Non-characteristic surface rupturing earthquakes on the ISTL active fault system, Japan

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Intraplate earthquakes generally have recurrence intervals of a few thousands to tens of thousands of years, in contrast to interplate earthquakes, which repeat at intervals shorter than a few hundred years. We here report the first evidence for an extremely short recurrence time on an intraplate fault in Japan. The Kamishiro fault consisting of the northern end of the Itoigawa-Shizuoka Tectonic Line active fault system generated a Mw 6.2 earthquake on 22 November 2014. The surface rupture extends for about 9 km long mostly along the previously mapped active faults, but the source fault is inferred to be about 20 km long by aftershock distribution. It indicates that the 2014 event was partially ruptured and non-characteristic event comparing with the total length of the Kamishiro fault for about 24 km long. A paleoseismological trench excavation across the 2014 surface rupture showed a down-dip increase in displacement along the fault strands of the 2014 earthquake and two prior paleoearthquakes. The slip of the penultimate earthquake was similar to the slip of 0.5 m with the 2014 earthquake at the trench site, and the timing was constrained to be after AD 1645. The antepenultimate event might be correlated with the historical AD 762/841 earthquake. Judging from the timing, the damaged area, and the amount of slip, we infer that the penultimate earthquake corresponds to the AD 1714 historical earthquake. Therefore, the Kamishiro fault has generated moderate sized earthquakes both in AD 1714 and 2014, with a recurrence interval of about 300 years. This recurrence interval of surface rupturing earthquakes is extremely short compared with intervals on other intraplate active faults known globally. In addition, the spatial extent of the 2014 surface rupture accords with the distribution of a serpentinite block. The relatively low coefficient of friction of serpentinite may account for the unusually frequent earthquakes. These findings would affect long-term forecast of earthquake probability and time-dependent seismic hazard assessment under the various geological settings in Japan.

Shallow crustal structures triggered by the M_L6.6 Meinong earthquake, southwestern Taiwan, from field investigation of surface deformation and damages

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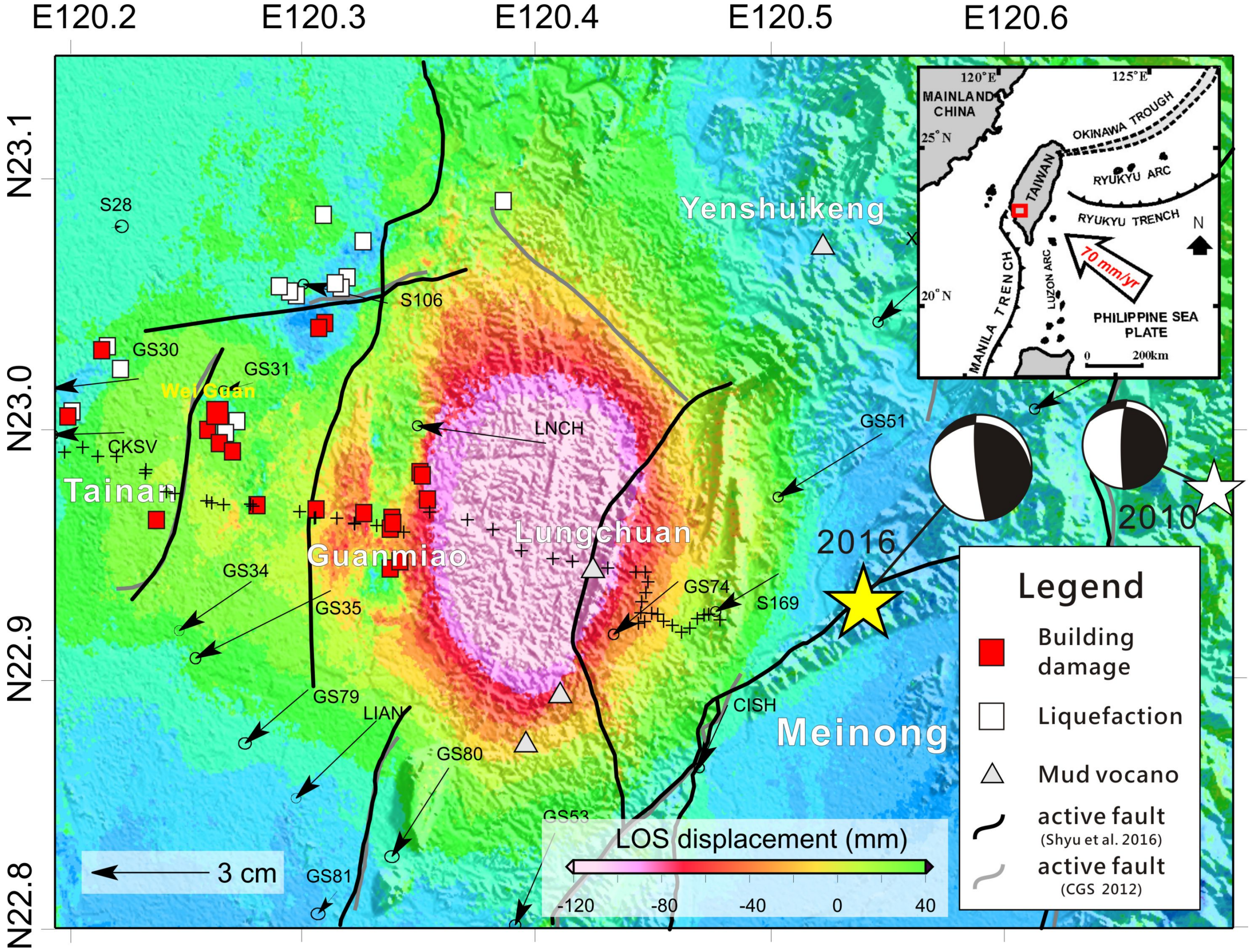
The M_L6.6 Meinong earthquake on 6 February 2016 caused serious damages in southwestern Taiwan. Coseismic displacement derived from GPS and InSAR shows ~10 cm dome-shaped surface uplift 15 km west of the epicenter with two clear N-S trending discontinuities in the InSAR fringes around the town of Guanmiao, which are highly related to building damages and surface cracks observed in the field. In this study, we integrate seismic reflection data, geologic data, and results from field investigation to construct shallow crustal structural geometry. The two lineaments near Guanmiao seen in the InSAR result may be induced by local shallow folding in the Liushuang - Erhchuangchi (LS-EC) Formation. Instead of being a traditional fault-bend fold, the significant uplift west of Guanmiao may be associated with pure shear deformation of clayey Gutingkeng (GTK) Formation. Our result suggests that lower crustal earthquakes can trigger active structures at shallower depths, which is capable of generating localized surface deformation and damages.

