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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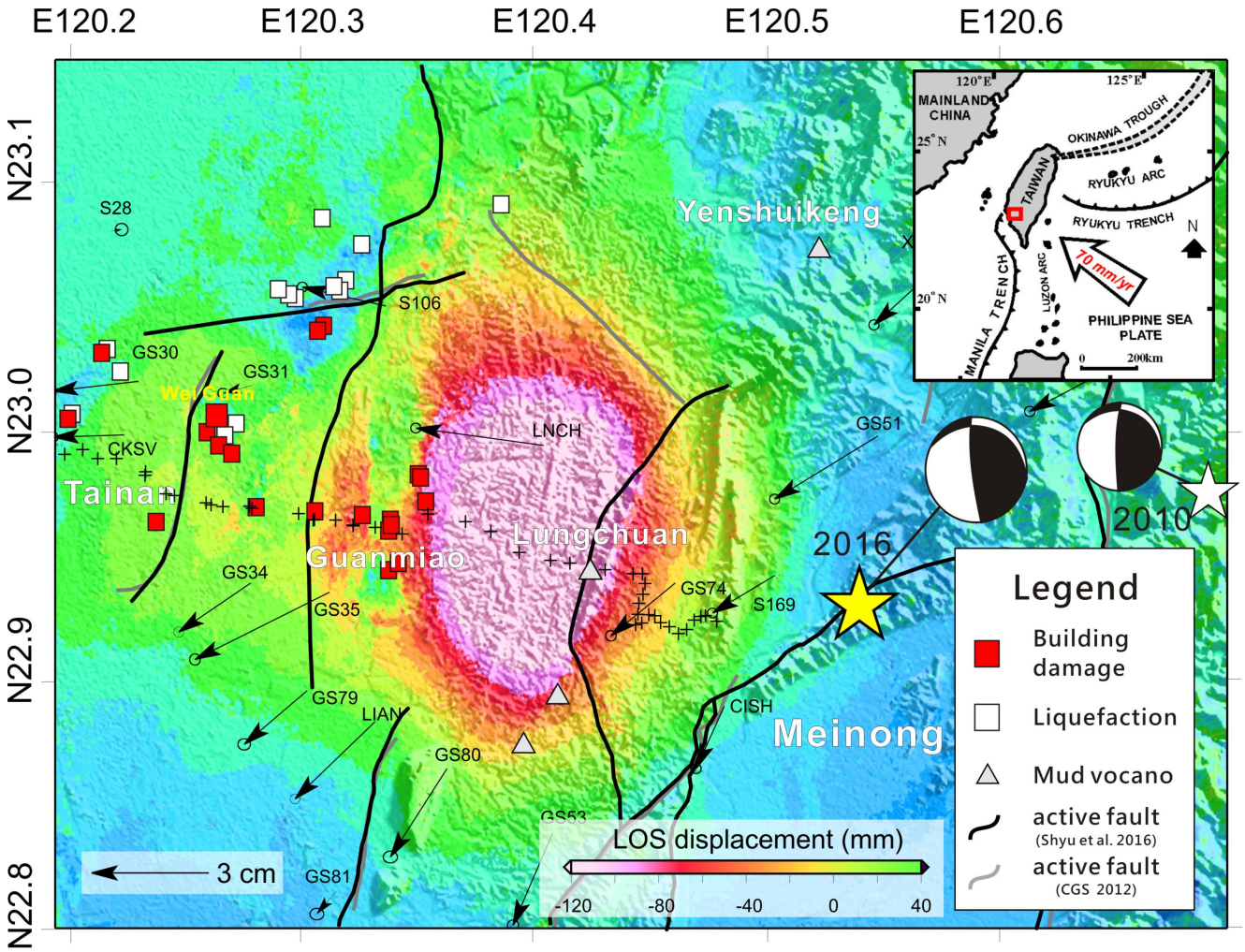
The M_L6.6 Meinong earthquake on 6 February 2016 caused serious damages in southwestern Taiwan. Coseismic displacement derived from GPS and InSAR shows ~10 cm dome-shaped surface uplift 15 km west of the epicenter with two clear N-S trending discontinuities in the InSAR fringes around the town of Guanmiao, 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



