3	Java - west	2	33 ± 18	19 ± 12	16	8	*Kopp et al.* (2002)
4	Java - east	1	15	7	16	10	*Wittwer et al.* (2006)
5	Sulawesi	9	26 ± 7	18 ± 9	18	8	*Kopp et al.* (1999)
6	Luzon - west	0			–	NA	*Hayes and Lewis* (1984)
7	Philippine	22	27 ± 11	26 ± 9	43	30	
8	Ryukyu	1	38	24	19	8	*Kodaira et al.* (1996)
9	Nankai/Kyushu	4	27 ± 5	15 ± 5	10	8	(multiple options)
10	Mariana	1	22	16	19	NA	
11	Izu-Bonin	1	15	22	22	6	*Takahashi et al.* (1998)
12	Japan - east	13	30 ± 10	16 ± 4	15	8	(multiple options)
13	Kurile/Hokkaido	32	30 ± 10	20 ± 6	22	13	*Nakanishi et al.* (2004)
14	Kamchatka	9	41 ± 14	29 ± 3	19	15	*Bürgmann et al.* (2005)
15	Aleutian - central	29	26 ± 7	21 ± 4	25	21	*Cross and Freymueller* (2007)
16	Aleutian - east	4	33 ± 4	23 ± 3	9	15	
17	Alaska	9	26 ± 8	12 ± 5	7	8	*Ye et al.* (1997)
18	Cascadia	1	15	9	9 ± 4	11	*Flück et al.* (1997)
19	Jalisco	2	21 ± 8	11 ± 2	19	14	
20	Mexico	24	23 ± 8	16 ± 5	14	14	
21	Central America	10	29 ± 8	21 ± 7	30	14	(multiple options)
22	Columbia	7	22 ± 7	18 ± 5	22	14	
23	Peru	2	18 ± 5	16 ± 3	14	14	
24	Chile - north	22	31 ± 11	20 ± 5	20	14	
25	Chile - central	6	38 ± 8	23 ± 4	16	14	
26	Antilles - east	0			16	NA	
27	Sandwich - east	1	15	16	31	16	*Vanneste and Larter* (2002)
28	Sandwich - north	3	14 ± 2	24 ± 4	–	16	*Vanneste and Larter* (2002)
29	Puysegur/Fiordland	5	24 ± 11	24 ± 9	–	NA	*Sutherland et al.* (2006)
30	Kermadec	31	34 ± 14	26 ± 6	23	26	
31	Tonga	1	29	22	23	26	
32	New Hebrides	35	28 ± 12	31 ± 8	36	32	
33	New Britain	30	39 ± 13	27 ± 7	30 ± 5	27	
	Cotabato	2	31 ± 3	30 ± 7	–		
	Negros/Sulu	2	24 ± 8	28 ± 11	–		
	Luzon - east	2	29 ± 9	27 ± 1	–		
	Antilles - north	0			16		
	Chile - south	0			–		
	Solomon - east	20	24 ± 11	33 ± 12	–		*Miura et al.* (2004)
	Solomon - west	12	43 ± 13	40 ± 6	35 ± 5		
TOTAL		371					

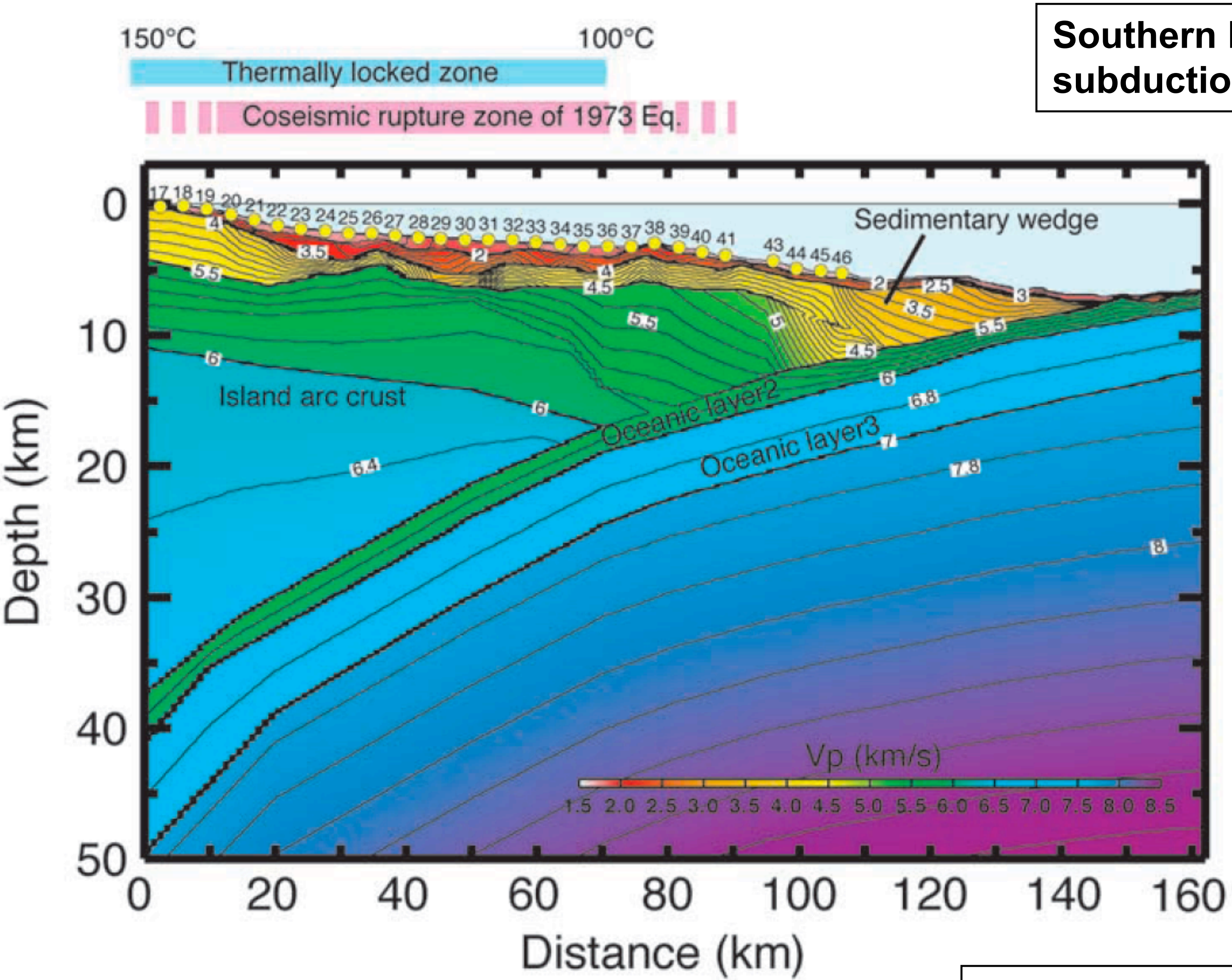
Eastern Japan subduction zone



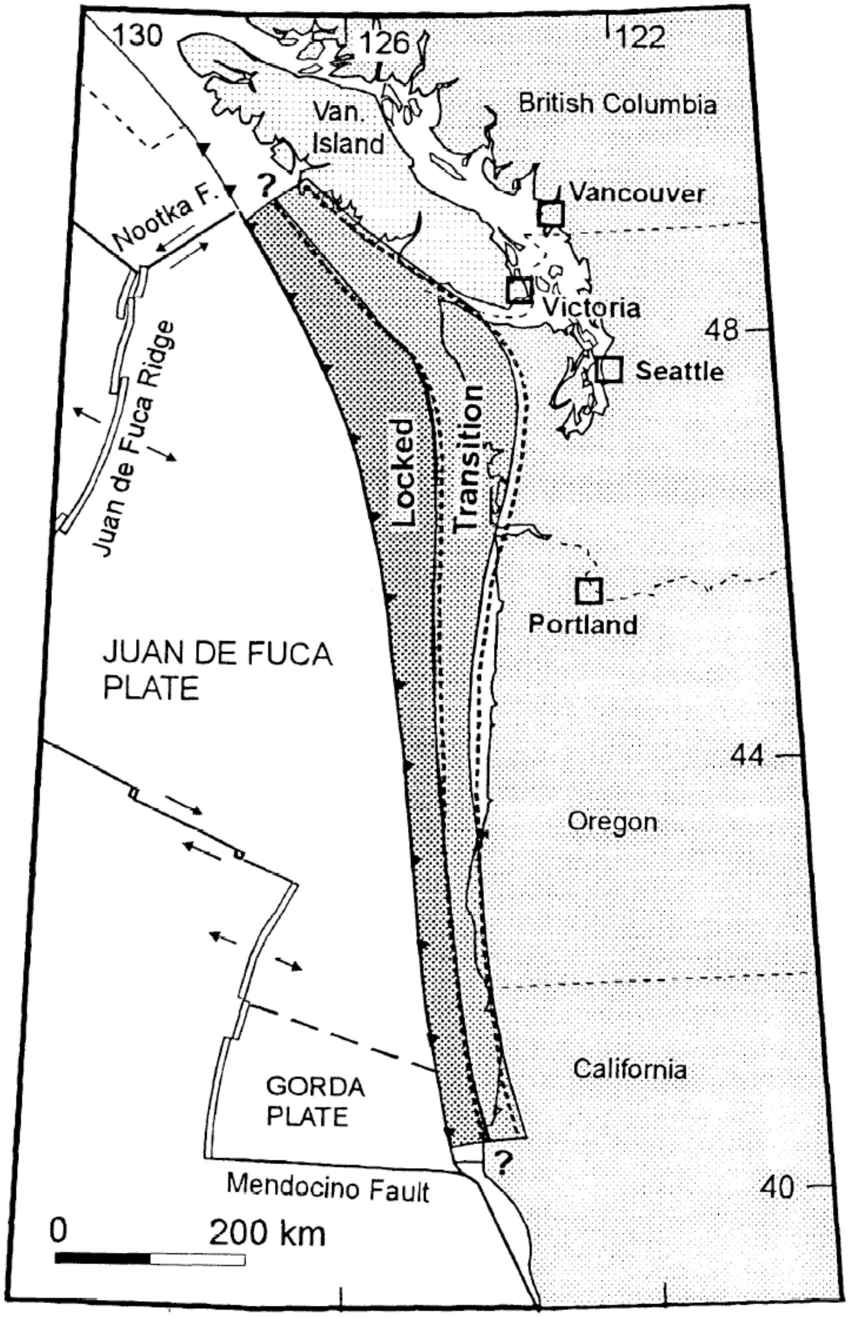
Miura et al. (2005)



