Japan Geoscience Union Meeting 2012
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SSS29-P01 Room:Convention Hall Time:May 22 17:00-18:30

# Three-dimensional attenuation structure beneath the Tokai region, central Japan

TAKAOKA, Hiroyuki[1*], TSUMURA, Noriko[1], KATO, Aitaro[2], Fukusuke Takahashi[1], NOZAKI, Kenji[1], IIDAKA, Takashi[2], IKUTA, Ryoya[3], YOSHIDA, Yasuhiro[4], KATSUMATA, Kei[5], IWASAKI, Takaya[2], SAKAI, Shin'ichi[2], YAMAOKA, Koshun[6], WATANABE, Toshiki[6], KUNITOMO, Takahiro[3], YAMAZAKI, Fumihito[6], OKUBO, Makoto[7], SUZUKI, Sadaomi[7], HIRATA, Naoshi[2]

[1]Graduate School of Science, Chiba University, [2]Earthquake Research Institute, University of Tokyo, [3]Faculty of Science, Shizuoka University, [4]Meteorological Research Institute, [5]Institute of Seismology and Volcanology, Hokkaido University, [6]Graduate School of Environmental Science, Nagoya University, [7]Tono Research Institute of Earthquake Science

Long term slow slip (LTSS) and non-volcanic low frequency earthquakes (LFEs) were reported in the central part of the Tokai district, central Japan. Such LTSS and LFE events are considered to take place at transition zone from stick-slip zone to stable sliding zone and to be associated with fluids on the subducting Philippine Sea plate's surface. To clarify the spatial variation of the physical properties in this region, we estimated a three dimensional seismic attenuation structure using joint inversion method.

In this study, we used 3688 spectra of 140 earthquakes which were observed by both temporary stations conducted from April to August in 2008 and permanent stations. Frequency band was divided equally among 24 between 0.78125 and 18.75 Hz and equally among 8 between 18.75 and 31.25 Hz. We gave Q blocks by dividing study area into 7 in the N-S direction between 137E and 138.5E degree, into 6 blocks in E-W direction between 34.5N and 35.7N, and 6 depth layers. We estimated frequency independent Q value of each block.

In the shallow depths from surface to 5km, we found a lower Q zone located along the Median tectonic line which divides the southwestern Japan into two parts; a old geologic belt and a new accretionary belt. In the lower crust of the land plate at the depths of 17 to 25km, a very high Q zone (about 2000) exists just above the region where large slip rate was observed in LTSS between 2001 and 2005. Since very few earthquakes occur in this high Q zone, that portion might consist of harder rocks than surroundings. On the contrary, the region just beneath the large slip zone has lower Q than surrounding area. Comparing our results with the seismic velocity structure derived from travel time tomography, we found the high Q zone approximately coincides with relatively high velocity zone, and lower Q zone corresponds to the relatively low velocity and high Vp/Vs region. As mentioned in previous studies, low Q zone with low velocity and high Vp/Vs is interpreted as the zone which involves high-pressure fluid. Probably the high Q zone above the large slip zone works as a cap rock and prevents the fluid moving toward the shallow part, then the fluid pressure becomes high and it affects the occurrence of slow slip in this region.

Keywords: attenuation structure, Q value, Tokai region, slow slip

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# Propagation dynamics of episodic tremor and slip governed by fault rheology and heterogeneity

ANDO, Ryosuke[1*], TAKEDA, Naoto[1], YAMASHITA, Teruo[2]

[1]Geological Survey of Japan, AIST, [2]Earthquake Research Institute, Univ Tokyo

Slow earthquakes called episodic tremor and slip (ETS) propagate over 100 kilometers at low velocities, ~10 kilometers per day, along several plate interfaces. These low velocities differentiate slow earthquakes from ordinary earthquakes, and thus understanding their propagation processes is fundamental to understand the diversity and universality of earthquake processes. Comprehensive modeling and previously-unreported correlations of migration patterns with energetics of tremor observed in Japan show that rheological fault heterogeneity essentially governs ETS propagations. The fault has persistent small-scale segmentation, where the propagations always energetically started in brittle sections and decelerated in the ductile sections; spontaneous rupture calculations constrain the ductility to that caused by the Newtonian plastic flow or dilatant strengthening, but not by large-scale fluid flows.

Keywords: Slow earthquake, Rheology, Tremor, Model, Rupture dynamics, Simulation

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# Shallow very low frequency earthquakes off Sanriku, Japan

MATSUZAWA, Takanori[1*], ASANO, Youichi[1], OBARA, Kazushige[2]

[1]NIED, [2]ERI, University of Tokyo

Activities of shallow very low frequency earthquakes (VLFEs) have been reported around the trench axis of the Nankai subduction zone and the off-Tokachi region (e.g., Obara and Ito, 2005; Asano et al., 2008). In NIED, epicenters of seismic sources including VLFEs are routinely located by an array analysis technique using Hi-net high-sensitivity accelerometers (Asano et al., 2008). Some of the epicenters are located off the Pacific coast of Tohoku, though the number in this region is much smaller than that in the off-Tokachi region. However, these events are not fully examined, as most of these sources have been thought to arise from earthquakes and microseisms. In addition, a slow slip event has been recently reported in the off-Sanriku region (Ito et al., 2010). In this study, we aim to detect VLFEs off Sanriku with a waveform correlation analysis.

The array analysis with Hi-net high-sensitivity accelerometers detected a seismic source off Sanriku at 22h, 10 March, 2011. We estimated a CMT solution of this event using F-net broadband seismometers and Hi-net high-sensitivity accelerometers (Ito and Obara, 2006). The result shows a reverse fault mechanism located at the depth of 18 km with Mw3.5. This event is not clear at the frequency of several Hz, and dominant at 0.05-0.1 Hz, though a typical dominant frequency of regular earthquakes with similar magnitude and close hypocenter is several Hz. Therefore, this event is considered as a VLFE.

Other VLFEs off Sanriku are detected by a waveform correlation analysis adopted in Asano et al. (2010). Averaged cross correlation values are calculated using broadband seismograms at six F-net stations which are bandpass-filtered between 0.02 to 0.1 Hz. The VLFE at 22h, 10 March 2011 are adopted as a template event in this correlation analysis. Epicenters of similar VLFEs are searched within the range of one degree both in the longitudinal and latitudinal direction. If the averaged cross correlation value is over 0.3, we manually check the waveforms and select the events which are not attributed to near- or far-field earthquakes and microseisms.

