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# The 20 January 2007, $M_w$ 4.5, Odaesan, Korea, earthquake

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**ABSTRACT: Results of analyses for the source parameters and ground responses of the 20 January 2007 Odaesan earthquake, Korea, are presented. We use the ground velocity and acceleration data recorded at the regional seismic stations located in southern Korea. For the determination of hypocenter and origin time, we use the program HYPO71 which has been generally used for the hypocenter determination of local earthquake and perform a depth phase analysis using arrival time difference of $P_n$ and $sP_n$ waves. The focal mechanism is obtained using a grid search algorithm with the polarities of the observed $P_g$, $P_n$ and *SH* waves. The moment magnitude ($M_w$) and dynamic stress drop are estimated using an iterative integral method with broadband seismic data. The estimated source parameters of the Odaesan earthquake are as follows: origin time 11:56:53.48 in UTC, latitude 37.686°N, longitude 128.589°E, focal depth 12.1 km, $M_w$ 4.5, dynamic stress drop 77.4 bars, the fault plane 19.69°, 69.74° and -165.02°, the auxiliary plane 284.40°, 75.97° and -20.91° in strike, dip and rake, respectively. Considering geological characteristics around the epicenter, the fault plane solution with the strike angle of 19.69° is consistant with that of the existing Woljeongsa fault. The largest peak ground acceleration (PGA), 0.157 g, was recorded at the DGY station located 7.5 km east of the epicenter. The maximum instrumental intensity is estimated as VII in the Modified Mercalli Intensity (MMI) scale.**

**Key words:** the 20 January 2007 Odaesan earthquake, focal mechanism, depth phase, dynamic stress drop, seismic moment, moment magnitude, peak ground acceleration, instrumental intensity

## 1. INTRODUCTION

On January 20, 2007, an earthquake of magnitude ($M_L$) 4.82 occurred at a place on the southern flank of Odaesan (Mt.), Gangwon Province, Korea. This earthquake was named concisely as the "Odaesan earthquake" after the Korea Meteorological Administration (KMA). People felt shaking of this earthquake at Gangneung, Wonju, Chuncheon, Seoul, Daejeon, Daegu, etc. They are located at distances of 27 km east, 57 km southwest, 69 km west, 149 km west, 181 km southwest and 215 km south of the epicenter. KMA announced the epicenter location (37.68°N, 128.59°E) and the local magnitude ($M_L$) 4.82 (KMA, 2007). Korea Institute of Geoscience and Mineral Resources (KIGAM) presented the epicenter location (37.6889°N, 128.5841°E) and the local magnitude ($M_L$) 4.9 in the preliminary report (KIGAM, 2007).

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The geology of the source region is composed mainly of biotite granite intruded in Jurassic. To the northwest of the source area is distributed migmatitic gneiss with small granitic bodies intruded in it. The Woljeongsa fault runs N10°E along a small river, Odaecheon, at a distance of 1 km to the east of the epicenter in the area of Jurassic granite of the source region (Cheong et al., 1975). The northern tip of the fault coincides with the contact line between the biotite granite and migmatitic gneiss to the north of the hypocenter. The South Korea Tectonic Line (SKTL) as major tectonic boundary between the Kyonggi Massif and the Yongnam Massif (Chough et al., 2000) is supposed to pass through the area near the source. However, the exact location is not known due to the intrusion of the Jurassic granite.

There have been some noticeable earthquakes occurring in the area near the epicenter of the Odaesan earthquake. The 13 December 1996, $M_L$ 4.5, Yeongwol earthquake occurred at 50-km south of the epicenter of the Odaesan earthquake (Fig. 1). Modified Mercali Intensity (MMI) by the Yeongwol earthquake was up to VII (Jo et al., 1997). In the historical time, an $M_L$ 6.5 earthquake occurred in Yangyang-Samcheok area on the June 26, 1681. Some walls and tiled roofs were collapsed by the historical Yangyang-Samcheok earthquake. Recently on the January 24, 1996, an $M_L$ 4.2 earthquake also occurred offshore Yangyang.

The Odaesan earthquake triggered almost all of seismic instruments at stations operated by KIGAM and KMA (Figs. 1 and 2) in southern Korea. This provides a good opportunity to analyze an earthquake of moderate size in the Korean Peninsula using modern digital data and techniques. In this article, we determine the source parameters of the event, present interpretations on possible focal mechanisms, and discuss the seismotecnonic implications of the earthquake.

## 2. SOURCE PARAMETERS

### 2.1. Event and Data

The recordings of the ground motions caused by the Odaesan earthquake can be obtained from the regional seismic networks in southern Korea. In order to compute the hypocenter and origin time, we use arrival times of the $P_g$ and $P_n$ waves obtained from the seismographs within 200-km epicentral distances. In order to compensate sparse cov-

