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Preface

1. Background

The "International Workshop on the Quantitative Prediction of Strong-motion and the Physics of Earthquake Source" was held in Tsukuba, Japan from 23 to 25 October 2000 with the total of 49 oral and poster presentations, 40 participants from Japan, US, France, Russia, PR China, and New Zealand, and about 30 observers. This workshop was sponsored by *Science and Technology Agency of Japan*, *National Science Foundation of the United States of America*, the *International Association on Seismology and Physics of the Earth's Interior*, and *Japan International Science and Technology Exchange Center*. In particular, Shigeo Kinoshita, together with his support staff at the *National Research Institute for Earth Science and Disaster Prevention of Japan*, worked tirelessly to arrange for the pre-, co- and post-stages of the workshop. Without his leadership and efforts, the workshop and the special issue would have been impossible.

2. Brief summary of the papers in this volume

The quantitative prediction of strong-motion and the physics of earthquake source have been progressing rapidly with the deployment of modern strong-motion networks and development of sophisticated computer algorithms for analysis and simulation of ground motion. Appropriately, one of the originators of strong-motion seismology, Aki, leads off the special issue with his perspective on the history of strong-motion seismology. This area of research is widely recognized as an effective bridge between earthquake information from earth sciences and engineering practice for mitigating earthquake hazard. Aki discusses the emergence of the concept of the master model for a broader integration of earthquake information, in which strong-motion seismology plays a key role, promoted at the *Southern California Earthquake Center* during the past decade.

In this issue there are many findings about source processes and propagation path effects by using strong-motion data obtained from dense arrays. Also, new methods of data analysis are presented. Dutta et al. estimate simultaneously earthquake source parameters, site responses, and S-wave attenuation in Anchorage, Alaska from a strong-motion network, using generalized inversion method. The main results show that the ratio of seismic energy to seismic moment E_s/M_o is almost constant (1.2×10^{-5}); M_o is proportional to f_c^{-3} for M_o ranging from 10^{14} to 2.1×10^{18} Nm where f_c is the corner frequency; and Q_s is slightly frequency dependent at frequencies from 0.25 to 20 Hz. Takenaka et al. describes the frequency dependence of the radiation pattern for S waves based on high-quality single station records from aftershocks of the 1997 Kagoshima earthquake. The energy fraction of the S waves energy can be well predicted by theoretical radiation coefficients for a double-couple source at frequencies less than 2 Hz; while it cannot be predicted at frequencies more than 3.5 Hz. The results provide important information for simulating strong ground motions, in particular, high frequency motions. Hoshiba describes frequency dependent effects of rupture directivity on source radiation. The effects are not readily apparent in observed records although this problem is not new. He succeeds in separating the rupture propagation effect in a broad frequency band, from low frequencies less than 1 Hz up to high frequencies more than 10 Hz, by applying a linear spectrum inversion technique using dense broadband and strong-motion network data. The observed frequency dependence of the rupture directivity effect cannot be explained by smooth rupture propagation; however, it can be explained by

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fluctuations of rupture velocity and slip velocity time functions.

Interesting findings about differences in the source effect between plate-boundary earthquakes and intra-slab earthquakes are presented by Morikawa and Sasatani. Using observations from a dense array in Hokkaido, Japan they show that intra-slab earthquakes have much larger peak horizontal accelerations and extensive felt areas compared with plate-boundary earthquakes. They demonstrate that the source effects for the 1993 Kushiro-oki and the 1994 Shikotan earthquakes, both intra-slab earthquakes along the southern Kuril-Hokkaido arc, depart from the omega-squared source model at high frequencies. Both radiate abnormally strong high-frequency motions after the propagation-path effects and site effects are carefully removed.