Southern Kurile subduction zone



Nakanishi et al. (2004)

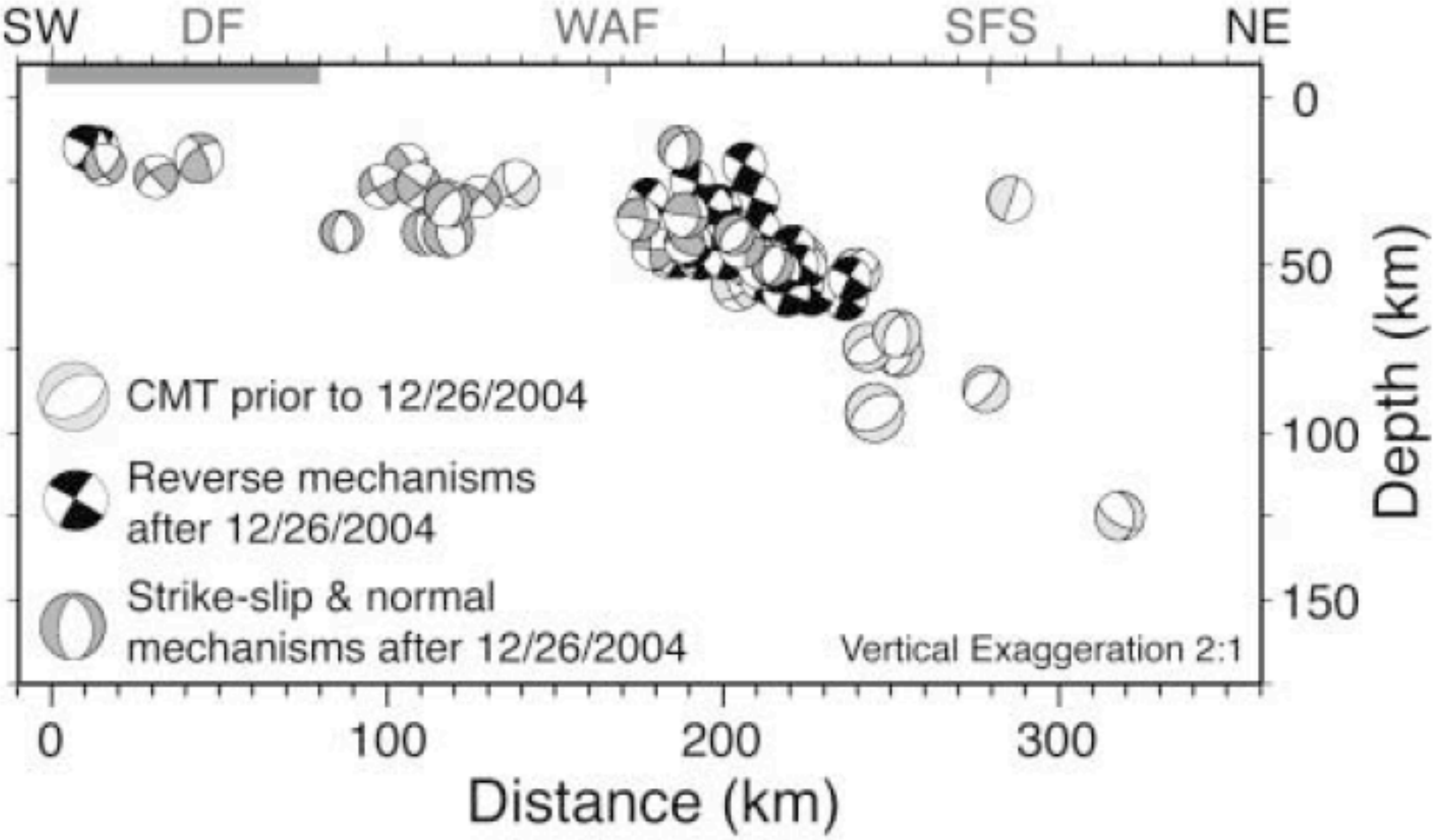


Fluck, Hyndman, Wang (1997)

Southernmost Andaman subduction zone

Dips angle on thrust events = 27 +/- 4

Harvard CMT = 8



Engdahl et al. (2007)

The maximum moment magnitude interplate thrust

name	M_w max			M_w max event — CMT			M_w max event — here		Reference
	RK80	CMT	here	date	(lon, lat)	depth-km	date	(lon, lat), depth	
Andaman	–	9.0	9.2	2004.12.26	(94.3, 3.1)	29	CMT		*Park et al.* (2005)
Sumatra	7.9	8.6	8.6	2005.03.28	(97.1, 1.7)	26	CMT		CMT
Java - west	7.1	7.7	7.7	2006.07.17	(107.8, -10.3)	20	CMT		CMT
Java - east	(7.1)	7.8	7.8	06.02.1994	(113.0, -11.0)	15	CMT		CMT
Sulawesi	–	7.9	7.9	1996.01.01	(119.9, 0.7)	15	CMT		CMT
Luzon - west	–	xx	7.0						
Philippine	–	7.5	7.5	1989.12.15	(127.0, 7.9)	37	CMT		CMT
Ryukyu	8.0	6.6	7.0	1996.10.18	(131.3, 30.5)	22			
Nankai/Kyushu	–	xx	8.3				1707.xx.xx	(xxx, xxx)	*Aida* (1981b)
Mariana	7.2	7.0	7.0	2001.10.12	(145.1, 12.9)	42	CMT		CMT
Izu–Bonin	7.2	6.5	7.0	2005.01.19	(142.0, 34.0)	15			
Japan - east	8.2	7.7	8.0	1994.12.28	(143.0, 40.6)	28	1896.06.15	(xxx, xxx)	*Tanioka and Satake* (1996)
Kurile/Hokkaido	8.5	8.3	8.5	2006.11.15	(154.3, 46.8)	13	1963.10.13	(xxx, xxx)	*Kanamori* (1970a)
Kamchatka	9.0	7.8	9.0	1997.12.05	(161.9, 54.3)	34	1952.11.04	(xxx, xxx)	*Kanamori* (1976)
Aleutian - central	(8.6)	7.9	8.7	1996.06.10	(-177.4, 51.1)	29	1965.02.04	(xxx, xxx)	*Wu and Kanamori* (1973)
Aleutian - east	8.6	6.9	8.6	1980.03.24	(-167.7, 53.0)	36	1957.03.09	(xxx, xxx)	*Johnson et al.* (1994)
Alaska	9.2	7.0	9.2	1989.09.04	(-157.2, 55.7)	26	1964.03.28	(xxx, xxx)	*Kanamori* (1970b)
Cascadia	–	7.2	9.0	1992.04.25	(-124.3, 40.2)	15	1700.01.26	(xxx, xxx)	*Satake et al.* (1996, 2003)