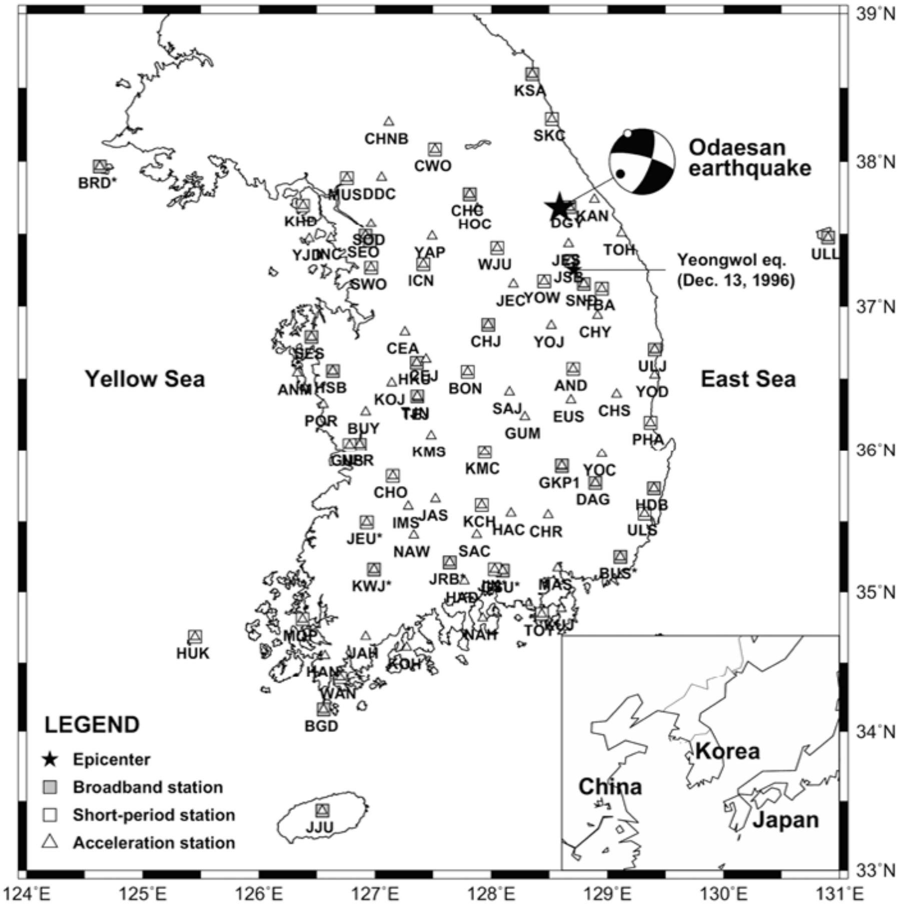


**Fig. 1.** Location map of seismic stations in southern Korea and the epicenter of the 20 January 2007 Odaesan, Korea, earthquake. The Odaesan earthquake triggered almost all of seismic instruments in southern Korea. The latitude and longitude of the epicenter are 37.686°N and 128.589°E, respectively. The focal depth is estimated as 12.1 km using a depth phase analysis with seven stations denoted by an asterisk (*). The focal mechanism of the earthquake computed in this study is shown by shape of beach ball.

erage at places in the east-to-north directions from the epicenter, we additionally analyze some of the $P_g$ wave arrival times from the accelerograms recorded within an epicentral distance of 130 km. For the computation of the hypocenter and origin time, we use the program HYPO71 that has been generally used for determining the hypocenter of local earthquake based on the arrival times of several phases with an 1-D crustal structure (Lee and Lahr, 1975). We adapt the three-layered 1-D crustal structure of Chang and Baag (2006) which was obtained from joint analysis of regional broadband waveforms and travel times in southern Korea. We assume that the ratio of $P$ and $S$ wave velocities ($V_P/V_S$) is 1.76 following Chang and Baag (2005).

The arrival times of the first-arriving $P$ and $S$ waves from 41 and 17 stations, respectively, are used for determining the hypocenter and origin time. Based on the picking quality, we assign a weighting factor ranging from 0.25 to 1 with a 0.25 increament to each data. The epicenter is computed as 37.686°N and 128.589°E (Fig. 1). The origin time of the earthquake is also determined as 11:56:53.48 in UTC (Coordinated Universal Time), i.e., 20:56:53.48 in Korean local time.

Generally, it is difficult to determine the focal depth using the first arrival phases with only a least-square method such as that of HYPO71. To determine the focal depth more precisely, we perform a depth phase analysis using the arrival time difference between $P_n$ and $sP_n$ phases (Bent and Perry, 2002). The $sP_n$ is defined as the $P_n$ wave converted at the free surface from the upgoing $S$ wave. The $sP_n$ phase shows a relatively large amplitude in the $P_n$ wave train and its delayed arrival time relative to that of the $P_n$ wave is independent of the epicentral distance and backazimuth. Thus, the focal depth can be determined using the arrival time difference between the $P_n$ and $sP_n$ waves. We select seven vertical-component seismograms with distinct $sP_n$ phases among the observed data at the epicentral distances larger than 250 km (Figs. 1 and 3). The seismograms are aligned to the $P_n$ onset time (solid line of Figure 3). The $sP_n$ wave was recorded after 4.6 seconds following the $P_n$ wave at every station (dashed line of Figure 3). A Butterworth filter with corner frequency of 1 Hz is applied to the records. The mean value of the arrival time difference is estimated as 4.6 seconds (Fig. 3). If the average velocities of $P$ and $S$ waves in the upper crust (less than 15 km) are assumed as 5.92 km/s and 3.37 km/s, respectively, and the $P$-wave velocity in the upper mantle is to be 7.88 km/s (Chang and Baag, 2005, 2006), the focal depth can be determined to be 12.1 km from the surface.

