

Relationships between moment magnitude and fault parameters: theoretical and semi-empirical relationships

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Abstract: Fault parameters are important in earthquake hazard analysis. In this paper, theoretical relationships between moment magnitude and fault parameters including subsurface rupture length, downdip rupture width, rupture area, and average slip over the fault surface are deduced based on seismological theory. These theoretical relationships are further simplified by applying similarity conditions and a unique form is established. Then, combining the simplified theoretical relationships between moment magnitude and fault parameters with seismic source data selected in this study, a practical semi-empirical relationship is established. The seismic source data selected is also used to derive empirical relationships between moment magnitude and fault parameters by the ordinary least square regression method. Comparisons between semi-empirical relationships and empirical relationships show that the former depict distribution trends of data better than the latter. It is also observed that downdip rupture widths of strike slip faults are saturated when moment magnitude is more than 7.0, but downdip rupture widths of dip slip faults are not saturated in the moment magnitude ranges of this study.

Keywords: earthquake hazard analysis; fault parameters; seismic moment; moment magnitude; semi-empirical relationships

Appendix A1

Table A1 Earthquake source parameters

No.	Location	Earthquake	Data	Slip type	M_S	M_W	M_0 (dyne·cm)		Rupture length (km)	Rupture width (km)	Rupture area (km ²)	Average slip (cm)
							W&C	This study				
1	Peru	Ancash	11/10/1946	N	7.2	7.28	9.4 0E+27	9.33E+26	28.	30.	840.	370.24
2	USA,CA	San Francisco	03/22/1957	N	5.3*	5.21	7.40E+24	7.33E+23	7.	5.	35.	6.98
3	USA, MT	Hebgen Lake	08/18/1959	N	7.6	7.29	9.50E+27	9.66E+26	45.	17.	765.	420.92
4	USA, Utah	Cache Valley	08/30/1962	N	5.7*	5.78	5.20E+25	5.25E+24	7.	8.	56.	31.25
5	USA, Idaho	Pocatello Valley	03/28/1975	N	6.0	6.06	1.40E+26	1.38E+25	15.	10.	150.	30.67
6	USA, Utah	Unita Basin	09/30/1977	N	5.1*	5.10		5.01E+23	2.	3.	6.	27.83
7	Greece	Thessaloniki	06/20/1978	N	6.4	6.43	5.02E+26	4.96E+25	28.	14.	392.	42.18
8	USA,CA	Wheeler Crest	10/04/1978	N	5.1	5.47	1.80E+25	1.80E+24	7.	5.5	38.5	15.58
9	France	Arudy	02/29/1980	N	4.9**	5.17	6.40E+24	6.38E+23	3.8	5.	19.	11.20
10	Italy	South Apennines	11/23/1980	N	6.9	6.91	2.60E+27	2.60E+26	60.	15.	900.	96.30
11	Greece	Corinth	03/04/1981	N	6.4	6.25	2.65E+26	2.66E+25	26.	18.	468.	18.95
12	North Yemen	Dhamar	12/13/1982	N	6.0	6.34	3.64E+26	3.63E+25	20.	7.	140.	86.43
13	Italy	Perugia	04/29/1984	N	5.3	5.65	3.50E+25	3.35E+24	17.	5.	85.	13.14
14	Italy	Lazio-Abruzzo	05/07/1984	N	5.8	6.00	1.12E+26	1.12E+25	4.5	10.	45.	82.96
15	Greece	Kalamata	09/13/1986	N	5.8	5.93	8.90E+25	8.81E+24	15.	14.	210.	13.98
16	New Zealand	Edgcumbe	03/02/1987	N	6.6	6.50	6.30E+26	6.31E+25	32.	14.	448.	46.95
17	Japan	Kameoka	05/28/1987	N	4.9*	4.90		2.51E+23	1.4	1.8	2.52	33.20
18	USA, Nevada	Little Skull Mtn.	06/29/1992	N	5.4	5.69	3.80E+25	3.85E+24	8.	4.5	36.	35.65