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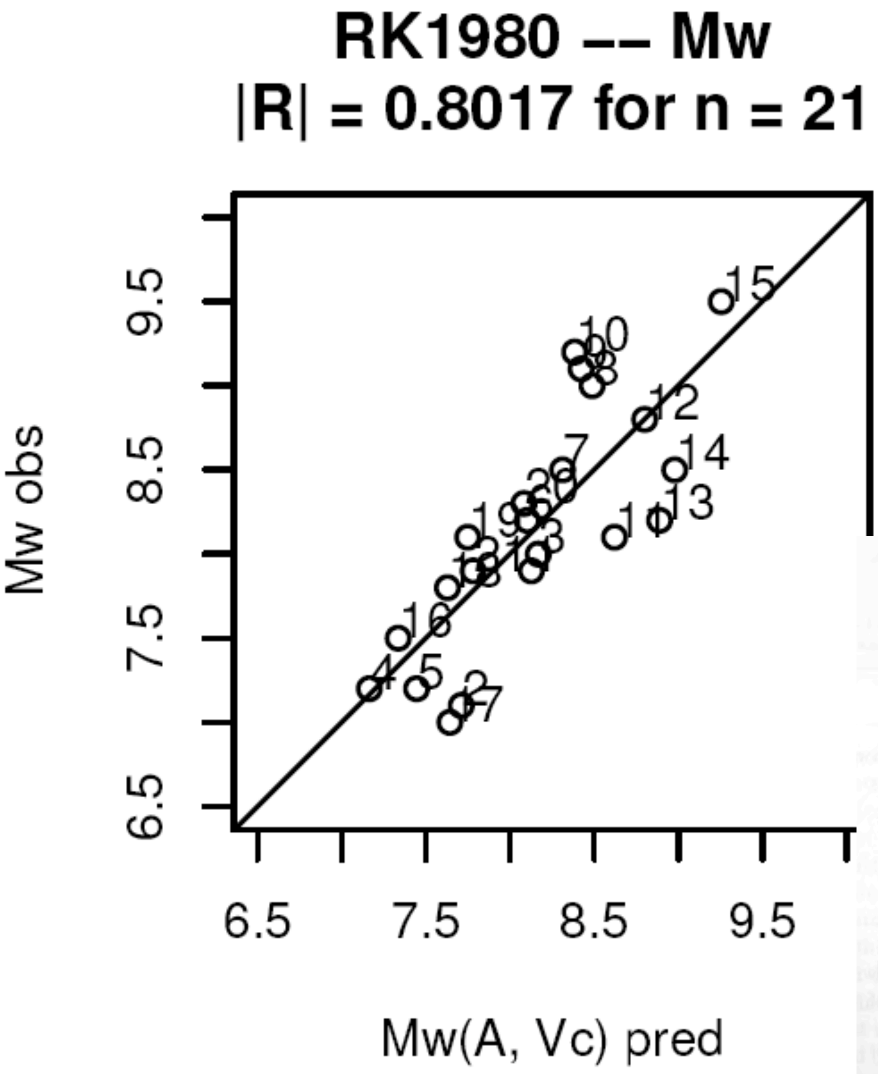
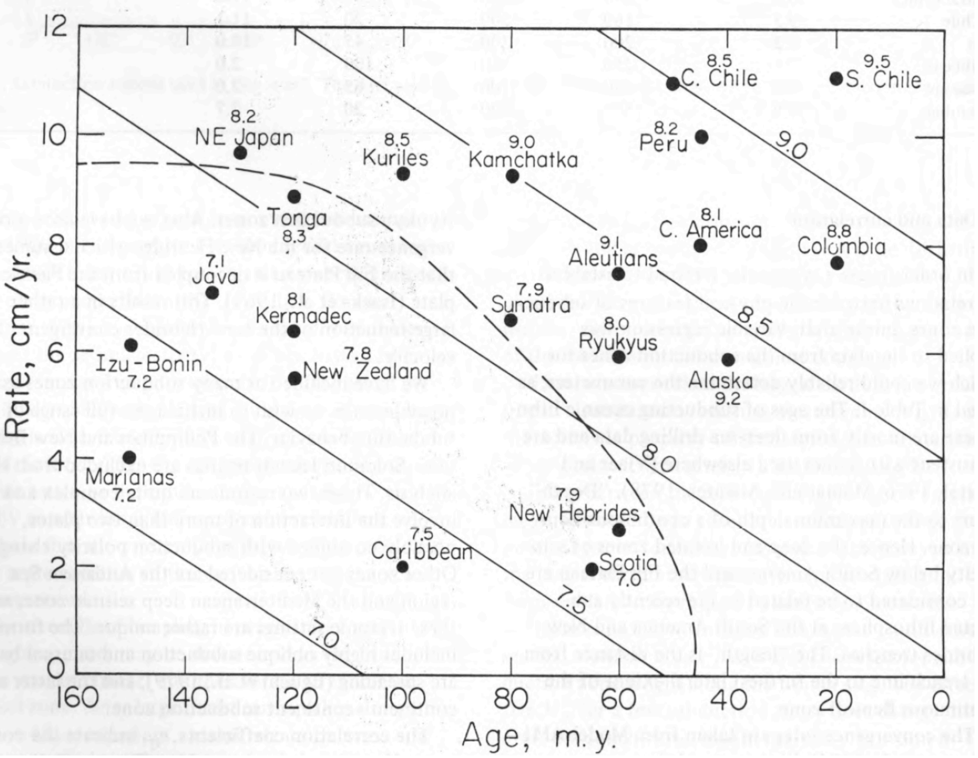
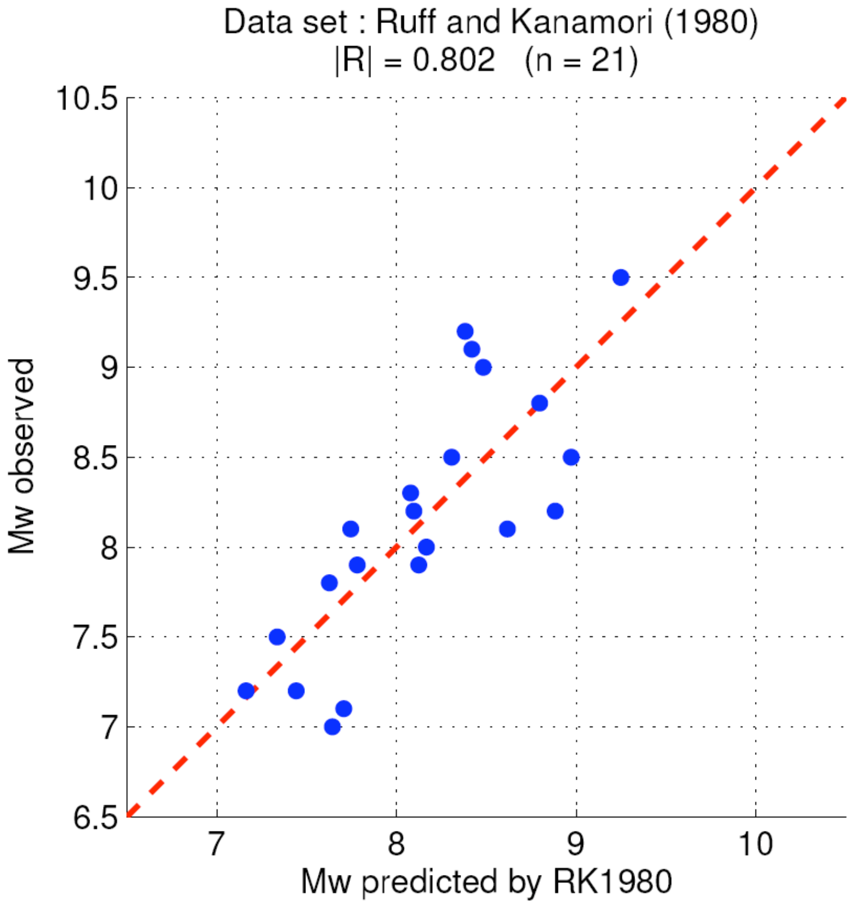
⋮ ⋮ ⋮ ⋮ ⋮

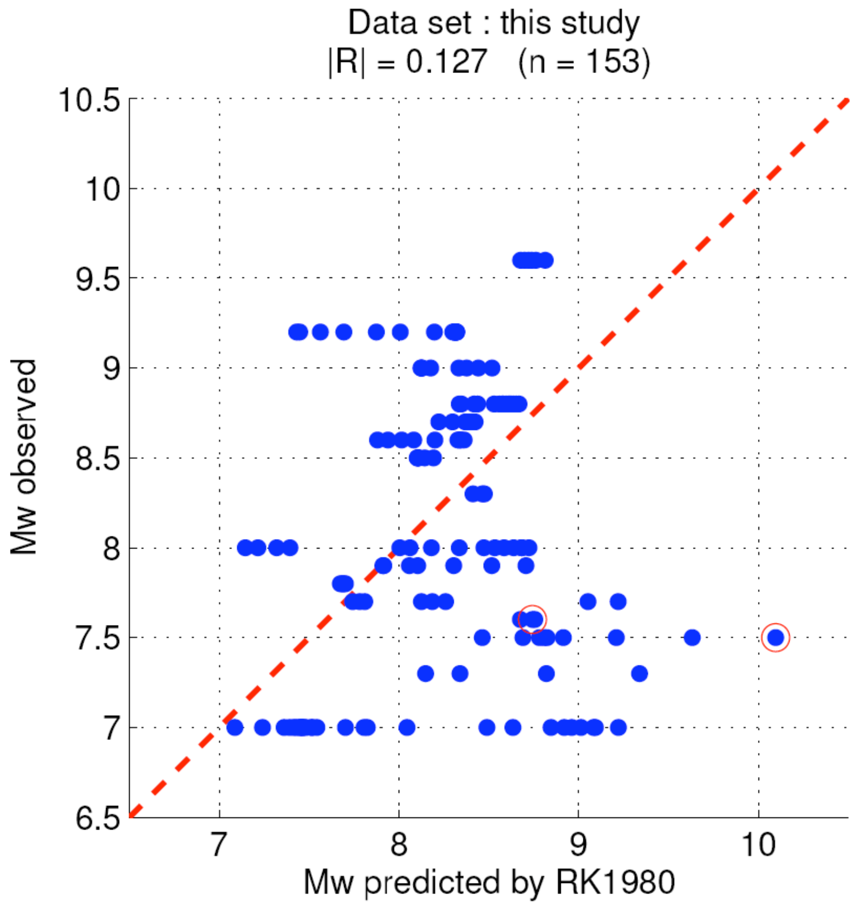
Jalisco	(8.1)	8.0	8.0	1995.10.09	(-104.8, 19.3)	15	CMT		CMT
Mexico	8.1	8.0	8.0	1985.09.19	(-102.0, 17.9)	21	CMT		CMT
Central America	(8.1)	7.6	7.6	1992.09.02	(-87.8, 11.2)	15	CMT		CMT
Colombia	8.8	8.1	8.8	1979.12.12	(-78.8, 2.3)	20	1906.01.31	(xxx, xxx)	*Kanamori and McNally* (1982)
Peru	8.2	7.5	8.8	1996.02.21	(-80.2, -10.0)	15	1746.10.29	(xxx, xxx)	*Beck and Nishenko* (1990)
Chile - north	8.5	8.4	8.8	2001.06.23	(-72.7, -17.3)	30	1868.08.13	(xxx, xxx)	*Dorbath et al.* (1990)
Chile - central	9.5	7.9	9.6	1985.03.03	(-71.7, -33.9)	41	1960.05.22	(xxx, xxx)	*Kanamori and Cipar* (1974)
Antilles - east	7.5	xx	7.0						
Sandwich - east	7.0	6.9	7.0	1987.01.30	(-26.8, -60.7)	15			
Sandwich - north	(7.0)	6.7	7.7	2000.11.07	(-29.2, -55.3)	16	1929.06.27	(xxx, xxx)	*Gutenberg and Richter* (1954)
Puysegur/Fiordland	–	7.3	7.3	1979.10.12	(165.8, -46.5)	20	CMT		CMT
Kermadec	8.1	7.9	7.9	1976B.01.14	(-176.8, -28.7)	18	CMT		CMT
		7.8		1976A.01.14	(-177.0, -29.7)	47	CMT		CMT
Tonga	8.3	7.5	7.5	1982.12.19	(-175.1, -24.3)	29	CMT		CMT
New Hebrides	7.9	7.7	7.7	1980.07.17	(166.0, -12.4)	34	CMT		CMT
New Britain	–	7.8	7.3	2000.11.16	(153.2, -5.0)	31	1987.10.16	(149.4, -6.2), 48	CMT
		7.8		2000.11.17	(153.3, -5.3)	17			
Cotabato	–	8.0	8.0	1976.08.16	(123.8, 7.1)	33	CMT		CMT
Negros/Sulu	–	6.9	7.0	1978.06.14	(122.4, 8.2)	30			
Luzon - east	–	7.2	7.2	1977.03.18	(122.6, 16.4)	35	CMT		CMT
Chile - south	–	xx	7.0						
Antilles - north	(7.5)	xx	8.0				1843.02.08	(xxx, xxx)	*Robson* (1964)
Solomon - east	–	7.5	7.5	1988.08.10	(160.8, -10.5)	16	CMT		CMT
Solomon - west	–	7.7	7.6	1995.08.16	(153.6, -5.5)	46	1975.07.20	(155.1, 6.6), 16	*Lay and Kanamori* (1980)



Applying my analysis to the same data set as Ruff and Kanamori (1980) and using the same set of available parameters, I get the exact same result (as expected).



