Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P01 Room:Convention Hall Time:May 27 10:30-13:00

Detection and analysis of early afterslip following the 2008 Iwate-Miyagi Nairiku, Japan, earthquake

Yusuke Yokota[1*], Kazuki Koketsu[1], Teruyuki Kato[1]

[1]ERI, University of Tokyo

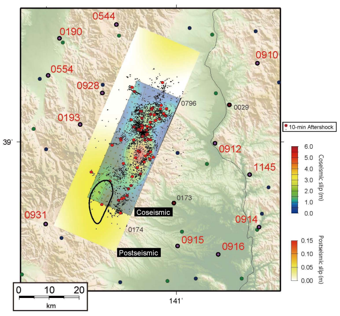
[Introduction] Afterslip is one of the slow earthquakes which have the long time period. Because of difficulty to observe and analyze the early afterslip phase, it's not clear how the early afterslip phase progresses. We first calculated time series of correlation coefficient between the 1-Hz GPS (Global Positioning System) waveform data and trends preliminary projected by afterslip near the mainshock and checked the afterslip signals. Because this data involved not only the afterslip signals but also the coseismic signals, we next enhanced the 1-Hz GPS waveform inversion to investigate simultaneously coseismic slip and early afterslip. Finally we investigated early (10-minutes) afterslip following the 2008 Iwate-Miyagi Nairiku, Japan, earthquake using this method.

[Detection] Static and dynamic ground displacements for this earthquake were observed at one-second intervals by a dense GPS network, called GEONET, operated by the Geographical Survey Institute of Japan (GSI) by processing GPS phase data using the method described by *Larson et al.* [2003]. This data was applied to infer the source process of this earthquake [*Yokota et al.*, 2009]. In this study, we first calculated time series of correlation coefficients between the 1-Hz GPS waveform data and trends preliminary projected by afterslip near the mainshock. The time series during about 2-hours before and after the mainshock showed the characteristic trends only during about 10 minutes after the mainshock.

[Inversion] In order to investigate simultaneously coseismic slip and early afterslip using this data, we next enhanced the 1-Hz GPS waveform inversion of *Yoshida et al.* [1996]. We adopted the 72 km x 24 km afterslip fault model with (strike, dip) = (203^o, 37^o), which was constructed by early aftershock distribution [*Enescu et al.*, 2010] and coseismic fault model used by *Yokota et al.* [2009]. We used the 1-Hz GPS data of 12 stations, which were selected from stations within approximately 50 km of the hypocenter so as to cover all directions. The GPS waveform data were windowed for 10 minutes. We calculated the dynamic Green's function for coseismic slip using FK method [*Zhu and Rivera*, 2002]. The slip rate function for afterslip was represented by B-spline function with knot interval of 60 seconds using the static Green's function calculated using FK method.

[Result] Figure shows the resultant slip distribution. This result suggests the total seismic moment of 3.0 x 10^{17} Nm (*Mw* ~ 5.5) and maximum slip of about 5 cm. Early afterslip distribution is compared with the coseismic slip distribution for the *Mw* ~ 6.9 mainshock and the 29-days afterslip distributions [*Iinuma et al.*, 2009]. The resultant early afterslip phases are inferred at the southwestern adjacent region of the main asperity, which are possibly triggered by the southern large asperity. The 29-day northern and eastern afterslips subsequently occurred. The resultant afterslip distribution and early (10-min) aftershock distributions determined by *Enescu et al.* [2010] are also partitioning in a complementary fashion. This result also shows that the afterslip does not evolve along the slow slip scaling [*Ide et al.*, 2007].

Acknowledgment. The GPS data were recorded by GEONET of the Geospatial Information Authority of Japan (GSI). We would like to thank them.



Keywords: early afterslip, high-rate GPS, the 2008 Iwate-Miyagi Nairiku, Japan, earthquake

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P02 Room:Convention Hall Time:May 27 10:30-13:00

Slow rupture velocity of two Indonesia earthquakes

Dun Wang[1*], James Mori[1]

[1]DPRI, Kyoto University

The 17 July 2006 Mw 7.8 Java earthquake and the 25 October Mw 7.8 Sumatra earthquake are the two typical tsunami earthquakes. We used modified back projection method to trace the rupture velocities of the two earthquakes. Weighting based on smoothed envelopes of a small earthquake recordings, is introduced when the waveforms are summated. The used small earthquakes have the same locations and focal mechanisms with the two tsunami earthquakes.

