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Paleoseismic studies along the Philippine fault zone, eastern Mindanao, Philippines
Paleoseismic studies along the Philippine fault zone, eastern Mindanao, Philippines

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The Philippine fault zone (PFZ) is one of the major strike-slip faults of the world that transects the entire length of the Philippine archipelago for more than 1,200 km from northwestern Luzon Island in the north to eastern Mindanao Island in the south. Consists of several segments, this arc-parallel, NW-SE trending, left-lateral fault zone is related to oblique subduction of the Philippine Sea plate beneath the Philippine island arc. This fault zone has been seismically active for the past 100 years with more than 10 earthquakes greater than M7. The most recent devastating earthquake was the 1990 Mw 7.7 Luzon earthquake that produced more than 120-km-long surface rupture along the Digdig fault with maximum horizontal slip of about 6m.

In Mindanao Island, the PFZ traverses its eastern portion for about 320km. It is characterized by fault parallel ridges, systematic deflection of stream and fluvial terraces, sag ponds and fresh tectonic scarps related to historical surface rupture. Historical documents also show possible surface-rupturing earthquakes such as the 1879 Ms 6.9 Surigao earthquake, 1891 Ms 7.2 Davao earthquake, and 1893 Ms 7.3 Monkayo earthquake. The fault trace in this island contains numerous geometric discontinuities such as en echelon steps and branching that may be used for segmentation of the fault zone. However, the timing of most recent earthquakes and recurrence intervals for these faults were poorly constrained. In order to reveal its paleoseismic activities, we have excavated multiple trenches across the different segments of the PFZ in Mindanao Island for the past two years.

Two sites were excavated across the Surigao fault located in the northern part of the island. Near vertical faults were identified on both sites and revealed evidence for at least two and probably three surface-rupturing earthquakes during the past 1,300 years that includes the 1879 Ms 6.9 Surigao earthquake. Prior analysis of aerial photographs and field observation along this segment also revealed fresh tectonic scarps and offset river terraces related to the surface rupture of the 1879 Surigao earthquake. In central part of eastern Mindanao, trench exposure in Compostela Valley across an east facing scarp that cuts an alluvial plain in an inter-valley mountain, exposed near vertical faults and contained evidence for at least two probably three or more surface-rupturing earthquakes for the 1,700 years that may include the 1893 Ms 7.3 Monkayo earthquake. Near the southern end of PFZ in Mindanao Island, trenching studies conducted north of Mati City showed a longer recurrence interval (> 1,000 years) compared to the other segments in this island. No historical earthquake (>M6) was documented in this area for the past 400 years.

Trench investigation conducted in this island revealed systematic variation of recurrence interval from 500-600 years in the northern part (Surigao segment), 500-1000 years in the central part (Compostela Valley) to > 1000 years along the southern end of the PFZ. This variation may be correlated to the southward decrease on slip rate along PFZ in this island from 24 mm/yr in the northern part (Surigao) to about 10 mm/yr in the south (Davao) derived from campaign type GPS survey (Aurelio, 2000, Island Arc).

キーワード: Philippine fault, paleoseismology, active tectonics, recurrence interval
Keywords: Philippine fault, paleoseismology, active tectonics, recurrence interval

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フィリピン地震火山監視強化と防災情報の利活用推進: その 2
Enhancement of Earthquake and Volcano Monitoring and Utilization of Disaster Information in the Philippines: Part 2

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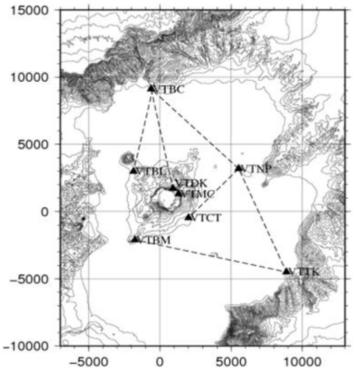
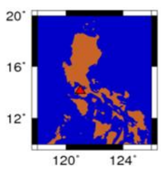
地球規模課題対応国際科学技術協力事業 (SATREPS) の研究課題「フィリピン地震火山監視能力強化と防災情報の利活用推進」(2010-2014) では、フィリピン火山地震研究所 (PHIVOLCS) と共同して (1) リアルタイム広帯域地震・強震・震度観測網と自動震源解析システムの導入による迅速で正確な震度分布と被害推定、(2)GPS 地殻変動および断層地質地形調査による大地震の発生ポテンシャル評価、(3) タール火山とマヨン火山のリアルタイム監視システムの構築、(4) 地震・火山情報ポータルサイトの構築とその利活用促進を行う。

