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Scaling Relations of Source Parameters of Earthquakes Occurring on Inland Crustal Mega-Fault Systems

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Abstract—We examined a new scaling relation between source area S and seismic moment M_0 for large crustal earthquakes on "mega-fault" systems, including earthquakes with magnitudes larger than M_w7.4. We focused on earthquakes that occurred on inland crustal mega-fault systems, such as the 2008 Wenchuan and 2002 Denali earthquakes, and compiled the source parameters using 11 inland crustal earthquakes which analyses of source rupture processes by waveform inversion as well as investigation of surface ruptures via geomorphological surveys. We found that the maximum surface rupture displacement is two to three times larger than the average slip on the source fault, and the length of the surface rupture is equivalent to the length of the source fault. Furthermore, our compiled data shows the displacement of the surface rupture D saturates around 10 m when the length of the surface rupture L reaches 100 km. Assuming that the average width of the source fault $W = 18$ km (for Japanese inland crustal earthquakes) and the saturated surface displacement $D = 10$ m, we found that the scaling relations between rupture area S and seismic moment M_0 have three stages. For the first stage, S is proportional to $M_0^{2/3}$ for earthquakes smaller than $M_0 = 7.5 \times 10^{18}$ Nm. For the second stage, S ranges from $M_0^{1/2}$ to $M_0^{2/3}$, depending on the thickness of the seismogenic zone. For the third stage, S is proportional to M_0 because of the saturation of the slip on the fault. From our compiled data, we derived the third scaling relation between source area S and seismic moment M_0 for inland crustal mega-fault systems to be S (km^2) $= 1.0 \times 10^{-17} M_0$ (Nm), where $M_0 > 1.8 \times 10^{20}$ (Nm).

Key words: Scaling relation, inland crustal earthquake, mega-fault systems, earthquake source model, strong ground motion prediction.

1. Introduction

In order to perform strong ground motion prediction, some fault parameters are estimated from empirical scaling relations. The major parameter is the magnitude of the earthquake that is often assumed from the source area using scaling relations between magnitude and source area, which will be discussed in this paper. The study for scaling relation of the rupture area to the seismic moment began with the pioneering work by KANAMORI and ANDERSON (1975). They proposed the empirical relations for seismic moment, magnitude, energy and rupture area using crustal and plate-boundary earthquakes with $M > 6$ and discussed the difference of stress drop between the crustal and plate-boundary earthquakes. Subsequently, MATSUDA (1975), SCHOLZ (1982), WELLS and COPPERSMITH (1994) and STIRLING *et al.* (2002) studied the scaling relations of various parameters using only crustal earthquakes. However, their datasets are not uniform because the parameters were estimated by various methods (e.g., surface observation, aftershock area, simulation).

To reflect the complex nature of large earthquakes, it is important to consider strong ground motion from the scaling relations derived from heterogeneous slip distributions estimated from observed seismic waveforms and geodetic data. Recently, numerous studies of source processes obtained from seismic waveform inversion have made it possible to conduct quantitative assessment

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for source parameters. Scaling relations of various source parameters of inland earthquakes that occur in crustal regions have been proposed considering heterogeneous slip distributions which were obtained from source inversion analysis by a substantial number of studies (e.g., Somerville *et al.* 1999; Mai and Beroza 2000; Irikura and Miyake 2001). Somerville *et al.* (1999) obtained the scaling relations for parameters, such as rupture area, seismic moment, average slip, and asperity area using 15 crustal earthquakes for which inversion analysis for finite-fault models were performed using seismic waveforms and geodetic data. Mai and Beroza (2000) compiled 31 slip models of 18 earthquakes for crustal and plate-boundary earthquakes and proposed the scaling relations for all events, strike-slip events and dip-slip events. Irikura and Miyake (2001) re-examined the relation of source area and seismic moment for large earthquakes by adding some data from Japanese inland earthquakes and the compiled data by Wells and Coppersmith (1994) to the dataset of Somerville *et al.* (1999), and suggested that from the saturation of the fault width, the bending of the scaling relations from Somerville *et al.* (1999) occurs at $M_0 = 7.5 \times 10^{18}$ Nm (M_w6.5). However, the maximum magnitude of earthquakes used by Somerville *et al.* (1999), Mai and Beroza (2000), and Irikura and Miyake (2001) were M_w7.2 (1992 Landers), M_w7.2 (1992 Landers) and M_w7.6 (1999 Chi–Chi), respectively, and earthquakes with magnitudes larger than M_w7.6 were not included in these previous studies.