19	USA, CA	Eureka Valley	05/17/ 1993	N	5.8	6.08	1.50E+26	1.48E+25	16.7	7.	116.9	42.20
20	USA, Idaho	Borah Peak	10/28/ 1983	N-LL	7.3	6.93	2.80E+27	2.79E+26	33.	20.	660.	140.91
21	USA, WA	Yellowstone	06/30/ 1975	N-RL	5.9	5.88	7.50E+25	7.41E+24	10.	5.	50.	49.40
22	USA, CA	Oroville	08/01/ 1975	N-RL	5.6	6.01	1.18E+26	1.16E+25	8.	10.	80.	48.33
23	England	Carlisle	12/26/ 1979	N-RL	4.8*	4.80		1.78E+23	4.	3.	12.	4.95
24	Japan	Niigata	01/16/ 1964	R	7.5	7.59	2.73E+28	2.72E+27	60.	30.	1800.	503.70
25	USA, CA	Point Mugu	02/21/ 1973	R	5.2	5.72	4.20E+25	4.27E+24	8.	3.3	26.4	53.91
26	USSR	Uzbekistan	04/08/ 1976	R	7.0	6.83	1.95E+27	1.97E+26	30.	20.	600.	109.44
27	Italy	Friuli	05/06/ 1976	R	6.5	6.49	6.00E+26	6.10E+25	19.	10.	190.	107.02
28	USSA	Uzbekistan	05/17/ 1976	R	7.0	6.84	2.07E+27	2.04E+26	48.	24.	1152.	59.03
29	China	Songpan,Huya	08/21/ 1976	R	6.4	6.37	4.00E+26	4.03E+25	12.	18.	216.	62.19
30	Argentina	Caucete	11/23/1977	R	7.4	7.48	1.89E+28	1.86E+27	80.	30.	2400.	258.33
31	Iran	Tabas-e-Golshan	09/16/ 1978	R	7.5	7.39	1.37E+28	1.37E+27	74.	22.	1628.	280.51
32	USA, CA	Malibu	01/01/ 1979	R	4.7	4.70		1.26E+23	5.	5.	25.	1.68
33	Yugoslavia	Montenegro	04/15/ 1979	R	6.9	6.98	3.29E+27	3.31E+26	50.	29.	1450.	76.09
34	Australia	Cadoux	06/02/ 1979	R	6.1	6.12	1.67E+26	1.70E+25	16.	6.	96.	59.03
35	Algeria	El Asnam	10/10/ 1980	R	7.3	7.10	5.08E+27	5.01E+26	55.	15.	825.	202.42
36	Canada	Miramichi	01/09/ 1982	R	5.2	5.55	2.40E+25	2.37E+24	5.5	4.	22.	35.91
37	USA, CA	Coalinga, Nunez	06/11/1983	R	5.4	5.42	1.50E+25	1.51E+24	8.	6.5	52.	9.68
38	USA, NY	Goodnow	10/07/ 1983	R	5.1*	4.89	2.40E+24	2.43E+23	1.5	2.	3.	27.00
39	Argentina	Mendoza	01/26/ 1985	R	5.9	5.87	7.20E+25	7.16E+24	16.	16.	256.	9.32
40	New Guinea	New Ireland	07/03/ 1985	R	7.2	7.23	7.90E+27	7.85E+26	48.	23.	1104.	237.02