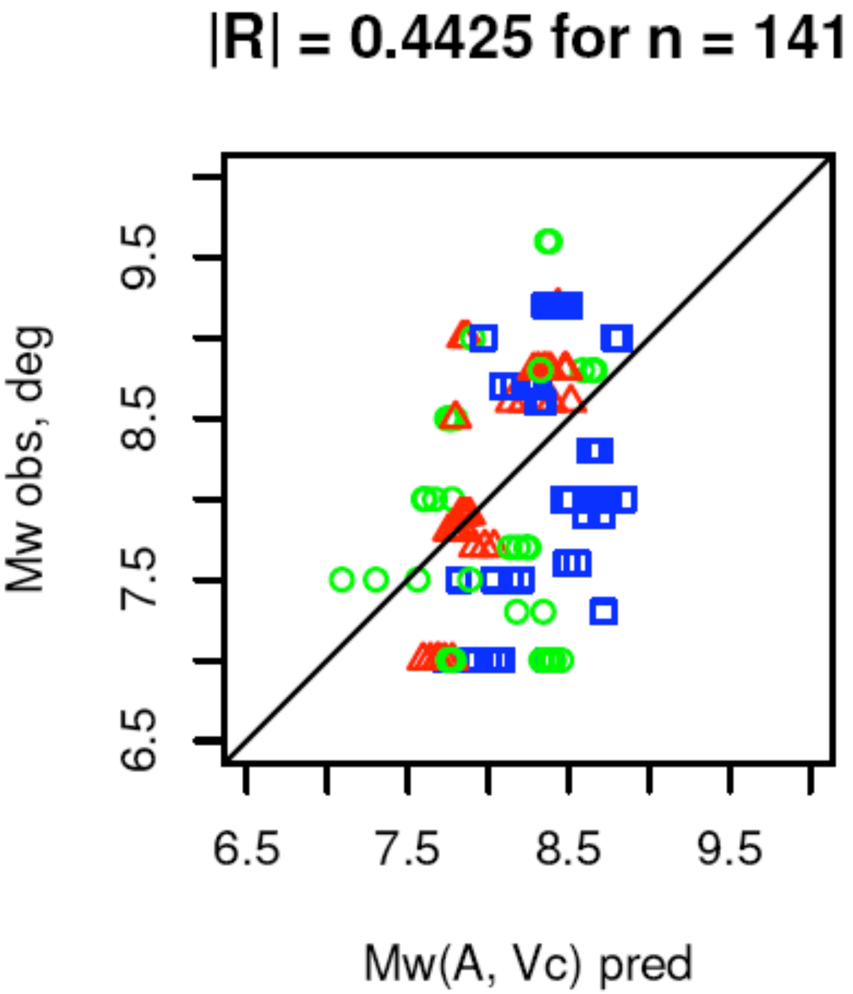

Data set : Ruff and Kanamori (1980)
|R| = 0.802 (n = 21)


Data set : this study
|R| = 0.127 (n = 153)

$$M_w = 7.95 + 0.0133\,V_c - 0.00879\,A, \qquad R = 0.802$$

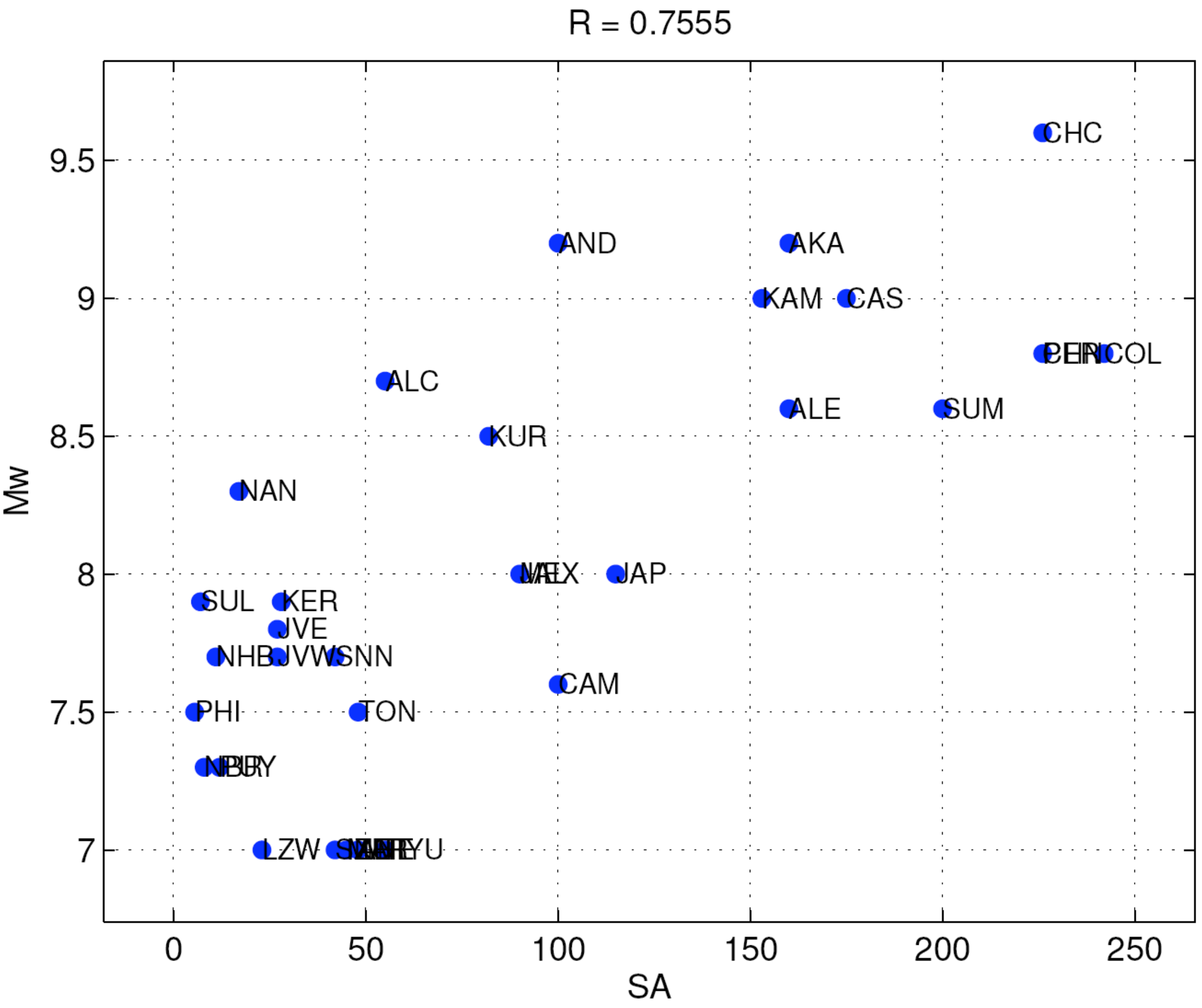
Tonga : 10.1 = 7.95 + 0.0133 (230) - 0.00879 (104)

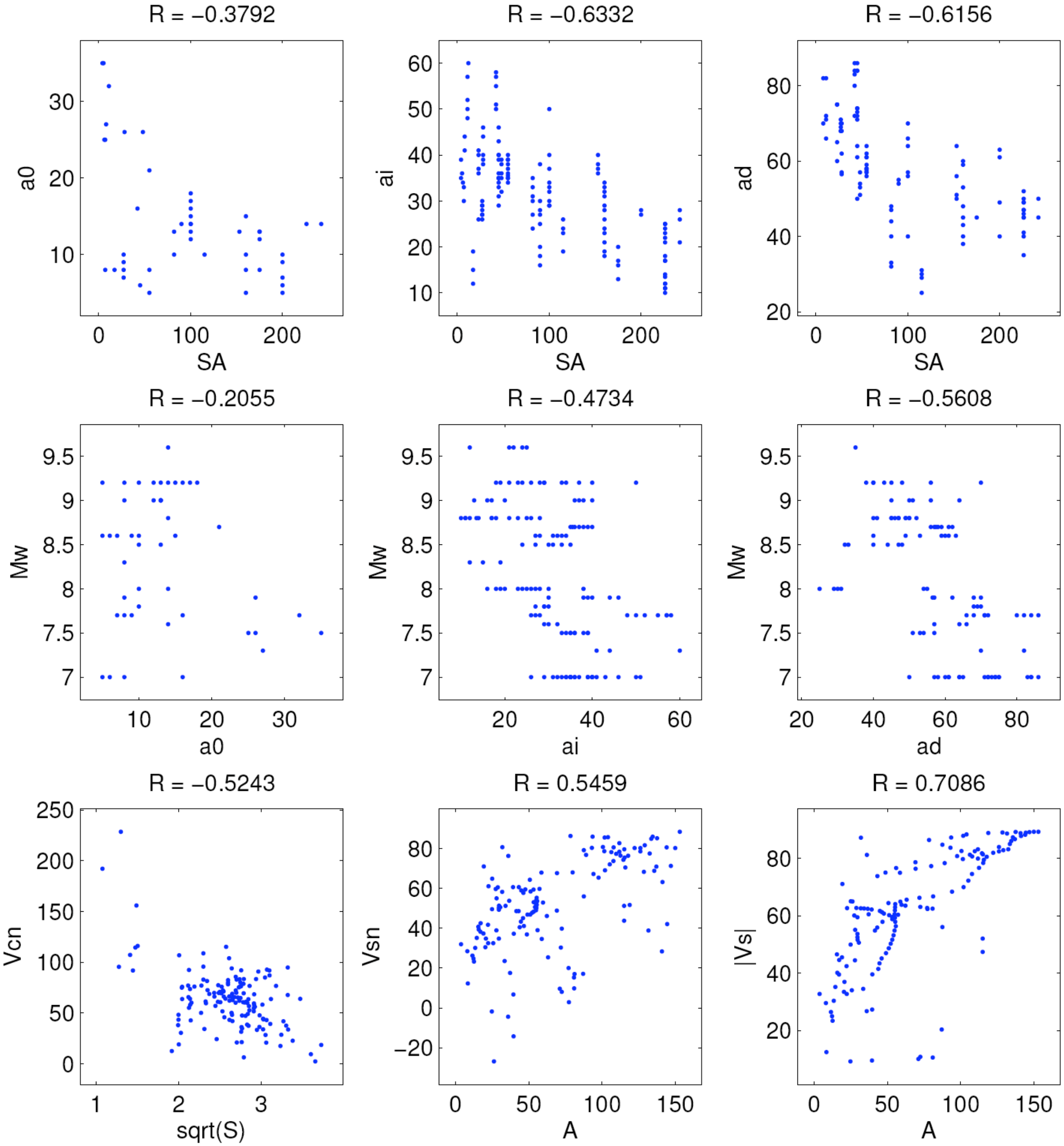
Nicaragua : 8.74 = 7.95 + 0.0133 (72) - 0.00879 (19)