Several *M*8 class earthquakes during the past decade, such as the 2002 Denali, 2005 Kashmir, and 2008 Wenchuan earthquakes, occurred on inland mega-fault systems extending over 100 km and caused extreme damage to the surrounding regions. Source inversion analyses of subsurface faults immediately after large earthquakes and detailed surface fault field surveys were conducted simultaneously. Therefore, a comparison between the surface rupture and subsurface rupture became possible. Irikura and Miyake (2011) suggested a three-stage scaling model in which the relation between seismic moment and the source area of Irikura and Miyake (2001) is bent at about M_w7.9, considering the data of the 2002 Denali and 2008 Wenchuan earthquakes; however, they did not give the apparent expression of the scaling relation.

In this paper, we examine the relation between seismic moment and source area used in the first step of predicting strong ground motion. For this purpose, we quantitatively compare parameters between the observed length and displacement of the surface rupture from field surveys and the estimated length and displacement of the subsurface source fault from source inversion analysis on some large earthquakes of magnitudes greater than M_w7.6 which were not included in previous studies. We discuss the scaling relation between seismic moment and rupture area for the active crustal mega-fault systems extending over 100 km (*M*8 class). Hereafter, we refer to an active crustal fault extending over 100 km as a "mega-fault."

2. *Subsurface and Surface Rupture Data*

We collected all available information about the slip amount on the subsurface source fault obtained via waveform and geodetic inversion and forward modeling for finite-fault models. We then examined the scaling relations for mega-fault systems using 11 worldwide earthquakes (Table 1). We used slip distributions estimated from waveform inversion compiled in the finite-source rupture model database (Mai 2007), as well as those published on the internet, presented at scientific meetings, and conveyed via personal communication. We trimmed the slip distribution results following the procedure of Somerville *et al.* (1999), in which a row or column of the fault edge of a rectangular fault composed of n × m subfaults is trimmed if the average slip of the row or column is <0.3 times the average slip of the entire rupture area. We did not follow this procedure for the 1891 Nobi earthquake because it is a model determined by forward simulation. After the trimming process, average (D_{sub_ave}) and maximum (D_{sub_max}) slips on the fault were estimated, as shown in Table 1.

Furthermore, we collected all available information about the observed surface rupture, such as length of fault L_{surf} and observed maximum displacement D_{surf}, for the 11 earthquakes, as shown in

Table 1

Source parameters derived via waveform inversion analysis

Event	L (km)	M_0 (10^{20} Nm)	M_w^a	D_{sub_ave} (m)	D_{sub_max} (m)	S (km^2)	References
2008 Wenchuan	281	11.0	8.0	3.4	10.2	11,460	Yagi *et al.* (2012) Nakamura *et al.* (2010) Koketsu *et al.* (2008) Sladen (2008) Ji and Hayes (2008)
2005 Kashmir	120	2.6	7.5	2.7	5.9	4,320	Yagi (personal)[b]
2002 Denali	320	7.7	7.9	3.4	10.5	7,827	Oglesby *et al.* (2004) Asano *et al.* (2005)
1999 Chi–Chi	89	3.5	7.6	3.5	16.3	3,435	Chi *et al.* (2001) Ma *et al.* (2001) Wu *et al.* (2001) Zen and Chen (2001) Sekiguchi and Iwata (2001)
1999 Izmit	126	2.1	7.5	2.4	7.4	2,499	Yagi and Kikuchi (2000) Bouchon *et al.* (2002) Delouis *et al.* (2002) Sekiguchi and Iwata (2002)
1999 Duzce	31	0.4	7.0	1.0	6.5	1,158	Delouis *et al.* (2004) Birgören *et al.* (2004)
1995 Hyogo-ken Nanbu	57	0.27	6.9	0.8	3.9	1,027	Yoshida *et al.* (1996) Horikawa *et al.* (1996) Wald (1996) Ide *et al.* (1996) Koketsu *et al.* (1998) Cho and Nakanishi (2000) Sekiguchi *et al.* (2002)
1992 Landers	74	0.77	7.2	2.3	6.5	1,090	Cohee and Beroza (1994) Wald and Heaton (1994) Cotton and Campillo (1995) Hernandez et al. (1999) Zeng and Anderson (2000)
1978 Tabas	95	0.58	7.1	0.5	2.1	4,275	Hartzell and Mendoza (1991)
1906 San Francisco	460	8.2	7.9	4.4	9.7	5,520	Song *et al.* (2008)
1891 Nobi	122	1.8	7.4	3.3	–	1,795	Fukuyama *et al.* (2007)

[a] M_w calculated from M_0 in this table

[b] The result from Parsons *et al.* (2006) was reanalyzed

Table 2. We relied on the reported values as the maximum observed surface rupture displacement, although it is difficult to say that the value is the actual maximum displacement on the fault because the maximum displacement would be influenced by the immediate local geology.