41	USA, CA	Kettleman Hills	08/04/ 1985	R	5.9	6.09	1.53E+26	1.53E+25	20.	8.3	166.	30.72
42	Canada	Nahanni	10/05/ 1985	R	6.6	6.64	1.02E+27	1.02E+26	32.	16.	512.	66.41
43	Canada	Nahanni	12/23/ 1985	R	6.9	6.75	1.50E+27	1.50E+26	40.	17.	680.	73.53
44	Taiwan	Hualien	05/20/ 1986	R	6.4	6.37	4.00E+26	4.03E+25	20.	24.	480.	27.99
45	USA, CA	Oceanside	07/13/ 1986	R	5.8	5.87	7.30E+25	7.16E+24	8.	7.	56.	42.62
46	Taiwan	Hualien	11/14/1986	R	7.8	7.33	1.10E+28	1.11E+27	48.	26.	1248.	296.47
47	USA, CA	Whittier Narrows	10/01/ 1987	R	5.7	6.01	1.04E+26	1.16E+25	5.	6.	30.	128.89
48	Australia	Tennant Creek	01/22/ 1988	R	6.3	6.26	2.80E+26	2.75E+25	13.	9.	117.	78.35
49	Australia	Tennant Creek	01/22/ 1998	R	6.7	6.58	8.20E+26	8.32E+25	19.	12.	228.	121.64
50	Canada	Saguenay	11/25/1988	R	5.8	5.84	6.40E+25	6.46E+24	23.	10.	230.	9.36
51	Algeria	Chenoua	10/29/ 1989	R	5.7	5.98	1.04E+26	1.05E+25	15.	10.	150.	23.33
52	Canada	Ungava	12/25/ 1989	R	6.3	5.98	1.04E+26	1.05E+25	10.	5.	50.	70.00
53	Japan	Southern Niigata	12/07/ 1990	R	5.1	5.28	9.20E+24	9.33E+23	6.5	5.	32.5	9.57
54	USA Oregon	Scotts Mills	03/25/ 1993	R	5.4	4.77	1.60E+24	1.60E+23	5.5	9.	49.5.	1.08
55	USA, CA	Kern Country	07/21/ 1952	R-LL	7.7	7.38	1.30E+28	1.32E+27	64.	19.	1216.	361.84
56	Australia	Meckering	10/14/ 1968	R-RL	6.9	6.61	9.30E+26	9.23E+25	20.	10.	200.	153.83
57	Japan	Akita	10/16/ 1970	R-RL	5.8	6.13	1.75E+26	1.76E+25	14.	11.	154.	38.10
58	USA, CA	San Fernando	02/09/ 1971	R-LL	6.5	6.64	1.04E+27	1.02E+26	17.	14.	238.	142.86
59	USSR	Tadzhikistan	08/11/1974	R-RL	7.3	7.06	4.38E+27	4.37E+26	30.	20.	600.	242.78
60	USA, CA	Santa Barbara	08/13/ 1978	R-LL	5.6	5.88	7.50E+25	7.41E+24	10.	5.	50.	49.40
61	Canada	Charlevoix	08/19/ 1979	R-RL	4.5	4.75	1.50E+24	1.50E+23	2.	2.	4.	12.50
62	USA, CA	Coalinga	05/02/ 1983	R-LL	6.5	6.38	4.10E+26	4.17E+25	27.	15.	405.	34.32