初年度である 2010 年度は、(A) 全国５箇所の衛星テレメタ観測点 (ビラク、ルバング、ギマラス、バタラサ、パガディアン) への広帯域地震計・強震計の整備とマニラの PHIVOLCS への自動震源解析システム (SWIFT) の導入、(B) 震度速報システムのプロトタイプソフトウェア開発と PHIVOLCS における試運転、(C) ミンダナオ島における GPS キャンペーン観測と過去のデータの解析、および GPS 連続観測点（ミンダナオ島ブツアン、タンダグ）の整備、(D) タール火山における５箇所の広帯域地震計、２箇所の空振計、３箇所の GPS、３箇所の電磁気観測装置の整備とテレメタシステムの導入、を行いデータ取得と解析か開始された。また、(E) 防災科研（つくば）の大型振動台を用いて、フィリピンで一般的なブロック組積造ノンエンジニアド住宅の比較倒壊実験を実施した。さらに PHIVOLCS 職員による日本の地震火山観測体制の視察、ならびにマニラにおけるプロジェクトワークショップを実施した。

2011 年度は、更に５箇所の広帯域地震計・強震計の設置、自動震源解析システムの運用、震度速報システムのマニラ周辺での試験運用、地震発生ポテンシャル評価のための GPS キャンペーン・連続観測の継続、断層地質・地形調査、タール火山の活動の総合的監視、マヨン火山への地震計・GPS の整備、住宅の簡易耐震診断と地域の脆弱性評価手法開発のための調査・実験、ポータルサイトの設計、等を計画している。





station	BB	SP	IF	GPS	EM
VTBC	*	*			
VTNP	*		*		
VTBM	*	*		*	*
VTDK	*		*	*	*
VTCT	*	*		*	
VTMC		*			*
VTTK		*			
VTBL		V			

V: vertical component only

キーワード: フィリピン, 地震, GPS, 火山, 監視, 防災情報
Keywords: Philippines, earthquake, GPS, volcano, monitoring, disaster information

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フィリピン・タール火山の火山監視観測網の構築
New multi-parameter observation network at Taal volcano, Philippines

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Hiroyuki Kumagai[1*], Tadashi Yamashina[1], Yuta Maeda[1], Rudy Lacson[2], Mel Figueroa[2], Toshiyasu Nagao[3], Akihiro Takeuchi[3], Yoichi Sasai[3], Takeshi Hashimoto[4], Paul Alanis[2], Juan Cordon[2], Fumiaki Kimata[5], Takahiro Ohkura[6], Hirotaka Obata[7], Akira Wada[7], Agnes Aguilar[2], Jaime Sincioco[2]

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Taal volcano is one of the most active volcanoes in the Philippines. After an exceptionally long dormant period since the last eruption in 1977, renewed volcanic activity began in April, 2010. We deployed a new multi-parameter observation network at Taal volcano in November, 2010. The network consists of seismic, electromagnetic, GPS, and infrasonic stations, and their real-time data are transmitted to the head office of the Philippine Institute for Volcanology and Seismology (PHIVOLCS) in Metro Manila. We installed broadband seismic sensors (Guralp CMG-40T: 0.02-60 s) and short-period seismic sensors (Kinemetrics SS-1: 1 s), and created a network of seven seismic stations (5 broadband and 2 short-period stations) at the volcano. Seismic data are digitized by either Kinemetrics K2 or Basalt 24-bit data logger with a sampling frequency of 50 Hz. We installed three Overhauser magnetometers with one fluxgate magnetometer on Volcano Island. Data from Overhauser and fluxgate magnetometers were digitized with sampling intervals of 10 and 0.1 s, respectively. Three GPS receivers (Trimble NetR5) with a sampling rate of 10 s were also installed on Volcano Island. We further installed two low-frequency infrasonic sensors (ACO TYPE7144/4144: 0.01-10 s). All these data are first telemetered to Taal Volcano Observatory by a local digital telemetry system using 2.4 GHz wireless LAN, and then transmitted to the PHIVOLCS head office through a satellite telemetry system in real-time. Seismic, magnetic, GPS, and infrasonic data are received and processed by four PCs and two cluster machines installed in the head office of PHIVOLCS. These real-time multi-parameter observation data are automatically processed to visualize their temporal variations through web systems. We are currently developing a seismic waveform inversion technique suitable for Taal volcano that holds lakes: Effects of water on Green's functions are investigated to properly estimate seismic source mechanisms using a waveform inversion approach. Systematic uses of quantitative analysis techniques to analyze the data from the network will be useful to detect possible precursors of eruptions and contribute to improved monitoring of Taal volcano.