Recent developments of numerical simulation techniques are reported in the following four papers. Xu et al. develop a parallel FEM for modeling nonlinear responses of three-dimensional heterogeneous basins and applied it to a numerical example to compute both effects of heterogeneous basins and inelastic soil behavior of the basin materials for strong ground motion. Their results are important for interpreting actual seismic records observed in the basins and for predicting strong ground motion. Yokoi develops a highly accurate method for calculating seismic response of three-dimensional valley with the oblique incidence of SH-wave. He shows that the third Born approximation for solutions of indirect boundary element method with the sparse matrix approximation can improve the accuracy of the results while drastically reducing the CPU time and storage. Honda and Yomogida improve the discrete wavenumber method for calculating accurate seismograms by finding a suitable value of the truncation value for summation over wavenumbers. They find that $4\,\mathrm{km}^{-1}$ is a reasonable value when a fault extends several kilometers or more. With the their value of k_{max}, the discrete wavenumber method accurately produces surface displacements, including static displacement in any realistic cases. Dong and Papageorgiou study a theoretical simulation of far-field body wave radiation from a quasi-dynamic source model with a general asymmetrical elliptical crack by employing Eshelby's static solution at every instant in time. They find that the seismic efficiency of asymmetrical fault models is smaller by a factor of 2–4 as compared with that of a symmetrical circular crack model. They attribute this feature to the fact that the asymmetrical models have average rupture velocity smaller than the symmetrical model.

Based on results of strong-motion data analysis and developments of numerical simulation techniques, new ideas for predicting strong ground motions are proposed by Archuleta et al. and Mai and Beroza. Archuleta et al. developed a method for simulating finite-fault site-specific acceleration time histories that include nonlinear soil response. The faulting is simulated as a stochastic process with the spatial variation of the key parameters determined by probability distribution functions. The wave propagation from source to site is accounted for small earthquake recordings. The mean acceleration response spectrum is near the median 10% in 50 years probabilistic seismic hazard analysis spectrum for the site. Mai and Beroza present a hybrid method for computing broadband strong-motion seismograms in near-field of large earthquakes. They combine complete seismograms at low-frequencies with ray theory seismograms at high frequencies and reconcile the amplitude spectra of those two sets of synthetic seismograms at intermediate frequencies. Ground motions from scenario earthquakes are calculated based on the spatial random-field model of complex earthquake slip. This method incorporates source characterization from kinematic source inversions and dynamic source modeling into probabilistic seismic hazard analysis.

Finally, new findings of ground motion faulting and faulting process modeling are presented. Somerville shows that forward rupture directivity forms a near-fault fault-normal narrow-band velocity pulse whose period increases with magnitude. This magnitude dependence of the period of the directivity pulse is related to source parameters, such as rise time and asperity dimension which generally increase with magnitude. This magnitude dependence of the pulse period results does not monotonically increase spectral amplitude at all periods with increasing magnitude, which is different from current ground motion models. Lei et al. studied detailed faulting process of a naturally healed fault with geometric/mechanical asperities in granitic porphyry samples. Based on the experimental study, they conclude that the fault rupture has a hierarchical nature. That is, the quasi-static nucleation of the fault rupture includes dynamic fracture of the asperities on the fault plane; while a quasi-static nucleation process, which again includes dynamic microfracturing, precedes the fracture of asperity. Brune describes precarious rocks as an evidence of ground motion intensity from trans-tensional strike-slip earthquakes. The results support recent evidence from physical and numerical models, and data regressions, indicating that ground motion for extensional strike-slip regions may be lower than for strike-slip faults with a large fault-normal tectonic stress component. This study will contribute to developing more detailed seismic hazards maps in the future.

3. Concluding remarks

This special issue summarizes recent developments on the quantitative prediction of strong-motion and the physics of earthquake source. Construction of modern dense strong-motion networks and development of numerical computer simulation techniques have significantly advanced the research in this field. The research fronts are presented, such as quantitative descriptions of source and propagation effects based on strong-motion data by dense array network, numerical techniques for accurate simulations, new ideas of strong-motion prediction, and new findings of ground motion and fault process modeling. This issue provides a milestone of strong-motion seismology and lays the groundwork for future research.

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