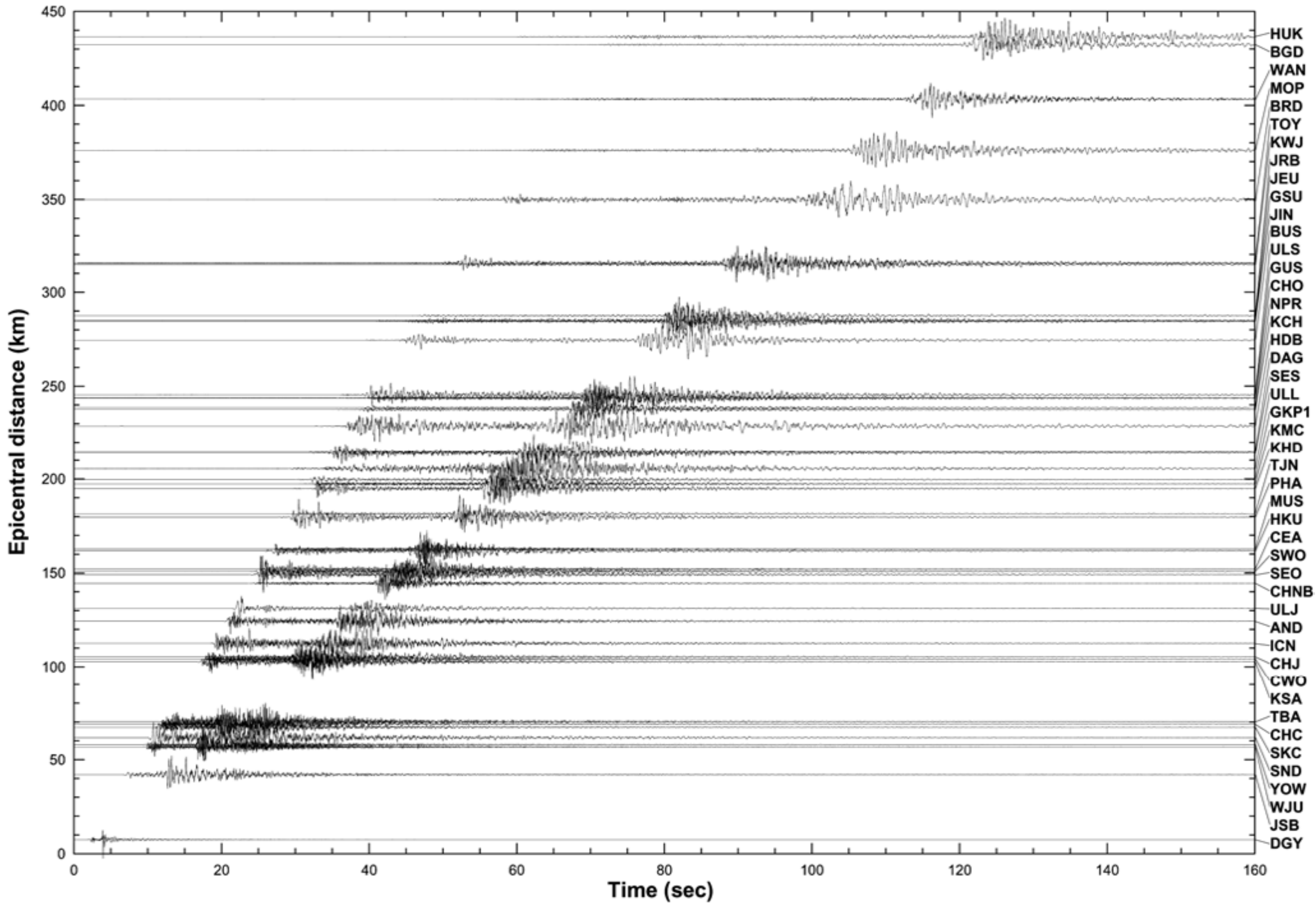


**Fig. 2.** Vertical-component velocity seismograms recorded at regional seismic stations in southern Korea. No activity of distinct surface wave is seen within 200 km of epicentral distance.

### 2.2. Focal Mechanism

The focal mechanism is one of the most important source parameters for understanding the nature of earthquakes. It reflects the stress direction and information on tectonic settings in the source region. If stations are distributed uniformly over azimuthal angles, the focal mechanism can be computed easily from *P*-wave polarities. We use the $P_g$- and $P_n$-wave polarities at 35 stations and *SH*-wave polarity determined at DGY station. The grid search algorithm of Snoke et al. (1984) is applied for the determination of the focal mechanism. This algorithm is used to search the source parameters of double-couple orientations with a 5° increment of the trend and plunge of the A and B axis. A total of 4 solutions agrees with all the $P_g$- and $P_n$-wave polarities. Figure 4 shows a stereographic plot of these orientations in the lower hemisphere with these orientations. Circles represent the piercing points of seismic rays to the stations on the focal sphere. The strike directions of two types of the fault solutions and auxiliary solutions are in NNE and SSW, respectively, and the dipping angles are nearly 70 degrees. The median of fault plane solutions is chosen as the best fit solution. The fault plane and auxiliary plane solutions in strike, dip, and rake are (19.69°, 69.74°, -165.02°) and (284.40°, 75.97°, -20.91°). The computational result suggests that the Odaesan earthquake was caused by a predominantly strike-slip fault. Details for the focal mechanism and structural aspects of the epicenter region will be mentioned at the discussion section.