The result shows a clear and unusual slow rupture velocity (1-1.5 km/s) for these two earthquakes. The reason for this extraordinary slow rupture velocity is not well known now. But the two earthquakes occurred at the shallow portions of the subduction zone, somehow suggesting a very close relation with the unique hydrologic properties.

Keywords: rupture velocity, back projection, tsunami earthquake

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P03 Room:Convention Hall Time:May 27 10:30-13:00

Source Characteristics of Outer Rise Earthquakes

Masahiro Nomoto[1*], Hiroe Miyake[2], Kazuki Koketsu[2]

[1]Fac. Sci., Univ. Tokyo, [2]Earthq. Res. Inst., Univ. Tokyo

An outer rise earthquake occurs in an oceanic plate beyond a trench axis. Due to the bending stress of the oceanic plate and the seismic stress transfer from a continental plate, normal and reverse faulting events are often observed (Lay et al., 1987). The focal depths of outer rise events are generally shallower than 30 km, therefore it well generates tsunami as seen during the 2009 Samoa earthquake (Mw 8.1). Around the Japan Islands, the 1933 Sanriku earthquake (Mj 8.1) is one of disastrous and significant examples, where the maximum tsunami height was 28.7 m and 3,064 people were dead or missing. The most recent outer rise earthquake is the 2010 off Chichijima earthquake (Mj 7.4), and tsunami 0.5 m high was observed after this event.

We performed source inversions of teleseismic body-wave data for outer rise earthquakes (Mw $>$ 7.0) around the Japan Islands in 1990 or later, then investigated rupture areas and average slips derived from the results of the source inversions and compared them with those of other kinds of earthquakes. Since outer rise earthquakes occur offshore, it is hard to obtain records observed in a near-source region, and therefore it is effective to analyze global data. We chose seven outer rise earthquakes. Those in the Pacific plate are the 2005 off Sanriku (Mw 7.0, 18.0 km deep, normal faulting), 2007 eastern Kuril Islands (Mw 8.1, 12.0 km deep, normal faulting), and 2009 eastern Kuril Islands (Mw 7.4, 45.2 km deep, reverse faulting), and 2010 off Chichijima (Mw 7.4, depth 18.6 km, normal faulting) earthquakes. The 1998 south off Ishigakijima (Mw 7.4, 22.9 km deep, strike-slip faulting), 2004 off Kii peninsula (Mw 7.2, 16.0 km deep, reverse faulting), and 2004 off Tokaido (Mw 7.4, 12.0 km deep, reverse faulting) earthquakes occurred in the Philippine Sea plate (The magnitudes and depths are reported by the Global CMT Project).

We used teleseismic data obtained from global observation networks through IRIS DMC. The velocity structure used is based on the Jeffreys-Bullen model, and we replaced a part of the top layer with the water layer of CRUST 2.0 in the source region. We first performed point source analyses, and then inversions for slip distributions on the finite faults determined from the results using the method of Kikuchi et al. (2003). Due to the low accuracy of the aftershock distribution, we used the residuals of an inversion for choosing the actual source fault out of two conjugate fault planes. The slip distributions of most outer rise earthquakes provided large slips above the hypocenters, and no systematic difference in source characteristics is found according to focal mechanisms and plates.

We extracted rupture areas and average slips from the resultant slip distributions using the method of Somerville et al. (1999). The results were compared to the scalings of crustal earthquakes (Somerville et al., 1999), plate-boundary earthquakes (Murotani et al., 2008), and intraslab earthquakes (Iwata and Asano, 2011). The rupture areas of outer rise earthquakes are similar to those of crustal and intraslab earthquakes, and the average slip of outer rise earthquakes are similar to those of crustal earthquakes. Therefore, the source characteristics of outer rise earthquakes are different not only from those of plate-boundary earthquakes (Ammon et al., 2008) but also those of intraslab earthquakes, though both outer rise and intraslab earthquakes belong to a category of intraplate earthquakes. In addition, shallow outer rise earthquakes such as the 2007 eastern Kuril Islands earthquake have obviously different source characteristics from those of intraslab earthquakes. Further investigation is necessary for outer rise earthquakes with smaller magnitudes.