SAR干渉画像に現れた阿蘇外輪山北西部の地表変位の現地検証とその解釈
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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ALOS-2データを用いたSAR干渉解析により確認された熊本地震に伴う小さな地表変位を示す線状の位相不連続のうち、阿蘇外輪山北西部に多数認められた概ね東西走向の長さ数kmの線状の位相不連続については、3次元地表変位量成分の解析（森下ほか2016）により、北部は南落ち、南部は北落ちの最大30cm程度の垂直変位を示しており、地震に伴う応力場の変化により二次的に生じた南北方向の伸張に伴う半地溝状の正断層群的な変動を示していると解釈されている（Fujiwara et al. 2016、藤原ほか2016）。

これらの位相不連続が現れている地点の現地調査を行ったところ、多数の不連続線上で地表変位を確認した。いずれも、走向はおおむね東西、開口幅、落差ともに最大30cm程度で、少なくとも数10m以上直線状に連続する。変位の向きは場所によって異なるが、すべて位置、走向、変位の向きはSAR干渉解析による分析ときわめてよく整合するものであった。地表地震断層と判断されかねない形状的特徴を示すものもあった。

地形との関係については、先行研究（九州活構造研究会1989，中田・今泉2002）において鞍岳断層群として示されている活断層上に、変動地形学的に推定された変位方向と一致して現れているほか、地形的には断層地形とは認められない位置に現れているものも多い。本地域は阿蘇山の火山活動に伴う火砕流や噴出物が厚く堆積しており、それらに埋もれた構造の活動が誘発されているとも考えられる。

地震に伴う応力の変化や地震動により既存の構造が誘発された受動的な変動、いわば「お付き合い」地表変動は、SAR干渉解析により地表の変位が面的かつ詳細に把握できるようになって以降、多く報告されている。これらは、報告のあった地震のみに特徴的に現れたわけではなく、もともと地震に伴って普遍的に発生していたかもしれない。これまで報告されている地表地震断層や、トレンチで認定されるイベントにも、このような受動的変動が含まれている可能性があり、活断層の活動履歴の評価に対する問題提起と考えるべきであろう。

キーワード：SAR干渉解析、地表変位、誘発変動、お付き合い変動
Keywords: SAR interferometry, surface ruptures, triggered displacement, accompanied displacement