For the data that we collected, there is some variability of parameters between studies if there are several analyses or surveys for one earthquake. The inversion result includes some arbitrariness from analyst to analyst, and the results should be influenced somewhat by the parameter settings used by each analyst. The purpose of this study is not to validate the data but to catch the overall characteristics of mega-fault scaling relations, so we used the average value of the parameters when there were more than two studies for an earthquake. The number of research groups for each earthquake can be found in the 'References' column in Tables 1 and 2, along with their references.

We compared these data with the parameters of 40 earthquakes selected by Hashimoto (2007) as having reliable subsurface source fault length data; these were selected from the 52 earthquakes in the catalogue of Stirling *et al.* (2002) (See Appendix). We then examined the scaling relations for mega-

Table 2

Source parameters derived from surface rupture observations

Event	L (km)	D_{surf} (m)	References
2008 Wenchuan	240	9.9	Lin *et al.* (2009) Liu-Zeng *et al.* (2009) Li *et al.* (2010)
2005 Kashmir	70	8.7	Kaneda *et al.* (2008)
2002 Denali	341	8.8	Eberhart-Phillips *et al.* (2003) Haeussler *et al.* (2004)
1999 Chi–Chi	85	10.7	Azuma *et al.* (2000) Yang *et al.* (2000) Dominguez *et al.* (2003) Lee *et al.* (2005)
1999 Izmit	145	5.3	Barka *et al.* (2002) Langridge *et al.* (2002) Lettis *et al.* (2002)
1999 Duzce	40	4.8	Akyüz *et al.* (2002)
1995 Hyogo-ken Nanbu	11	2.5	Awata *et al.* (1996) Nakata and Okada (1999)
1992 Landers	85	6.0	Sieh *et al.* (1993)
1978 Tabas	85	3.0	Berberian (1979)
1906 San Francisco	480	8.6	Thatcher *et al.* (1997)
1891 Nobi	80	7.7	Matsuda (1974) Japan Nuclear Energy Safety Organization Research (2006)

fault systems. In this study, we also included earthquakes that were analyzed after Stirling *et al.* (2002) compiled their data. As for the 1978 Tabas earthquake, the 1992 Landers earthquake, and the 1995 Hyogo-ken Nanbu earthquake, they are examined in Somerville *et al.* (1999). We added some new results about the 1992 Landers earthquake and the 1995 Hyogo-ken Nanbu earthquake, because more detailed data has been published. As for the subsurface source fault length of the 1891 Nobi earthquake, we used the result derived by Fukuyama *et al.* (2007) that considers the fault model including the Gifu-Ichinomiya fault. However, there are still debates about whether the rupture actually propagated to this fault or not. Analysis of the source process using waveform for earthquakes on mega-fault systems that extend more than 80 km in Japan is restricted to the 1891 Nobi earthquake (Fukuyama *et al.* 2007). Since the 1891 Nobi earthquake occurred at the dawn of instrumental observation, the observed seismogram needs to be used carefully and research results using these data also need to be interpreted accordingly.

3. *Comparisons Between Source Parameters Derived from Waveform Analysis and Field Measurement Survey*

In order to examine the scaling relations of earthquake source parameters with subsurface source faults and surface ruptures, we consider the parameters obtained from the 11 earthquakes in Tables 1 and 2 and the 40 earthquakes with reliable parameters selected by Hashimoto (2007) in Table 3. The relation between S and M_0 derived via waveform analysis for the large- and mega-fault systems is shown in Fig. 1. Data points greater than M_w6.5 used in this study are within the relation of Somerville *et al.* (1999), which is S (km^2) = 2.23 × 10^{-15} (M_0 (Nm) × 10^7)$^{2/3}$, and Irikura and Miyake (2001), which is S (km^2) = 4.24 × 10^{-11} (M_0 (Nm) × 10^7)$^{1/2}$, except for the 1978 Tabas earthquake. For the 1978 Tabas earthquake, the seismic moment obtained via waveform inversion ($M_0 = 5.8 \times 10^{19}$ Nm) and that obtained from the Global Centroid Moment Tensor catalogue ($M_0 = 1.3 \times 10^{20}$ Nm) are substantially different.