Keywords: Meinong earthquake, InSAR


E120.2
E120.3
E120.4
E120.5
E120.6
N23.1
N23.0
N22.9
N22.8
S28
S106
GS30
GS31
Wei Guan
CKSV
Tainan
LNCH
Lungchuan
Guanmiao
GS34
GS35
GS74
S169
GS51
Yenshuikeng
2016
2010
GS79
LIAN
GS80
CISH
Meinong
GS53
GS81
3 cm
LOS displacement (mm)
-120
-80
-40
0
40
Legend
Building damage
Liquefaction
Mud vocano
active fault
(Shyu et al. 2016)
active fault
(CGS 2012)
MAINLAND CHINA
120°E
125°E
25°N
20°N
OKINAWA TROUGH
TAIWAN
RYUKYU ARC
RYUKYU TRENCH
MANILA TRENCH
LUZON ARC
70 mm/yr
PHILIPPINE SEA PLATE
N
0
200km

Field survey and interpretation of the surface linear ruptures in northwest of the outer rim of the Aso caldera emerged on SAR interferogram

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Among many linear discontinuities identified using satellite radar interferometry images of the ALOS-2 showing small surface displacement associated with the 2016 Kumamoto Earthquake, vertical displacement pattern of east-west linear discontinuities with the lengths of a few kilometers in northwest area of the outer rim of the Aso caldera shows south-side-down in northern part and north-side-down in southern part by three dimensional deformation analysis (Morishita et. al., 2016), suggesting half-graben-like normal faulting triggered by north-south tensional stress field derived secondary from the stress changes associated with the main source faulting (Fujiwara et. al. 2016).
We carried out field surveys of the sites on these discontinuities and identified characteristic surface ruptures at many places. Strikes are approximately east-west and both width and throw are 30 cm at maximum. Such ruptures continue straightly at least a few tens meters. All of positions, strikes and direction of surface ruptures are consistent with the assumption by SAR interferometry. Some of those have characteristics in shape that can be misread as surface earthquake faults.
From the geomorphologic point of view, raptures are found on “Kuratake Faults” identified by preceding literatures (Kyushu Active Fault Research Group 1989, Nakata and Imaizumi 2002) with the displacement direction in accordance with geomorphological assumption. Besides, many ruptures were found where geomorphologically active faults are not recognized. This area is thickly covered by the pyroclastic flow deposits and volcanic products from Aso Volcano, consequently it is inferred that activities of buried tectonic structure were triggered.
Recently passive, or “accompanied” deformation of existing structure triggered by the change of stress field or seismic motion associated with earthquakes have been often reported since SAR interferometry has enabled the seamless and detailed understanding of surface deformation. These passive deformation might have occurred universally in nature and not special for the reported events. Such passive deformation may be possibly included in the list of past surface earthquake faults and events recognized by trench surveys. We should start the discussion on the issue of reexamination of identification of characteristic earthquake events of active faults.