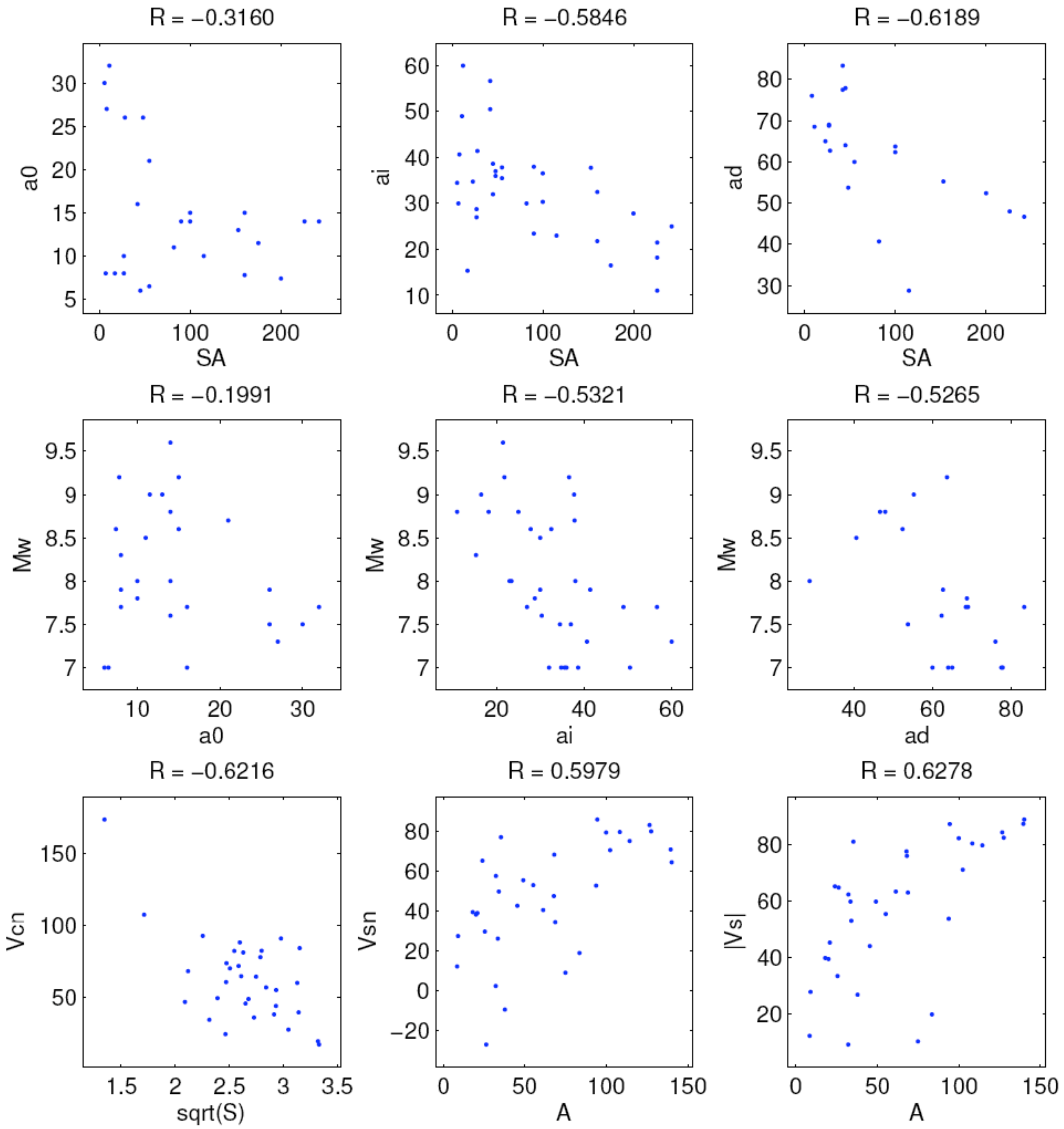


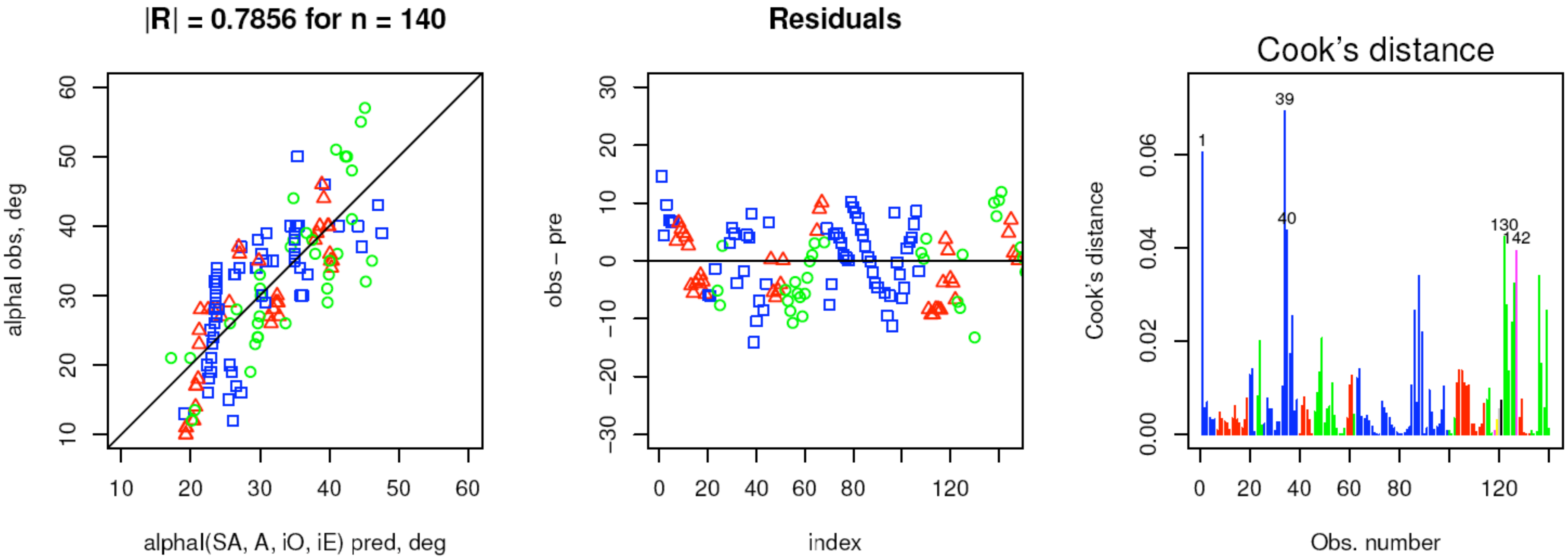
If we FORCE the model to have Vc and A, then we obtain a very poor fit.

--> Vc and A do not explain the variation in Mw in the new data set.


R = 0.7555
Mw
SA
9.5
9
8.5
8
7.5
7
0
50
100
150
200
250
CHC
AND
AKA
KAM
CAS
COL
ALC
ALE
SUM
KUR
NAN
JAP
SUL
KER
JVE
NHB
JVW
SNN
CAM
PHI
TON
LZW
RYU


R = −0.3792
a0
SA
0
100
200
10
20
30
R = −0.6332
ai
SA
10
20
30
40
50
60
R = −0.6156
ad
SA
20
40
60
80
R = −0.2055
Mw
a0
7
7.5
8
8.5
9
9.5
R = −0.4734
Mw
ai
R = −0.5608
Mw
ad
R = −0.5243
Vcn
sqrt(S)
0
50
100
150
200
250
1
2
3
R = 0.5459
Vsn
A
−20
0
20
40
60
80
50
150
R = 0.7086
|Vs|
A


R = −0.3160
a0
SA
5
10
15
20
25
30
0
100
200
R = −0.5846
ai
SA
10
20
30
40
50
60
0
100
200
R = −0.6189
ad
SA
30
40
50
60
70
80
0
100
200
R = −0.1991
Mw
a0
7
7.5
8
8.5
9
9.5
10
20
30
R = −0.5321
Mw
ai
7
7.5
8
8.5
9
9.5
20
40
60
R = −0.5265
Mw
ad
7
7.5
8
8.5
9
9.5
40
60
80
R = −0.6216
Vcn
sqrt(S)
50
100
150
1.5
2
2.5
3
3.5
R = 0.5979
Vsn
A
−20
0
20
40
60
80
0
50
100
150
R = 0.6278
|Vs|
A
20
40
60
80
0
50
100
150



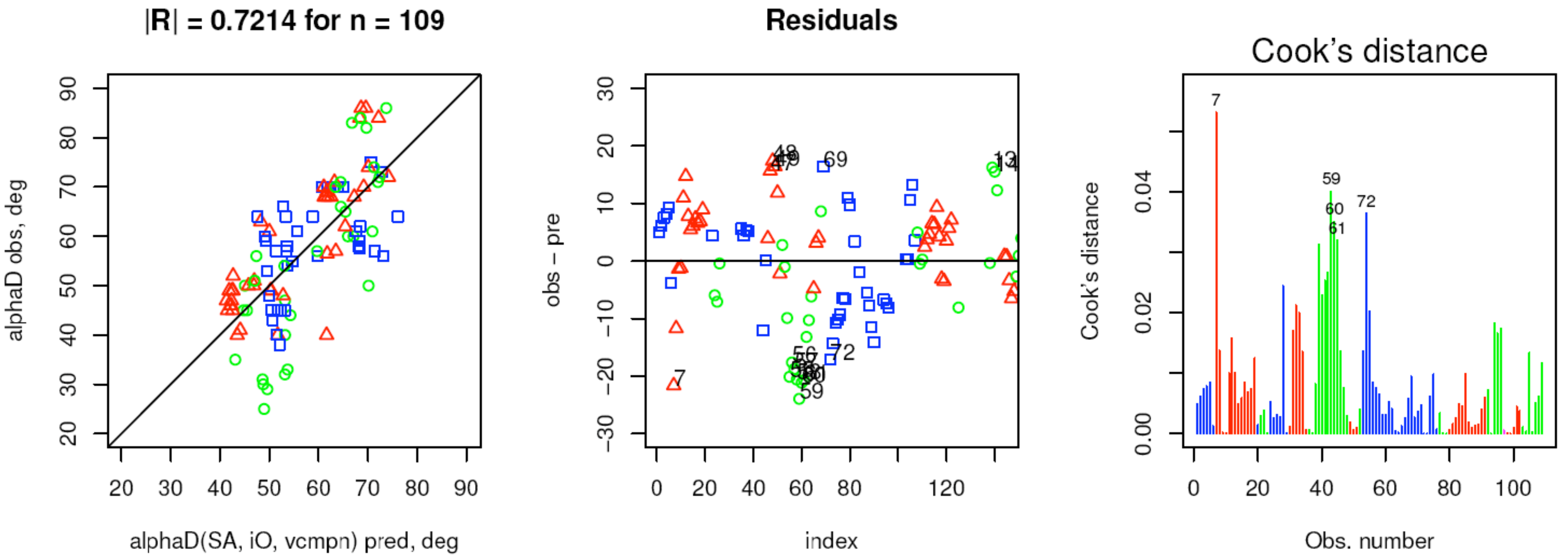
$$\alpha_i \quad = \quad 21.8 + 7.4\,O + 8.1\,E + 1.03\sqrt{A} - 0.036\,SA \qquad\qquad |R| = 0.7856$$