From the relation between the observed maximum surface displacement D_{surf} and subsurface slip D_{sub_ave} recalculated from the trimmed slip distributions, we found that D_{surf} is two to three times larger than D_{sub_ave}, as shown in Fig. 2a. If we have the relation between M_0 and S, the empirical average slip on the subsurface source fault is estimated from D (m) = M_0 (Nm)/(μS (km^2) × 10^6), where μ is the rigidity (N/m^2) of the medium at the source fault. Since D_{sub_ave} and D are equivalent on average, as shown in Fig. 3, we can check the validity of the fault parameters derived for strong ground motion prediction by comparing the ratio between estimated D_{sub_ave} and observed D_{surf} against Fig. 2a. If we need to go further and try to estimate M_0 from S, we need a new scaling relation equation for large magnitudes. We will discuss this in the next section.

In addition, we also found that for mega-fault systems, the length of surface rupture L_{surf} is nearly equal to the length of subsurface source fault L_{sub}, as shown in Fig. 4. This relation is very useful because it shows that L_{sub} can be determined from surface observations, L_{surf}. From the relation between estimated L_{sub} and observed D_{surf} for mega-fault systems, as shown in Fig. 5, D_{surf} saturates at about 10 m when L_{sub} (or L_{surf}) exceeds 100 km. Although there are studies that show maximum surface slip further exceeds 10 m, the main purpose of this study is to grasp the average characteristics of the source parameters, so we focus on the "average" of the maximum surface slip. Figure 2b shows the relation between the estimated maximum slip on the subsurface source fault D_{sub_max} and observed D_{surf}. We can see that D_{surf} is almost equal to or smaller than D_{sub_max}. This suggests that among the various fault parameters, D_{sub_max} can be approximated to be D_{surf} in case of mega-fault systems. Although it is difficult to clearly indicate that D_{sub_max} and D_{sub_ave} saturate at a certain value, we assume that they saturate along with D_{surf}, since some studies report that the displacement saturates from the relation between the fault length and displacements (Manighetti *et al.* 2007; Shaw and Scholz 2001; Shaw 2013). As for relations for low-angle thrust faults, careful examination is necessary in the future.

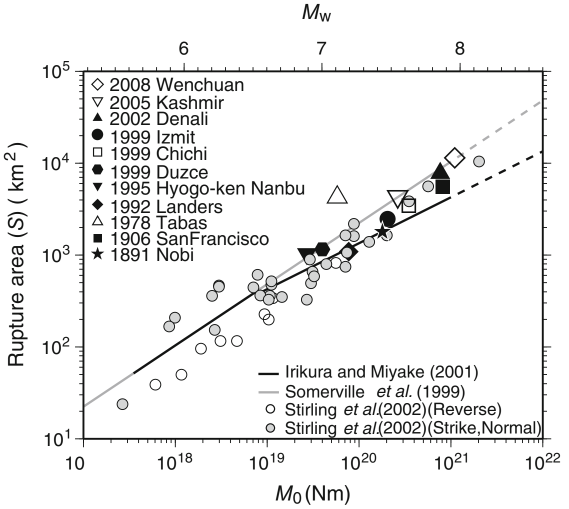

Figure 1

Relation between seismic moment (M_0) derived from waveform analysis and rupture area (S). *Gray* and *open small circles* are after Stirling *et al.* (2002) for reverse and strike or normal faults, respectively. *Black* and *gray solid lines* are scaling relations by Irikura and Miyake (2001) and Somerville *et al.* (1999), respectively

3.1. *Scaling Relation of Seismic Moment and Source Area for Mega-Fault Systems*

In order to estimate M_0 from S for mega-thrust earthquakes, we examined a way to modify the scaling relation of previous studies, especially for