Keywords: SAR interferometry, surface ruptures, triggered displacement, accompanied displacement

Surface rupture characteristics of the 2016 Kumamoto earthquake from compare of LiDAR DEM

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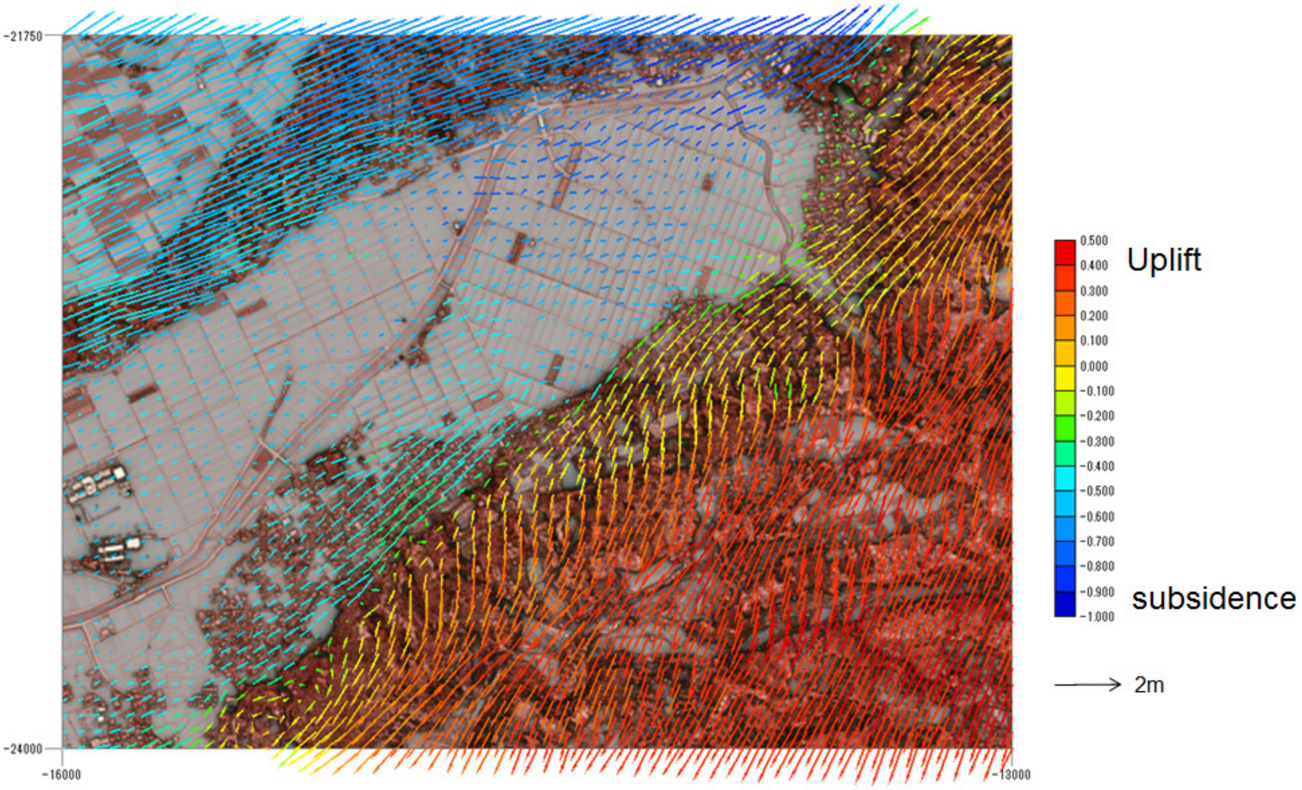
In the earthquake of M 7.3 occurred in Kumamoto Prefecture at 1:25 on April 16, 2016 (hereinafter referred to as the Kumamoto earthquake), surface earthquake faults had appeared in the area including Aso-city to Mifune-cho. In order to grasp these ground deformation quantitatively and quantitatively, the authors used airborne LIDAR data captured at two time periods immediately before this earthquake (April 15,14: 59 - 19: 20) and immediately after (April 23,10: 14 - 11: 53).
Elevation difference using mesh data is common as a method of comparing terrain data at multiple times. However, when large horizontal displacement is involved such as fault displacement, accurate fluctuation situation cannot be grasped by this method.
Therefore, we investigated a method to calculate three dimensional displacement vector by using point cloud data acquired by aviation laser measurement. An ICP (Iterative Closest Point) method is a general technique for registration between two point clouds. By repeating the process of obtaining the nearest neighbor point between two point clouds as the corresponding point and estimating the geometric transformation of reducing the distance of the corresponding point, it is possible to perform automatic positioning without a marker. In this study, we also adopted a method (CCICP: Classification and Combined ICP) that also takes into consideration minimizing the distance between the plane and the plane that the point group comprises.
Model area was set up near Mt. Miyake in Mashiki Town and CCICP method was applied as shown in Fig.1. From this result, it was confirmed that two right lateral strike-slip faults in the east-west direction along the north and south edges of the Kiyamagawa Lowland and the northwest-southeastward fault going on to it.
In addition, the uplift was observed in the mountainous area on the south side and the subsidence in the plateau portion on the north side. It was revealed that in some places where there are almost no horizontal movement locally in the vicinity where the fault crosses.