63	Canada	Prince George	03/21/1986	R-RL	5.2	5.54	2.30E+25	2.29E+24	6.	8.	48.	15.90
64	Australia	Marryat Creek	03/30/1986	R-LL	5.8	5.79	5.40E+25	5.43E+24	13.	3.	39.	46.41
65	Australia	Tennant Creek	01/22/1988	R-LL	6.4	6.38	4.10E+26	4.17E+25	13.	9.	117.	118.80
66	USSR	Armenia	12/07/1988	R-RL	6.8	6.76	1.53E+27	1.55E+26	38.	11.	418.	123.61
67	USA, CA	Sierra Madre	06/28/1991	R-LL	5.1	5.62	3.00E+25	3.02E+24	4.	5.	20.	50.33
68	USA, CA	Ragged Point	09/17/1991	R-RL	4.5	5.10	5.00E+24	5.01E+23	1.1	2.	2.2	75.91
69	New Zealand	Glasgow	05/24/1968	R-LL	7.1	7.07	4.50E+27	4.52E+26	41.	18.	738.	204.16
70	USA, CA	Arroyo, Salada	03/19/1954	RL	6.2	6.27	2.89E+26	2.85E+25	15.	12.	180.	52.78
71	USA, Alaska	Lituya Bay	07/10/1958	RL	7.9	7.77	5.10E+28	5.07E+27	350.	12.	4200.	402.38
72	Japan	Wakasa-Bay	03/26/1963	RL	6.5	6.28	3.00E+26	2.95E+25	20.	8.	160.	61.46
73	USA, CA	Watsonville	09/14/1963	RL	5.4	5.17	6.30E+24	6.38E+23	7.	3.5	24.5	8.68
74	USA, CA	Corralitos	11/16/1964	RL	5.1*	5.10		5.01E+23	4.	4.	16.	10.44
75	USA, CA	Antioch	09/10/1965	RL	4.9*	4.90		2.51E+23	3.	6.	18.	4.65
76	USA, CA	Parkfield	06/28/1966	RL	6.4	6.25	2.70E+26	2.66E+25	35.	10.	350.	25.33
77	USA, Nevada	Caliente-Clover	08/16/1966	RL	5.8*	5.58	2.60E+25	2.63E+24	11.	6.	66.	13.28
78	USA, CA	Borrego Mtn.	04/09/1968	RL	6.8	6.63	1.00E+27	9.89E+25	40.	10.	400.	82.42
79	Japan	Gifu	09/09/1969	RL	6.6	6.34	3.60E+26	3.63E+25	18.	10.	180.	67.22
80	South Africa	Ceres	09/29/1969	RL	6.3	6.37	4.00E+26	4.03E+25	20.	9.	180.	74.63
81	USA, Alaska	Sitka	07/30/1972	RL	7.6	7.70	4.00E+28	3.98E+27	180.	10.	1800.	737.04
82	USA, CA	Stone Canyon	09/04/1972	RL	4.7*	4.83	2.00E+24	1.97E+23	2.6	2.3	5.98.	10.98
83	USA, CA	San Jun Bautista	10/03/1972	RL	4.8*	4.77	1.60E+24	1.60E+23	4.3	2.5	10.75	4.96
84	USA, CA	House Canyon	08/02/1975	RL	4.7*	5.00	3.50E+24	3.55E+23	2.	2.	4.	29.58
85	China	Tangshan	07/27/1976	RL	7.8	7.46	1.76E+28	1.74E+27	70.	24.	1680.	345.24
86	Mexico	Mesade Andrade	12/07/1976	RL	5.7	5.61	2.90E+25	2.92E+24	9.	5.	45.	21.63
87	USA, CA	Willits	11/22/1977	RL	4.8*	5.24	8.20E+24	8.13E+23	5.	7.5	37.5	7.23
88	Iran	Bob-Tangol	12/19/1977	RL	5.8	5.89	7.60E+25	7.67E+24	14.	12.	168.	15.22
89	Japan	Izu-Oshima	01/14/1978	RL	6.6	6.71	1.32E+27	1.30E+26	50.	10.	500.	86.67
90	USA, WA	South PugetSound	03/11/1978	RL	4.8*	4.80		1.78E+23	2.5	4.	10.	5.93
91	USA, CA	Homestead Valley	03/15/1979	RL	5.6	5.55	2.41E+25	2.37E+24	6.	4.	24.	32.94
92	USA, CA	Coyote Lake	08/06/1979	RL	5.7	5.77	5.10E+25	5.07E+24	14.	10.	140.	12.07
93	USA, CA	El Centro	10/15/1979	RL	6.7	6.53	7.12E+26	7.00E+25	51.	12.	612.	38.13
94	USA, CA	Greenville	01/24/1980	RL	5.9	5.82	6.00E+25	6.03E+24	11.5	12.	138.	14.57
95	USA, CA	Anza	02/25/1980	RL	4.7	5.04	4.10E+24	4.07E+23	2.5	2.5	6.25	21.71
96	Mexico	Mexicali Valley	06/09/1980	RL	6.4	6.40	4.50E+26	4.47E+25	28.	8.	224.	66.52
97	USA, KY	Sharpsburg	07/27/1980	RL	4.7	5.06	4.30E+24	4.37E+23	4.	5.	20.	7.28
98	USA, WA	Elk Lake	02/14/1981	RL	4.8	5.3	1.00E+25	1.00E+24	6.	7.	42.	7.94
99	USA, CA	Anza	06/15/1982	RL	4.8*	4.79	1.70E+24	1.72E+23	2.5	3.	7.5	7.64
100	USA, CA	Morgan Hill	04/24/1984	RL	6.1	6.28	3.00E+26	2.95E+25	26.	8.	208.	47.28
101	USA, Alaska	Sutton, Talkeetn	08/14/1984	RL	5.2	5.84	6.40E+25	6.46E+24	8.	6.	48.	44.86
102	Japan	Naganoken-Seibu	09/14/1984	RL	6.1	6.24	2.60E+26	2.57E+25	12.	8.	96.	89.24
103	USA, CA	Tres Pinos	01/26/1986	RL	5.3	5.42	1.50E+25	1.51E+24	11.	5.	55.	9.15
104	USA, CA	Mt Lewis	03/31/1986	RL	5.5	5.64	3.20E+25	3.24E+24	5.5	4.	22.	49.09
105	USA, CA	Chalfant Valley	07/21/1986	RL	6.2	6.31	3.20E+26	3.27E+25	20.	11.	220.	49.55