Applying this technique to the period between 2005 to 14:46, 11 March 2011, we detected two VLFEs on 12 December 2007, one VLFE on 5 July 2009, and another VLFE on 10 March 2011. Activities of VLFEs off Sanriku are much lower than that off Tokachi, where accumulated counts of VLFEs are about six thousand (Asano, 2011). These VLFEs are located at the north of the aftershock area of the M7.3 off-Sanriku earthquake on 9 March 2011. In addition, the activity of regular earthquakes is low in this region. It is not revealed whether the VLFEs occur on the plate interface or within the overriding plate in this region. If we assume that the VLFEs are slip of plate interface, our result implies that frictional property shows stable sliding at this region in a usual state. Shibazaki et al. (2011) numerically reproduced large and great earthquakes which recur at the intervals of one hundred and several hundred years, respectively. In their model, it is assumed that the surrounding region of asperities shows a velocity-strengthening behavior at low and intermediate slip velocity, and strong velocity-weakening at high slip velocity. The detected VLFEs are located at the surrounding region of the asperity of the M 7.3 off-Sanriku earthquake on 9 March 2011, and at the region with large slip of the 2011 off the Pacific coast of Tohoku earthquake. Perhaps, the frictional property assumed in Shibazaki et al. (2011) may be actually important in the seismic cycles of the Tohoku region. A further observation at ocean bottom in this region would reveal the detailed activity of VLFEs.

Keywords: very low frequency earthquake, Off Sanriku

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# 3D modeling of the cycle of a great Tohoku-oki earthquake considering thermal pressurization

SHIBAZAKI, Bunichiro[1*], NODA, Hiroyuki[2], SHIMAMOTO, Toshihiko[3], HORI, Takane[2]

[1]IISEE, Building Research Institute, [2]IFREE, JAMSTEC, [3]China Earthquake Administration

During the 2011 Tohoku-oki earthquake, large slips occurred in the region near the trench off Miyagi (e.g. Fujii et al. 2011). Hasegawa et al. (2011) showed that during the earthquake, the background deviatoric stress was completely released. This result suggests that the frictional strength decreased considerably. Recent studies on the fault rheology show that a considerable weakening can occur at a high slip velocity because of thermal pressurization or thermal weakening processes (Tanikawa and Shimamoto, 2009; Di Toro et al., 2011; Tsutsumi et al., 2011). Noda and Lapusta (2010) performed 3D simulations of earthquake sequences with evolving temperature and pore pressure resulting from shear heating, and they found that regions of more efficient thermal pressurization produce relatively large slips, resulting in large events with long interseismic periods. Mitsui et al. (2012) developed a 2D quasi-dynamic earthquake cycle model of the Tohoku-oki earthquake by considering thermal pressurization. The present study develops a 3D quasi-dynamic earthquake cycle model of the Tohoku-oki earthquake by considering thermal pressurization. We use a spectral solver for 1D diffusion problem developed by Noda and Lapusta (2010) to efficiently calculate the temperature and pore pressure evolution on a fault plane. We set several asperities in the regions off Miyagi, off Fukushima, and off Ibaraki, and set long asperities near the trench. We set the frictional properties of velocity weakening in the asperities; however, we set velocity strengthening outside of the asperities. Further, we set a low value for hydraulic diffusivity in the shallower part of the plate interface off Miyagi. The preliminary results show that M7.5 class earthquakes occur at the zone with relatively large hydraulic diffusivity. When rupture occurs around the low hydraulic diffusivity zone, significant thermal pressurization occurs and results in large and fast slips. This rupture propagates to the surrounding region and to the asperities of M7.5 earthquakes, because thermal pressurization occurs as a result of large slip even in the region of large hydraulic diffusivity.

Keywords: the 2011 Tohoku-oki earthquake, 3D earthquake cycle model, thermal pressurization

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# Mechanical processes of preparation for large scale events

HORI, Takane[1*], SAKAGUCHI, Hide[1]

[1]IFREE, JAMSTEC

In order to forecast the occurrence of large events in the Earth's crust, we need to understand their preparation process. Although some precursory phenomena have been proposed as preparation process for large events, most of their mechanical background is not clear. To understand the mechanical processes before large scale events, we examine numerical experiments in which multi-scale events spontaneously occur using discrete element method. The results show that before the occurrence of large events, the deviation of the direction of principal stress axes becomes small in a surrounding area of the large events. This represents a kind of homogenization of the stress field before a large event. After the large event, the stress distribution becomes scattered where only small events can occur.

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# Numerical simulation of a shape of an off-fault microcrack distribution observed in natural faults

INAGAWA, Satoshi[1*], SUZUKI, Takehito[2], NAMIKI, Atsuko[2]

[1]ERI, Univ. Tokyo, [2]DEPS, Univ. Tokyo

Rupture propagation on a fault plane forms microcracks outside the slip zone. Formation of microcracks consumes the energy for the rupture propagation. Off-fault microcracks are thus important and has been investigated in both field observations (Vermilye and Scholz, 1998) and numerical calculations (Andrews, 2005; Hok *et al*., 2010). The number density of the microcracks outside the slip zone inferred from numerical experiments sometimes differs from those obtained in the field observations. Field observations show that the number density of the microcracks is almost constant along the fault direction whereas, in the numerical experiments, the width of the region in which microcracks distribute increases linearly with the rupture propagation distance. This result from numerical experiment suggests that number density of microcracks around a fault increases proportionally to the propagation distance.

In this study, we assume a two-dimensional mode III fault and show that the initial stress field affects the microcrack distribution. We use the Coulomb failure criterion both for the rupture propagation on the fault plane and formation of the microcracks. In order to use the Coulomb failure criterion for the off-fault failure, we calculate maximum shear stress and normal stress at each locus. When these stresses satisfy the Coulomb failure criterion, off-fault microcracks form. We vary the initial stress field and cohesion as parameters.

We find that, when the initial shear stress (sigma_yz) which drives the on-fault rupture propagation decreases linearly along the fault, the final stress drop becomes negative and fault-tip growth is arrested. In this situation, the width of the microcrack distribution does not increase as a function of the rupture propagation distance, but becomes almost constant. This result is similar to the distribution observed in natural faults. In contrast, when the initial shear stress decreases linearly perpendicular to the fault plane, the width of the microcrack distribution perpendicular to the fault plane does not decrease.