Keywords: LiDAR, Active Fault, 2016 Kumamoto Earthquake, Iterative Closest Point algorithm


-21750
-24000
-16000
-13000
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
-0.600
-0.700
-0.800
-0.900
-1.000
Uplift
subsidence
2m

Rupture features of the 2016 Mw6.2 Norcia earthquake and its possible relationship with strong seismic hazards

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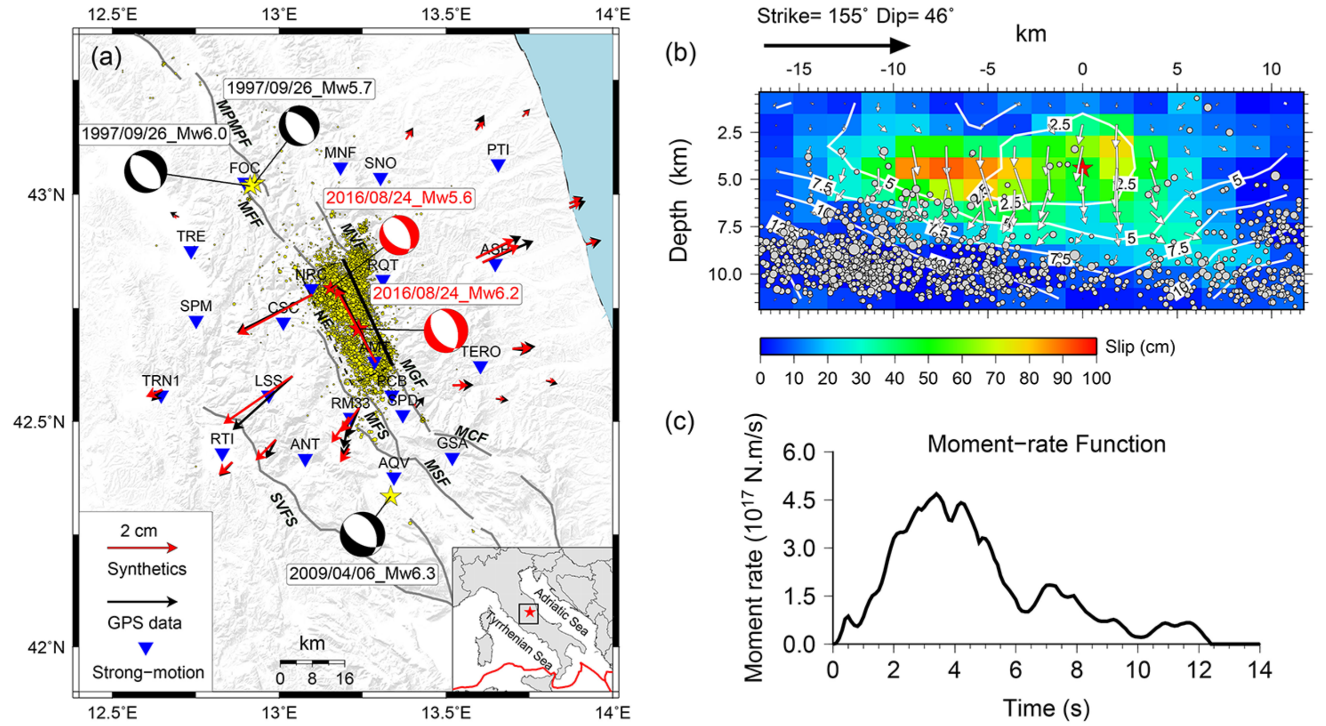
For analyzing possible reasons for the heavy damage and seismogenic features of the 24 August 2016 Norcia earthquake, we constructed and analyzed its rupture process by incorporating datasets of near-field strong motion, teleseismic and static GPS displacements. The optimized model revealed a relatively compact slip pattern with mainly normal fault components. The maximum slip was around 0.9 m, while the rupture areas extended ˜11 km and ˜20 km along dip and strike, respectively. The total seismic moment was 2.3×10^{18} Nm, equivalent to Mw 6.2. Most seismic moments were released within 10 s, radiating 3.5×10^{13} J of seismic energy. The rupture history showed asymmetric propagation and is characterized by a relatively high rupture velocity within the first 6 s with a maximum of ˜3.2 km/s. The mainshock slip pattern correlated well with the aftershocks distribution, and most of the accumulated strain was released in the east of seismic gap between the nearby 1997 and 2009 earthquake sequences.