### 2.3. Moment Magnitude and Dynamic Stress Drop

The magnitude of the earthquake can be estimated variously using the body wave amplitude, surface wave amplitude, seismic sigmal duration, etc. It is well known that the moment magnitude ($M_w$) reflects the energy release from the earthquake very well, because it is estimated from the seismic moment of the source. Provided that the earthquake source can be explained by the Brune's $\omega^{-2}$ source model, the relationship among the seismic moment ($M_0$), corner frequency ($f_c$), and dynamic stress drop ($\Delta\sigma$) can be represented by

$$f_c = 4.9 \times 10^6 \beta (\Delta\sigma / M_0)^{1/3} \quad (1)$$

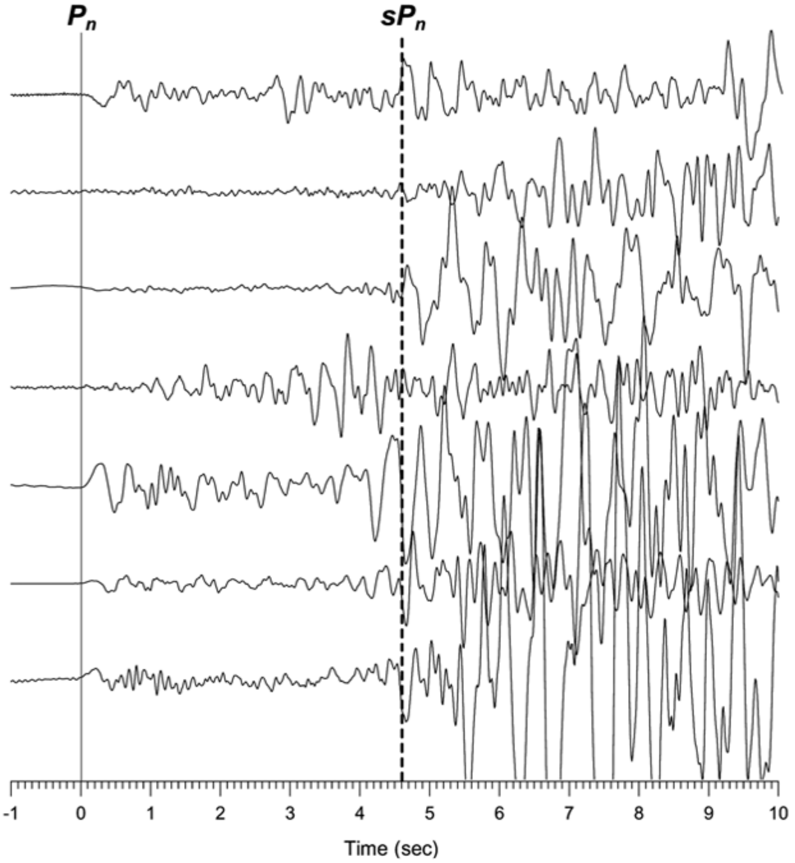


**Fig. 3.** $P_n$ and $sP_n$ vertical-component velocity seismograms recorded at selected seven stations beyond 250-km epicentral distance (see also Fig. 1). A Butterworth filter with corner frequency of 1 Hz is applied to the records. The seismograms are aligned with the $P_n$ onset time (solid line) The $sP_n$ wave was recorded after 4.6 sec following the $P_n$ wave at every station (dashed line). The station name, epicentral distance, and azimuth are given at the end of each seismic trace. The estimated focal depth is 12.1 km from the surface.

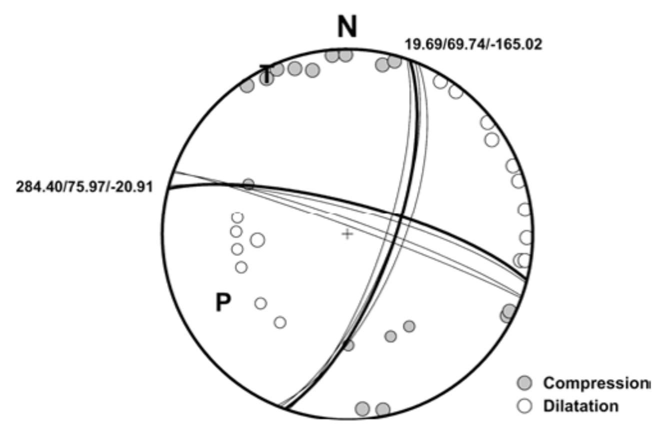


**Fig. 4.** Equal area projection of the focal mechanism of the 20 January 2007 Odaesan, Korea, earthquake. The polarities of the $P_g$, $P_n$ and *SH* waves are used for computation. Large and small circles indicate the $P_g$ and $P_n$ waves, respectively. Total 4 solutions are obtained using a grid search algorithm and the median of solutions is 19.69°, 69.74° and -165.02° for the first fault plane, and 284.40°, 75.97° and -20.91° for the auxiliary plane in strike, dip, and rake, respectively. The first plane has a strike direction similar to that of the existing Woljeongsa fault at 1-km distance to the east from the epicenter.