Another our finding is that larger cohesion makes the width of the microcrack distribution smaller. We obtain similar results when the lithostatic stress is larger. This is because both cohesion and the lithostatic stress increases the critical stress to cause failure.

We infer that the microcrack distribution can become a measure of the initial stress field.

Keywords: microcrack, numerical simulation, stress field, arrest of fault-tip growth

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# Dynamic change of flow rate in impermeable fault rock

TANIKAWA, Wataru[1*], HIROSE, Takehiro[1], HIDEKI, Mukoyoshi[2]

[1]JAMSTEC/Kochi Institute for Core Sample Research, [2]Marine Works Japan LTD.

Hydrological and hydro-geochemical changes are often observed soon after big earthquakes at active faults and hot springs, and a part of them were caused by a rapid change of permeability structure of a fault zone. Change of fluid transport properties in fault zones plays an important role in dynamic processes during large earthquakes as well as earthquake cycle processes. However, the physical and chemical processes responsible for the evolution of hydrological properties in fault zones during earthquake are not well known.

Therefore a rotary shear testing apparatus at Kochi Core Center was used to understand the physical process for the changes of fluid transport properties in a fault zone by real-time measurement of gas flow rates during and after frictional sliding.

We prepared a pair of hollow cylinder (inner diameter=9 mm, outer diameter= 25 mm, length=20 mm), and to demonstrated the frictional sliding, one cylindrical specimen was fixed and the other rotated under a fixed axial stress. To measure the permeability, radial flow from the inner wall to the outer wall of the specimen was induced by applying a differential pore pressure between the inner and outer walls. Real-time change in permeability is evaluated by monitoring the flow rate during the frictional test. Nitorgen gas was used as a pore fluid. We conducted friction tests at various slip rates (0.076 mm/s to 190 mm/s) and 2 MPa of normal stress with 1.5m of displacement. We used Aji granite in friction tests, and gas permeability of intact host rock that shows $10^{-19}$ $m^2$ was lower than that of the simulated fault specimen before sliding ($10^{-16}$ $m^2$ at 2 MPa of normal stress, and $10^{-18}$ $m^2$ at 50 MPa).

Permeability is changed during the sliding in all tests, and when initial permeability is smaller than $10^{-17}$ $m^2$, average flow rate during sliding increases, on the contrary, flow rate decreases during sliding when initial permeability is larger than $10^{-17}$ $m^2$. Flow rate decreased by 10 % of the flow rate at the end of sliding, reaching a steady state within ten minutes, but for slip velocities greater than 50 mm/s, the flow rate increased after the end of sliding. The reduction in flow rate after sliding is probably caused by the thermal expansion of sliding surface due to frictional heating, and the cooling after sliding decreased the aperture and results in the decrease in permeability of slip surface. Increase in flow rate at high velocity condition is induced by the increase in viscosity of nitrogen gas by frictional heating.

At the same slip velocity, average flow rate during sliding is proportional to coefficient of friction. Slip surfaces of hollow specimen is partly covered with sheet silicate fine-grained gouge layers, and the gouge layers imply low friction and low permeability. Therefore the increase in the ratio of gouge materials among the contact area will induce a reduction in flow rate that associates with lower friction and permeability. A connectivity of sheet-silicate gouge layers will influence on the permeability as well. In the future, we can estimate the friction coefficient from the flow rate or permeability of sliding surface of active fault zone by applying our study.

Keywords: permeability, frictional heating, wear, earthquake, fault, flow rate

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# Energy partition for grain crushing in quartz gouge and sintering effect during subseismic to seismic fault motion

TOGO, Tetsuhiro[1*], FUKUYAMA, Eiichi[1], SHIMAMOTO, Toshihiko[2]

[1]National Research Institute for Earth Science and Disaster Prevention, [2]Institute of Geology, China Earthquake Administration

To determine how much of the frictional energy consume in grain crushing is important because this fraction will affect the energy used for frictional heating which in turn can affect the mechanical properties of a fault during seismic fault motion. In addition, it is geologically important to understand the formation and developing process of the mature fault zones.

Thus we have conducted friction experiments on quartz gouge as a simple case at subseismic to seismic slip rates. Quartz was selected because it is a very common mineral in fault zones and its surface energy is measured (about 1 J/m2, Brace and Walsh, 1962). Brunauer-Emmett-Teller (BET) surface area of quartz gouge was measured before and after shearing. Measurement of BET surface area provides more direct data on surface-area change than grain-size measurement does. Our recent results show that grain crushing absorbed only 0.02~0.22 % of frictional work. Thus, grain comminution is unlikely to be an important energy sink at least for mature faults with well-developed slip zone.

Another new finding from our study is that the BET surface area of quartz gouge deformed at high slip rates begins to decrease after a certain displacement. Sawai et al. (2009) also have found that the surface area of Nojima fault gouge decreases, rather than increases, with shearing deformation at seismic slip rates. Our observations of quartz gouge revealed that fine grains formed cohesive aggregates and dendritic clusters. In particular, the dense granular aggregate strongly suggests that sintering of gouge partially occurred. The bulk temperature rise in quartz gouge in our experiments would be on the order of several hundred degrees Centigrade in view of recent experiments under similar conditions and temperature calculations (Mizoguchi et al., 2009; Kitajima et al., 2010; Han et al., 2011). This may not be enough for full sintering to occur, but flash heating probably contribute to partial sintering (see Rice, 2006; Han et al., 2007a, 2007b; Oohashi et al., 2011).

Keywords: High-velocity frictional experiment, Energy budget, Fracture energy, Sintering

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# An effect of grain size on high velocity slip behaviors of olivine aggregates

KINOSHITA, Chihiro[1*], HIROSE, Takehiro[2]

[1]Graduate School of science,Kyoto University, [2]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology

Olivine is a key mineral that controls the slip behavior of seismic faults in deep oceanic crusts at mid-ocean ridges and subduction zones. However, its frictional property is not well understood, especially at coseismic slip velocity (i.e. >0.1 m/s). In this experimental study we crushed and sieved San Carlos olivine into four grain size ranges (3, 5, 15, 35, and >50 micron). The olivine aggregates of 0.5 g were deformed dry to >10 m displacement at velocity of 0.0013-1.3 m/s and normal stress of 0.5-2.0 MPa using a rotary-shear apparatus, in order to reveal the effect of initial grain size on slip behavior at high velocities. In addition, we examined the microstructures of the simulated fault zone that control the high-velocity slip behaviors using a FE-SEM.