Keywords: Norcia earthquake, Rupture features, Joint inversion, Seismic hazards



An example of slip on a capable fault: Near-field co-seismic deformation of the 30th October Central Italy earthquake (6.6 Mw) measured using low-cost GNSS

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Capable faults and the ground motions they produce in the near-field are of great importance to the construction of major infrastructure facilities such as nuclear plants, yet few datasets exist to constrain these effects. Here we present a record of co-seismic displacement of the 30th October Central Italy earthquake measured in the near-field using low-cost GNSS, an example of co-seismic slip on a capable fault. Four low-cost GNSS units were installed across the causative Mt. Vettore fault as two footwall-hangingwall pairs with baselines of 1,286 m and 1,870 m with an along-strike separation of 6.2 km. The displacement records reveal near-synchronous co-seismic displacement along each baseline, values of finite co-seismic displacement, rise-time and rupture velocity. A rigorous comparison of these values has been conducted using independent datasets of displacement and acceleration derived from regional GPS, InSAR, a local strong motion station and mapping of surface ruptures which intersect the two baselines. This comparison and analysis, whilst not without discrepancy, validates low-cost GNSS for the first time as an appropriate method for the temporal measurement of near-field co-seismic displacement. The derived empirical values will benefit the process of fault rupture modelling and accurate ground motion prediction in the near-field of capable faults worldwide.

Keywords: capable fault, surface ruptures, near-field co-seismic deformation , low-cost GNSS, 30th October Central italy earthquake


MANCHESTER
UNITED
THE
NORTH
FACE

Co-seismic offsets and damage associated with the Hundalee Fault during the 2016 Kaikoura, New Zealand, M7.8 earthquake

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The 14 November 2016 Kaikoura M 7.8 earthquake occurred in the northern part of South Island, New Zealand. Complex co-seismic faults and crustal deformations occurred over a strike length of at least 150 km, both on land and off shore, with extensive landsliding that caused great damage to the national highway and railway.

We conducted a field survey on the Hundalee Fault and associated features from 19-21 December 2016 as one of multi-institutional teams. Field investigation started by 5 hours air reconnaissance from a helicopter. At temporary landing sites (site A and B, Figure) on a NNW-SSE fault in mountain terrain, we found up-down relative movement with eastern side uplifted ~1m at A but western side uplifted ~0.6m at B suggested a complex dip-slip movement possibly with some sinistral strike-slip.

On ground survey, co-seismic fault displacements recorded mainly at C, D, E, F and G (Figure). Nearby the previously mapped line of the NE-SW Hundalee Fault on GNS Science geological map, surface rupture had the NW side uplifted at D, F, while a SE side uplift at E, suggests that the Hundalee Fault rupture was complex. The maximum vertical displacement on the Hundalee Fault was ~1.5 m, there accompanied by as much as ~3.7 m dextral offset, as measured across offset road and railway at F. The coast around beach G was uplifted coseismically ~1-2 m. Residence house damaged at H as well as some other houses along the Hundalee Fault.

According to the updated survey results of the multi-institutional research team (GNS, 2016), the Hundalee Fault was one of more than 12 individual faults that collectively ruptured during the earthquake.

We will present the updated work and more observed points based on the on-going summary.