2016年熊本地震における詳細な地形データを用いた地震断層の三次元変位解析事例

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

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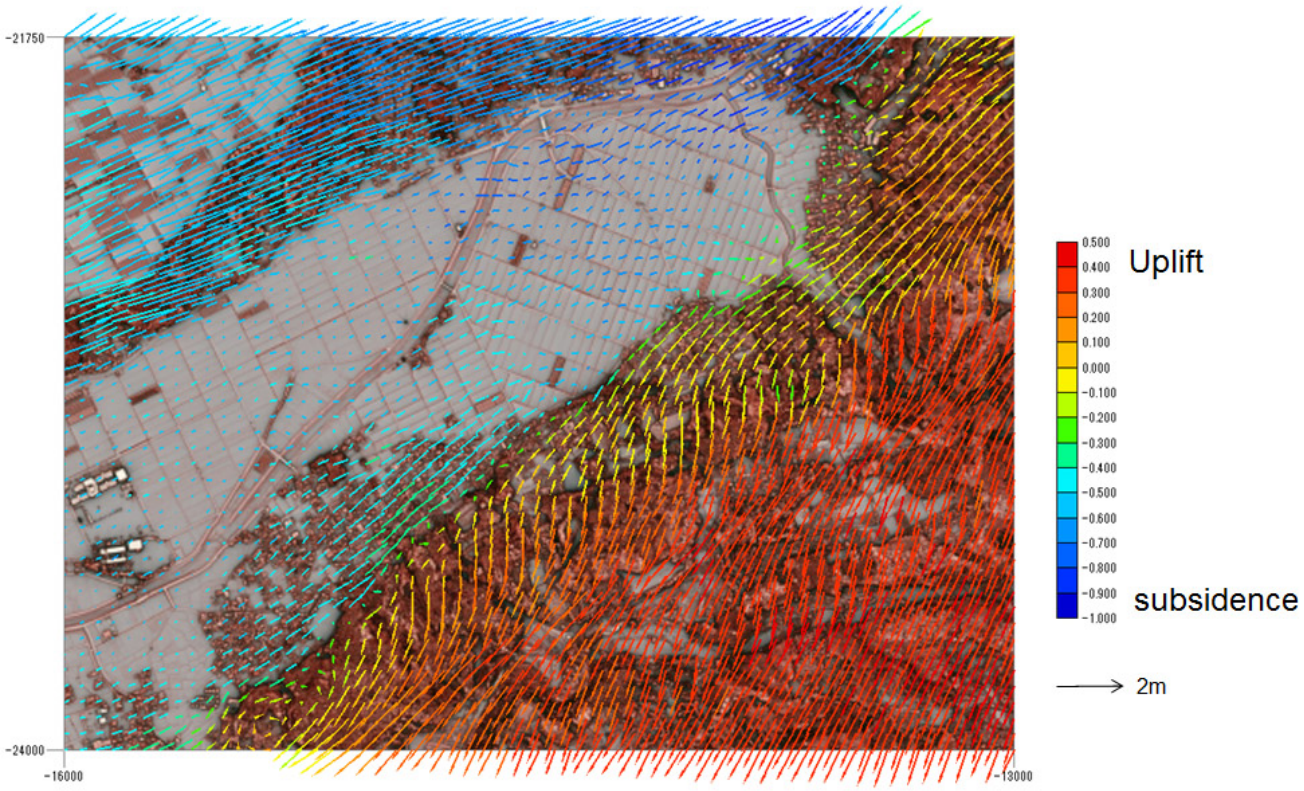
平成28年(2016年)4月16日1時25分に熊本県で発生したM7.3の地震（以下、熊本地震）では、阿蘇市から御船町にかけて地表地震断層の出現が確認されている。これらの地盤変状を面的・定量的に把握するため、筆者らは、この地震直前（4月15日15時-19時20分）と直後（4月23日10時14分-11時53分）の2時期に実施した航空レーザ計測データを用いた検討を進めてきた。

複数時期の地形データを比較する手法としては、メッシュデータを用いた標高差分が一般的である。しかしながら、今回の地震断層のように大きな水平変位を伴う場合、水平成分と垂直成分の見極めが難しい。

そこで、航空レーザ計測により取得された点群データを用い、3次元の変位ベクトルを計算する手法について検討した。複数の点群間で位置合わせを行う一般的な手法としてICP (Iterative Closest Point)手法がある。これは、2つの点群間の最近傍点を対応点として求め、対応点の距離を縮小する幾何変換を推定する処理を繰り返すことで、マーカ等がなくても自動的な位置合わせを可能とするものである。本検討では、さらに点群の構成する面と面の距離も最小化することも考慮した手法（CCICP: Classification and Combined ICP）を採用した。

益城町三竹北方付近にモデル地域を設定し、CCICP手法を適用した。図に示す。水平方向の変位をベクトルの向きと大きさで、鉛直方向の変位を色分けで示している。この結果より、木山川低地の南北端に沿う東西方向の2条の右横ずれ断層と、北西−南東方向にのびる左横ずれの共役断層が確認できた。また、南側の山地部では隆起方向、北側の台地部では沈降方向である。断層が分岐する付近では、局所的に水平移動成分がほとんどない場所もあること等が明らかとなった。

キーワード：航空レーザ、活断層、2016年熊本地震、ICP手法
Keywords: LiDAR, Active Fault, 2016 Kumamoto Earthquake, Iterative Closest Point algorithm