The experiments at high velocity showed a typical slip weakening behavior: friction coefficient is 0.7-0.9 at the initiation of slip and it decays exponentially to a steady-state stage of 0.2-0.3 over a slip weakening distance Dc. Dc decreases from 40.0 to 4.0 m as increase in normal stress from 0.5 to 2.0 MPa, respectively, following a power-law relation. There is no clear grain size dependence of friction level and Dc. In contrast, slip weakening behaviors are invisible at velocities of < 0.13 m/s. Such slip-weakening and velocity-weakening behaviors of olivine aggregates are quite similar with other rocks sheared at high velocities (e.g., Di Toro et al., 2011).

A slip localized zone forms during high-velocity sliding and is composed of fine-grained olivine with less than 1 micron. Interestingly thickness of the localized zone tends to become thinner for initially finer grains: thickness of localized zone is 50,33 and 3 micron, respectively. This implies that a positive feedback process between grain-size reduction and slip localization could operate within a gouge zone during cosesmic sliding leading to the dynamic weakening of faults.

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# The influence of lubricating agents for the strength reduction of faults

OOHASHI, Kiyokazu[1*], HIROSE, Takehiro[2]

[1]Graduate School of Science, Chiba University, [2]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology

The weakness of mature faults, which is presumed by lack of heat flow anomaly and stress orientations around faults, is still open to argument. One of the explanations for these weak faults is that the presence of weak minerals (fault lubricants) such as phyllosilicates along the fault zones. Frictional experiments on bimineralic mixtures with phyllosilicates are conducted to examine its operation for weakening agent (e.g. Logan and Rauenzahn, 1987; Brown et al., 2003; Takahashi et al., 2007; Crawford et al., 2008). However, these previous studies are conducted with limited shear strain (mostly $<10$) in spite of significance of fabric development on weakening has been pointed out (Collettini et al., 2009). We thus performed large strain, friction experiments on graphite- and smectite-quartz bimineralic gouges using rotary-shear, low- to high-velocity friction testing apparatus to understand how frictional behavior changes with fraction and shear strain.

Experiments were done with dry and water-saturated conditions for graphite and smectite mixtures, respectively. Experimental results clearly indicated that the steady-state friction of the mixture gouge decreases exponentially with content of graphite/smectite (see figure); it starts to reduce at fraction of 5 vol% and reached to the almost same level of pure graphite/smectite at the fraction of $>30$ vol%. According to textural observation for the graphite mixtures, weakening of $<28$ vol% mixtures is associated with formation of slip-localized zone and development of graphite-lubricated, throughgoing slip surface with progressive shearing. On the other hand, $>28$ vol% of mixtures show diffused, graphite matrix flow within the slip-localized zone due to the development of graphite connection parallels to the Y- and P-surfaces. The relationship between strength versus graphite fraction evolves from early gentle to later abrupt sigmoidal curve with increasing shear strain (see figure). These trends are quite different from that of previous studies, and highlight the importance of shear strain and accompanied textural development on formation of weak fault.

[References]

Brown, K. M., A. Koef, M. B. Underwood, and J. L. Weinberger (2003), Compositional and fluid pressure controls on the state of stress on the Nankai subduction thrust: A weak plate boundary, Earth Planet. Sci. Lett., 214, 589?603, doi: 10.1016/S0012-821X(03)00388-1.

Collettini, C., A. Niemeijer, C. Viti, and C. Marone (2009), Fault zone fabric and fault weakness, Nature, 462, 907?910, doi:10.1038/nature08585.

Crawford, B. R., D. R. Faulkner, and E. H. Rutter (2008), Strength, porosity, and permeability development during hydrostatic and shear loading of synthetic quartz-clay fault gouge, J. Geophys. Res., 113, B03207, doi:10.1029/2006JB004634.

Logan, J. M., and A. Rauenzahn (1987), Frictional dependence of gouge mixtures of quartz and montmorillonite on velocity, composition and fabric, Tectonophysics, 144, 87?108, doi:10.1016/0040-1951(87)90010-2.

Takahashi, M., K. Mizoguchi, K. Kitamura, and K. Masuda (2007), Effects of clay content on the frictional strength and fluid transport property of faults, J. Geophys. Res., 112, B08206, doi:10.1029/2006JB004678.

Keywords: Fault lubricant, Graphite, Smectite, Fault gouge, Fault weakening, Friction experiment

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# Effects of confining pressure and mineral property on rupture propagation process revealed by unstable-slip experiments

HIRAUCHI, Ken-ichi[1*], MUTO, Jun[2], OTSUKI, Kenshiro[2]

[1]Dept. Earth Planet. Syst. Sci., Hiroshima Univ., [2]Dept. Earth Sci., Tohoku Univ.

Episodic slow slip events, as defined by anomalously low rupture velocity within a range of 5 to 15 km/d (0.06 to 0.17 m/s), have been observed in subduction zones, and occur as shear slip on the plate interface downdip of the seismogenic zone. A considerable body of evidence points to high fluid pressures on the plate interface that may reduce effective normal stress and enable slow slip. Laboratory observations on rocks have shown that nucleation of unstable slip consists of an interval of fault creep that localizes and accelerates to a dynamic rupture, with propagating velocity comparable to shear wave velocity of the material. However, in spite of the importance of low effective normal stress in causing slow slip events, the effect of normal stress on the rupture properties of the fault has been yet explored.

In this study, unstable-slip experiments were conducted in a gas-medium apparatus at room temperature, confining pressures of 60-180 MPa, and a nominal strain rate of 1 x 10-3 s-1. We used powders of lizardite/chrysotile (liz/ctl), antigorite, and olivine as the starting material, producing a ˜0.7-mm-thick layer of simulated fault gouge between two gabbroic forcing blocks. To monitor directly the strain field parallel to the fault surface, four strain gauges were mounted onto the lower gabbro cylinder along the fault. The friction coefficient was 0.48-0.58 for liz/ctl and 0.67-0.72 for antigorite, while olivine has a friction coefficient of 0.72-0.73.