where $\beta$ is the shear wave velocity (Brune, 1970). The units of $f_c$, $\beta$, $\Delta\sigma$, and $M_0$ are in Hz, km/s, bars, and dyne·cm. The seismic moment ($M_0$) is obtained from the lower frequency asymptote of the source spectrum of displacement. We used an iterative integration method of Jo and Baag (2001) for the determination of the seismic moment and dynamic stress drop that is a modification of the techniques of Snoke (1987) and Andrews (1986). The moment magnitude can be estimated using the relation of Hank and Kanamori (1979) given by

$$M_w = \frac{2}{3}\log M_0 - 10.7\,. \qquad (2)$$

We use 12 velocity seismograms of the *S* wave recorded at seven broadband stations within 200-km epicentral distances. In order to obtain the source spectrum of displacement, we modify the observed broadband seismograms considering the anelastic attenuation and geometric spreading in the frequency domain. The seismic quality factor *Q* value of 2067 (Jo and Baag, 2003) is applied to construct the source spectrum. Because surface waves are not developed sufficiently within 200 km distance, we assume that the amplitude decay by the geometric spreading is inversely proportional to the hypocentral distance (*R*) in km. We apply the iterative integral method (Jo and Baag, 2001) to the source spectra of displacement of which frequency range is 0.5-30 Hz. The computed mean values of the moment magnitude and the dynamic stress drop are 4.5 and 77.4-bar (Fig. 5 and Table 1) with the standard deviations of 0.24 and 34.9, respectively.

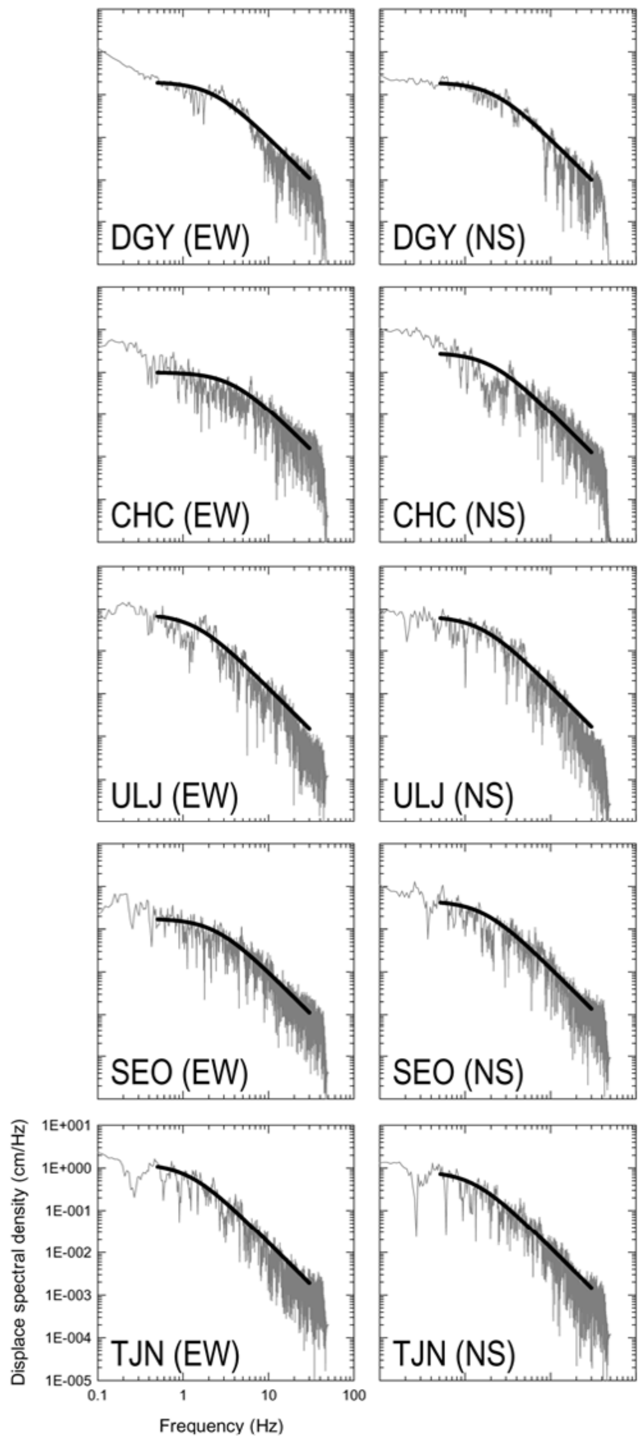


**Fig. 5.** Displacement source spectra (gray lines) of the Odaesan earthquake obtained from 10 horizontal-component velocity seismograms recorded at 5 broadband seismic stations. The Brune's displacement $\omega^{-2}$ source spectra (thick lines) are presented for comparison with the observed source spectra. The Brune's source spectra are computed for the frequency range from 0.3 to 30 Hz using the seismic moment, corner frequency, and dynamic stress drop estimated from the data at each station. The mean values of the moment magnitude and dynamic stress drop are estimated as 4.5 and 77.4-bar, respectively.

We also estimate the moment magnitude and dynamic stress drop using the acceleration data recorded at the same sites of broadband stations as those for the first computational scheme. Mean values of the moment magnitude and dynamic stress drop obtained from the acceleration data are similar to those from the velocity data (Table 2).