Reference: GNS, 2016, http://info.geonet.org.nz/pages/viewpage.action?pageId=20971550

Keywords: Kaikoura earthquake, field investigation, co-seismic fault, New Zealand, Hundalee fault


B
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B
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G
F
C
W
B
E
A
C
D
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Oaro
Monument
Date on
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161220
161221
Hundalee Coseismic faults by Ken Hao.
Background by GNS.
:Sinistral offset
:Uplifted side
0 0.35 0.7 1.4 2.1 2.8
Kilometers
A
N
F
NE
F
NE

Satellite SAR differential interferometry analysis on surface deformation associated with 2011 and 2016 earthquakes in northern part of Ibaraki prefecture

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Surface deformation pattern associated with earthquakes occurred in northern part of Ibaraki prefecture on March 19, 2011, and on December 28, 2016, was investigated by using co-seismic pairs of Satellite SAR data. Two co-seismic pairs of ALOS PALSAR data observed from the ascending and the descending orbits were used for the analysis of the earthquake in 2011. The earthquake occurred in 2016 can be covered by two co-seismic pairs of Sentinel-1 CSAR data acquired in ascending and descending orbits. The distribution patterns of vertical and horizontal (E-W) surface displacement associated with these two earthquakes were derived from the 2.5 dimensional analyses using these SAR data pairs. As the co-seismic pairs of ALOS PALSAR data contain non-uniform regional displacement pattern associated with M9.0 the 2011 off the Pacific coast of Tohoku Earthquake, occurred on March 11, 2011, the displacement amount along the line of sight of interferometric pairs were simulated from GNSS data and were removed from the differential interferograms, in order to extract local displacement associated with the earthquake on March 19, 2011. Fault traces inferred from the satellite SAR differential interferometry analyses of earthquakes in 2011 and 2016 perfectly coincide, indicating that these earthquakes, from macroscopic viewpoint, may be associated with the activity of the same fault. Geographic location of the peak of vertical displacement was found not to coincide with that of horizontal displacement by 2.5 dimensional analyses, for both earthquakes. The distribution patterns of vertical and horizontal displacement indicate the normal fault activity along the listric fault. Amount of the surface displacement associated with the earthquake in 2011 is as twice as of that in 2016, in both vertical and horizontal directions, which may reflect the difference in the distance from the hypocenters to the fault trace.

Keywords: Northern part of Ibaraki Prefecture, Earthquake, Surface displacement, Satellite SAR Differential Interferometry, 2.5 dimensional analysis

Recurrence of similar surface ruptures associated with the M 6 earthquakes of 2011 and 2016, northern Ibaraki, Japan

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The Mw 9.0 Tohoku earthquake of 2011 triggered unusual normal-fault-type earthquakes in the southern part of Abukuma mountains, a fore arc mountain of northeast Honshu arc, Japan. Most remarkable earthquake swarm has occurred in the northern part of Ibaraki prefecture with two of moderate earthquakes, Mj 6.1 of March 19, 2011 and Mj 6.3 of December 28, 2016 earthquakes.

We conducted a field survey on the surface ruptures on January 5, 2017, and found a surface ruptures and destruction of artificial structures such as roads and a bridge caused by faulting. These ruptures were found in a 2.5-km-long section with a trend of NNW-SSE along a linear discontinuity of satellite radar interferometry image provide by the Geospatial Information Authority of Japan (2016). At Mochiyama (N36.821, E140.610) in the northern part of the section three ruptures zones cross a paved road at a low angle. We measured the fault displacement at about 15 cm in vertical across the 6-m-wide rupture zone, and 5-6 cm in horizontal-dip component for each of two rupture zones. Some of fissures seem to be older than the 2016 earthquake because those had filled with dirt. Aoyagi et al. (2015) reported that some ruptures appeared associated with the 2011 event at the same location. At the Shin-Koyama bridge site (N36.806, E140.626) in the southern part of the section many of fissures appeared across a prefectural highway rtunning perpendicular to the linear discontinuity of interferometry image. The fissures occurred in a 170 m section of the paved road and the bridge completed in 1993. The total amount of width of those fissures reaches 29 cm. The fault displacement occurred in two steps, because some of new fissures and destructions appeared along the repaired ones. The distribution pattern and amount of displacement are very similar between those two events. Those fissures occurred on both sides of the bridge, suggesting that they are fault origin, not due to landslide. At the 0.5 km southern point of the bridge, new and old minor fissures also appeared on the pavement of a forest road. Along further 3-km-long southern section of the linear discontinuity of interferometry image, 1-2 cm-wide fissures were observed.

Our findings of two steps of surface rupturing suggest that the 2011 and 2016 earthquakes produced the similar surface faulting repeatedly with only 6 years of interval. The ruptures occurred in a Mesozoic granitic batholith where neither of geological and geomorphological faults has mapped. Repeating of 2011 and 2016 small surface faulting might be the characteristics of triggered events on immature fault.

Reference:

1) Aoyagi, Y., Onuma, T., Oku, T. and Sasaki, T., 2015, Proceedings of the Symposium on Fault Displacement Evaluation, 31-38.
2) Geospatial Information Authority of Japan, 2016, http://www.gsi.go.jp/BOUSAI/H28-ibaraki-earthquake-index.html. (Feb. 15, 2017, last access)

Keywords: surface rupture, recurrence of faulting, triggered earthquake, 2016 northern Ibaraki earthquake

Preliminary report of co-seismic surface rupture produced by the 28 December 2016 Hokubu-Ibaraki earthquake, northern Kanto region, Japan.