The stress-strain curves exhibit an initial linear elastic portion, a strain-hardening range in which stress increases with strain and, finally, a range in which the stress levels off or drops off until one sudden, large unstable-slip occurs. At $P_c$ = 100 and 140 MPa for antigorite and olivine, the shear stress dropped to a residual value at least within 50 us during the unstable-slip event. The rupture propagated bilaterally at speeds ranging from a few hundreds meters to a few kilometers per seconds. At $P_c$ = 100-180 MPa for liz/ctl and $P_c$ = 60 MPa for antigorite and olivine, the local strains show that a rupture started to propagate slowly at speeds in the range of 0.7 to 2.0 m/s. Eventually, a rupture propagates at fast speeds. At $P_c$ = 60 MPa for liz/ctl, the shear stress decreased very slowly towards a residual value within ˜1 s. The local strains show that a rupture nucleated just before the onset of stress drops, and then propagated at speeds ranging from 0.07 to 0.25 m/s.

There is no systematic dependence of confining pressure on the observed rupture velocity during the fast stress drops. In contrast, the rupture velocity during the slow stress drops appears to decrease with decreasing confining pressure. We thus conclude that the slow rupture propagation process along the gouge-bearing fault is affected by intrinsic material property and confining pressure. A series of slow earthquakes including slow slip may reflect differences in the size and duration of slow rupture phase, which becomes dominant if the weak material exist on the fault at low effective normal stress. In particular, the rupture property characterized by a slow stress drop with anomalously low rupture velocity observed at $P_c$ = 60 MPa for liz/ctl might be analogous to that of slow slip events in nature.

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# Contrasting hydrological and mechanical properties between hemipelagic and turbidite muds from the shallow Nankai Trough

TAKAHASHI, Miki[1*], AZUMA, Shuhei[2], UEHARA, Shin-ichi[3], Atsuyuki Inoue[2], KANAGAWA, Kyuichi[2]

[1]GSJ, AIST, [2]Graduate School of Science,Chiba University, [3]Faculty of Science, Toho University

We found that two mud samples cored from shallow (c.a.1000 mbsf) accretionary sediments at Site C0002 of IODP Exp. 315 are different in origin; one is a hemipelagic mud and the other is a turbidite mud. The hemipelagic mud sample is poorer in quartz and feldspar (34 wt%), richer in clay minerals (41 wt%) and uniformly fine-grained, whereas the turbidite mud sample is richer in quartz and feldspar (51 wt%), poorer in clay minerals (37 wt%) and poorly sorted. The former has a small porosity of 11%, while the latter has a large porosity of 38%.

At room temperature, in-situ confining pressures of 36-38 MPa and water pressures of 28-29 MPa, the hemipelagic mud sample has a smaller permeability of $2.9*10^{-19}$ $m^2$, while that the turbidite mud sample has a larger permeability of $2.3*10^{-18}$ $m^2$. Triaxial compression experiments at these conditions and an axial displacement rate of 10 micron/s reveal that the former exhibits a smaller peak strength of 14.5 MPa followed by a slow failure lasting for a minute, whereas that the latter exhibits a larger peak strength of c.a. 20 MPa followed by a rapid failure within seconds. Friction experiments at these conditions and axial displacement rates changed stepwise among 0.1, 1 and 10 micron/s reveal that the hemipelagic mud sample has a much smaller friction (friction coefficient = 0.25) than the turbidite mud sample (friction coefficient = 0.53). Although both samples exhibit rate-strengthening behavior upon velocity stepping, the velocity dependence of the former is much larger than that of the latter. In addition, a certain type of flow likely contributes to the former's frictional strength.

Such contrasting hydrological, mechanical and frictional properties between hemipelagic and turbidite muds have important implications for faulting in the shallow Nankai Trough accretionary prism. Faulting would preferentially occur in the hemipelagic mud, because it is weaker than the turbidite mud. The faulting in the hemipelagic mud would occur slowly, and therefore is a possible source of very low frequency earthquakes recently found in the shallow Nankai Trough accretionary prism. Faults formed in the hemipelagic mud are also much weaker in strength than those in the turbidite mud. In addition, the hemipelagic mud is much less porous and permeable than the turbidite mud so that in the former pore pressure likely builds up during deformation and thermal pressurization is expected to occur during faulting, which results in further weakening and large displacements. Our results may constrain the possible properties of mud to generate tsunami earthquakes in the shallow Nankai Trough accretionary prism.

Keywords: Nankai Trough, hemipelagic mud, turbidite mud, permeability, strength, frictional properties

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# Characterization of carbonaceous materials in the Taiwan Chelungpu fault by microRaman spectroscopy

MAEKAWA, Yuka[1*], YABUTA, Hikaru[1], HIRONO, Tetsuro[1]

[1]Department of Earth & Space Science, Osaka Univ.

Coseismic slip during an earthquake induces frictional heating in fault zone. Determination of the temperature recorded in the fault is important for estimating the dynamic shear stress and displacement during the earthquake. Here we performed raman spectroscopic analysis of carbonaceous materials from the Taiwan Chelungpu fault, and discuss the capability as new temperature proxy during the earthquake.

Keywords: carbonaceous materials, Raman spectroscopy

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# Detection of frictional heat in seismic faults by vitrinite reflectance :Insights from high-velocity friction experiment

KITAMURA, Manami[1*], HIDEKI, Mukoyoshi[2], HIROSE, Takehiro[3]

[1]Depart. of Earth and Planetary Systems Science, Graduate School of Science, Hiroshima University, [2]Marine Works Japan Ltd.,

Quantitative assessment of heat generation along faults during fault movement is of primary importance in understanding the dynamics of earthquakes. Last several years localized heat anomaly in a fault zone due to rapid seismic sliding has been detected by various analyses of fault zone materials, such as ferromagnetic resonance signal (Fukuchi et al., 2005), trace elements and isotopes (e.g., Ishikawa et al., 2008) and mineralogical change of clay (e.g., Hirono et al., 2008) and vitrinite reflectance (e.g., Sakaguchi et al., 2011). Among them, vitrinite reflectance method has been used as a geological thermometer for a long time because of its simple and easy way. However, a conversion equation from vitrinite reflectance ($R_o$) to temperature (e.g., Baker 1988) can not apply for $R_o$ measured in the fault zone as frictional heating duration is quite short and the parallel chemical reaction (or stabilization of kerogen thermal maturation) must not be reached.