106	USA, Illinois	Wabash Valley	06/10/ 1987	RL	4.4	4.96	3.10E+24	3.09E+23	1.7	3.	5.1	20.20
107	USA, Utah	Lakside	09/25/ 1987	RL	4.6	5.02	3.80E+24	3.80E+23	5.5	6.	33.	3.84
108	USA, CA	Superstition Hills	11/24/1987	RL	6.6	6.61	9.20E+26	9.23E+25	30.	11.	330.	93.23
109	China	Lancang-Gengma	11/06/1988	RL	7.3	7.13	5.47E+27	5.56E+26	80.	20.	1600.	115.83
110	USA, CA	Lee Vining	10/24/ 1990	RL	5.2	5.33	1.10E+25	1.11E+24	4.	4.	16.	23.13
111	USA, CA	Joshua Tree	04/23/ 1992	RL	6.3	6.27	2.90E+26	2.85E+25	15.	13.	195.	48.72
112	USA, CA	Landers	06/28/ 1992	RL	7.6	7.34	1.14E+28	1.15E+27	62.	12.	744.	515.23
113	USA, CA	Loma Prieta	10/18/ 1989	RL-R	7.1	6.92	2.67E+28	2.69E+26	40.	16.	640.	140.10
114	USA, CA	Coyote Mountain	04/28/ 1969	RL-N	5.8*	5.69	3.80E+25	3.85E+24	10.	3.	30.	42.78
115	Japan	Izu-Okii	05/08/ 1974	RL-R	6.5	6.54	7.20E+26	7.24E+25	18.	11.	198.	121.89
116	New Zealand	Matata	05/31/ 1977	RL-N	5.4*	5.61	2.90E+25	2.92E+24	8.5	5.	42.5	22.91
117	Belgium	Liege	11/08/1983	RL-R	4.3	4.77	1.60E+24	1.60E+23	5.	3.	15.	3.56
118	West Africa	Guinea	12/22/ 1983	RL-N	6.2	6.32	3.40E+26	3.39E+25	27.	14.	378.	29.89
119	USA, WY	Laramie	10/18/ 1984	RL-N	5.1	5.31	1.02E+25	1.04E+24	3.	3.	9.	38.52
120	USA, CA	No. Palm Springs	07/08/ 1986	RL-R	6.0	6.13	1.73E+26	1.76E+25	16.	9.	144.	40.74
121	USA, CA	Truckee	09/12/ 1966	LL	5.9	5.96	9.70E+25	9.77E+24	13.	7.	91.	35.79
122	Iran	Dasht-e-Bayaz	08/31/ 1968	LL	7.1	7.23	7.80E+27	7.85E+26	110.	20.	2200.	118.94
123	USA, Alaska	Rampart	10/29/ 1968	LL	6.5	6.69	1.20E+27	1.22E+26	30.	8.	240.	169.45
124	USA, CA	Bear Valley	02/27/ 1972	LL	4.7*	4.57	8.00E+23	8.04E+22	3.8	2.5	9.5	2.82
125	Nicaragua	Managua	12/23/ 1972	LL	6.2	6.20	3.30E+26	2.24E+25	15.	8.	120.	62.22
126	China	Luhuo	02/06/ 1973	LL	7.3	7.47	1.80E+28	1.80E+27	110.	13.	1430.	419.58
127	China	Haicheng	02/04/ 1975	LL	7.4	6.99	3.45E+27	3.43E+26	60.	15.	900.	127.04
128	Guatemala	Motagua	02/04/ 1976	LL	7.5	7.63	3.10E+28	3.13E+27	257.	13.	3341.	312.28
129	Germany	Swabian Jura	03/09/ 1978	LL	5.3	5.21	7.40E+24	7.33E+23	4.5	6.	27.	9.05
130	USA, CA	Mammoth Lakes	05/27/ 1980	LL	6.1	5.99	1.09E+26	1.08E+25	9.	11.	99.	36.36
131	Japan	Izu-Hanto-Toho	06/29/ 1980	LL	6.2	6.39	4.30E+26	4.32E+25	14.	10.	140.	102.86