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1. Central Research Institute of Electric Power Industry, 2. Dia consultants

A normal faulting earthquake (Mj: 6.3) occurred at northern Ibaraki, northern Kanto region, Japan, in 28 December 2016 (JMA, 2016). InSAR imaging revealed 2 km length of NW-SE trending crustal offset, maximum ~27 cm of western crustal movement away from satellite and ~6 cm of eastern crustal movement toward satellite (GIAJ, 2016). In the source area, seismicity has abruptly increased since the 2011 off Tohoku earthquake and another moderate (Mj: 6.1) earthquake of normal faulting prior to this event occurred in 19 March 2011. We conducted field survey immediately after the 2016 earthquake to check the surface fault rupture.
We recognized intermittent open cracks along with the InSAR offset. These cracks occurred from northern Mochiyama-area (N36°49′20", E140°36′36") to southern upstream of Koyama-dam (N36°47′54", E140°37′45") and it has ~3.4 km of total length. The distribution of open cracks located at upstream of valley and tip of ridge in right bank (south-west side) of Mochiyama-river between Mochiyama-area and Tomioka-area. In Mochiyama-area, surface rupture of the 2011 earthquake was also suggested by field survey on deformation zone across the asphalt road and leaned trees on its extension (Aoyagi et al., 2015). We observed a clear expansion of the deformation zone (distribution and crack width) after the 2016 earthquake. Additionally, we found fault zone just under small crack at southern tip of trace. The fault zone has ~40 cm width of fault gouge zone consisting of at least two layers of fault gouge. Sharp fault surface (N6°W strike, 67°W dip) recognized along with fault gouge zone may be latest slip surface because colluvium that covers fault surface is deformed. Fault striations (72°NNW rake) recognized inferred latest slip surface are consistent with the 2016 fault-plane mechanism. We concluded these intermittent cracks are tectonic surface rupture by these observations.

Aoyagi Y., T. Onuma, T. Oku, and T. Sasaki (2015): Fault displacement evaluation by InSAR for the recent moderate earthquakes in Japan. Proceedings of the Symposium on Fault Displacement Evaluation, I-5, pp.31-38 (in Japanese).
Geospatial Information Authority of Japan (GIAJ), 2016, Information of earthquake in northern Ibaraki prefecture. http://www.gsi.go.jp/BOUSAI/H28-ibaraki-earthquake-index.html (in Japanese).
Japan Meteorological Agency (JMA), 2016, Earthquake report of Northern Ibaraki prefecture, 28 December, 2016. http://www.jma.go.jp/jma/press/1612/28a/kaisetsu201612282345.pdf (in Japanese).

Keywords: coseismic surface rupture, InSAR, fault zone

Study on the Evaluation Method for Fault Displacement: Probabilistic Approach Based on Japanese Earthquake Rupture Data - Principal fault displacements along the fault-

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The purpose of Probabilistic Fault Displacement Hazard Analysis (PFDHA) is estimate fault displacement values and its extent of the impact. There are two types of fault displacement related to the earthquake fault: principal fault displacement and distributed fault displacement. Distributed fault displacement should be evaluated in important facilities, such as Nuclear Installations. PFDHA estimates principal fault and distributed fault displacement. For estimation, PFDHA uses distance-displacement functions, which are constructed from field measurement data. We constructed slip distance relation of principal fault displacement based on Japanese strike and reverse slip earthquakes in order to apply to Japan area that of subduction field. However, observed displacement data are sparse, especially reverse faults. Takao et al. (2013) tried to estimate the relation using all type fault systems (reverse fault and strike slip) so in this time, we try to estimate distance-displacement functions each strike slip fault type and reverse fault type especially add new fault displacement data set.
To normalized slip function data, several criteria were provided by several researchers. We normalized principal fault displacement data based on several methods and compared slip-distance functions. We normalized by maximum displacement rate, normalized by mean displacement rate. The normalized by total length of Japanese reverse fault data did not show particular trend slip distance relation. In the case of segmented data, the slip-distance relationship indicated similar trend as strike slip faults. We will also discuss the relation between principal fault displacement distributions with source fault character.
According to slip distribution function (Petersen et al., 2011), strike slip fault type shows the ratio of normalized displacement are decreased toward to the edge of fault. However, the data set of Japanese strike slip fault data not so decrease in the end of the fault. This result indicates that the fault displacement is difficult to appear at the edge of the fault displacement in Japan.
This research was part of the 2014-2015 research project ‘Development of evaluating method for fault displacement ‘ by the Secretariat of Nuclear Regulation Authority (NRA), Japan.