Thus, in order to describe a kinetic model of vitrinite thermal maturation at coseismic conditions, we deformed a simulated gouge (a mixture of 90 wt% quartz and 10 wt% vitrinite) at slip velocities of 0.0013 m/s to 1.3 m/s, normal stress of 1.0 MPa and displacement of 15 m under anoxic, nitrogen atmosphere, while measuring temperature in the gouge zone by thermocouples. At velocity of 1.3 m/s, $R_o$ increases from ~1.0 to ~6.0% as a result that temperature in the gouge zone increases gradually with displacement to ~270?C. In contrast, at velocity of 0.0013 m/s, temperature keeps nearly room temperature, most of Ro does not change except for few grains in the slip localized zone. Such grains with high $R_o$ at low velocity may be due to flash temperature at asperity contacts and/or mechanochemical effects that could mature vitrinite. A dynamic kinetic model of vitrinite maturation at different coseismic slip conditions is needed for precise estimation of temperature anomaly along seismic faults and for development of a fault thermometer.

Keywords: fault, frictional heat, Vitrinite reflectance, carbonaceous material

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# Detection of seismic frictional heat using scanning ESR microscopy

FUKUCHI, Tatsuro[1*]

[1]Yamaguchi University

The estimate of seismic frictional heat is important to evaluate the total earthquake energy budget. The frictional heat strongly depends on the width of heat generation, so that we need to determine it to exactly estimate the frictional heat from a fault rock. In addition, we must sequentially detect the index of the frictional heat at a resolution of 1 mm or less. In this study, I will explain how to detect the frictional heat from the ESR signals as indices of frictional heat and how to determine the width of heat generation using scanning ESR (electron spin resonance) microscopy. The fault rocks studied are a crushing-originated pseudotachylyte distributed in the Nojima fault zone, Hyogo Prefecture and a melting-originated pseudotachylyte in the Uchinoura shear zone, Kagoshima Prefecture, and besides indurated black materials in the Taiwan Chelungpu fault deep drill Hole B cores (Ma et al., 2006).

The target signals for the detection of frictional heat are FMR (ferrimagnetic resonance) signals produced from iron-bearing minerals and a paramagnetic organic radical produced from organic materials by thermal decomposition during frictional heating. A distinctive FMR signal is detected from the Nojima pseudotachylyte, whose source rock is the granitic fault gouge. Its magnetic source was considered to be maghemite (gamma-$Fe_2O_3$) with low crystallinity produced by the thermal dehydration of lepidocrocite (gamma-FeOOH) in the fault gouge on the basis of its g-value and lineshape (Fukuchi et al., 2007). However, detailed analyses of ESR spectra indicate that magnetite ($Fe_3O_4$) with low crystallinity produced by instantaneously thermal decomposition of siderite ($FeCO_3$) also shows the similar g-value and lineshape. If taking account of the initial temperature (about 200 degree C) at the time of formation of the Nojima pseudotachylyte, lepidocrocite cannot stably exist under such high temperature. Therefore, the magnetic source of the FMR signal may be derived from magnetite with low crystallinity produced by thermal decomposition of siderite. The Uchinoura pseudotachylyte whose source rock is the granitic rock also shows a distinctive FMR signal. Since thermal experiments revealed that magnetite can be produced by thermal decomposition of biotite, the magnetic source of the FMR signal may be derived from the biotite-originated magnetite (Fukuchi, 2012). On the other hand, no prominent FMR signal is detected from the black material in the Taiwan Chelungpu fault zone, so that I use a paramagnetic organic radical (g=2.004), which may be produced by thermal decomposition of organic materials in muddy stone.

The scanning ESR microscope used for the detection of frictional heat has a $TE_{111}$ mode cavity with a pinhole of 1.6-2.6mm in diameter and an internal 100kHz modulation coil that improves the detection sensitivity. At this stage, the resolution of detection is estimated at 0.1 mm. 2-Dimensional ESR analyses indicate that the multiple peaks of FMR signal intensity having resulted from ancient frictional heating events are detected from the Nojima pseudotachylyte and the width of heat generation is estimated at 0.5-1.0 mm. In case of the Uchinoura pseudotachylyte, the contacting part with an intrusion vein shows very high FMR signal intensity, while the inner part of the intrusion vein has almost uniform and low signal intensity. Since FMR signals disappear just at the moment their magnetic source minerals melt, we can judge the origin of pseudotachylyte (melting or crushing) from the FMR signal intensity and distribution inside the pseudotachylyte vein. On the other hand, the black material in the Chelungpu fault zone shows a higher 2-D intensity of organic radical than its source rock.

Keywords: electron spin resonance, ferrimagnetic resonance, ESR microscopy, organic radical, earthquake, frictional heat

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# Microstructures of pulverized fault rocks: Examples from San Andreas Fault and Arima-Takatsuki Tectonic Line

NAKATANI, Tsurugi[1*], MUTO, Jun[1], NISHIKAWA, Osamu[2], NAGAHAMA, Hiroyuki[1]

[1]Department of Geoenviromental Sceinces, Graduate School of Science, Tohoku University, [2]Faculty of Engineering and Resource Science, Akita University

Fault damage zone is gradually formed into the surroundings of the fault layer by the overlap of shear strain and the accumulation of wear (Sholtz, 1987Geology). However, it have been reported recently that 'pulverized fault rocks', characterized by no shear strain and remarkable shatter in situ, are distributed along large strike slip faults such as SAF (Dor et al., 2006EPSL). The development of such damage zones cannot be explained by the conception of wear. In recent study, it is thought that it formed in a moment when an earthquake rupture progresses on a fault plane. Moreover, it argues about the asymmetry of the fault damage zone, because 70% or more of pulverized fault rocks in the SAF are distributed over the northeast side of the fault (Dor et al., 2006EPSL). The factor of mechanism which asymmetrical fault damage zone formed are propagative direction of earthquake rupture (Di Toro et al., 2005Nature), hardness of the rock (Ben-Zion et al., 2005EPSL) and supershear rupture (Doan and Gary, 2009Nature Geo).

Nevertheless, there are the following questions in the lithological characteristic and mechanism of pulverized fault rocks. Because pulverized fault rocks have been studied mainly along the SAF (Dor et al., 2006EPSL), it is not understood whether the microstructure and fracture pattern of pulverized fault rocks change with different tectonic settings and rock compositions. Moreover, pulverized fault rocks reported in the SAF are mainly focused on the quartz particles in the granite (Dor et al., 2009PAGEOPH), so the characteristic of the fracture pattern on other rocks and minerals is not clear. It is also not clear that the difference from the deformation process by the weathering and the other brittle fault rocks such as the fault gauge.