A steeper intermediate dip is promoted by:

- a younger subduction zone
- an older subducting slab
- an upper plate that is oceanic
- a subduction transect near the edge of a subduction zone

$$\boxed{\alpha_i \quad = \quad 21.8 + 7.4\,O + 8.1\,E + 1.03\sqrt{A} - 0.036\,SA \qquad\qquad |R| = 0.7856}$$

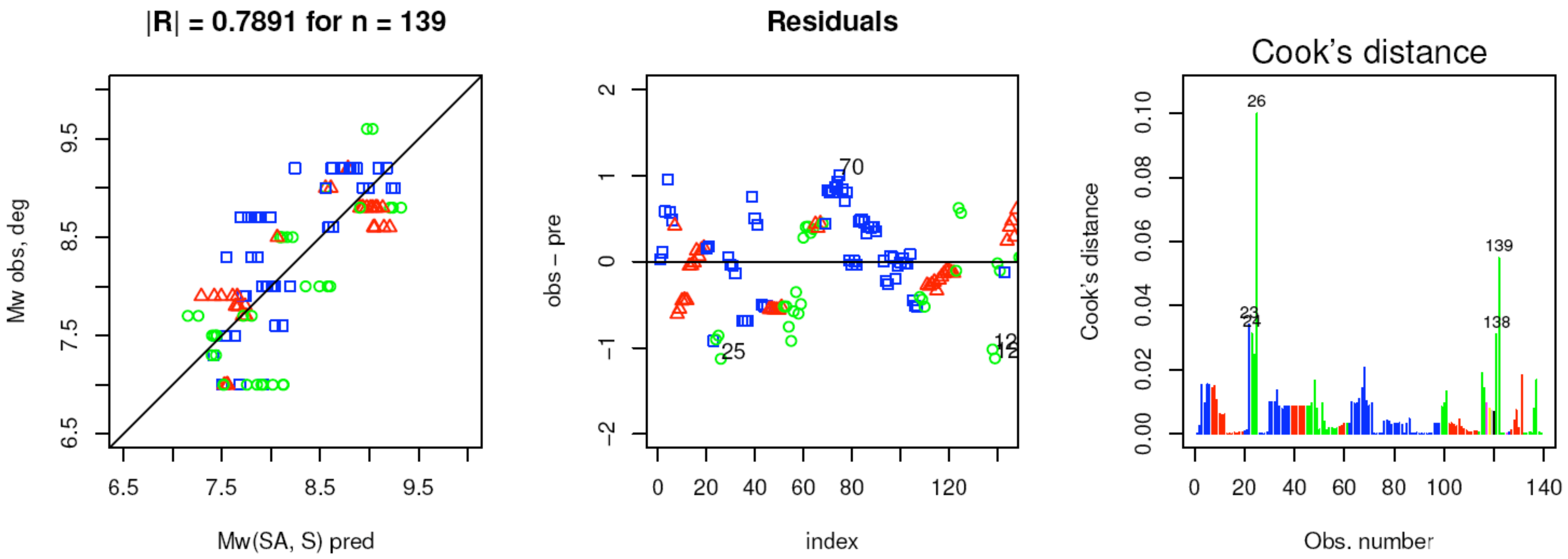
```
alphaI ~ SA + A + iO + iE
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 21.821523   2.578544   8.463 3.84e-14 ***
SAp         -0.036061   0.009163  -3.935 0.000132 ***
Ap           1.034575   0.241451   4.285 3.45e-05 ***
iO           7.428971   1.431568   5.189 7.57e-07 ***
iE           8.069908   1.398924   5.769 5.21e-08 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 6.37 on 135 degrees of freedom
Multiple R-Squared: 0.6171,Adjusted R-squared: 0.6058
F-statistic: 54.39 on 4 and 135 DF,  p-value: < 2.2e-16
```



$$\alpha_d \quad = \quad 73.39 + 8.9\,O - 0.17\,V_{\rm cmp} - 0.090\,SA \qquad\qquad |R| = 0.7214$$

A steeper **deep dip** is promoted by:

- a younger subduction zone
- an upper plate that is oceanic
- a lower convergence velocity



$$M_w \;=\; 7.0 + 0.0076\,SA + 0.022\,\sqrt{S} \qquad\qquad |R| = 0.7891$$

A greater **Mw-max** is promoted by:

an older subduction zone

a greater sediment thickness at the trench

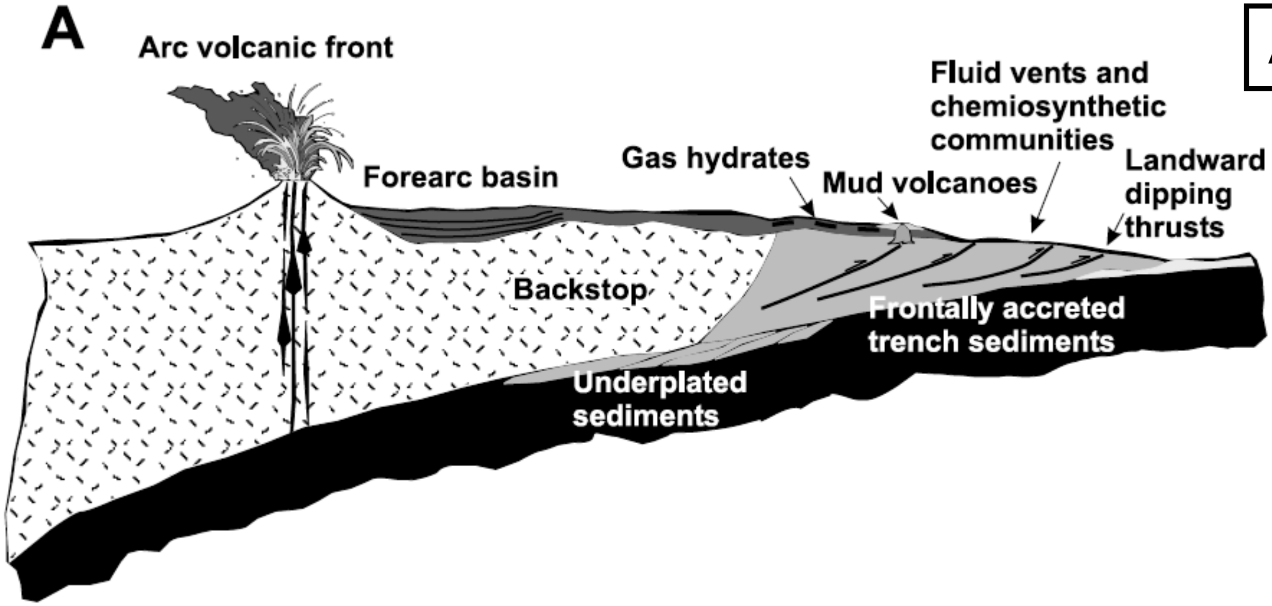
Summary

1. We have compiled a comprehensive set of subduction zone parameters for 159 transects.
2. The analyses of Ruff and Kanamori (1980) and Jarrard (1986) are excellent, given the data sets available at the time.
3. **Initial results** of linear regression using the new dataset suggest that :
    1. The relationship Mw(Vc, A) of Ruff and Kanamori is not valid.
    2. Mw depends on the long-term evolution of the subduction interface (SA, age of subduction zone).
    3. Intermediate dip depends on SA, age of plate, whether the upper plate is oceanic, and whether the transect is near the edge of a subduction zone.
    4. Deep dip depends on SA and Vc and whether upper plate is oceanic.

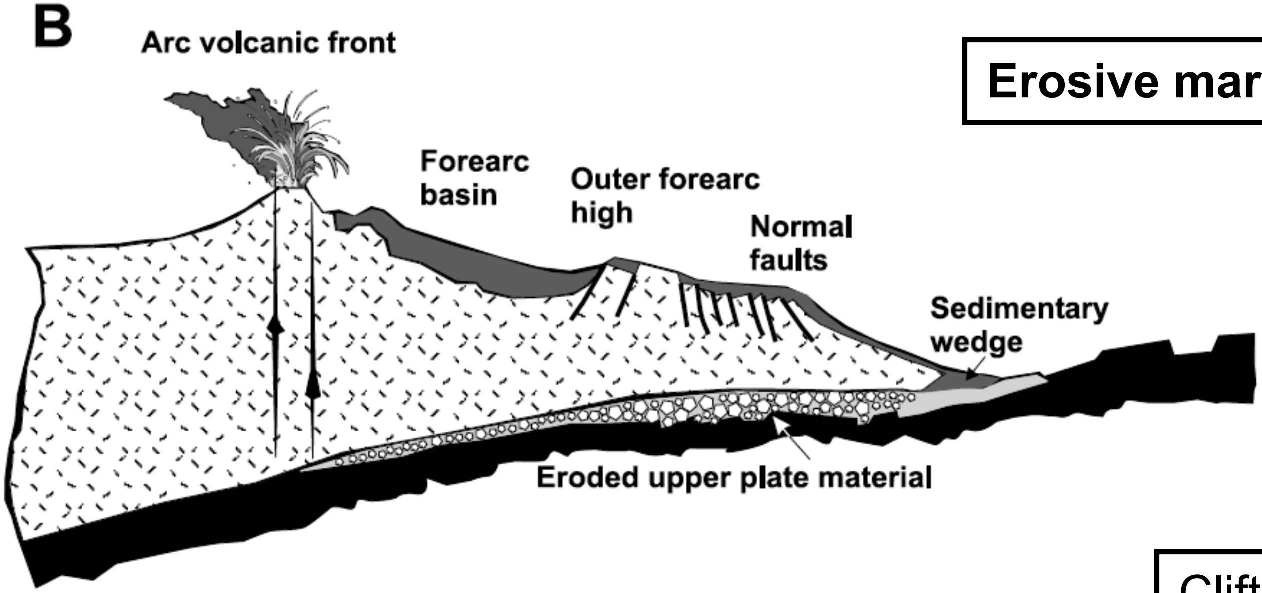
What parameters did we ignore?