Keywords: outer rise earthquakes, source characteristics, source inversion, slip distributions

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P04 Room:Convention Hall Time:May 27 10:30-13:00

The Source Process of the 2010 Canterbury, New Zealand, Earthquake

Sunhe Yun[1*], Yosuke Aoki[1], Yusuke Yokota[1], Yasuyuki Kawazoe[1], Satoko Oki[1], Kazuki Koketsu[1]

[1]ERI, Univ. of Tokyo

In the Canterbury region of New Zealand's South Island, a moment magnitude (Mw) 7.1 earthquake occurred at 4:35 a.m. local time (16:35 p.m. on November 5 UT) on November 6th, 2010. The hypocenter located by GNS was at (43.55S, 172.18E) and a depth of 10 km. Although the Mw is quite large and the epicenter is only about 40 kilometers west of Christchurch whose population is about 400,000, no deaths were reported according to CNN. In the south of the hypocenter, fault traces were found on the ground surface, and the rupture offset locally reached more than 4m [Quigley, 2010].

We first performed point source inversions of W-phase and P-wave waveforms using the methods developed by Kanamori and Rivera [2008] and Kikuchi and Kanamori [1991], respectively, to derive the focal mechanism of the earthquake. The strike, dip, and rake angles obtained from the W-phase and the P-wave waveforms are (85, 68, 169) and (268, 70, -175) in degree, respectively. Both of the derived solutions suggest focal mechanisms of right-lateral strike slip on an almost vertical fault planes. However, they have different dip directions, and we cannot determine which fault plane is collect from the waveform data. This confusion is also seen from source fault models derived by various institutes. To identify the actual fault plane, we plotted aftershocks occurring in the first 24 hours, but no significant plane was defined. We then took an advantage of the surface fault traces considering their relative location to the surface extensions of the fault planes. In the result, the fault plane derived by the P-wave waveforms is selected.

Interferometric synthetic aperture radar (InSAR) data from both Japanese and European satellites provided high quality maps of surface displacements by this earthquake. According to these results, there observed very large right lateral displacements in the south of the hypocenter followed by a 3kmˆ2-area of little displacement at the western edge. And a northwest-southeast displacement in relatively large area was located in the 10km west of the hypocenter, implying a reverse fault.

Based on the aftershock distribution, surface fault traces and the InSAR image, we set two faults. One includes the hypocenter (fault1), and the other in the western area with NW-SE displacements (fault2). For the fault parameters of each fault, we used the ones from the P-wave focal mechanism and the aftershock distribution in the first 1-week. We next performed a finite source inversion of teleseismic waveform data and strong motion data using this source fault model and the method of Yoshida et al. [1996]. We adopted the CRUST 2.0 model for the crustal structure and used the rigidity based on this model. For the smoothness constraint of the slip distribution and the weight of the constraint, we used a discrete Laplacian in space and Akaike's Baysian Information Criterion (ABIC)[Akaike, 1980], respectively.

The resultant slip distribution is in good agreement with surface fault traces and the InSAR observation. The slip distribution close to the surface fault traces showed large eastward slips. In addition, there derived NW-SE slips in the west and southeast of faults 1 and 2, which are also consistent with the InSAR observation.

In summary, we first derived the focal mechanisms by the waveform inversions. Additionally to the focal mechanisms, we then used the observed data by InSAR and surface fault traces to determine the appropriate fault plane. The obtained slip distribution is in good agreement with the surface fault traces, and the displacements derived from the InSAR image. This study indicates the usefulness of the field fault observation and the InSAR data when it is difficult to identify the appropriate fault parameters only by waveform inversion.

Keywords: source process, inversion, InSAR, focal mechanism, slip distribution, surface fault traces

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P05 Room:Convention Hall Time:May 27 10:30-13:00

Effect of various factors on the estimation of source process by the waveform inversion of teleseismic body waves

Hisahiko Kubo[1*], Yasumaro Kakehi[1]

[1]Kobe University

In this study, we perform a test for investigating effect of various factors on the estimation of source process by the waveform inversion of teleseismic body waves. The test is constructed from four steps. First, we assume a slip distribution model. Second, synthetic waveforms at assumed stations are calculated based on the assumed model. Third, using the calculated waveforms as observed waveforms, we conduct waveform inversions in various analysis conditions. Fourth, we compare the obtained slip distribution with the assumed model in each condition.

We assume 24 stations with an equal azimuth interval of 15 deg and a common epicentral distance of 90 deg. P-wave part with a time length of 85s of the up-down component at each station is used for the waveform inversion.