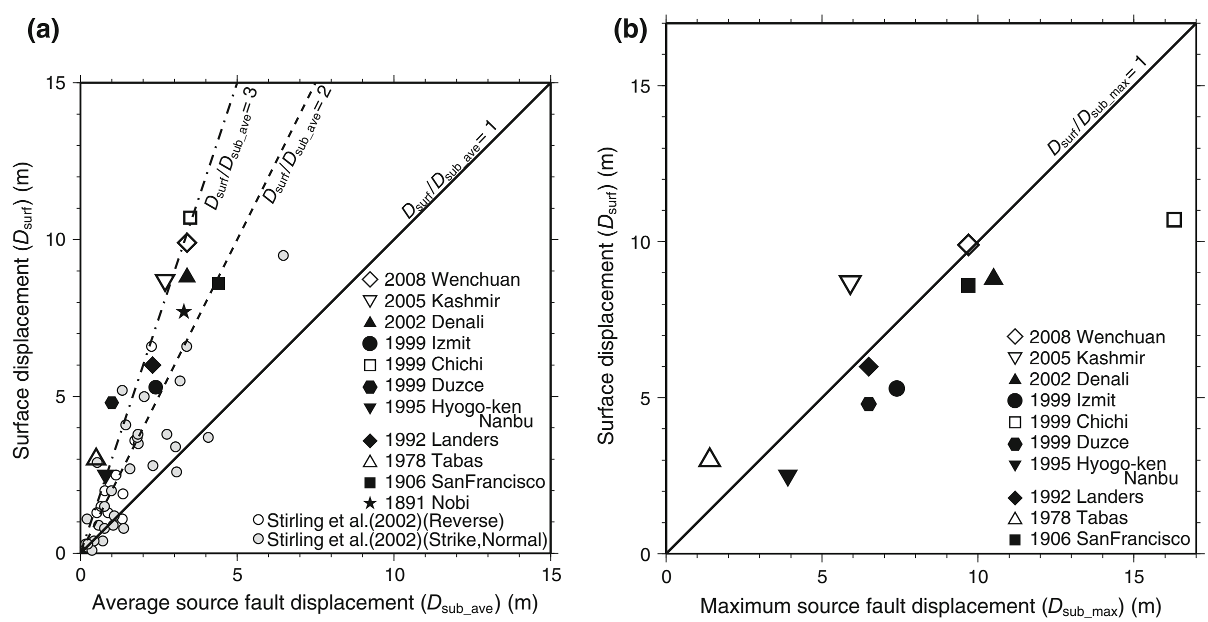

Figure 2

a Relation between average slip of the subsurface source fault (D_{sub_ave}) and maximum displacement of the surface rupture (D_{surf}). *Solid*, *dashed*, and *broken lines* denote a one-to-one, two-to-one, and three-to-one ratio between D_{surf} and D_{sub_ave}, respectively. **b** Relation between maximum slip of the subsurface source fault (D_{sub_max}) and maximum displacement of the surface rupture (D_{surf})

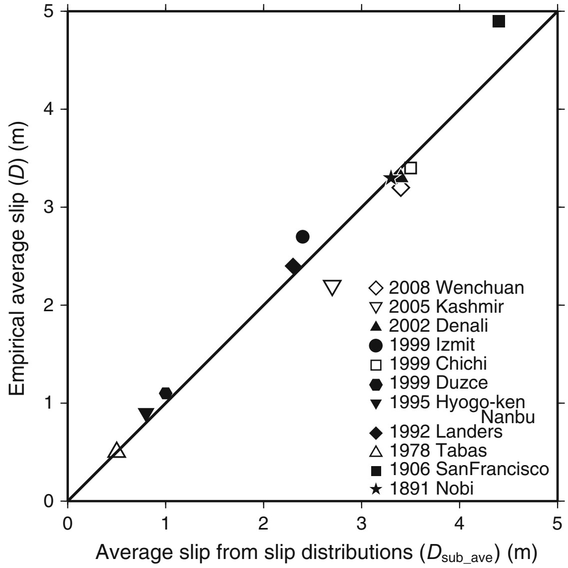

Figure 3
Relation between average slip distributions estimated by inversion analysis (D_{sub_ave}) and empirical average slip (D). A *solid line* denotes a one-to-one ratio