## 3. GROUND MOTION

### 3.1. Peak Ground Acceleration

87 accelerographs have been operated by KMA and KIGAM in southern Korea (Fig. 1) and all of them recorded ground motions by the Odaesan earthquake. The peak ground motion (PGA) is especially important for engineering seismology and seismic hazard assessment. Generally, PGA is the peak amplitude of the transverse component of accelerograms obtained by rotating horizontal components using the back-azimuth angle of the station. Figure 6 shows the distribution of PGAs against the hypocentral distances. The spatial distribution of PGAs are shown by Figure 7. The maximum PGA value recorded at the closest station, DGY, is 0.157 g where 1 g corresponds to 980 $cm/s^2$. Solid lines of Figure 6 show attenuations in the $M_w$ 4.0-6.0 earthquakes for southern Korea estimated by Junn et al. (2002). At TOH, DDC and BUY stations, the PGAs are larger than other stations at similar hypocentral distances. On the other hand, the borehole stations such as JSB, HSB and HDB, the ground accelerations are recorded relatively smaller than those at others.

### 3.2. Instrumental Intensity

The instrumental intensities in the modified Mercali Intensity (MMI) scale are deduced from the PGA values (Fig. 7). We use the empirical relationship between PGA ($cm/s^2$) and maximum MMI ($I_{max}$) for southern Korea proposed by Kim et al. (2006):

$$\ln(\mathrm{PGA}) = 0.58 I_{max} + 1.0 \quad (I_{max} \geq 2). \qquad (3)$$

The maximum intensity is estimated as VII at the DGY station nearest to the epicenter. At the KAN station with epicentral distance of 28.7 km, the instrumental intensity is VI. The intensity values decrease rapidly at places about 100 km away from the epicenter. However, the instrumental intensities are estimated as MMI III, relatively large value at stations DDC and BUY with epicentral distances of 136 km and 216 km, respectively. These phenomena seem to result from the site effects at each station.

## 4. DISCUSSIONS

The velocity structure of the crust and upper mantle is important to determine the earthquake hypocenter and ori-

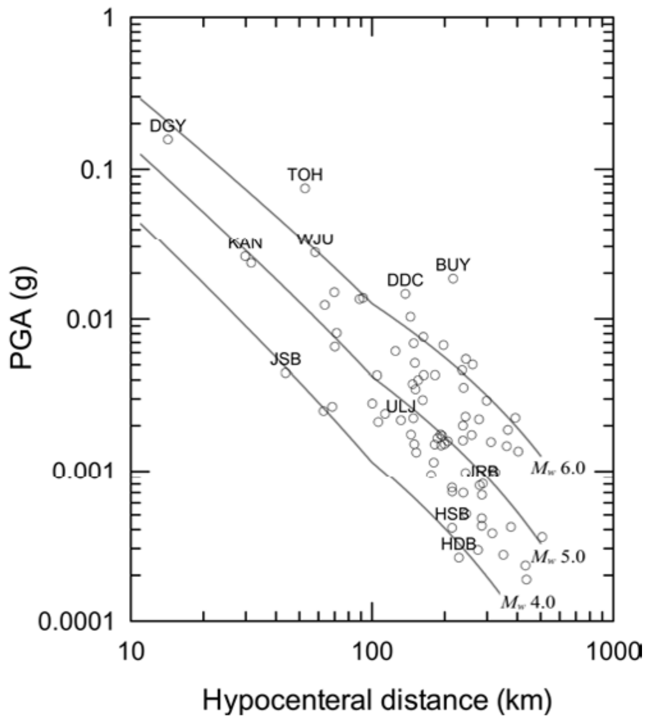


**Fig. 6.** Distribution of PGAs recorded at stations recording accelerograms in southern Korea. Names of some special stations are also noted. Solid lines show attenuations of $M_w$ 4.0-6.0 earthquakes in southern Korea estimated by Junn et al. (2002). The maximum PGA of 0.157 g is recorded at the DGY station at hypocentral distance 14.3 km. At TOH, DDC and BUY stations, the PGAs are larger than other stations at similar hypocentral distances. On the other hand, the borehole stations such as JSB, HSB and HDB, the ground accelerations are recorded relatively smaller than those at others.

**Table 1.** List of the moment magnitudes and dynamic stress drops of the 20 January 2007 Odaesan, Korea, earthquake estimated using broadband velocity seismograms at five stations.

| Station ID | Component | $\Omega_0$ (cm/Hz) | $f_c$ (Hz) | $M_w$ | $\Delta\sigma$ (bar) |
|---|---|---|---|---|---|
| DGY | EW | 0.199 | 2.25 | 4.30 | 72.1 |
| | NS | 0.195 | 2.18 | 4.30 | 64.5 |
| CHC | EW | 0.101 | 3.79 | 4.11 | 174.4 |
| | NS | 0.289 | 1.99 | 4.41 | 72.5 |
| ULJ | EW | 0.726 | 1.36 | 4.68 | 58.6 |
| | NS | 0.644 | 1.53 | 4.64 | 73.6 |
| SEO | EW | 0.178 | 2.39 | 4.27 | 77.0 |
| | NS | 0.458 | 1.64 | 4.54 | 64.9 |
| TJN | EW | 1.262 | 1.17 | 4.84 | 64.1 |
| | NS | 0.843 | 1.25 | 4.72 | 52.1 |
| Mean | | 0.489 | 1.96 | 4.48 | 77.4 |
| Standard deviation | | 0.375 | 0.78 | 0.24 | 34.9 |