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

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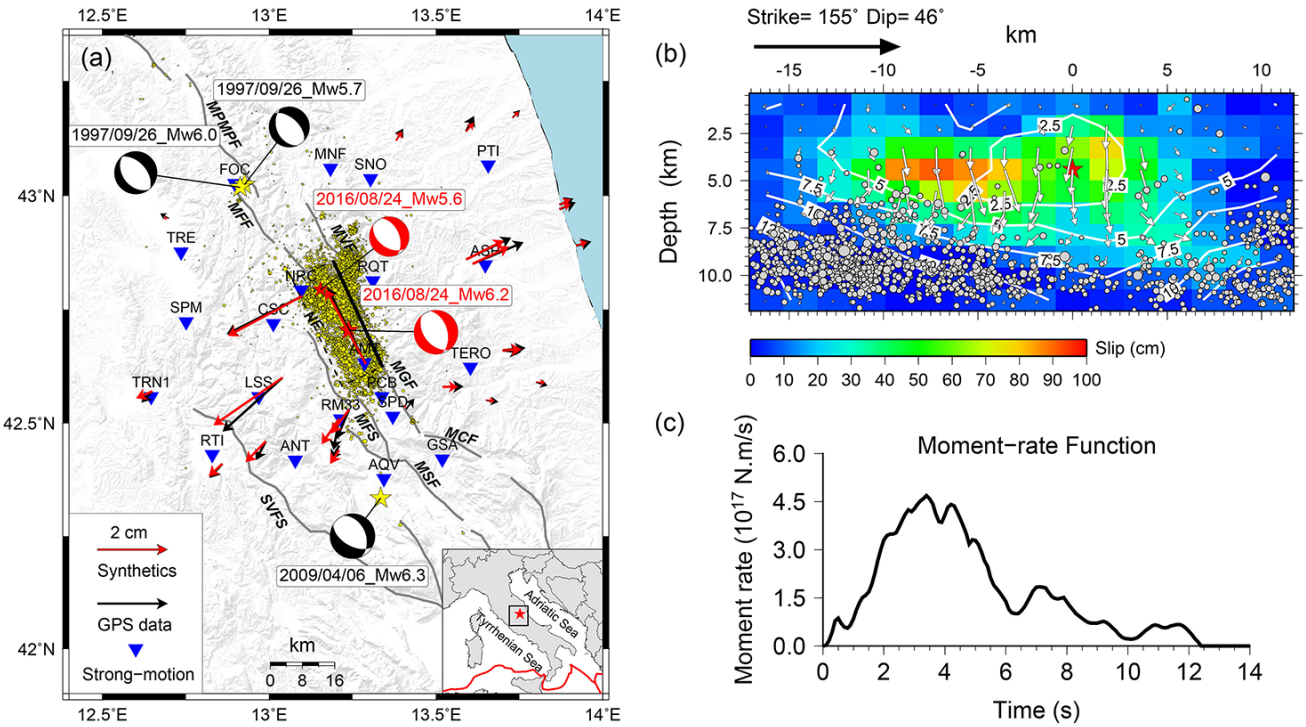
For analyzing possible reasons for the heavy damage and seismogenic features of the 24 August 2016 Norcia earthquake, we constructed and analyzed its rupture process by incorporating datasets of near-field strong motion, teleseismic and static GPS displacements. The optimized model revealed a relatively 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

2016 Kaikoura (New Zealand) M7.8大地震におけるHundalee断層帯の変動と被害調査
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

キーワード：カイコウラ地震、現地調査、地震断層、ニュージーランド、Hundalee fault
Keywords: Kaikoura earthquake, field investigation, co-seismic fault, New Zealand, Hundalee fault

平成23年と平成28年の茨城県北部の地震に伴う地表変動の衛星SAR差分干渉解析

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

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平成23年3月19日と平成28年12月28日に茨城県北部で生じた地震に関して，地震前後のALOS PALSARデータ（平成23年）とSentinel-1 CSARデータ（平成28年）の差分干渉解析を実施し，地表変位量の分布パターンを調査した。2件の地震ともに，北行軌道と南行軌道の干渉ペアが利用可能であり，これらを用いて2.5次元解析を実施して変位量を東西方向と上下方向に分解し，変位の分布パターンを比較した。平成23年の地震前後の干渉ペアは，東北地方太平洋沖地震による広域変位量を含むため，電子基準点データにより広域変位量をシミュレートしてこれを除き，局地変位量を算出した。断層の地表トレースは，平成23年と平成28年でほぼ同一であり，巨視的には，同じ断層が活動した可能性が高いと考えられる。2.5次元解析の結果，上下方向と東西方向の最大変位量の位置は異なることが判明し，その分布パターンから，リストリックな形状を成す断層面に沿う正断層の活動が示唆される。これらの地震に伴い生じた地表変位量は，上下方向・東西方向とも，平成28年の地震のものに比べて平成23年のものが2倍程度大きく，震源から断層の地表トレース付近までの距離の違いを反映しているものと考えられる。震源の深さは，気象庁の発表に基づくと平成23年の地震が約5km，平成28年の地震は約11kmであり，断層の地表トレースからの震央までの距離は，平成23年の地震で約5km，平成28年の地震で約12kmである。