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Ground deformation of Guntur, Sinabung and Merapi volcanoes, in Indonesia by continuous GPS observation

Ground deformation of Guntur, Sinabung and Merapi volcanoes, in Indonesia by continuous GPS observation

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Indonesia is the greatest volcano-country in the world, with 129 active volcanoes. Prediction of volcanic eruption and mitigation of volcanic hazards are urgently required. However, many active volcanoes are equipped with only one seismic station. For the mid- and long- term prediction and evaluation of post-eruptive activity, continuous observations of ground deformations are necessary. Therefore, we have recently installed GPS stations in Guntur , Sinabung and Merapi volcanoes.

Guntur volcano complex is located 35 km SE of Bandung city, West Java, Indonesia. Although Guntur volcano has been dormant in eruptive activity since 1847, seismicity of volcanic earthquakes is active and mid- and long-term prediction of volcanic eruption is required for reduction of volcanic hazards. On the other hand, ground deformation monitoring is important to evaluate post-deformation of eruption and/or transition of eruptive style.

Sinabung volcano in North Sumatra erupted on August 2010 after >400 years dormancy. The eruptive activity began with phreatic eruption and declined in September, however seismicity on and around the volcano was still high even after the eruptions. An explosive eruption occurred on October 26, 2010 at Merapi volcano in Central Java and the eruptive activity was followed by continuous occurrence of pyroclastic flow from the summit crater during the period from November 3- 5.

In October 2009, 3 stations were installed in the area surrounding Masigit-Parukuyan-Kabuyutan-Guntur craters of the Gntur volcano. Each station is equipped with a dual-frequency GPS receiver (Leica GRX1200+GNSS). A battery and a solar panel were used for power supply for the receiver. Similar observation systems were installed at Merapi volcano in December 2010 and at Sinabung volcano in February 2011. Receivers (Leica GR10) are installed at the flanks of these volcanoes. Continuous observation with a sampling rate of 1second is performed at all stations and GPS data are saved as RINEX file. At the Guntur volcano, observed data is retrieved via the WLAN installed between each station and the Guntur Volcano observatory (POST). We applied a PPP (precise point positioning) using GPS analysis software, GIPSY-OASIS II Ver.5.0. In the analysis, JPL precise ephemeris is used, and dairy coordinates are calculated in the frame of ITRF2005. From the obtained coordinates, we can calculate baseline among stations.

We compare the result in the Guntur volcano with a past leveling result. By precise leveling surveys during the period from August 1996 to November 1997, the uplift around the summit area was detected (Hendrasto et al., 1998). Using grid search assuming a Mogi source as the deformation source, location of the source and volume change were determined. The obtained source is located at a depth of 5 km beneath Mt. Masigit (Sadikin, 2008). With this position fixed, volume change between each leveling survey was calculated. Total volume of the pressure source increased by 1.5∗10ˆ6 mˆ3 during the period from August 1996 to December 2002 and volume increase rate is estimated to be 2.5∗10ˆ5 mˆ3/year(Sadikin, 2008). If we apply this average rate to the GPS observation period, we expect a inflation with a volume change of 2.75∗10ˆ5 mˆ3 which cases 0.5cm baselines change among GPS sites. Any significant changes can not be recognized in our GPS measurement. This means deformation rate at the Mogi source beneath Mt. Masigit was smaller than the average rate obtained by leveling data during the period from August 1996 to December 2002 when the seismicity of volcanic earthquakes of Guntur volcano was high.

Keywords: volcano monitoring, GPS, indonesia

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カリウム-アルゴン年代に基づくスンダ弧バリ・東部ジャワのカルデラ火山地域における火山活動の長期時空間分布の検討
Long-term distribution of volcanic activity around calderas in Bali and East Java, Indonesia, determined by K-Ar dating

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インドネシアの Bali と東部 Java 地域には大規模噴火を繰り返した複数のカルデラ火山が分布するが，カルデラ形成に至る火山活動の長期変化は年代値が少なく未解明である．そこで，各カルデラ火山と周辺に分布する先カルデラ活動の火山岩類を主たる対象に，現地での地形解析と溶岩のカリウムーアルゴン年代測定を体系的・網羅的に実施している，