Assuming a down-dip extension type earthquake in the upper plane of the double seismic zone in the Pacific slab beneath Northeastern Japan, we adopt two types of the fault planes: low-angle thrust fault plane and high-angle thrust fault plane. Mechanism of the former is (strike, dip, rake) = (0deg, 20deg, 90deg) and that of the latter is (strike, dip, rake) = (180deg, 70deg, 90deg). The hypocenter depth is assumed to be 70km.

The assumed fault plane is 36km x 24km, divided into 4km x 4km subfaults. The assumed slip distribution is composed of two large-slip areas. One large-slip area has a slip amount of 2.5m over an area of 12km x 8km near the hypocenter. Another has a slip amount of 2.5m over an area of 12km x 12km at about 20km southwest of the hypocenter. A Slip amount in the back ground area is assumed to be zero.

The waveform inversion is done using multiple time window analysis. By using a nonnegative constraint, the rake angle of the slip vector of each subfault is allowed to vary within the central angle +/- 45 deg. A spatial and temporal smoothing constraint is used. The value of smoothing strength parameter is fixed in all the inversions. The values of other source parameters (e.g. first time window velocity) are also fixed.

First, effect of using depth phase is checked by comparing the two cases; one case where only direct waves are used for the inversion, and the other where both of direct waves and depth phases are used.

The assumed model is recovered fairly well in the latter case. In contrast, it is not recovered well in the former case. This result is seen for both of the two types of the fault plane. Since travel times of depth phases are sensitive to source depth, use of depth phases is interpreted to improve the resolution in depth direction. Additionally, recovery of the slip distribution in the case of the high-angle fault plane is better than in the case of the low-angle fault plane. Since the depth difference between adjacent subfaults along a dip direction in the case of the low-angle fault plane is smaller than in the case of the high-angle fault plane, it becomes difficult to distinguish depth phases from adjacent subfaults on the time axis in the case of the low-angle fault plane.

Next, effect of station distribution related to the directivity on the estimation of the source model is checked. The 24 stations are divided into four groups according to the azimuth; 45deg-135deg (group A), 135deg-225deg (group B), 225deg-315deg (group C) and 315deg-45deg (group D). And we conduct a waveform inversion for each station group. Group B is in the direction of forward directivity and group D is in the direction of backward directivity.

Recovery of slip distribution in the case of using group B is not as good as for the case of using other groups. This result is seen for both of the two types of the fault plane. Since the difference between travel times from adjacent subfaults is small at the stations in the direction of forward directivity, it becomes difficult to distinguish the waves from the adjacent subfaults.

Acknowledgments: We used the program of Kikuchi and Kanamori (1982) for calculating the Green functions of telesesimic body waves.

Keywords: waveform inversion, teleseismic body wave, depth phase, directivity

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P06 Room:Convention Hall Time:May 27 10:30-13:00

Multiple centroid moment tensor analyses using Green's functions computed for a 3-D earth model

Tatsuhiko Hara[1*]

[1]IISEE, BRI

We performed multiple centroid moment tensor (CMT) inversion for 25 large earthquakes that occurred since 1995. Following the algorithm of Hara (2002, A42, 2002 Fall Meeting, SSJ), the inversion was carried out by two steps. In the first step, we performed ordinary CMT inversion. In the second step, we divided an event into two subevents and performed simultaneous inversion for CMTs of two subevents. In each step, we used the iterative linearized inversion technique of Hara (1997, GJI, 130, 251-256). In this technique, Green's functions are calculated using the Direct Solution Method (Hara et al., 1991, GJI, 104, 523-540), in which effects of three dimensional earth structure can be accurately considered. For a three dimensional earth model, we construct our model based on SAW24B16 (Megnin and Romanowicz, 2000, GJI, 143,709-728) in this study. The data for inversion were spectra in the frequency band 2 and 4 mHz, which we calculated from VHZ channel waveform data retrieved from the IRIS DMC. As initial guesses for the first step, we used solutions of the Global CMT catalog (http://www.globalcmt.org/).

For 12 events, CMTs of two subevents were determined stably, and the results are consistent with previous studies in terms of direction of rupture propagation and source duration. This result suggests that it is possible to construct a set of multiple CMT solutions by the data analysis procedure of the present study. We plan to investigate whether modification of the way to set initial guesses for the second step may improve results for the other events.