- Strain class of upper plate

1. Wedge taper angle
2. Arc-trench distance, width/depth of seismogenic zone, etc



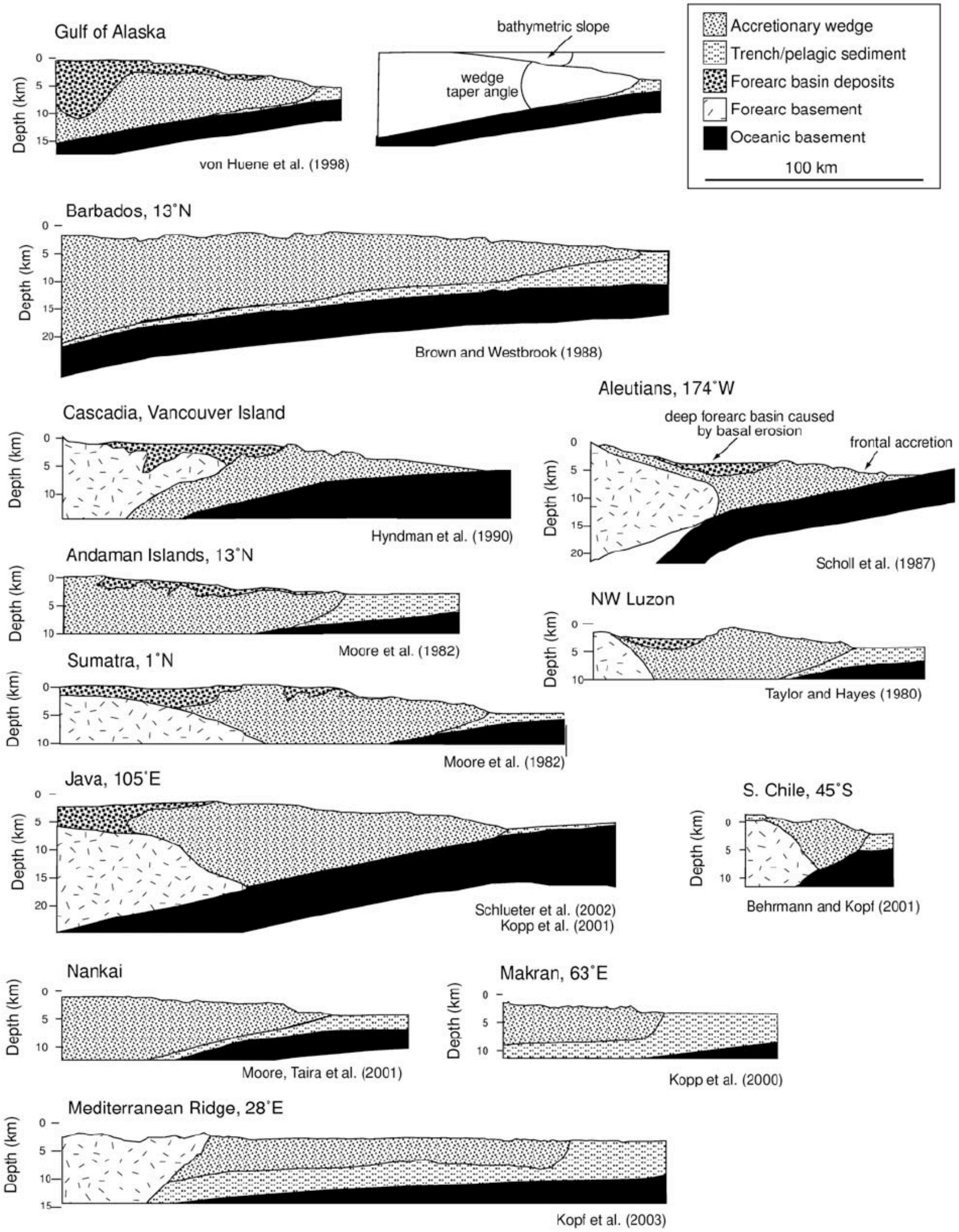
Accretionary margin



Erosive margin

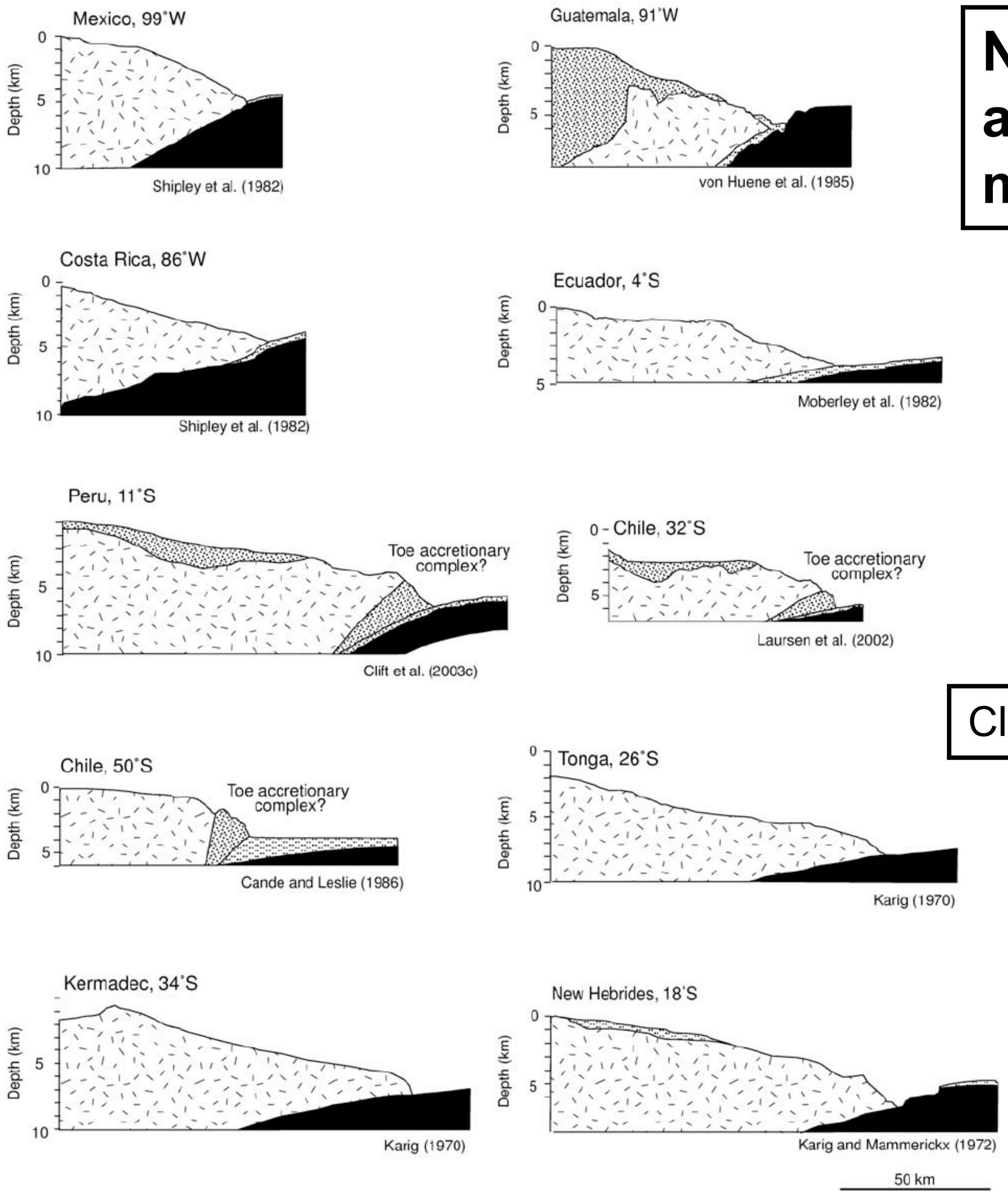
Clift and Vannucchi (2004)

Accretionary plate margins



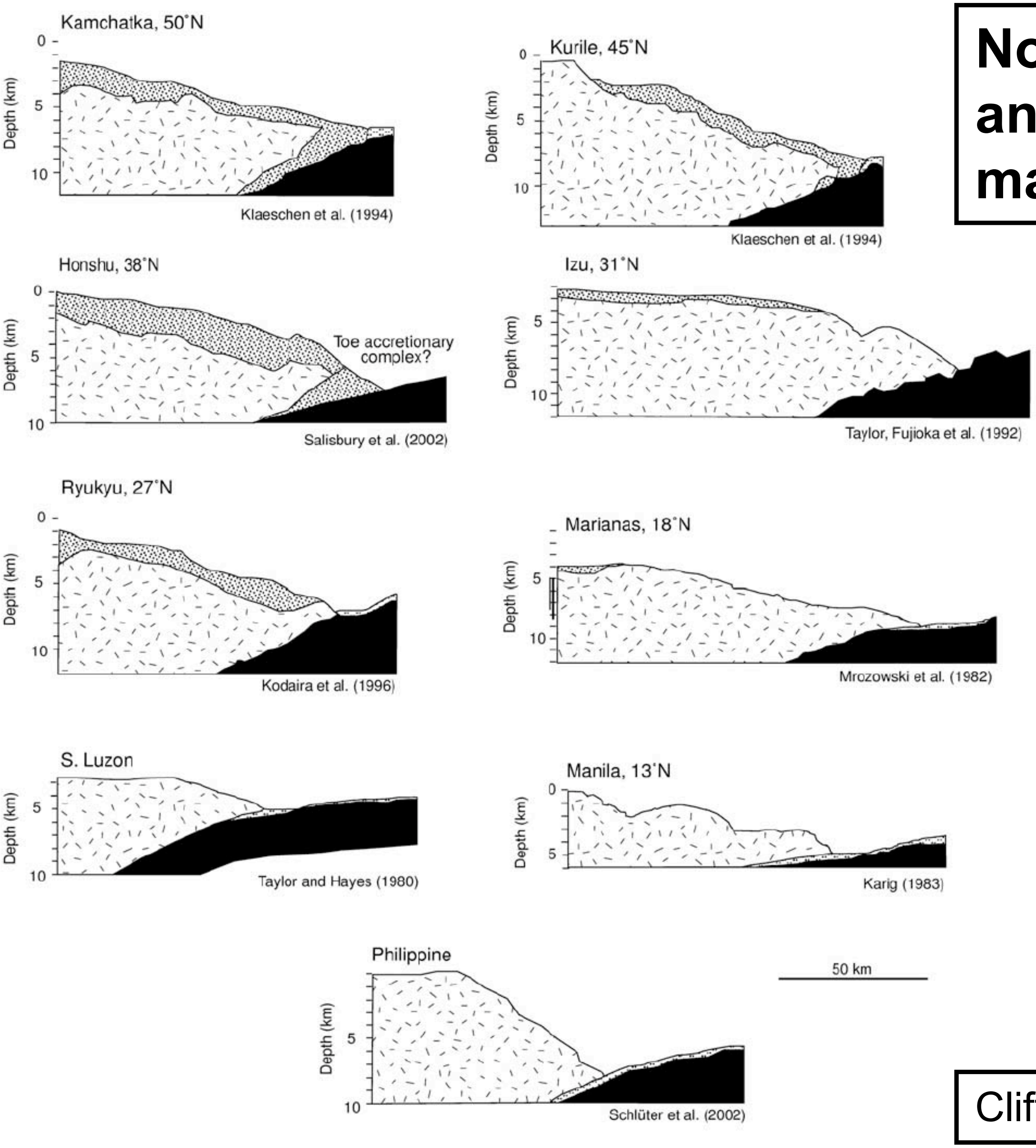
Clift and Vannucchi (2004)