Bali には Batur, Bratan の 2 つのカルデラ火山があり，Agung 火山と共に活火山である． K-Ar 年代測定の結果，Bali 地域には 1.6Ma, 0.7-0.5Ma と 0.2Ma-現在の 3 つの活動期があり，Batur, Bratan カルデラ火山はともに，外輪山が 0.5Ma までに形成された古い火山と 0.2Ma よりも新しい火山から構成されることが明らかになった．各火山の形成時期は以下のとおりである．

(a) Batur の外輪山 Penulisan のうち北斜面にある開析された火山体底部・上部の各溶岩の年代がいずれも 0.5Ma で互いに一致した．

(b) Agung 火山東麓に分布する地形が開析された火山体（Tapis）の溶岩も年代が 0.5Ma であり，Penulisan の各試料と一致した．

(c) Penulisan に区分されてきた溶岩のうち，北東山麓の地形が相対的に開析されていない地域の溶岩から 0.2Ma の年代が得られた．また，Batur の外輪山東部の火山体 (Abang) の基底部溶岩から約 15 万年前と，上記の 2 試料よりやや新しく，誤差範囲で一致する年代が得られた．

(d) Batur, Bratan 火山の中間に分布する標高 706m の小規模な火山の溶岩からも 0.2Ma の年代が得られた．

(e) Bratan 火山北麓の開析された火山体から 0.5Ma の年代が得られた．

(f) Bratan 火山北部の台地を構成する Old Buyan Bratan の無斑晶質溶岩から 0.2Ma の年代を得た．

(g) Bratan 火山の南西側に位置する Batukau 火山の南西山麓に分布する溶岩からも 0.2Ma の年代が得られた．

(h) Bratan 火山北西方の Asah 近傍に分布する溶岩から 1.6Ma の年代を得た．この溶岩は新第三系 Djembrana 火山岩類に区分されてきたが第四系であることが明らかとなった．

東部 Java に位置する Tengger 火山は体積 1600km3 に及ぶカルデラ火山であり，その活動期は Ngadisari と Tengger の 2 回のカルデラ形成により区分されている．Tengger カルデラ内には活火山である Bromo がある．先カルデラ期の成層火山体 (広義の Old Tengger) は，Kukusan (400km3) とそれを覆う狭義の Old Tengger から成る．Tengger 火山周辺域の活動時期について，以下の各事項が明らかとなった．

(i) Tengger カルデラ形成噴火時の噴出物に挟在する溶岩から 0.3Ma の年代を得た．Tengger カルデラの形成時期は 30 万年前と考えられ，従来説と比べ大幅に遡る．

(j) カルデラ北西壁を構成するする溶岩の年代は，基底部・頂部とも約 0.45Ma で互いに一致した．これに対し，カルデラ南東壁の底部と火山体北西麓の溶岩の年代は約 0.3Ma で互いに一致した．よって，Tengger 火山は，成層火山体とカルデラが場所をずらしつつ，2 回形成されたと考えられる．

(k) Ngadisari カルデラ形成噴火・イントラカルデラ期の活動時期は，(i)(j) の各年代に挟まれる期間，すなわち 30-45 万年前に該当すると考えられ，既往値と比べ 2-3 倍古くまで遡ることになる．

(l) 北西部の Kukusan の溶岩から 1.7Ma の年代を得た．Kukusan は Tengger より古い火山であり，Tengger 火山地域の火山活動は 170 万年前まで遡る．

(m) Kukusan の馬蹄形凹地を埋める溶岩から 0.08Ma の年代を得た．これは Kukusan と比べはるかに新しく，後カルデラ期には北西山麓で側火口が形成された．

(n) 東部地域の火砕丘の火山弾の年代は 0.25Ma であり，Tengger カルデラの形成よりやや新しい．

(o) Tengger，Semeru 両火山の中間に分布する火山群では，溶岩について 2-4 万年前の年代が得られた．これは既往 14C 年代とも整合的である．この火山群は Semeru の古期ではなく新しい時期の活動と位置付けられる．

(p) Semeru 火山南麓にある最下位ユニットの溶岩は，0.5Ma である．Semeru 火山の活動は 50 万年前まで遡る．

なお，本研究の地質調査は，JST-JICA-RISTEK-LIPI の地球規模課題対応国際科学技術協力事業「インドネシアにおける地震火山の総合防災策」の一部として実施している．

キーワード: カルデラ, 火山, カリウム-アルゴン法, 第四紀, インドネシア
Keywords: caldera, volcano, K-Ar dating, Quaternary, Indonesia