Keywords: multiple CMT, 3-D earth model

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P07 Room:Convention Hall Time:May 27 10:30-13:00

Numerical experiments of rupture process inversion using the 2.5 dimension finite difference method

Tatsuhiko Hara[1*], Naoki Nishimura[2], Taro Okamoto[3], Yuji Yagi[2], Hiroshi Takenaka[4]

[1]IISEE, BRI, [2]Life & Env. Sci., Univ. Tsukuba, [3]Tokyo Institute of Technology, [4]Kyushu University

We performed a numerical experiment to investigate accuracy and reliability of rupture process inversion using synthetic seismograms computed for a realistic structure model by the 2.5-D finite difference method (Takenaka and Okamoto, Proc. Int. Workshop on Scientific Use of Submarine Cables, 23-26, 1997; Okamoto and Takenaka, Advances in Geosciences, Vol.13, 215-229, 2009). The target event of this experiment is the 1994 far east off Sanriku earthquake (Mw 7.7 after Global CMT Catalog). Okamoto et al. (2010, P3-29, 2010 Fall Meeting, SSJ) constructed a structure model of crust and mantle surrounding the source region of this event, and showed that the observed waveforms of middle size (Mw 5.9-6.4) events that occurred near the source region were well reproduced by using the model. We constructed an earthquake source process model in this numerical experiment, which we call "input source process model", as follows. We placed three, localized asperities (small areas with large slips) in the shallow, middle and deep parts of the assumed fault plane, respectively. The rupture velocity was set to 2.5 km/s. The rupture starts from the shallowest asperity and propagates toward the deeper part of the fault. For this input source process model, we computed synthetic seismograms for teleseismic P waves using the 2.5-D finite difference method (Takenaka and Okamoto, 1997; Okamoto and Takenaka, 2009). Then, we performed rupture process inversion of these synthetic seismograms using inversion algorithm by Yagi and Fukahata (2008. Geophys. J. Int., 175, 215-221). Green's functions were computed using the method of Kikuchi and Kanamori (1991, BSSA, 81, 2335-2350).

The obtained rupture process model showed three areas with large slips corresponding to three small asperities in the input source process model. This result suggests that it is possible to obtain overall feature of rupture process by applying inversion algorithm of Yagi and Fukahata (2008) to teleseismic P waves. We also note that the areas of asperities in the inversion result are much larger than those in the input source process model. Such "smearing" effect has also been pointed out by Okamoto and Takenaka (EPS, 61, e17-e20, 2009) in the results of the synthetic experiments of the inversion for the slip distribution of tsunami earthquake. Because of the smearing effect, it might be difficult to reveal fine features in the "true" slip distribution.

Keywords: Rupture process inversion, Numerical experiment, 2.5 dimension finite difference method

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P08 Room:Convention Hall Time:May 27 10:30-13:00

Rupture process analysis of the 1994 far east off Sanriku earthquake using the 2.5 dimension finite difference method

Taro Okamoto[1*], Tatsuhiko Hara[2], Hiroshi Takenaka[3]

[1]Tokyo Institute of Technology, [2]IISEE, BRI, [3]Kyushu University

The effect of the near-source heterogeneous structure on the teleseismic body waveforms can become large for shallow subduction zone earthquakes: large amplitude later phases are generated as a result of the distortions in the ray paths due to the heterogeneous structure. Such structural effect must be carefully considered in evaluating the results of the source process inversion.

As an example of the source process analysis by considering the effect of the near-source structure, we perform inversion of teleseismic P waveforms for space-time slip distribution of the 1994 far east off Sanriku earthquake (the origin time: 12:19:23.60 UTC, December, 28; location: 40.45 degree N, 143.49 degree E; depth 33.0 km after USGS. Mw: 7.7 after Global CMT Catalog). The broadband waveform data were retrieved from the IRIS DMC. We integrate the velocity records to obtain displacement records, and applied band-pass filter with the pass-band between 0.007 Hz and 0.2 Hz to obtain displacement record for inversion. In order to consider the effects of crust and mantle structure around the source region, we constructed the structure model referring to the studies by Ito et al. (2004, EPSL, 223, 163-175), Ito et al. (2002, Zisin2, 54, 507-520), Amante and Eakins (2009, NOAA Technical Memorandum NESDIS NGDC-24, 19 pp.), Bassin et al. (2000, EOS Trans AGU, 81, F897). We presented the results of comparison between observed waveforms of middle size (Mw: 5.9-6.4) earthquakes that occurred in the source region and synthetic waveforms computed for this model using the 2.5 dimension finite difference method (REF) and showed that this model well explained the observed waveform data (Okamoto et al., 2010, P3-29, 2010 Fall Meeting, SSJ).