Non-accretionary and erosive plate margins

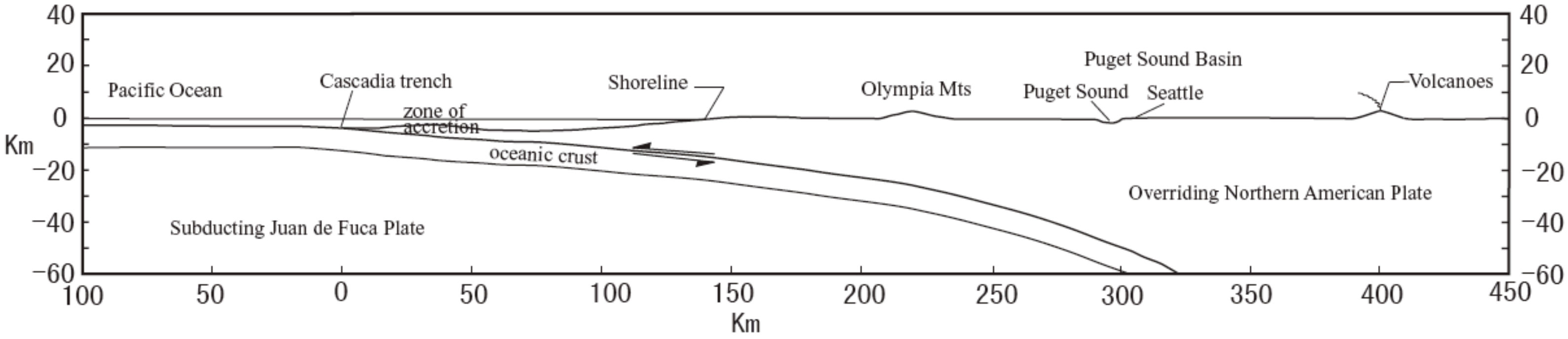


Clift and Vannucchi (2004)

Non-accretionary and erosive plate margins



Clift and Vannucchi (2004)



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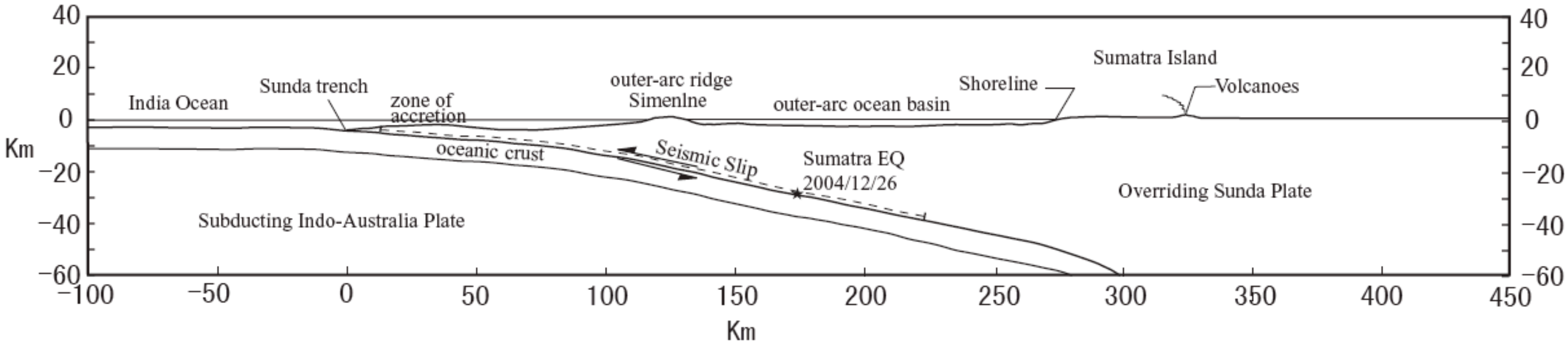

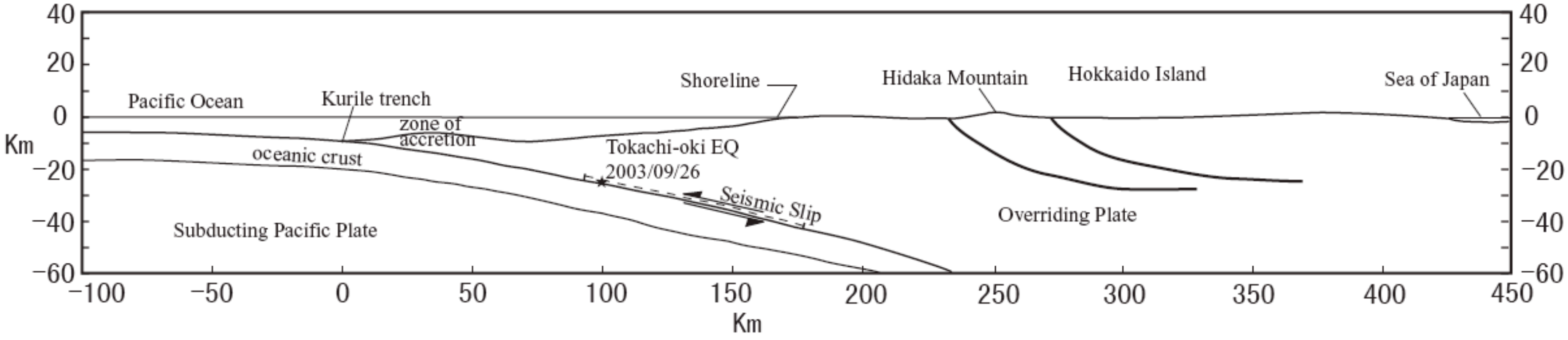

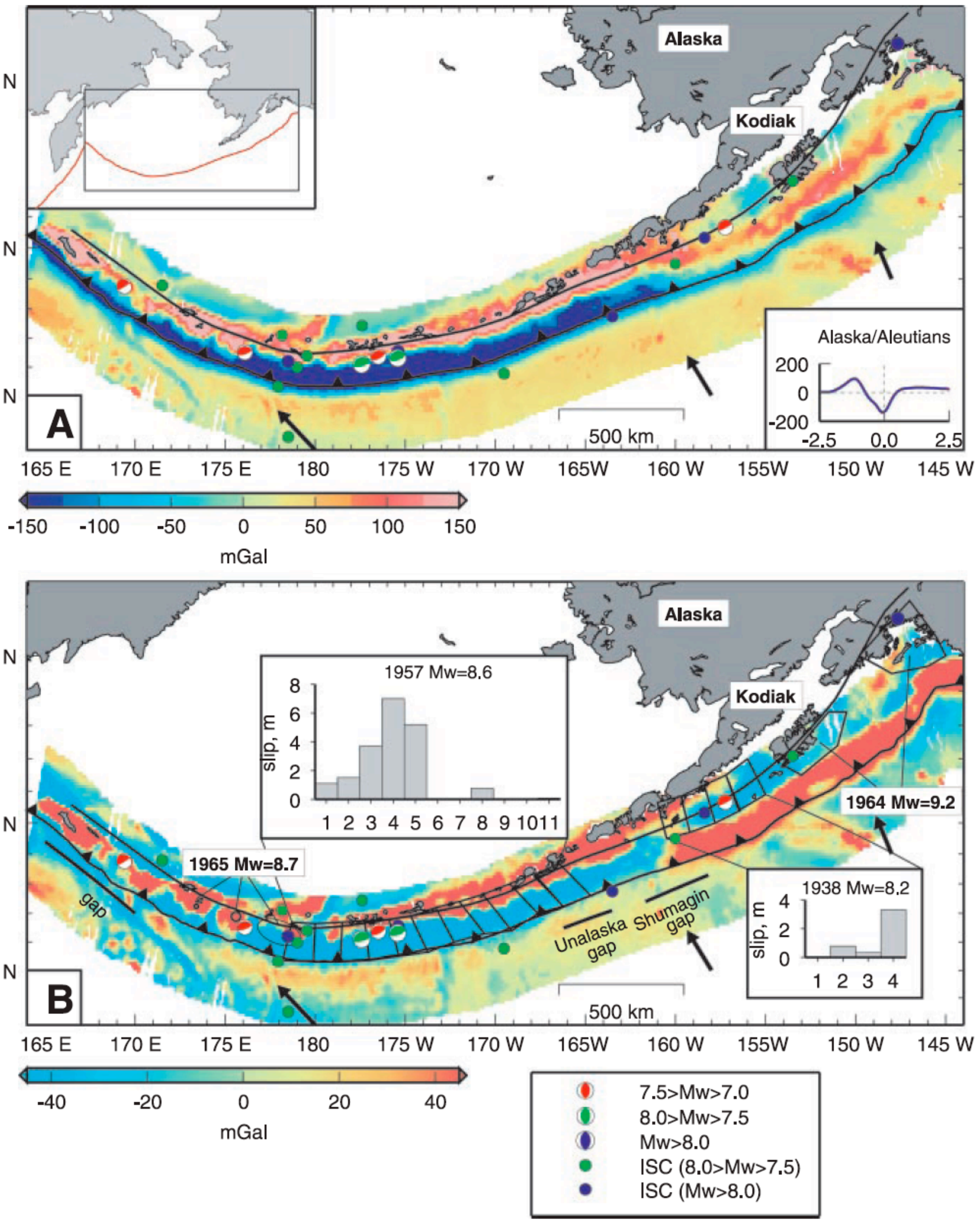

Song and Simons (2003)