132	China	Daofu	01/23/ 1981	LL	6.8	6.64	1.01E+27	1.02E+26	46.	15.	690.	49.28
133	USA, CA	Round Valley	11/23/1984	LL	5.7	5.83	6.20E+25	6.24E+24	7.	7.	49.	42.45
134	New Guinea	New Britan	05/10/ 1985	LL	7.1	7.19	6.93E+27	6.84E+26	50.	15.	750.	304.00
135	Algeria	Constantine	10/27/ 1985	LL	5.9	6.00	1.11E+26	1.12E+25	21.	13.	273.	13.68
136	EL Salvador	San Salvador	10/10/ 1986	LL	5.4	5.74	4.50E+25	4.57E+24	6.	7.5	45.	33.85
137	USA, CA	Elmore Ranch	11/24/1987	LL	6.2	6.20	2.60E+26	2.24E+25	30.	12.	360.	20.74
138	USA, Utah	South Wasatch	01/30/ 1989	LL	4.8	5.33	1.10E+25	1.11E+24	5.	4.	20.	18.50
139	Japan	Izu-Oshima	02/20/ 1990	LL	6.4	6.37	4.05E+26	4.03E+25	19.	12.	228.	58.92
140	USA, CA	Upland	02/28/ 1990	LL	5.5	5.59	2.70E+25	2.72E+24	4.	7.	28.	32.38
141	Philippines	Luzon	07/16/ 1990	LL	7.8	7.74	4.60E+28	4.57E+27	120.	20.	2400.	634.72
142	USA, CA	Big Bear	06/28/ 1992	LL	6.7	6.68	1.16E+27	1.18E+26	20.	10.	200.	196.67
143	Yugoslavia	Skopje	07/26/ 1963	LL-N	6.1	5.99	1.10E+26	1.08E+25	17.	11.	187.	19.25
144	Japan	Oita Prefecture	04/20/ 1975	LL-R	6.1	6.32	3.40E+26	3.39E+25	10.	10.	100.	113.00
145	China	Songpan, Huya	08/16/ 1976	LL-R	6.9	6.71	1.30E+27	1.30E+26	30.	12.	360.	120.37
146	China	Songpan, Huya	08/23/ 1976	LL-R	6.7	6.58	8.40E+26	8.32E+25	22.	11.	242.	114.60
147	Japan	Omachi	12/30/ 1986	LL-R	5.3	5.51	2.10E+25	2.07E+24	7.	4.	28.	24.64
148	China	Xunwu	08/02/ 1987	LL-N	4.8	5.01	3.60E+24	3.67E+23	4.	4.	16.	7.65
149	USA, Utah	Colorado Plateau	08/14/ 1988	LL-N	5.3*	5.30		1.00E+24	5.	7.	35.	9.52

150	USA, CA	Northridge	01/17/ 1994	R	6.66	1.10 E+26	18.	21.	378.0	97.00
151	Japan	Iwata	03/09/ 1998	R	5.90	6.00E+24	12.	12.	144.	13.89
152	Taiwan	ChiChi	09/20/ 1999	R	7.60	2.70E+27	78.	44.	3432.	262.24
153	Japan	Geiyo	03/24/ 2001	N	6.8	3.30E+26	30.	21.	630.	174.60
154	Japan	Kobe	01/17/ 1995	SS	6.90	2.40E+26	60.	20.	1200.	66.67
155	Japan	Kagoshima	03/26/ 1997	SS	6.10	1.20E+25	18.	12.	216.	18.52
156	Japan	Yamaguchi	06/25/ 1997	SS	5.80	6.00E+24	16.	14.	224.	8.93
157	Turkey	Kocaeli	08/17/ 1999	SS	7.40	1.52E+27	141.	23.28	3284.48	154.36
158	Jaapan	Tottori	06/10/ 2000	SS	6.80	1.90E+26	33.	21.	693.	91.39

Note: * local or Richter magnitude; * * body-wave magnitude.

NNormal fault; RReverse fault; RLRight lateral; LLeft lateral; SStrike slip fault.