We conducted field surveys on ATTL and SAF, and evaluated microstructures of pulverized rocks by using a scanning electron microscope. Pulverized fault rocks which consist of a granite shows thin black with mica, and white with quartz and feldspar. It easily pulverizes by rubbing between fingers. Under the microscope, the intense fractures were observed only in framework silicates (tectosilicates) such as quartz and feldspar. They are shattered to 10-100 micrometers and show fracture pattern of the web structure. However, the original igneous textures of the host rock is maintained and there are not fine-grained matrices which consist only of finely communicated grains like fault gouges. The fractured grains are in the state which left the outside, and the crack of uneven quality exists in the inside of particles. Some quartz particles were seen that the crack goes through different particles and the crack was radiately developed from the contact point of particles. The fracture planes of quartz are smooth with river patterns. The fragments are angler shape and do not show any effect of wear. On the other hand, the fracture planes of feldspar are rough. Inosilicates such as amphiboles are crushed to 10-100 micrometers and have been fragmented along cleavages. The fracture planes are smooth and fragments have angler shapes. Some of amphiboles fracture to different direction from cleavages. Biotite (phyllosilicate) was found to be hardly shattered but kinked along basal planes. They don't show any asymmetric shear structures like mica fish often observed in fault guoges. SEM analysis of these minerals shown above clarified that clay minerals like kaolinite and smectite, and the alteration minerals like sericite and chlorite have not been observed. From the analysis, pulverized rocks have following characteristics: 1) small amount of strains, 2) no shear deformation with asymmetric structures or grain rotations, 3) volume expansions. The observations indicate that pulverized fault rocks differs from the fault gouges formed by wear and shear deformation.

Keywords: pulverized fault rocks, damage zone, fracture pattern

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# Formation process of slickenside developed on the Glarus thrust

NISHIWAKI, Takafumi[1*], ANDO, Jun-ichi[1], OHFUJI, Hiroaki[2]

[1]Department of Earth and Planetary Systems Science, Graduate School of Science, Hiroshima University, [2]Geodynamics Research Center, Ehime University

We observe microstructures of slickenside developed on the Glarus thrust to clarify its formation process mainly with optical and electron microscopy. Glarus thrust is one of the biggest faults in the world, whose lateral displacement is about 30-40 km. We collected the fallen Lochseiten limestone at Linthal, Swiss. The sharp slickenside is developed in our sample.

The summary of our microstructural observations is the followings. 1) The slickenside was generated during faulting, which was accompanied with brittle deformation of limestone. The brittle deformation occurred at the area only within ca. 1 cm distance from slickenside. 2) The fine calcite grains with several um in size occupy at the area away from the above. These grains were deformed by dislocation creep. And they make a strong lattice preferred orientation created under dextral shear stress condition. The shear direction is absolutely parallel to striation on the slickenside. These results suggest strongly that the Lochseiten limestone were deformed by both of plastic and brittle manners at the same stress condition. Now, we observe the microstructure of the slickenside surface to clarify its formation mechanism.

Keywords: slickenside, faulting, microstructure, Glarus thrust

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# Mylonite shear localized region with finite length, associated with mylonitic pseudotachylyte; an ancient hypocenter?

UEDA, Tadamasa[1*]

[1]Div. Earth&Planetary Sci., Kyoto Univ.

A mylonite shear localization structure with a finite length in the direction of shear plane, associated with fault vein of mylonitic pseudotachylyte, occurs in the Balmuccia peridotite massif, Ivrea zone, Italy.

The shear localized regionn cut primary pyroxenite marker dykes and deform them macroscopically. The marker dykes distribute with interval of ~1m, so the rough distribution of the shear localized region can be recognized by marker dyke deformation. The size of the shear localized region recognized on outcrop surface is, at most, ~40cm across shear plane and ~2m along shear plane. The maximum shear strain recognized by deflection of the marker dyke is at least 2. Shear localized region with such size and shear strain is rare. The shear localized region is associated with mylonitic pseudotachylyte fault of ~1mm thickness on the plane where the shear localization is at maximum. Porphyroclast elongation direction in mylonitic pseudotachylyte fault vein plunges ~50degrees against outcrop surface. Offset of marker dykes by the fault in total is ~40cm on outcrop surface. The intense shear localization is observed only on southeastern side of the fault.

The mylonite in shear localized region consists of ultramafic protomylonite with recrystallized grains of ~20microns diameter and porphyroclasts of ~2mm diameter. The volume percentage of recrystallized grains increase from ~15% (peridotite), ~5% (pyroxenite) up to ~40% (peridotite, pyroxenite) in shear localized region. The mineral assemblages of recrystallized grains both in peridotite and pyroxenite are olivine, clinopyroxene, orthopyroxene, spinel, and hornblende, whereas hornblende is absent in the coarse grained primary peridotite. Porphyroclasts shows undulatory extinction. Purely monophase dynamic recrystallization is extremely rare, and recrystallized grains in olivine porphyroclast are always associated with small amount of spinel, often with clinopyroxene or orthopyroxene. Some clinopyroxene porphyroclasts shows grain bending and splitting associated with undulatory extinction and apature-filling spinel deformed by intra-crystalline diffusion creep. Geothermemetric estimation of the mylonitization around shear localized region yielded 800~850degreesC.

The fact that shear localized region mainly observed on one side of the fault indicates fault developed after shear localized region is formed. The lithology of fault walls is peridotite and pyroxenite for both sides, so, if the shear localization had postdated seismicity, shear localized region would have been observed on both sides. The other part of the shear localized region is thought to have moved away from outcrop surface by out-of-surface component of slip displacement. Therefore, the rather flattened shear localized region predates the rupture nucleation.

Because there is shear localization, mylonitization is thought to be strain softening process. Existence of soft material in flat body in deformed media yields stress concentration around tips. However, the mylonitization is associated and hence accommodated with hornblende-forming chemical reaction, and recrystallization temperature estimation yielded quasi-uniform temperature. Hence, the mylonitization is thought to have proceeded only at a constant rate constrained by the ambient temperature. As the shear localized region grows larger and becomes elongated, stress around the shear localized region tip grows because of increase of aspect ratio of the region. However, because the mylonitization proceeds only at a constant rate, the mylonitization cannot fully relax the stress concentration. Such formation of finite length shear localization region associated with thermally rate-limited weakening process will inevitably accumulate stress around its tips until breaking the surrounding stronger media even under a far-field stress lower than fracture strength.