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KH10-5 スマトラ北西沖調査航海概要ー高分解能 MCS 調査ー
High-resolution MCS survey during KH-10-5 Leg.1 off northwest Sumatra cruise

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A huge ocean-wide tsunami, with average heights of more than 20 meters along the west coast of the northern tip of Sumatra followed the 2004 Sumatra-Andaman earthquake (Mw9.2). Several working hypotheses have been proposed, but the generation mechanism for this tsunami remains unresolved. Most of these hypotheses suggest a possible coseismic slip on splay faults in the outer-arc-high off northwest Sumatra. Among these splay faults, the Middle Thrust (or possibly the Lower Thrust), can best account for features of the Indian Ocean tsunamis observed at regional and ocean-wide distances. To map fault traces and other geological structures that may be contributed by splay fault displacements, we conducted the KY09-09 bathymetry survey offshore northern Sumatra in 2009. The aim of that survey was to identify a fault trace that could be considered a candidate for the Middle Thrust (Hirata et al.,2010).

In early November 2010, we have conducted another high-density survey of the likely source region for the tsunami. This survey consists of a MCS (GI-gun, G=45 cuin and I=105 cuin; true GI-gun mode shooting every 10 sec; a 1,200 m-long, 48 channel solid streamer cable) and a 3.5 kHz Sub-Bottom Profiler (automatic ping intervals depending on water depth). A MNBS bathymetry survey using the SEABEAM 2120, shipboard gravity measurement, and 3-component magnetic measurement have also conducted as well. The survey ship speed was set at averagely 4 knots relative to ground. We designed the acoustic survey lines to cross a series of ridges and troughs parallel to the local trench axis and hence to sample fault traces that are candidates of the Main Thrust, the Lower Thrust, the Middle Thrust, the Upper Thrust in the outer-arc high.

The primary objective of the KH-10-5 cruise are to image detailed deformation structure in the uppermost sediment layers, up to 1 second bsfl in TWT, that are plausibly related to deformation occurred along fault traces. Our final goals are (1) to understand the geological structures in the outer-arc high off northwest Sumatra and their deformation history and (2) to resolve the generation mechanism of the Dec 2004 huge tsunami.

Approximately 480 nautical miles of MCS and SBP data were acquired during the KH-10-5 cruise(Figure 1). During the survey, we produced band-pass filtered, single channel profiles as preliminary results for all the survey lines. We could obtain clear images down to about 1.5 sec (TWT) in the trench fill and a maximum of about 1 sec (TWT) in small troughs in the outer-arc high. In Lines 5 and 6, a kink folding and landward vergent backthrusts were identified near the trench. Many of the small basins on the outer-arc high show deformed sediment layer structures, indicating either folding or faulting. Many SBP profiles also show deformation pattern in the uppermost sediment layers that are consistent with deeper deformation imaged by single-channel data. But some of them seem inconsistent, suggesting a difference in deformation pattern between recent (uppermost) and old (substrata) sedimentation periods. In the region where the Middle thrust is postulated, we found abundant evidences of faulting and folding of the sediment within small basins, along lines 4, 5, 6, 8, 10, 11 and 12. But these results are based on onboard processing and are tentative. We are going to process the MCS data and then interpret detailed geological structure in the near future.

Figure 1
The survey lines (heavy black lines) during the KH10-5 cruise. Main structural features (dashed): WAF, West Andaman Fault; UT, Upper Thrust, ; MT, Middle Thrust; LT, Lower Thrust; M'T, Main Thrust. DF, Deformation Front. UT and LT, are depicted according to Sibuet et al. (2007); MT according to Hirata et al. (2010).

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キーワード: スマトラ, 海底, 調査, 反射法, サブボトム, 断層
Keywords: sumatra, seafloor, survey, reflection, subbottom, fault

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2010年インドネシア，メンタワイ地震の津波波形インバージョン
Tsunami Waveform Inversion of the 2010 Mentawai, Indonesia Earthquake

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We performed a tsunami waveform inversion of the Mentawai, Indonesia earthquake (Mw 7.7, USGS) on October 25, 2010. The tsunami generated by this earthquake was about 4 to 7 m height and killed at least 445 on Mentawai Islands. Seismological analyses (e.g., USGS or NIED) indicate that this earthquake was tsunami earthquake with a long (˜ 100 s) duration. The tsunami was recorded at tide gauge and DART stations located in and around the Indian Ocean. We downloaded the tide gauge and DART data from WCATWC's, IOC's and NOAA's web sites and inverted the tsunami waveform data recorded at 9 tide gauges in Indonesia, Cocos, Sri Lanka, Maldives and a DART station located at southeast from the source region.