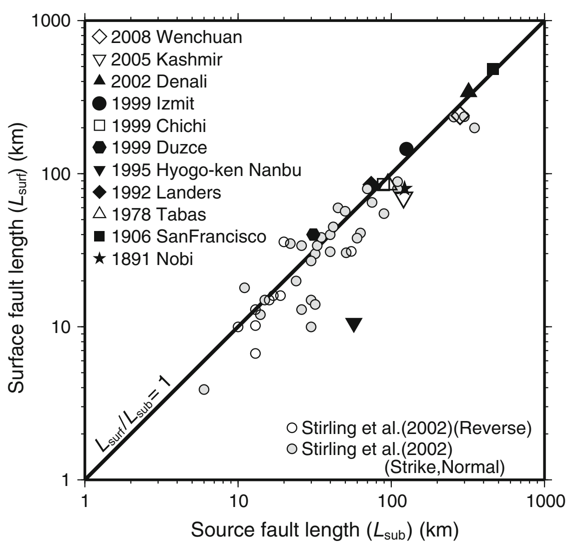

Figure 4
Relation between the subsurface source fault length (L_{sub}) and the maximum surface rupture (L_{surf}). A *solid line* denotes one-to-one ratio between L_{surf} and L_{sub}

large magnitudes. Irikura and Miyake (2001) and Hanks and Bakun (2002) showed a bending of the scaling relations for S and M_0 of Somerville *et al.* (1999) at M_w6.5 ($M_0 = 7.5 \times 10^{18}$ Nm) and Wells and Coppersmith (1994) at M_w6.7 ($M_0 = 1.4 \times 10^{19}$

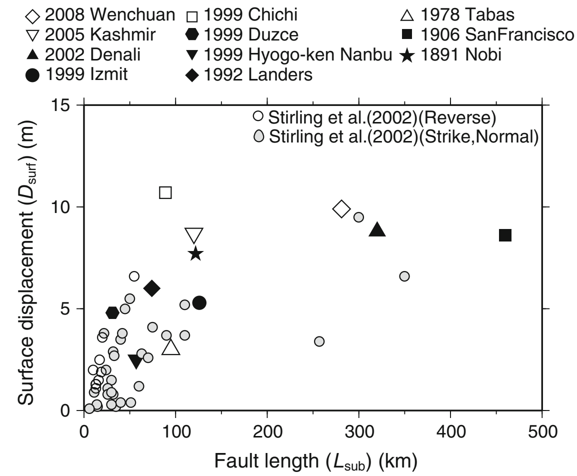

Figure 5
Relation between the subsurface source fault length (L_{sub}) and the maximum displacement of the surface rupture (D_{surf})

Nm), respectively, and S becomes proportional to $M_0^{1/2}$ from $M_0^{2/3}$ beyond this bending. Irikura and Miyake (2011) proposed a three-stage scaling relation between S and M_0 based on the idea that the second bending of the relation depends on the theory that the fault slip saturates when the fault length is greater than approximately ten times the fault width (Scholz 2002) and S becomes proportional to M_0 after the second bending. In this study, we adopt the their idea that the scaling relation has a second bending point to make a three-stage scaling relation by incorporating the fact that the slip on the fault saturates beyond a certain fault length and attempt to estimate the second bending point based on our database.

The second stage of scaling M_0 versus S beyond the first bending point due to saturation of the fault width is the same as Irikura and Miyake (2001). Since D_{surf} seems to saturate at 10 m when L_{surf} exceeds 100 km, as seen in Fig. 5, there will be a second bending point and, beyond this point, we can get the third stage of the scaling relation where M_0 is proportional only to L_{surf} or L_{sub}. If we assume that D_{sub_max} saturates at $D = 10$ m beyond the fault length $L = 100$ km and the fault width W is 18 km, M_0 of the second bending point can be derived as $M_0 = 1.8 \times 10^{20}$ Nm (M_w7.4) from $S = 1{,}800$ km^2 and the scaling relations of Irikura and Miyake (2001) up to this magnitude. $W = 18$ km is the average width of inland active faults estimated from the relations of Matsuda (1975), Takemura (1990), and Irikura and Miyake (2001).

Beyond $M_0 = 1.8 \times 10^{20}$ Nm, S will be proportional to M_0, and the scaling relation between M_0 and S can be derived as

$$S(\mathrm{km}^2) = 1.0 \times 10^{-17} M_0(\mathrm{Nm}), \qquad (1)$$

as shown with the solid line in Fig. 6. The average slip D_{sub_ave} will be about 3.3 m for the applicable magnitude range of this scaling relation, if we assume rigidity $\mu = 3.0 \times 10^{10}$ N/m^2. From these relations, we are able to estimate M_0 from S, but we need to be careful to determine the upper limit since there are no data available for earthquakes with fault lengths exceeding 500 km. In order to verify the goodness of fit of the new scaling relation, we calculated the standard deviations for the magnitude range over M_w 7.4. The standard deviations calculated from the scaling relation equation of this study, Irikura and Miyake (2001), and Somerville *et al.* (1999) were 1.34, 1.69, and 1.51, respectively. The standard deviation for the scaling relation estimated from this study is lower compared to the two previous studies for earthquakes larger than M_w7.4.