Using the Green's functions computed for the model, we invert the data for the slip distribution following the inversion procedure developed by Okamoto and Takenaka (EPS, 61, e17-e20, 2009). The preliminary inversion resulted in a small (weak) moment release near the rupture starting point, and a large (strong) moment release around the middle of the fault after about 30 s from the onset. In the companion paper (Hara et al., this meeting), we will present results of the synthetic experiments of this inversion.

Keywords: Rupture process analysis, 2.5 dimension finite difference method, 1994 far east off Sanriku earthquake

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P09 Room:Convention Hall Time:May 27 10:30-13:00

On the repeatability of the rupturing processes of the moderate-sized repeating earthquakes

Kouhei Shimamura[1*], Toru Matsuzawa[1], Tomomi Okada[1], Naoki Uchida[1]

[1]RCPEV, Science, Tohoku University

We have investigated rupture processes of moderate-sized repeating earthquakes showing that the processes can be changed from event to event even in the characteristic earthquake sequence off Kamaishi, Iwate Prefecture, Japan (Shimamura et al., 2011). In this study, we investigate rupturing processes of two moderate-sized earthquakes (M5.7 on May 12, 1997 and M5.6 on October 22, 2005) in the repeating earthquake sequence (Hasegawa et al., 2005; Yamada et al., 2009) off Iwaki, Fukushima Prefecture, Japan. Results of preliminary analyses indicate that the rupturing processes of the two events are considerably different: the 1997 event ruptured several small seismic patches while the 2005 event ruptured only one large seismic patch. Amplitude spectra estimated from spectral-ratio technique shows that the two events have almost the same amplitudes and shapes for the frequency range below 1 Hz. However, above 1 Hz higher than corner frequencies of around 0.3Hz, two spectra are very different and the 1997 event has another peak around 3 Hz. This characteristic can be explained by the rupturing of plural small patches investigated in the preliminary analyses of the rupturing processes. This result indicates that an asperity can be occasionally ruptured in different ways than usual suggesting that time variation of the pore pressure may cause the change in the rupturing processes as proposed by Seno (2003).

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P10 Room:Convention Hall Time:May 27 10:30-13:00

Subsidiary multiple crack generation during unstable fast rupture in Agarose-gel fault

Satoshi Fujita[1*], Osamu Kuwano[1], Tetsuya Kusakabe[1], Yuuki Kodera[1], Nobuki Kame[1], Masao Nakatani[1]

[1]ERI, The University of Tokyo.

It is well known that earthquake faulting is followed by shear rupture propagation. It is very hard to see dynamic faulting under the ground. In order to observe such a shear rupture many attempts are done in experiments that samples with photo-elasticity are broken under a uni-axial loading and dynamic rupture nucleation is triggered by a explosion. It is, however, far from the actual earthquake nucleation that starts spontaneously. Here we try to nucleate dynamic rupture spontaneously.

We made gel plates (250x400x10mm) including a weak plane, and set it under an uni-axial compression. The gel has two advantages over rock samples. One is that the stress field of sample can be observed by photoelasticity. Another is that dynamic rupture is easy to be observed because of the significant low s-wave velocity, 7m/s. We change strength of the weak-plane so that we can control generation of subsidiary cracking off the main rupture.

We successfully generated subsidiary off-fault cracks when the weak-plane strength is relatively high. We observe significant deceleration of rupture velocity of the main fault during growth of subsidiary cracks. This can be attributed to the energy consumption due to increase of surface energy.

We also discuss geometry of off-fault comparing to theoretical prediction.

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P11 Room:Convention Hall Time:May 27 10:30-13:00

Effects of off-fault damage on the tendency of fault branching

Shintaro Tamura[1*], Satoshi Ide[1]

[1]EPS, Univ. of Tokyo

Fault zones are an elastic medium with distributed damage varying the elastic stiffness of the medium. Considering effects of inelastic behaviors of fault zones is important for understanding physics of macroscopic rupture dynamics. Our main issue is to evaluate these effects on a spontaneously propagating mode II crack on a bimaterial interface (the main fault) and a branching fault.

We develop an explicit finite element code to model dynamic rupture process in a damaged medium. An equation of motion and a kinetic equation for damage evolution introduced by Lyakhovsky et al., 1997 are solved. Slip on the main and branching faults is implemented by split-nodes with a slip-weakening friction law. Outer boundaries are absorbing boundary. We assume homogeneous prestress.