**Table 2.** List of the moment magnitudes and dynamic stress drops of the 20 January 2007 Odaesan, Korea, earthquake estimated using accelerograms at five stations.

| Station ID | Component | $\Omega_0$ (cm/Hz) | $f_c$ (Hz) | $M_w$ | $\Delta\sigma$ (bar) |
|---|---|---|---|---|---|
| DGY | EW | 0.217 | 2.31 | 4.33 | 85.7 |
| | NS | 0.188 | 2.40 | 4.29 | 83.0 |
| CHC | EW | 0.105 | 3.43 | 4.12 | 134.6 |
| | NS | 0.299 | 1.90 | 4.42 | 65.0 |
| ULJ | EW | 0.725 | 1.34 | 4.68 | 55.7 |
| | NS | 0.674 | 1.47 | 4.66 | 68.2 |
| SEO | EW | 0.183 | 2.23 | 4.28 | 64.5 |
| | NS | 0.474 | 1.57 | 4.55 | 57.9 |
| TJN | EW | 1.320 | 1.08 | 4.85 | 53.2 |
| | NS | 0.884 | 1.18 | 4.74 | 46.8 |
| Mean | | 0.507 | 1.89 | 4.49 | 71.5 |
| Standard deviation | | 0.391 | 0.72 | 0.24 | 25.4 |

gin time. In this study, we used the crustal model of Chang and Baag (2006) for southern Korea. In addition, the $V_P/V_S$ ratio of 1.76 was used to obtain the $S$ wave velocity structure, because the $V_P/V_S$ ratio ranges from 1.72 to 1.80 in southern Korea (Chang and Baag, 2005). KMA and KIGAM announced the epicenter of the Odaesan earthquake. The locations are (37.68°N, 128.59°E) and (37.6889°N, 128.5841°E), respectively (KMA, 2007; KIGAM, 2007) that are very close to the epicenter estimated in this study. On the other hand, U.S. Geological Survey (USGS) also estimated the epicenter using the teleseismic data. The location, 37.643°N/128.472°E, is 11 km away from the epicenter estimated in this study.

The focal depth of the Odaesan earthquake was estimated using the arrival time differences between $P_n$ and $sP_n$ waves. This depth phase analysis technique had been successfully applied to the 2004 offshore Uljin, Korea, earthquake by Kang and Baag (2004). Although the $sP_n$ phase is recorded at the epicentral distances larger than 250 km where the travel time of the $P_g$ wave is larger than that of the $sP_n$ wave, this technique is useful to determine the focal depth in southern Korea. The estimated focal depth of 12.1 km in the current study is close with the estimation of 13.1 km by KIGAM (2007). Kim (2007) and Herrmann (2007) mentioned in their preliminary reports that the focal depths were estimated as 10-15 km and 8-12 km, respectively, using a waveform fitting analysis.

The focal mechanism of the Odaesan earthquake shows a trend and plunge of 240.99°/24.60° and 332.92°/4.21° for the P and T axes, respectively (Fig. 4). At 1-km distance to the east from the epicenter, the Woljeongsa fault runs N10°E along a small river, Odaecheon, in the area of Jurassic granite according to the explanatory text of the geological map of Odaesan sheet published at KIGAM (Cheong, 1975). The northern tip of the SKTL located in the source region was smeared by granite intruded in Jurassic. There is a possibility that one of the two fault plane solutions, i.e., the right-lateral strike slip fault with strike of 19.69°, dip of

69.74°, and rake of -165.02° may correspond to the Woljeongsa fault.

The dynamic stress drop is important for source scaling of earthquakes. We estimated the dynamic stress drops independently using broadband velocity data and the acceleration data. Based on our results, the dynamic stress drops computed using the broadband velocity data and the acceleration data are close to each other with average values of 77.4 and 71.5 bars, respectively (Tables 1 and 2). In this study, we choose 77.4 bars as the representative value for the dynamic stress drop of the Odaesan earthquake. Kang and Baag (2004) computed the dynamic stress drop of 23 bars for the 04 June 2004 offshore Uljin earthquake that is much smaller than that of the Odaesan earthquake. Total 6 aftershocks of the offshore Uljin earthquake occurred during one month offshore Uljin area (see also Table 1 of Kang and Baag, 2004). In the case of the Odaesan earthquake, however, no meaningful aftershock ($M_L$>2.0) has followed the earthquake. We think that the accumulated stress around the fault seems to be released fully by the Odaesan earthquake.

The moment magnitude 4.5 computed in this study for the Odaesan earthquake is a little smaller than local magnitudes 4.82 and 4.9 announced by KMA (2007) and KIGAM (2007), respectively. USGS reported the body wave magnitude to be 4.4 (USGS, 2007). From the empirical relationship between $M_w$ and $M_L$ in the eastern North America (Boore and Atkinson, 1987), the moment magnitude tends to be estimated smaller than the local magnitude in the range from 3.0 to 7.0 for the same earthquake. It seems to be natural that the $M_w$ estimated in this study is smaller than the local magnitudes by KMA and KIGAM.