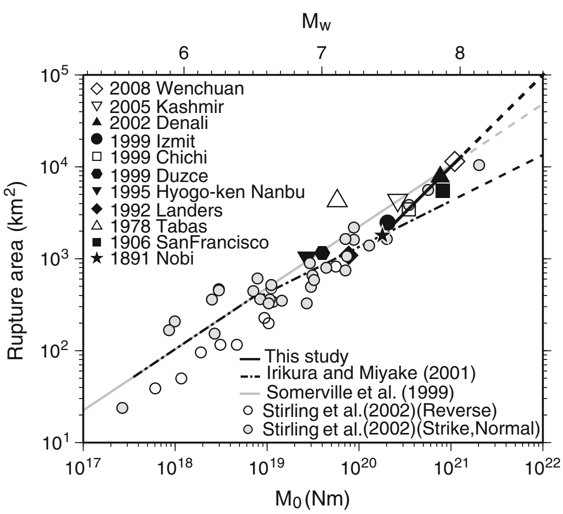

Figure 6

New scaling relation between seismic moment (M_0) and rupture area (S) proposed by this study. A *solid line* denotes the newly obtained third-stage scaling. A *dashed line* is an extrapolation of the new scaling relation

Shaw (2009) suggested the three-stage scaling model between the source area and magnitude for strike-slip events. The second and third stages for large and great events were estimated from saturation of the fault width at the seismogenic depth, which is assumed to be 16 km. The first and second stages are similar to the relation of Irikura and Miyake (2001), and the bending of the third stage is around M_w 7.5, which is close to the bending point of this study. However, the relation is different because Shaw (2009) assumed that the stress drop is constant from small to large earthquakes. Furthermore, it may differ because we used many heterogeneous source processes estimated via large earthquake waveform inversions.

4. Conclusions

In this study, we investigated scaling relations of earthquakes occurring on inland crustal mega-fault systems. From the data of 11 large- and mega-fault earthquakes that occurred thoughout the world, we found that rupture area S is actually between the relation proportioal to seismic moment ${M_0}^{1/2}$ proposed by Irikura and Miyake (2001) and the relation proportional to ${M_0}^{2/3}$ proposed by Somerville *et al.* (1999) beyond $M_0 = 7.5 \times 10^{18}$ Nm. Those two relations give the upper and lower limits of M_0 for a given S, respectively. We also found that the observed maximum surface displacement D_{surf} is two to three times larger than the average slip of subsurface source fault D_{sub_ave} and is almost equal to the maximum slip of subsurface source fault D_{sub_max}. The lengths of subsurface source fault L_{sub} and surface rupture L_{surf} are nearly equal, and the observed D_{surf} saturates at 10 m when the fault length is 100 km and longer.

As a result, assuming that the displacement of the source fault saturates if the fault exceeds a length of 100 km and the source fault width saturates at 18 km on average, we obtained a new third scaling relation between source area S and seismic moment M_0 for mega-fault systems, S (km^2) $= 1.0 \times 10^{-17}$ M_0 (Nm), when $M_0 > 1.8 \times 10^{20}$ (Nm).

Irikura and Miyake (2011) suggested the three-stage scaling model between the seismic moment and the source area, but they did not estimate the scaling relation for the third stage. Now, we have proposed a new scaling relation for this third stage for earthquakes with magnitudes over M_w7.4; it is expected that appropriate strong ground motion prediction will be performed using the magnitude from our new third stage scaling relation obtained from heterogeneous large earthquake slip distributions.

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Appendix

The dataset re-examined from the data of Stirling *et al.* (2002) by Hashimoto (2007). Table 3 shows the parameters of 40 earthquakes with reliable values from which the fault length and displacement of both subsurface and surface were obtained.