Keywords: shear localization, mylonite, pseudotachylyte, pre-seismic deformation, seismogenic process, brittle-ductile transition zone

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# Minor element characteristics of melt-origin and crush-origin pseudotachylytes

HONDA, Go[1], ISHIKAWA, Tsuyoshi[2], HIRONO, Tetsuro[1*], TAKAGI, Hideo[3]

[1]Osaka University, [2]JAMSTEC-Kochi, [3]Department of Earth Science, Faculty of Education and Integrated Arts and Sciences, Waseda Universit

Origin of pseudotachylyte is generally divided into melt-related and crush-related types. Melt-origin type contains melt-ralated textures such as glass, glassy material, spherulites, dendritic microlites, vesicles, amygdules, rounded and embayed clasts, and sulfide blebs. In contrast, crush-origin type shows none of these melt textures. However, the development of these textures is dependent on not only maximum temperature reached but also cooling rate. Therefore, the distinguishing between them is difficult. We here adopt the chemical analysis of both types using ICP-mass, and analyzed the trace element and Sr isotope compositions in order to find the good proxy to distinguish their origins. We investigated melt-origin pseudotachylyte from the Asuke Shear Zone and crush-origin pseudotachylyte from the Iida-Matsukawa fault. In this presentation, we show these preliminary results and discuss their characteristics.

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# Noble gas release and frictional degassing from faults during coseismic sliding: under controlled gas environment

SATO, Keiko[1*], HIROSE, Takehiro[2], KUMAGAI, Hidenori[1], TAMURA, Hajimu[1], Masumi Sakaguchi[3], SUZUKI, Katsuhiko[1]

[1]IFREE, JAMSTEC, [2]KCC, JAMSTEC, [3]Marine Works, JAPAN

Noble gases very limitedly react with other elements because of their inert nature. Therefore, isotope ratios of noble gases in certain minerals are believed to reflect well those of their ambient reservoirs when the temperatures of the minerals containing them went up to their closure temperatures, or higher.

We have reported the resetting of isotope signatures of noble gases released during rotary-shear high-velocity friction experiment on the Aji granite samples shaped as cylinders and rotated at 1.6 m/s at a constant normal stress of 1.4 MPa. Friction increased with slip and reached maximum value at ~ 5 seconds ("first fuse"; Hirose et al, 2005) after the beginning of the slip. Completely melted glass formed by frictional heat was found only on the sliding surface. The most part of the post experiment specimen were little or not melted, which is possibly due to very short duration of the experiment.

Under controlled gas environment of gabbroid experiment, limited "first fusion" occurred at the first temperature maxima (corresponding to the displacement of Magnitude -2 ~ -3). Then, friction suddenly dropped down, and decreased gradually further in several seconds associated with moderate melting ("second fuse", corresponding to the displacement of the Magnitude 5 or larger, e.g. Kanamori et al., 2005).

Compared with gabbroid experiments, Ar gas degassed at the "first fusion" when a granite was used for the starting material for the experiment because the granite used, with an age of 77.2 ~ 87.1 Ma (Yuhara, 2008), contained abundant radiogenic 40Ar. Ar was clearly emitted after only 5 seconds sliding, and with more amounts than with the gabbroid sliding. Also, the timing of melting depended on the atmospheres of the experiment; whether moist-air, dry-air, He or Ar was used in the experiment. These results suggest that the dissipation of friction-induced heat depends on the mass numbers of the ambient gases. Furthermore, in the case that a sedimentary rock containing much higher potassium is in contact with a fault, emission of 40Ar may be faster and much intense during the fault motion. Thus, the liberation of volatiles believed to be detected in some large earthquakes may be controlled by ambient condition of the fault.

Keywords: noble gas, degassing, frictional heating, granit, gabbro

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# Amorphization of dolerite gouges and its effects on their frictinnal properties

WADA, Jun-ichi[1*], KANAGAWA, Kyuichi[1], Masao Nakatani[2], Hiromine Mochizuki[2], HIROSE, Takehiro[3], Jun-ichi Ando[4], Noboru Furukawa[1], Atsuyuki Inoue[1]

[1]Department of Earth Sciences, chiba university, Japan, [2]Earthquake Research Institute, University of Tokyo, Japan, [3]Kochi Institute for Core Sample Research, JAMSTEC, Japan, [4]Department of Earth and Planetary Systems Science, Hiroshima University, Japan

We have ground crashed and sieved grains of dolerite using an automated flint mill for 10 minutes, and 6, 12, 24, 36, 48 and 60 hours. Grinding was interrupted for about 15 minutes at every three hours in order to prevent oxidation caused by frictional heat during grinding. TEM observations reveal the abundant presence of submicron-size rounded amorphous grain in ground gouges. Quantitative XRD analyses indicate that amorphous phase is absent in the gouges ground for 10 minutes, but that its amount increases linearly up to ?40 wt% with grinding time up to 36 hours. Grinding for more than 36 hours, however, does not result in any further increase in the amount of amorphous phase. This is probably due to the grinding power of the mill used. SEM observations of ground gouges reveal the abundant presence of the rounded grain with an angular clast core and amorphous mantle, likely grown by accretion of amorphous material around a clast grain as accretionary lapilli. Similar rounded grains have been found in natural and experimentally produced clay-rich fault gouges, and are called ”clay-clast aggregates”. This ”clay-clast aggregate”-like grain increases in amount with grinding time.

We have then conducted friction experiments on the gouges ground for 10 minutes and 36 hours at a normal stress of 7 MPa and displacement rates changed stepwise between 1 and 10 micrometer/s by using a biaxial shear apparatus. The gouge ground for 10 minutes lacking amorphous phase has a larger friction (˜0.6), and exhibits velocity-weakening behavior, whereas the gouge ground for 36 hours containing ˜40 wt% amorphous phase has a smaller friction (˜0.55), and exhibits a quasi-neutral velocity dependence of friction. Thus amorphization of gouge not only reduces frictional strength, but also affects to velocity dependence of friction.