Keywords: fault displacement, PFDHA

Evaluation of earthquake source fault length from active fault and subsurface information

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In a strong ground motion prediction, the evaluation of fault length is important because fault dimension provides the size of an earthquake. The Headquarters for Earthquake Research Promotion published Regarding the revised Methods of evaluating active fault in 2010. This method estimates the subsurface fault based on the combination of active fault and subsurface information, such as geological structure and geophysical information. We evaluated lengths of Japanese inland earthquakes, according the above mentioned methods. The estimated fault length in mature active fault zone were similar or longer than that of the earthquake source fault inferred from strong ground motion inversion. On the contrary, the estimated fault length in immature fault zone were shorter than that of inverted results.
This research was part of the 2014-2016 research project ‘Improvement for uncertainty of strong ground motion predictio ‘ by the Secretariat of Nuclear Regulation Authority (NRA), Japan.

Keywords: fault length, active fault, earthquake source fault

Investigation of off-fault displacement

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1. Geo-Research Institute, 2. KOZO KEIKAKU ENGINEERING Inc., 3. Aichi Institute of Technology

Discontinuous distributed fault displacements occur around the primary surface rupture in the earthquake. Evaluation of off-fault displacement is important for mitigation of fault displament hazards. There are two types of off-fault displacement in the view point of a prediction problem. The displacement does not occur only on the active fault, but also off the active fault. Petersen et al. (2011) introduced mapping accuracy for the strike-slip fault. We estimated the mapping accuracy of several Japanese earthquakes at distinct fault side, i.e. hanging-wall/foot-wall by measuring distances between active fault traces and primary surface ruptures. Based on estimation of the mapping accuracy of strike-slip fault, narrow bell-shaped displacement profile across the active faults was inferred. On the contrary, wide bell-shaped displacement profile was estimated and the center shifted to the foot-wall side, in the case of the reverse-fault. The other off-fault displacement is the displacement on the secondary faults. This type of displacement of reverse fault focuses on the hanging-wall. These differences are important to estimation of fault displacement hazard.

Acknowledgments: This research was part of the 2014-2016 research project ‘Development of evaluating method for fault displacement ‘ by the Secretariat of Nuclear Regulation Authority (NRA), Japan. A part of displacement data was used from Kagohara et al. (2007), which was partly supported by the Grant-in-Aid for Scientific Research (no. 17200053) by Ministry of Education, Science, Sports and Culture.

Keywords: fault displacement hazard, secondary fault

Study on the evaluation method for fault displacement: Deterministic evaluation approach based three step considerations.

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Fault displacement hazards are very important to enhance seismic safety of nuclear installations. In Japan, important nuclear facilities must be installed in the ground where there is no risk of displacement. And also IAEA Specific Safety Guide (SSG) -9 provides guidelines and procedures for assessing the potential for fault displacement (capability) at or near the site for both new and existing nuclear power plants.
Under such background, we are investigating the possibility of evaluation by both deterministic evaluation method and probabilistic evaluation method as to whether or not fault displacement occurs on the ground surface when earthquake occurs.
In this paper, we focus on fault displacement and introduce the concept of deterministic evaluation methods for fault displacement.

We are planning to evaluate fault displacement will occur on the ground surface due to earthquake occurrence by the following three steps.
step1) Construction characterized source models. We will construct a characterized source models that can reproduce strong ground motion near the seismic source with for less than period of 10 seconds.
step2) Consider conduct dynamic rupture simulation with each parameter of the characterized source model constructed in step 1 as input. By dynamic rupture simulation, evaluate the permanent displacement appearing on the ground surface due to the displacement of principal fault. (In step 2, consider calculation area that wide area including the principal fault is taken into both the depth direction and the horizontal direction.)
step3) in step3, targeting a very narrow range of the ground surface (ex. few hundred meters to several kilometers), we consideration a very soft and discontinuous nature of the surface, evaluate displacement by numerical analysis method represented in the finite element method, or the like. In this study, we have conducted a combination of the finite element method (FEM) and the particle method (SPH) method for the analysis method.

In accordance with the above flow, we conducted a tentative analysis for the 1999 Chi-Chi earthquake and compared displacement of observation records and analysis result.

This research was part of the 2016 research project ‘Development of evaluating method for fault displacement ‘ by the Secretariat of Nuclear Regulation Authority (S/NRA), Japan.

Keywords: deterministic approaches, characterized source model, dynamic rupture simulation, subsurface rupture simulation