キーワード：茨城県北部、地震、地表変位、衛星SAR差分干渉、2.5次元解析
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)

キーワード：地表地震断層、断層活動の繰り返し、誘発地震、2016年茨城県北部の地震

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

2016年12月28日茨城北部の地震による地表地震断層(序報)
Preliminary report of co-seismic surface rupture produced by the 28 December 2016 Hokubu-Ibaraki earthquake, northern Kanto region, Japan.

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2016年12月28日に茨城県北部を震源とする地震が発生した。震源の深さは約11 km、地震の規模を示すマグニチュードは6.3で、正断層型と推定されている(気象庁, 2016)。地震直後に公表されたInSARの解析画像によると、北西ー南東方向に約2kmにわたって変位の不連続が認められ、西側の地盤が最大約27cm衛星から遠ざかる一方、東側の地盤は最大約6cm衛星に近づくような変動が検出された(国土地理院, 2016)。震源域では、東北地方太平洋沖地震直後から地震活動が活発化し、2011年3月19日にもMj6.1の正断層型の地震が発生している。筆者らは、2016年の地震による地表地震断層の出現の有無を確かめるため、地震直後に現地踏査を実施した。

踏査の結果、InSARの不連続線に沿って開口クラックが断続的に続くことが確認された。クラックは北端の持山集落(N36° 49′ 20 ", E140°36′ 36 ")から南に向かって小山ダム上流部の支流(N36°47′54", E140°37′ 45")の約3.4 kmに渡って出現していることが明らかとなった。持山集落から富岡集落にかけての区間では、持山川の右岸（南西側）斜面に連続性の良いクラックが出現しており、これらの出現位置は谷部で上流側に入り込み、尾根部で先端側に移動する。なお、持山集落では、2011年3月19日の地震の後にも、舗装道路を斜めに横断する南西低下の変形帯が生じており、その延長上の杉が傾斜していることから、地表地震断層が出現したと考えられている（青柳ほか，2015）。今回の地震では、この変形帯（亀裂の分布範囲、個々の亀裂幅）が明らかに拡大していることを確認した。また、断続的なクラックの南端付近で、クラックの直下に断層破砕帯が露出した。破砕帯は幅40cm程度の断層ガウジ帯を伴い、その断層ガウジ帯は少なくとも2枚の断層ガウジからなる層状構造を呈する。断層ガウジ帯に沿っては直線性に富む断層面(N6°W, 67°W)が認められ、崖錐堆積物を変形させていたことから、最新活動面であると思われる。最新活動面では条線(レイク角72°NNW)が認められ、そのセンスは今回の発震機構と調和的である。以上の調査結果を統合すると、今回出現した断続的なクラックは地表地震断層であると考えられる。

青柳恭平・大沼巧・奥智也・佐々木俊法, 2015, InSAR解析によって検出した小規模な地震断層の最大変位量と長さの関係. 断層変位評価に関するシンポジウム講演論文集，I-5，pp.31-38.

国土地理院, 2016, 茨城県北部の地震に関する情報. http://www.gsi.go.jp/BOUSAI/H28-ibaraki-earthquake-index.html.

気象庁, 2016, 「平成23年(2011年)東北地方太平洋沖地震」について(第80報)ー平成28年12月28日21時38分頃の茨城県北部の地震ー. http://www.jma.go.jp/jma/press/1612/28a/kaisetsu201612282345.pdf.

キーワード：地表地震断層、InSAR、断層破砕帯
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.

キーワード：断層変位、PFDHA
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.

キーワード：断層長、活断層、震源断層
Keywords: fault length, active fault, earthquake source fault

Investigation of off-fault displacement

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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.

キーワード：断層変位ハザード、副断層
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.

キーワード：決定論的アプローチ、特性化震源モデル、動力学破壊シミュレーション、表層の破壊シミュレーション
Keywords: deterministic approaches, characterized source model, dynamic rupture simulation, subsurface rupture simulation