In order to estimate the slip distribution on the fault, 8 subfaults (4 along strike by 2 downdip) are assumed with the each subfault size of 50 km x 50 km. The focal mechanism is strike of 326 deg, dip of 12 deg and slip of 101 deg for each subfault from the USGS's Wphase moment tensor solution. The top depths of the shallower and deeper subfaults are 3 km and 13.4 km, respectively. Static seafloor deformation (Okada, 1985, BSSA) is calculated for each subfault model as an initial condition for the tsunami numerical computation. We adopted a constant rise time (or slip duration) of 30 s for each subfault. In order to calculate Green's functions from each subfault to the stations, the linear shallow-water equations were numerically solved by using a finite-difference method (Satake, 1995, PAGEOPH). For the far filed stations, we used a basic bathymetry grid of 2 arc-minute with finer grids of 24 arc-second around tide gauges, resampled from GEBCO_08 30 arc-second grid data. For the near field stations (Padang, Enggano, Tanahbalah and Telukdalam in Indonesia), an uniform grid of 12 arc-second was used, which was also resample form GEBCO_08.

The inversion indicates that large slips more than 2 m are located at the shallower subfaults near the trench, a feature similar to other tsunami earthquakes (e.g., Satake and Tanioka, 1999, PAGEOPH; Fujii and Satake, 2006, GRL). The total seismic moment is 4.3 x 10^{20} Nm (Mw 7.7) and the fault length is about 150 km. The synthetic tsunami waveforms generally agree with the observed ones. However, we found that the observed tsunami at Padang is not well reproduced, which is more sensitive to the solution of the slip distribution than the other stations. More detailed tsunami modeling may be required to estimate a reliable tsunami source model, by updating the bathymetry data with nautical charts and adopting a finer grid to express the complicated shorelines.

キーワード: 2010年メンタワイ地震, 津波地震, 検潮所, DART, 津波波源, 津波波形インバージョン
Keywords: 2010 Mentawai Earthquake, Tsunami Earthquake, Tide Gauge, DART, Tsunami Source, Tsunami Waveform Inversion

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2006 年ジョグジャカルタ地震の震源断層と破壊過程
Source fault and rupture process of the 2006 Yogyakarta earthquake

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The Yogyakarta earthquake with a moment magnitude of 6.3 occurred in the central part of Java, Indonesia on 26 May 2006 at 22:54 UTC, causing severe damage to the densely populated area of the Yogyakarta region. About 6,000 people were killed, and 50,000 were injured. The Opak River fault, located along the damage area, was thought to be a possible source fault of the earthquake, whereas the aftershocks were distributed 10 - 20km east of the Opak River fault (Walter et al., 2007).

Therefore, to clarify the source fault geometry, we first analyzed SAR data. We obtained an InSAR image by comparing the data acquired before and after the earthquake (29 April and 14 June, 2006).

We derived the surface trace of the actual source fault from this InSAR image. We next located three point sources by performing the waveform inversions of Kikuchi and Kanamori [1991] at various positions along the derived fault trace. We chose 29 teleseismic stations at epicentral distances between 30 and 100 degree, and retrieved vertical components of broadband P-wave seismograms for these stations from the Data Management Center of IRIS.

Using the obtained locations and focal mechanisms of point sources together with the aftershock distribution,by Walter et al. (2007) and our InSAR image, we defined the two-segment fault plane and its larger segment was assumed to be bent. We next performed a finite fault inversion of the teleseismic data using the method of Kikuchi et al. [2003]. The Green' s functions were computed with the method of Kikuchi and Kanamori [1991]. In addition to the teleseismic data, we further included strong motion waveform data observed at the NIED stations called BJI and LEM, and performed a joint inversion of the both data using the method by Yoshida et al. [1996] with the revisions by Hikima and Koketsu [2005].

This study identifies the source fault of the 2006 Yogyakarta earthquake and derived its rupture process by the waveform inversions. The inversion results imply that the Yogyakarta earthquake consists of two subevents and the larger one occurred 20 s prior to the smaller one.

キーワード: ジョグジャカルタ地震, 震源過程
Keywords: Yogyakarta earthquake, source process

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レシーバ関数法を用いた浅い構造の推定：タブリーズ、イラン、の例
Receiver function method for estimation of the shallow structure: example for Tabriz, Iran

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キーワード: 浅い速度構造, レシーバ関数法, 強震動
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