The maximum PGA is 0.157 g at station DGY. At the stations of TOH, BUY, DDC and WJU, ground motions are relatively stronger than other sites (Fig. 6). On the other hand, at the borehole stations such as JSB, HSB and HDB, weaker ground motions are recorded. Although the moment magnitude is estimated as 4.5 in this study (Table 1), the distribution range of PGA that can be affected by site properties is comparatively broad (Fig. 6). Thus, it is important to use well-recorded data for the computation of source parameters (e.g., moment magnitude, stress drop, corner frequency, etc).

The instrumental intensity were estimated using the PGA values at all stations in southern Korea except the borehole sites such as CHNB, HSB, JRB and JSB (Fig. 7). The instrumental intensity value at the nearest station DGY is estimated VII in the MMI scale. KMA reported the value of MMI VI for the maximum intensity from felt reports The acceleration-intensity relationship for the instrumental intensity

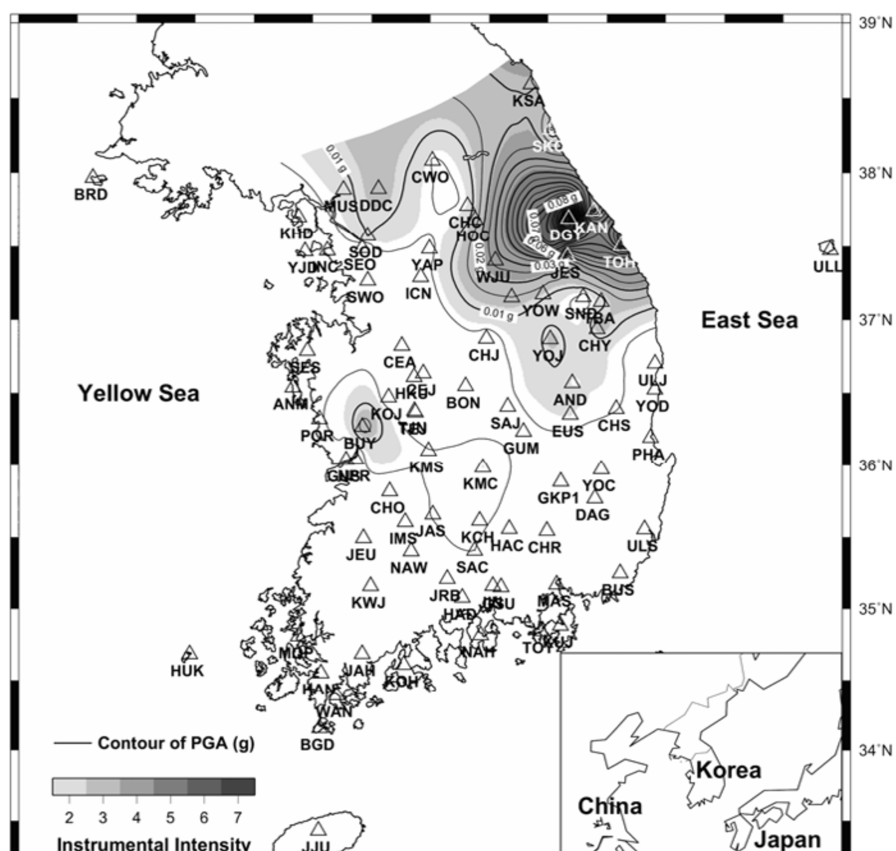


**Fig. 7.** Distribution of instrumental intensities of the 20 January 2007 Odaesan, Korea, earthquake in MMI. The instrumental intensities are computed using the PGAs at all acceleration stations (△) except borehole stations. The maximum intensity is computed as MMI VII at station DGY. The intensities decrease rapidly with distance beyond 200 km. Relatively large instrumental intensities are estimated at stations DDC, BUY, KMC and JAS.

**Table 3.** Source parameters of the 2007 Odaesan, Korea, earthquake.

| Date | Time in UTC (hh:mm:ss.ss) | Latitude (°N) | Longitude (°E) | Depth (km) | Seismic moment (dyne·cm) | Moment magnitude | Stress drop (bar) | Corner frequency (Hz) | Focal mechanisms (strike/dip/rake) |
|---|---|---|---|---|---|---|---|---|---|
| January 20, 2007 | 11:56:53.48 | 37.686 | 128.589 | 12.1 | $5.9\times10^{22}$ | 4.5 | 77.4 | 1.96 | 19.69°/69.74°/-165.02°<br>284.40°/75.97/-20.91 |

proposed by Kim et al. (2006) appears to be useful for the description of the instrumental intensity in southern Korea.

## 5. CONCLUSIONS

The source parameters of the 20 January 2007 Odaesan earthquake is analyzed using digital seismic records from the seismic stations in the southern Korea. The estimated source parameters of the earthquake are as follows: origin time 11:56:53.48 in UTC, latitude 37.686°N, longitude 128.589°E, focal depth 12.1 km, $M_w$ 4.5, dynamic stress drop 77.4 bars, the fault plane 19.69°, 69.74°, and -165.02°, the auxiliary plane 284.40°, 75.97° and -20.91° in strike, dip and rake, respectively (Table 3). Considering the geological information around the epicenter, the fault plane solution with the strike angle of 19.69° corresponds to the existing Woljeongsa fault. The largest PGA, 0.157 g, was recorded at the DGY station located 7.5 km east of the epicenter. The maximum instrumental intensity is estimated as VII in MMI scale.

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