We solve the dynamic rupture problem with the branching fault in homogeneous prestress with various values for the rupture velocity, the branching angle between the main and the branching angle, the material contrast, and the coefficients of damage evolution. We find that the damage is enhanced around crack tip when the rupture velocity is close to the generalized Rayleigh velocity. When the rupture front approaches a branching point, damage evolution at the branching point affects the tendency of fault branching.

Keywords: dynamic rupture propagation, branching fault, off-fault damage

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P12 Room:Convention Hall Time:May 27 10:30-13:00

AE characteristics in a triaxial extension test

Hironori Kawakata[1*], Naoki Takahashi[2], Manabu Takahashi[3], Nana Yoshimitsu[1]

[1]Ritsumeikan University, [2]Sumitomo Mitsui Construction Co., Ltd., [3]AIST

When a high deviatoric stress is applied to a granular rock, there occurs microfractures which accompanied by ultrasonic waves called acoustic emission (AE) are observed. AE is an elastic wave radiated in a deformation process, which is similar to a seismic wave. Some AEs correspond to open crack mode microfractures, and others correspond to shear mode microfractures. AE has been studied to monitor deformation process in a rock sample under a compressive stress state (e.g., Scholz, 1968; Lockner et al., 1992). Although it is expected that AE occurs prior to the main fracture in an unloading process under triaxial extensive stress state, the activity and characteristics of the AE have not been studied.

We carried out continuous AE measurement in a triaxial extension test under a confining pressure of 80 MPa, using a cylindrical Kimachi sandstone sample, 100 mm in height and 50 mm in diameter. The fractured sample showed an extensive fracture plane and a shear fracture plane. Waveforms of the same AE event recorded by different sensors are similar to each other, except for polarities of initial motion. We found AE waveforms with polarity of all dilatational and those with polarity of both dilatational and compressional, which indicates that there occurred both open crack mode microfractures and shear mode microfractures.

Keywords: Triaxial extension test, Kimachi sandstone, Acoustic emission, Focal mechanism

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P13 Room:Convention Hall Time:May 27 10:30-13:00

The simulation of seismic nucleation by modified RSF law added stress dependent term.

Satoshi Fujita[1*], Nobuki Kame[1]

[1]ERI, The University of Tokyo.

We simulate earthquake nucleation of faults with revised rate- and state- dependent friction law proposed by Nagata (PhD thesis, 2008). The major revisions in the friction law are (1) parameters a and b (direct effect and strength healing rate, respectively) are three times larger than the traditional believed values and (2) the strength evolution law is revised incorporating a newly noticed weakening effect by an increase of shear stress.

We consider a planar fault with a revised friction in an infinite isotropic homogeneous medium. We simulate quasi-static slip evolution process controlled by (a) the revised friction law and by (b) the traditionally believed slowness law. We compare the results so that we can extract the effect of the newly proposed friction law.

We first investigate nucleation process under a high loading rate. In this case the strength healing is negligible and strength weakening is dominant. Simulation results for both friction laws shows a similar tendency: the most rapidly slipping portion of the fault patch constricts to a sub patch with a certain length. This is because the modified law produces significant difference in only the strength evolution compared with the original slowness law, that is, the evolutions of slip-rate and stress are similar to those of the original law.

We second investigate nucleation process under a slow loading rate. In this case the strength healing is comparable to that of weakening. Our preliminary simulation results show significant difference that nucleation length tends to be shorter with the modified law than the original slowness law. This is because larger healing occurs out side the sub patch and it prevents the sub path to grow larger.

Keywords: earthquake, nucleation, RSF

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS025-P14 Room:Convention Hall Time:May 27 10:30-13:00

Elasto-dynamic analysis of non-planar fault based on XFEM

Ryosuke Ando[1*], Shogo Nakasumi[2]

[1]AIST/GSJ, [2]AIST/AMRI

XFEM (Extended Finite Element Method) is a type of a mesh-free method based on the finite element method (FEM). XFEM has merits in capable of treating arbitrary geometry of cracks. We develop a numerical calculation algorithm based on XFEM for dynamic growth of cracks in an elastic-medium. In this presentation, we will show some preliminary results from the calculations and compare with the results of BIEM analysis.

Keywords: Extended finite element method, XFEM, non-planar fault, elasto-dynamic, fracture, numerical analysis