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Source Process of the 2003 Bam, Iran, Earthquake inferred from Joint Inversion of Teleseismic and Strong Motion Data

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We attempt to determine precise fault geometry and source process of the December 26, 2003 Bam earthquake from southeast Iran, and answer the question why a moderate event (Mw 6.5) resulted in such a large disaster. Previous studies showed that the earthquake was caused by a subsurface rupture on previously unknown strike-slip fault. A remarkable record obtained at the strong-motion station inside the city of Bam and 5 km from the epicenter shows the PGA value of 988 gal in the UD component and two pulses with a dominant frequency of 1 Hz in the horizontal components. It was inferred that the large PGA value recorded at Bam station and the proportion of damage provoked by this event might be explained by the combination of the forward rupture directivity effect towards the city of Bam and a large speed of the rupture front over the fault (Bouchon et al., 2005). Although, there have been proposed several fault models of this event from geodetic data (Talebian et al., 2004; Wang et al., 2004; Fielding et al., 2005) and aftershock analysis (Nakamura et al., 2005), they are varying significantly in there location and some of them propose existence of the fault branching towards the north, beneath the city of Bam.

We inverted teleseismic and strong motion data to determine the precise fault configuration and rupture process of the 2003 Bam earthquake. It is expected that the combination of this two different datasets will offer a more stable image of the source area, while each of the teleseismic and strong motion data carries information on different period ranges of the process at the source. To infer the general rupture process, we first analyzed teleseismic dataset. We applied the moment tensor analysis as well as the source inversion method developed by Kikuchi and Kanamori (1982, 1991) and Kikuchi et al. (2003) to 23 P- and 17 SH- far-field displacement waveforms from IRIS-DMC database. The hypocenter location was assumed to be at 29.050N, 58.365E and the initial fault dimensions to be 25 km in length by 20 km in width, as determined from the aftershock distribution (Suzuki et al., 2005). The result of the teleseimsic source inversions shows the slip distribution that confirms a single asperity, as suggested by Yamanaka (2003), with the rupture propagated S-N direction along almost vertical strike-slip fault with the following fault parameters: strike 176°, dip 88°, rake 166°. The hypocentral depth of the best model is estimated to be 8 km. In the next step, using the finite fault parameters resulted from the teleseismic waveform inversion, we applied the inversion method of Yoshida et al. (1996) to strong motion records of BHRC stations from Iran. We used three components of velocity records at BAM, ABR and MOH stations to infer the precise epicenter location and rupture velocity. According to our analysis, a single fault model characterized by the appropriate location of the hypocenter, on the fault plane derived from aftershock distribution by Nakamura et al. (2005), can explain both the directivity and double pulses for three components at Bam station. We used both the ABIC criteria and fitting of observed and synthetic waveforms as the objective judgment of the best model selection. We also determined the rupture velocity that minimizes the residuals between observed and synthetic waveforms to be 2.9 km/s. This agrees with the result of the Rayleigh-like speed of the rupture pointed out by Bouchon et al. (2005). Finally, we performed the joined inversion of the teleseismic and strong motion datasets to obtain a stable source model for the 2003 Bam event. The inversion methods and datasets are the same as in the single dataset analysis. We used the finite fault parameters as determined from the teleseismic waveform inversion and the epicenter location and rupture velocity resulted from strong motion waveform inversion. Our joint inversion result shows that both teleseismic and strong motion datasets can be satisfactory explained by a single fault model with the single asperity located slightly above the hypocenter and rupture propagation in S-N direction. We estimated seismic moment of 6.94E+18 Nm, total rupture duration of 12 sec, and the maximum slip value of around 1.2 m. We propose that characteristics of the strong motion records at Bam station to be the combination of the forward directivity effect with a large speed of the rupture front and the variation of the rake angles.