Table 3

Data of earthquakes from Stirling et al. (2002) used in this paper, re-examined by Hashimoto (2007)

Event	Date	ST[a]	M_w (seis)	M_0	Dsurf_max (m)	LGTHMX subs (km)[b]	LGTHMX surf (km)[b]	WMX (km)[c]
Avezzano	13/01/15	N	6.62	1.07E + 19	2	24	20	15
North-Izu	25/11/30	SR	6.89	2.72E + 19	3.8	22	35	15
Imperial-Valley	19/05/40	S	6.92	3.02E + 19	5	45	60	11
Rainbow-Mountain	6/07/54	N	6.22	2.69E + 18	0.9	11	18	14
Stillwater	24/08/54	N	6.55	8.41E + 18	0.81	26	34	14
Fairview-Peak	16/12/54	SN	7.17	7.16E + 19	5.5	50	57	15
Dixie-Valley	16/12/54	SN	6.94	3.24E + 19	3.8	42	45	14
Gobi-Altai	4/12/57	S	8.14	2.04E + 21	9.5	300	236	35
Lituya-Bay	10/07/58	S	7.77	5.69E + 20	6.6	350	200	16
Parkfield	28/06/66	S	6.25	2.99E + 18	0.2	35	38.5	13
Mogod	5/01/67	S	7.03	4.42E + 19	3.5	40	40	20
Mudurna-Valley	22/07/67	S	7.34	1.29E + 20	2.6	70	80	20
Borrego-Mountain	9/04/68	S	6.63	1.11E + 19	0.39	40	31	13
Dashi-e-Bayaz	31/08/68	S	7.23	8.81E + 19	5.2	110	80	20
Meckering	14/10/68	RS	6.61	1.04E + 19	3.6	20	36	10
Alasehir-Valley	28/03/69	N	6.71	1.46E + 19	0.82	32	30	11
Gediz	28/03/70	N	7.18	7.41E + 19	2.8	63	41	17
San-Fernando	9/02/71	RS	6.64	1.15E + 19	2.5	17	16	20
Luhuo	8/02/73	S	7.47	2.02E + 20	3.65	110	89	15
Motagua	4/02/76	S	7.63	3.51E + 20	3.4	257	235	15
Caldiran	24/11/76	S	7.23	8.81E + 19	3.7	90	55	18
Bob-Tangol	19/12/77	S	5.89	8.61E + 17	0.3	14	12	12
Homestead-Valley	15/03/79	S	5.55	2.66E + 17	0.1	6	3.9	4
Cadoux	2/06/79	R	6.12	1.91E + 18	1.5	16	15	6
El-Centro	15/10/79	S	6.53	7.85E + 18	0.35	51	30.5	12
Koli	27/11/79	SR	7.17	7.16E + 19	4.1	75	65	22

Table 3 *continued*

Event	Date	ST[a]	M_w (seis)	M_0	Dsurf_max (m)	LGTHMX subs (km)[b]	LGTHMX surf (km)[b]	WMX (km)[c]
El-Asnam	10/10/80	R	7.1	5.62E + 19	6.6	55	31.2	15
South-Apennines	23/11/80	N	6.91	2.92E + 19	1.15	60	38	15
Corinth	24/02/81	N	6.63	1.11E + 19	1.5	30	15	16
Corinth	04/03/81	N	6.25	2.99E + 18	1.1	26	13	18
Borah-Peak	28/10/83	NS	6.93	3.13E + 19	2.7	33	34	20
Marryal-Creak	30/03/86	RS	5.79	6.10E + 17	1.3	13	13	3
Kalamata	13/09/86	N	5.93	9.89E + 17	0.16	15	15	14
Edgecumbe	2/03/87	N	6.5	7.08E + 18	2.9	32	14	14
Elmore-Ranch	24/11/87	S	6.2	2.51E + 18	0.28	30	10	12
Superstition-Hills	24/11/87	S	6.61	1.04E + 19	0.92	30	27	11
Tennant-Creek	22/01/88	RS	6.38	4.68E + 18	1.1	13	6.7	9
Tennant-Creek	22/01/88	R	6.26	3.09E + 18	1.3	13	10.2	9
Tennant-Creek	22/01/88	R	6.58	9.33E + 18	1.9	19	16	12
Ungava	25/12/89	R	5.98	1.17E + 18	2	10	10	5

[a] *ST* slip type, *S* strike, *R* reverse, *N* normal

[b] *LGTHMX* maximum length

[c] *WMX* maximum rupture width

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